The Volcano Letter



The Volcano Letter



Edited by Richard S. Fiske, Tom Simkin, and Elizabeth A. Nielsen

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The logo on the cover and title page of this volume first appeared in Number 436 of *The Volcano Letter*, June 1936, and was used frequently thereafter. A translation of the Latin phrase is: No More Abandoned or Buried Cities.

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THE VOLCANO LETTER

A Weekly news leaflet of the Hawaiian Volcano Research Association

Sent free to libraries and to members. Dues of Association $5 per annum. Members receive in addition the illustrated Monthly Bulletin of the Hawaiian Volcano Observatory. Anyone may join the Association and thereby support Pacific volcano research. The Society has also patrons—individuals, firms and institutions.

No. 262 RELEASED WITHOUT COPYRIGHT RESTRICTION January 2, 1930

KILAUEA REPORT No. 936

WEEK ENDING JANUARY 1, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There has been no visible change in volcanic conditions at Kilauea during the past week. Halemaumau pit remains quiet. No new scars are to be seen on the walls and no new slides have been reported.

On December 30 an observer noted that a section of the center of the July grotto had fallen. Steam was noticeably absent at the vents within the pit on this day and on January 1, although rainy weather has been prevalent during the week.

Nine seismic disturbances were recorded by the seismographs. Of these five shocks, of very feeble intensity, gave an average distance to origin of 44 miles. One feeble earthquake, at 11:52 p. m. December 29, indicated an origin 9 miles from the observatory.

Microseimic motion was slight. Tilt accumulated moderately strong ENE.

ACTIVITY OF PELEE, MARTINIQUE

Little has been heard from Martinique since the terrible destruction of St. Pierre in 1902 by volcanic blast from Pelée. This volcano is in the middle of the Caribbee Islands, which extend in a curve from Porto Rico to Trinidad.

September 16, 1929, ash eruptions began again from the crater of Mount Pelée. At 8:45 p. m. September 26 an earthquake lasted a minute and a half at Fort de France. October 14 Pelée burst into eruption more strongly than in September. This calmed down on the 18th, but October 19 the director of the volcano observatory reported for the early morning of that day an outbreak stronger than the two preceding. Gas and ashes were thrown up, and the flashes of light lasted for 10 minutes. Intermittent rumblings and bursts of white steam accompanied the eruption, the dust column rose nearly 4,000 feet, and cinders were showered over the country. The activity occurred at the head of the valley of the Riviere Blanche, just as in 1902, beside the ruins of the famous lava spine which rose in that year.

The complete evacuation of Prêcheur, Saint-Pierre, and Morne-Rouge has been ordered by the authorities. It appears that Saint-Pierre had risen from its ashes by 1923, and possessed 1,000 inhabitants, more than 100 houses, a club, shops, a restaurant, a market, and a custom house. There is a daily steamer from Fort de France, and the town has running water, a sewage system, and is presided over by a mayor. The 1929 activity appeared to have been kindled at about the September equinox, just as was the seismic shaking in Hawaii, but like the latter, it dwindled. New activity is reported in December. (Seismological Despatches, Georgetown University; London Times, Oct. 21; New York Times, Sept. 21 and Oct. 20, Nov. 4.) T. A. J.

REVIVAL OF SANTA-MARIA, GUATEMALA

It will be remembered that the Pelée eruptions of May, 1902, were followed in October of that year by disastrous ash falls and floods from Santa-Maria volcano in Guatemala. In like manner the Pelée outbreak in September, 1929, is followed by a disastrous explosive eruption at Santa-Maria. This volcano is 12,361 feet high.

The volcano dominates the coffee lands of western Guatemala. Between 1922 and 1925 (Volcano Letter No. 87, Aug. 26, 1926) new stiff lava rose in the vast crater which the 1902 eruption had left in the flank of the mountain. The new plug replaced the crater with a lava hill 1,600 feet high and 4,000 feet across. Its top was a cluster of smoking turrets.

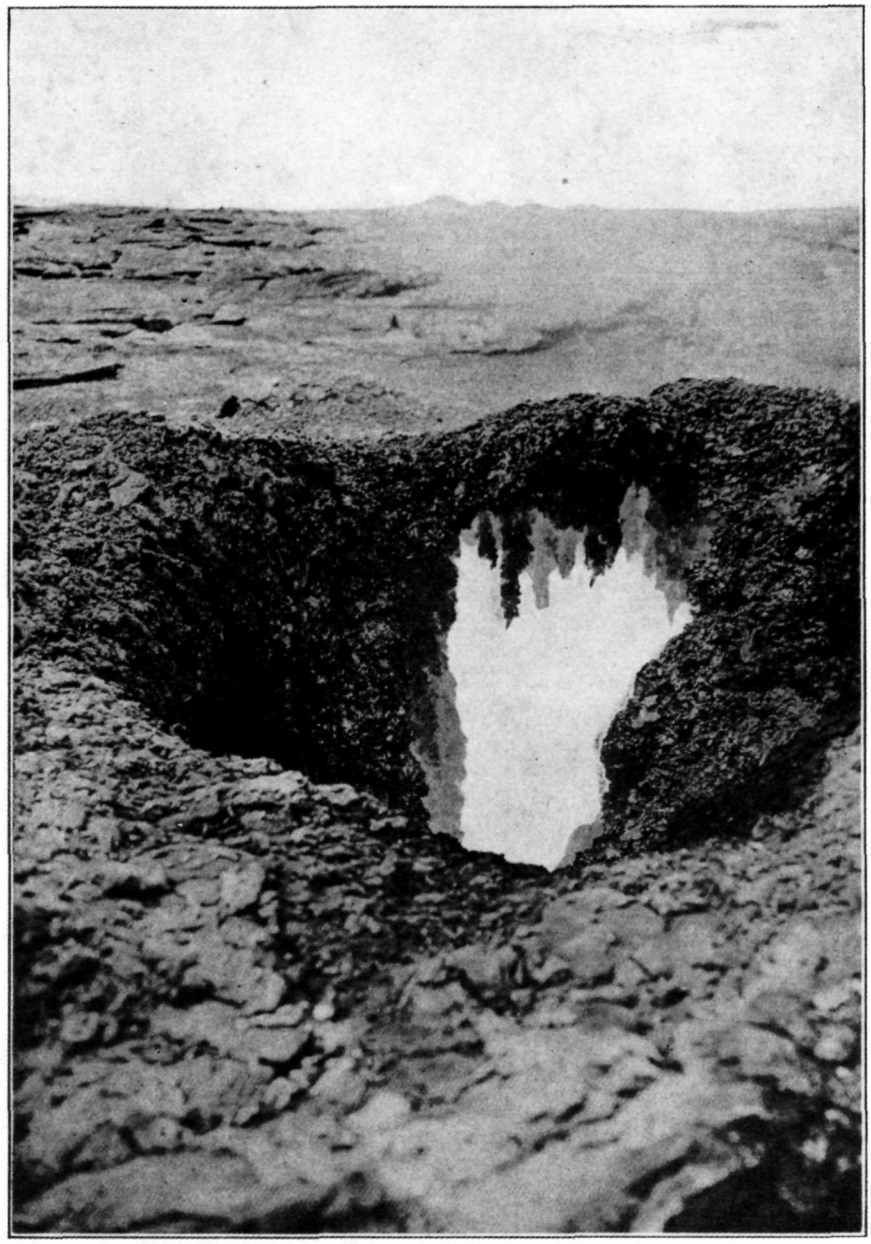
We now have despatches of November 5 and 8 which are difficult to interpret because of the newspaper habit of calling everything "lava" that pours from a volcano (Chicago Tribune, Paris, Nov. 5, and New York Times, Nov. 8). The "lava" is presumably glowing ash and mud floods.

On November 4, 1929, after three days of increasing rumblings, hot ash was vomited up about the new plug, probably cauliflower clouds of ash and steam shot thousands of feet into the air, incandescent blasts of falling material were impelled downward, and torrents of rainfall mixed with the hot ash to swell all the streams. Probably there was engulfment of the lava plug and widening of the crater. Heavy showers of ash were still falling November 7. There were destroyed villages, coffee plantations, and farms. El Palmar suffered the most, 21 bodies being recovered there. El Palmar is six miles south of the crater.

In the zone between Mazatenango, 15 miles to the south, and the crater cavity half-way up the mountain, the country is completely covered with ashes, and the air smells of sulphur. The buildings of El Palmar and the farmhouses thereabout still stand. On November 7 there were people still to be seen in the streets. Forty-five deaths are reported as the total, and loss of farm property in the coffee district to the value of one million dollars. Eight coffee plantations were destroyed, and the losses of life appear to be due to suffocation with hot ash, to burns, and to bombardment from falling stones, just as in 1902. Some bodies were found of persons who had climbed trees. The green foliage was burned to a dirty brown. T. A. J.

The Volcano Letter

No. 263—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | January 9, 1930



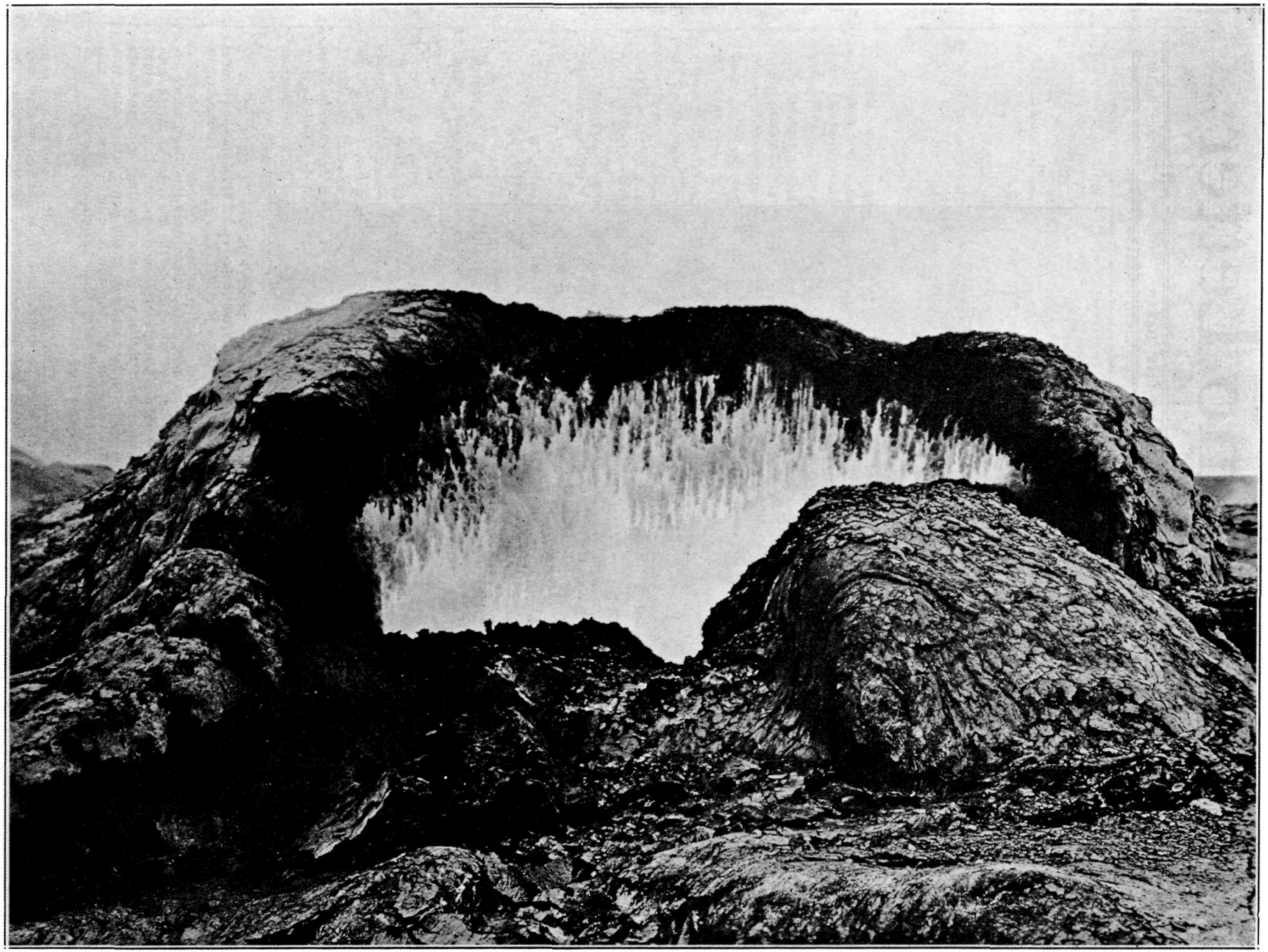
Looking into red hot tunnel hung with stalactites at orifice of eastern breathing cone, February 13, 1919, 11 a. m. This is inside Halemaumau pit on the inner floor when the lava lakes were level with rim of pit. The glowing tunnel connects through to the largest lake, and lava was splashing inside the tunnel. —Photo Jaggar.

BREATHING CONES

The extraordinary lava activity of the year 1919 at Halemaumau, the fire pit of Kilauea, marked the peak of the eleven-year cycle. To a tourist who sees the vast cauldron of today, a thousand feet deep and three thousand feet across, it is hard to realize that glowing molten slag was overflowing the edge of the pit a decade ago. The pit had its definite margin of cold rock, but within that margin and overlapping it there were lava lakes, pots, driblet spires, flow heaps, tunnels, stalactite grottoes, smoke holes, and breathing cones.

The East Cone of the spring of 1919 was a low hillock built up around a lava pot on the inner floor of Halemaumau. Visitors habitually walked over this floor, which extended from the lakes inside the pit area to merge with the overflows outside. This pot was supplied with glowing, gassy melt through a tunnel leading from the main lake. With the rise and fall of the liquid lava a cone was built around the pot, and the interior ceiling of the tunnel became hung with huge gas-glazed stalactites three or four feet long.

One could stand on the rim of this conelet, and gaze into the open pot where lava of bright yellow glow was splashing 15 feet below. Under the lip of the orifice the interior chamber was bright orange with incandescence, hung with the delicately sculptured fiery stalactites



Rift Oven of the Red Solfatara. This photograph was taken by evening light April 4, 1921, with panchromatic plate and deep red filter. The glowing oven, 9 feet high and 20 feet across, stood over the rift about 500 feet outside Halemau mau and remained like this throughout the spring. Photo Jaggar

shaped like long bunches of grapes. By night a banner was visible of blue-green flame fluttering above the orifice sending off pale blue transparent fumes acrid with sulphur.

As a whole during this period the lakes were rising, the inner floor was being overflowed in spasms, and the heaps, cones, and spiracles were building up. The East Cone hissed and breathed and roared at different times. Sometimes it would vomit up its molten stuff like an artesian well, and give vent to a glowing flow. At such times the pot and tunnel were obliterated, only to reappear with the stalactites reforming when the outflow ceased.

The grape-like droplets, and the gray, yellow, red, or brown glazes on the surface of these stalactites are not the result of direct spatter. There are other stalactites in curtains and frozen drip points which are formed by direct splash. The grape bunches, however, and the long worm-like stalactites are formed by the remelting of the roof of the cavern by slow action of the intensely hot burning gases. This burning is converted into a blow-torch effect when air has access to the tunnel so as to convert the combustible gases from the boiling lava into oxidation flames. When air reaches the volcanic gas pipe suddenly, the change in the iron oxides of the glaze may be equally sudden, and a whole cavern may be caused to glow by the access of air alone.

The illustration on the first page shows the East Cone here described at a time when the liquid lava was about 15 feet down. The second illustration shows a similar cone that developed over a crack about 500 feet away from Halemaumau in the direction of the desert to the southwest in the spring of 1921. This cone it was that displayed several times an extraordinary revival of glowing through access of air below while its walls were still hot.

This second cone was called the Rift Oven of the Red Solfatara. It was over the great deep crack that leads from Halemaumau radially down the mountain to the southwest. The two long, black gashes standing vertical in the present wall of Halemaumau as seen by tourists to the left of the visitors' station are where this rift emerges into the pit. It can be readily understood that if lava now rose into those tunnels by the filling up of the pit, and a vertical shaft outside of the pit led from the uppermost tunnel to a cone on the surface, that the gases from the boiling lava in the shaft would heat the cone. This was exactly the situation of 1921. The cone breathed and puffed, lava was visible far down the shaft, pale flame played around the orifice, and sulphurous gas was given off.

There was direct connection between the lava in this well and the lava lakes in the pit, but often the lava in the well by reason of gas frothing would stand much higher than the same liquid in the open pit. The gases kept the well at bright orange glow and maintained the stalactites, even when the heat from the open lakes and the glow above the pit decreased strongly. With the liquid lava 200 feet down the well in April, 1921, the glow was maintained up to the top, in a shaft 10 to 15 feet in diameter, by the action of burning gases. Finally there came a time, however, when the interior of the oven became dark red and even black and the stalactites were seen to be a silvery gray with the black oxide of iron. The hot gases continued to rise.

Now came the extraordinary and dramatic demonstration of what air could do in heating up a volcanic furnace. All this time the lava lakes in Halemaumau had been above the level of the wall tunnel. In July the lava lakes lowered below the tunnel so that a black cavern or arcade could be seen, just as at present, leading into the wall at the southwest. Immediately an air blast, smelling strongly of sulphuric acid came rushing with a roar up the outside well, where quiet gas had been rising before. The shaft, oven, stalactites, and the entire lining of an adjoining tunnel all began to glow again, the tunnel walls becoming red hot away out to its remoter entrance 150 feet away from the rift. Incandescent sparks were visible after nightfall in the blast. Then the furnace cooled off again and within four days the wells and the tunnel were dark, but the steel-gray glaze of magnetic needles of iron oxide, the common lining of such caves, had changed to brick red. T. A. J.

KILAUEA REPORT No. 937

WEEK ENDING JANUARY 5, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The current report on volcanic conditions in Hawaii overlaps the preceding one by two days, as it introduces a new series of weekly reports ending at midnight Sundays. This is for convenience in the new series of the Volcano Letter, beginning 1930, prepared at the station on Mondays instead of Wednesdays.

For the week ending January 5, 1930, there is little change in Halemaumau pit. On December 30 part of the July fountain heap had slightly fallen in the middle. There is remarkably little steam emerging from the floor and talus slopes, in spite of recent rains. This is in contrast to the rim cracks outside of the pit, which on January 1 at 2 p. m. sent up much vapor. Much fine material was observed lying thickly on the talus at the north. January 3 much steam arose from the pit, in general blending with the clouds above, and from the cracks of the Kilauea floor. At 9:30 a. m. January 4 there was more vapor at the Halemaumau vents, particularly on the south wall.

Eight very feeble local earthquakes were recorded by the Observatory seismagraphs, and five of these indicated average distance of 44 miles, corresponding as heretofore since September to the distance of Hualalai from the station. One very feeble shock indicated distance of origin 19 miles.

Microseismic motion for the week was slight, and tilt accumulated strongly to the southwest. This tilt is characteristic of the seasonal curves for January.

HAWAIIAN VOLCANOES IN 1929

The end of 1929 finds the Hawaiian volcanoes quiet, but the year has produced three notable activities, two of them volcanic eruptions and one a seismic spasm of extraordinary quality. The first was the influx of new lava in the bottom of Halemaumau in February, following upon similar fillings of the bottom in July 1924 and 1927, and in January 1928. The second 1929 event was a similar influx in July and each of these eruptions of lava leaves a new floor higher than before so that the pit has decreased some 300 feet in depth since June of 1924.

A curve platted to follow the progress of these fillings of Halemaumau in relation to the lapse of time indicates decrease of interval between eruptions, so that the expectation was recorded that lava activity might return in the autumn of 1929 unless the magma were to rise in one of the other volcanoes. There are three of these which are potentially active, Mauna Loa, Hualalai, and Haleakala.

The seismic spasm which began in September and has continued, dwindling, ever since, appeared to confirm this expectation. The evidence of locality points to Hualalai. The shaking was violent in North Kona, reached its maximum October 5, and now has become very slight, but still shows signs of life. The indication is that the underground lava column at the Mauna Loa center, which for many years has vented itself to the southwest, is now pressing up along rifts extending toward the northwest and may eventually find release there.

Meanwhile nothing new has happened in the craters of Kilauea and Mauna Loa. The July lava in Halemaumau pit at Kilauea Volcano solidified with some shrinkage, leaving the scar of its big southwestern fountains in a built-up heap surrounded by pumice and shaped like an armchair, and leaving what was the lake area a lumpy floor surrounded by a rampart. The only changes have been falls of rock from the walls of the pit slightly overlapping the new lava floor with their debris.

Seismic phenomena local to Kilauea have not been remarkable during the last part of the year, and there is nothing in tilt, tremor, or earthquakes indicative of a change of magmatic action under Kilauea Volcano. The avalanching at Halemaumau in December has been remarkably slight. T. A. J.



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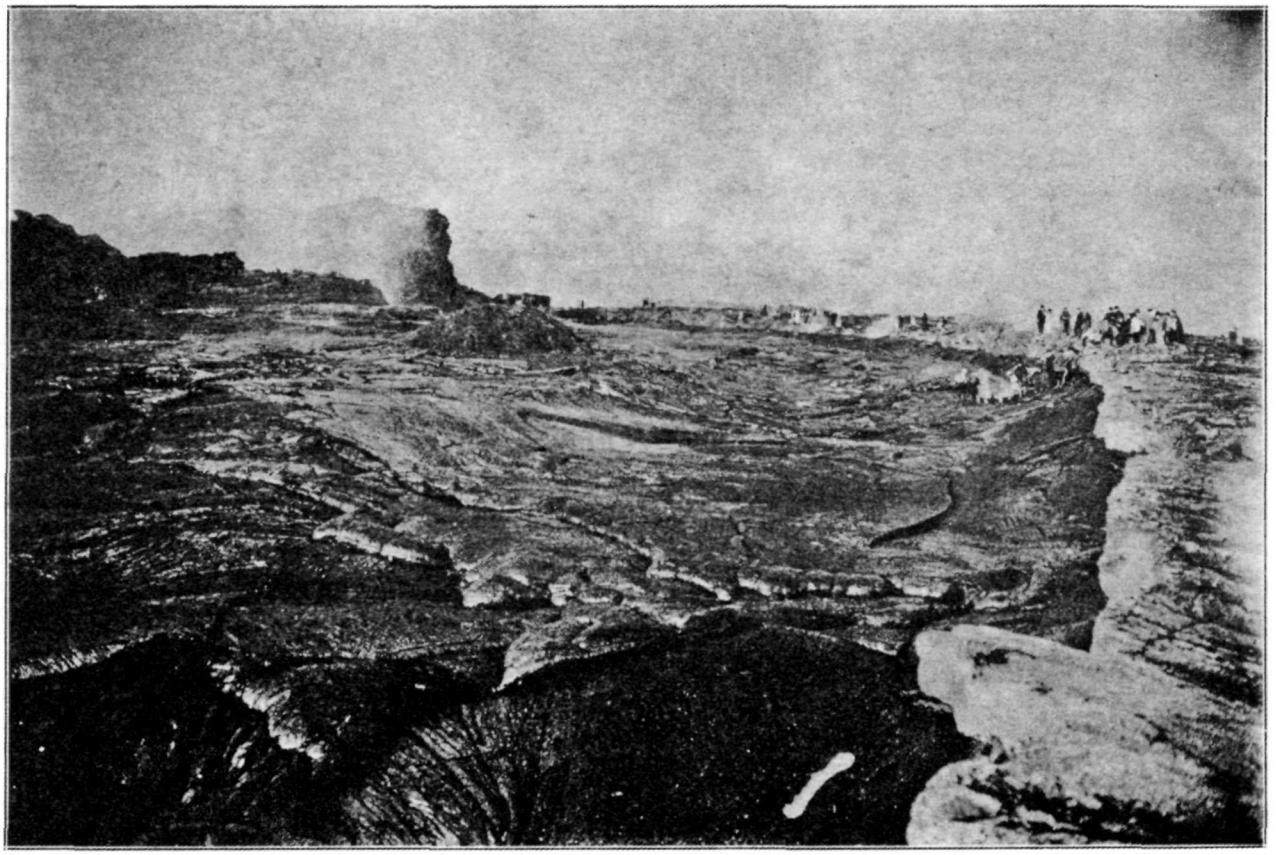
The Volcano Letter

No. 264—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 16, 1930



The southeastern rim of Halemaumau on February 22, 1918, the day before the pit overflowed the road terminus. The light ground at the right is the rim, the dark foreground is the overflow lava of the fountaining lakes, which are among the crags at the left. The rim rock shows no swelling.

THE SWELLING OF VOLCANOES

The edge of Kilauea Crater is a live place, no matter what the eruptions are doing. The ground under the Observatory and the hotel is always tipping away from the center of the crater, or else tipping back again. The ground at the edge of the firepit, always visited by the tourists, tips back and forth still more strongly than the rim of the greater crater. The ground between Volcano House and Hilo actually rose by amounts measurable in feet between 1912 and 1922 and sank by similar amounts at the time of the great engulfment eruption of 1924. This engulfment enlarged Halemaumau pit, by caving-in of the rim, some 700 feet outward on all sides. There is thus a cycle of swelling and shrinking in a volcano, and this note is to call attention to the gradations of swelling which have been studied by the Observatory.

Measured Tipping of the Ground.

Tipping of the ground is one of the subjects studied with pendulums at the Hawaiian Volcano Observatory. This means that the flat floor of the seismograph cellar tips a little each day back and forth. Accumulated tilting in a week becomes a real change in the plumb line. At the edge of a sink crater in the top of a lava dome over red-hot lava a little way down—such is the situation of the Observatory—it may be readily understood that when molten lava pours forth from the pit inside of the crater, an increased heat and pressure inside the mountain is developed. The effect of this should be a small swelling up of the mountain, measurable as tilt away from the center. Just such tilt was measured on the seismographs during the years leading to the great overflows which built up the Kilauea floor between 1918 and 1921. And the reverse of this, a strong, sudden and large inward tip toward the center happened in 1924 when the lava sank away. This was accompanied by collapse of the pit and the famous steam-blast eruption.

Visible Swelling at the Pit.

But this swelling of the volcano at the edge of the pit itself was so tremendous that it actually became visible. We are now speaking of Halemaumau, the inner pit of the Kilauea sink, more than two miles from the Observatory, and itself the crater of the domed-up inner floor of the large sink. The first illustration shows the southeastern rim of Halemaumau on February 22, 1918. The crowd of people is clustered on the rim, and a few of them have stepped down and are walking on the shells of new hardened lava which by rising has just reached the rim level.



At this time, December 28, 1920, great outflows poured from Halemaumau through the breathing rift cones just outside. This picture shows the Red Solfatara, with bright orange and yellow sulphur and selenium, in foreground, and flows around the cones.

It is as though the present floor which tourists see one thousand feet down were up to the level of the rim station.

This picture was taken the day before the inner lava overflowed the rim. The black crags on the left are adjacent to the lava lake, and represent blocks of the overflow benches of the lake which had been uplifted. There is a rectangular stone shelter on the rim of the pit in the background, and this was the principal tourist station of that time. The lake of slag was boiling and fountaining as a large puddle of molten stuff, generally in clover-leaf shape, off to the left of the picture, with risings and fallings from hour to hour which made the black fill in the foreground.

At this time the light-colored rim of the pit on the right was rising. The rise only showed as a faint tip away from the center. Then came the overflow which sent a torrent of candy-like lava a half mile away over the automobile road, and the inner floor of the pit swelled up into more crags. Within six days the old rock of the southwest rim of the pit had been pushed up nine feet in a ridge showing the profile of a half arch on the outer side, while the wall inside remained upright. This old, hard rock moved like broken wax. A year later came another spasm of swelling extending the pressure ridge for several hundred feet around to the tourist station. A six-foot leveled platform of concrete used as a surveying station was tipped back 45 degrees until it fell to pieces. By August of 1919 a similar leveled concrete platform 100 yards back from the rim of the pit on the north side was tilted away from the center 10 degrees or more. Meantime there had been numerous overflows and gushings of lava up cracks back from the rim of the pit. It was clear that in fissures of unknown form the underpinning of the floor of the greater crater was surcharged with lava that caused it to swell.

This whole period of 1919-20 was a time of repeated risings and outflows about Kilauea Crater as a center. The pressure ridge around the south rim of Halemaumau became a great feature 15 or 20 feet high, and persisted until a deep collapse occurred in April, 1921. Our second picture shows the same rift cone that contained the glowing stalactites in the second illustration of Volcano Let-

ter No. 263, but at this earlier time the cone vent was vomiting out lava flows and burying brilliant colored deposits of alum, epsom salts, selenium and sulphur. This cone was over the deep crack leading from Halemaumau to the southwest, and about 500 feet from the edge of the firepit.

The illustration on the last page is a photograph of the first concrete monument above referred to. It shows the round surveying station on the old rim of the pit actually heaved up into the air and tipped back, so that all the ridge which extends across the picture had been the flat edge of the pit only two weeks before. The observer is looking toward the pit.

A Pendulum Set up at Halemaumau.

All this evidence of visible swelling when the lava was high made it interesting to place at the rim of the pit a machine to microscope such movements. A seismograph pendulum was set up in a stone hut a few hundred feet back from the tourist station at the southeast rim of the present big cauldron. A horizontal pendulum is somewhat like a barnyard gate. The boy sitting on the gate corresponds to the lead weight. If the gate post is tipped away from the pasture, and the gate is unlatched, the boy swings out toward the road. Just so it is with the pendulum at the crater, with a hinge at one side, attached to a concrete post, and the gate-like pendulum hung parallel to the edge of the pit. If lava comes into the bottom of the big pit so as to swell up the whole dome floor of the larger Kilauea Crater, the pendulum should swing away from the center of the pit. If the bottom of the pit collapses, the pendulum should swing toward it.

The pendulum at Halemaumau writes all day long on a sheet of paper which is pulled under its pen by a clockwork. If the pendulum swings away from the pit the written line shows it, and the amount of the swing may be measured for any hour of the day, and for any day of the year, by the position of the line on the paper. To revert to the boy on the gate, if an automobile were dragging a sheet of white canvas along the road, and the boy on the open gate dug his muddy heel into the canvas, the mark would show how much the gate was open. So it is with a seismogram.

The outbreak of lava far down in Halemaumau February 20, 1929, wrote a complete autograph on this instrument, 1,100 feet above it and at least half a mile from the center of fountaining. First there were little earthquakes written on the instrument and then a tipping of the ground away from the pit. The moment the lava fountaining began, the seismograph pen started writing a strong back-and-forth line like a tremulous invalid, and the tipping stopped. This tremor continued and became excessively strong toward the end of the two days' activity, and then the tipping began to go in the opposite direction, namely, toward the pit. This tipping and tremor continued up to the moment when the fountaining stopped, when the line became smooth and straight. These sheets of paper taking the pulse of an active crater for the three days, February 19, 20 and 21, 1929, are epoch-making in the history of science. They prove that a microscopic record of a lava outbreak may tell the story with perfect fidelity.

Swelling and Shrinking on a Large Scale.

We have seen that the visible gushing lava swells and shrinks its containing vessel, that the mountain top swelled and contracted during the cycle of activity from 1913 to 1924, and that these things were measured by instruments designed to show the trembling and tipping of the ground, and measured also by the careful methods of the surveyor. These last made use of the telescope, the level bubble, and the exact determination of mean sea level at Hilo with the aid of the tide gauge.

When the traveler gazes at the pure curve of the dome of Mauna Loa, he may well make inquiry, "How much of that is swelling?" This leads to the question, "How large a part do swelling and shrinking play in the mechanism of building active volcanoes?" And going still farther to such a region as eastern Japan or western California, where volcanic heat is still rampant and where great earthquakes occur, he may well ask, "Does not this mechanism of volcano swelling, deep under the earth's crust, play an important part in the uplift of the shore lines in both these uplifed lands?"

In Hawaii itself the question of large scale uplift and breakdown of the islands is of intense interest both geographically and with respect to the passage of time. The geographic evidence is the astonishingly regular gradation of height or uplift of the islands as we go from east to west; Hawaii is the highest and contains the active volcanoes; Midway Island, far away at the west, is a tiny coral reef. In between there are intermediate islands containing old volcanic rock. The time evidence shows that Kilauea at the east, among the active volcanoes, almost continuously ejects liquid lava, but is breaking down along its shore line. Mauna Loa, next to the west, is less continuously active, and Hualalai, farther west, has still greater intervals. Haleakala, the last of the four volcanoes with an active record, was probably last flowing very long ago, about 1750, and its crater is a more broken structure. In time and space the Hawaiian Islands are swelling and swollen at the east, and shrinking or shrunken at the west. T. A. J.

KILAUEA REPORT NO. 938

WEEK ENDING JANUARY 12, 1930

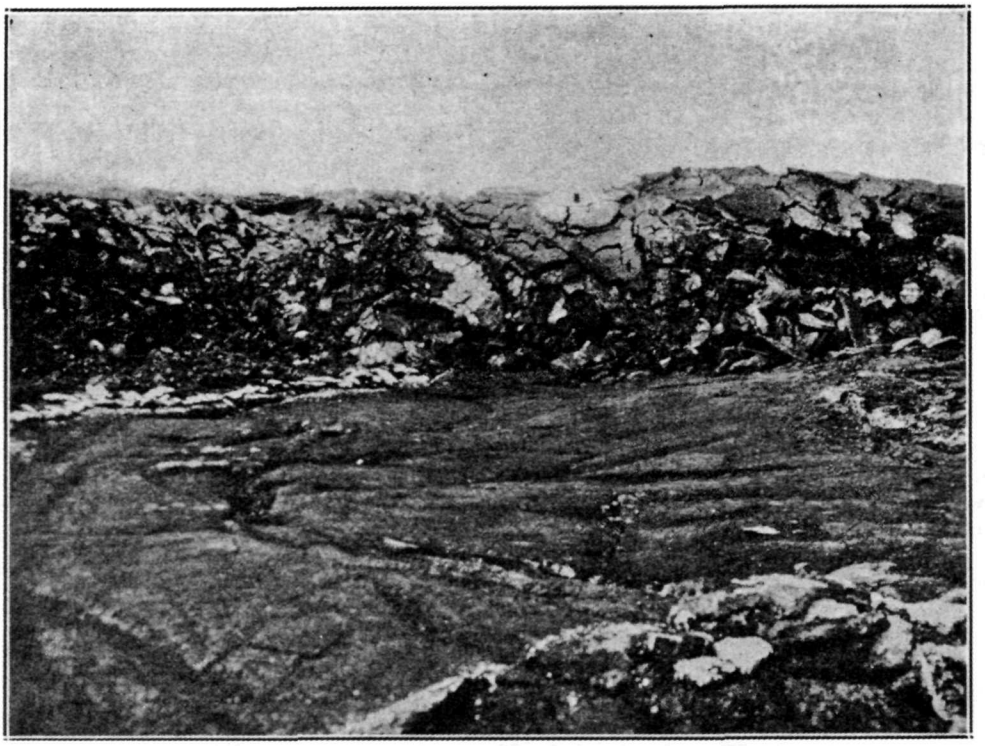
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The Hawaiian volcanoes remained quiet, fresh snow was observed on Mauna Kea and Mauna Loa when the mountains cleared January 8, and on Hualalai an odor of spicy sulphur was noticed by the foresters near the western summit January 7. A similar odor had been perceived there by the forest ranger December 31.

At Halemaumau dust from a slide at the north side of the pit was observed during the forenoon January 8, and the wall there was afterwards seen to be grooved from the loss of fresh debris, which lay on the talus below.

The seismographs at Kilauea Observatory registered 19 local disturbances for the week, of which 12 were tremors, lasting each from 15 to 45 seconds, and seven were very feeble earthquakes. One such earthquake indicated origin distance 52 miles, time 6:08 p. m., January 8. This probably centered in North Kona. Microseismic motion for the week was slight, and tilt was slight to the southeast.



The rim of Halemaumau, looking straight toward the pit. This photograph, March 6, 1919, shows southeast surveying station tipped up away from the pit on a pressure ridge 15 feet high. The swelling had begun suddenly February 25. Photos Jaggar.

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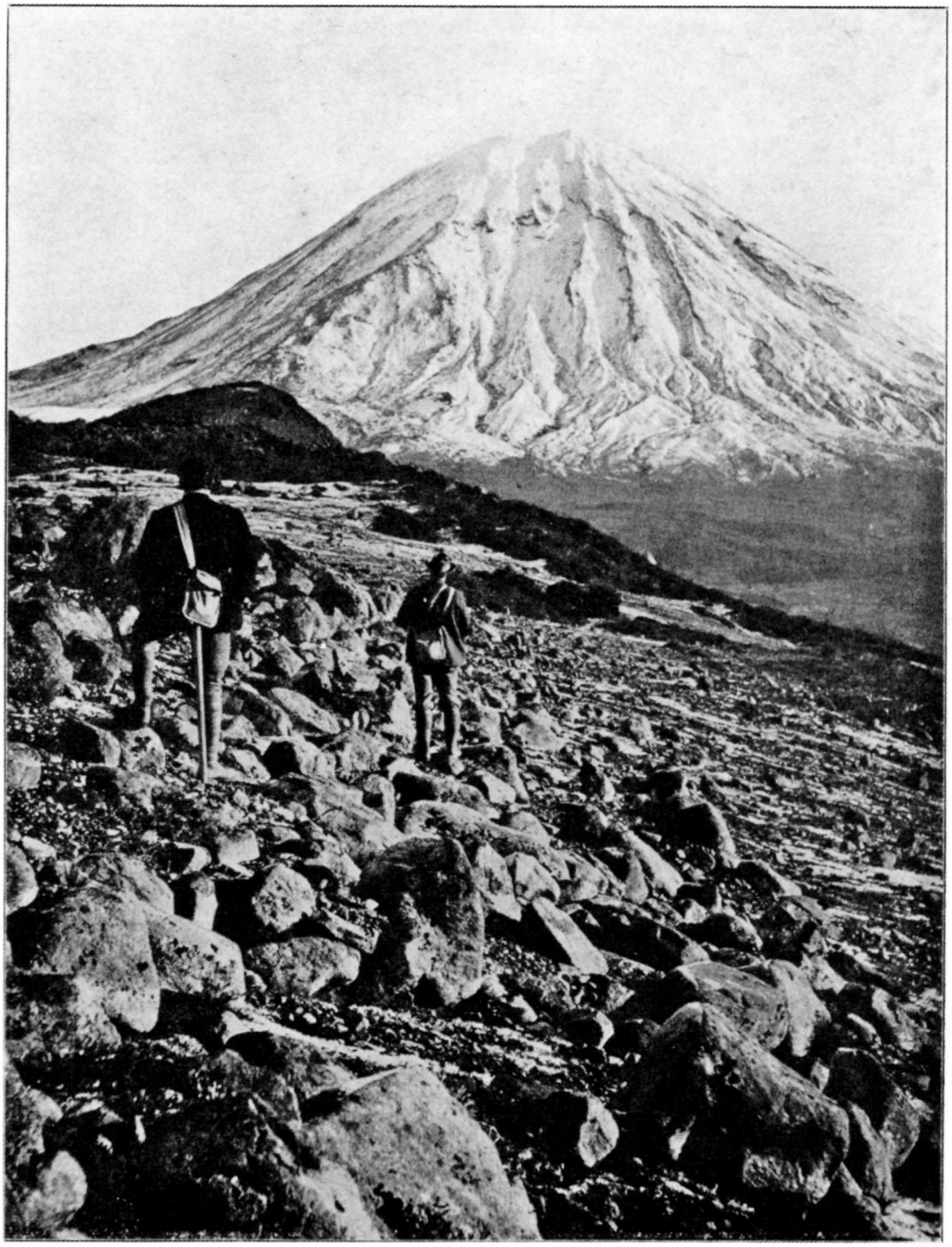
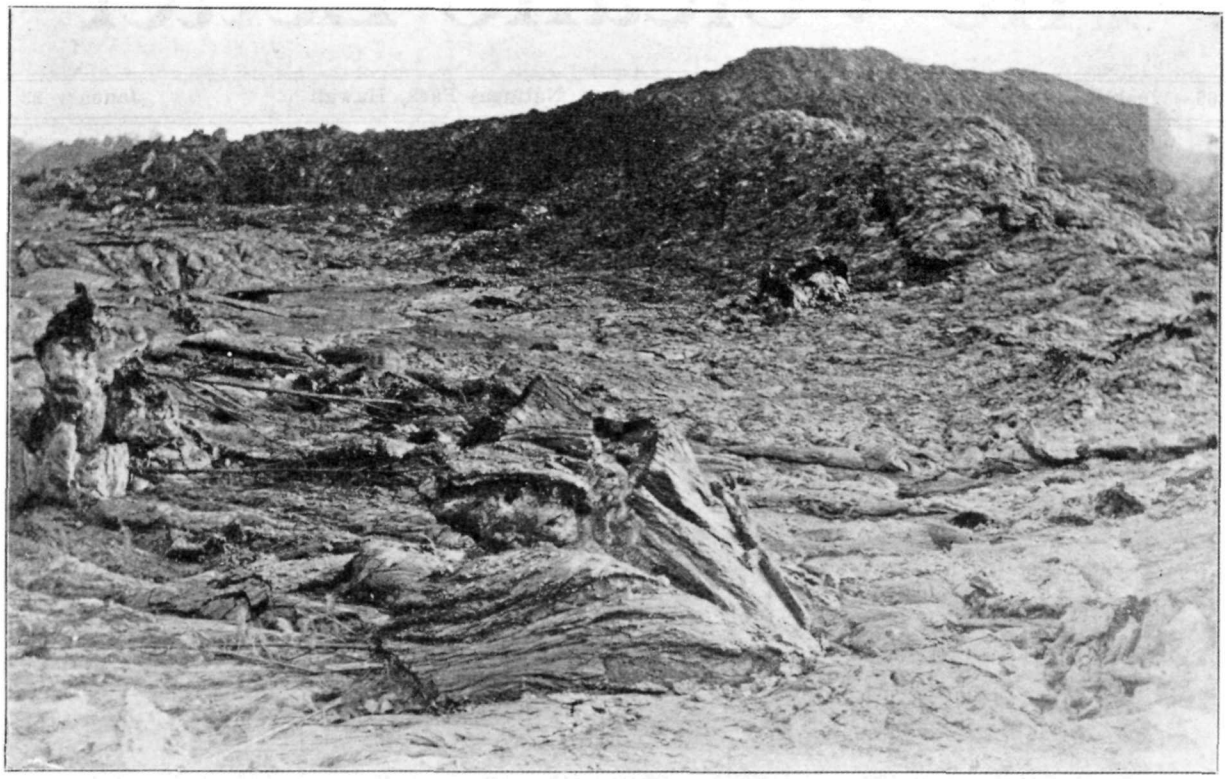
No. 265—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | January 23, 1930



Ngauruhoe Volcano, New Zealand National Park, as seen in winter from the Eastern side. This is the most active of the splendid volcanic cones of New Zealand, a nd was throwing out rocks and had glowing lava within its crater in March, 1928. —Photo Malcolm Ross.



Fresh Pahoehoe Lava on Niuafou, 1913. There has been much controversy about whether historic lava flows have occurred in the Tonga Islands. This photograph, with fresh source cones and ropy basalt of 1912, when there was an eruption near Futu, settles the question in the affirmative. Photo from Captain Crawford, Canadian Australasian Steamship Company.

VOLCANOES OF NEW ZEALAND-TONGA BELT

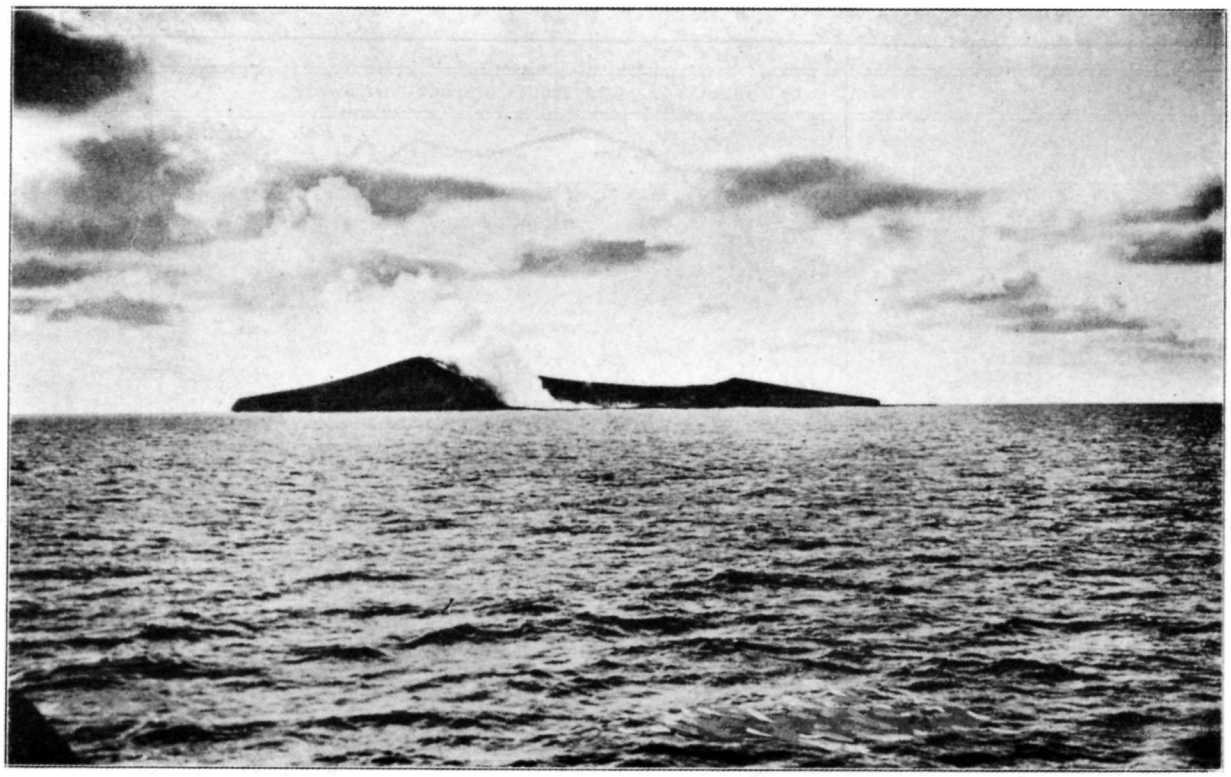
The recent disastrous earthquake in the mountains near Murchison, at the northern part of the South Island of New Zealand, makes the study of rift lines or faults carried out by the New Zealand Geological Survey of great importance in connection with the meaning of volcanoes. Mr. L. I. Grange, of that Survey, has been making a detailed geological survey of the active volcanic zone of the North Island, and believes that the area of greatest interest for earthquakes and volcanoes is the 72 miles in a generally NNE direction between Lake Rotorua and Lake Taupo. An active fault, the Paeroa Rift, has been located through the volcanic district trending northeast in the direction of White Island from Lake Taupo, and if this fault were projected southward 200 miles it would go through well known earthquake centers in the western part of Cook Strait, and then pass through Nelson. If projected it would pass close to Murchison. The big displacement which has been studied at White Creek is eight miles farther west. The New Zealand geologists do not connect the fault movements of the South Island with anything but mountain-building forces. There are no volcanoes in the South Island. But large, active faults of both islands trend NE-SW, and the possibility should not be overlooked that deep volcanic faults with intrusive magma extend under the southern mountains.

This relationship makes the volcanoes of the New Zealand belt worthy of review. Along this great crack south of Lake Taupo lie the three big volcanoes Tongariro, Ngauruhoe, and Ruapehu, the last farthest south. These are in the National Park. Ngauruhoe is 7,515 feet high and has had eruptions 11 times since 1839. Its eruption of March, 1928, was reviewed in the Volcano Letter (No. 216, February 14, 1929).

The crater of Ngauruhoe has recently been described by F. W. G. White, and the inner crater has been continually changing. The walls of the outer crater are very precipitous, and in 1896 there was a hole on the southwest side of the level floor of the main crater. Earlier there had been an inner crater toward the northwest, and this all suggests what is so common in Hawaii, that the central level floor is the top of a lava plug, and that the gases of explosive eruptions churn out their vents around the wall crack at the borders of this plug. The southwest hole has become enlarged to be the principal center of activity.

In January, 1929, the activity was so slight that White went to the bottom of the innermost pit. The old northwest pit had become a rounded depression covered with ice. The walls of the southwest active pit were partly precipitous. In a conical hollow on the northeast side, Grange had seen lava in this pit in 1928. Its slopes were now steaming and there were two holes in the bottom from which hot air was issuing, each a foot and a half in diameter. The remainder of the bottom was covered with sandy material washed in among bowlders, and there was very little sulphur in the crater. The only other solfataric place that was steaming was well up on the edge at a rock projection east of the northern lip of the outer crater. The crater contained more ice and showed less activity than usual, at the time of White's visit (N. Z. Jour. Sci. and Tech. June, 1929, p. 48).

As has been pointed out in the review of J. Allan Thomson's admirable summary of the New Zealand volcanic belt (Volcano Letter No. 158), the question of lava flows from Ngauruhoe in 1869 and 1881 has been disputed. An aa flow now at the foot of the mountain is attributed to the 1869 eruption, and inside the conelet of March, 1928, wholly within the crater, Grange saw red-hot lava that appeared viscous, with blue smoke escaping through it with a tremendous roar, which flung up red-hot fragments 50 feet. The presence of lava in the center is thus unquestionable. The great explosive disaster at Tarawera Volcano in 1886, in the North Island, about midway between the active volcano White Island in the Bay of Plenty and the National Park group of volcanoes, has given New Zealand the reputation, like Java and Japan, of producing chiefly ash explosions. In all three of these lands we are learning more and more that andesitic and



Falcon Island, reported to have disappeared in 1913, reappeared with a violent series of explosions October 4, 1927, building up basaltic ash, scoria, pumice and lava blocks to make a cone and crater in the Tonga Islands. Photo from Andrew Thomson, Apia Observatory.

basaltic magma, or underground lava, which occasionally comes to the surface, is the prime mover of volcanism. but does not flow out so freely as in Samoa and Hawaii.

It seems likely that if we could know of all the submarine lava flows which come out through cracks in the bottom of the sea, between New Zealand and Samoa, we might discover that lava outflow is not so rare as has been imagined. The photograph reproduced on the second page is quite like the lava flows of western Samoa, and this unquestionably was pouring over the surface of the Island Niuafou in 1912. The description of the 1929 eruption of Niuafou, which follows this article, leaves no doubt that lava flow is characteristic of this island, and Niuafou is not more than 250 miles from Savaii where the great lava floods of western Samoa occurred in 1906-11.

The recent eruption of Falcon Island (Volcano Letter Nos. 151 and 210) has been newly reviewed by the investigators who studied it for the Bishop Museum (Amer. Journ. Sci. Dec. 1929, Falcon Island, by Hoffmeister, Ladd, and Alling. See photograph this page) to the effect that the great volcanic crack in the earth's crust which has piled up the line of Tonga-New Zealand volcanoes, starts at Savaii and extends across Cook Strait into the South Island of New Zealand. The formations along the line are said by Park to be "broken, sharply folded, faulted, sheared and up-tilted" Niuafou lies off the line to the west 150 miles, but it is doubtless part of the same system. These explorers of Falcon Island reach the conclusion that many of the atolls, or horseshoe-shaped coral reefs of the southwest Pacific, may have been started by corals and other organisms building on a circular bank built up by a temporary volcano such as Falcon and later cut down by the waves. It may be added that while such volcanoes exhibit chiefly fragmental material, it must be remembered that a pile of solid lava in the form of a dome probably exists beneath. How an outflow of liquid lava like one of the Mauna Loa flows, would behave under deep, cold water is a matter of theory, not of observation.

ERUPTION ON NIUAFOU, TONGA ISLANDS

Niuafou is a roughly circular wooded island about 20 miles in circumference in the middle of the triangle of ocean between Fiji, Tonga, and Samoa. It is about 600 feet high. There are many craters, including a large main lagoon near the center of the island, where there are hot springs. The shoreline is worn into lava cliffs.

There is difference of opinion as to whether lava flows have occurred; Sapper cites destruction of villages by lateral lava flow in 1853 and 1867 (Vulkankunde, p. 336). Thomson allows only explosive eruptions (N. Z. Jour. Sci. Tech. 1926, p. 369) as the 1886 outbreak destroyed the coconuts and covered the surface with 2 to 20 feet of ash.

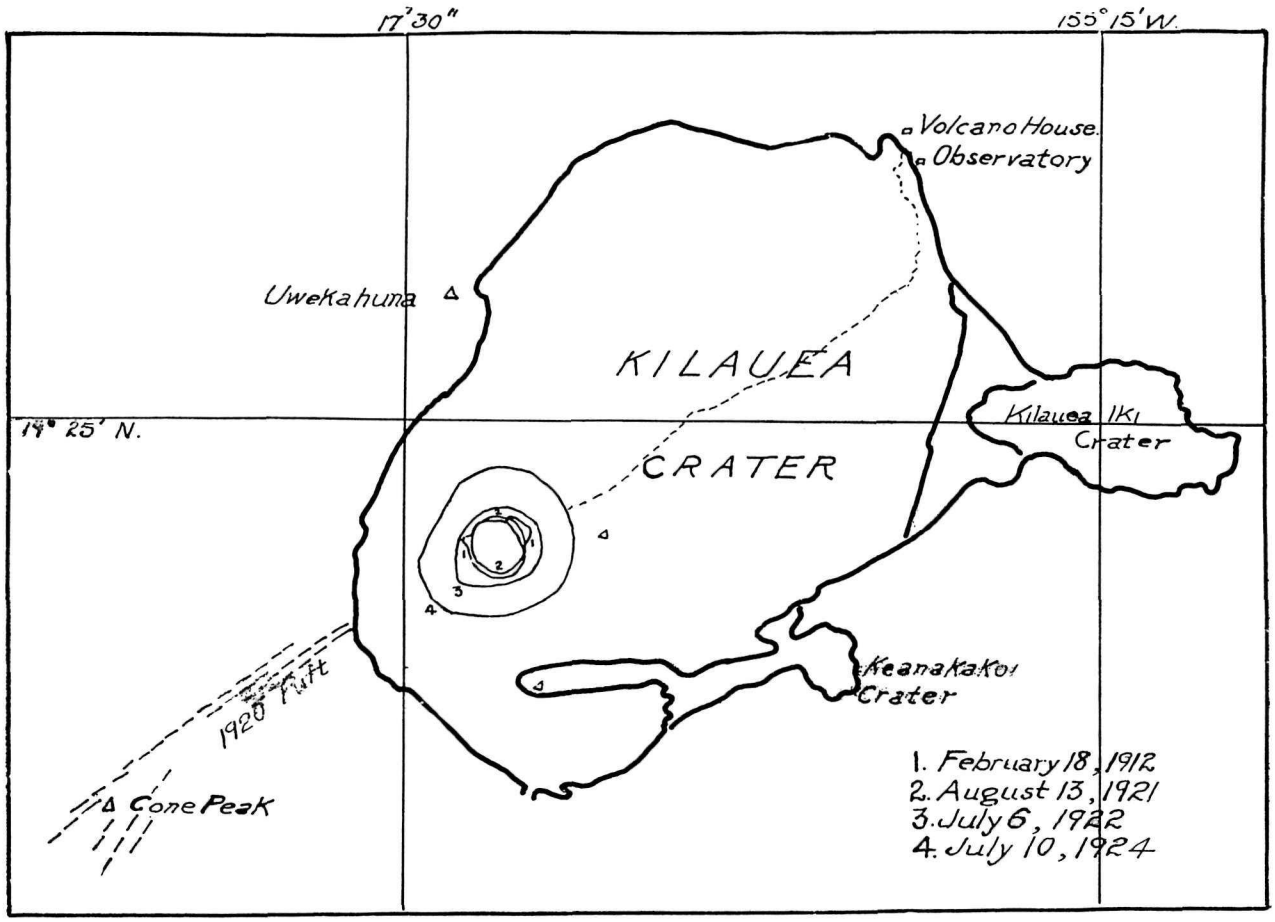
In spite of 5 eruptions in 115 years, Niuafou has nine seaboard villages with a population near 1,000, and belongs to the Tongan monarchy under British protectorate.

The last eruption was in 1912, when 30 craters were in action between the lagoon and the strandline near the village Futu, on the west side of the island. Pahoehoe lava flowed into the sea. Of this we possess a photograph taken in 1913, (see second page).

The new eruption July 25, 1929, was similar and wrecked Futu. It began at 4 a. m., overrunning a long strip of coast a mile wide. Copra crops, houses, horses and pigs were burned and buried.

Three craters burst open without warning to the south of Futu. The populace hurried to Agaha, the larger village at the northwest, and took refuge on the high ground back of it. Their discomfort was increased by rain and wind.

The correspondent (Auckland Star, Aug. 6, 1929) climbed on horseback to Hala-gutu, the high lip of the interior crater lake, and saw that a chain of craters was forming along the low coast land. Each vent belched out molten rock and deep red flames. "Among the clouds and swirls of smoke and fumes were to be seen streams of lava thrusting their way in tortuous twists and turns through the rich vegetation, scorching it to brown and black cinder."



The recent enlargement of Halemaumau Pit, the inner lava cauldron of Kilauea is here shown. The lava rose and overflowed, and the pit grew smaller, for outlines 1 and 2. The pit enlarged by collapse for 3 and 4.

The smoke cleared July 26. At the extremity of the flow 40 acres of new ground had formed, altering the contour of the coast line. Halfway between there and Futu, goats were marooned on a new islet. Sulphurous fumes were bad, but the explorer with his two native companions finally reached the ruins of Futu by boat. The village site was a field of smoking lava, only a third of the habitations escaping destruction. Native houses were found battered to the ground by the hot wind blasts. Numbers of animals, including horses which had broken tether, were found alive in the village remnant. The stone Roman Catholic church was burnt out, and the lava had flowed round a cemetery, leaving the stone cross intact in its center. The Wesleyan mission church escaped. No lives were lost.

The foregoing account is sufficiently definite and circumstantial to indicate that this eruption was a lava flow. There is no mention of darkness or ash fall. It seems likely that Niuafou is the crest of a volcano recently built above sea level, liable to both outflow and steam blast.

Niuafou is reported to have many earthquake shocks, "almost of daily occurrence" (Sydney Morning Herald, Aug. 2, 1929). These are attributed by the natives to their god Maui, rocking the island by his troubled subterranean sleep. It is hard to imagine a better place for the study of tilt and volcanic earthquakes, and this island is strategically placed for very interesting geophysical and oceanographic observations. There ought to be a seismograph station there with a permanent staff in close touch with the Observatory at Apia. T. A. J.

KILAUEA REPORT No. 939

WEEK ENDING JANUARY 19, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The week has produced no change in the Hawaiian volcanoes, new snow has fallen on the mountains, and in Halemaumau pit of Kilauea Crater all that is noticed is the presence of a few new scars due to slides along the north and northwest walls. On January 15 in the afternoon of a dry day there was almost no steam in the bottom of the pit, but in the forenoon of January 18, after heavy rain, much visible vapor rose from cracks. This is characteristic also of the outer floor of the greater crater.

The seismographs for the week ending midnight January 19 registered 10 local disturbances, of which five were tremors less than one minute long and five were very feeble local earthquakes, one of which indicated distance from Observatory 48 miles. A weakly recorded distant earthquake began 6:50 a. m., January 17 and registered for 4 m. 47 s. Microseismic motion was moderate for the week, and tilting of the ground was strong SW.

THE VOLCANO LETTER

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The Volcano Letter

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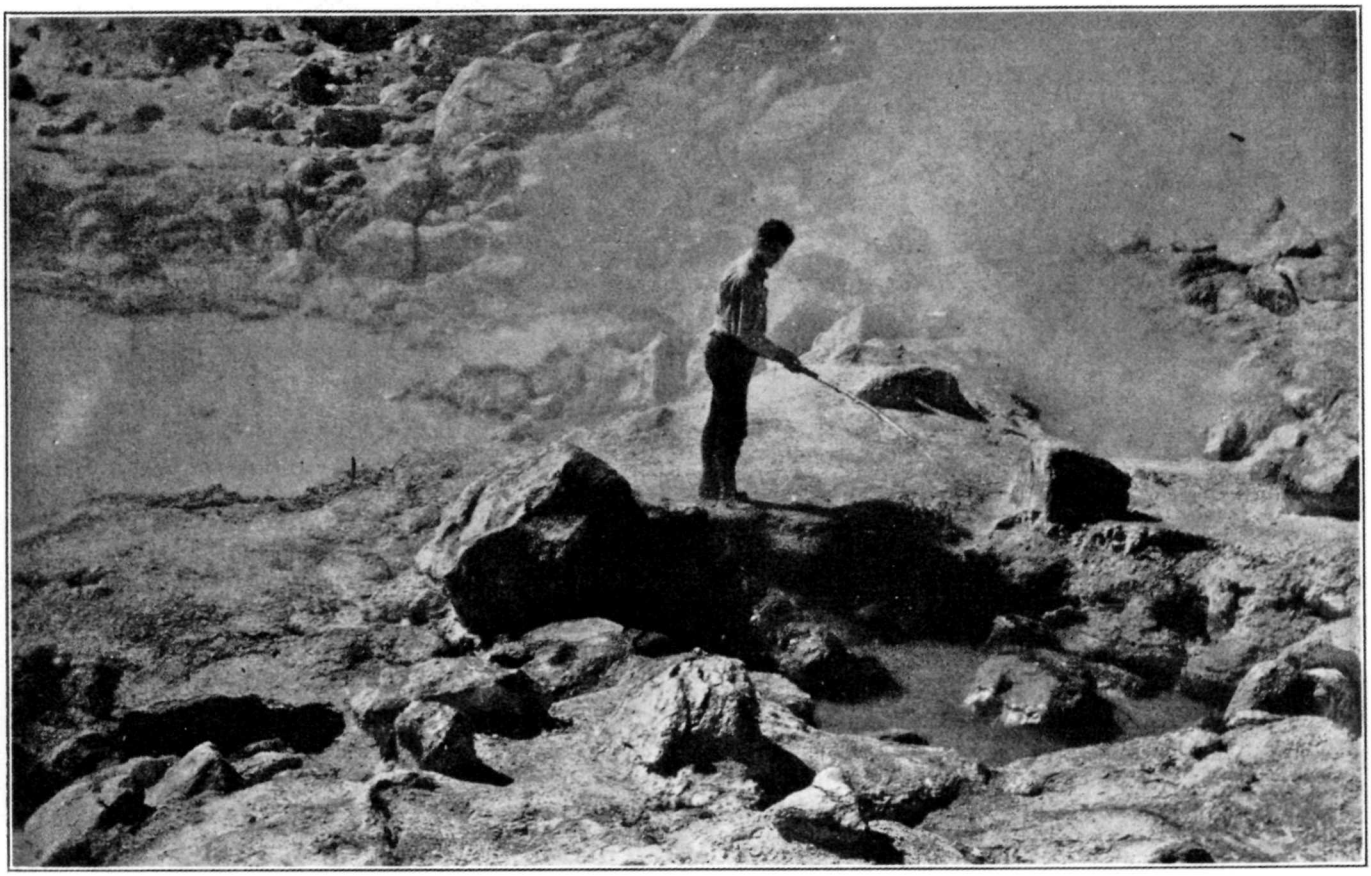
NO. 266—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | Jan. 30, 1930



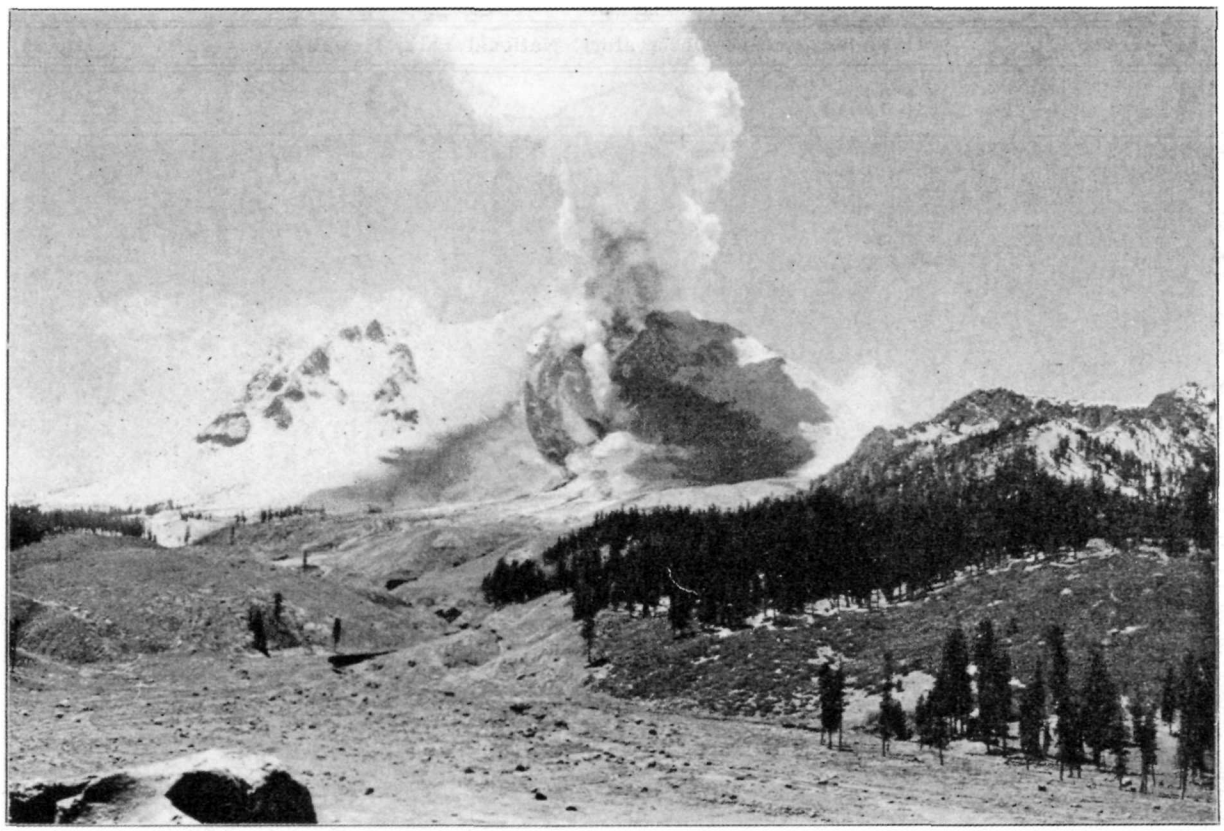
Bumpass Hell, one of the solfataras with boiling waters far up the slopes of Lassen Volcano in California. The pool is black because of a scum which overs it consisting of minute particles of sulphide of iron, or pyrite. The observer from Lassen Volcano Observatory is at work immersing a thermometer in the scalding waters. Photo R. H. Finch, August 26, 1927.

MUD FLOW ERUPTION OF LASSEN VOLCANO

On May 30, 1914, the old crater depression on top of Lassen Peak, a volcano in northern California, ejected dust and steam, the crater hole enlarged, explosions increased in number during the year, occurring every few days and rarely lasting more than 20 minutes. A big eruption occurred May 19, 1915, which devastated the creeks northeast of the volcano with a mud flood. Three days later, May 22, a much bigger explosion occurred, producing a down-rushing steam blast which overturned trees and cut a swath through the forest in the same direction as the preceding flood for at least four miles. The explanation of the mud flood has been problematical, as Lassen had no crater lake, as in the case of Mount Pelee in Martinique. Lassen was, however, covered with snow. The resident photographer and creator of the Lassen Museum, B. F. Loomis, believed that both Lassen eruptions gave vent to liquid water from within the mountain, a region of many hot springs, and that the water was followed by steam. (A Pictorial History of Lassen Volcano, Anderson, California, 1926.)

Dispute centers about this water question. Day and Allen (Volcanic Activity in Hot Springs of Lassen Peak, Carnegie Institution) attribute the flow to the melting of snow by the several agencies hot rain, hot volcanic ash, and a hot blast of gas. Day has shown that the mud flow started some distance below the crater rim. The flood originated in an embayment on the northeast slope of Lassen Peak that was uniformly covered by snow with a depth of several feet over most of the area. (See third picture on page 3).

It is hard to believe that hot water came out of the mountain in such volumes, but the writer agrees with Loomis that the evidence does not indicate the occurrence of a hot blast or any considerable explosion just prior to the mud flow of May 19, 1915 Except for a small flood below the western flow of aa lava that came out of a notch in the crater, the notheast flood was the only important one of this date. Even if there had been an explosion, any rain accompanying it would probably have been but little warmer than any other rain—certainly not hot. It is also doubtful under the conditions existing on Lassen Peak at



Lassen Volcano in eruption, photographed from the northeast by B. F. Loomis at 2:30 p. m., May 22, 1915, a few hours before the biggest eruption. Flood wash of May 19 in the foreground. Note the crateral gash, the cut in the snow, and the ash stain on the snow at the left. This is the critical picture. No sign of horizontal blast.

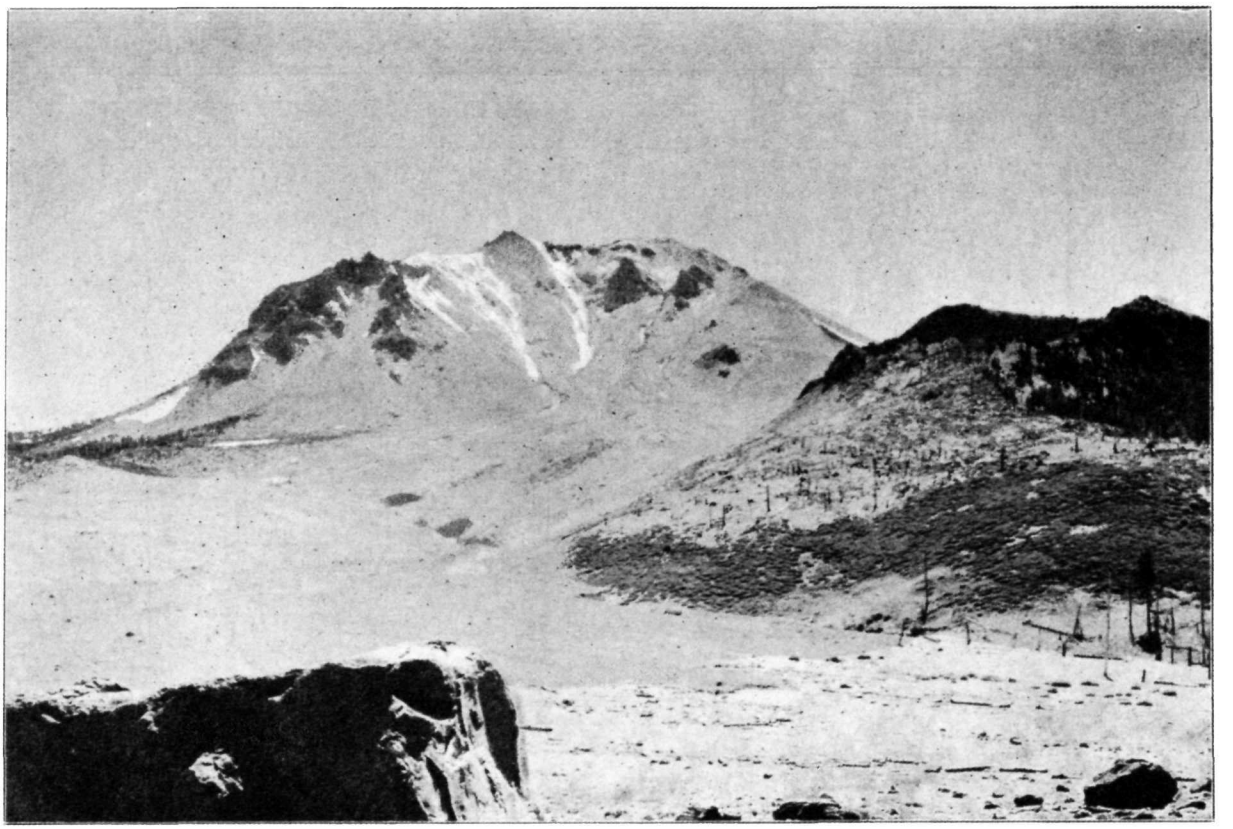
that time, whether a rainstorm unless of very unusual intensity, could cause a flood of the magnitude observed. If there were no explosion and no hot blast, then there would not have been any hot ash deposit nor warm rain.

It is true that the known explosions of May 22, 1915, three days later, produced several small mud flows. The behavior of rain on snow is worthy of some discussion. A few feet of snow of uniform covering can absorb several inches of rainfall so that the rain produces but little immediate run-off. If there had been bare spots in the snow field, water could have accumulated so as to run under the snow in considerable quantities in caverns and, in a place as steep as the Lassen slope, might have undermined so as to start avalnches. A hot blast, unless long continued, or a slight deposit of volcanic ash would produce much the same effect as a rain—a melting of superficial layers of snow and an absorption of the water by lower layers. A hot blast or a hot ashfall on a steep slope not uniformly covered with snow, could start streams under the snow as in the case of rain, and might thereby cause avalanches. It would seem that the Day and Allen theory of rain and ash may be questioned as a sufficient cause for the tremendous Lassen mud flow of May 19, 1915.

An examination of enlargement of the photograph (see illustration top of page) taken by Mr. Loomis immediately after the mud flow of May 19, 1915, and just before the maximum explosive eruption which occurred on the evening of May 22 (this photograph was taken at 2:30 p. m. that same day, May 22, and the great explosion occurred while the party was returning home), and of other photographs, and of the material transported by the mud flow, all indicates that a large volume of hot lava poured through this eastern notch of the crater where the V-shaped column of steam extends down the mountainside.

There is much new lava that was carried in fragments down the flood. The source of this at the flow in the notch was not only much more voluminous than the one through the western notch of the crater, but as would be expected it was probably as a whole more molten and less viscous. The lava flow could easily have melted the snow down to the ground and have sent a stream of warm water under the snow lower down the slope. An avalanche mixed with hot rock could have been started in this way and might have produced a flood of the magnitude observed, if great snowdrifts were present.

Minor mud flows did accompany the explosions on May 22, 1915. There was a horizontal component of this explosion that was parallel to the course of the upper part of the mud flow on May 19, 1915. The area affected by this blast was much wider than the area devastated by the mud flow of May 19, so that the blast encountered snow banks with exposed edges. The largest mud flow that accompanied this explosion followed the course



Lassen Volcano after it had quieted down, summer of 1924, showing linear remnant snowdrifts in summit gulches only. All the rest is the debris of May 22, 1915, and later, showing removal of the forest by the blast. Photo Loomis.

of the one on May 19th. Much hot ash was thrown out by this eruption, and at places where there was still a uniform snow covering, the mud flows occasioned by hot ash and possibly by mud rain at this time for the most part remained on top of the snow. R. H. F.

THE LASSEN MYTH

In 1915 the Lassen eruption awakened the public to the knowledge that this volcano is active. It was immediately dubbed "the only active volcano on the mainland of the United States". Nothing could be more erroneous.

Geologists have long known that the volcanoes of the northwest are potentially active. Tradition has it that Mount Saint Helen's and Mount Baker have both had eruptions in historic time. The Cinder Cone east of Lassen was well known to the Indians and to geologists as the maker of a modern lava flow within a century. Eighteen volcanoes lie along the Cascade fault in Oregon, and many more extend north through Washington into British Columbia. At Geyserville just north of San Francisco there is rushing volcanic steam under high pressure. This was in the epicentral belt of the San Francisco earthquake.

Mount Shasta or any of the volcanoes exhibiting fresh lava flows in the northwestern United States might erupt at any time. Intervals between outbreaks are long in continental volcanoes of this class, and the white man's history is short. T. A. J.

KILAUEA REPORT NO. 946

WEEK ENDING JANUARY 26, 1930

Section of Volcanology, U. S. Geological Survey

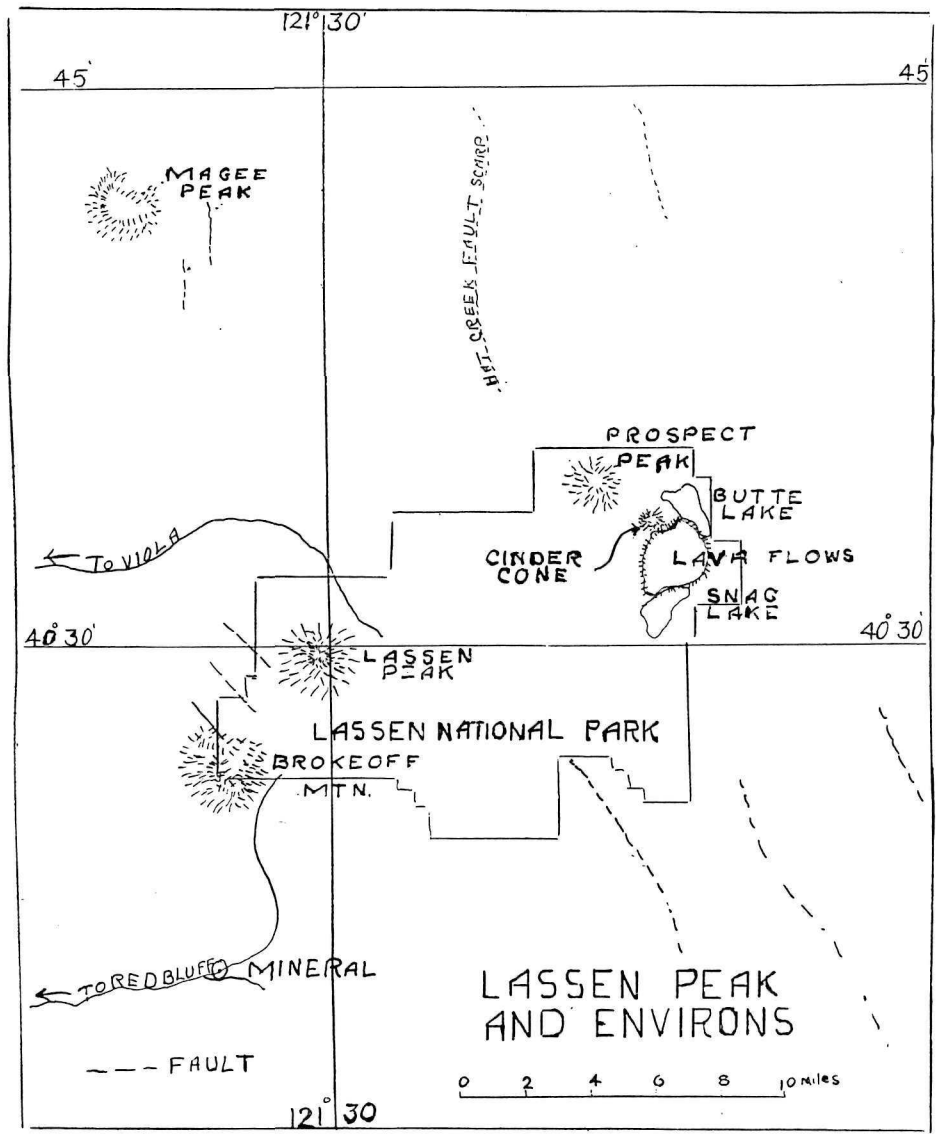
T. A. Jaggar, Volcanologist in Charge

There are still no changes in the appearance of the Kilauea fire pit to be construed as indicating lava activity. The volcano remains quiet.

On January 20 there was very little steaming. A new scar was seen on the northeast wall, caused by a slide. Early on the 22d considerable steam rose from the various Kilauea floor vapor vents and two large columns rose from the Halemaumau rims south and southwest. A new scar from a slide showed on the north wall. At 11:45 a. m., January 23, thin gray dust from an avalanche rose over the northeast corner of the pit. At 4 p. m. dust rose on the north side. On the 24th, at 6:15 and 7:30 a. m. more dust from slides was seen.

The instruments at the Observatory recorded six tremors and three very feeble earthquakes. One of the latter, occurring at 2:09 a. m., January 23, indicated 34 miles as the distance to origin.

Tilting of the ground at the Observatory accumulated moderately to the NNE. Microseismic motion was slight.



Sketch map of Lassen National Park showing position of Lassen Peak. Observatory is at Mineral, R. H. Finch in charge. The eruption flood devastated a sector due northeast from the summit in the direction of the Hat Creek fault scarp, making flood damage down Lost Creek due north of the mountain.

THE VOLCANO LETTER

The Volcano Letter combines, after January 1, 1930, the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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The Volcano Letter

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No. 267—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 6, 1930



New lava filling bottom of Halemaumau as seen from east side of pit, 5:30 p. m., July 9, 1927. Torrent pouring in from high cone on talus at the left. Three inflows have occurred, burying this floor, since 1927. Photo Tai Sing Loo, copyright.

KILAUEA'S LIGHTED FURNACE

Travelers do not realize, when they visit the silent, sleeping fire pit, that the live smelting furnace of Kilauea is ready for action at any moment. It is hard for them to imagine that it is possible for the liquid lava to spurt up through the rocks at the side of the black lava floor while they are watching, and without doing them any harm. The liquid lava of the inner pit never does anyone any harm. Pele comes back with the silent gleam of a beacon light at night, with only a wisp of vapor, and then the slag fountains wax in vigor and majesty. All of this happened twice, with magnificent fireworks, during the past year.

These demonstrations that the pilot light is always burning have occurred seven times since the summer of 1924. That summer the lava began to flow into the bottom of Halemaumau, two years later gigantic floods of lava streamed to the sea from Mauna Loa, and in midsummer of 1927 four beautiful fountains of fiery melt appeared in the bottom of the Kilauea fire pit. They came quietly in the midnight hours of July 6-7, sending up fume which reflected the glowing jets beneath. They covered up the earlier lava floor, and the liquid basalt spread out into a molten lake so as to drown the vents of two of the fountains. The vents lay in a line tending to be parallel to the great west cliff of Kilauea Crater. And this bluff in turn is parallel to the cracks that lead out into the southwestern desert. These facts mean that under the round craters there are straight fissures going down deep, and it is up these fissures the lava comes.

The first picture is looking toward the west from the eastern rim of Halemaumau near where tourists stand at present. It shows on the left the two new source cones of 1927, and the top of the higher one stood 122 feet above the level of the liquid lake below. This vent had broken out through the slide-rock slope far above the bottom of the pit. The picture was taken two days after the beginning of the eruption when 30 acres of new lava had spread over the bottom. The jets on the first day had begun with blue flames and rushes of gas, followed by light basaltic pumice with the gas jets, and this in turn became more viscous although all such lava is more or less a froth. At the fountain jet it is bright yellow, but the blobs of freezing froth which drop back on the cones change color to orange, scarlet, crimson, maroon, purple and black. By "freezing" is meant consolidating from a molten condition. The material is a true glass containing



Halemaumau bottom from the east, 8:15 a. m., January 11, 1928, when the two black flows had squeezed up cracks in front of landslip shown in background. Foreground is floor of July, 1927. Photo Wilson.

much iron oxide which gives the thin edges a greenish brown translucent color. The ingredients are silica, alumina, iron, lime and the alkalies as in the slags of commerce. The temperature is around 2,000 degrees Fahrenheit. The gases which maintain this temperature and are actually burning in their upward rush are hydrogen, sulphur and the oxides of carbon.

After the first day only the large southernmost vent (the left-hand cone of the picture) was visibly working, and after 13 days the eruption of 1927 ceased. It will be noticed from the picture how strikingly the process inside Halemaumau resembles a river and its delta. The molten streams meander and distribute on their flood plain and build lobes penetrating the hollows between the different talus slopes. Then the lower portion actually becoems a liquid lake, within ramparts of its own solidification, and when the eruption ends the slag pool loses gas and shrinks, leaving the ramparts standing up as a border, which shows in the picture. There is just such a border in the bottom of the present pit at the beginning of 1930, and this is remnant from the solidified pool of July, 1929. To return to 1927, the molten lake filled to a depth of about 80 feet, most of this pouring in during the first day, and the diameters were 1,760 by 1,420 feet.

The psychological effects on the community are characterized by intense enthusiasm, and a rush to see the fireworks, which is like the opening of a world's fair. In the early morning of the first outbreak in 1927 there were 50 spectators at Halemaumau, during the first day there were 1,800 visitors, and on succeeding days the numbers diminished to just such extent as the spectacular quality of the performance decreased.

When the lava sinks away after such a release of gas pressure, and the eruption comes to an end, there is a tendency to collapse of the mountain blocks which were held apart before. The walls of the pit lean inward and large rock slides occur from time to time; the eruption of July, 1927, came to an end on the 20th of that month and on July 24 slides were incessant and the air above the pit was heavy with dust. Also the mountain blocks grate against each other and this makes perceptible earthquakes. These local seismic movements do no damage and are mostly known only by the records of the delicate instruments at the Observatory. There are tremors all the time everywhere in the world. The volcano observatory is feeling the pulse of the ground, and the lists in the weekly Kilauea Report are merely adding statistics, that point the way to the meaning of the next outbreak of fireworks. There are quick-period tremors and tippings of the ground, suddenly increasing at time of outbreak. Other wise the tippings are seasonal as recorded for January, 1930, in this number of the Volcano Letter. (last page)

January of 1928 produced an upwelling of new lava shown by the small black flows that came up cracks in the lava floor left by the July eruption of 1927 (see second picture). The photograph is from about the same point of view as before. It will be observed that the July floor was squeezed down by an immense avalanche in the background, which had fallen from the wall at midnight January 10-11, 1928. Red glow immediately appeared, the outflow was sluggish with only a slight blue flame, and the measurable flowing lasted only an hour or two. The

effect was as though liquid lava were present as a remnant from July under the crust, but peculiar seismic disturbances in December, 1927, the month before the outbreak, makes it more probable that it was a half-hearted eruption brought into being by the shock of the avalanche.

The year 1929 was ushered in, by such a disturbance underneath the pit, that an immense avalanche carried away the tourist station in January, and this was followed February 20, 1929, by a new eruption of lava, in the bottom of Halemaumau, of short life and great intensity. The Volcano House watchman saw a black dust cloud rise from the pit, followed by white steam in the moonlight, at the usual hour near 1 o'clock at night. He notified the community by a bugle call. A bright glare developed over the pit. At 2 a. m., a line of fountains lay across the bottom of the pit in a northeast-southwest direction as before but close under the west wall of the pit, and this time the biggest fountain was at the north end of the crack. It shot out its jets diagonally eastward to a height of 225 feet and built up a big pumice cone. The line of fountains was about 1,000 feet long, spraying upward in a cluster of jets that soon became engulfed in the new lake under the west wall of Halemaumau but made a magnificent display, doming up the golden fluid with a boiling 50 feet high, and making concentric and radial cracks of incandescence in the dark crust of the pool, the blocks of which eternally streamed into the center of activity and sank. Meantime there developed an even pattern of bright lines streaming outward like a fan from the huge northern fountain. The rumbling thud of the fountains became deep and heavy with occasional detonations. The cone at the north changed to an armchair in shape, and on the second day the southern group of fountains (left-hand in third and fourth illustrations) went out of action in the forenoon, the lake subsided and left a border rampart, and at 1:10 p. m., February 21, 1929, the eruption came to an end. The two pictures show the new flood on the bottom of the pit from the same point of view as the earlier photographs, the first exhibiting the high activity at the beginning and at night, the second the dwindling activity of the second day after a lava shore line had solidified. The other activities of 1929 will be described in a later issue. T. A. J.

KILAUEA REPORT No. 941

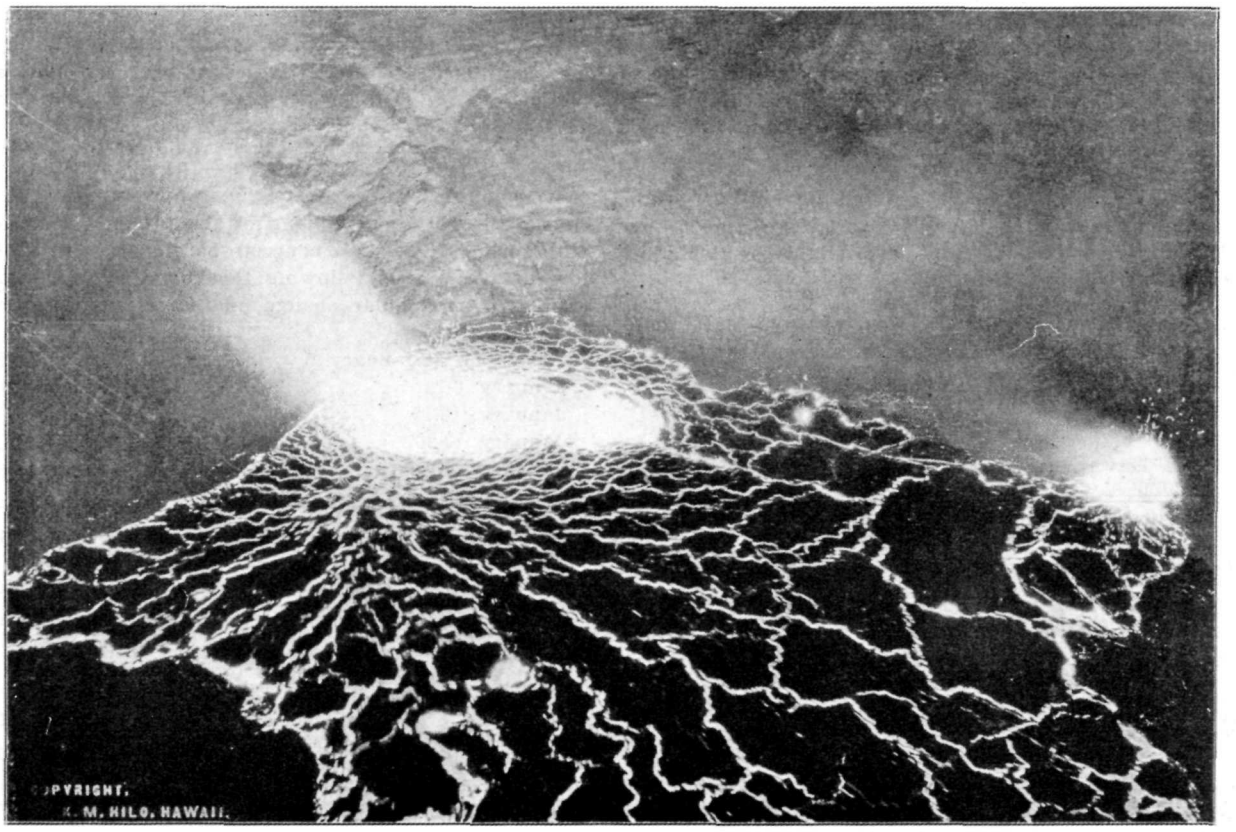
WEEK ENDING FEBRUARY 2, 1930

Section of Volcanology, U. S. Geological Survey

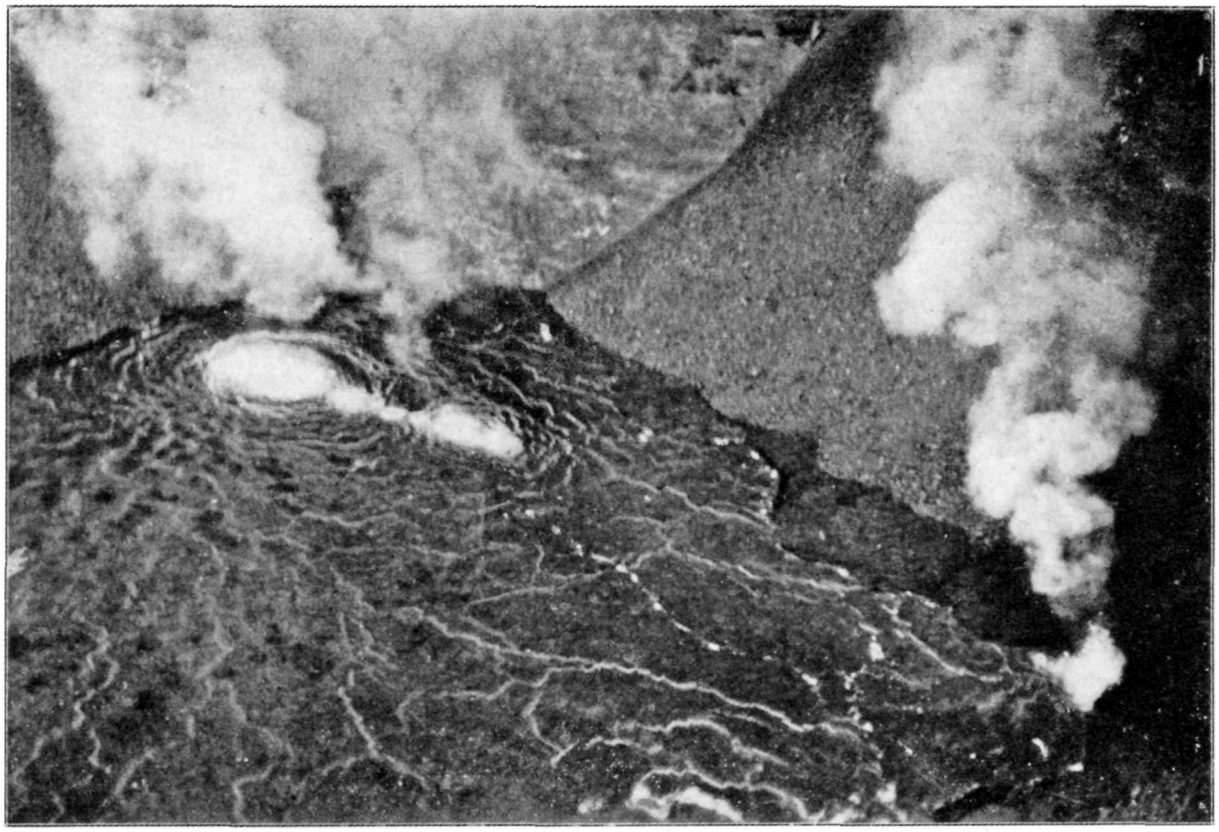
T. A. Jaggar, Volcanologist in Charge

On January 27 at 2 p. m., dust rose from a slide at the northern wall of Halemaumau, and at 3:30 p. m. more thin dust was seen over the pit. On January 29 at 1:30 p. m., the wind was blowing a heavy gale from the south, and the Halemaumau orifice was nearly hidden from view of the observatory by the dust. Great clouds of dust were blowing in the Kau Desert. The wind increased during the day so that wind tremor was strong on the seismograms. On January 31, after a rainstorm, the walls were dark red with wetting, there was the usual steam, and some fresh debris was observed on the northeast talus.

Fifteen seismic disturbances were registered at Kilauea. Seven were tremors and six were very feeble local seisms, three of which indicated average distance to origin 41 miles corresponding to the North Kona center. One very feeble seism indicated origin 18 miles away, possibly corresponding in origin to another feeble shock, origin distance 23 miles, at 2:38 a. m., January 29. A slight shock



Glowing and fountaining liquid lava pool at dawn, Feb-ruary 20, 1929. Interior of Halemaumau from the east, big north fountain on right. This buried the floor of July, 1927, to a depth of 64 feet. Photo Maehara, copyright.



This photograph is a daylight view, same scene as the last, at 6:30 a. m. of the second and last day of the eruption, February 21, 1929, when the fountains had dwindled. In the background is the northwest talus. Condensation of fume over the fountains and deep rumble had increased. Solidified rampart shore of lake is shown. On the right is the grotto which had been built high by the large fountain. The source crack lay along the line connecting this grotto with the line of fountains at the left, all of which at first had been a fissure following the edge of the plug left by the July eruption of 1927. The former plug lifts like a cork in a funnel, and the slag froth escapes between the cork and the wall. Photo Maehara.

was more strongly felt at 6:42 p. m., January 29, origin distance 48 miles, probably felt generally on the island of Hawaii. Very feeble, feeble and slight are technical terms of increasing intensities.

Microseismic motion for the week was moderate both E-W and S-W, and tilting of the ground was very strong SW.

JANUARY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory, on the northeast edge of Kilauea Crater, just opposite the Volcano House, the tilting or tipping of the ground as measured with seismographs in a concrete basement was as follows for the five weeks following December 29, 1929. This is expressed as angular change and direction of motion of the plumb line.

December 30-January 5	3 21 seconds SW
January 6-12	1.33 seconds SSE
January 13-19	3.75 seconds NNE
January 20-26	2 06 seconds NNE
January 27-February 2	5.38 seconds SW

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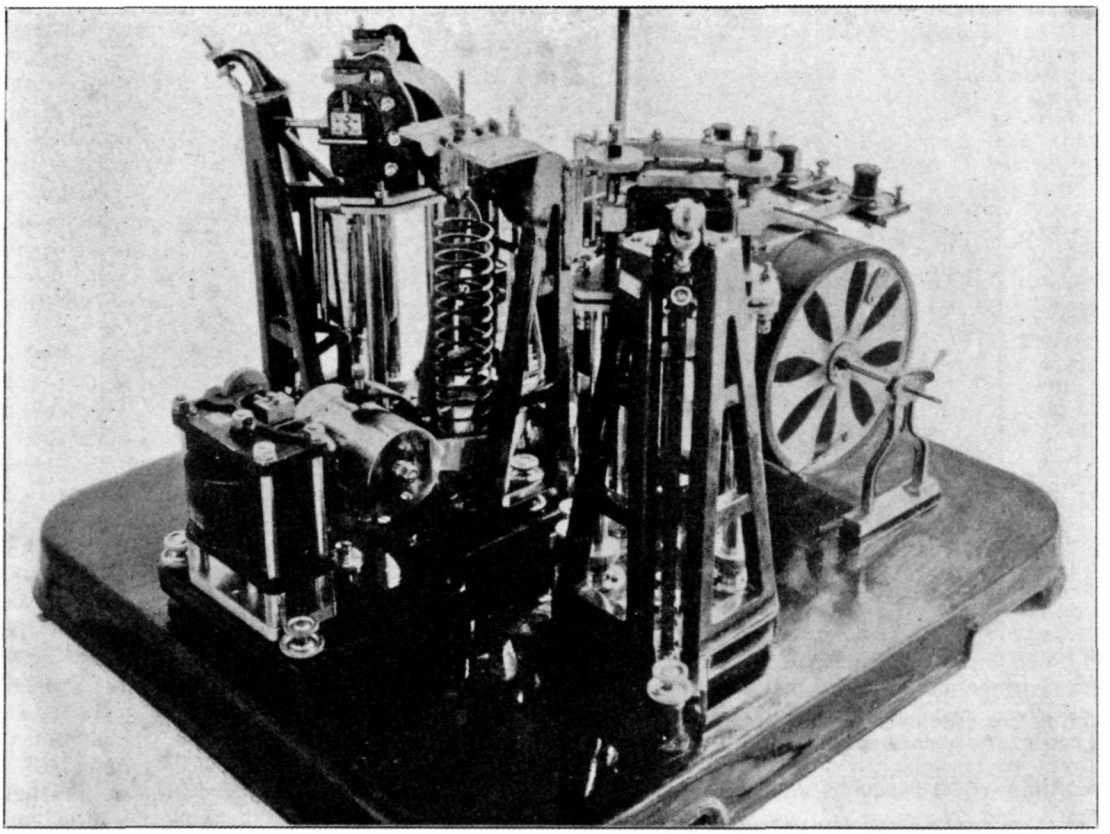
The Volcano Letter

268

Two dollars per year — Ten cents per copy

No. 268—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 13, 1930



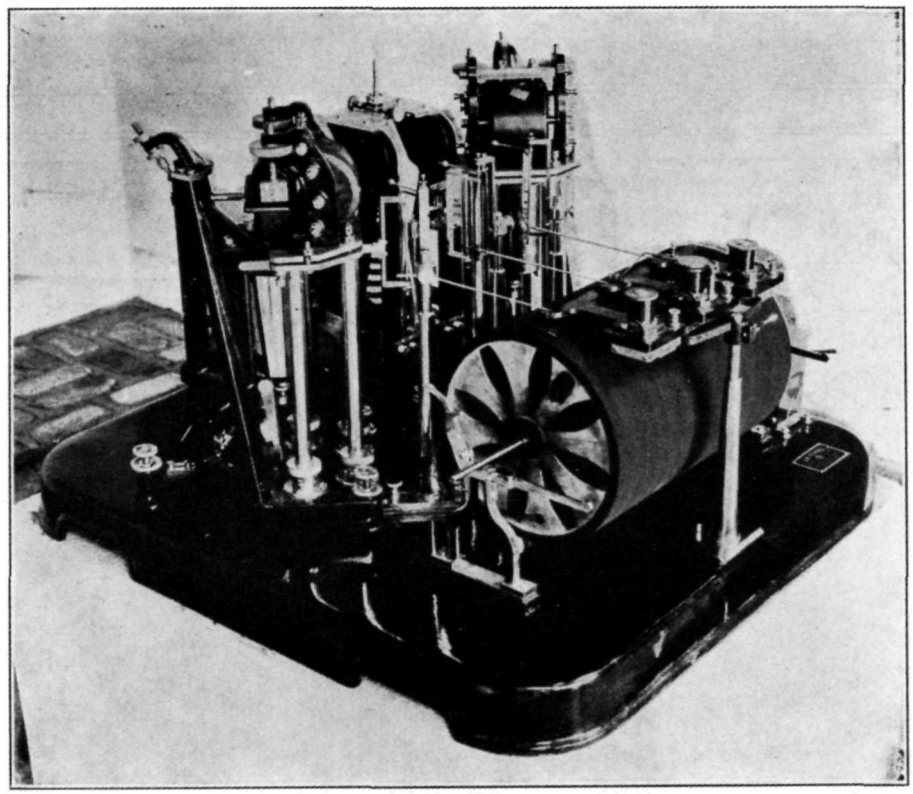
Back of Imamura seismograph as installed at Uwekahuna Observatory, Kilauea Crater. Vertical component pendulum on the left, recording drum on the right. Large gleaming cylinder in background is one of the horizontal pendulums under its damping magnet.

HOW THE SEISMOGRAPH WORKS

There is much misunderstanding about seismographs and earthquakes. One woman visited the seismograph cellar at the Hawaiian Volcano Observatory, and was observed to be looking around in all the corners of the room, seeking for something. When asked what she was looking for, she remarked that she was searching for the main wire. It later appeared that she thought the seismograph was connected in some mysterious electrical fashion with the inside of the volcano. Probably most travelers who see for the first time the excellent little seismograph, made in Japan, exhibited in the alcove of the Uwekahuna Observatory and Museum at Kilauea, as shown in the above picture, imagine it is far too complicated for them to understand. As a matter of fact the principles involved are extremely simple.

The reason the picture looks so jumbled is that this instrument attempts to combine six different things. These are respectively three different pendulums, a damping or clogging apparatus to keep the pendulums from swinging too much on their own account, a recording machine to compel all three pendulums to write their autographs on smoked paper all the time with high magnification of their relative movement, and a time-keeping device which also is compelled to mark the minutes on the paper. Each of these things by itself is very simple, but to make all work in harmony on one piece of paper is like asking a wrist watch to make a record of everything the wearer does.

There are three japanned openwork iron frames in a line across the baseplate, each holding a 13-pound cylindrical weight lightly hung on pivots. These are the pendulums and these are at the heart of the apparatus. Two of them are hung like doors at right angles to each other; their free motion is much like that of the needle holder of a gramophone. If with the sound box turned back, you hit with your fist the side of the gramophone cabinet, the sound box will jump towards your fist. If you hit the other side it will jump the other way. If you let the sound box hang down without any record under it, and imagine it immersed in a tumbler of oil, it will move through the oil by the amount that you have displaced the cabinet, but it will not waggle back and forth afterwards. That is what is meant by damping. It is an oil damper. The machine in the picture uses magnetism for damping, the rounded objects at the top and at the left being horseshoe magnets with a plate between the poles which is attached in each case to the cylindrical weight. The magnetic forces restrain the weight from waggling. The left-hand weight is hung on a spiral spring as shown, and differs from the other two in that its motion is up and down like the child's wooden ball hanging from an elastic band.



Imamura Seismograph, Uwekahuna Observatory, showing the pendulums at the back, the three slender pens, the clock-driven drum covered with smoked paper, and the three electro-magnets (spools) at the right. These lift the pen points once a minute.

This is called the vertical pendulum and registers up-down motion of the ground. The other two are horizontal pendulums and register east-west and north-south motion of the ground.

Now let us look at picture No. 2. This is the same instrument seen from the front. The heavy baseplate is set on concrete, this is on bedrock, and the alcove is protected from wind currents. Three very dainty slender levers protrude from a magnifying connection with the three pendulums. They are the three straight lines that look like strings protruding horizontally from the group of pendulums, and at their right-hand outer ends they hold tiny pivoted steel pens which rest on the smoked paper that covers the surface of the big cylindrical drum. If there is a north-south movement of the ground, the farther pen will move back and forth on the smoked paper 50 times farther than the ground itself moves; the middle pen similarly magnifies 50 times the up-and-down motion of the ground, and the near pen the east-west motion. Accordingly the single sheet of smoked paper will receive a back-and-forth white line for all three motions of the same earthquake, and we may compare side by side at that place on the paper, how much the motion was north-south, up-down, and east-west.

A digression is necessary here, because the reader thinks that the pendulum moves. It is perfectly true that if I move the pendulum with my finger, the pen will move 50 times as much. The seismograph, however, is not designed to ask the earthquake to move the pendulum. It rather asks the pendulum to stand still while the earth oscillates under it. This is what you ask the gramophone arm to do when you move the cabinet sidewise. If the iron door of a basement furnace is hanging open, and an earthquake moves the cellar sidewise, the door at first swings (apparently) in the opposite direction from the cellar. What it really does is to stand still by its inertia, while the furnace does the moving. So it is with the seismograph pendulums.

The time when the earthquake began at the instrument, the time when its vibrations changed from very short tremors to longer movements, the time occupied by each independent back-and-forth movement (known as the "period" of the earth wave), the time when the long movements slowed down to short movements again, and the time when the last trace of quaking stopped, are all important features of a seismogram. The seismogram is the paper record, the seismograph is the instrument itself. It will be seen above that if the paper stood still and an earthquake happened, we would get three short lines scratched on the smoke of the smudged white paper surface. This smoking, by the way, is obtained by merely twirling the paper-covered drum over a smoking kerosene lamp. The three short lines on stationary paper would tell us that there had been an earthquake, and how long its biggest oscillations were, respectively north-south, up-down, and east-west. But it would not tell us how long it lasted, nor at what o'clock it occurred. Here is where the drum comes in.

The surface of the drum is turning around all the time on a screw spindle that passes through the center of the drum, turned by a clockwork at the end of the drum. A fresh paper is wrapped around the drum and started every morning when the clockwork is wound. The three pens are thus writing lines round and round the drum, and the screw spindle pushes the drum along lengthwise, so that when a complete revolution is made each pen is

offset a little from its previous position. Thus each pen writes a band of lines, each line corresponding to an hour, say, and the band of 24 lines corresponding to the pen's work for the 24 hours of the day. If the ground does not move, the lines are straight and smooth and owe their existence solely to the rotation of the drum. If, however, an earthquake occurs each pen departs from its straight line and writes a zigzag, lasting as long as the earthquake lasts, its back-and-forth scrapings being close together if the earthquake is of quick period, and being far apart if the earthquake motion is slow. This is best understood by reference to the print of an actual seismogram on Page Four. There is an upper and lower band of lines, the upper south-north, the lower east-west. Near the bottom of each band there are big back-and-forth scrapings of very slow earthquake waves that came from a center in southeastern Alaska October 24, 1927. Right in the middle of this there are quick back-and-forth scrapings, the record of a local earthquake here at Kilauea Volcano at 6:20 a. m., feebly felt, on the same day. Possibly the slow wave motion of the big distant earthquake, 2,700 miles away, released the accumulated friction of the local mountain block in Hawaii, which slipped and jarred the island.

In the middle of the close-set lines of the local earthquake will be seen a gap in the record. There are in fact gaps of this kind a little less than an inch and a half apart on all the lines, marking the minutes. These are marked in on the seismogram by the three electromagnets, which look like spools at the right of the drum in the pictures.

The electromagnets are connected by wires through a battery with a big pendulum clock that hangs on the wall of the seismograph alcove. This clock closes a contact once a minute with its second hand, and once an hour with its minute hand, and the electric impulse lifts the three little pen points off the drum for about a second, and thereby creates a minute mark in the form of a gap in the line. A longer gap is made on the hour. The operator, when he puts on the drum in the morning, writes on the smoke the time of starting, and the rest is easy. With these time marks we may measure all the facts of time and duration of the earthquakes, and their several phases.

The picture on the third page shows a simplified single-pendulum seismograph set on a concrete shaking table, which is attached to a lathe chuck, through which in the shop of the Observatory artificial earthquakes may be made. This is a horizontal pendulum, and the big black cylinder is its swinging weight. At the right-hand end, also on the concrete table, are the drum and driving clock with a single writing pen and electromagnet. The lever from the lathe has its motion reduced at the steel rollers underneath the concrete table, so that the very small motions of the ground, which are characteristic of a local earthquake, may be imitated. T. A. J.

KILAUEA REPORT No. 942

WEEK ENDING FEBRUARY 9, 1930

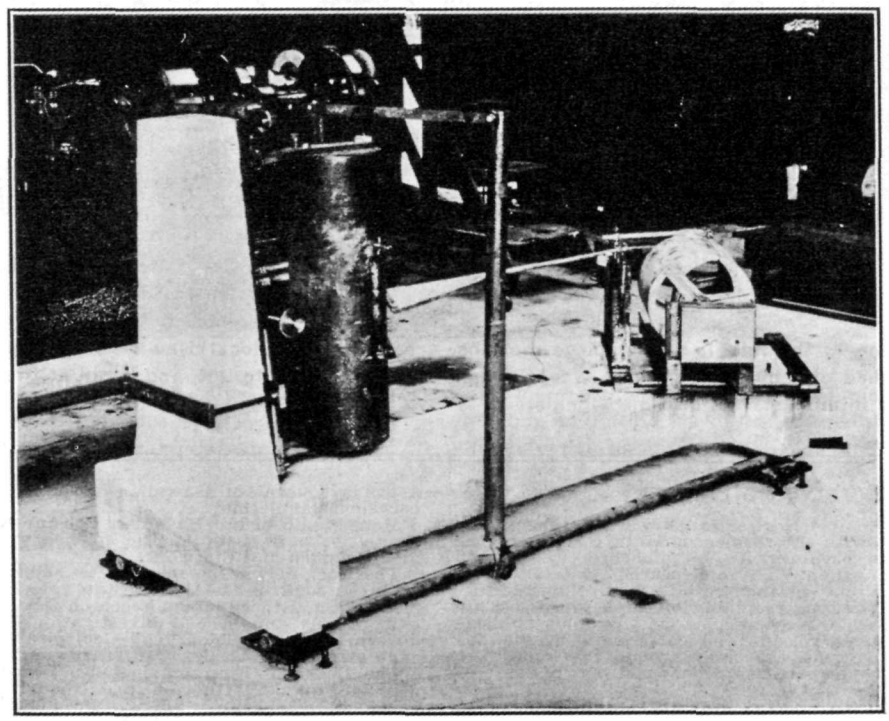
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau pit continues quiet On February 5 a few big bowlders from a recent avalanche lay on the southeast talus. A fresh streak of debris was also on the same talus heap. Steam was absent on the crater's floor. On February 8 no changes were observed, and there was very little steam.

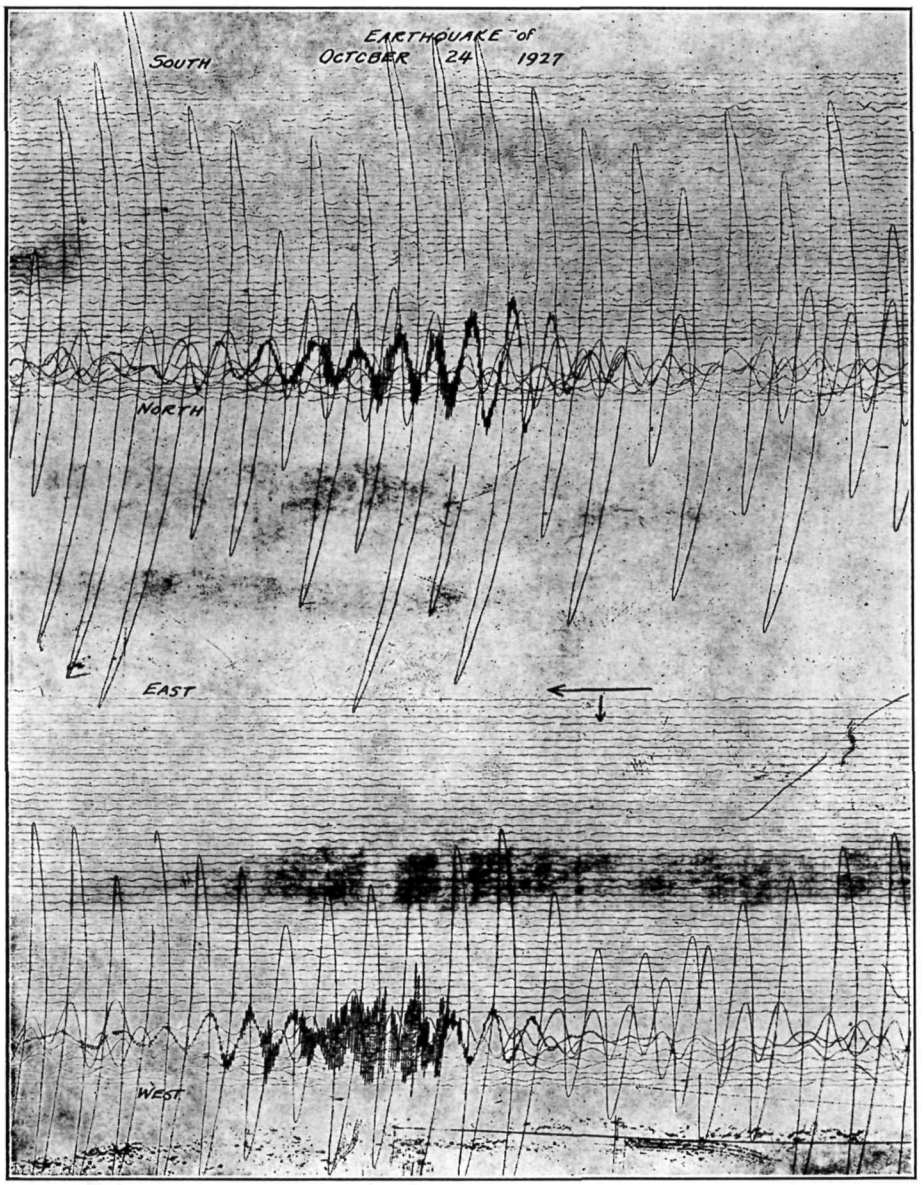
The seismographs at the Observatory recorded eight tremors, two very feeble and four feeble seisms. The feeble shocks were felt in some places on the island, and occurred as follows:

February 2, 6:02 p.m., indicated distance 32 miles
February 8, 8:06 p.m., indicated distance 32 miles
February 8, 8:13 p.m., indicated distance 23 miles
February 9, 9:43 a.m., indicated distance 40 miles

Microseismic motion was slightly stronger than normal early in the week, decreasing to normal on the 6th. Tilt accumulated moderately strong to the northeast, directly reverse to the direction of tilt during the previous week.



Concrete oscillating table operated by a lathe chuck. The complete single Hawaiian type pendulum is hung on the table, along with its recording drum, and subjected to artificial earthquakes. In Hawaiian Volcano Observatory shop.



Seismograms of the two earthquakes October 24, 1927. The upper and lower bands of lines register a night's work of the seismograph. The upper is north-south motion. The lower is east-west motion. The big oscillations shown are the faint slow waves of an Alaskan giant earthquake as registered in Hawaii. The close-set zigzags, like shading in the middle of the large motions, are made by a local Hawaiian earthquake, which possibly was "touched off" by the big earth waves. Lines read from right to left, and begin at the top. The breaks in the lines are minute marks, or time signals.

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269

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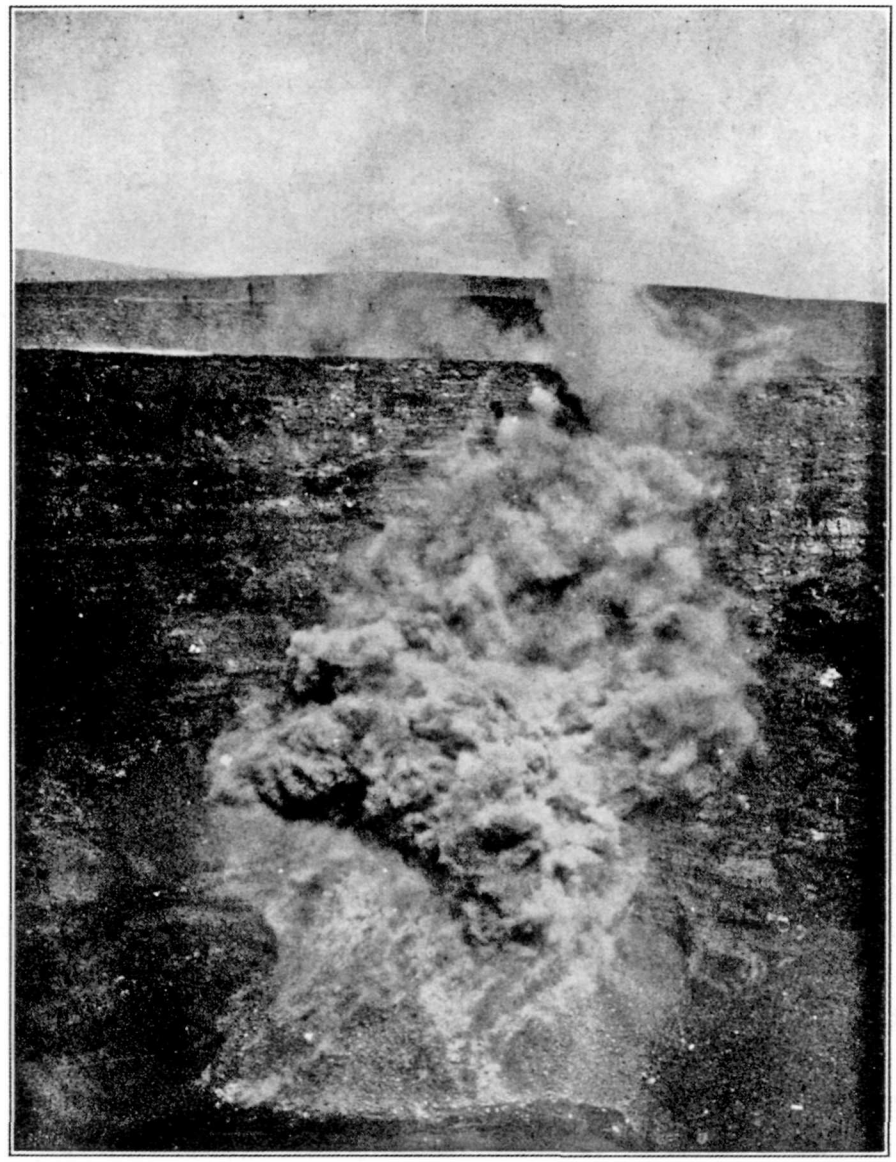
No. 269—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 20, 1930



Avalanche falling on northwest talus of Halemaumau 10:27 a. m. October 5, 1927. This picture shows how cauliflower clouds of dust are easily generated by the grinding of falling rock. An exaggeration of this with all the walls falling at once, and steam rushing up, is what happens in an explosive volcanic eruption. Photo Evans.

MEANING OF CRATER AVALANCHES

Many visitors to the fire pit of Kilauea happen upon the adventure of seeing and hearing large or small slides of broken rock that fall from the walls of the pit. A splendid motion picture of such a slide is exhibited to tourists at the Uwekahuna Observatory. The lower portion of the rock wall begins to "work", and black cascades of gravel and dust are seen streaming down the notches to the talus. Then pieces of the wall flake off higher up. Finally a very large piece shows itself to be in process of separating from the face of the wall, with black cascades on each side, the moving portion being a flat cake of wide area often extending to the very top edge. All the rock matter breaks up on its impact below, and during the crushing and grinding of its separation from the wall, hundreds of tons being involved. The talus or slide rock slope below receives the impact, is built up at the top, and tends to become steeper than the angle of rest. This starts a sliding in the debris slope, and great clouds in "cauliflower" form carry the dust boiling above the edge of the pit. These slides have been renewed from time to time during the past six years, becoming very vigorous from no apparent cause.

The photograph on the first page and the map on Page Four show one of these avalanches and the contour plan of its results. The place where this avalanche occurred in 1927 is the wall in the upper left-hand rectangle of the map. The evenly spaced contour lines of the lighter portion of the map of the pit are mostly slide-rock slopes of about 30 degrees inclination. The flat of the bottom lava is out-

Two photographs of the north corner of Halemaumau pit showing the detail of the wall before and after avalanches of February 18 and 20, 1928. The first January 2, 1923, shows two talus cones, the prow of the big sill next above, and a light band above that which is a cross section of an old debris slope with lava flows on the right lapping against it. The second February 26, 1928, shows the same scene after the avalanches had scoured the talus cone and the wall above had flaked off all the way to the top. Photo Wilson.

lined in dots. The rock wall shows close-set and irregular contour lines. This wall exhibits a flat bench of light shading in the upper right-hand rectangles. This bench is the top of a thick sill or sheet of intrusive lava which was red hot but hard at the end of the explosive eruption of 1924, when that wall of the pit broke and started red hot avalanches from this sill. The sill is well shown in the first of the two pictures on Page Two as a rock ledge shaped like the prow of a boat next above the talus slopes and to the right of the sharp pointed talus cone.

When this map was made in July of 1928 the surveys showed that there had been four cavings-in from the rim during the preceding 12 months. Over this northwest talus a strip 700 feet long and containing nearly an acre of rock was missing. The picture on Page One shows how it happened, but a still bigger avalanche here January 11, 1928, had caused the debris slope below to break away as a landslip and flow out over the floor. Other portions of the rock wall, totally changed since the surveys of a year before, were at the southwest, at the north-northeast, and a long, narrow strip three-quarters of an acre in extent at the east-northeast. When we add to this the tremendous southeastern caving in of the rim of the pit which occurred in January of 1929, making it necessary to change the inspection station at the road terminus, it will be seen that two years of wall-breaking had pretty well encircled the pit.

This gradual encircling of the pit by slides was noticed during the early years of the work of the Observatory, when lava was almost continuously present, rising and falling in the pit. The times of maximum avalanching were also times of maximum subsidence of the lava, of maximum local earthquake frequency, and of maximum inward tipping of the ground toward the center of subsidence. The jarring of earthquakes doubtless loosens the wall material, but no conspicuous causal relation whereby earthquakes make avalanches has appeared. In some definite cases, on the other hand, avalanches conspicuously make earthquakes. The greatest of these was the grand avalanching that enlarged the pit during the explosive eruption of 1924. Since then there has been instituted measurement of the width of cracks close to the edge of Halemaumau. In January, 1928, when the big avalanching at the northwest was starting, crack measurement showed an opening of five inches in 11 days, and leveling revealed a lowering in eight months of nearly half a foot for the ground at the edge of the pit. The ground was tipping in toward the crater center during these weeks. During a time of similar opening of cracks in August, 1928, an avalanche of large size occurred which produced a tremor record much larger on a seismograph nearer to the pit than on the Observatory seismographs, and showing other evidence that the slide was the cause of the tremor.

Now if we examine the map on the last page, we shall see these border cracks as dotted lines just back from the edge of the pit, and parallel to the edge in many places. It also appears that the pit is a pentagon rather than a circle, the five angles being at the tops of the taluses southwest, northwest, north-northeast, east and south. Each of these angles has a reason for its existence, and the reasons are evident. The straight sides of the pit southeast and northwest roughly conform to the rift system that extends far out into the desert. The steep southwest wall is a cross fracture between these two more gently sloping rift walls. The northeast side is very steep and clearly determined by the two ends of the big sill which have been places of motion and weakness since 1924. The short north wall is a cross facture between the sill wall and the rift wall, a remnant, so to speak, adjusting the big hole, during its engulfment, to the controlling deep joints. This formation of a pentagon has repeatedly been observed in photographs of the craters on the moon, which are also engulfment pits. The fundamental cause, then, of straight sides to an otherwise circular pit, is a guidance by deep straight fissures or lines of weakness in a process of breaking which is controlled by a small center of engulfment.

The meaning of crater avalanches reverts to a center of engulfment. Why should there be a center of falling in? This takes us back to how a volcano begins. It begins by lava welling up a crack. If it kept on welling up the whole length of the crack it would make an even ridge. It does not do this. Cracks are not regular and the narrower places become clogged. Then the wider places become centers rather than linear fissures. They become centers because the upflow is through the soft material of their own overflow. The crack is buried far below and an oval or circular heap of new lava becomes the dominant structure up which the eruptions are building. If the eruptions were perfectly continuous, without alternations of gas and liquid, and without alternations of rising and falling, there would be no craters. There would be a lava lake eternally overflowing. There is no visible pit when Halemaumau fills to the brim. The pit is the product of a sinking back of the lava whereby the hardened walls fall in, and reveal something of the shape of the well. The volcanologist as a detective has to learn from what happens by cracking, shaking, steaming, and tipping of the outside ground, what is the probable shape of the bottom of the well when the lava retreats.

This is no simple matter, and the accumulated learning of the world from the mapping of cross sections of old volcanoes, from the study of volcanic earthquakes, from the reports of explosive eruptions, and from studies of physical geography of craters, needs study in order to make an accurate guess as to what the lava column would look like if we could cut a slice through the volcano straight down for seven miles. For there is seven miles of lava building if the Hawaiian ridge started in a deep part of the Pacific. Computations suggested that the lava column sank about a mile under Kilauea in 1924, and that previously it may have wedged out right and left several miles in some kind of underground reservoir. The pit was left a rather flat funnel, but some of the flatness is due to the debris plugging the bottom. Our work with instruments is like that of the surgeon with the X-ray and the stethoscope. We must learn the internal organs of a volcano, the chemistry of its digestion and excretion, the cycle of its breathing, and the shape of its alimentary canal.

The avalaches grow more or less frequent as the walls of the pit are more or less undermined. Under the debris is a rock wall of flat slope. Is this a wall, or is it a congestion of gigantic wall slabs? Have these slaps slipped down? And are they jammed about the center? Such a notion of the structure agrees with the fact that eruptions start through crevices high up around the border of the inner pit bottom. Are these slabs the top of a column of debris which fell in, in 1924? And is this whole column being infiltrated with lava? If so, does the column lower when the stiff lava lowers, and so start earth tremors and avalanches? And does it rise when the lava expands, and so stop all undermining?

This would cause the outside country to tip away. Such is the fact when lava rises. And also the avalanches cease when lava rises. Thus it appears that the rock slides are not only what creates these pits and keeps them circular. The slides are also indicative of what is going on far below. T.A.J.

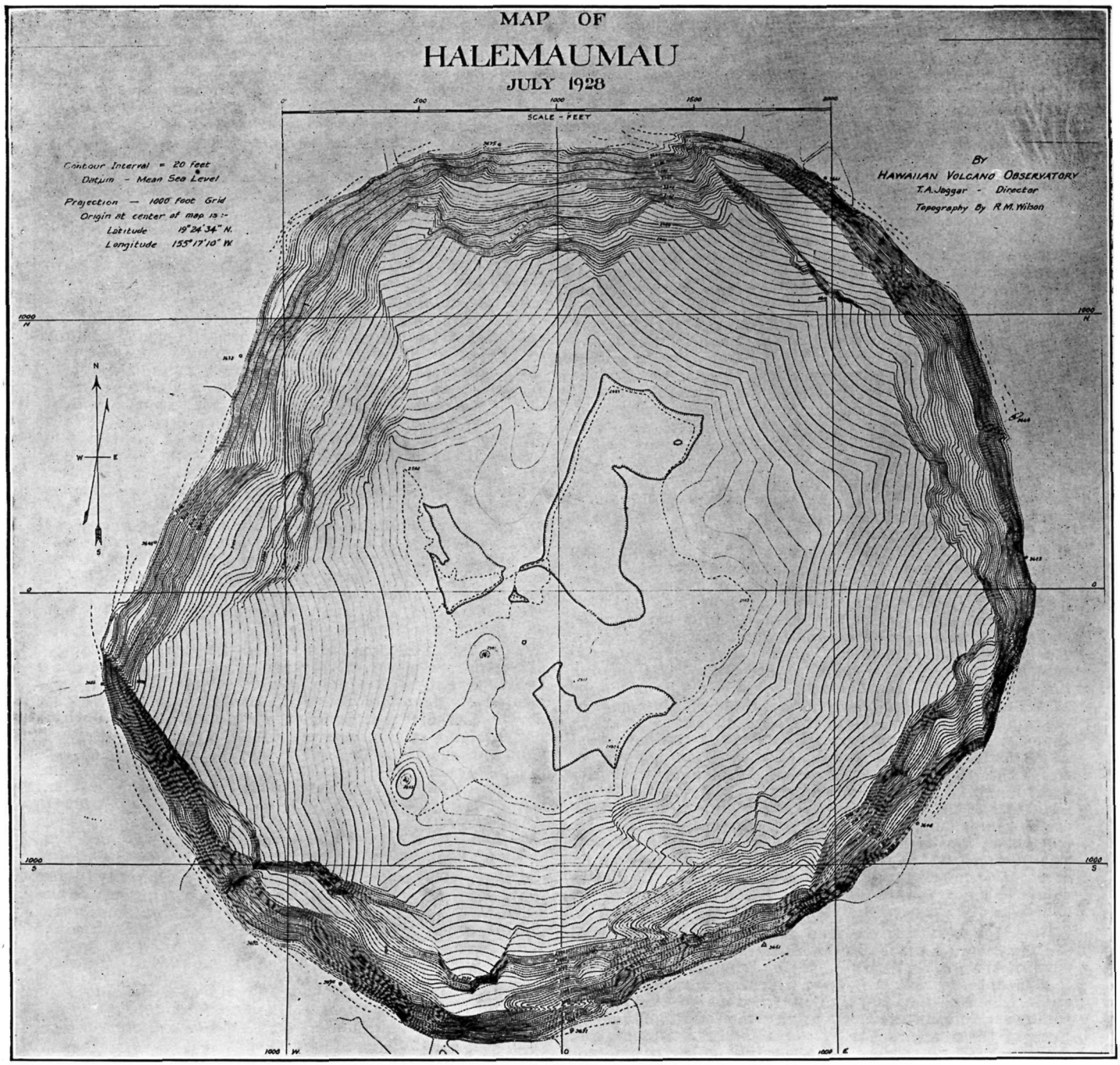
KILAUEA REPORT No. 943

WEEK ENDING FEBRUARY 16, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On February 11 at 1:30 p. m., gray dust rose from an avalanche within Halemaumau pit apparently from the west side. This lasted for several minutes. Another was reported at the north wall of the pit at 4:10 p. m. Inspection on February 12 indicated that the slides had been voluminous, leaving much dust. At 8 a. m. February 14 a convection cloud hung over the pit, and a similar condition at 9 a. m today, February 17, appeared as a high column of vapor from the northeast wall of the pit, occasioned by unusually calm conditions which had covered the whole floor of Kilauea Crater with a steam fog.

The seismographs at the Observatory registered 16 tremors and 7 very feeble local seisms during the week ended at midnight February 16, two of the shocks indicating origin distance 23 miles and one a distance of 43 miles. These distances correspond closely to Mauna Loa and Hualalai. The tremors did not exceed one minute in duration.

Microseismic motion for the week has been slight, and tilt accumulated strong SW, again reversing the direction of the previous week. Such strong pulsations of tilting sometimes indicate underground lava movement.



Map of Halemaumau Pit, contour interval 20 feet, surveyed July, 1928 by R. M. Wilson. Dotted outline is lava bottom of July 1927. Dotted lines at edge of pit are cracks. Talus slopes make the open contours of the lower area. The rectangular net marks 1000-foot intervals. Bottom is 2482 and top 3692 feet above sea-level. The rock wall extends clear to the bottom in funnel shape northwest and southeast, between the northwest and west taluses, and between the southeast and south taluses. The two black spots in the southwest wall are caverns on the Kau Rift, and the line of four cones across the bottom follows this fissure, which determines the longer axis of the pit.

ILLUSTRATED LECTURES IN HONOLULU

A course of five illustrated lectures by T. A. Jaggar on "How the Volcano works" is in progress in Honolulu, and the dates have been changed. The place is the ballroom of the Royal Hawaiian Hotel, the hour nine in the evenings of February 11 and 24, March 14 and 24, and April 14. These are open meetings of the Hawaiian Volcano Research Association during the tourist season.

THE VOLCANO LETTER

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The Volcano Letter

270

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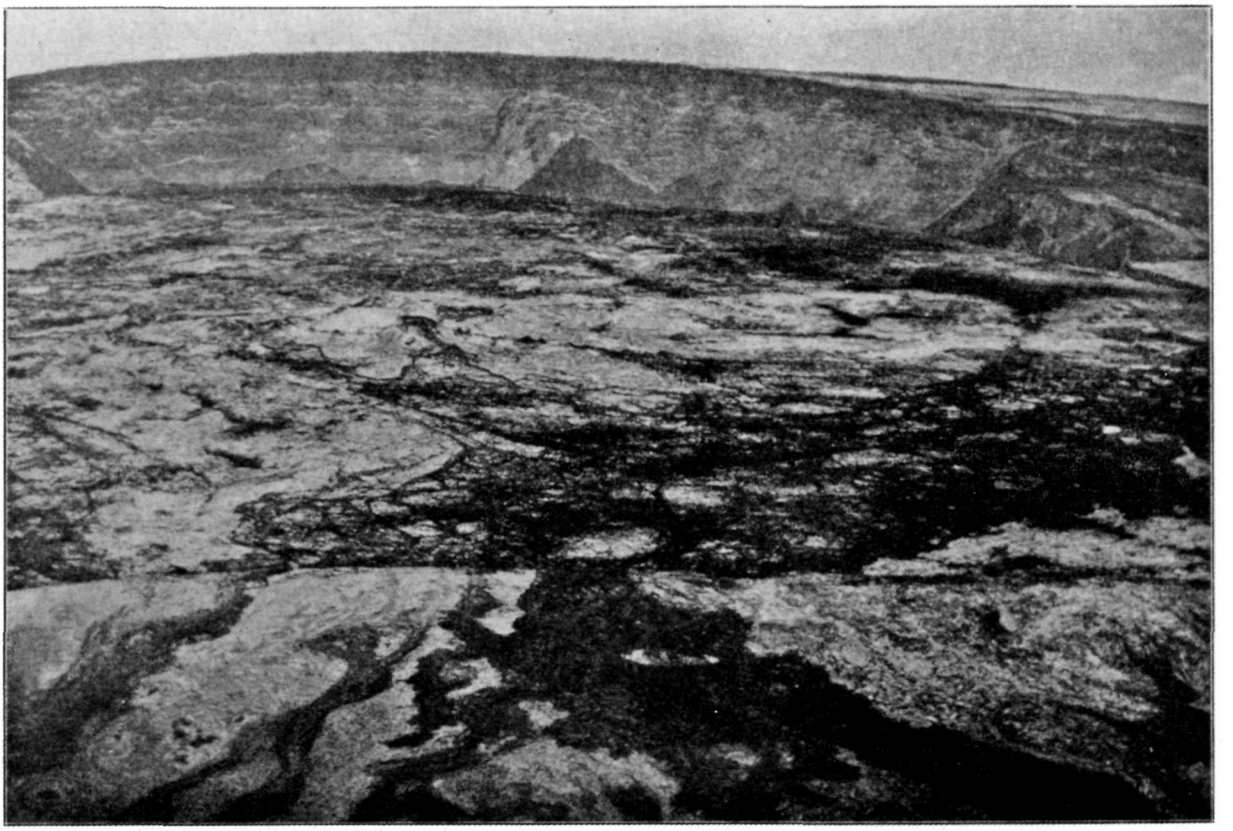
NO. 270—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 27, 1930



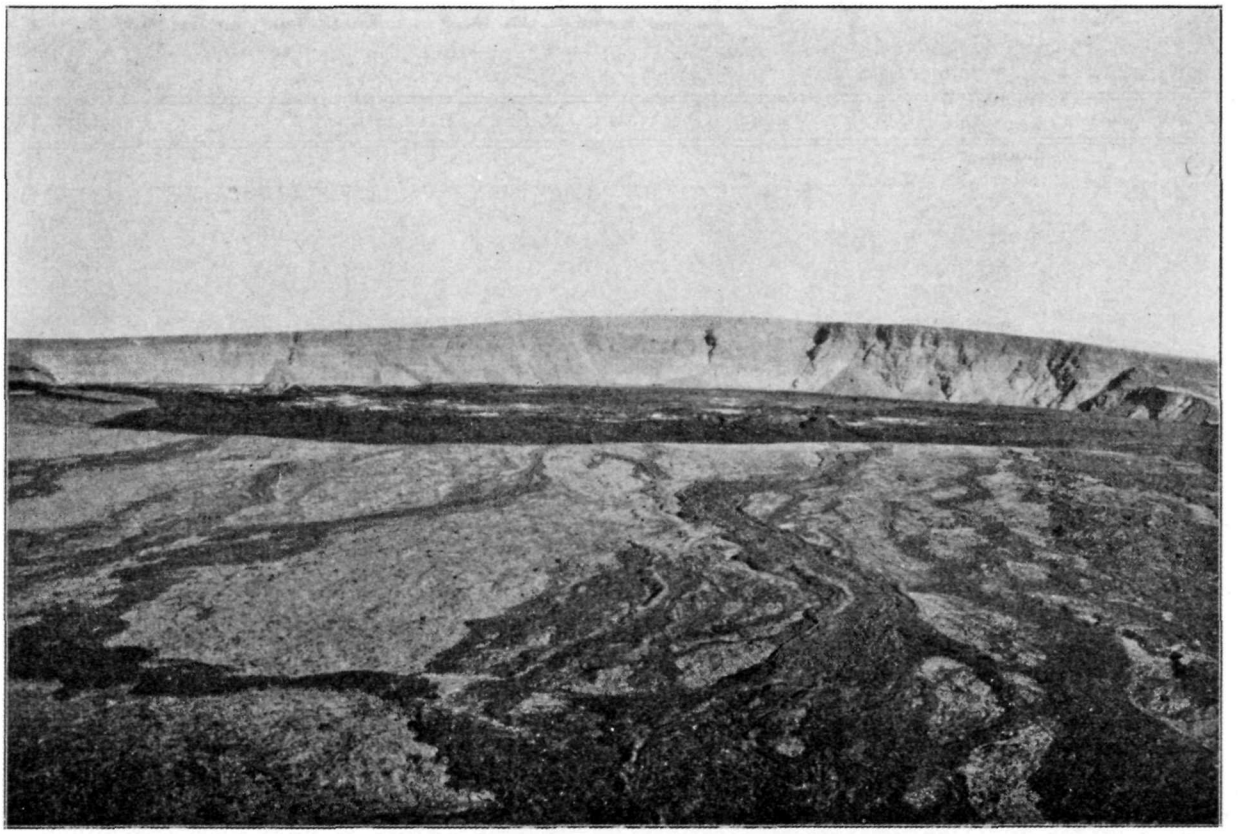
Mokuaweoweo, the summit crater of Mauna Loa, at 8:45 a. m. October 9, 1929, photographed from the east from an airplane at elevation 15,200 feet. This shows part of the northern half of the crater mantled with a light snowfall, the high western wall, and the cone of 1896 in the bottom, with the eruption crack of 1914 athwart it showing a line of spatter heaps of lava. In the foreground are clinker flows of the east edge of the cauldron. Photo Bureau of Aeronautics, U. S. Navy, by permission of Rear Admiral George F. Marvell, Commandant Pearl Harbor, Hawaii.

AIRPLANES FOR VOLCANOLOGY

The volcano Pelee in Martinique developed gas and ash eruption in the autumn of 1929 which was renewed in December (Volcano Letter No. 262, January 2, 1930). The following is a picturesque statement of our modern birds-eye viewpoint: "A student of the Imperial College of Tropical Agriculture, who returned to Trinidad January 12, 1930, from leave in the United States, in an airplane of the West Indies Airways, says that Martinique was hidden in a volcanic cloud through which could be caught glimpses of silent villages and deserted cocoa estates. The northern part of the island has been evacuated and public gatherings are prohibited." (London Times January 14, 1930.)

Thanks to the U. S. Army and Navy air services, planes and air photographers have been placed at the service of the U. S. Geological Survey so that mapping of the culture and the drainage of southeastern Alaska, the Mississippi Valley and the island of Oahu in Hawaii, as well as many other places, is more perfect and less expensive than ever before. Repeatedly airplanes with photographers have been supplied to the Hawaiian Volcano Observatory, in times of stress, on the island of Hawaii, and the results have revealed the meaning of lava outbreak on these vast flat volcanoes, in a way that could never be approached by land expeditions. Over Vesuvius both motion and still pictures have been taken of the crater activity. One of the most remarkable monographs on craters ever published is entitled, "Volcano Studies in Java," by N. J. M. Taverne of the Netherlands East Indies Volcano Service, issued in 1926, containing supurb photogravures of 24 craters pictured from the air over a wild mountainous country of savage jungles. The pictures reveal the cones in profile, the gullys on their flanks, extraordinary lava plugs standing in relief, the distribution of hot springs and solfataras in the jungle, double craters and inner benches, details of relief in adjacent peaks which it would take years to map, inner lava floors and domes, crater lakes, flank craters and sharp peaks with lava plugs, and all the manifold complexities of unsuspected pits in the jungle and erosion of ash covered surfaces that might be missed entirely by a land expendition.

During the recent seismic activity in September-October, 1929, on the western side of Hawaii, the writer was privileged to inspect the whole eastern, southern, and western flanks of the island mass in a Naval plane at elevations from 10,000 to 12,000 feet, traveling about 160 miles from Hilo over Kilauea Volcano, across the great rifts that extend down the southwestern flank of Mauna Loa, and then northward over Kona across the divide between Mauna Loa and Hualalai. The relief of the great Hawaiian turtleback mountains, with the straight fault cliffs and sink craters, the lines of circular pits on Kilauea, and the lines of pumice cones on Mauna Loa, all revealing meandering black aa flows like giant serpents leading to the



Mokuaweoweo from the southeast, photographed from an airplane, June 25, 1929, showing on the crater floor the cone of 1914 on the left and the cones of 1896 on the right, both amid patches of solfataric whitish stain. Phcto by permission 11th Photo Section Air Corps, U. S. Army.

sea, is in marked contrast to the steep cones of Java. The visibility was excellent on this flight and no trace of new outbreak correlated with the earthquake spasm was found. It would have taken weeks to explore the same territory with pack train, and even then a small outbreak might have escaped notice.

Thanks to the courtesy of Rear Admiral George F. Marvell, Commandant of the Pearl Harbor Naval Station, U. S. Navy, we are permitted to exhibit on Page One a photograph of Mokuaweoweo, the summit crater of Mauna Loa, made by J. A. Pringle with a hand-held 4 by 5-inch camera and 10-inch lens at 8:45 a. m. October 9, 1929, from the east at elevation 15,200 feet. This was photographed from a small scout plane capable of flying at these high altitudes. The far rim of this sink crater is at elevation 13,653 feet above sea level, and the area is coated with a light fall of recent snow. This serves to exhibit on the floor of the crater the old cone of 1896, cut across from left to right with the gash and line of driblet cones that were formed in 1914. In the foreground is the east edge of the crater with aa flows, and the dark objects under the distant cliffs are talus slopes. If there had been new activity it would have appeared as spurting lava sending up clouds of blue sulphurous gas.

It is of interest to compare this same scene, photographed without snow from a greater distance by the Eleventh Photo Section of the Air Corps, U. S. Army, June 25, 1929 (Page Two). Here there is sulphurous stain on the black lava floor of the crater, and as this picture is taken from the southeast the 1896 cones appear on the right and the cone built by the large fountain of 1914 is shown at the left. The angle in the high cliffs at the back where the white expanse changes to shadowed bluff, is the angle in plan between the southwestern and northeastern rifts of the Mauna Loa dome. Extended down the mountain the northeastern rift is the seat of a line of cinder cones that poured flows toward Hilo in the nineteenth century. On the other side of the mountain the Kahuku rift gave vent to an increasing succession of flows from 1868 to 1926, the later ones devastating portions of South Kona.

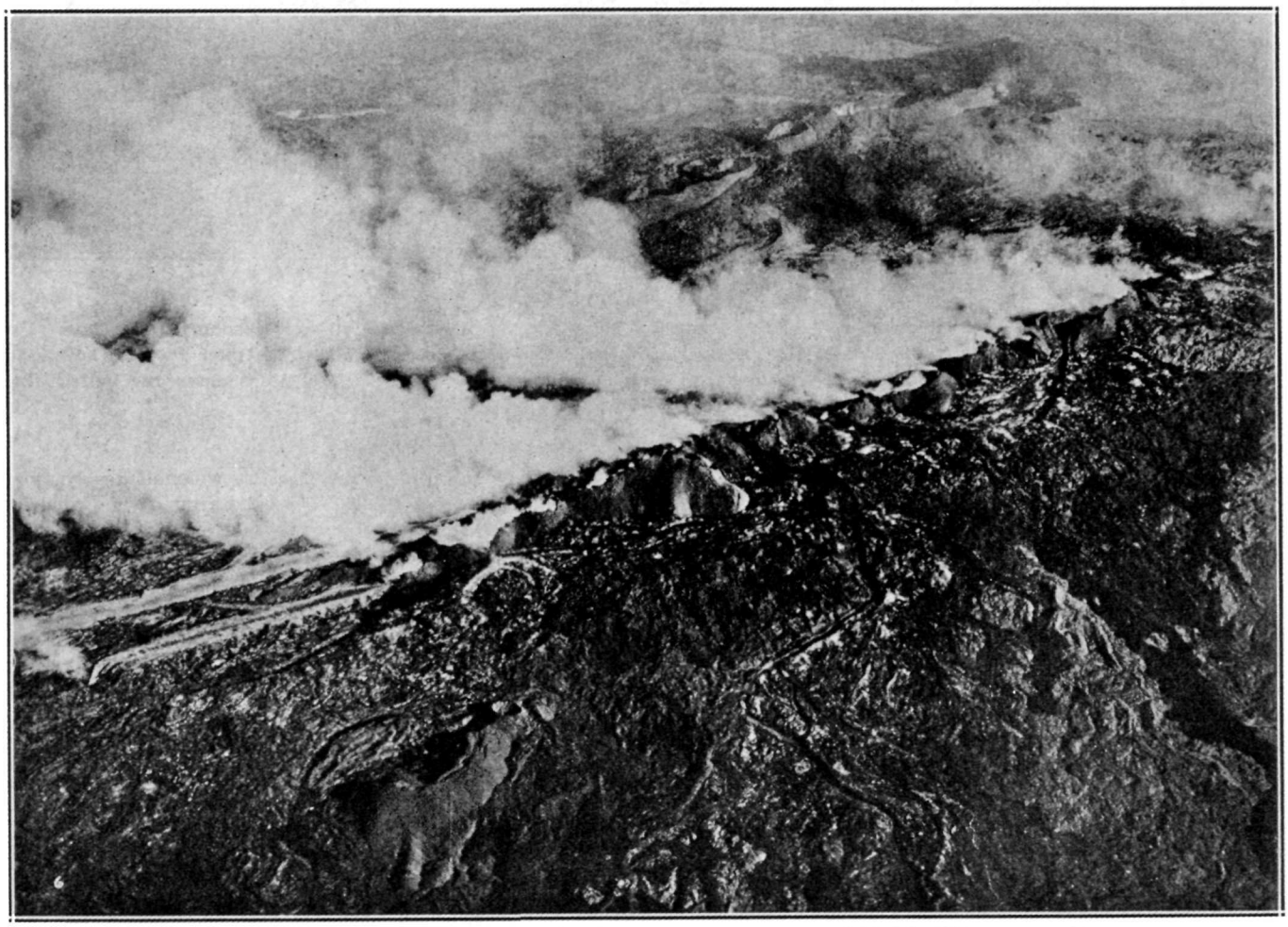
The photograph on Page Three follows the eruption of April, 1926, down the southwestern ridge of Mauna Loa and presents a most comprehensive picture from the air revealing how the mountain ruptures along a belt of parallel cracks. This place is the source, about 7,600 feet above sea level, of the actual flood of slag which swept down on the village of Hoopuloa at the sea shore, and destroyed it. The aviators were flying along the southeastern side of the rift belt and the wind was blowing from the eastward so that the fumes sweep off to the west in the picture. In the foreground is shown an old cone containing a large crater and two smaller ones over a crack in general parallel to the active fissure, and in the background the line of dead cup craters, also parallel to the 1926 rift, is the scene of the tremendous eruption of the Alika flow of 1919. Here then are several active cracks parallel to each other, all constituting a rift belt, or fractured zone of the mountain, several miles wide. The active crack of 1926 is very straight and had built up a dozen cones each 50 to 75 feet high along about two miles of length shown in the picture. The right-hand end is up the mountain and the left-hand end shows two white streams of lava flowing in very straight courses down the mountain. The nearer one is flowing along the fissure and has found an open vent on the fissure into which it cascades. There are other live streams behind the smoke, vented by the middle and lower cones shown. The upper cones on the right have gone out of action, and one of their dead river beds is shown in the lower right-hand part of the picture. All of the live streams were distributing over the flat upland, but they united in a single torrent when they passed over the shoulder of the mountain and went down the steep slope through the forest into South Kona. A characteristic detail of the actual lava river is the dark line of rafts and partly congealed crusts carried down the middle of the stream, while the border portion remains

bright and glowing with escaping gases along the belt of friction on the banks.

These pictures illustrate the alignment stage of volcanic outpouring, before the accumulations have built high enough to obscure the fissure and to produce a dome rather than a ridge. There are many heaps and pittings along fracture belts on the moon which are strikingly similar to the detail of this Mauna Loa fissure eruption. It is the occurrence of pits in direct relation to fracture lines around the edges of the big craters, and to straight fault fissures, on the moon, that effectively denies the validity of the impact theory of lunar craters. This theory imagines pits to have been made by the impact of meteorites. When the pits are definitely grouped along fractures, and smaller ones are structurally related to the lines of breakage around the edges of the bigger craters, it is incredible that meteorites should have sought out lines of cracking for their impacts. There is every reason for believing that the lunar craters resemble the Hawaiian pits in a sequence beginning with rampart rings of large diameter, and ending with small pits along curved fractures, the curves being guided by the older and larger domes and rings, which broke down when they became decadent.

The last air picture of the Army aviators gives a wonderful map of the western shore of Hawaii at Hoopuloa April 17, 1926, at 4 p. m., about 12 hours before the front of aa lava entered and burned the town, obliterated the harbor and the road, and crushed and buried the wharf. Here the winding stream through the flow is only faintly seen, and the main character of the advancing fronts, 20 to 40 feet high, is that of a caterpillar tractor. An upper layer of bowlders and gravel is rolled forward on a viscous red-hot paste inside, tumbles down at the front in a debris slope, and this is eternally overridden by the advancing mass for which it lays the track. The flow consists of four different mechanisms. There is the main river, the overflow fields of clinkery bowlders, the main front, and the subordinate fronts at the sides of the flow which build lobes and widen the slag flood as a whole at the expense of its height. It is interesting to observe in this picture the two ancient lava rivers right and left of the 1926 stream. It is the notch between their two deltas that had created Hoopuloa Harbor. It was the valley between their two heaps that guided the Hoopuloa flow straight down on the village which had unwittingly assembled its houses in this fatal lowland. Exactly the same lesson has been taught again and again by Vesuvius, and never has been learned. The lowlands and bays are attractive to the vine growers and the fishermen, but if they sought safety in a volcanic land they would be compelled to rebuild on the ridges and the points of land.

T. A. J.



Southwest slope of Mauna Loa giving vent to fissure eruption of lava April 18, 1926. This is the rift source of the lava flow that destroyed Hoopuloa fishing village. The line of cones is at elevation 7,600 feet, photographed from an airplane looking north showing lava source of 1919 in background, ancient cone in foreground, live lava streams on left, and dead flows of the new eruption on the right. Photo 11th Photo Section Air Corps U. S. Army.



Airplane photograph of Hoopuloa at 4 p. m. April 17, 1926, 12 hours before the village was buried. Aa lava flow with front 1,100 feet wide, 30 feet high, advancing 3 feet per minute. The tongues would push forward now here, now there. The two old lava stream beds on each side show how the new flow crept down the valley in between. Photo 11th Photo Section, U. S. Army Air Corps.

KILAUEA REPORT No. 944

WEEK ENDING FEBRUARY 23, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Many avalanches have occurred during the week at Halemaumau. The whole north wall has been working between the niches extending upward from the tops of the north and northwest taluses, rocks trickling almost continuously. Dust from the slides lay thickest on the west side of the floor. Avalanches were sometimes heard at the Uwekahuna Observatory, the rumbling of the sliding masses of debris preceding by several seconds the appearance of the dust clouds above the rim of the pit.

Cracks along the east rim show a slight widening, and one of the measured points, No. 14, widened nearly two feet since December 4, 1929. Here the ground shows much cracking and settling, as though this end of the big sill were working in sympathy with the north end. Few slides have been noted here, however.

There was increase of copper salt southeast noticed February 17. With dry weather steaming has been very slight at Halemaumau.

There were 13 tremors, nine very feeble seisms, and one slight seism recorded by the seismographs. The slight shock occurred on February 19 at 5:42 p. m., with indicated distance to origin 27 miles, and was felt strongest in Kau District.

Microseismic motion was slight. Tilt accumulated moderately SSE.

THE VOLCANO LETTER

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The Volcano Letter

271

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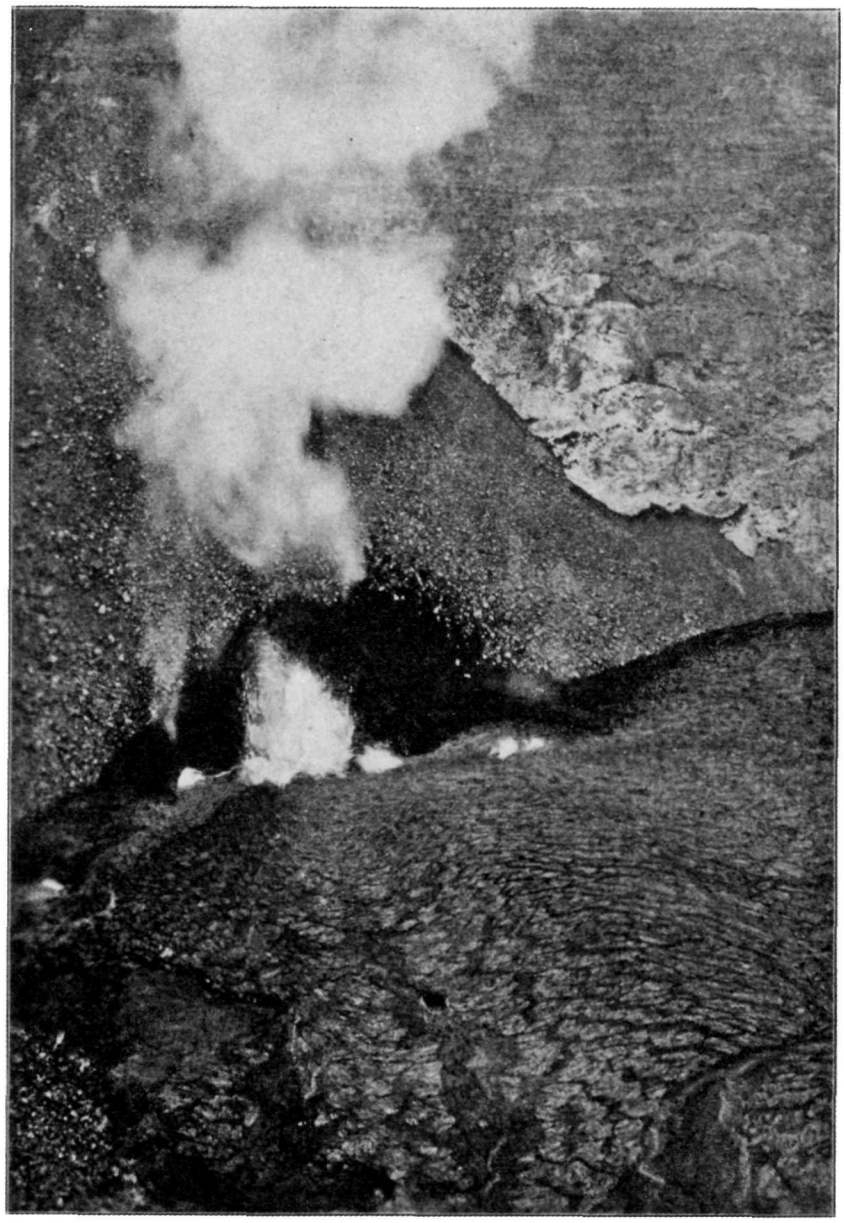
No. 271—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 6, 1930

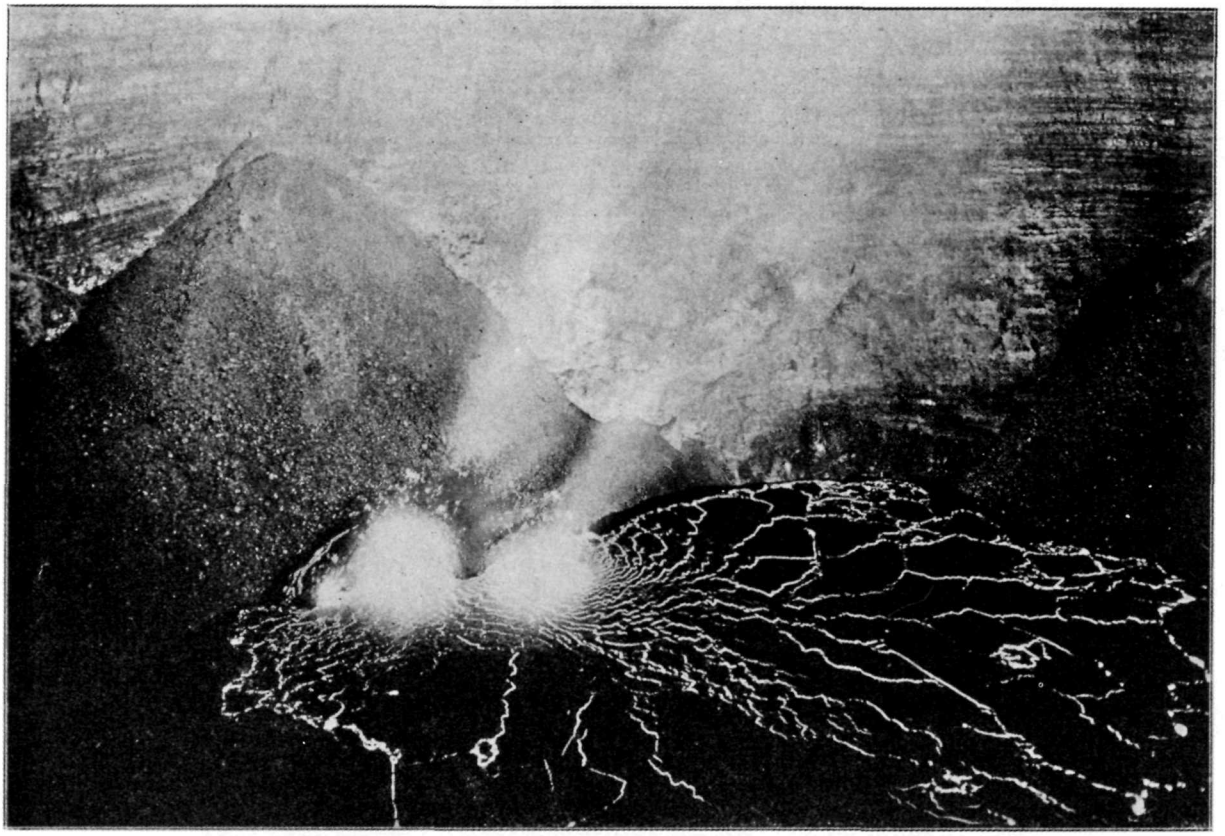


Interior of Halemaumou pit July 28, 1929, showing west wall, the great west talus slope, the triple fountain niche with condensing fume, and the built up rampart around the borders of the new lake. Photo M. Furuya. Copyright.

KILAUEA ERUPTION IN JULY, 1929

The fiery activity of the bottom of Halemaumau pit, the inner cup of Kilauea Crater, which was described in Volcano Letter No. 267 as being so brilliant in February of 1929, now seems to visitors to be a myth, particularly as recent avalanches coated the black lava floor with pinkish dust. But the inrush of lava in spectacular fountains was not limited to February of last year. The process was repeated during the last week of July, with a performance of magnificent fireworks that lasted four days, when thousands of automobiles brought a vast flock of visitors from near and far to stand spellbound night and day on the edge of the fire pit, like a congregation of worshippers. At such times the psychological effect on the community is one of the wonders. The Observatory workers surveying at the far edge of the cauldron, looking across at the tourist station, see a stationary line of human beings four deep in coats of many colors, fringing the top edge of the abyss. Behind them is a steady stream of newcomers, and still farther back the endless snaky line of motor cars winding up the cliff, like ants at the approaches to an ant-hill. And at night the ants are all aglow in their progress, and those clustered on the rim twinkle like fireflies with their flashlights, while the volcanic fires illumine the line of white faces stationed motionless above the cliff. And the cliff is flooded with glaring rosy light.

This July outbreak developed its maximum inflow of



Halemaumau at dawn July 28, 1929, showing the active grottoes and bright line pattern of new lava lake with the west and northwest taluses in the background. The active belt of February had been along the base of the right-hand talus shown (see photograph Page Three). The new active crack was along the base of the left-hand talus. Photo Hilo Photo Works.

lava at the western edge of the floor of February, and on a line of cracking intermediate between the February fissure and the crack straight across the middle of the pit which had been the source of the 1927 inflow. This can be understood by an examination of the picture on Page Two, where the line of the new July fountains is parallel to the base of the big left-hand talus cone. Comparing the picture on Page Three it will be seen that the February fountains extended from the extreme right, which is the north corner of the floor, to the big belt of boiling lava that lay under the wall between the two taluses. This last photograph shows the shape of the lava pool of February and the floor left behind when it cooled off. The new crack of July followed the upper left-hand shore line of the pool shown on Page Three, that is, the lava cracked its way up one margin of the February fill, doubtless lifting that fill as a wedge-shaped cork and tipping it a little away from the western talus slope. It may have been the same mass of lava, still liquid below, recharging itself with gas until it could lift the plug.

What happened in July to inaugurate the new eruption was, firstly, a series of very small earthquakes a few minutes apart about 4:35 a. m. July 25, 1929, registered on the seismographs but not felt at the Observatory on the edge of the greater crater next to the Volcano House. These little jarrings were each accompanied by a tilting of the ground to the east. Then spasmodic tremors developed in the lines written on the smoked paper of the instrument by the tiny steel pens, and after 6:30 a. m. this became a strong continuous tremor well known to the seismologist as the volcanic vibration which is a sure sign of lava fountains in Halemaumau pit, two miles away. At 6:10 a. m. a cloud of bluish smoke was rising from the pit.

The observers at once drove to Halemaumau and found inside the pit two fountains of lava spurting high from above the lower edge of the large western talus cone. The blue smoke that rose from them smelled strongly of sulphurous acid gas, and sometimes there were puffs of brown sulphur fume. Then the new heat made a billow of moisture cloud shape itself high above the pit. The fountains gained strength, always sending a cascade down to flood the February floor of the pit, and began to fling blobs of pumice-like lava 200 feet into the air, along with strings and shreds of brown spun glass. This material falling back built up a greenish brown mossy bank against the slide-rock slope. New lava vents opened between the two groups of fountains and the glowing melt oozed up through the crevices of the slide rock, trickled down to the floor below, crusted over, and left a glowing hole at the top and a bright cavern at the base. From this cavern a steady stream of golden fluid poured. Within an hour two-thirds of the February floor was covered.

The next event was a tunneling, under this floor, of the new lava, which ridged up the old slabs like a mole hill and sent a blast of gas out through a small orifice with a roar. Then sputtering lava fountains broke through the cracks along with flames and hot brown fume, and the roaring became spasmodic. By 8:30 a. m. the fragments of slag from the big fountains were falling forward on the new pool, the jets rising with a slow, majestic, steeply curved trajectory, of bright blood-red color, and made up of light weight material which fell lazily. By noon there were whirlwinds at the edge of the pit created by the tremendous updraft over the hot lake, and one could collect pellets of brown pumice, some of them two inches long, which were falling outside of the pit. There were also many glassy needles sometimes clustered together in straight sticks resembling golden straws. Tangles of Pele's hair were falling. This is made by the sputter and bluster of the gas rushing through the puddles of glass of which the fountains are composed, and so spinning siliceous cobwebs.

Quickly the older floor became covered ,and it was possible to estimate how deep was the new fill from the peak of the cone of 1927 which stands 2,643 feet above sea level near the south edge of the February floor, and from the February grotto of the north fountain which had

built up a high bank 2,635 feet above sea level. There was a terrace 30 feet high left by slumping in February, and this new fill of July had 30 feet of central saucer to fill up before it could surmount the terrace. On the second day, July 26, the new lake surrounded the remnant peak of the 1927 cone and about 10 a. m. it half encircled the north grotto heap of February, 1929. During the first 24 hours the lava rose 44 feet, at the end of 48 hours the depth had increased to 77 feet, and on the morning of the fourth day, July 28, the pit had been filled 88 feet. After 85 hours of inpouring, the afternoon of July 28, and just before the eruption stopped, the maximum elevation of the new lake surface was 2,640 feet above sea level, or 94 feet above the floor it had flooded. This entirely drowned the grotto heap of February, and left the 1927 cone protruding only three feet above the new fill. Then there was a sinking back, leaving a border terrace as before and lowering the central floor about 40 feet.

The eruption remained very brilliant at night during the three evenings of activity. Glowing cascades poured over ramparts along the edges of the new fill. The source fountains built up grotto niches like armchairs as shown on Page One. The surface crusts of the lake cracked up and foundered, and as in the February eruption there was a streaming-out of the surface skin on the slag pool making radial bright lines incessantly in motion away from the source region of the fountaining jets. The built-up spatter walls at these fountains would cave in and leave red-hot walls. A tropic bird flying around the interior of the pit was overcome by the gases, fell into the lava lake, and it was a pitiful sight to see it burst into flame. Broad spatter banks were built back of the large fountain group. Once or twice a fall of rocks occurred at the north wall of the pit. The source fountains finally developed three niches as shown in the pictures. The lava would slop down, making a glistening bank in daylight against the talus slope. This bank was eternally breaking down in red-hot landslides. Finally irregular clotted crust islands were left over the surface of the floor. The bottom had increased in length from 1,500 feet to 2,100 feet, and in width from 1,000 feet to 1,700 feet. Its area is about 50 acres, the volume of frothy lava that poured in, in three and a half days, was 127 million cubic feet, and the new rock that remained after shrinkage was 98 million cubic feet, equalling about 8 million tons of new matter. The pit before had been 1,105 feet deep, afterwards it was 1,050 feet deep. T.A.J.

KILAUEA REPORT No. 945

WEEK ENDING MARCH 2, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

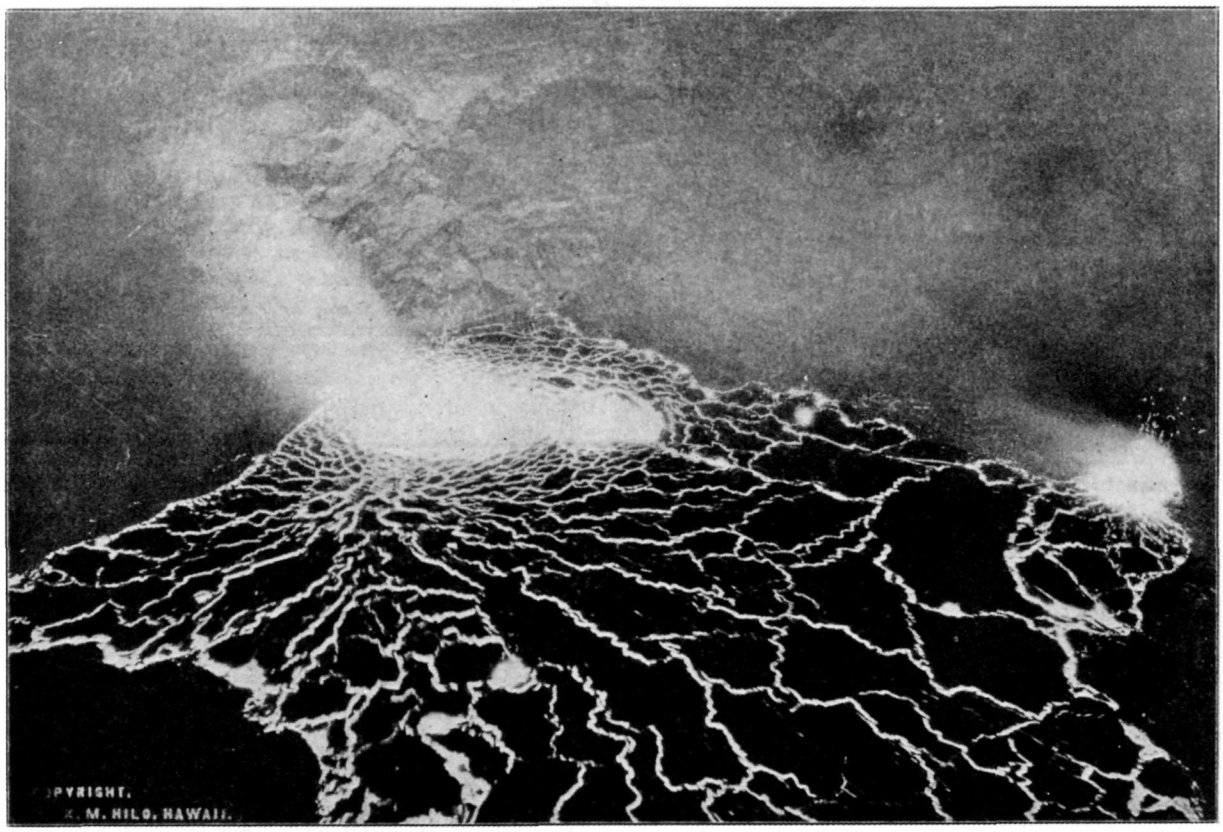
Little of importance has happened at Halemaumau pit during the past week. On February 25 the dust on the crater floor had been washed away by heavy rains. Dust from slides was seen occasionally during the week, notably at 12:30 p. m. and 1:08 p. m. February 26. Vapor was notably absent from the usual places March 1.

The seismographs registered three very feeble local seisms indicating distances of origin 34, 44, and 51 miles; and 8 spells of tremor. Microseismic motion increased February 27-28 along with strong northeast wind, and has otherwise been moderate. Tilting of the ground was strong NE.

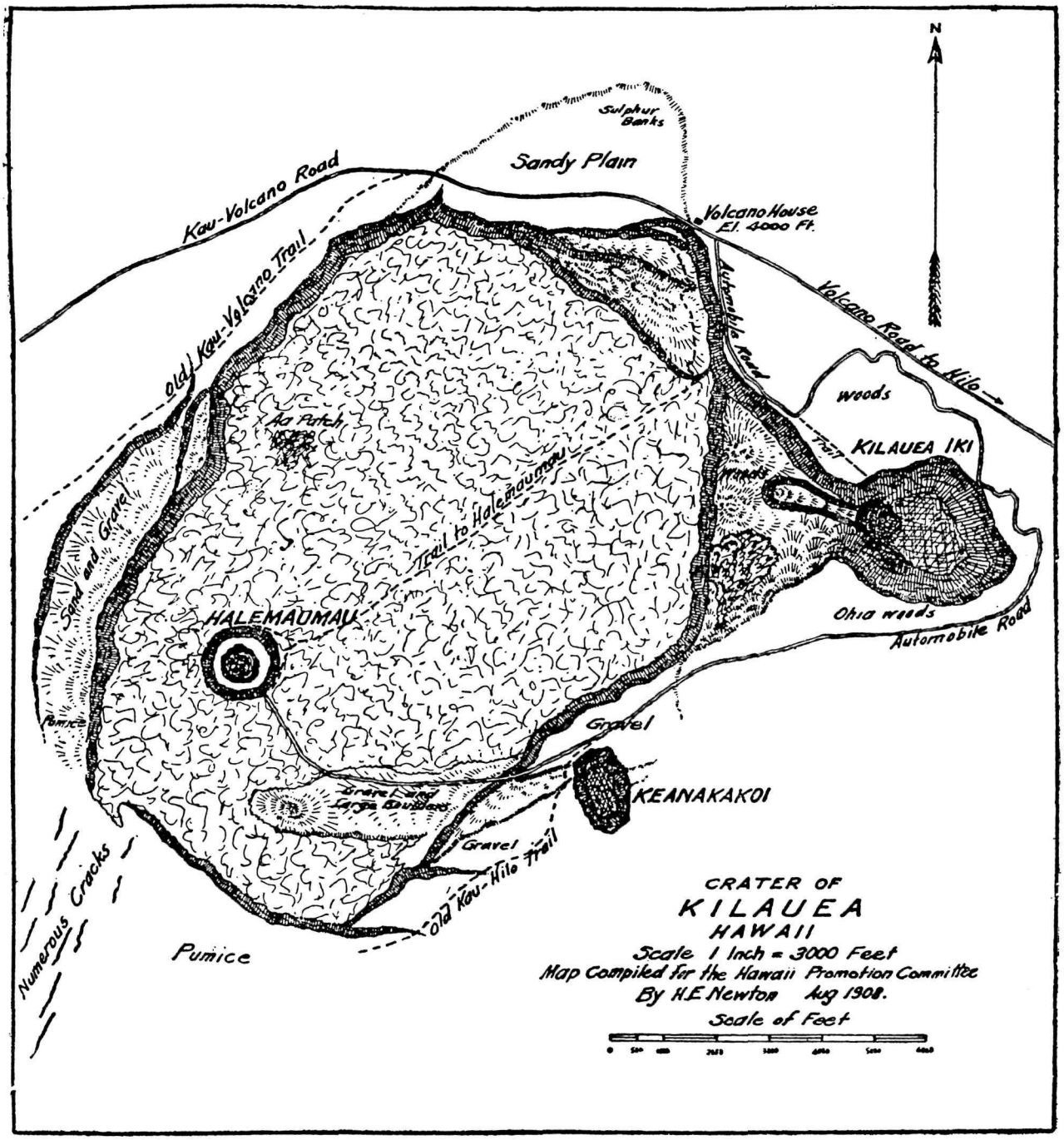
FEBRUARY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory, on the northeast edge of Kilauea Crater, just opposite the Volcano House, the tilting or tipping of the ground as measured with seismographs in a concrete basement was as follows, expressed as angular change and direction of motion of the plumb line:

January 27—February 2	5.38 seconds	SW
February 3—9	3.03 seconds	NE
February 10—16	2.66 seconds	SW
February 17—23	1.39 seconds	SSE
February 24—March 2	5.26 seconds	NE



The eruption of February 20, 1929, for comparison, showing approximate outline of the floor over which the new eruption poured its lava. The new eruption source was at the extreme left, and all the area here shown had become cold and solid when the July flood began. Photo Maehara. Copyright.



Old map of Kilauea, showing general relation of Halemaumau to Kilauea Crater. Present inner pit is much larger, and the new Chain of Craters Road now extends off to the southeast.

THE VOLCANO LETTER

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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The Volcano Letter

272

Two dollars per year — Ten cents per copy

No. 272—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 13, 1930



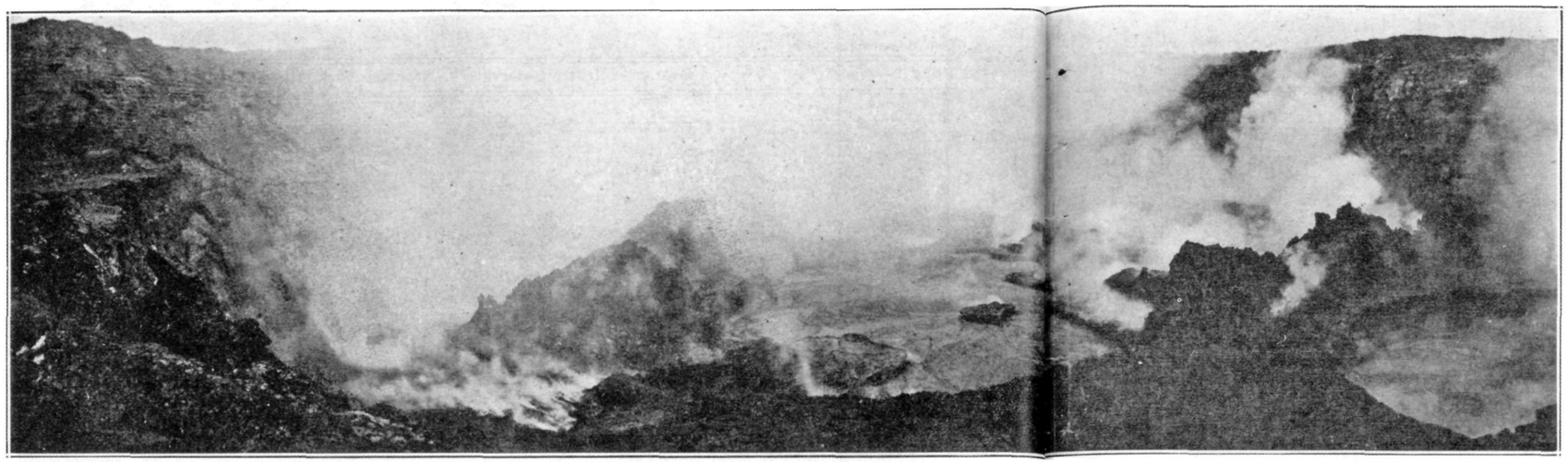
Interior of Halemaumau pit September 20, 1921. Crust of the north pool of the main lake in the foreground is being overflowed with liquid lava by the cracking up and sinking of the surface blocks. The crags are old overflow platforms, inside the pit, swollen up and tilted. Photo Jaggar.

LAVA FROTH AND LAVA PASTE

One of the most far-reaching discoveries made by continuous observation of the liquid lavas in the fire pit at Kilauea is that the lava in motion divides itself into two substances. This fact has been misapprehended in the past, owing to the supposition that the one substance is the liquid or molten material, and the other substance is the portion which has solidified. What are here referred to are two substances, both of which are liquid. Generally their viscosity differs, so that the one substance is highly fluid, and the other substance, forming the bottoms of the lava lakes, the side walls of the lava lakes, and forming the beds and marginal fields of the lava rivers, is semi-solid or pasty but mobile and red-hot. And this mobility shows itself in that the bottoms and side walls of the lava lakes, and the overflow fields of the lava flows all move with the liquid torrents, but with a more uniform pasty flow.

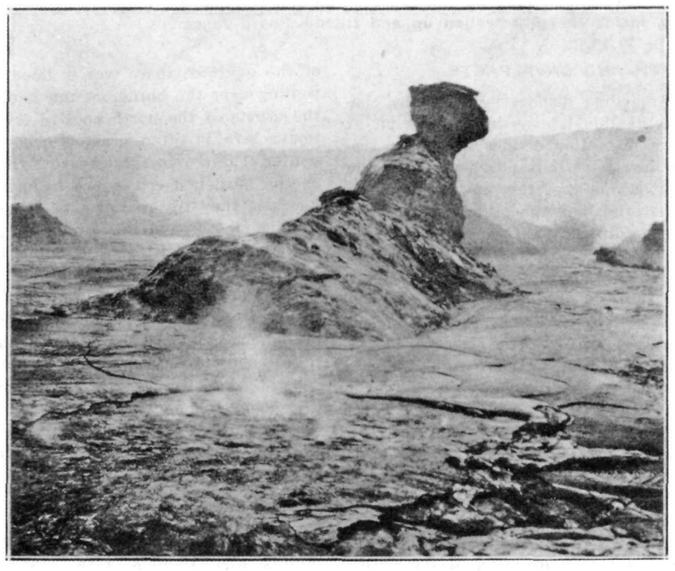
In the photograph on Page One the observer is looking toward the middle of Halemaumau pit from the north rim in September, 1921, when the lava column as a whole was rising. The black cliff in the background is the rim of the pit. There had been a strong lowering of the entire circle of crags and lava lakes during the preceding six months, and now the lava was rising again. The lowering in question had followed the tremendous overflowing of the pit rim in March, 1921. So the two equinoxes had produced risings. When the picture was taken, the very day of the equinox, there was a flood of glowing liquid lava welling over the border of the liquid lake and up through the crusts of the north pool in the foreground. A lake of liquid lava is often crusted over like a frozen pond in winter. The crusts burst apart if the pond below rises, and as the hardened crusts are heavier than the gassy froth beneath, they tip up and sink. That is what is happening in this picture and the jumble of peaks is a part of the paste on top of which the liquid lake maintained an irregular shallow saucer of its own. The platform in the foreground was a part of the rim of this saucer. The flat crusts being flooded on the left were the frozen surface of the main lake. The high peak on the right stood 105 feet above the lake which was boiling and liquid in the central region among the crags. The lake surface stood 75 feet below the pit rim.

The reader may well ask, "How can a jumble of peaks be a paste? Surely these are floating islands in the lava?" This conception of floating islands is a time-honored fallacy. Solidified basalt has a higher specific gravity, therefore is heavier, than liquid basaltic melt. Much more is it heavier than gas-foamed liquid basaltic melt of the fountaining and flaming lava lakes. Therefore solidified crusts sink, and solid crags and peaks certainly do not float on liquid lava. These solid crags grade downward into a red-hot, dense, heavy substance which from time to time has revealed itself as continuous with the rock of the crags, extending under the liquid lakes as submerged



Halemaumau from the north September 14, 1920, after many months of low and smoky lava. The small island in lava lake is the same as the one suddenly uplifted in the picture below. Photo Hilo Photo Works.

incandescent cliff or bank or shoal. The nature of the revelation has been by sudden uplift, forty feet in a few hours, of the shoreline of a lava lake, or by sudden downward drainage of the lake itself. These processes have revealed smooth glazed surfaces under the lake, and comparatively small wells or tunnels feeding the liquid slag into the shallow lake basin. The half-hardened paste of the inner crag matter is the substance from which these basins are sculptured. All the lake basins are shallow, because the lakes are puddles of rapidly cooling melt maintained liquid by the hot gases which are rapidly escaping. The lakes cool and partially solidify on the bottom and



Island in the central lava lake of Halemaumau which was lifted suddenly March 15-16, 1921, by the swelling up of the lake bottom, revealing a mushroom stem and a broad base. This heaving of the lava paste preceded the gushing of the liquid lava March 18. Photo Jaggar

at the sides. The side solidification forms a rampart over which the rising lake floods in short-lived fills which stratify. The feeding well, up which the hot lava froth rises through a deep accumulation of this lava paste, has its walls continually congealing inward in proportion to the volume and heat of the oncoming new lava from the depths.

The two pictures on Page Two exhibit a small flat lava islet which lifted itself suddenly just before the intense overflowing of March, 1921. This performance was one of the revelations above referred to. The first picture, in September, 1920, was taken when the lava lake had reached a low position of 280 feet below the rim of Halemaumau, and the jumble of crags and lakes was very smoky. The whole lava column had been lowering during 1920. About the September equinox of that year it started to rise just after this picture was taken. The flat triangular islet represented the top of a shoal in the lake, and appeared or disappeared according as the lake lowered or rose more than the pasty lava column of the crags. The islet was a part of this stiff lava column through which a honeycomb of wells fed the lake. When measurements were made with transit from the edge of the pit during the next six months, both the crags and the liquid rose together, the liquid greatly gaining on the crags and partially drowning them about January 1, 1921. Then there was a temporary lowering when the crags emerged again, but the crags also lowered more slowly than the lake. This kind of alternation is the rule in measurements of the rise and fall of the lava column, and these measurements are part of the proof that we have to deal with two substances in the pit, a slow and steady larger mass of paste, and a more tumultuous and erratic smaller body of froth.

The lower picture, and the map on Page Four show what happened just before the intense effervescence and overflow of Halemaumau of March 18, 1921. The islet had reappeared and is shown on the map just under the words "Cent Lake". This central lake was 110 feet below the rim March 14. Then crags and lakes began to rise. This inconspicuous little island, a few feet across, between March 15 and 16 suddenly lifted from beneath the lake, and became a huge ungainly gray monster with rounded back, flat topped head, and slender neck. This great bulk of lake bottom substance, which was pushed up faster than the liquid in the center of the pit, demonstrated a swelling in the under paste that was exceptional.

During the next 24 hours the crags rose 10 feet, and then came the intense fountaining up of the liquid in artesian fashion so as to fill the whole vast cylinder of Halemaumau to overflowing in six hours. Approximately 283,000 cubic feet of liquid entered the pit in that time, allowing 50 per cent of the space to the hard paste. This would imply an inflow of more than 47,000 cubic feet per hour.

The lifted islet in the third picture stood like a thin-stemmed wine glass on top of the newly uplifted hill of lava dross. The summit stood 40 feet above the lake like a tilted toadstool threatening to fall at any moment. A portion of it broke away the next day. The lower hill was a rounded black elephant's back with a smooth surface and some shore marks steeply upturned. Evidently the stem of the islet had narrowed just below lake level in the days before the uplift and during the uplift the whole mass was toppled over towards the west.

In the cross-section under the map (Page Four), a feeding well is indicated at the southeast, and one of the connecting tunnels following the wall crack, or edge region, of the fill, at the northwest. These tunnels have the same kind of history as the wells. They represent a solidifying inward of the walls of a surface stream of slag, until the stream is flowing in a sewer pipe of its own making. The cross-section shows how much bulkier is the paste or craggy matter, as compared with the liquid. There is good reason, based on experiment, for thinking that the rising liquid gets hotter upward, being heated by reactions between the gases that are escaping from solution to the bubble form, and are increasingly mixing with oxygen. Technically we speak of the paste as the "bench magma," the word "magma" meaning dough, and the liquid lakes or flows as "lake magma." This dual quality of basaltic lava we shall have to consider further in treating of smooth-lava and clinker-lava flows. T.A.J.

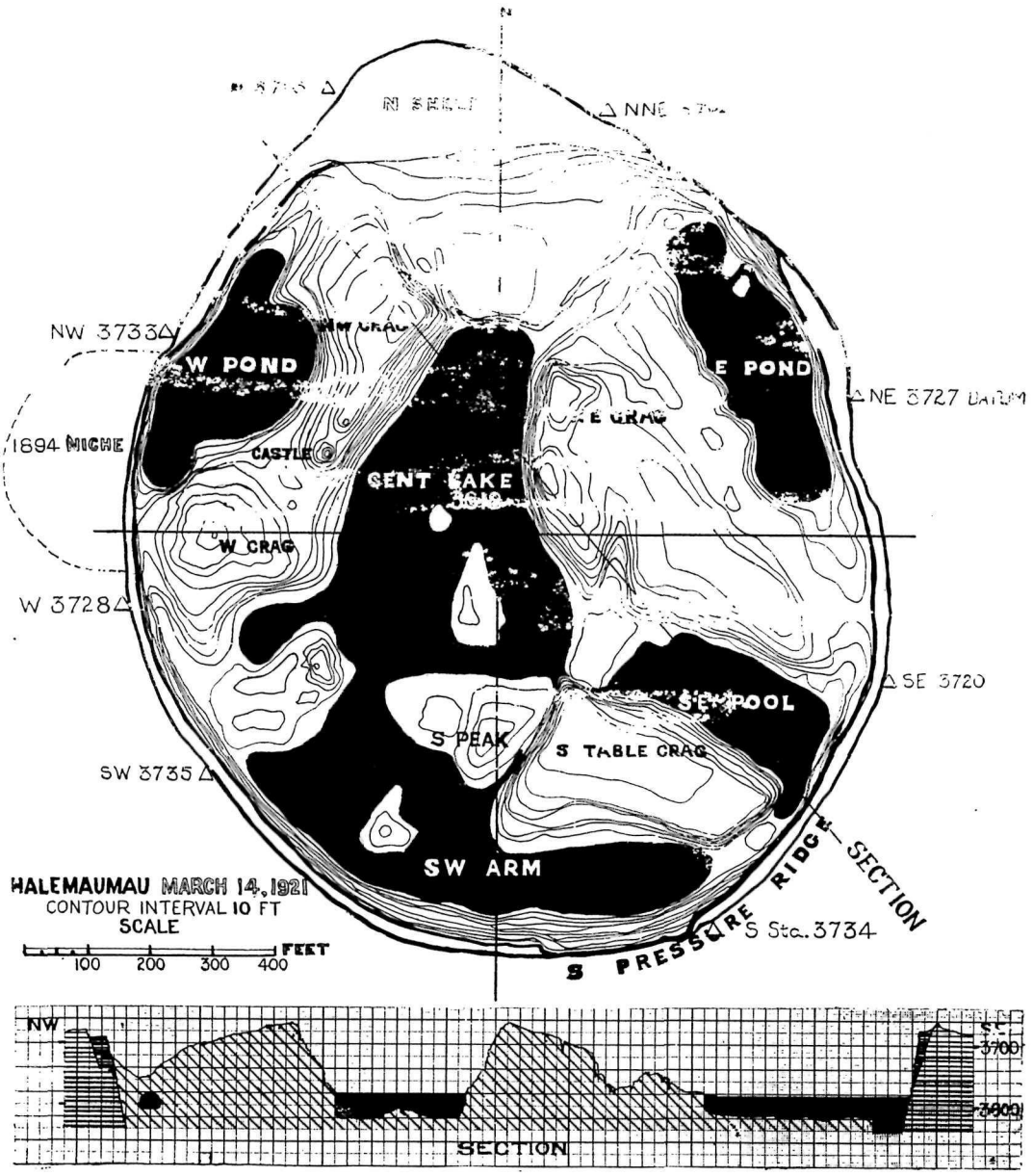
KILAUEA REPORT No. 946

WEEK ENDING MARCH 9, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On March 5 it was evident at the north wall of Halemaumau that sliding had been resumed leaving fresh breaks in the wall. About six slides were noted by workmen during the day. The roar of a slide was heard at 2:34 p. m., and another was seen a few minutes later, both causing dust to rise. The pit seismograph indicated 12 avalanche tremors during the preceding day. At 3:15 p. m. there was another dust cloud. Two dust clouds at 11:15 a. m. and 11:40 a. m. March 6 indicated fairly large avalanches. On March 8 there were slides at the north and northwest walls, and on March 9 slides were numerous during the forenoon, one making a large dust cloud at 10:50 a. m. About 4 p. m. a very large cauliflower cloud rose over the whole pit from an unusual avalanche.

The seismographs at Kilauea registered during the week 5 tremors, 7 very feeble local seisms, and one rcorded as feeble indicating origin distance 9 miles 10:56 p. m. March 8, and reported as felt in Hilo. Three other distances indicated for very feeble shocks were 31, 38, and 46 miles. Kapapala reports numerous recent shocks. The tremors lasted from one-quarter to three-quarters minute. Microseismic motion was slight, and tilting of the ground was slight to the north.



Map and profile section of Halemaumau, surveyed March 14, 1921. Shows the very small central islet before its upheaval March 16. Elevations in feet, bench lava in 10-foot contours referred to lake level, liquid lava black. Surveying stations indicated by triangles. Survey by Jaggar.

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The Volcano Letter

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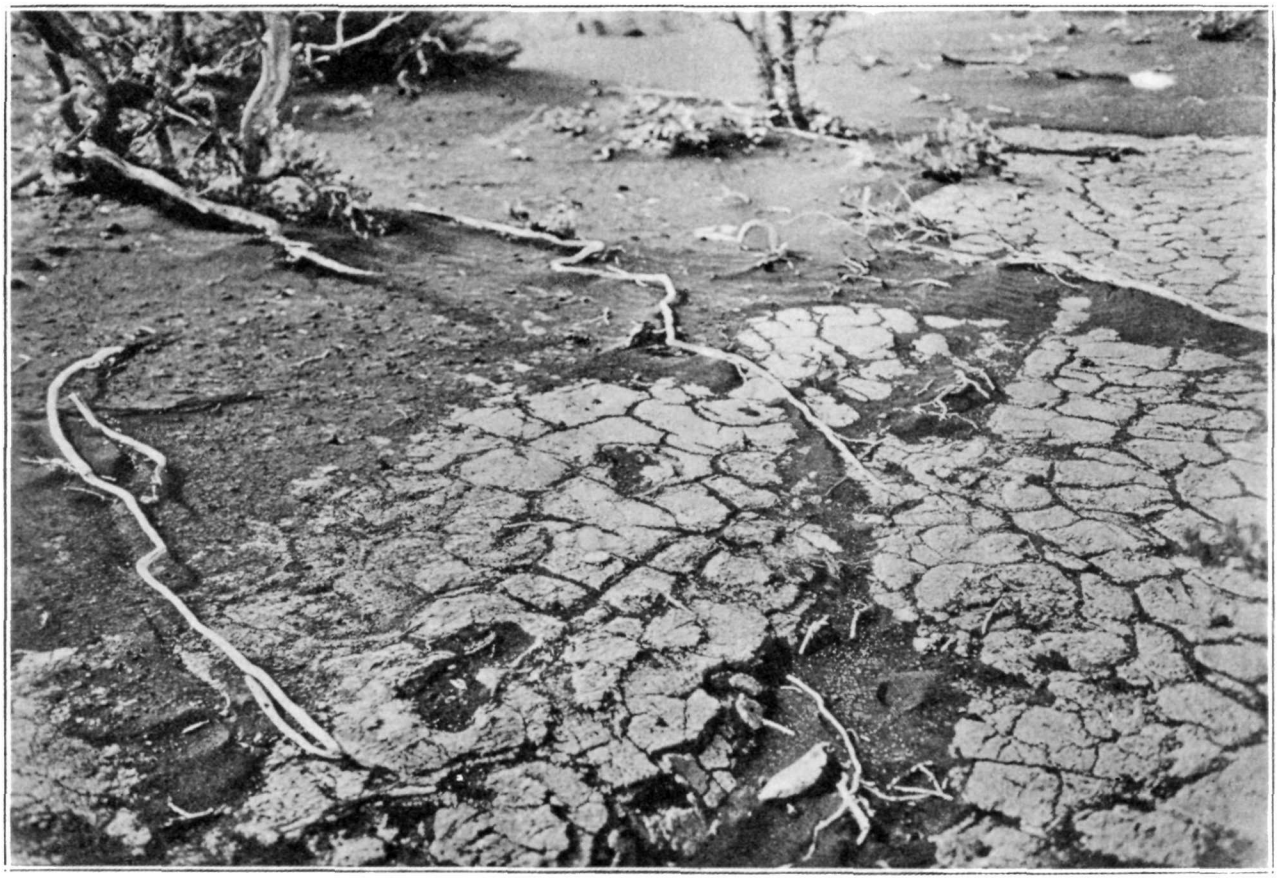
No. 273—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 20, 1930



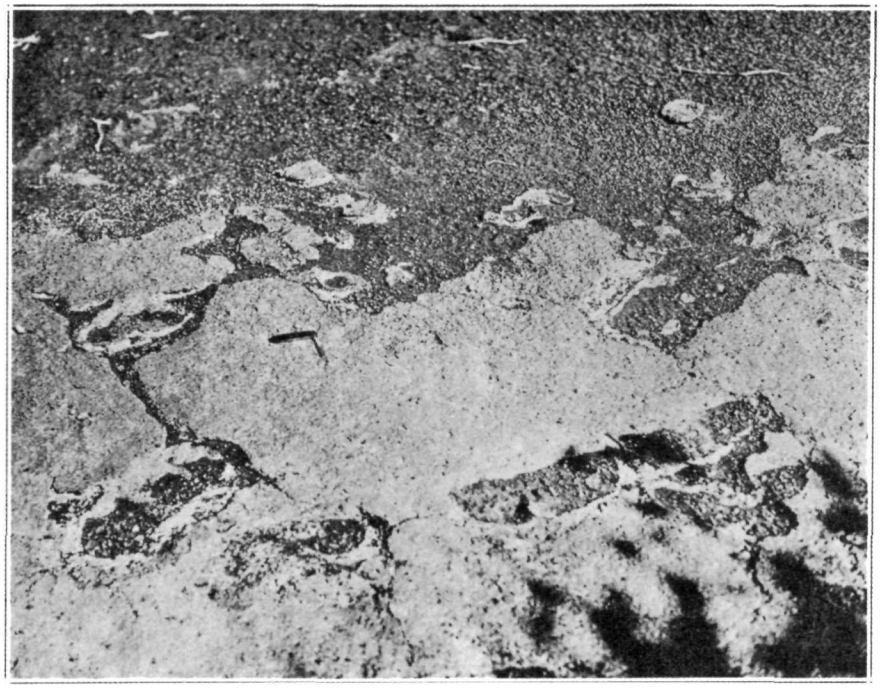
Photograph of fossil human footprints in the lower of two layers of Kilauea ash mud of 1790. The upper layer is here eroded away. There was black sand and cinder between the two layers. The ash is a hardened natural cement. As these footprints are in the ash of the first ash eruption, and are elsewhere buried under the second ash layer, they must date from the eruptive period. Photo Jaggar.

THE HUMAN FOOTPRINTS IN KILAUEA'S ASH BED

Two archeological discoveries of interest as bearing upon the human side of the ancient eruptions of Kilauea were made in 1919 and 1920 as incidents of the work of the Hawaiian Volcano Observatory. One of these was the finding by R. H. Finch of well preserved hardened footprints in what had been the ash-mud of heavy rainfalls in the Kau Desert southwest of Kilauea Crater, dating from the explosive eruption of that crater about 1790. The other was the unearthing of a skeleton on the second shelf of Uwekahuna bluff by the late Joseph Hedemann. This discovery was made February 21, 1919, among the big bowlders a little way below the Uwekahuna Museum, and the remains appeared to represent a very ancient burial of a woman in reclining posture, half covered with ash and washed soil, and walled in between two large rocks. The evidence indicated a time of burial not far removed from 1790. The locations of these two finds may be identified on the accompanying map of Hawaii as just to the west of the head of the flow of 1920 at the edge of the National Park, for the footprints, and the west cliff of Kilauea Crater, for the skeleton.

The photograph shown on Page One exhibits a surface of ancient, sun-cracked mud which consists of what geologists call pisolitic ash. Pisolites are little pea-shaped balls occurring all through a layer of the ancient rock dust that fell over the country during an explosive eruption. This dust was hurled upward in the midst of clouds of steam, and fell round about like snow. It is characteristic of such times that the atmospheric moisture condenses as heavy rainfall ,usually with thunder and lightning. When the dust is caught in the raindrops, the rain falls as mud. If such mud drops fall along with dry ash, or into beds of dry ash, they will form a layer of pellets. These pellet layers were common in the explosive eruption of Kilauea in 1924, and at Vesuvius in 1906. If the rain is abundant the ground may be muddy while still preserving the identity of the pellets. If this muddy ground is afterwards heated by the sun, it will shrink and crack in irregular blocks as shown in the picture. The volcanic dust had been greatly roasted by the combined fire and steam activities of the eruption of 1790, and this made it into a weak Portland cement. On drying it would harden and resist erosion for many years.

Between the two white sticks in the foreground of the picture may be seen two footprints which are the impressions in this muddy cement of large, naked, human feet advancing toward the observer, the left foot at the back with its ball joint and big toe clearly seen on the left-hand side of the impression, and the right foot in front showing complete heel and toes, the print being filled with drifted black sand. The stride was long and in a direction down the mountain with the ball of the foot digging in as though the man were hurrying. It will be observed that the drifted dune sand and cinder lie over



Footprints of adult, probably the mother, in hardened ash of foreground, and of child in background. They show the impress of separate toes. These were progressing to the right, or down the mountain. Penknife shows scale. This is the upper ash layer, without sun cracks, and the little white pellets are fossil mud raindrops. Photos Jaggar

this layer of sun-cracked mud. This fact is of importance, for in the second photograph on Page Two, footprints are shown in another and higher layer of the same kind of ash filled with fossil raindrop pellets, having the dark cinder underneath the ash layer. This upper layer is also cemented, but it is everywhere lacking in the sun cracks, which are characteristic of the lower layer. The upper layer has pebbles which fell during the eruption, the lower layer has none. Everywhere the two layers may be found in this same relation, with the dark sand and cinder in between, and the whole thickness from two to six feet of beds in different places. What they mean is that there was a first eruption that deposited the lower ash and pellet layer without any pebbles; then there was a more violent eruption which buried this layer under sand and cinder; finally came more fine ash, mud pellets, and a little cinder to pepper this last layer with pebbles. These several eruptions may have been hours or days apart.

Now we have shown in photograph No. 1 that after the first layer was formed and before the sun had come out and dried it, a big native strode down the mountain and left his footprints, before the violent flurry of ash and cinders buried them up. The surface that we see in this photograph has been washed clean by more recent rains, for nine-tenths of the ash of this period has been eroded away. It is only in a few fortunate hollows that this footprint record is preserved. A few other footprints have been discovered in the lower sun-cracked layer, and they usually show that the makers were running and going down hill. On the other hand, the footprints in the upper layer are more leisurely, are crowded in large numbers and represent men, women, and children, and are progressing both up and down the mountain. In other words, the persons present at the time of the lower layer were there in the midst of the dangerous period, with more eruptions yet to come. This succession proves conclusively that the footprint-making was contemporaneous with those explosive eruptions.

Who made the footprints? Why were natives in considerable numbers crossing the mountain just at the time of this dangerous eruption? The missionary Ellis tells us (Narrative of Tour Through Hawaii, by William Ellis, *Hawaiian Gazette Company Ltd., Honolulu, 1917*) that Keoua considered himself the legitimate heir to the throne of the island of Hawaii and in the year 1789 marched from Hilo with all his forces to attack the warriors of Kamehameha in Kau and Kona. He crossed Kilauea Volcano, and "an eruption took place that very night, and destroyed the warriors of two small villages, in all about 80 men." The Hawaiians told Ellis that Pele favored Kamehameha, and aided his cause by destroying Keoua's soldiers. Keoua had broken the tabu of Kilauea, Pele was exceedingly angry "and soon after sunset repeatedly shook the earth with the most violent heaving motion, sent up a column of dense black smoke, followed by the most brilliant flames."

"A violent percussion was afterwards felt, streams of bright red lava were spouted up, and immense rocks in a state of ignition were thrown to a great height in the air. A volley of smaller stones, thrown with much greater velocity and force, instantly followed the larger ones, and striking them caused the larger stones to burst frequently with a report like thunder, accompanied by the most vivid flashes of lightning."

"Many of Keoua's people were killed by the falling fragments of rocks, and many were actually buried beneath the overwhelming mass of ashes and lava." Not intimidated by this event, Keoua continued his march, and the volcano continued its action, confining its operation within the boundaries of Kilauea. Ellis states that he heard this account several times from natives with some little variation as to the numbers killed, and a variant of the story said that Pele appeared to Keoua, in the column of smoke as it rose from the crater. The main facts about the natural history of the eruption he believed to be true.

Other accounts of this eruption indicated that Keoua camped three nights at the volcano while eruptions were in progress, especially at night. On the fourth day he divided his people into three companies, with the chief's division in front, and they had not proceeded far before the ground shook violently, and then an immense black cloud rose out of the crater and produced darkness. Black sand, stones, and dust came down in a destructive shower, some of the first party were killed, and all of the second division were asphyxiated with the hot dust and their corpses were discovered by the third division, some lying down, others sitting up and clasped in farewell embrace. The warriors had their families and livestock with them, and the only living being discovered was a solitary hog.

It is probable that the fossil footprints were made by Keoua's people. The second picture shows the footprints of an adult in front and a child in the background headed down the mountain at the locality west of Mauna Iki where probably the natives were beyond immediate danger, trudging through rain-soaked puddles of muddy ash. This material now is hard enough for a man to walk over it with heavy boots without breaking the shell. Some broken crusts may be seen in the foreground on Page One. This trail of fossil footprints has been followed uphill from the southwest for seven miles in the direction of the west side of Kilauea Crater to a point a mile and three quarters southwest of Uwekahuna bluff. Here the material of the upper layers is coarse and pebbly, but a lower layer of fine ash, corresponding to the mud-cracked stratum of Photograph One, reveals footprints at the margins of erosion patches where the bottom layers protrude. The track of a barefoot adult was found headed south, with stride 24 inches long and foot 10½ inches long, and some of the ash surfaces showed raindrop imprints as well as the pellets. Other tracks were headed north, made by a smaller person, with long strides as though running. There are several places along the trail where the walkers converged to narrow passes so that the ash was beaten down by many feet. (For discussion see Bull. Hawn. Volc. Obsy., July and October, 1921.)

The burial represented by the skeleton (now in the Bishop Museum) lay just on the line of this trail where it would have passed Kilauea. The ash there is too pebbly to preserve any footprints. The skeleton may have been one of the priestesses of Pele. There was formerly a heiau or Hawaiian temple to Pele somewhere in this vicinity. It is also possible that this was one of the victims of the eruption among Keoua's people. T.A.J.

KILAUEA REPORT No. 947

WEEK ENDING MARCH 16, 1930

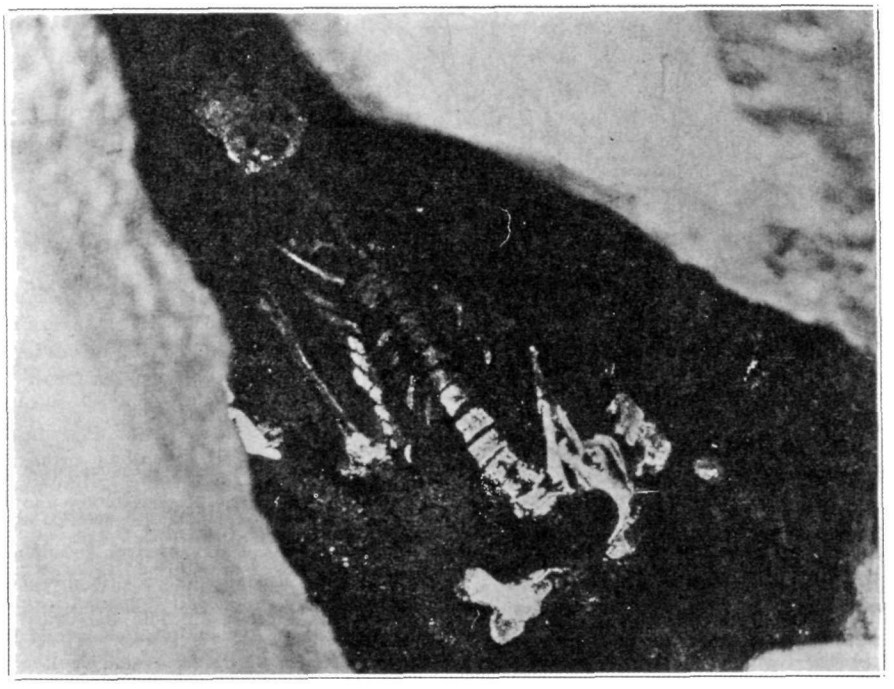
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Numerous slides occurred at Halemaumau March 10 to 14. These were mostly from the north rim and wall, as during previous weeks. The seismograph near Halemaumau recorded many avalanche tremors not strong enough to be registered on the Observatory instruments farther away. Probably the largest slide during the week was at 8:35 p. m. March 12. Sliding was nearly continuous between 6:30 and 7 a. m. March 14, and a few light falls of rocks were heard later in the day.

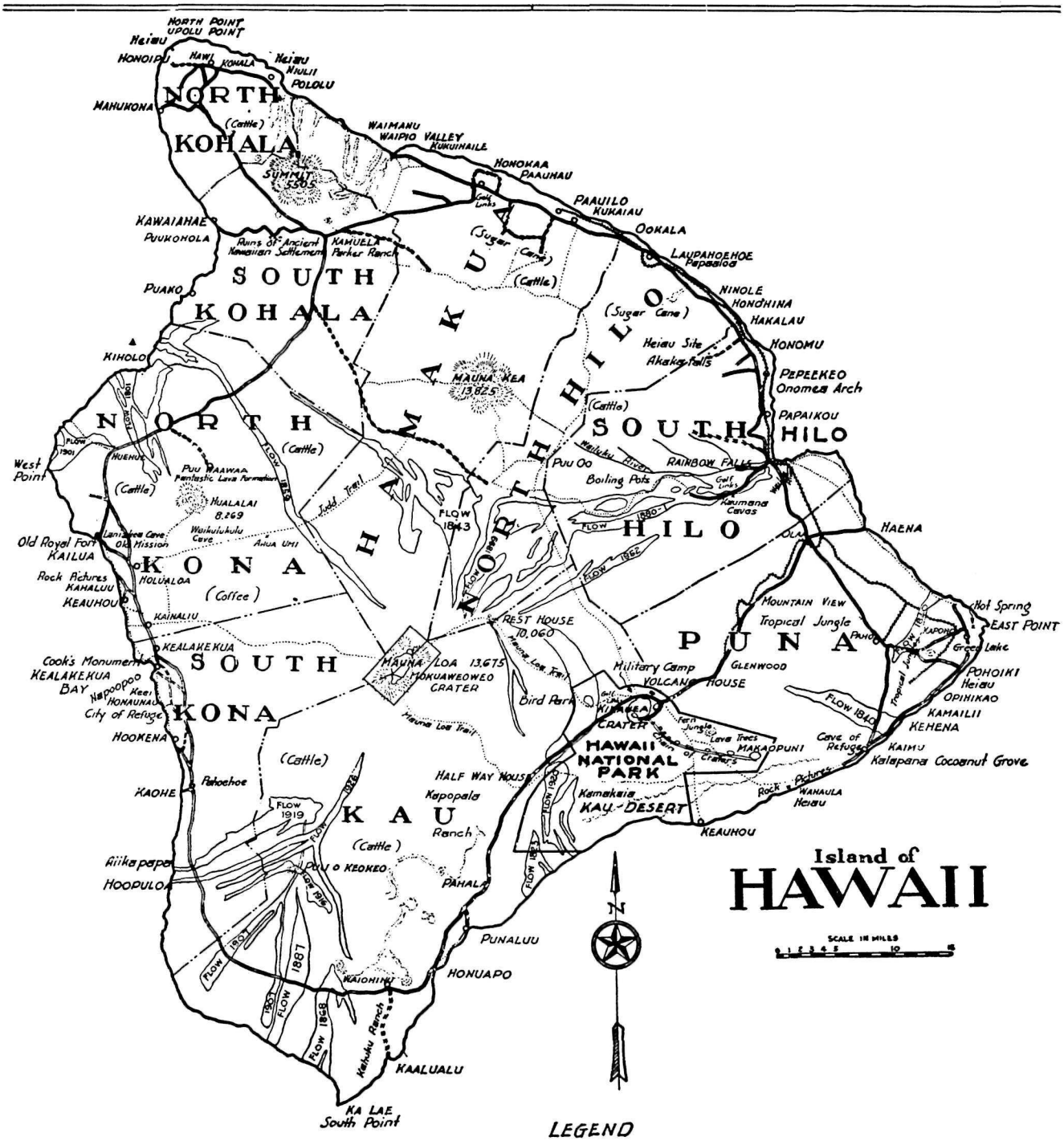
Heavy rains fell, causing much steam at times. Steam was as usual on the south talus and wall.

A total of 15 seismic disturbances were recorded by the instruments at Kilauea, divided as follows: nine tremors, five very feeble seisms, and one feeble seism felt locally and in Kau at 6:01 a. m. March 13. Its indicated distance to origin was 10 miles.

Tilt at the Observatory was moderate to the southwest. Microseismic motion was slightly stronger than normal.



Skeleton burial found lying in niche between bowlders on high east face of Uwekahuna bluff, the west cliff of Kilauea Crater. The skeleton was in a half-seated position, facing toward Halemaumau, walled in in front. Length from skull to end of spine 27.5 inches. Photographed February 25, 1919.



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274

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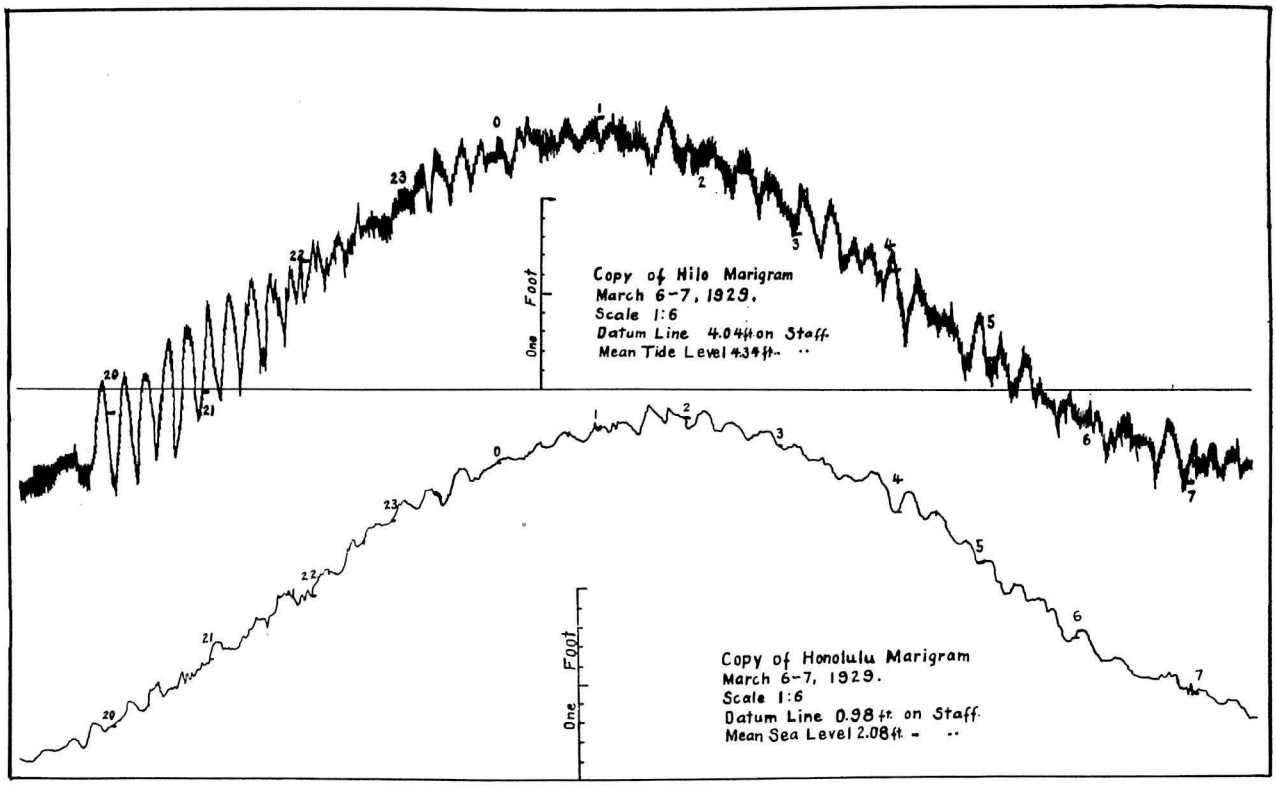
No. 274—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 27, 1930



Tide gauge writings at Hilo and Honolulu showing on the left of the Hilo marigram the pronounced waves of the ocean from a distant submarine earthquake off the Aleutian Islands March 6, 1929. The Honolulu record shows only a faint trace. The datum line for each marigram is at the base of the one-foot scale.

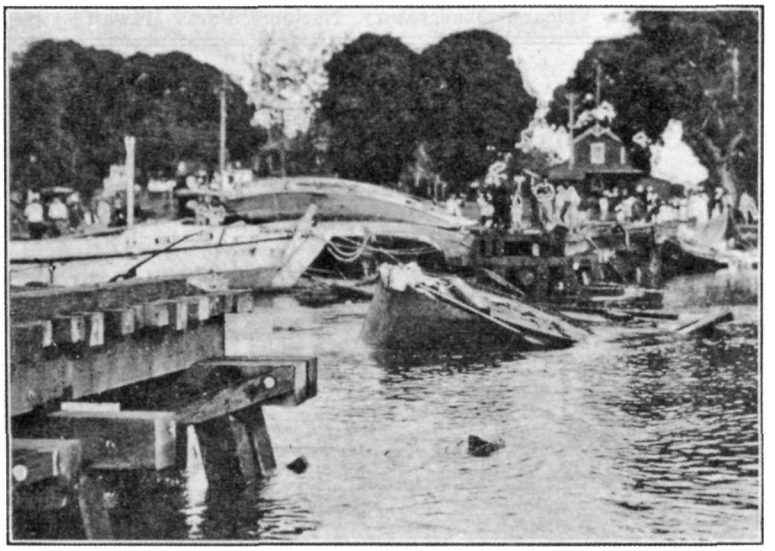
OCEAN WAVES FROM SUBMARINE EARTHQUAKES

In the Volcano Letter of February 13, 1930, a seismogram is shown, the autograph written by a pendulum at Kilauea Volcano recording slow waves through the mountain from a gigantic earthquake in southeastern Alaska. The earthquake originated in the mountains 2,700 miles away, and a few minutes later the magnifying apparatus attached to the pendulum in Hawaii indicated swayings with a period of 10 seconds, elastic wave movements swinging the rock of the Hawaiian ridge back and forth about one thirtieth of an inch. At the source the jolts may have shaken the mountains back and forth several inches in a period of a second or so. The waves slow down and widen out as they progress rapidly through the substance of the globe.

This earthquake was in the mountains and so did not affect the sea bottom. But there are many such earthquakes off the coast of Alaska and the Aleutian Islands which jolt the deep valleys under the sea, and probably drop the bottoms of those valleys, sometimes by several feet. On the coast there was a measured lift of over 40 feet during an earthquake spasm in 1899 at Yakutat Bay. These lifts of the continent are believed compensated by drops of the sea bottom. Such movements may be more than 100 miles long, and a large block of water of the ocean is instantly and violently disturbed. This water is thrown into what is called a tidal wave, or tsunami, having its own period and rate of propagation across the ocean dependent on reflection from the shores, on resonance with or opposition to the normal tide waves of that ocean, on the depth of the ocean both at the place of disturbance and along the route of travel, and finally, for any place where the tidal wave is received, on the shelving quality of the shore and the local complication with waves due to the wind.

There is popular misunderstanding about what a tidal wave can do when it arrives. Hundreds of sea waves due to earthquakes arrive at San Francisco, Los Angeles, Callao, Queensland, Japan and Hawaii which are recorded only by the tide gauges. The public does not know of their existence. When a very exceptional one piles up the waters in a confined bay back of a shelving bottom there may be a disaster, but these are rare. Much the same kind of a disastrous shore flood may be produced by persistent hurricane winds as in the Galveston, Mobile and Florida disasters. In all cases the piling of the waters goes into unfortunate rythmic harmony with the local waves and tides, for every bay has its own normal swing of several minutes duration, like a big pendulum.

The two tracings of tide gauge curves on Page One represent the swing of the same tide for 12 hours beginning at 7 p. m. (19 o'clock) March 6, 1929, the range be-



Wreckage in Wailoa River February 3, 1923, at Hilo, Hawaii, due to the piling up of the waters from a distant Aleutian earthquake under the Gulf of Alaska seven hours earlier. Sampans were thrown over the railway bridge which was destroyed, at Waiakea station. Photo Morihiro.

ing about two feet up to 2 a. m. March 7, and back again by the same amount around 8 a. m. of that date. The upper curve was written by a float under the wharf at the head of Hilo Harbor back of the breakwater, and the lower curve was similarly written for Honolulu Harbor. It will be observed that both curves in the right-hand halves exhibit three or four swings to the hour each 20 or 15 minutes long. These are the normal seiches or water basin swayings dependent on the sizes and shapes of the Hilo and Honolulu basins respectively. When the earthquake wave comes in, as strongly shown in the 15-minute pulsations at 20 o'clock on the left-hand side of the Hilo marigram, and hardly shown at all on the Honolulu marigram, this normal pulse of the bay is exaggerated into a pronounced oscillation which dwindles and dies in three hours.

This tidal wave movement of Hilo Bay was forecast on the seismographs in Hilo, at Kilauea, at Kona, and in Honolulu about 3:11 p. m. by the outbreak, so to speak, on the writing pens, of the record of a tremendous submarine Aleutian earthquake. The imperceptible underground waves caused the wirting pens on the Hilo seismograph to swing back and forth 10 inches and to write for more than three hours; and even to write the record of the earth wave that went around the other side of the globe remote from us so as to arrive here at the end of about four hours. This means a very big earthquake; the origin was indicated by the seismogram to be 2,200 statute miles away and that distance could not mean a mainland earthquake, therefore a submarine disturbance was a certainty. The evidence favored an origin either north-northwest or south-southeast of Hilo, which would be either near the Aleutian Islands, or else near the Marquesas Islands. If it were north, the expectable ocean wave would reach the north side of Oahu and the east shores of Maui and Hawaii; if it were south, the stronger movement of the waters might have been recorded at Honolulu, but past experience did not make a southern origin probable.

The nature of the seismogram resembled that of an Alaskan earthquake of February 3, 1923, which had made a destructive tidal wave at Kahului in Maui and at Hilo in Hawaii about seven hours after the earthquake happened in the north Pacific. The record had come to our seismographs about seven minutes after the jolt at the origin. There was thus plenty of time to notify Hilo of the possibilities in the case, and this notification was given, but was not on that occasion taken seriously. The indicated distance to origin in 1923 was 2,500 statute miles, and the origin proved to be under the ocean about 250 miles ESE of Unimak Pass in the Gulf of Alaska. There was probably a sudden inrush of ocean waters over a lowered sea bottom, and then a wave spread out across the Pacific with a speed proportionate to its size. It is this great speed which makes these waves comparable to tides, and the free wave of the daily tide lifted by sun and moon in the north Atlantic Ocean, a basin 3,000 miles wide, travels some 500 miles an hour. Either a tide or an earthquake wave may become dangerous if forced on a shelving shore. The Galveston flood was a wind-forced tide. The wave of 1923 at Hilo began about 12:30 p. m. and smashed sampans over the Hilo railroad bridge across the Wailoa River (see photographs Pages Two and Three). This wave reached Haleiwa in northern Oahu at 12:02 p. m., and it traveled thence to Hilo at about 5.18 statute miles per minute. At Waikiki in Honolulu the first movement was a long recession of the waters revealing new reefs during about 20 minutes. Then there were in-and-out surges at intervals of 15 to 20 minutes. This

earthquake was strongly felt in Alaska, was registered on seismographs all over the world, and the sea wave was registered on tide gauges in San Francisco, South America, and at Adelaide, Australia.

Returning to the seismogram of March 6, 1929, although the origin was even nearer than the center of February 3, 1923, and the amplitude of the motion in Hawaii was greater, and although Unalaska reported a severe shock on land and telegrams from steamers confirmed the location as south of the middle Aleutian Islands, where the crews on the vessels felt the bump; yet the amplitude of the sea wave, as shown on Page One, was only about seven inches at Hilo and two inches in Honolulu, and the surge in the sampan basin of the Wailoa River, lasting from 7:45 p. m. until 10 p. m. at intervals of 15 minutes, was something over a foot. Even this movement at its maximum between 8 and 9 p. m. was sufficient to break the stern lines of a steamer at one of the wharves back of the Hilo breakwater. The sampan fleet anchored out in the bay until the disturbance was over. The harbor authorities are always notified of the facts by the Hawaiian Volcano Obesrvatory and take proper precautions, just as any sailor would do at the possible approach of a storm. There is usually much less danger than in the case of a storm, but it would be folly to be unprepared.

Of 11 sea waves due to earthquakes on the sea floor which have been discussed at the Hawaiian station, the rate of propagation has varied from 284 to 481 statute miles per hour. An earthquake 3,915 statute miles from Kilauea in the Acapulco deep, jolted coast towns of Mexico at 4:49 p. m. June 16, 1928, and the sea wave arrived at Hilo 1:18 a. m. June 17, traveling 7.7 miles per minute. The waters at Hilo rose and fell 1.32 feet, the periodic oscillations were 15 to 22 minutes, and the water disturbance was indicated for more than 24 hours. The record was very feeble on the Honolulu tide gauge. On the other hand, an earthquake near Kamchatka December 28, 1927, 3,310 miles away made a tide record as well marked in Honolulu as in Hilo, the sea wave traveling 7.3 miles per minute. (See Page Four.) T. A. J.

KILAUEA REPORT No. 948

WEEK ENDING MARCH 23, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There were fewer slides at Halemaumau than during the previous week, though avalanche dust was observed on the 17th, 18th, and 19th. On March 22 a big scar was noticed above the northwest talus. There was little change in steaming.

Seven seisms, the smallest number since early September, 1929, were recorded by the Kilauea instruments. Two were tremors and five were very feeble seisms.

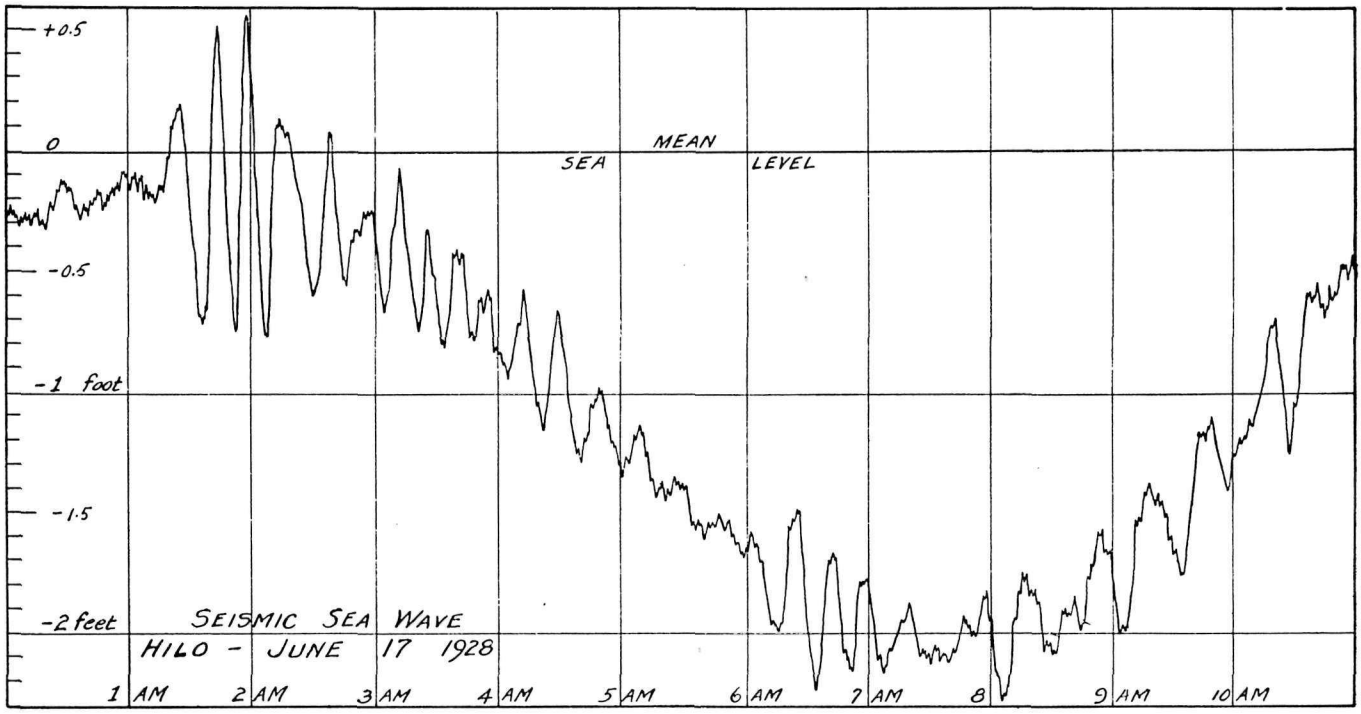
Tilting of the ground was slight southwest. Microseismic motion was normal.

NOTICE

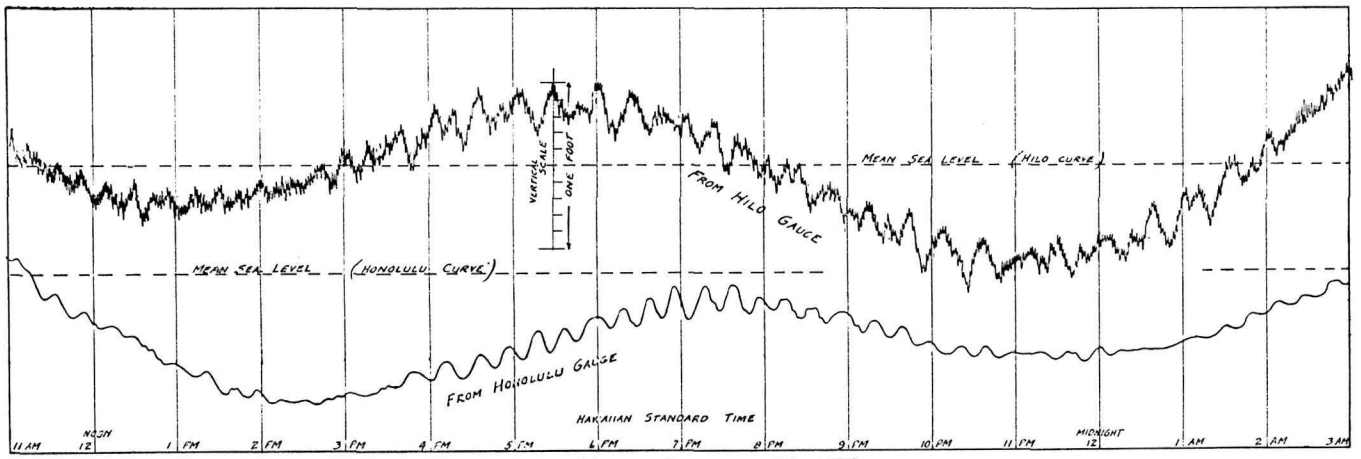
Copies of the Title Page and Index for 1929 have recently been mailed to all persons on the Volcano Letter mailing list during that year. A copy will be sent to any person sending application to the Hawaiian Volcano Observatory, National Park, Hawaii.



Railroad embankment washed down by tidal wave between Hilo and Kuhio Wharf February 3, 1923. The major wave at Hilo was the third noticed visually, and the waters rose over 20 feet in places damaging wooden houses and wharves. Damage was done also at Kahului in Maui. Photo Morihiro.



Tide gauge record of seismic sea wave, Hilo, Hawaii, June 17, 1928 This was made by an earthquake off Mexico.



TIDAL WAVE, DECEMBER 28 1927

Tide gauge records for Hilo and Honolulu compared. These were written December 28, 1927, by a seismic sea wave from an earthquake off Kamtchatka in a direction N 22 W. from Hawaii, and so registering more strongly in Honolulu than in the figure on Page One.

THE VOLCANO LETTER

The Volcano Letter combines, after January 1, 1930, the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

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Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

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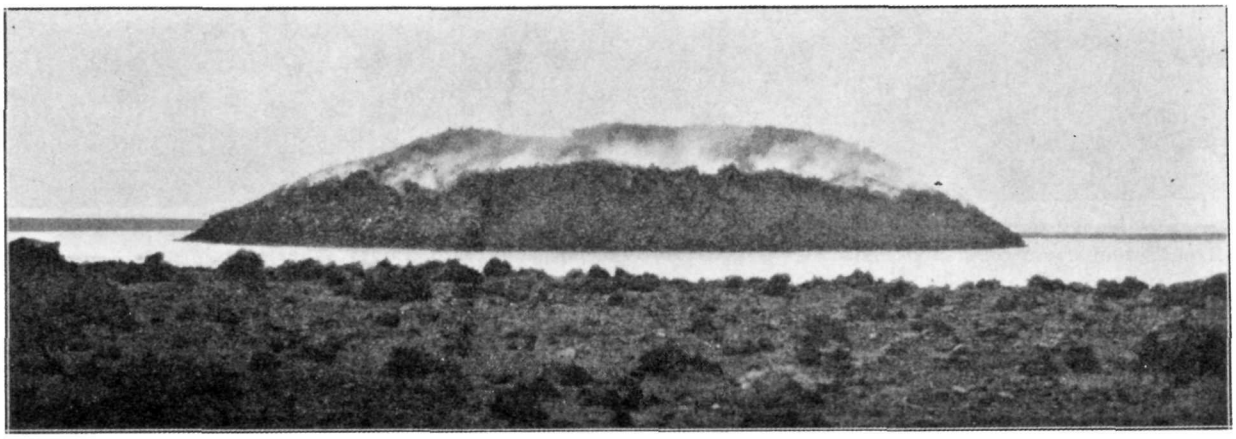
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 275—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 3, 1930



Bogoslof Volcano in the Aleutian Islands, belonging to the United States. New lava heap in warm salt lagoon, surrounded by a ring of explosion debris, about June 28, 1928. The two older peaks are right and left outside the picture. Photo looking southwest, by Captain Roy A. Wheeler, Alaska Game Commission.

RECENT ACTIVITY OF BOGOSLOF VOLCANO

If the reader studies the map on the back hereof, he will find that nearly all of the steamship courses radiating from Honolulu either reach or pass by lands of active volcanoes. The northern course reaching Unalaska in a distance of 2,016 nautical miles, touches the middle of the Aleutian chain containing forty cones which have had historical eruptions. To the east this curve extends up the Alaskan Peninsula, to the west it goes through the Aleutian Islands to Attu, the whole length being some 1,500 statute miles. On the globe this is nearly a circular arc about the inner bight of the gulf of Anadyr as a center. None of these island volcanic arcs is truly circular; they are always somewhat straight at one end and hooked at the other. So in this case the curvature is greater at the western end. As in most of the island arcs, the active volcanoes tend to line the inner side of the curvature, toward the shallower ocean, in this case the Bering Sea .The same thing is true of the Caribbee Islands confining the eastern of the Caribbean Sea; and Martinique with its destructive volcano Pelee ,is the gem in the midddle of that volcanic necklace.

When the real meaning for this hook and curve alignment of volcanic islands has been discovered, we shall know much more about the globe than we know now. Underneath the volcanoes in the Aleutian Islands there are old granites and sedimentary rocks, exposed especially on the Pacific side, which protrude from the Alaskan continent, folded and pinched along axes parallel with the island line, and falling off to a profoundly deep trench to the south. This trench is also straight on the east and hooked northward at the west. This trench is over 20,000 feet deep. A basin more than 10,000 feet deep extends into the southwestern half of Bering Sea, but the rest of this inland sea is very shallow. The Aleutian Islands are really a submerged peninsula extending westward from Unalaska with the mountain peaks rising above the waves. Just in the eastern corner of the deeper basin of Bering Sea, and 40 miles north of Umnak, the large island next west of Unalaska, some rocky pinnacles stand in the ocean where on either side the water is 6,000 feet deep. These rocks are sometimes connected into a single island called Bogoslof, and at other times a channel between two of them has been washed clear by the sea. They are of enormous interest, for they consist of nothing other than the peak of a 6,600-foot volcano which during the last two centuries has been squeezing up stiff lava like paste from a paste tube, to add to the volume of its apex.

The rise of the first rocky spine above the water at Bogoslof was reported by early navigators about 1768 and was called Ship Rock. Another stiff aa crag of andesite, Castle Rock, rose to the southeast of Ship Rock with much explosion and oceanic disturbance in 1796, alarming the natives of Unalaska. According to Krusenstern, who made



Sea lion herd at east end of Bogoslof, June 1928. Photo Wheeler

a map in 1826, Castle Rock was then two nautical miles long, 4,000 feet wide, and 350 feet high, without summit crater, and with pinnacles on top. Castle Rock was extensively washed away and made smaller during the nineteenth century. In 1883 a new eruption began and a huge tabular crag of lava rose precipitously from the sea more than a mile to the northwest of Castle Rock and enclosed Ship Rock in its debris in the space between, the bombs and gravel and sand beaches joining the two peaks to form an elongate island. For more than a decade the boiling continued at Grewingk, as the table rock was called, but the erosion of the arctic storms, and explosive outbreaks, destroyed Ship Rock, and opened a channel between Castle Rock and Grewingk, which were apparently dead at the beginning of the twentieth century.

In 1906 new lava monsters began to rear their heads from the squirming lava tangle inside the undersea volcanic mountain, and these first appeared as a steaming new heap about midway between the two older islands, connected with the northwest table Grewingk by a low flat ridge of debris but separated from Castle Rock by a channel seven fathoms deep. The new mound was conical in appearance, with sulphurous eruptive rocks emitting large volumes of steam, and showing at the summit a broken horn bending to the northeast like the famous Pelee spine in Martinique, and consisting of a mass which had been forced up through an aperture while in a plastic condition, with smooth and scored sides. The new hill was named Metcalf Cone. The heat of the steam jets varied from 94° to 224° F., and cracks in the rock were hot enough to light paper. Metcalf Cone measured 2,000 feet across the base and 400 feet high. There were the usual alternations of explosive eruption with rising stiff lava, and at the beginning of 1907 Metcalf Cone was broken in two, while the channel between it and Castle Rock had filled itself with a new steaming heap of lava, McCulloch Peak.

At this time the writer visited Bogoslof, and on August 7, 1907, landed in a dory in the midst of a herd of roaring sea lions. The precipitous cliffs were covered with millions of murres and herring-gulls, and the air was darkened by myriads of them in rapid flight. Bogoslof was now a continuous island two miles long, the two active cones were 400 and 500 feet high, McCulloch Peak was three-quarters surrounded by steaming salt water at 90° F., and it looked like a huge lumpy potato with the bulbous lumps split apart, and the whole jagged mass encircled by debris slopes that led down into the orange-colored warm water of the lagoon. Immediately adjacent to it was the Metcalf half-dome, with the central spine wonderfully revealed in cross section. The spire appeared in the cliff like an inverted fish horn, its base 360 feet across and its top rounded both in plan and profile like a beak. There were regular markings on the rounded surface horizontally, as though the horn has been shoved up at intervals. It was like a great worm rising from its burrow with its head turned toward the east. It was 400 feet high and at the top it was broken away through lack of support into a ragged 40-foot precipice, overhanging the back slope.

Bogoslof in 1907 was at its maximum of volume above the waves, for the period since the big island of 1796 had been eroded away. It was now four rocky hills, Castle Rock at the southeast, then McCulloch Peak fuming and tumbling and encircled by sand bars and lagoons, then the half-dome of Metcalf Cone with its spine, bordered by a dry lagoon on the north, and at the northwest the tabular rock Grewingk with gravel banks piled against it. Our party discovered elevated rock platforms backed by sea caves which had been at sea level a year before, so that everything indicated that the huge pressure inside the submerged volcano, which was pushing up McCulloch Peak, was also lifting the volcano on its back and carrying the chain of islets with it. This heaving of the older land was

particularly interesting, because the main island of Unalaska showed elevated sea benches, and now we know that at Kilauea, during the rising lava period of 1913-1922, the mountain top surrounding Kilauea Crater was lifted more than two feet, and carried the Volcano House up with it. In other words, the turtle-back of a volcano swells when the lava rises and flows out, and shrinks when the lava sinks back.

September 1, 1907, a dense black cloud rose from Bogoslof, ash and sand fell at Unalaska mantling everything with a snowstorm of rock powder a quarter inch deep, and there were rain and lightning and distant rumbling. McCulloch Peak had blown itself up. A steaming lagoon was left in its place, the rest of the island was piled high with fallen debris, and the backslope of Metcalf Cone had the smooth concave cone profile of a Vesuvius. There appeared to be a rythmic sequence to the events whereby Metcalf Cone built itself up 400 feet high and 2,000 feet across, lived 10 months and exploded, then McCulloch Cone was built up 450 feet high and 2,000 feet across, lived 10 months, and was destroyed. It is probable that this means a pulsation of rise and fall of lava, and when the lowering comes, the sea water penetrates the hot voids below, under great pressure and by many inlets, generates steam, and the path of least resistance for the exit of the steam is through the crannies of the wall crack, around the crater edges of the risen lava column.

In July, 1908, the remains of Metcalf Peak had subsided and there had probably been another explosion the previous winter. There was renewed activity in the bay surrounded by beaches that lay between Castle Rock and Grewingk, in September, 1909. A new lagoon was formed shut off from the sea, and two small lava islands arose which in June, 1910, had united and reached a height 178 feet above the water. A survey September 10, 1910, made the island one and a half statute miles long and three-quarters of a mile wide. The old rocks were becoming smaller. A new explosion September 18-19 1910, sent up immense clouds of vapor, smoke, and ashes, flames were reported, and a true crater was opened in the top of the central peak. This was the first time that a real crater within one of the lava domes was ever seen and photographed by the Coast Guard officers who have done so much valuable work in making these reports on Bogoslof. In July, 1913, this crater had steam and smoke slowly issuing from it, but the following year all smoking had ceased. During the next eight years Tahoma Peak, as the new hill of 1910 was called, was eroded away, and a channel was again opened between Castle Rock and Grewingk so that a boat could sail between the two older islands. Grewingk had greatly diminished in size, and Castle Rock was now two rocky horns with a big accumulation of sand and gravel heaps piled against them, especially on the northern and eastern sides, these trailing off into a long sand spit at the north, and the whole of this larger island was surrounded by sand beaches.

The writer visited Bogoslof for the second time July 6, 1927, and found a new period of moderate lava activity inaugurated, with a pile of steaming lava rising from a warm lagoon in the midst of sand banks, and again these banks joined all of Bogoslof into one island with a complete ring-shaped salt water lagoon, surrounded in turn by a complete ring of sand permitting no connection with the sea except by seepage. The lagoon was at 70° F., there were the usual herds of sea lions and myriads of birds, the bottom sand and pebbles of the lagoon were all coated with orange colored ochre, the lagoon was everywhere only two or three feet deep, there were numerous skeletons of dead birds on the beach, and in the sand were impact craters made by newly fallen bombs having rough aa surfaces. There were blocks of pumice one to two feet in diameter. The central lava heap (see Page One) was about 200 feet high and 1,000 feet wide. Its crest consisted of uniform aa clinker, steaming much more heavily than in this picture of a year later. It made no noise, and it is characteristic of Bogoslof that during most of the visits reported noise has been absent. In September of 1910, however, a week before the explosive eruption, roaring steam jets were found. in 1927 the annular ridge of gravel, sand, and explosion products stood about 10 feet above tide.

The new activity had started in July of 1926 when there was open water between the two older rocks. An explosive eruption was then seen by a whaler, and the natives reported explosions July 17 as seen from nearby islands. The water was greatly muddied and the whaler on August 12 saw black smoke with darkness accompanied by thunder and lightning, ending with a cloud of white steam and "fire" about 2 p. m. There was also an explosion in December, 1926, and it is probable that the lava dome of 1927 emerged thereafter. Probably the eruption began with a series of lava pulsations, alternating with explosion. In 1928 the activity was mild as shown in our pictures. A landing party on Bogoslof July 27, 1929 reported all quiet.

T. A. J.

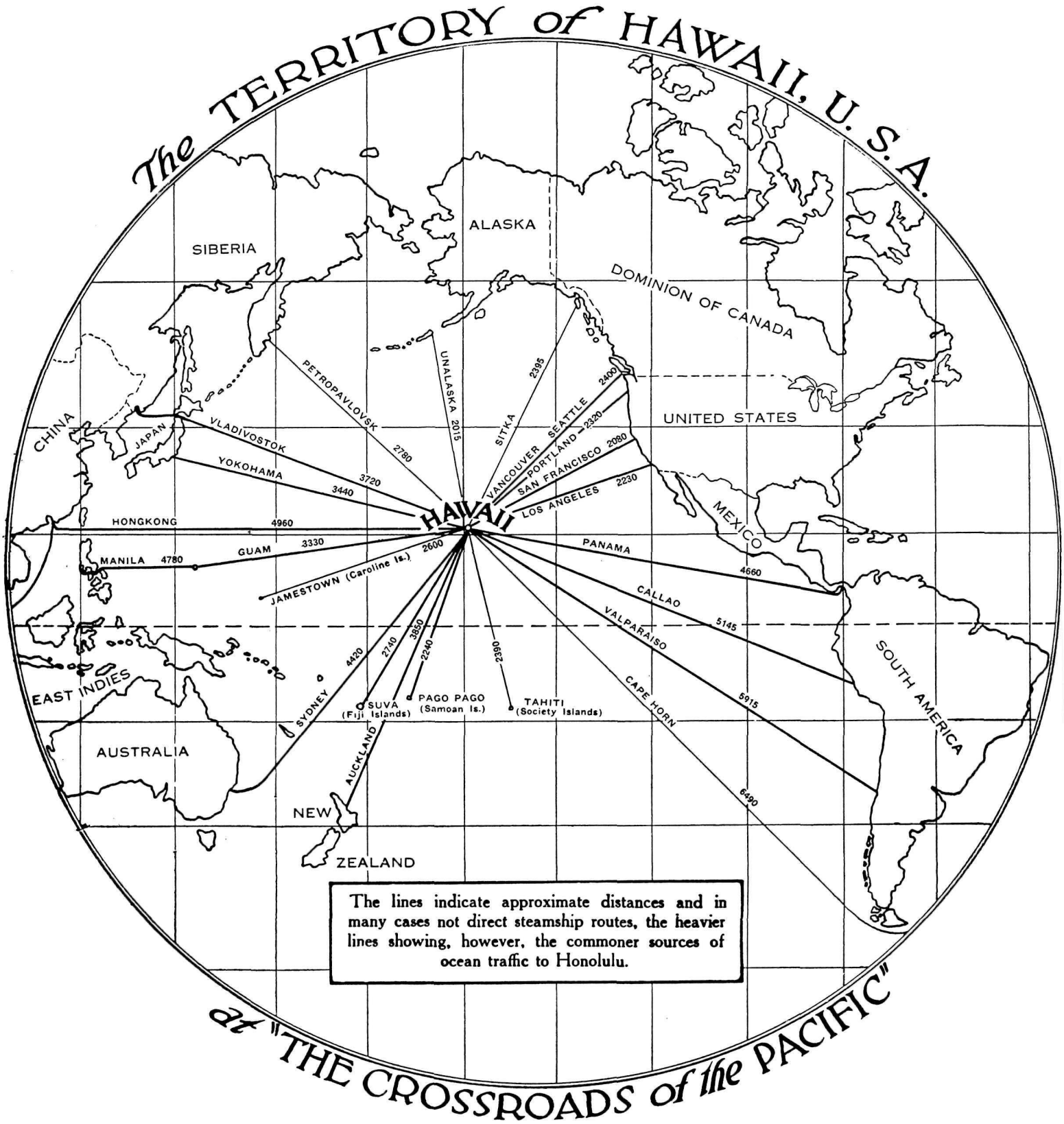
KILAUEA REPORT No. 949

WEEK ENDING MARCH 30, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Kilauea remains quiet. Halemaumau on March 26 exhibited a few fallen rocks at the north, and the pit seismograph showed some avalanche tremors. At 10:30 a. m. March 28 a little dust arose from the northeast wall, and such dust was seen occasionally March 30. At 3 p. m. March 30 there was fresh dust on the northwest wall and a triangle on the floor below was stained with dust. Otherwise the floor was mostly washed bare. A wide area of greenish-white solfataric stain has developed at the south edge of the floor. New bowlders extend out on the eastern floor. The talus NNW has increased in height, and a deep notch in the wall above the north talus has been extended upward.

Four very feeble local seisms have occurred during the week showing tendency to east tilt accompanying the shocks. Nine tremors are recorded each lasting less than a minute. Microseismic motion has been very slight, and tilt was moderate NNE.



Pacific Ocean, showing distances in nautical miles from Honolulu to the surrounding girdle of volcanic lands. Seismographs of the Section of Volcanology, U. S. Geological Survey are at Hawaii, California, Kodiak on W. side of Gulf of Alaska ,and Unalaska.

THE VOLCANO LETTER

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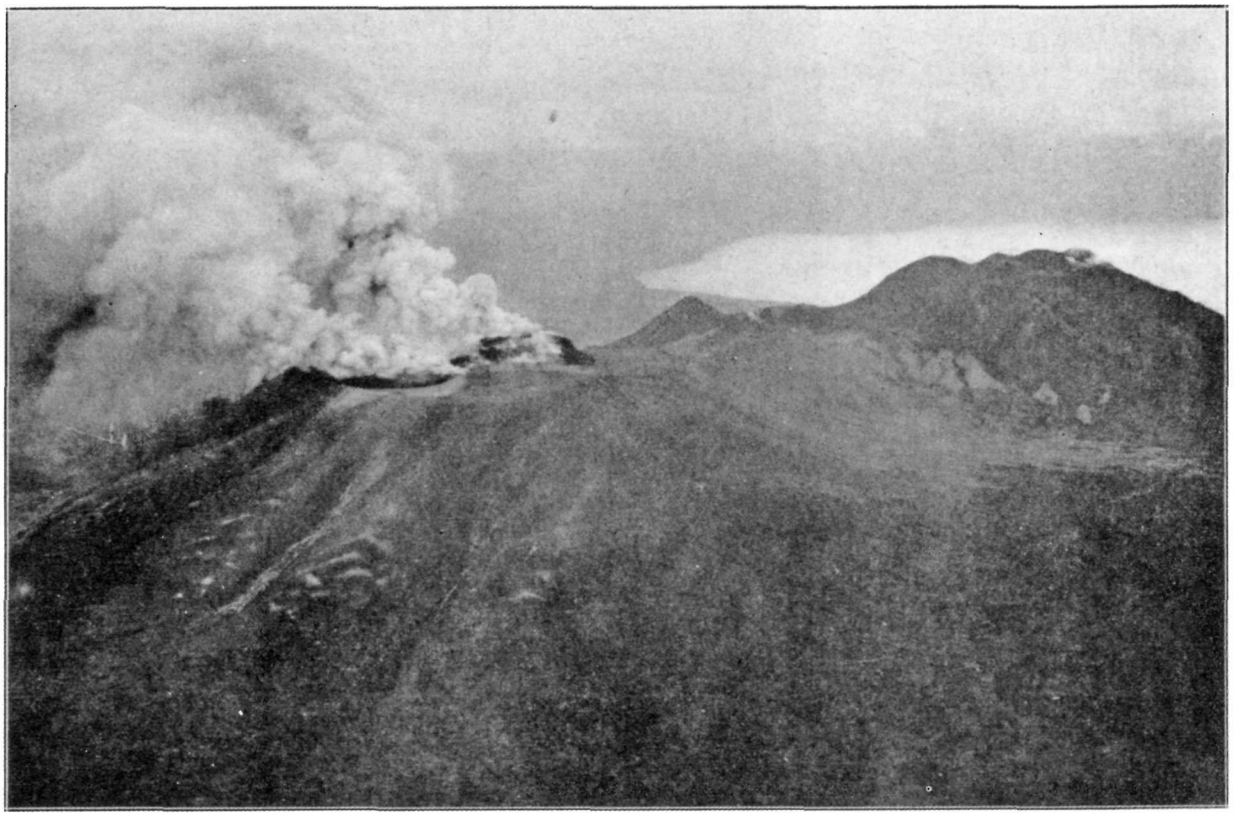
The Volcano Letter

276

Two dollars per year — Ten cents per copy

No. 276—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 10, 1930



Tarumai Volcano in Hokkaido, North Japan, from an airplane looking northwest, photographed by the Otaru Shimbun 1:45 p. m. October 19, 1926. New activity of gas eruption through the summit lava dome of 1909, and through cracks south of the dome. Lake Shikots in the background. Photo from H. Tanakadate

ERUPTIONS OF TARUMAI VOLCANO

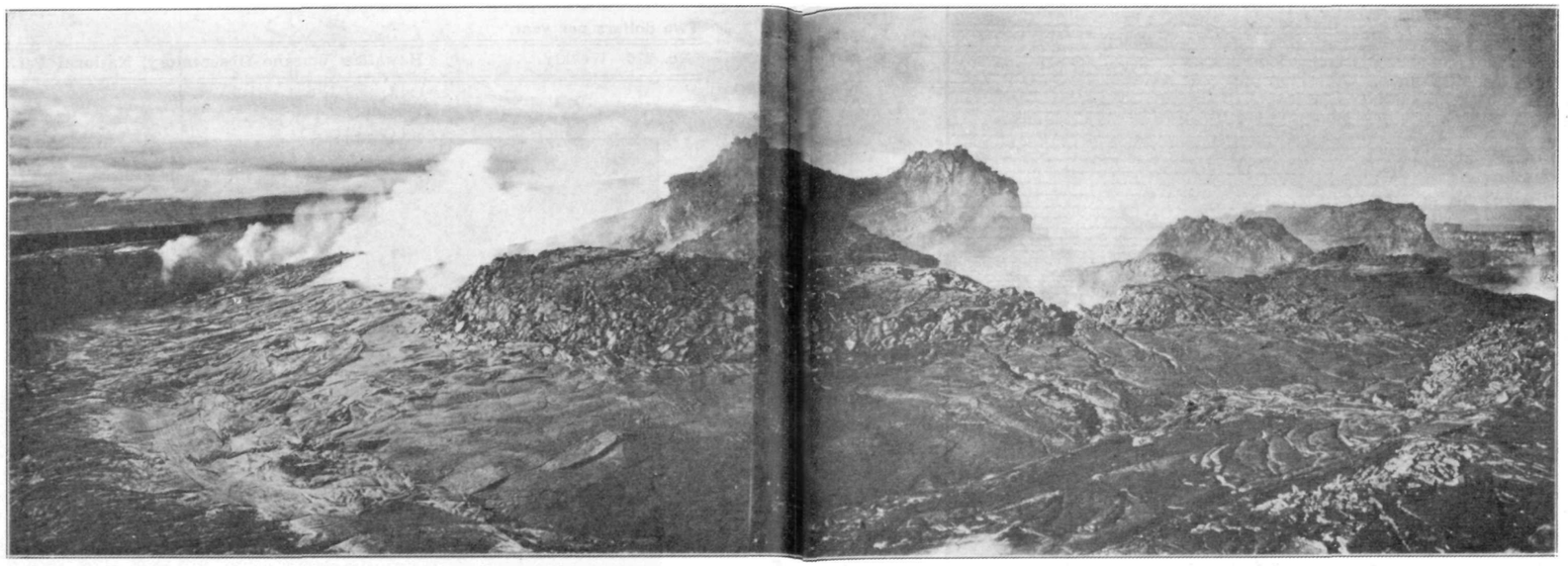
Tarumai is in the forested mountains of southern Hokkaido, the north island of Japan. It is one of several volcanoes in that vicinity which have had many eruptions, of steam, sulphurous gases, and stiff andesite lavas. Ta rumai is a cone of ash and pumice 3,300 feet high which renewed its activity after a long repose in the spring ot 1909. It had been quiet since 1894.

From January to April of 1909 there were numerous explosive "cauliflower clouds" that went up from the cup in the summit cone. April 19th revealed a new lava dome on top of the crater. A very stiff aa flow upward had taken place, lifting the crater floor, opening outward like a flower in its calyx, and finally filling the former crater and rising above it 440 feet. The dome was all covered with jagged lumps and had a diameter of 1,400 feet. The rock was hypersthene andesite. The mountain was now 130 feet higher than it had been by reason of this addition to its summit. (See photograph Page One).

The lava dome of Tarumai was much like the several domes of Bogoslof in the Aleutian Islands, and made of similar rock. On May 9, 1909, the writer visited Tarumai and with a thermo-element thrust into a crack a foot deep in the tumble of crags at the side of the lava heap determined a maximum temperature of 855° F. (457° C.). This was more than hot enough to burn wood. The dome was steaming, particularly around the edges. This new lump remained on top of the mountain.

In 1917 the gas activity through a fissure in the lava dome started new eruption sending up fire, sulphurous smoke and ash, with much trembling. Such activity continued in 1918, 1919, 1920, 1921, and 1923, forming craterlets in the dome precipitating ash and lapilli over the surrounding country. Small stones fell on a village Tomakomai in 1919, eleven miles to the southeast of the mountain. In 1923 ash fell on the city of Sapporo, the capital of Hokkaido, 25 miles to the north of Tarumai.

The photograph on Page One was kindly furnished by Professor H. Tanakadate and was taken from the airplane of the Otaru Shimbun at 1:45 p. m. October 19, 1926. At this time a new series of gas-made ruptures broke athwart the lava mound as well as across the mountain summit to the south of it. Stones fell about the mountain, the usual cauliflower clouds shot into the air, and ash fell 220 miles to the east. The picture was taken from the southeast, and shows both the lava heap of 1909 and the ground to the south of it smoking, while off to the north two and a half miles away stands Tarumai's twin volcano Fuupushinupuri, and behind it in the distance stands lake Shikots.



Halemaumau January 14, 1918, showing the hard top of the lava column swollen up like the crust on a pudding as an incipient dome with stages of higher and higher swelling from the outside edge inward. The steaming cliff on the left, and the distant whitish cliff with stone shelter on top at the extreme right, are the edges of the pit. The lava lake is in the fume amid the central crags. Photo Jaggar.

Tanakadate has classified the volcanoes of Japan, (Proc. Fourth Pac. Sci. Cong., Java 1929 pp. 621-631) as ranging from abortive eruptions with no explosions or outflow, to liquid lava lakes in a crater. The abortive eruptions have many earthquakes localized about a dormant volcano. This is the same kind of activity as was localized in Hawaii in October, 1929, about the volcano Hualalai. Hakone is a district adjunct to Fujiyama which has frequently shown swarms of earthquakes, and in the Izu Peninsula south from there such earthquakes are producing damage and alarm at this moment.

At Oshima Island out in Sagami Bay opposite the Izu Peninsula is a fuming volcano, seen by tourists arriving at Yokohama, which is characterized by liquid lava, of rather stiff aa type usually, that rises and falls in its crater. This is Mihara Volcano, and comes nearer to the Kilauea type than anything else in Japan. Sakurajima produced a stiff lava flow, Tarumai dome was still stiffer, Usu, a few miles to the south of Tarumai, produced earthquakes and a lifted block of the mountain flank in 1910, with no lava except what was thrown up as bombs. Bandaisan in 1888, in central Japan, disrupted a mountainside with steam explosion, and other volcanoes throw out crater lakes and make mud floods, with no apparent lava. Many of these produce elevation of the country.

GROUND MOVEMENT IN A VOLCANO

The Volcano Letter has called attention (No. 264) to the swelling of volcanoes and in describing Bogoslof last week we pointed out that the eruptions of 1907 indicated uplift of sea shore in a year. A publication entitled "Topographical Changes accompanying Earthquakes or Volcanic Eruptions," by A. Imamura (Publ. Earthq. Invest. Comm. Japan No. 25, 1930), makes the following statement: "The character of the acute earth tiltings which accompany an earthquake is inferable from the chronic tiltings that precede the earthquake, and vice versa. And topographical changes which take place prior to volcanic eruptions have characteristics in common with those that take place prior to earthquakes."

These statements may be paraphrased by saying that either a great earthquake or a volcanic eruption indicate that acute earth tilting or tipping of the surrounding country is taking place. This tilting may accompany either a lift of the country or a dropping of the country. Experience shows that the center of the rising or the lowering of the country during the crisis may involve a mosaic of crustal blocks in case of an earthquake, but is apt to involve the crater itself in case of an eruption. And finally this accute uplift or lowering of country indicates that chronic tiltings of the region may be inferred as preceding the crisis, and these chronic tiltings are now being measured. This measurement is of the utmost importance for the future of seismology and volcanology. The reason for this importance is that probably prediction of cycles and crises may be based on knowledge of chronic movements. Chronic tippings have been measured for years in Hawaii and Japan, and their relations to small local earthquakes are like the relations of strain in a timber to its creakings. It seems probable that there is here open to view a new vista in volcano-earthquake science.

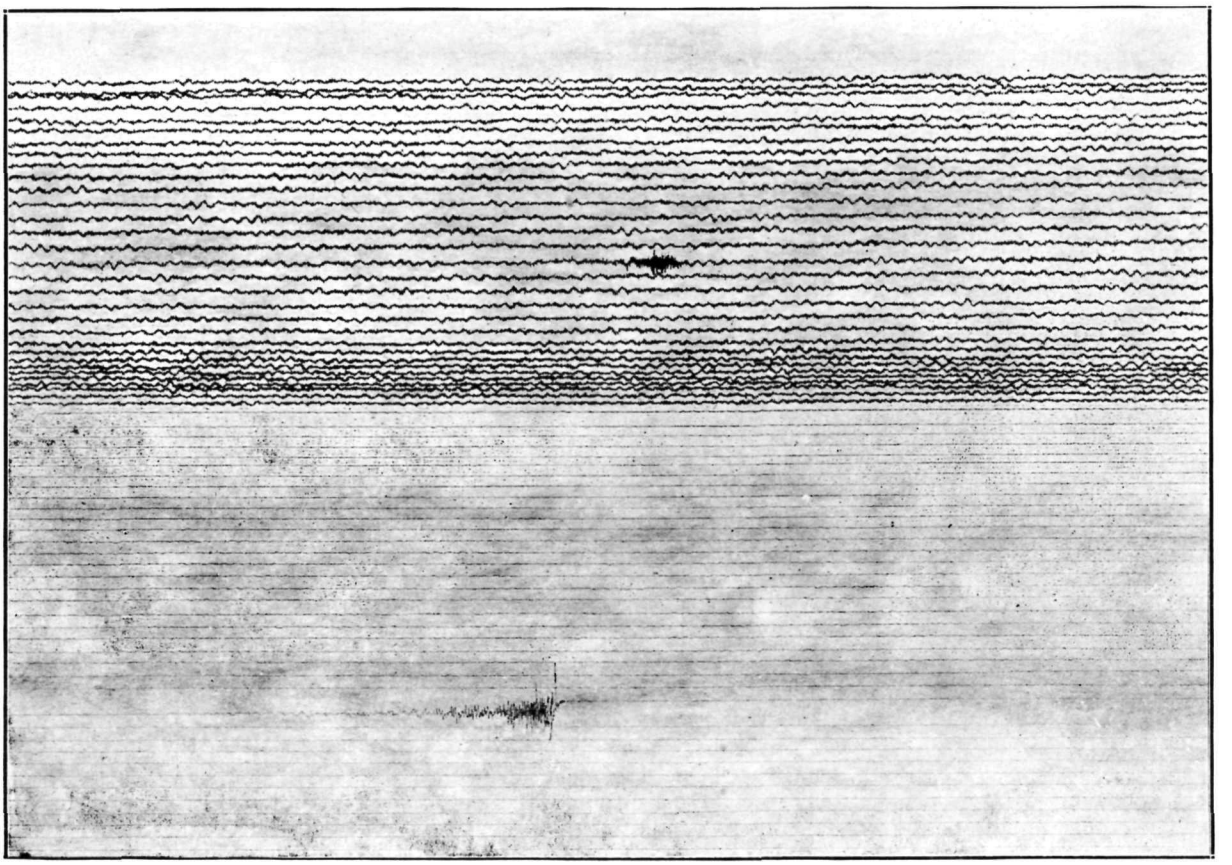
The review of Tarumai eruptions in the preceding article exhibits a pair of volcanic mountains close by a depressed lake basin. This relationship in Japanese volcanoes is very common. It appears to mean fault blocks which are tipped or warped down in the mosaic of the earth's crust under the lake basin, and swollen up under the volcano. The pairing of the two follows some definite and important law in the mechanism of the earth's crust. The lake basin lowers through the ages and the volcano dome swells up.

The picture (Pages Two-Three) of the inner floor of Haleamumau pit at the active center of Kilauea Volcano in a time of great activity of rising lava, and just before the first overflows within Kilauea Crater during the last eleven-year cycle, as shown above, is comparable to Tarumai. If the reader will examine carefully the left-hand side of this picture, he will see that within the low cliff the curve of a swollen dome, like the crust of a pudding, circles into the foreground of the picture and passes on around to the right of the big cluster of crags in the middle. If he will look still farther inside the curve, he will see a swollen inner dome in a half circle between him and the central crag. And beyond this is the group of central crags pushed up still higher as irregular blocks, and amid these blocks lay the liquid lava lakes fountaining and streaming among the wells that led up from the lava column below to the apertures amid the crags. This is all just as true a lava dome as the one on Tarumai.

Now this deep lava in its rising at Kilauea was lifting the surrounding outer country. This was proved by leveling in 1912 and again in 1922. The edge of the pit was lifted from five to fifteen feet, and the edge of the outer crater was lifted over two feet. The seismographs there showed a strong and progressive tilting away of the ground.

The illustration on Page Four is a part of the wonderful seismogram described in Volcano Letter No. 264 as the autograph written by a pendulum hung like a door parallel to the edge of Halemaumau with a pen attached to it that wrote the lines round and round a drum turned by clockwork. The drum moved on a screw during the day toward the pit so that the pen would normally have written lines one-twentieth of an inch apart. This normal writing is shown by the light lines in the lower half of the picture. The autograph of the earth here shown is a record of the activity of big fountains of lava in Halemaumau pit half a mile away. The top line was the beginning of the autograph of the ground the morning of February 21, and this was the day when the fountaining stopped. Each successive line from the top downward is part of a half hour following the preceding line. The dark lines of the upper half of the seismogram are full of tremor from the lava fountaining. They open apart at first because the gas pressure was high, the crater was lifting, the seismograph cellar floor was tilting away from the center of the pit, and the writing pen moved away from the lines it had previously written. In the midst of this came a little earthquake showing black on the diagram.

Then at noon the gas pressure gave out, the lava began to go down, the ground tilted back toward the pit, and the lines became crowded, though the fountaining and the tremor still continued. Just before the fountaining stopped between 1 and 2 p. m., the record of tremor also stopped, everything became stationary, the tipping of the ground toward the pit ceased, and the lines on the seismogram recorded the event perfectly by no longer exhibiting tremor and by becoming normally spaced without any crowd-



Seismogram of February 21, 1929, written at the edge of Halemaumau pit in a closed hut by a horiontal pendulum with the writing boom hung tangential to the curvature of the pit. Tremor due to lava activity at the top, inward tilting due to sinking lava shown by crowded lines in the middle, cessation of activity and a local earthquake shown by normal lines at the bottom.

ing. About midnight February 21-22, as shown in the lower part of the seismogram, a normal local earthquake was felt and this as shown was accompanied by a widening apart of the line as though upward pressure were restored and the earthquake were a creaking of a block tending to tilt suddenly. This is what is meant by tilt accompanying local earthquakes. It is hard to imagine a more fascinating earth autograph than this one showing the tremor and centrifugal tilt above, the centripetal tilt in the crowded middle lines, and the sudden resumption of normal conditions at the bottom, all corresponding to observed volcanic activity.

T. A. J.

KILAUEA REPORT No. 950

WEEK ENDING APRIL 6, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Dust from slides has been seen at Halemaumau at 2:35 p. m., 3 p. m., and 4:15 p. m. March 31, and at 4 p. m. April 2. These slides produced much fresh material on the eastern talus heaps. On April 3 steaming on the south talus was very slight. A big slide occurred NE at 2:45 p. m. April 4 producing important changes in the region of the 14-ton bowlder northeast of the tourist station. The next day a number of large stones lay on the lava floor at the east side and steam was noticeably absent. At 10:25 a. m. dust again rose at the NE.

The Observatory seismographs have recorded 5 very feeble local seisms and 12 tremors during the week. Microseismic motion has been slight, and tilting of the ground slight NE.

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The Volcano Letter

277

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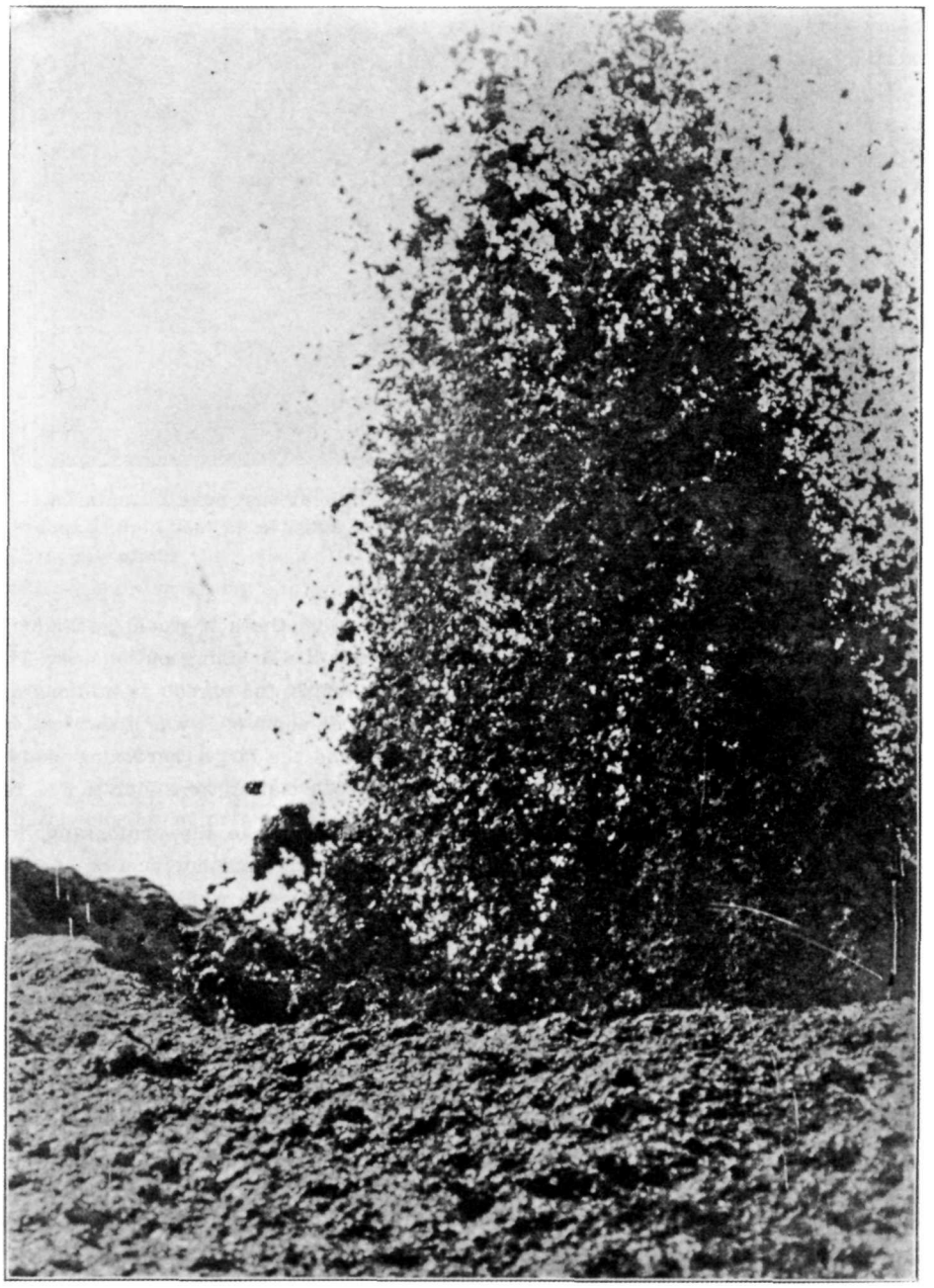
No. 277—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 17, 1939

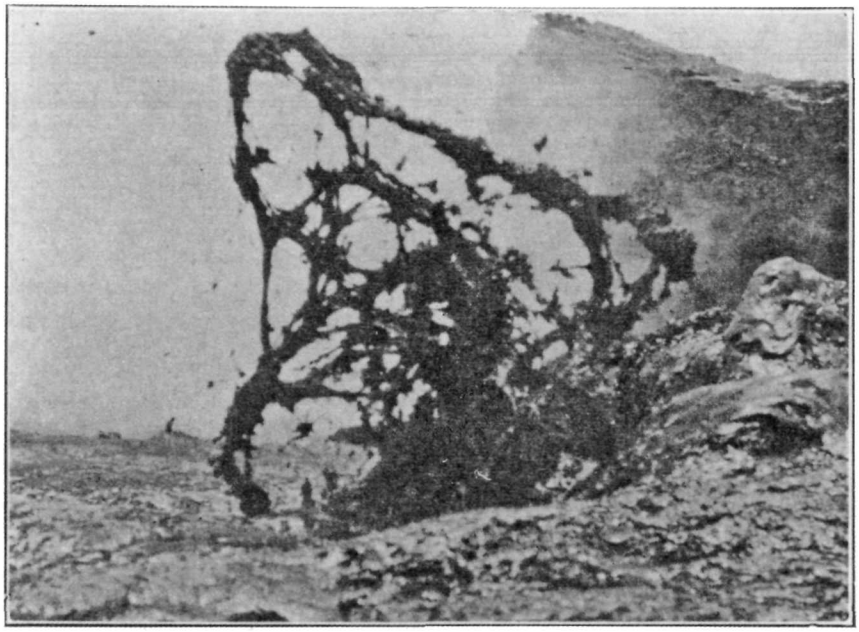


Gigantic incandescent lava froth fountain at north crater of Alika flow source, eruption of Mauna Loa October 25, 1919. Fountaining 50 feet away and 200 feet high, looking west from edge of new cone 200 feet above surrounding country. Southwest rift of Mauna Loa 7,834 feet above sea level. Photo Jaggar.

THE BUBBLING AND GUSHING OF LAVA

If a volcano enthusiast among Hawaii residents had written the title of this article, he would have called it "lava *fountains*."

Such is the common term used in Hawaii for the uprush of liquid lava at one place. This upward rushing of slag makes in the liquid lava lakes of Halemaumau the clustered burst of big bubbles through the slaggy skin in the middle, called "central fountains." The agent that lifts the central fountains is gas, but W. L. Green in the nineteenth century thought it was air. When these bursting bubbles recur about once a minute at Kilauea, they have often been called "Old Faithful," and for many months about 1910-12 Old Faithful stayed in nearly the same place. In 1913 there came a time when there were two pools, and the new pool had a "New Faithful." Then in 1916 and



Eorder fountain of heavy lava spinning Pele's hair at east cove of main lake May 23, 1917, interior of Halemaumau pit. Lava spurt is 15 feet high. Exposure 1/100 second. Photo Jaggar.

thereafter when experiments were conducted at the edge of the lava lakes, many fountains were studied which had a tendency to migrate along the surfaces of the streaming pools with repeated bursts of gas, the gas sometimes flaming, at other times making puffs of unburned, brown, sulphur fume. These migrations commonly ended at a "border grotto," a place of continuous marginal fountaining or bubble bursting, where the black vitreous melt was flung over the bank and built up an oven. The continuity of the effervescence here indicated some localized disturbance such as a subsurface streaming against the bank to determine a continued release of gas bubbles. And sometimes these continuous fountains formed in the middle of the lake indicating a subsurface pouring of lava down a well, and thereby a stirring out of the bubbles, which rose and burst eternally.

When a pot of porridge boils, it is not customary to call the bubbling places "fountains." "Fountain" is a misnomer for the golden slaggy dome bursts of incandescence in a liquid lava pond. The layman conjures up a picture of a spouting jet over an artesian well or an oil gusher when he hears the word "fountain." Just such fountains occur in lava. The picture on Page One, a very lucky snap shot, shows a true lava fountain 200 feet high. This was made at the time when in 1919 Mauna Loa had opened a crack in its flank releasing gas-charged lava from the depths to spout up like an oil gusher. After a month this had built up a cone 200 feet high with a marvelous cauldron of violently seething golden glassy froth boiling inside, and from the tube below a jet of this molten basaltic pumice was shooting into the air through the pool without interruption. Sometimes it would go higher, sometimes lower. For weeks it was going continuously. The material separated into lumps and shreds as millions of bubbles expanded in the pool, some of it was drawn out into hairs and membranes, and the larger hardening skeins and slops of this molten rock matter were four to five feet long.

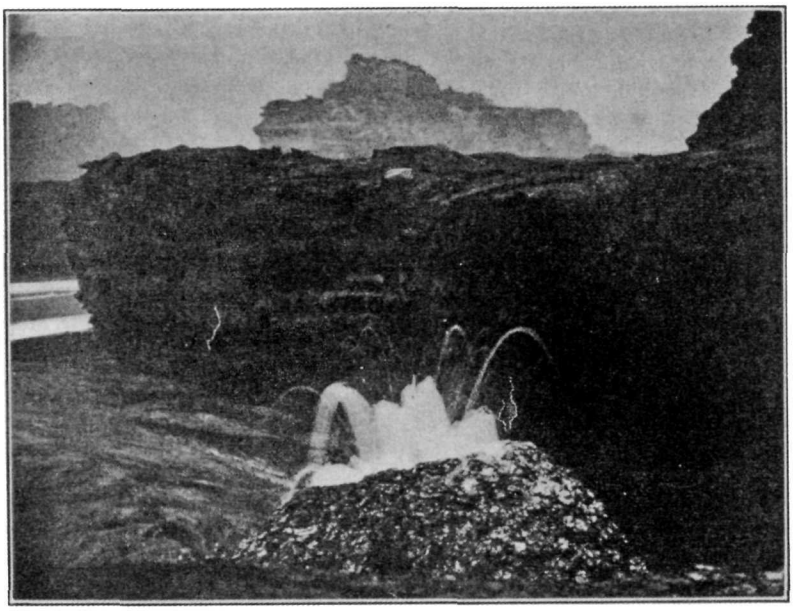
In order to take the photograph, it was necessary to clamber up through hot pumice of buff color on the outside of the cone to windward, where over the summit edge lay the fountaining basin with its gigantic waves surging forward to a cascading outlet at the right. From under the back wall of this cup rose a geyser of fiery fragments, the pieces bright red-hot and very porous, and at the edge there were occasional fragments still glowing, showing that from moment to moment the jet was turned, like a lawn sprinkler, first in one direction and then in another. This made it necessary to take some chances in running in to within 50 feet of the nearest falling jets, on the summit edge, point and snap the camera, and get away without being bombarded. The sensation of looking up at that towering curve of rising and falling bombs, the highest pieces shooting from 200 to 300 feet above the summit, and the lighter ones seeming to float like burning paper, all with intolerable heat and a complex of rumbling, whirring, and pounding noises as the larger lumps flopped down on the ground close at hand and stuck there, viscid and glistening, was an adventure to be remembered. More than a second or two of that heat would have ruined the camera. The crater was like a titanic open chalice of fiery liquor foaming in scarlet surges, these being impelled continuously forward by the geyser jets behind, the flood lift-

ed by the jets losing its liquid aspect almost instantly, and the expanding gas within giving it the appearance of very loosely knitted worsted. The beaten foam quickly quieted down to form black curds where the pond cascaded through the sluiceway leading to outflow. The color of the molten stuff is bright yellow at night, but in daylight is a reddish transparent tone with a luster like jelly, brightly glistening in the sunlight, and with purplish shadows, the jet distinctly changing color with the cooling from orange on the rising side to wine color on the falling slope of the arch.

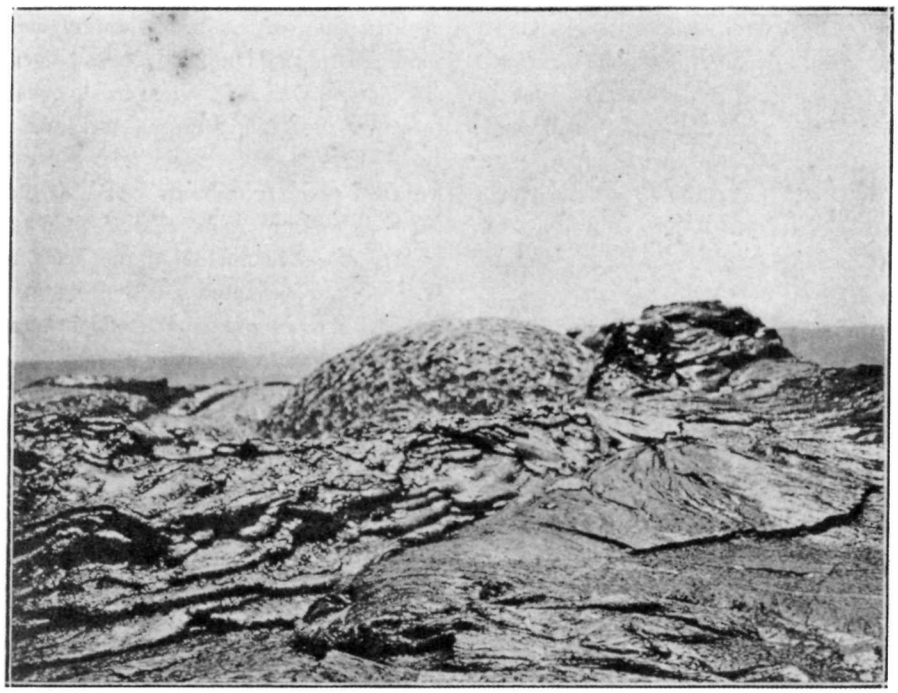
Such is the most magnificent of the true lava fountains and it may well be compared to the prominences on the sun, but the latter are wholly of gas. Probably in both cases hydrogen is the dominant gas. A tremendous banner of burning gas stands above the Mauna Loa fountain at night, salmon and rose with bands of green. The motive power is gas expansion, just as it is in the bubble bursts of Kilauea. In the picture on Page Two the camera is 25 feet from a border fountain in Halemaumau, the lava lake being beyond and to the left, and the foreground is the lake margin. This shows the process of spinning Pele's hair. Gas is rushing up through a stiff, viscous lava, and carrying the lava with it, drawing it out into shreds, and the bank reflects it back into the lake like a surf repelled from a rocky shore. The tangle of fine glassy cobwebs, puffed and blistered by the endlessly bursting glass blisters on the melt, is caught up by rising heat currents of air and carried away by the wind.

This same corner two months before was building a border cone through the closing in of a marginal grotto so that the oven became entirely enclosed except for a crater through the top (see Page Three). Here we have a beehive cone with a lava fountain inside, connected by a tunnel with the lake, only a few feet away. Such cones are generally formed by a crack opening in one bank of the lava lake, and allowing the lava to penetrate it and start convectional streaming with release of gas. This makes a spurting fountain in the crack which opens a circular crater and roofs over its cupola and its tunnel. It is only one step farther to the place where such gushing of gas-charged molten glass, escaping from Halemaumau through a large radial crack at a place 500 feet from the pit (Page Four) wells up in a dome through a shell or half-cone of its own spatter and marginal congealing and keeps on welling up like an artesian gusher with its surface eternally coated with a net of bubble membranes, as shown in the picture, and so forming a "standing fountain," the source of a flow which was pouring off to the south on the Kilauea floor during the great crisis of overflow at Halemaumau in March, 1921. Thus we see that there is a transition from the central to the border fountains, and from the border fountains to outflow fountains. The explanation of the rhythmic fountains such as Old Faithful appears to be that they are always over a small well under the shallow lake, where the convectional circulation is draining the gas-charged liquid downward, and stirring out an accumulation of bubbles which cluster together and escape at regular intervals through the viscous lava of the lake surface. Whether there shall be rhythmic release or continuous escape probably depends on the depth and viscosity.

T.A.J.



Same east cove of Halemaumau as Page Two, on March 30, 1917, in the evening. Flaming and spurting cone, exposed for 30 seconds, and exhibiting a succession of jets. **Photo Jaggar.**



Smooth dome fountain at source of flow outside of Halemaumau 500 feet to the southwest, March 20, 1921. The liquid part stood nine feet high, of orange incandescence, rising from under the knob on the right and pouring away into the background. Photo Jaggar.

KILAUEA REPORT No. 951

WEEK ENDING APRIL 13, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On April 9 a big scar on the east wall under the 14-ton bowlder showed as the location origin of the avalanche of April 4, which threw immense rocks far out on the lava floor of Halemaumau. The 14-ton bowlder is doomed to fall into the pit with the ledge which helps to support it on the east rim. This was the largest rock blown out during the explosive eruption of May, 1924.

The sulphur stain on the south bottom of the pit has become whitish in color. Steaming is as usual, and no other changes are to be reported.

The seismographs at the Volcano Observatory registered 12 tremors, the longest having a duration of three-quarters minute; and one very feeble seism. The net accumulation of tilt for the week was slight south. Microseismic motion was normal.

MARCH TILTING OF THE GROUND

At the Hawaiian Volcano Observatory the tilting or tipping of the ground in the seismograph cellar, expressed as angular change and direction of motion of the plumb line, was as follows:

March 3—9	1.03 seconds	NNE
March 10—16	2.32 seconds	WSW
March 17—23	1.06 seconds	SSW
March 24—30	2.05 seconds	NNE

This computation is by overlapping seven-day means. January and February were by direct reading (Volcano Letter No. 267 and No. 271).

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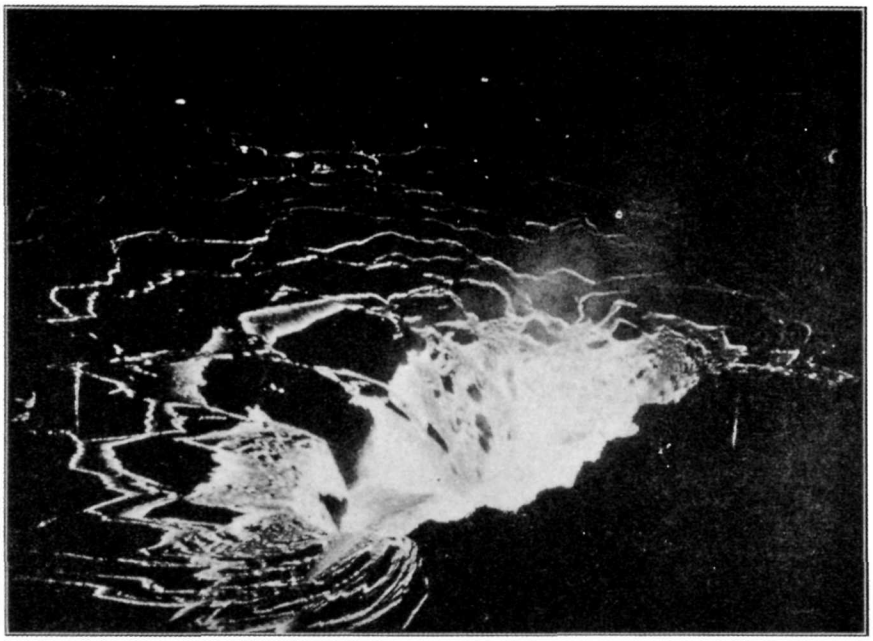
The Volcano Letter

278

Two dollars per year — Ten cents per copy

No. 278—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 24, 1930



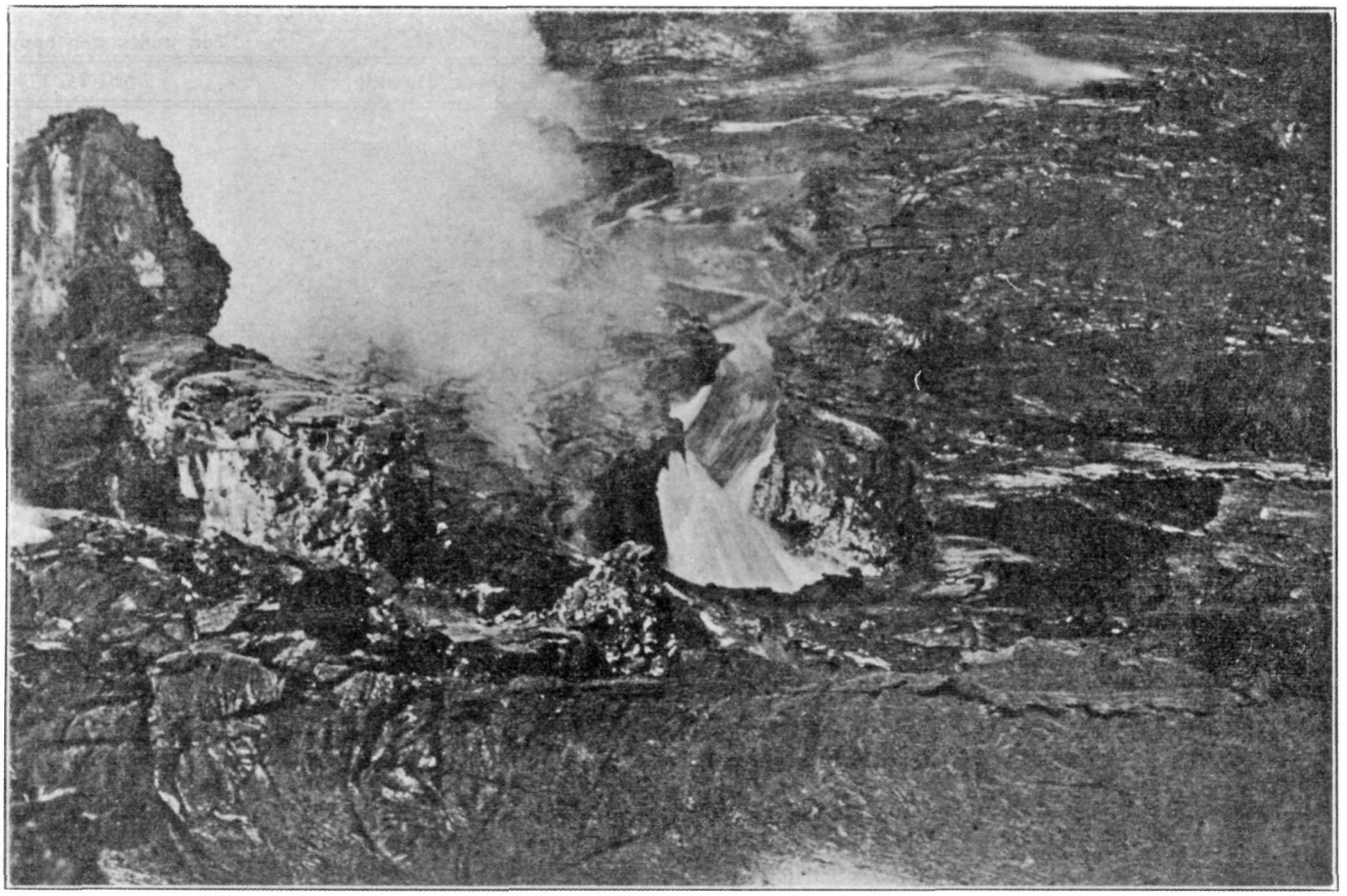
Lava cascade into North Pool of Halemaumau, 7 p. m. December 21, 1923, showing the concentric breaking of crusts as the incandescent fluid was sucked down a well which had temporarily become a sinkhole. Photo Finch.



Overflow flood of lava from North Pool of Halemaumau January 8, 1924, the North Pool lying in the middle of the radial flows. These cascade into the main lake in eight fiery ribbons shown in the foreground. Photo Emerson.

LAVA CASCADES IN HALEMAUMAU

To understand the distinction between lava paste and lava froth in Halemaumau pit of Kilauea Volcano, the observer should compare the happenings of different periods, when in the one case the froth (liquid lava) fountains up in artesian fashion through one of the wells or shafts that leads down through the paste (bench lava); and in



Cascade from remnant lake after a subsidence, into a sinkhole in what had been lake bottom in January,1917. Photograph was taken February 14, 1917, revealing the former bottom of the lake as a shallow affair about 40 feet below the former lake level. This bottom is the lava paste or bench lava. Photo Jaggar.

the other case the froth lowers in its well so that the remaining liquid lava rising through other wells streams across the lake area and cascades down into the evacuated shaft. Lava pulsations up and down for periods of a week or more are characteristic of a time of high activity, and the feeding well, which this week is overflowing on one side of the pit, may next week be receiving a cataract of golden incandescent fluid from its neighbors.

The general arrangement at a time of high rising, when the lava was actually level with the rim of Halemaumau, and had just been overflowing on the northeast, is shown in the map on the last page. This was in January, 1921, when there had been a big December rise, and the lava paste, shown by the shaded block in the cross-section, had been lifted bodily within the funnel, so that wells for the liquid lava were developed at the two wall cracks right and left (shown in black). The section goes from southwest to northeast, and the northeast margin of the pit is shown freshly overflowed in plan and section. This of course was a cascade into the open country. Now if we suppose the well, shown at the left in the section, to lose its supply of feeding lava in the depths and reverse its flow from up to down, while the right-hand well, connected by tunnels with all the lakes, keeps on bubbling up strongly, there will be developed a cascade into the left-hand well. Whatever may be the cause, it is a fact that the wells maintain different levels in the circulation, from time to time. (See Volcano Letter No. 272.)

The most intense fluctuation between different wells in the paste, with domings up and outflow over one well one week, and siskings down with inward cascades in the same well the next week, occurred during the last great rise of Halemaumau lava that preceded the explosive eruption of 1924. There had been a big subsidence in the pit of 400 feet in August, 1923, accompanied by the outflow in the forest near Makaopuhi on the Chain of Craters road. There was immediate rapid recovery in Halemaumau throughout the autumn of 1923, developing an enormous lava fill, from wall to wall, only 114 feet down January 21, 1924. At times this was a sea of liquid lava when all the bench lava was flooded, at other times it was a large shallow heart-shaped pool surrounded by a flat platform, with four low islands, and at the north an isolated pond of liquid lava in the platform between the two lobes of the heart. This was called the North Pool.

It is of interest to note that the lava paste, represented by the islands and platforms, was doing some horizontal moving which the islands exhibited. Thus in November, when at the beginning of the month the lava was 320 feet down and by fairly uniform rising stood only 260 feet below the rim November 30th, an island in the main pool, which had been there for several weeks, moved nearly to the southeast bank during November 24-25. A second island had appeared in the main pool November 10, disappeared on the 12th, reappeared on the 13th, and soon thereafter became joined to the larger island. In December the lava showed numerous oscillations in level, making a net gain of 39 feet.

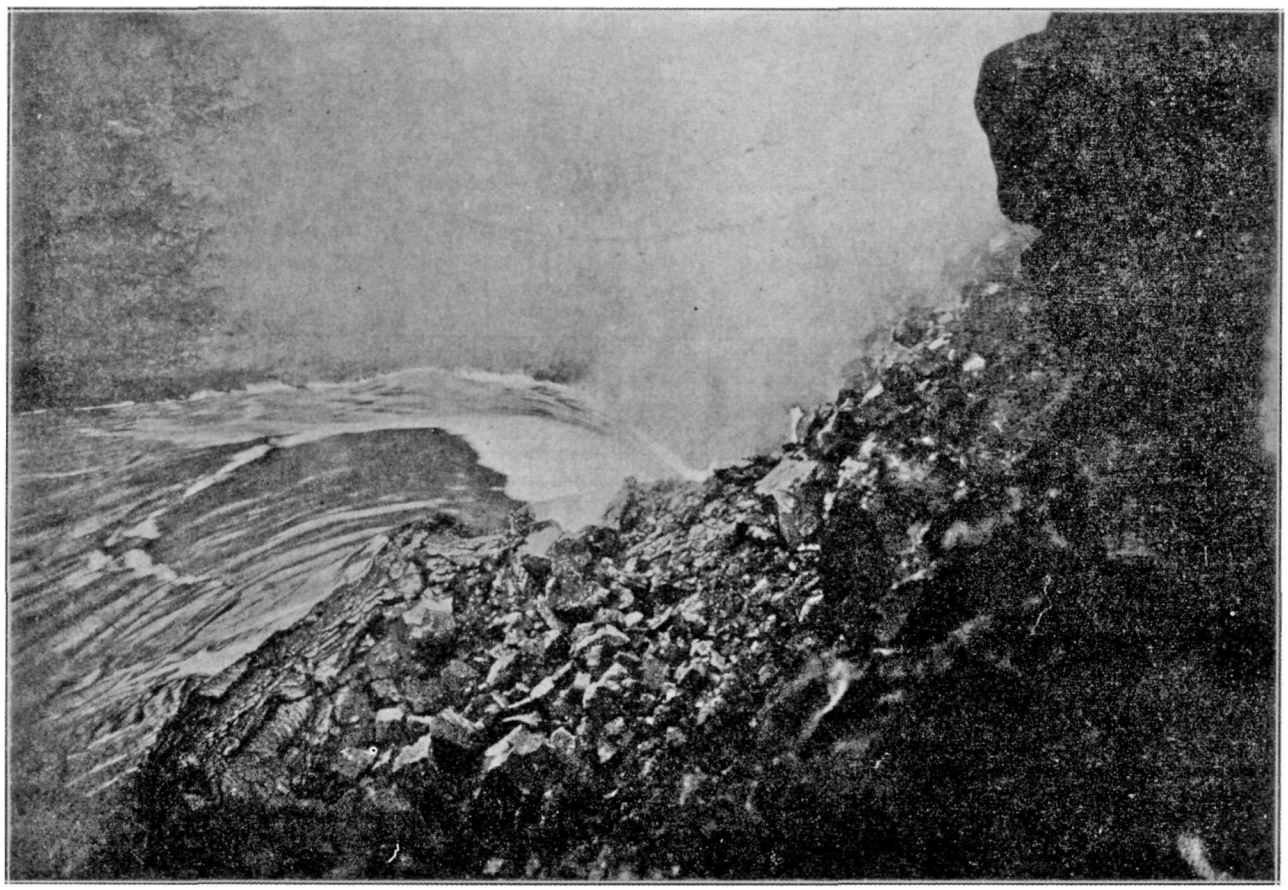
These oscillations of December, 1923, are what produced the spectacular cascades. The dominant rising was at the south, and on December 7 there was a very strong spurt with downrushing cascade into the North Pool. These performances were repeated about once a week so that on the 14th and 21st December (see first photograph) similar torrential cataracts into this pool reached still greater size. On the 27th the influx was repeated

with very rapid fluctuations, so that during a half hour more than ten million cubic feet of lava was poured out, and over 40 acres were covered with the molten flood that drowned all islands and individual lakes. Then tumultuous fountains would break out at various places, some of the source wells would become sinkholes, and in all five wells were located.

In January, 1924, the weekly periodic flooding continued, but the North Pool sometimes became a source, and on January 8 (see second photograph) this pool was sending out extremely liquid radial torrents which cascaded into the main lake, as shown in the picture. The heat was almost unbearable at many places on the rim of the pit. A cone at one side discharged gas through a crack near its base. Several islands were drowned. On January 18 the liquid rose 65 feet in less than 16 hours so that on January 21 the lake was 45 acres in extent with no islands or separate pools visible, and the tumultuous fountains often hurled up spray 100 feet into the air. These violent fluctuations continued in February, but after February 12 the whole lava column including the paste lowered gradually until by February 21 the floor was 380 feet below the rim, the cascades into the North Pool being repeated February 15, 17 and 18, sometimes with a drop of 40 feet, while the main source was a south feeding well from which bright lines radiated. The topography of the paste lava reappeared and then collapsed around the northern pool along with the development of fume. Glow was last seen at the southeast, where there had been a conelet. In April came the subsidence and earthquakes in Puna, and in May the gigantic collapse at Halemaumau, accompanied by steam-blast eruption.

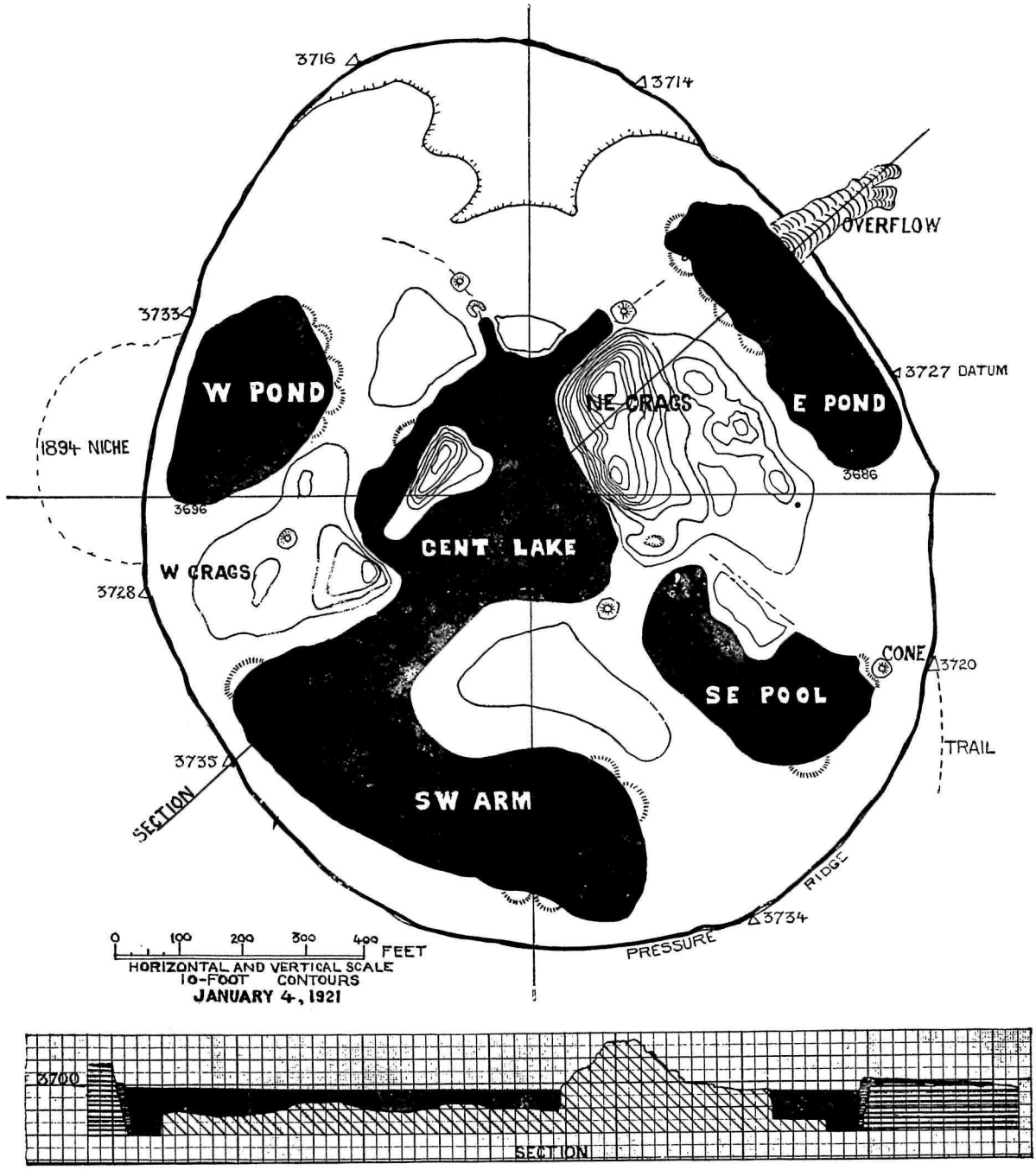
What process causes a well to be a feeder one day and a sinkhole the next is a matter of speculation, but there are many measurements on hand at the Hawaiian Volcano Observatory, the study of which may help to solve this problem. If the map and cross-section on Page Four are compared with those of Page Four of Volcano Letter No. 272, it will be seen that January 4 differs from March 14 of 1921 in that the paste lava block had been lifted clear of the two walls so that there were cracks filled with liquid lava on each side, whereas in March the level was lower and the cake of paste, which must be shaped like an inverted cone to fit the funnel of the pit, was settled differently within the tapering shaft. The lift of the paste as a whole is somehow connected with the gas expansion of the deep magma, from solution in which the gases escape and unite with increased heat and consequent liquefaction of the melt in which they formed bubbles, and it is highly probable that the few wells of the upper part of the combined lava column fork out into a network of wells down below. This network expands and lifts the whole sponge. If this is what happens, probably the upper harder part of the paste, with its crags and floors and overflows, is always breaking into blocks with doming and splitting of the crust, and this motion changes the relation of the different wells to each other. There is a circulation of the liquid froth with a maximum of rising where it is lightest and hottest, and of sinking where it has lost its gas and become heaviest. It is also eternally solidifying here and liquifying there, the partial solidification adding to the material of the paste. Thus the source wells and sinkholes shift in accordance with the equilibria of all these processes.

The photograph on Page Two shows the southern part of what had been the lava lake of Halemaumau a few days before, in February, 1917, when a sinking spell had revealed a well under the lake where the fountains had been. Into this well now there was a mighty cataract of molten lava with hot flame of pale bluish aspect rising from the sinkhole, and fume condensing above and to the left. This was the first great topographic demonstration of the shallowness of the lava lakes. The picture on Page Three, shows a marginal cataract of 1919 of the same character, with the whole lake pouring continuously into a void, tearing great skins on its surface, all of this ac-



Main lake in Halemaumau cascading into a well at the Northeast cove June 9, 1919, a process that kept on for 11days without altering the relative level of the lake, though the entire lava column was sinking at this time.

Photo Jaggar.



Map of Halemaumau and profile section January 4, 1921. Elevations above sea level in feet. Liquid lava black, diagonal shading bench lava, broken lines are cracks. This situation followed a marked rise in December when the liquid lava had gained at the expense of the crags and islands, and had overflowed the rim of the pit from the East Pond.

companying subsidence of the lava column and disturbance of the bench lava, but all a part of normal circulation phenomena, and not an outflow, for the level of the lake remained relatively constant for 11 days while the cascade persistently poured into the gulf. The lava lake even rose at times, relative to its own banks, while this was going on. T.A.J.

KILAUEA REPORT No. 952
WEEK ENDING APRIL 20, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

No changes in Halemaumau have been noted except additional rocks on the bottom below the 14-ton bowlder. The bowlder has not changed its position. Crack measurements show no changes near the tourist observation station.

Dense steam was rising from Halemaumau on the afternoon of April 18 and the morning of the 19th due to light rains.

Ten seismic disturbances were registered by the instruments at the Observatory during the week, classified as follows: Six tremors, the longest with three-fourths minute duration; three very feeble seisms, one showing an origin 18 miles away; one distant earthquake, the long wave recording feebly at 9:09 p. m. April 15.

Tilt accumulated moderately SW. Microseismic motion was slight.

The Volcano Letter

279

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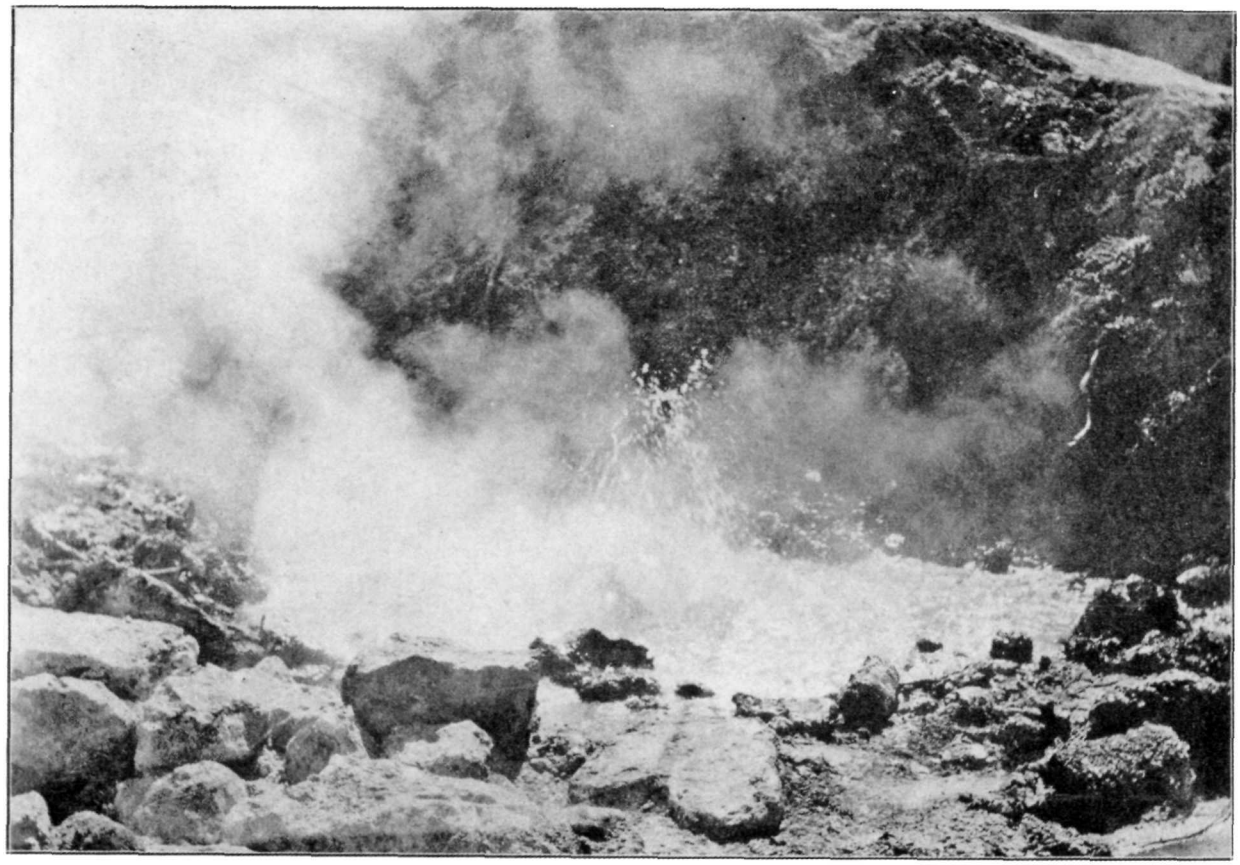
No. 279—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 1, 1930



Boiling pool of solfataric water in Devil's Kitchen, five miles southeast of Lassen Peak, August 17, 1929. **Photo C. A. Huff.**

LASSEN REPORT No. 25

LASSEN VOLCANO OBSERVATORY
R. H. Finch, Associate Volcanologist

SEASONAL VARIATIONS IN HOT SPRINGS

During the summer of 1928 the most active vent in the Supan solfatara, Lassen National Park, showed the following temperatures:

Early Summer	194° Fahr.
July 28	240° Fahr.
Sept.	235° Fahr.

Similar variations of this vent have been noted in other years.

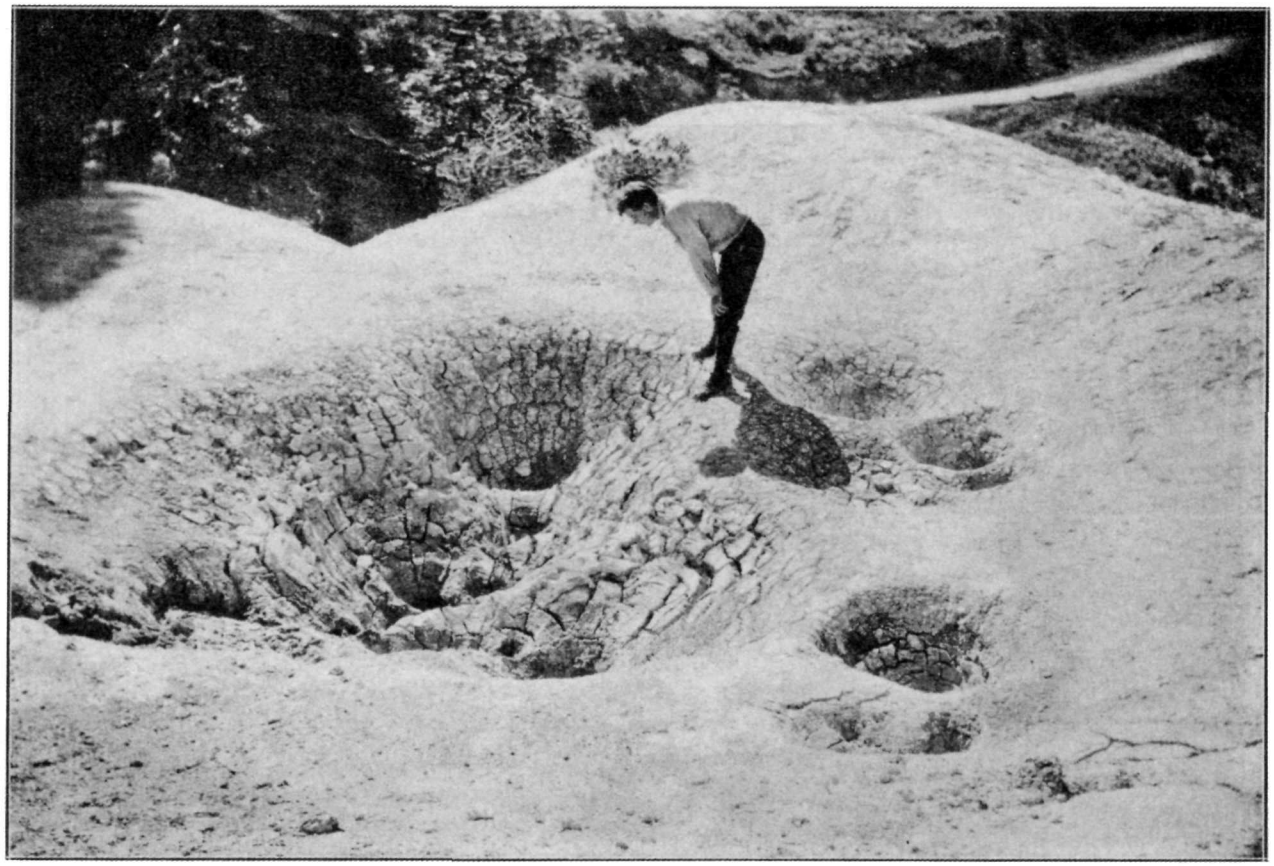
Whatever the ultimate source of the heat of hot springs a decrease in the amount of discharge should allow the smaller volume to be more highly heated. As is to be expected, there is a seasonal variation in the temperature of many hot springs, the highest temperatures occurring in the dry season and the lowest temperatures in the wet season. Why, then, should the hot spring under discussion show a maximum temperature in July instead of in September. There was no rain between July 28 and September 5.

Now it is commonly noted that with the shorter days and increasingly cooler nights that are reached in September and October, there is a tendency for many springs to show an increase in discharge. Some that ceased to discharge in July or August or earlier will start flowing in September or October without any rain having fallen to furnish additional moisture. This phenomenon is especially striking in California where in many places there is commonly no rain between June and September. It is also noticeable at many other places with less seasonal contrast in precipitation. The increased discharge in the autumn is undoubtedly due to a decrease in evaporation.

The mud pots shown on page two, which are near the active hot spring under discussion, showed no water on August 27, 1929, and on September 30th there was over one foot of water in the largest hole with no rain having occurred between the two dates. The unexpected decrease in temperature of the hot spring noted must have been due to a slight increase in discharge.

SLIPPING AT SUPAN SLOPE

At Supan Solfatara a line of stakes placed 50 feet apart in November, 1927, parallel with the valley, and across a belt of fissures where slipping is in progress in the highly solfataric soil, has been remeasured from time to time with both tape and transit. Some of the stakes were disturbed, and in general the region of stake No. 0, one thous-



Mud pots in the Supan Solfatara, three miles south of Lassen summit, showing no water August 27, 1929. A month later water had risen in the large hole without any rain in the intervening period. Photo Finch.

and feet up the slope from stake No. 20, moved downhill 3 inches toward No. 20 as shown by transit measurements. Some of the intervening cracks diminished in width, the upper land overriding the lower land, so that some of the 50-foot intervals between stakes show a minus change. The following are the changes:

Stake Interval	Nov. 1927 to July 1928	July 1928 to Aug. 1929
No. 0-1	+0.1 foot	+0.3 foot
No. 2-3	+1.4	—0.4
No. 3-4	+1.3	0.0
No. 4-5	0.0	+0.2
No. 5-6	—0.6	—0.2
No. 6-7	—0.4	0.0
No. 7-8	—0.2	0.0
No. 8-9	—0.2	0.0
No. 10-11	—0.1	0.0
No. 11-12	+0.2	0.0
No. 12-13	—0.4	—0.1
No. 13-14	—0.1	0.0
No. 14-15	—0.1	—0.1
No. 15-16	—0.2	0.0
No. 18-19	0.0	+0.2

EARTHQUAKES AT LASSEN VOLCANO OBSERVATORY

The number of earthquakes of local origin recorded at the seismograph in the Lassen Volcano Observatory at Mineral, California, during the calendar year 1929 was 96. The indicated distance to origin for the local shocks ranges from 8 to 12 miles, which is about the distance of the Lassen Volcano mass. The numbers of shocks recorded during the three complete years since the establishment of the observatory are:

Year	Number of Quakes
1927	266
1928	37
1929	96

Tilting in 1929 was much the same as during the preceding two years, and frequent adjustments of the instruments were necessary. The accumulated tilting of the ground appears to be greater than what can be accounted for by the changes of atmospheric temperature. In the winter season of 1928-29 there was a pronounced accumulation of southwest tilt, possibly due to a doming of the Lassen volcanic mass.

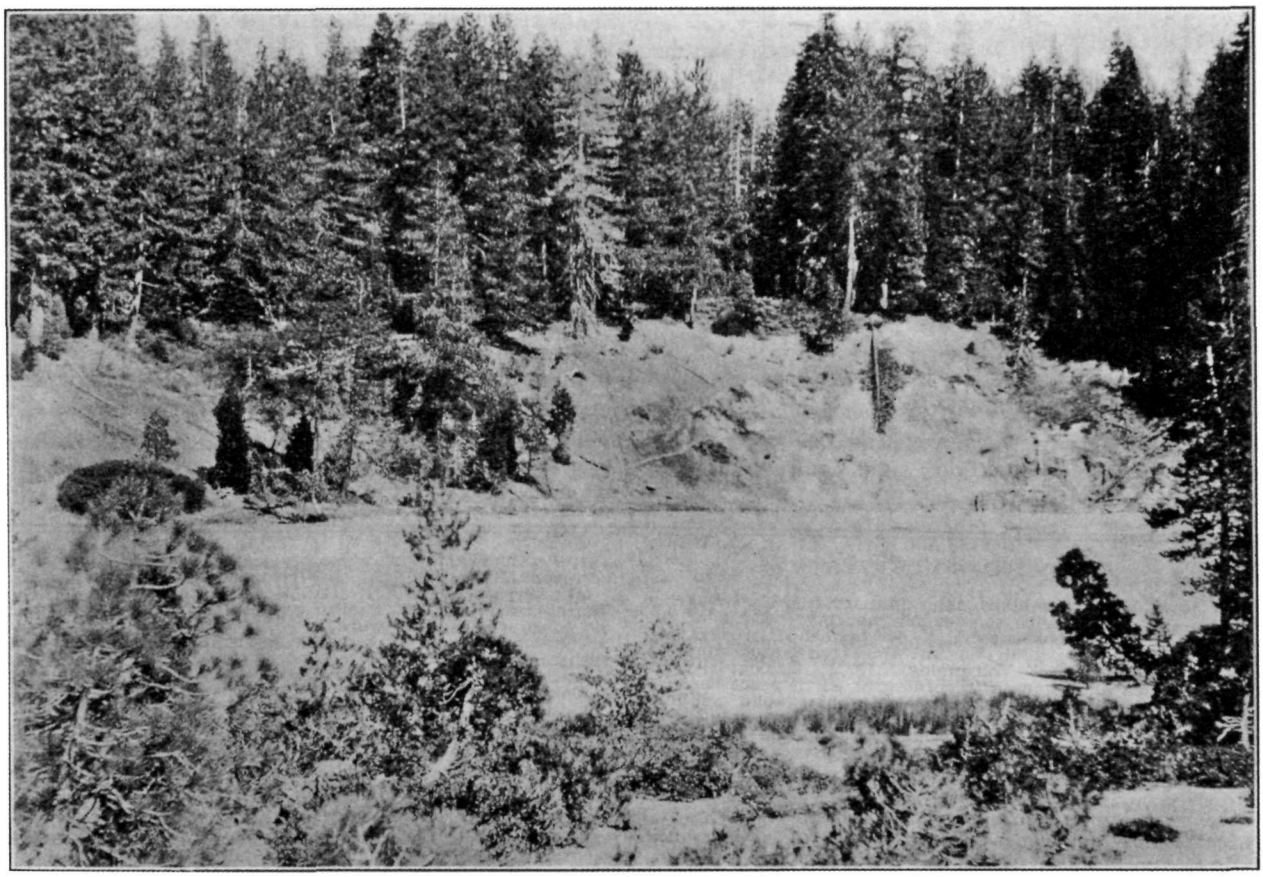
TEMPERATURE CHANGES LASSEN HOT SPRINGS

The following are a few of the measurements made at the different hot springs in Lassen Volcanic National Park, to show comparative data for different years. The later measurements made by Lassen Volcano Observatory are compared with each other and also with the records of Day, Allen and Diller between 1915 and 1923 (See Volcano Letter No. 238).

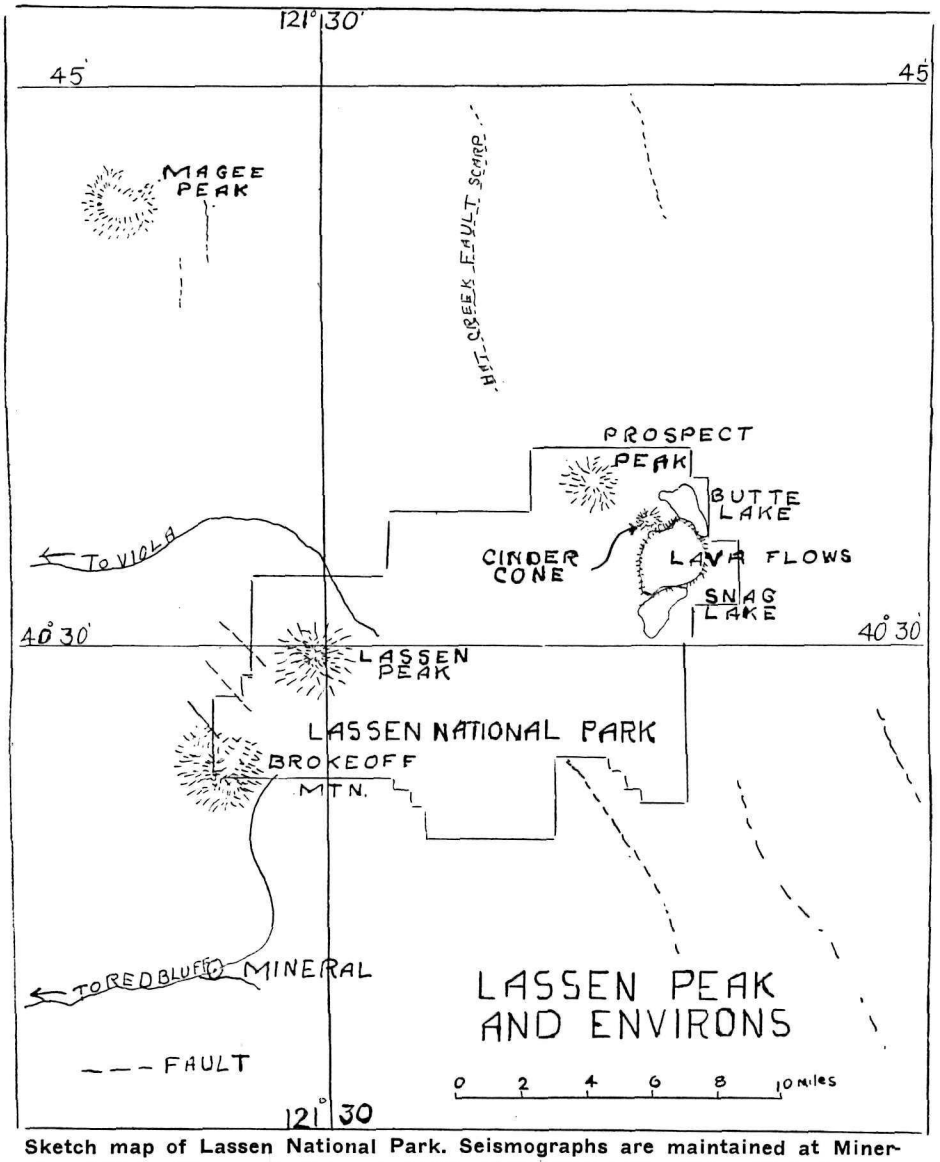
Location	Day-Allen	OBSERVATORY 1927	1928	1929
Supan's Solfatara				
Big Steamer, Aug. 11, 1923	185°F	Jan. 13 .... 194°F. July 6 ..... 174 Sept. 23 240	July 28 .... 240°F. Sept. 5 235	Aug. 27 .... 197°F.
Bumpass Hell				
Large steam vent west of northwest pool, July 3, 1922	196	July 6 183	Sept. 5 192	Aug. 26 176
Spring No. 8, June 5, 1916	242	Aug. 26 194	Sept. 5 194	Aug. 26 198
Spring No. 10, Aug. 10, 1923	198	Aug. 26 194	Sept. 5 174	Aug. 26 198
Spring No. 14, Aug. 11, 1923	201	Aug. 26 217	Sept. 5 190	Aug. 26 197
Boiling Lake				
Steam vent south end, June 30, 1922 (The ground here subsided several feet 1927-28)	201	July 8 212	Aug. 11 204	Aug. 17 200
Boiling pool south, July 3, 1922	201	July 8 200	Aug. 11 192	Aug. 17 198
Devil's Kitchen				
Northwest boiling pot, June, 1922	196	July 8 198	Aug. 11 189	Aug. 17 195
Southern pool, June, 1922	201	July 8 199	Aug. 11 198	Aug. 17 199
South pot, July, 1915	201	July 8 198	Aug. 11 199	Aug. 17 197
Morgan Springs				
The Growler, (Diller) 1921	204	Aug. 24 200		
Spring No. 1		Aug. 24 175	Aug. 7 177	Aug. 22 168
Steam pool No. 17		Aug. 24 201	Aug. 7 201	Aug. 22 201
Spring No. 6, NE		Aug. 24 146	Aug. 7 176	Aug. 22 195
Spring No. 23		Aug. 24 183	Aug. 7 192	(Many of the spgs. were dry)

The above are not necessarily entirely identical places as the springs shift and vary and the thermometer exposure differs. In 1929 the Morgan Springs showed increase in incrustations and the volume was diminished.

R. H. F.



Boiling lake near Drakesbad, Lassen Volcanic National Park, July 8, 1927. This is six miles southeast of Lassen Peak. **Photo Finch.**



Sketch map of Lassen National Park. Seismographs are maintained at Mineral and Viola. Morgan Springs are south of the Park; the other solfataric areas are close to Lassen Peak.

KILAUEA REPORT No. 953

WEEK ENDING APRIL 27, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains very quiet, only slight rock slides being noticed April 21 and 26.

Seven local seismic movements were registered by the Observatory seismographs during the week, of which four were tremors, each lasting from a half minute to a minute; and three were very feeble seisms. Microseismic motion was normal or slight, and tilting of the ground was strong NNE.

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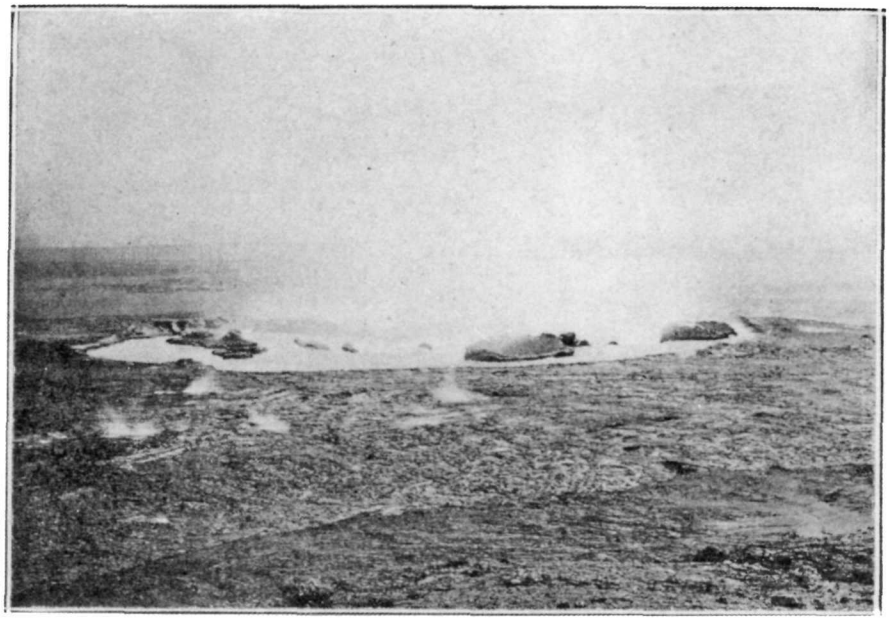
No. 280—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 8, 1930



Distant photograph of Halemaumau pit March 25, 1921, from the summit of Uwekahuna Bluff, near where the museum now stands. Shows the entire circle of the pit filled with overflowing liquid lava that was rushing around the islands to the south cauldron in the background.—Photo Jaggar.

WHEN KILAUEA FIRE-PIT OVERFLOWED

To the visiting traveler it seems quite incredible that the vast yawning cauldron of Halemaumau, the lava pit of the inner floor of Kilauea Crater, was overflowing its lips in five directions at the March equinox of 1921, only nine years ago. The following is condensed from the Journal of the first three weeks of March, 1921:

"At the beginning of March the continued subsidence of the lava in the pit made the scene surpassingly impressive owing to the great inner crags towering above the five lava lakes. The walls around the several lakes were sheer precipices, 70 feet high in places, and the rim of the pit stood 90 feet above the liquid lava. Some of the crags on March 6 were still subsiding steadily. The second week in March produced slow subsidence, both lakes and crags lowering a foot or two per day. The glow from the pit at night was dark red.

"The third week produced a spectacular rise, after beginning with dull, crusted, stationary lakes." March 15 inaugurated the rising by a swelling up of the lake bottom and heaving into the air the elephantine island exhibited in cut three of Volcano Letter No. 272. "Suddenly March 18 the crusts broke up, violent fountaining began, the lakes rose 40 feet in a few hours and united into one around the crags as islands, and the overflows escaped from the rim of the pit on three different sides. The overflow northeast swept down for a mile in the Volcano House direction, crossed the trail, and made aa lava at its front." This is what tourists see when they walk out to the pit from the Volcano House.

"The gas release which followed the overflowing produced three sinkhole cauldrons inside the pit which developed enormous clusters of roaring fountains, inrushing cascades (see Volcano Letter No. 278) and upthrown slaggy flings that formed ramparts. (Volcano Letter No. 277). Showers of grit and spun glass fell to leeward. The eruption continued steadfastly, with pit in adjustment to overflow, and the crag islands, which had risen less than the liquid, began to disappear. The longest flow was pouring all over the southern end of Kilauea Crater and out through a gap in the wall of Kilauea Crater, where it advanced a third of a mile into the desert and stopped."

"This activity was accompanied by whirlwinds generated by uprush of hot gas carrying shells and fragments of glowing basalt hundreds of feet into the air and lifting the fountains and burning gases into streamers of fire. These whirls made loud roaring noise, and the larger fragments fell several hundreds yards from the pit. At night the illumination was so great that print could be easily read at the Observatory two miles away.



Halemaumau pit brimming full, with its hot lake and crag in the foreground. In the background stands Mauna Loa with a remarkable convection cloud over it, probably due to a gas eruption at its summit crater. Photograph by Jaggar, March 19, 1921.

"The end of the month started a rapid sinking of the lava column, crags and lake lowered 10 feet or more per day, whirlpools and shifting sinkholes formed, the crags increasingly emerged from the liquid, fume became thicker the outflows of course ceased, and glowing wells were left over underground chambers at the source cones of the flows."

The first picture the visitor may compare with what he sees today when standing at the Uwekahuna Observatory, where the motion pictures are shown. This is a view taken March 25, 1921, looking down at what had been Halemaumau pit. Except that the pit at that time was somewhat smaller than at present, the effect is exactly as though one looked down at the present cauldron filled brimming full of liquid molten lava which was overflowing off to the right. At the far side of the white lake of molten stuff is seen at the left the pressure ridge of the southeast rim, which was near the road terminus. When the picture was taken, there was a great sinkhole cauldron at the pressure ridge, and most of the surface streaming of the lava through channels amid the crags was toward this sinkhole. The dark foreground is the terrace of Uwekahuna Bluff making this somewhat of a birdseye view, with the observer looking down at a landscape 500 feet below him.

A group of earthquakes immediately before and during the first days of this March rising of 1921 was felt in the southern and western parts of Hawaii, showing that the lava under Mauna Loa took part in the movement that was vented at Kilauea. There was almost certainly some gas effect of outrush at the summit crater of Mauna Loa, for at 3 p. m. March 19, 1921, a remarkable mushroom cumulus of what appeared to be a steam cloud with a stem, developed over the summit of Mauna Loa, its substance an ordinary cloud, but its persistency and situation suggesting a heating effect, in or near the summit crater of Mauna Loa. There was no activity of Mauna Loa otherwise reported. The large picture on Page Two shows this mushroom over Mauna Loa, taken from the east side of the boiling, rushing, lava lake of Halemaumau, and showing what was left of the great northwest crag of the fire-pit with the streaming and fountaining melt all around it. In the foreground is shown the glistening spatter lava and the general shimmer is due to the intensely hot gas rising from a million bubblings.

This overflowing of 1921 was the last of a series of such floods from Halemaumau which had been building up the Kilauea Crater floor at different times during the years 1918, 1919, 1920, and 1921. The last picture on Page Four shows the detail of a portion of the actual southwestern rim of Halemaumau in process of overflowing in 1919, and this was a third time within a twelemonth that this had happened. The light-colored surface at the left in the photograph is the Kilauea Crater floor with the western bluff behind it and the northeastern slope of Mauna Loa still farther in the background. All the dark lava on the right is the Halemaumau interior brimming full of lava, and in the foreground streams of this lava are seen flooding over the broken rocks of the rim in pahoehoe festoons like treacle or candy. These flows are pouring away to the left. The white post on a small bluff near the middle of the picture was the southwestern trig station of the Halemaumau rim. Here again the observer of the present day sees what it would be like to have the lava of the floor of the pit up to his level and trickling over a low part of the present rim, while he stood beside it, and watched it flow. It is extremely difficult for most travelers to visualize this, or to imagine that that still black floor of the pit as he sees it today is capable of breaking out in a moment and making lava floods, tending in the course of years to fill up the cauldron. T.A.J.

KILAUEA REPORT No. 954

WEEK ENDING MAY 4, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

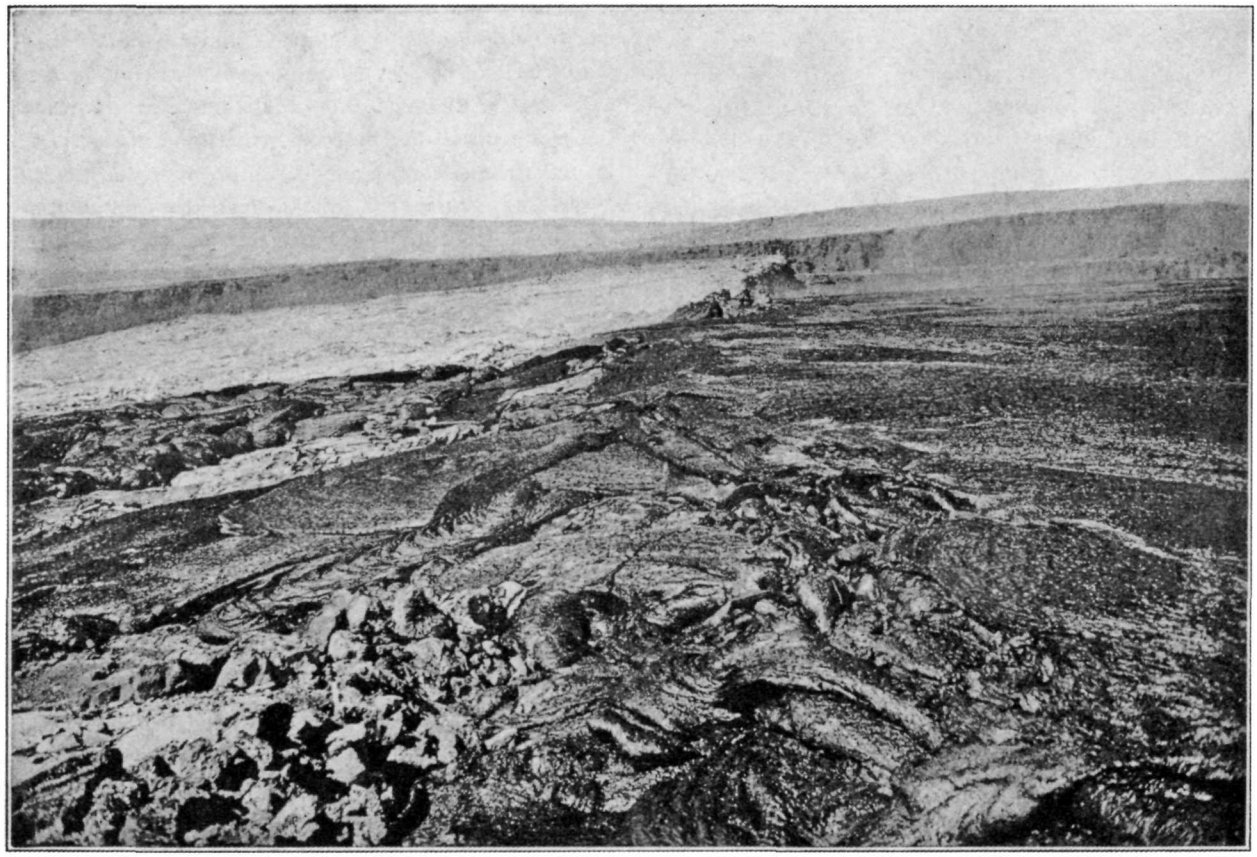
Halemaumau remains quiet, but a few rocks were heard falling from the north rim at 10 a. m. April 28. A white sulphurous spot was noted in the southwestern wall, and with very rainy weather steaming is seen at the south talus.

Eleven seismic disturbances of local origin were registered during the week, of which five were very feeble seisms. One of these indicated origin distance nine miles and was accompanied by tilt east, and another origin distance 16 miles and was accompanied by tilt south. There were six tremor spasms lasting each from one-quarter minute to one minute. Microseismic motion for the week was slight, and tilting of the ground was slight NW.

APRIL TILTING OF THE GROUND

At the Hawaiian Volcano Observatory the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

March 31-April 6	1.11 seconds NE.
April 7-13	0.79 seconds SW.
April 14-20	1.03 seconds SW.
April 21-27	2.42 seconds NE.



Looking along the south margin of Halemaumau January 19, 1919, Uwekahuna Bluff in the background. In foreground lava of Halemaumau overflowing the rim in trickling streams.—Photo Jaggar.

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281

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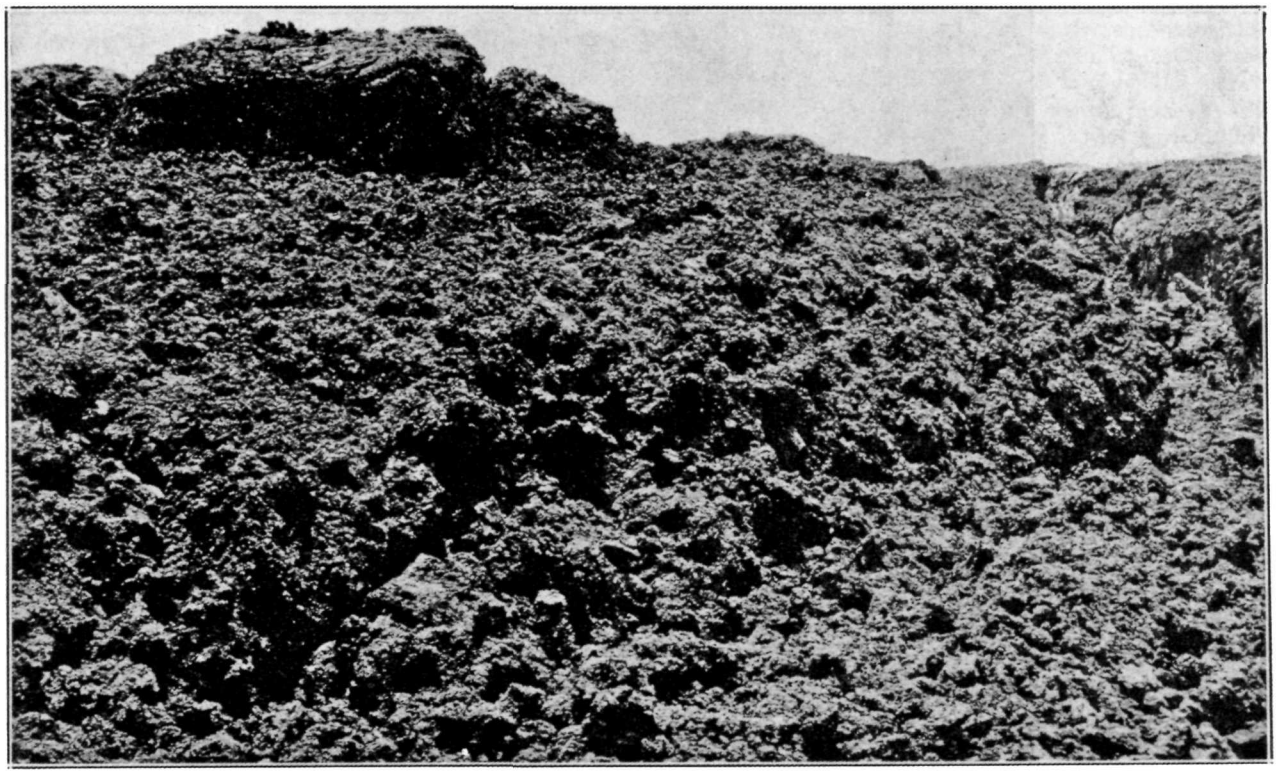
No. 281 Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 15, 1930



Aa lava and channel of Alika flow in South Kona on the slope of Mauna Loa, 1919. This shows typical aa texture on the bank that congealed after the glowing stream ceased flowing. This stream, 40 feet wide, swept through the channel for days at eleven miles per hour.—Photo Kanemori.

DISTINCTION BETWEEN PAHOEHOE AND AA OR BLOCK LAVA

The picture shown above represents a characteristic surface of what the Hawaiians call aa lava (pronounced ah-ah), in contrast to the smooth candy-like surfaces (pahoehoe) of basalt shown on Page Two. In the experience of the Hawaiian Volcano Observatory four eruptions of Mauna Loa have been studied, many years of lava activity in Halemaumau pit at Kilauea have been occupied with photographing and note-taking amid spouting and streaming basaltic melt, and three times the flanks of Kilauea Mountain have given vent to flowing lava, with both the aa and pahoehoe types represented. It is generally agreed by investigators that there is no essential difference chemically between aa and pahoehoe, and it is well known on Mauna Loa and Kilauea that the fountaining pahoehoe at the source of a flow may turn into aa clinkers within a half mile of the vent, and remain aa for the rest of its course down the mountain into the sea. It must not be inferred from appearances that pahoehoe is more liquid and rapid flowing. Some aa flows have rushed down Mauna Loa very rapidly, the source region making a glassy and frothy pahoehoe which quickly transformed itself to clinker a short distance away from the source. Some pahoehoe flows at the end of an eruptive period have found their way down the mountain very slowly as the end-stage of the outflow, the progress being through tunnels and crusts of their own making. When an observer stands on the bank of a golden, liquid torrent of lava flowing so rapidly as to make no crusts or skins, he can not tell from the appearance of the liquid whether it will solidify as pahoehoe or aa.

It thus appears that both pahoehoe and aa may occur on the same flow, that they both have the same chemical composition, that they both flow rapidly at times and slowly at other times, that they both may be very sluggish and viscous or swift and liquid, and that in general pahoehoe is conspicuous around the summit craters and near the vents of outflow, and aa is characteristic of the long flows far down the mountain slopes. Two notable exceptions to this last generalization were the last stages of the eruptive period of the 1881 flow from Mauna Loa to Hilo, which was pahoehoe, and the last stages of the



Rift floods of pahoehoe in the timber of the Mauna Iki region, December 24, 1919, six miles southwest of Kilauea. These flows came up a crack in the mountain, drained down the level of Halemaumau, poured out for seven months, and built up a hill.—Photo Finch.

eruptive period of the 1920 flow from Mauna Iki on Kilauea, which also was pahoehoe. The former flowed 30 miles from the vent as smooth lava in tunnels, and the latter five miles from the vent. In both these eruptions the early stages of the eruptive period produced aa flows whenever the scurce heap (pahoehoe) gave vent to a long flood down the mountain slopes. There is a suggestion here that crystallization is stimulated by free flowing of highly liquid frothy melt, that more crystallization or "sugaring" due to stirring may be the characteristic of the clinkering that is distinctive of aa lava, and that such internal stirring is stimulated by the greater gas-bubble content of the lava at the beginning of an eruptive period.

The photograph on Page One shows on the right the channel which had been occupied by a torrent of brilliant yellow molten slag for many days in September-October, 1919, where the Alika flow in South Kona crossed the road about 1,400 feet above sea level. On either side for a width of 2,000 feet this torrent had created a clinker field by backing up and overflowing from time to time during the eruption. The progress downhill through the forest was first a tongue of aa lava that pushed over the brow of the mountain into the steeper country and marched forward like a caterpillar tractor dumping talus over its front and then overriding the fragments beneath. This advance was about one mile per hour. After it reached the sea the congealed sides of the flow became the clinker field, and the stream inside rapidly narrowed and started its pulsations of backing up and making lateral tongues of overflow, now here, now there. Wherever any of the lava congealed, except within a half-mile of the source crack at 8,000 feet elevation, it solidified as clinker or aa as shown on Page One. The narrowed torrent was very brilliant, flowing perhaps eleven miles per hour, bringing large rafts or blocks of material broken away from the banks, and occasionally dumping these on one side or the other during a spell of overflow. Such a raft is shown in the stranded lump on the left of the picture. The process of solidifying, when one watched a tongue of overflow cooling, proceeded without any skins forming, and with the development of small black dots on the surface of the incandescent liquid, these becoming centers of congelation accompanied by a sprouting or crumpling action which made the whole hardening area appear like a bed of coals, with cherry red glow in the cracks. Flames are often seen among the cracks, but they are deceptive in a flow of this kind, because it contains so much burning vegetable matter that it is impossible to distinguish true volcanic flames. The surface of a cooling aa flow is excessively hot, with intense radiation like a bed of coals. In contrast to this, the surface of a pahoehoe flow starts to skin over with a membrane of glass the moment it begins to cool, this membrane draws out millions of oval bubbles so that the appearance is like layers of netting one above the other, and the result is a thickening, glassy skin which wrinkles into ropes and folds the size of which is dependent on the thickness of the flexible crust avail able. This vesicular crust is an excellent heat insulator, so that one may approach close to the front of the bellying toes of a pahoehoe flow before he perceives that the sluggish monster is hot and creeping forward. There is no suggestion of cracks or flames, unless a heavy hardened crust breaks open and gives vent to a new tongue, which emerges as a rounded bulb encased in a newly formed skin.

It will be seen from this description that the surface

of pahoehoe lava is characteristically glassy. The surface of the lumps and sprouts of aa lava is an endlessly broken jumble of partially crystalline rock, bounded by broken gas vesicles. After both kinds of flows are cold and solidified, the rock of the interior is a continuous sheet of largely crystalline basalt with many gas blebs or vesicles, and such interior rock is just the same for both kinds of flows. The broken bowldery appearance of the surface of an aa flow is largely an illusion, as many of the bowlders are not loose at all, but are sprouts and crags connected with the continuous ledge beneath. There are, however, many flows which break up these crags into bowlders which are rolled along on the surface of the paste and become plastered like snowballs into rounded spheres coated on the outside with lava layers.

Dr. O. H. Emerson made experiments in 1926 (American Journal of Science August, 1926, page 109) by melting Hawaiian lava in crucibles and stirring the melt. It was found that the tendency to crystallize was greatly enhanced by the stirring, the material along the walls of the crucible being glassy with some crystal nuclei, while the stirred parts consisted of a mass of small crystals with some glass in the interstices. Both aa and pahoehoe lava from Hawaiian flows were ground to powder and melted, and both when stirred produced typical aa clinker or arborescence. The mass was at a yellowish white heat and had the consistency of honey; it was allowed to cool in the dying fire, being at the same time constantly stirred with an iron rod. When the ball of slag was broken open the interior was aa and the outside was pahoehoe. It thus appears that higher crystallinity favors congealing as aa if the material is stirred in the open, and from this it might be argued that the more crystallized material under a pahoehoe skin should flow out as aa if it were allowed to escape. Exactly this has happened at Kilauea. Repeatedly lava domes of pahoehoe have formed, like the one at Mauna Iki which invaded the forest six miles southwest of Kilauea in December, 1919 (see photograph Page Two). When this dome reached a certain height, it burst open and gave vent to aa lava rivers repeatedly (see Page Three). On Page Four is shown the lower slope of aa beneath an island in Halemaumau which was suddenly lifted 40 feet in a night in 1917. This indicated that a sudden disturbance of the equilibrium of the pahoehoe crusts in the Kilauea fire-pit so as to cause a sudden congealing of the lava paste, may reveal crystallinity in that paste quite capable of making aa. By thrusting steel pipes into the lava lakes, the stirred melt which crystallized on the outside of the pipes in clots was drawn out as typical aa lumps, although the lakes themselves maintained an equilibrium which made only pahoehoe skins and crusts on their surfaces and at their shores. T.A.J.

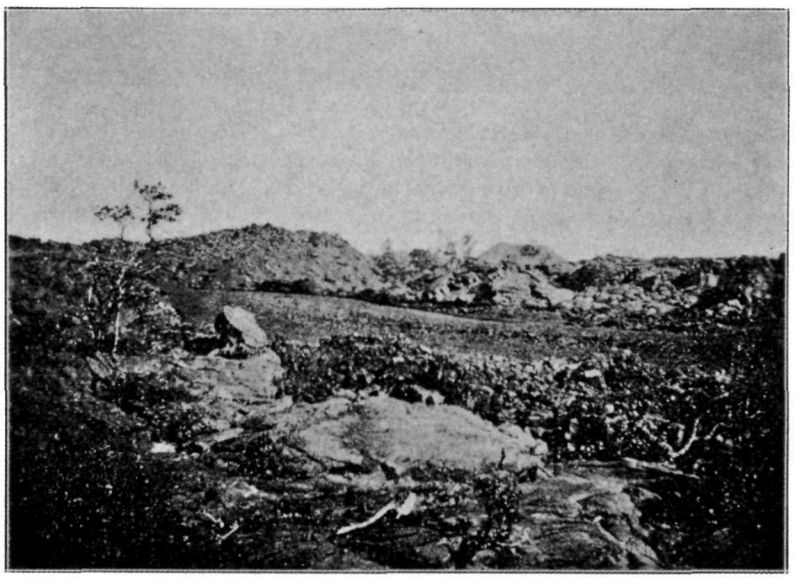
KILAUEA REPORT No. 955

WEEK ENDING MAY 11, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

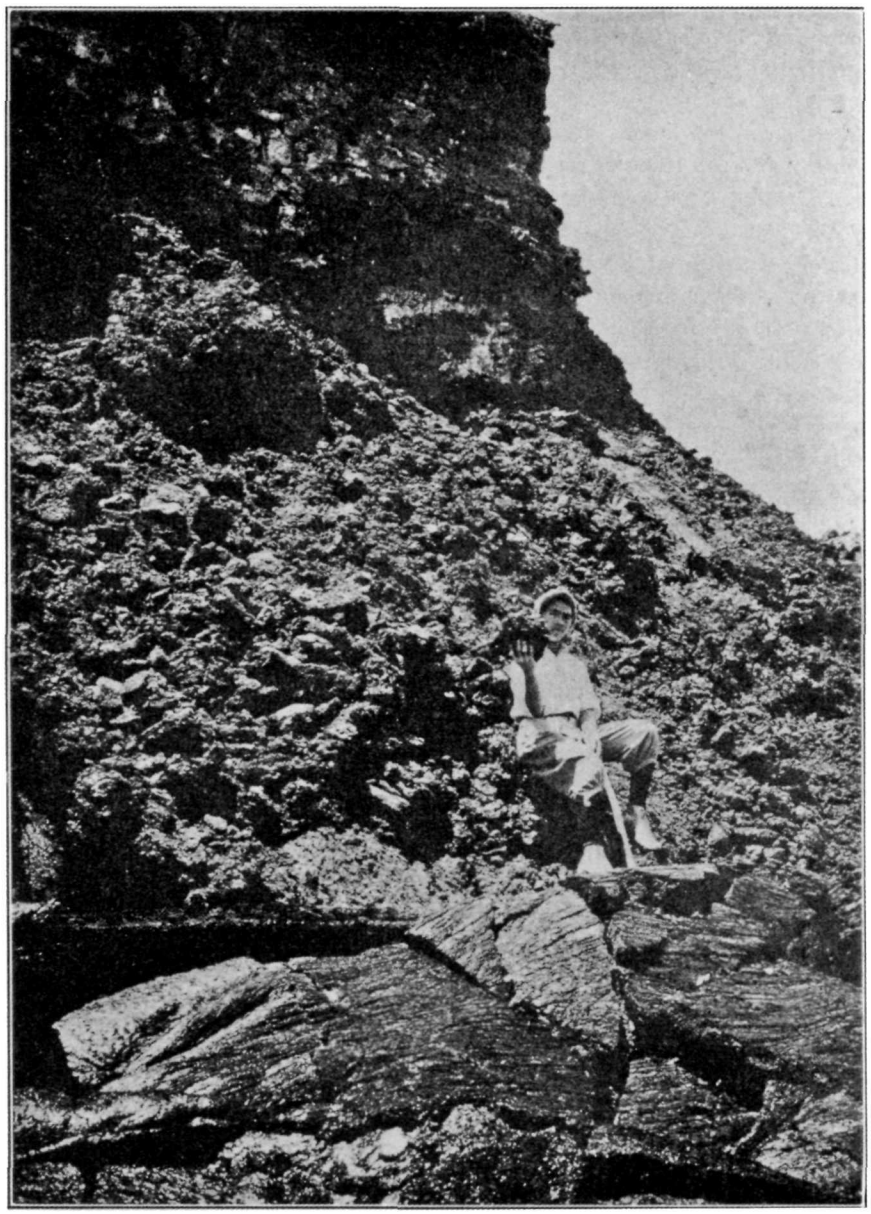
No changes have been observed at Halemaumau during the past week. Steaming is slight at all vents, and working of the walls has been negligible. Small slides on the north wall were noticed on May 10 and 11.

The Observatory instruments have recorded seismic disturbances as follows: 11 temors, the longest with duration 1.5 minutes; 3 very feeble seisms; 1 distant earthquake very feebly recorded on the north-south component at 3:54 a. m. May 9.

Microseismic motion was slight; tilt accumulated slight SSW.



An aa lava river which flowed five miles down the mountain from Mauna Iki, and was pahoehoe lava at the source. It turned into aa a few hundred yards away from the source and was first observed December 31, 1919. This shows the characteristic dark stream with clinkery surface, so different from the glistening folds and festoons of pahoehoe.—Photo Finch.



Aa pedestal of island in Halemaumau April 5, 1917. Two weeks earlier this island had been pushed up suddenly while an adjacent larger crag subsided and the underpinning of the island was revealed as a raw reddish wall of aa lava, in contrast to the slabs of pahoehoe in the foreground.—Photo Jaggar.

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The Volcano Letter

282

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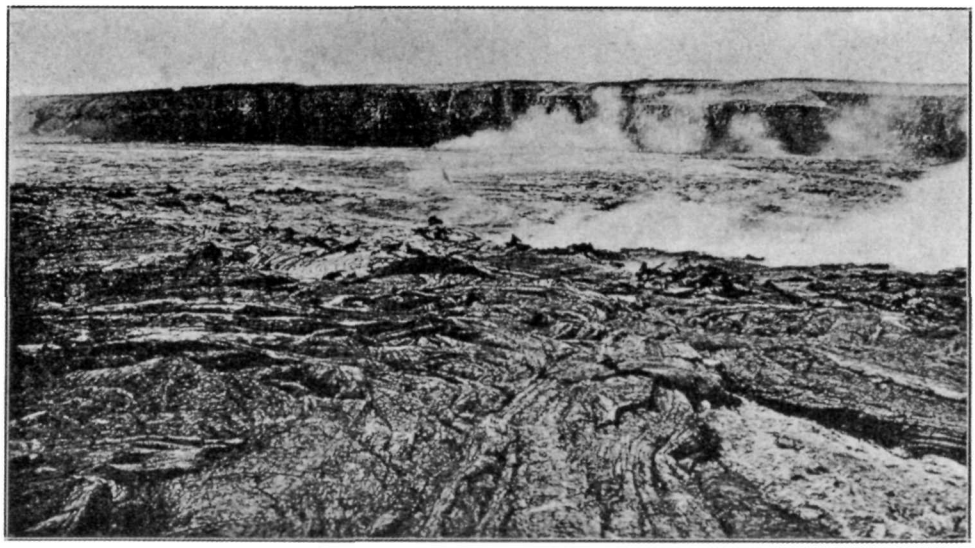
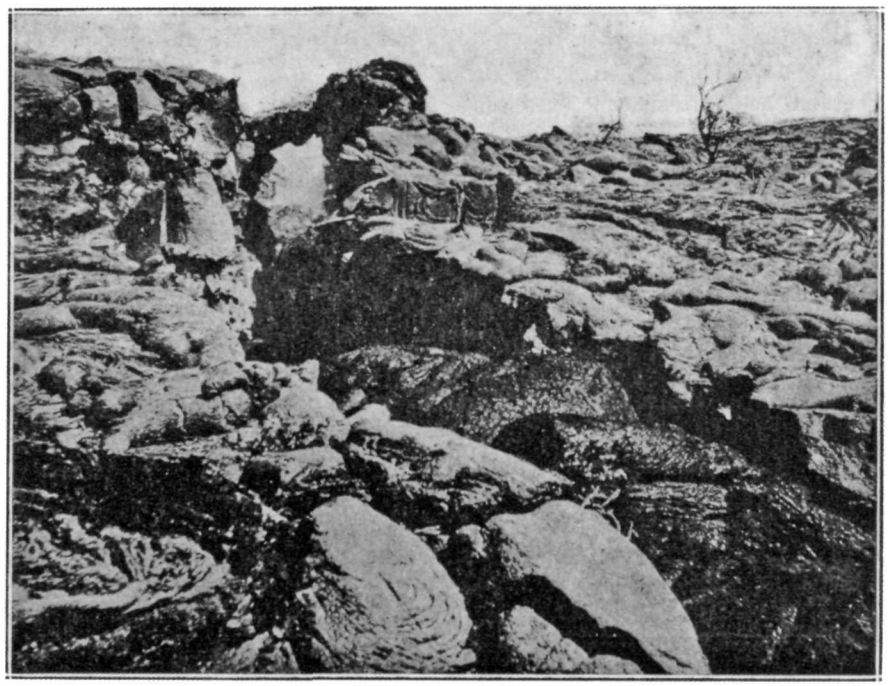
No. 282—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 22, 1930



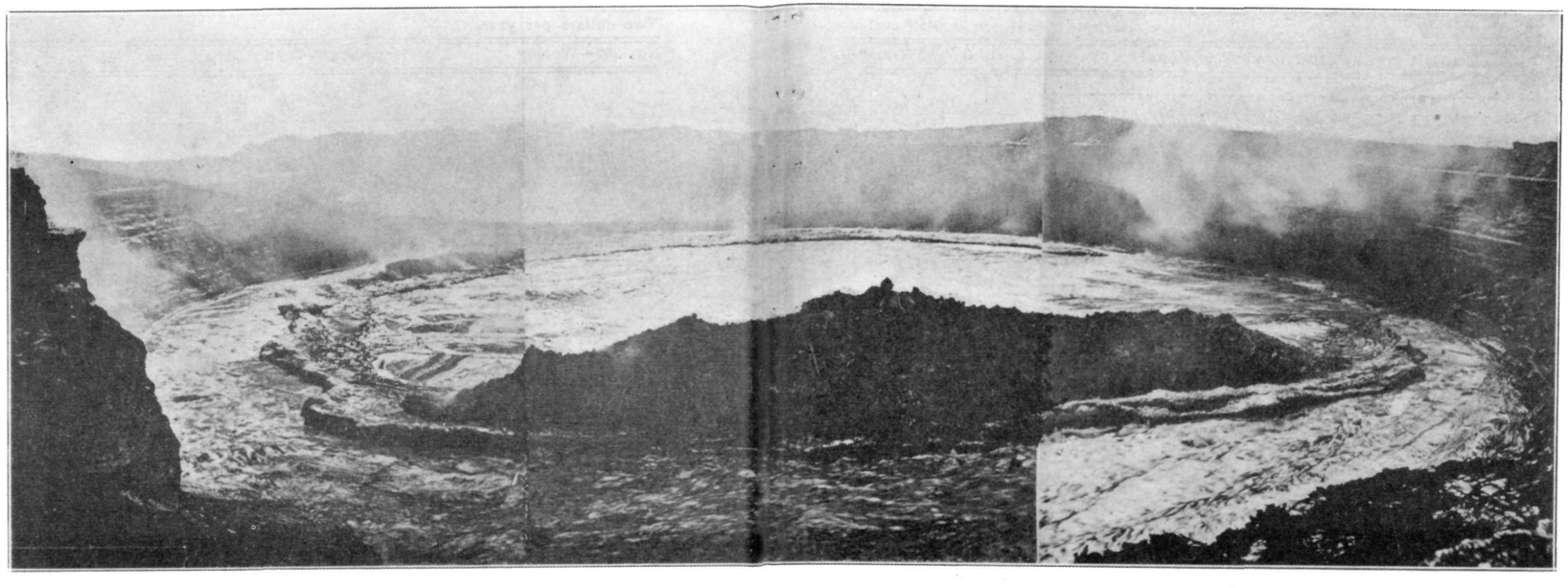
The steam belts border a flood of liquid lava, fed by about 50 fountains spurting from a radial crack, extending from Halemaumau to the southwest wall of Kilauea. December 15, 1919, 11:30 a. m..



The Kau Desert rift, opening and showing black pahoehoe lava rising up the crack, here about four feet wide. The western of two fissures about five miles southwest of Halemaumau, December 22, 1919.

WHEN KILAUEA MOUNTAIN BROKE OPEN 1920

Flank outbreaks down the sides of the mountain at Kilauea Volcano, by the splitting open of the ground and letting out the lava from Halemaumau through underground fractures extending all the way from the crater to the place of outbreak, are rare on Kilauea, though similar fissure eruptions have been common on Mauna Loa since the first white explorers came here. The map on the last page indicates the main Kilauea outflow fissures along the chain of craters to the east extending all the way to Ka-



Ring-island of bench magma in Halemaumau looking SSW with outer ring-pool fountaining strongly, and inner lagoon quiet. The island is the top of a lily-shaped cake of lava paste lifted rapidly so as to part from its containing funnel and let the liquid fill the wall-crack. Photos Jaggar.

poho, and along a similar chain of craters to the southwest marked by the flows of 1920 and 1823. There is another small flow area of 1868 between the last two. These eastern and southern belts mark definite rift zones of very ancient origin extending from Kilauea Crater as vertical cracks, somewhat curved in plan, down the slopes below sea level. They mean that a slice of the mountain southeast of the crater is broken and tending to fall away toward the ocean, and the fault cliffs back of Keauhou are parallel slices already slipping into the sea.

Some visitors to Hawaii National Park take the trail to Mauna Iki in the Kau Desert. Mauna Iki is a fresh lava hill so hot through cracks on its top that sticks burst into flame when thrust inside. Mauna Iki was completely built by lava welling up the southwest rift beginning December 15, 1919, and continuing action until the autumn of 1920. The breaking open of the mountain began by a radial split across the floor of Kilauea Crater southwest from Halemaumau December 15, 1919, at 11 a. m. whereby floods of lava formed steaming lakes along the foot of the southwestern walls of Kilauea. (See first photograph Page One.)

The next thing that happened was the rising of steam along the southwestern Kau Desert cracks outside of Kilauea Crater, and when these old cracks were examined, a freshly opened zone was found of many parallel cracks showing new breaks in the dirt, extending for a mile and a half away from the edge of Kilauea Crater. This zone was a quarter mile wide. The larger chasms had yawned open and engulfed their dirt fills. Creaking and tumbling could be heard within them. One of them, on this day of the outbreak across the Kilauea floor, was found in the afternoon to be 80 feet deep and five feet wide, away down to a narrower space that led below to black depths. Acid sulphurous steam arose with a temperature above 100° F., and along the line of the principal crack five steam columns had appeared, four of these being in a group near to Kilauea.

This gushing of the first day on the Kilauea floor pulled the level of the lava lake in Halemaumau down from 35 feet below the rim, to 148 feet on December 16, but the outflow in the south part of the greater crater stopped within an hour of its first eruption. In the afternoon of December 15 a swarm of earthquakes recorded on the instruments indicated that a sharp readjustment was going on along the rift belt, and doubtless lava was pouring from Halemaumau into underground cracks that were opening in that direction within the larger mountain edifice. When the first outflow on the Kilauea floor was seen, the cliff bounding the big crater, along the line of the gushing crack in the floor, was seen to make little avalanches, indicating that the crack in motion extended beyond the mere crater fill. After December 16 the lava in Halemaumau rose again until the liquid was even five feet higher in the pit (30 feet below rim) on December 22, than it had been on December 15. This created a new tension in the mountain and the flank rifts which had been opening in the Kau Desert started flowing so that the level of Halemaumau lowered again. Outflow on the southwestern Kilauea floor was resumed December 19 as soon as the liquid in the pit reached the level of the outflow vents.

The splitting open of the outside mountain was dramatic in its quietness. It seems quite incredible that a vast rocky dome made of heavy black basalt can split asunder along nine miles down its slope and give vent to increasing lava flows without any big earthquakes or explosions. But this is just what happened.

The writer followed these events day after day and watched the splitting of the ground farther and farther away from Kilauea Crater. December 21, starting at the southwest edge of Kilauea Crater, he found an open network of gaping fissures, and the five-foot crack of December 15 was now a chasm 15 feet wide, broken through rock below and volcanic ash above, the sand continuously slipping on the inner slopes and thereby giving evidence of motion in progress. Farther away down a crack four feet wide sluggish pahoehoe lava could be seen 50 feet below the surface, welling up in heavy snake-like folds, throwing out incandescent toes, and making a crackling noise by reason of the heating and snapping of the adjacent rock. No vapor arose here, the steam columns always coming from small cracks of presumably wet ground adjacent to the lava fillings.

Beyond Cone Peak, which lies on the rift zone a mile and three quarters from Halemaumau, the ground was freshly broken along an active zone a quarter mile wide with two main cracks, and these two cracks in the region west of Puu Koae showed live lava inside which reached the surface level of the mountain along a half mile of the surface about five miles from Halemaumau. As one walked down the mountain live lava was seen in the western crack at considerable depths, and a half mile farther this lava rose to the surface level, filling the crack with heavy black pahoehoe through which hissing gas vents were flaming and either building small spiracles or heaving the skin on roundish puddles. An occasional deep detonation suggested that the crack was being heaved open in the depths by the expanding lava. Ot one place the crack overflowed in two small pools 30 to 50 feet in diameter. The pools were crusted over and glowing toes oozed out from under their marginal skirts. A line of 15 spitting and spurting driblet cones followed the crack through the pools, and farther downhill this crack narrowed and was marked only by vapor jets. Thereafter the activity was transferred to the eastern crack which extended farther down the mountain and emitted bluish-brown fume and was full of hardened lava apparently stagnating level with the surface of the country. The gas hissed through spatter cones and the adjacent ground was splashed with spatter lumps from a previous spurting action which had ceased. The character of these cracks with their black fills is well shown by the second photograph, Page One.

After this about Christmas time of 1919 the fissures in the desert split their way day after day to a point nine miles from Halemaumau where the live crack opened beneath deep banks of dune sand, and the lava built up a hill 80 feet high in the forest. The outflowing pahoehoe made tree moulds, and when it penetrated old caverns in the forest the mixture of carbon gas and air made explosions that ruptured the cavern roofs and flung rock fragments away from the holes. Then the activity of outflow centered about floods of pahoehoe lava two miles long and three quarters of a mile wide with liquid lakes and pits on top. This was Mauna Iki, the new "baby Mauna Loa" in shape, and so named "little mountain."

The remarkable ring-shaped island in Halemaumau exhibited on Page Two-Three was the conspicuous feature of the interior of the pit at the time of these ups and downs that accompanied the Mauna Iki flowing. This ring-crag of bench magma was surrounded by an outer ring-pool fountaining violently, and contained an inner circular pond of quiet lava. The ring-island was the top of a lily-shaped column of the stiff lava paste moulded to the funnel shape of the containing pit, and lifted very rapidly so as to part from the walls between November 28 and December 15, 1919. Up the space between it and the walls boiled the foamy or liquid lava following as usual the wall-crack, or marginal fissure between wall and plug. This was the very peak or climax of the 1913-1924 cycle, when Mauna Loa had just been flowing, and Kilauea was about to flow.

T.A.J.

KILAUEA REPORT No. 956

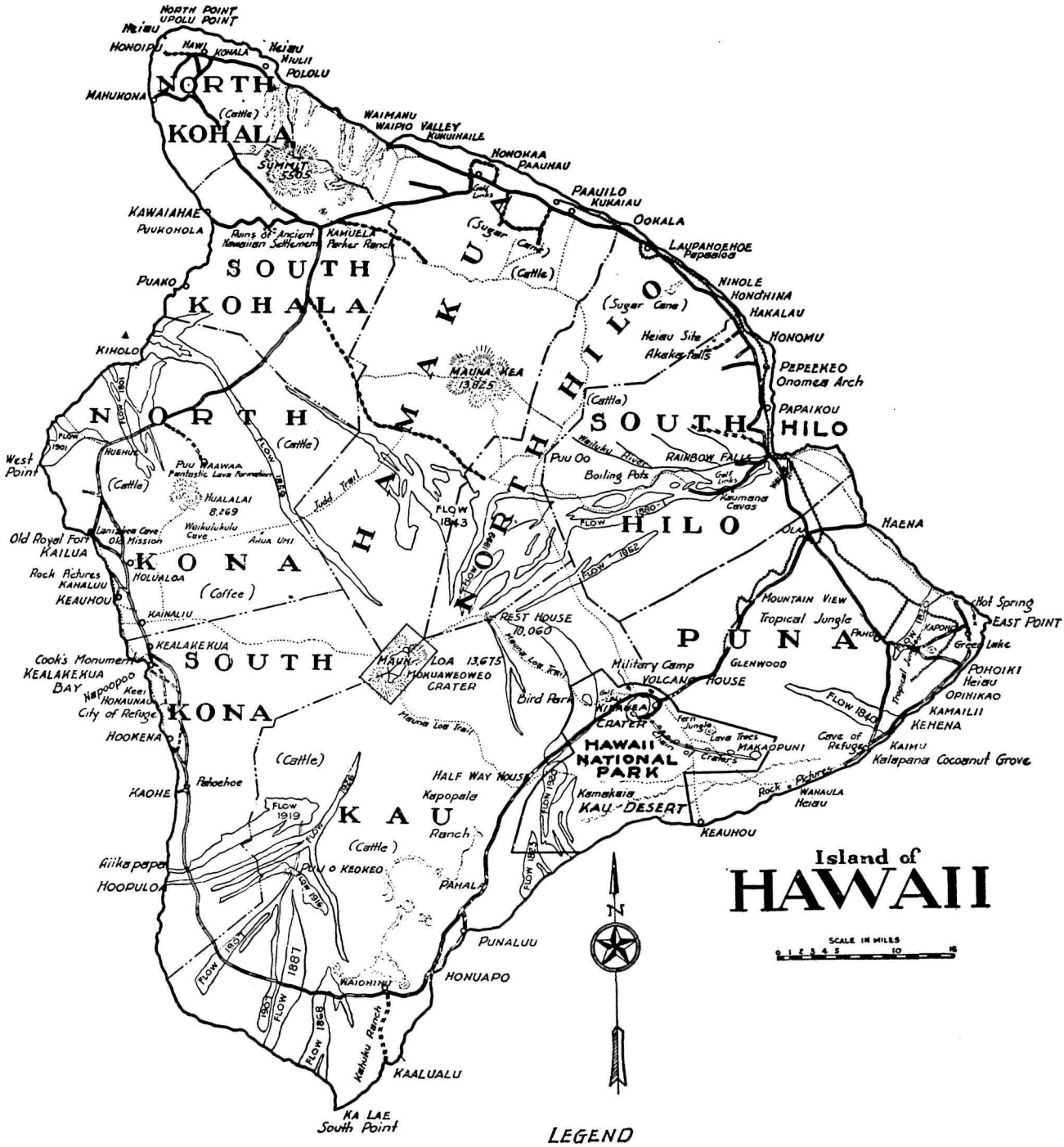
WEEK ENDING MAY 18, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit in Kilauea Volcano the steam on the south talus disappears entirely on dry days and rock slides are infrequent and very small. The pit is unusually quiet.

At the Kilauea Volcano Observatory eight very feeble local seisms have been registered during the week, three of them idicating respective distances of origin 15, 16, and 23 miles. Eleven spasms of tremor have been recorded, mostly from one-half to three minutes long, but two unusual periods of tremor lasted 10 and 12 minutes. Microseismic motion was normal, and tilting of the ground was slight SW.



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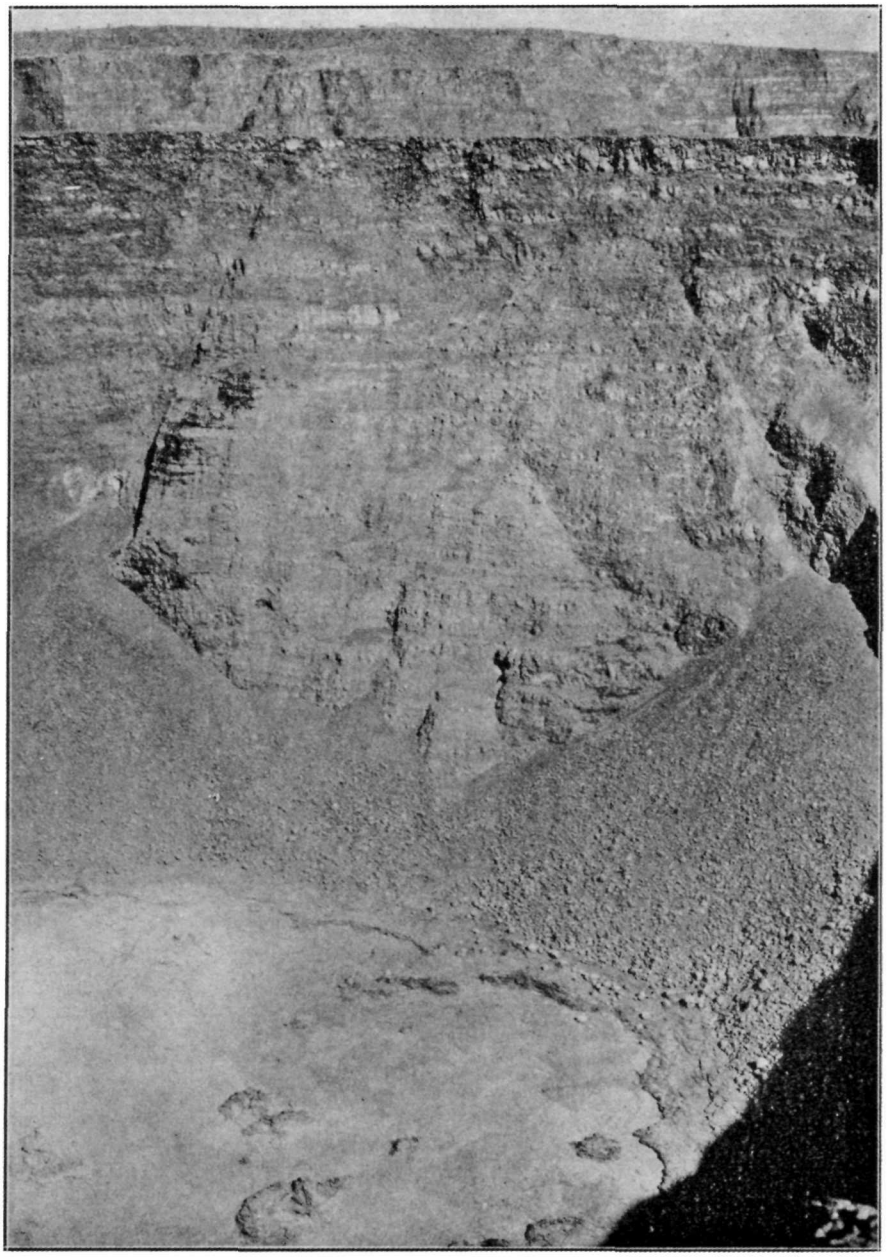
No. 283—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 29, 1930



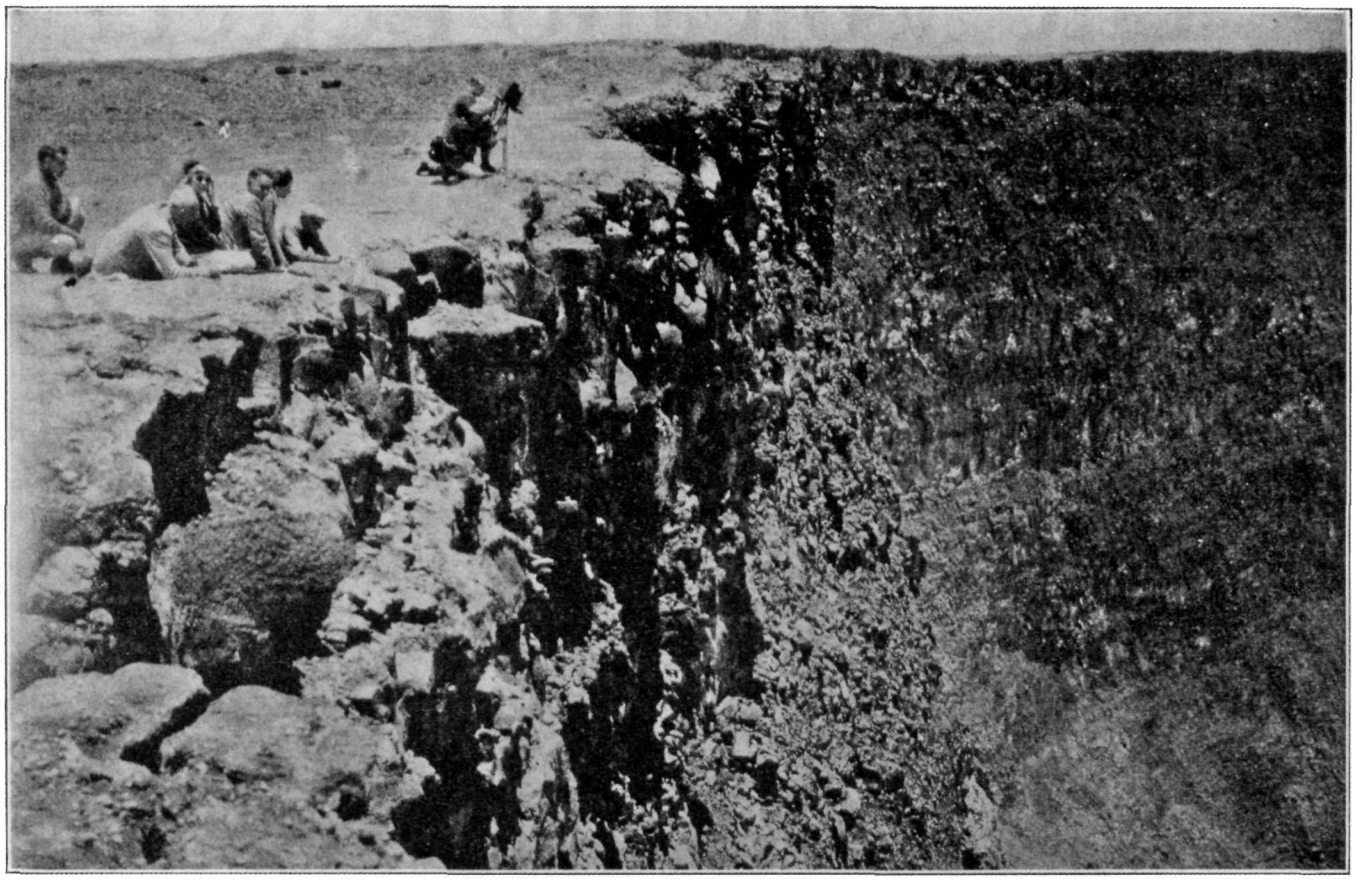
North rim of Halemaumau February 20, 1930, showing wall newly stripped off to build a new small talus between the two large taluses, thus coating the lava floor with dust. Avalanching has developed cracks into gulches up the wall right and left. Photo Jaggar.

RIM CRACKS AND CRATER SLIDES

The tourist visiting Halemaumau pit at Kilauea Volcano is now barred from the immediate edge of the pit by a rope fence which guides him to a station off to the east, which is safer than that part of the rim of the pit which is immediately opposite the automobile terminus. This breakage of the upper rim of Halemaumau so as to destroy the usefulness of the National Park station at the southeast, which had hitherto been considered very safe, occurred unexpectedly early in January, 1929, when big avalanches occurred at the south corner of the pit.

Referring to the map on Page Four, it will be seen that there are numerous cracks indicated as more or less parallel to the pit rim, but lying outside the edge of the pit and expressed as dotted lines. These indicate that the rock of the steep upper wall surrounding the pit is everywhere weak and tending to split off through the undermining action of the movement of the lava under the central part of the bottom of the pit. This was explained in Volcano Letter No. 269.

It is of interest to note that big spells of avalanching occurred in January, 1928, at the northwest; in January, 1929, at the south; and in February, 1930, at the north and northwest again. The photograph on Page One was taken on February 20, 1930, from the eastern rim of the pit, and shows the lava floor which had been left by the July eruption, 1929, completely coated with new pinkish dust from slides



Southeast rim of Halemaumau looking south during activity of July, 1927. There are other cracks back of the observers. Photo Tai Sing Loo.

which had been falling from the eastern, northern, and western walls throughout January and February, becoming strongest during the week ending February 23, 1930. These avalanches send a cloud of dust downward and forward when the falling rock matter strikes the floor, the dust cloud boils vortically, and as it loses velocity it dumps its dust on the ground beneath. In the picture it is evident that dust from the slides lay thickest on the west side of the floor, and the wall above was seen to be scarred and streaked from repeated falls. It will be seen that the north-northeast talus, on the right of the picture, and the northwest talus on the left, are both surmounted by gulches which extend up the wall above, and these gulches terminate at the upper rim in cracks which are shown at the top of the map. The rock wall between these gulches constitutes a buttress or slab backed by these cracks, the slides are eating away the cracks and weakening the buttress, and so the buttress is breaking up, making the small middle talus, and getting ready for a big slide from the top.

Now it is a remarkable thing that when these spells of general sliding occur, the rim cracks tend to widen, even on sides of the pit remote from the avalanches of that particular time. Thus we find the statement in the Kilauea Report for February 23, 1930, that crack No. 14 (easternmost of the cracks just below right side of the map) widened nearly two feet since December 4, 1929. These cracks along the southeastern side of the pit have been marked with paint at a number of points, and the places have been numbered.

This work was started by R. M. Wilson on July 6, 1927, after observation of the Halemaumau rim during the previous month had shown that cracks were widening and slides were occurring simultaneusly, with increasing effect to the date mentioned. This action at that time was chiefly at the east. Mr. R. B. Hodges was detailed to conduct the measurements of the cracks from time to time and has done so since 1927. It happened that this month of working of the Halemaumau wall slabs immediately preceded the outbreak of July 7, 1927, and this made the measurement of the cracks doubly interesting. There was every suggestion that the widening of the cracks, the working of the walls, and the consequent avalanches accompanied tumescence or uplift of the rock structure surrounding the lava column just prior to its outbreak.

The procedure of crack measurement is very simple. The photograph on Page Two shows a characteristic small crack in the foreground at the left, this being that portion of the rim of Halemaumau looking south where excessive opening of cracks occurred in January, 1919, back of where the group of people is shown. This photograph shows the change of angle on the right from steep cliff above to funnel slope below. The photograph on Page Three shows the caliper used as adjusted to two paint marks on opposite sides of a crack at a numbered location. The caliper is adjusted to the crack, and the departure of its two points is measured with steel tape. Fifteen points along cracks were so marked and measured along the southeastern rim of the pit. These fifteen locations had dwindled to five remaining unbroken and accessible on April 14, 1930. The others had either caved in over the rim of the pit, or had become dangerously inaccessible as wide chasms, or had broken down at their marked points. The striking obvious feature of the motion of the cracks was that they had been opening and collapsing, and the pit rim had been enlarging, during these two and three-quarters years.

Measurement on six selected crack locations progressively northeastward back from the southeastern rim of the pit, the last No. 14 being in the vacinity of the fourteen-ton bowlder of 1924, is shown in the table for 15 of the 34 dates of measurement since 1927. This table shows the actual widths of cracks as they changed from date to date, reading downward. Reading from left to right for the same date cracks 10, 13 and 14 are on the same fissure growing wider as it approaches the place where it emerges on the edge of the pit. Cracks 3 and 4 are a little farther west. (These cracks extend from trig station 3641 to 3646 on the southeast side of the map Page Four.)

OPENING OF RIM CRACKS SOUTHEAST OF HALEMAUMAU

Caliper Measurements in Feet, of Distances Apart of Paint Marks on Opposite Sides of Each Crack, from 1927 to 1930

Date	Crack 3	Crack 4	Crack 5	Crack 10	Crack 13	Crack 14
July 6, 1927	2.14	1.17	0.42	0.77	1.54	1.63
July 24, 1927	2.17	1.25		0.77	1.61	1.65
Sept. 3, 1927	Gone in	1.65	0.44	0.79	1 61	
Oct. 1, 1927		1.83	0.45	0.80	1.67	1.82
Dec. 6, 1927		1.83	0.44	0.81	1.77	1.96
Feb. 13, 1928		1.83	0.50	0.84	2.35	2.75
April 21, 1928		1.83	0.51	0.87	2.41	2.90
June 18, 1928		1.83	0.57	0.84	2.46	3.00
Sept. 10, 1928		1.83	0.54	0.88	2.47	3.17
Dec. 4, 1928		1.83	0.56	0.89	2.50	3.24
Mar. 29, 1929		1.91	0.70	0.90	2 52	3.36
July 7, 1929		1.96	0.72	0.91	2.57	3.60
Dec. 4, 1929		2.20	0.73	0.95	Broken	3.96
Feb. 19, 1930		2.22	0.74	0.96		5.71
April 14, 1930		2.25	0.73	0.98		Inaccessible



Marked crack where it emerges southeast rim of Halemaumau, showing method of measurement with wooden calipers at painted spots.

The table shows that all the cracks have tended to open gradu ally, and that the same crack has widened the more the nearer it approached the pit rim as an open chasm. The cases of a crack becoming narrower are only three, and of a few hundredths of a foot. As the cracks fill below with fallen debris it is natural that they should fail to close. The two remarkable features of the table are the steadiness of the process of yawning open in all the cracks, and the greater opening the wider the crack. It is evident that this belt of cracks at the southeast has been steadily yawning open and that it was stimulated in its opening along with eastern avalanches of June, 1927, preceding the eruption of the following month, and that it was stimulated extensively along with southern avalanches of January, 1929, preceding the eruption of the following month. That eruption of February, 1929, produced five seconds of accumulated tilt away from the pit (see Volcano Letter No. 264). This confirms the notion that the yawning open of the cracks is an upward swelling of the inner dome of Kilauea. The first large change in the crack of Nos. 10 to 14 followed the eruption of January 11, 1928, and there were considerable changes after the eruption of July 25, 1929. The big avalanching spells circled the pit as follows: E, June, 1927; SSW, September, 1927; NW, January, 1928 S, January, 1929; NNW, February, 1920. The study of cracks coupled with study of tilt and avalanches is evidently a profitable activity for volcanology at craters.

T.A.J.

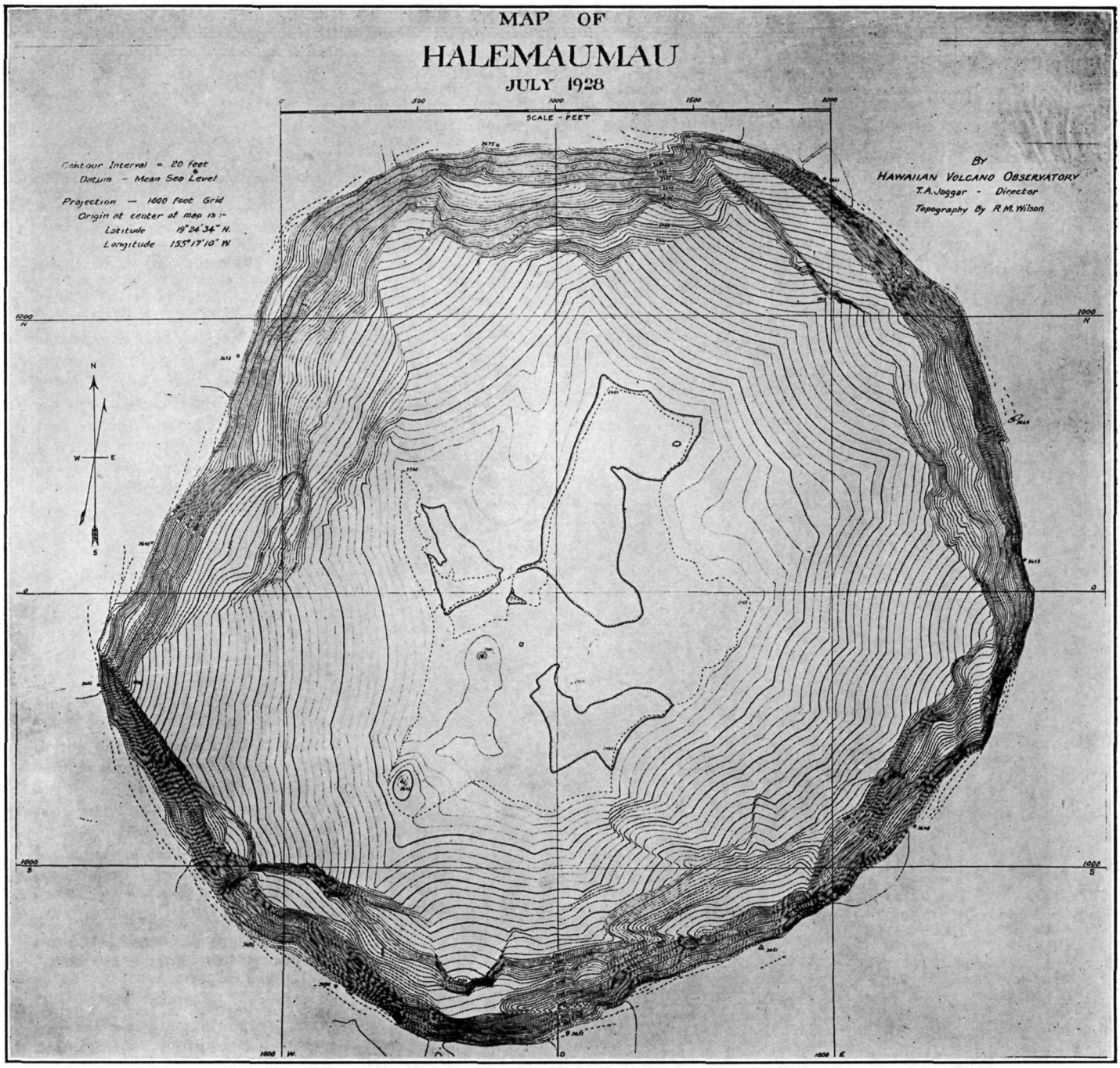
KILAUEA REPORT No. 957

WEEK ENDING MAY 25, 1930

Section of Volcanology, U. S. Geological Survey; T. A. Jaggar, Volcanologist in Charge

The inner pit of Kilauea Crater has shown nothing of interest during the week. Some fresh debris lay on the east talus May 23 and a few rocks were heard falling on the north wall.

The seismographs at Kilauea Volcano, at Hilo, and at Kealakekua have registered some unusually intense local disturbances. The Kilauea instruments recorded 11 local



Map of Halemaumau pit, contour interval 20 feet, showing cracks by dotted lines at edge of pit. The long, straight sides of the pit are SE and WNW, and these are backed by curved cracks completing the northeastern circular curve of the pit. Pit axis follows rift NE-SW.

seisms, of which five were tremors, three very feeble, two feeble, and one a moderate earthquake. The tremors lasted from one-quarter to one minute, and one of these was accompanied by tilt to the east. One of the very feeble shocks indicated origin distance 16 miles, and another showed tilt to the east. The two feeble shocks indicated origin distances 106 and 61 miles, respectively, were felt locally, and the times of beginning were 2:47 a. m. and 6:52 p. m. May 20. The perceptible periods of vibration were rather slow on the east side of the island, and quicker in North Kona, suggesting an origin in the Hualalai direction. Like the Hualalai shocks of October, 1929, the perceptibility was more pronounced in North Hilo than at Kilauea.

The moderate shock occurred at 8:17 p. m. May 25, was strongly felt all over the island, no overturning of objects has been reported, and the accounts indicate stronger motion in Kau and Puna than in Kohala and Kona. At the Kilauea Obseravtory all the seismographs were dismantled, but the Uwekahuna instrument restored its pens and recorded the declining vibrations. The vertical component instrument showed a heavy downward fling as though the earthquake were epicentral at Kilauea. The first movement flung off all the pens instantly at Kilauea, but is reported to have written a short preliminary on the seismograph at Kealakekua in Kona. The first fling of the ground at Kilauea was downward to the south and east, and the restoration of the pens indicated tilt to the south and west. Keaau Beach in Puna, where the Hualalai shocks of 1929 were barely felt, perceived this shock strongly. At a Hilo theater the motion began with a swaying, followed by strong jerks that quickly ended, first to the northeast then to the southwest. The motion was not prolonged like the Hualalai shock of October 5, 1929. Puwaawaa reports a long vibration not particularly strong, Honokahau a moderate shock accompanied with thunderous noise, Kealakekua an alarmingly sudden quake, but without the overturning power of the Hualalai shocks. All of these facts suggest a deep movement somewhere under Kilauea and Mauna Loa.

Microseismic motion for the week was slight, and tilt at Kilauea was slight to the west.

The Volcano Letter

284

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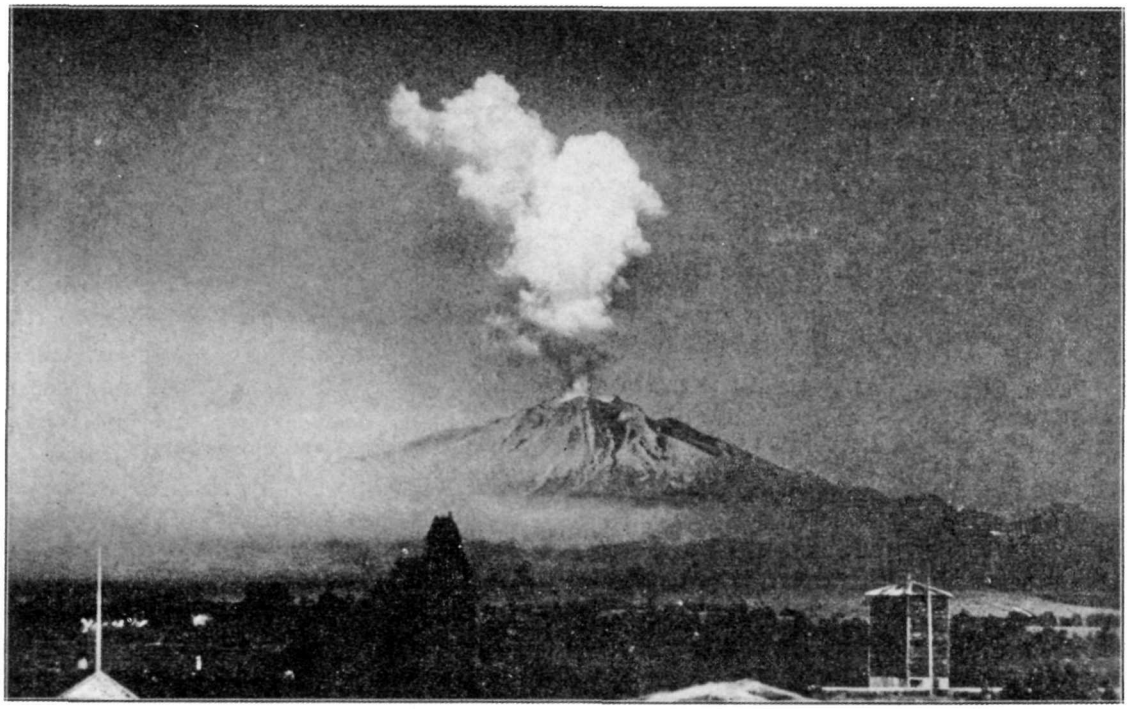
No. 284—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — June 5, 1930



Eruption of Calbuco Volcano, Chile, January 6, 1929, photograph taken from Puerto Varas probably in early forenoon. Photo Karl. Steam apparently issuing with force. Pall of ash to the left.

EDITORIAL NOTE

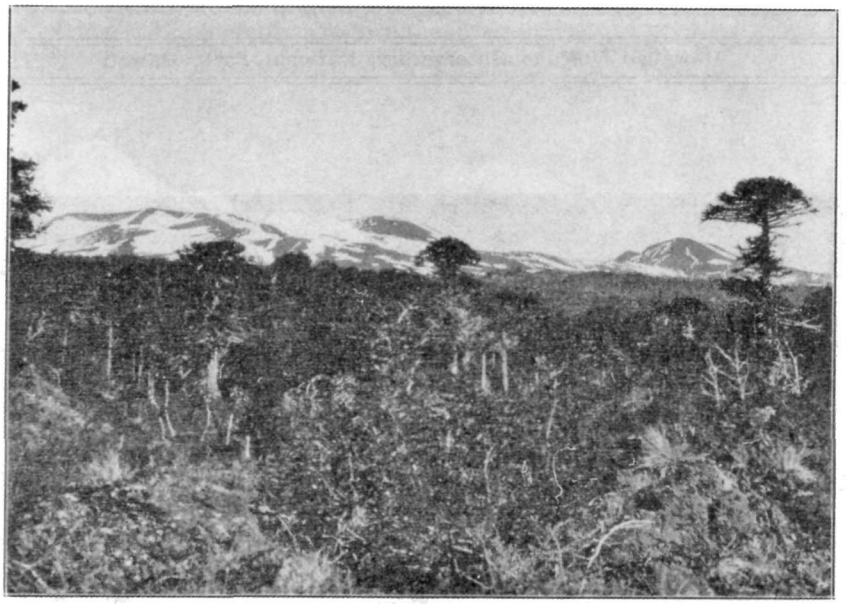
As reported in Volcano Letter No. 235, Dr. John B. Stone during the winter 1929-30 completed on February 12, 1930, at Valparaiso an exploration of some volcanoes in south-central Chile occupying three months and six days. This was done under his appointment as Research Fellow of the Hawaiian Volcano Research Association. Starting from the scene of the recent disastrous earthquake at the city of Talca, Dr. Stone passed by the active volcano Quizapu near Cerro Azul, and then visited in turn the volcanoes Chillan, Antuco, Llaima, Villarica, Osorno, and Calbuco, climbing several of these. He observed from a little distance the volcanoes Trolguaca, Lonquimai, Quetrupillan, Shoshuenco, and Puyehue. All of these are potentially active and all lie between the latitudes 35° and 42° S. This region offers a great field of volcano research in the midst of a land of serious earthquakes, and it is to be hoped that Dr. Stone's investigations will stimulate public and private endeavor to create volcano observatories in Chile. The following is a first note on Chilean volcanoes.

TWO ACTIVE VOLCANOES OF CHILE

By JOHN B. STONE

The Chilean volcanoes east of the capital city, Santiago, lie near the crest of that portion of the Andes chain that includes the highest summits of the western hemisphere, but farther south the volcanoes are lower down on the west flank of the cordillera. In the region between the cities of Temuco and Puerto Montt, or roughly between the latitudes of 38° 30′ and 41° 30′ south, they lie along the line where the farms of the central longitudinal valley give way to the forests and mountains of the high Andes, and their summits reach only 6,000 to 10,000 feet above sea level. The two most active volcanoes of this region are Llaima and Calbuco. Both lie in a rainy belt and as a consequence their lower slopes are heavily wooded and their summits are capped by snow and glacial ice.

As seen from the southwest Llaima is an elongated cone with one principal summit and another slightly smaller and lower one off to the southeast. In December



Llaima Volcano, Chile, from the west. Araucanian pines and old aa lava in foreground. Photo Stone.

1929, the mountain was still covered far down its slopes by the snows of the preceding southern winter, and both the summit craters were emitting streamers of dense white fume.

The journey to Llaima is best begun from the provincial capital Temuco. A branch off the main north-and-south railroad extends for nearly 35 miles across partly cleared and cultivated lands and past several large, prosperous farms to the little village of Cherquenco. Beyond Cherquenco the forest is less broken by farms but is dotted with little sawmills producing rough lumber, which is hauled to the railroad on clumsy two-wheeled ox-carts. One of the sources of good lumber is the sharply defined belt of Araucanian pines that girdles the upper slopes of the volcano. The Araucanian pine or "monkey-puzzle" tree is similar to its close relative the Norfolk Island pine, familiar in the Hawaiian Islands (see Page Two). A sawmill high up in the pine forest on the northwest slope of Llaima was a convenient base of operations for the writer during the bad weather that prevailed at the time of his visit.

The double cone of Llaima stands on a broad base or platform built by earlier volcanic activity. Part of this platform and of the cone also are covered by basaltic aa flows, but the northwest summit cone and the southern slope of the mountain are largely concealed from observation by glaciers. Shiny black scoriae are common on the surface, and a layer two or three inches thick covers the glacial ice on the south side. Llaima was active from October 5 to 8 and again from November 27 to December 5, 1927, and at that time a "river of fire" is said to have been seen on the south slope. No recent flow could be distinguished by the writer beneath the winter snow, but a line of cones was seen far around to the southeast. These cones may mark the source of a flow as well as the site of the fountains which produced the fresh scoriae. Unfortunately it was impossible to reach them. Another possibility is that the scoriae were produced by fountaining in the summit craters and that the "river of fire" consisted only of the freshly fallen and still glowing cinders.

Calbuco is the farthest south of the volcanoes in the continuous mainland part of Chile, although others are known in the region of fiords and glaciers extending from Puerto Montt to the Straits of Magellan. Calbuco was observed in activity by Darwin in 1835, but had long been inactive before 1893 and had accumulated a thick cap of ice and snow. In the latter year the volcano returned to life. The heat of the eruption melted the ice and snow and caused floods that swept down the mountain leaving paths which can still be seen. Fortunately the country affected is very sparsely settled even now so that little damage was done, but the occurrence illustrates the most serious danger in this land of intermittent volcanic activity and heavy snowfall. An even greater flood occurred at Villarica volcano in 1910.

The last eruption of Calbuco was on January 6, 1929 (see Page One), and lasted only a few hours. Dull underground noises in the night of January 5 had warned the few people living on the north side of the volcano and they had fled from their little farms taking with them what livestock they could collect. At about 2 a. m. on the 6th a great flash shot from the top of the mountain

and was followed by an enormous cloud of ash accompanied by much lightning. The ash eruption continued until the early hours of daylight. Only coarse sand reached the highest house on the mountain, but before the west wind the fine ash drifted far off to the east so that a layer a few millimeters thick was formed at Peulla 35 miles away, and light dust reached the end of the State Railway in Argentina more than 100 miles away. A terrific blast blew down the valleys on the north slope killing and leveling the brush and small trees growing there (see Page Three). Floods from the melted snow and ice rushed down the stream channels killing the trees along their margins and dumping volcanic sand on a few cultivated fields near the lake. For two weeks after the eruption no rain fell to wash the covering of ash from the grass and leaves so that cattle had to pick a meager nourishment from the tips of the highest bunch grass which had shed some of the dust.

On January 19, 1930, the writer and a Chilean helper made the first ascent to the crater of Calbuco since the eruption of the previous year. The route from Ensenada on Lake Llanquihue leads up a valley swept by the floods of 1893 and 1929. Exposures in the steep walls of the stream channel show a history of past explosive eruptions. Lava flows reaching the lower slopes are rare and none is seen on the surface, but everywhere there is a deep cover of broken rock and sand like that thrown out by Kilauea in 1924. The new crater of Calbuco is a straight-sided hole perhaps 500 feet across (see Page Four). The rim, especially around the northeast edge is deeply covered by gravel and ejected blocks. Thick white fume escapes in several places from the talus slopes inside the pit. The crater plainly owes its present shape in part to collapse after the explosions.

KILAUEA REPORT No. 958

WEEK ENDING JUNE 1, 1930

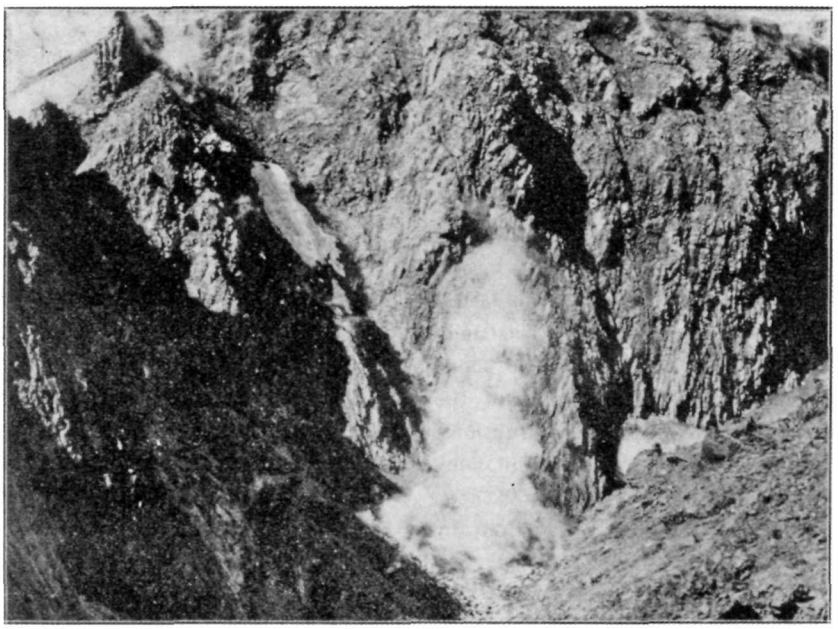
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Kilauea Volcano continues to be quiet and without visible signs of magmatic change. Early in the week numerous small rock falls occurred from the north wall of Halemaumau, the slides at times accumulating sufficient material to make dust clouds. Much fine debris has piled up against the foot of the wall between the two large north talus heaps. The fire pit was without sounds and with very little steam at the end of the week.

The seismographs registered nine tremors, two of which lasted one minute each; one very feeble seism, with origin distance 28 miles; and one distant earthquake recording feebly at 12:08 a. m. May 31. Microseismic motion was slight throughout the week. Tilt accumulated very slight WSW.



Brush in valley of Rio Caliente killed and bent over by eruption of Calbuco Volcano in Chile in 1929. Photo Stone.



Looking into the new crater of Calbuco Volcano, Chile, from the north. Photo January 19, 1930, by Stone. Thick white fume issuing from talus.

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The Volcano Letter

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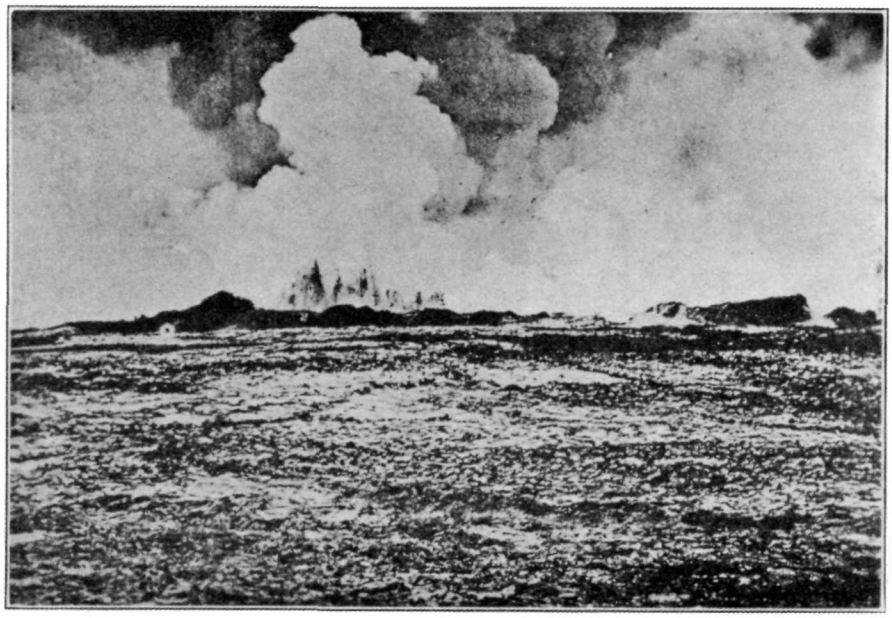
No. 285—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 12, 1930



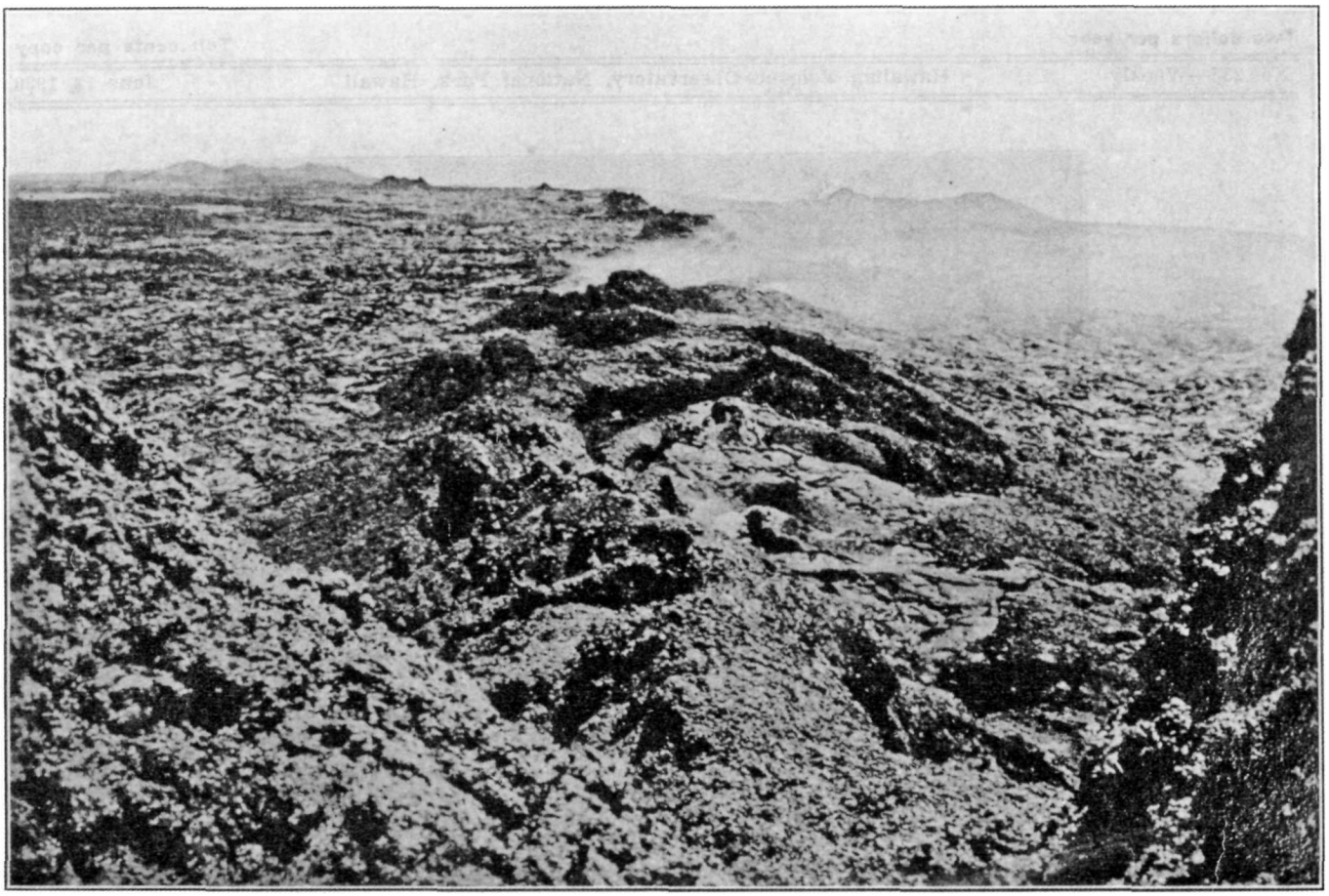
Mauna Loa rift source from the east, October 1, 1919, showing lava fountains, steam, and fume spouting up within ramparts of pumice. The new cones extend right and left outside the picture. Photo Jaggar.

SOURCE VENTS FOR MAUNA LOA FLOWS

There is apt to be much confusion in the mind of a visiting traveler when he hears talk of a lava flow. Careless writers are apt to speak of a lava flow in Halemaumau pit. An eruption of lava in the bottom of this great pit depressed below the southern floor of the larger crater of Kilauea is not a lava flow in the Hawaiian sense. A lava flow means to the residents of these islands an outbreak on one of the volcanic mountains which courses down the flank and is prone to enter the ocean if it lasts long enough. While it is possible for such a flow to arise by lava overwelling the brim of a summit crater, and although there have been short historical flows which originated in or near the summit craters of Kilauea, Mauna Loa, and Hualalai, none of these has ever traveled far. Usually such flows are confined within the compass of the large summit sink-craters by the overflow of the inner pit or the development up a crack of a new cone by rupture of the crater floor. The great lava flows of history, in the Hawaiian sense (see map last page), have emerged from the mountain flank along well known rifts that have been the sites of many outbreaks. The places of outflow have been from one to twenty miles away from the large summit craters, but there is generally a preliminary gush of some sort at the summit region.

Several pictures of Mauna Loa rift sources have recently been printed in the Volcano Letter (Nos. 270, 277). The well known rifts on Mauna Loa extend southwest and east-northeast from the summit. Indeed there is a strong suggestion that about the Rest House at the north at elevation 10,060 a new hump or dome is building up about the eastern rift, and that similarly a separate volcano is building about Puu o Keokeo as a center at elevation 6,870 to the south. An understanding of these rift belts as zones of potential weakness on volcanoes is essential to the understanding of lava flows. These radial fractures in a volcanic edifice may be curved or straight, several or few, but they stand for a deep-seated breakage in the dome, and along these broken belts there is underground connection along upright fractures with the central pipe, and this in turn is nothing more than the upright line of meeting of the rifts. Observation of the miniature slag lakes and overflow floors of the inner pit of Kilauea has shown how this fracturing of a dome happens. The overflow about a vent forms a slag heap. The slag heap becomes hard inside while remaining red hot. Renewed overflow at the central vent is accompanied by swelling gas pressures which rupture the heap. The lines of rupture are apt to be along the boundaries of three or more sectors. These sectoral cracks open widest along the contour of the heap which is lengthened the most by the swelling action. This is where the summit plateau changes its grade to a steeper marginal slope. There is probably a systematic geometry of building up domes and breaking them which has produced the strikingly uniform distances and triangular arrangement of crater summits on Hawaii.

The picture on Page One was made on October 1, 1919, when the writer was approaching the spouting source crack of the Alika flow from the east and looking from an old red cone at the new constructions of the active belt at a place about five miles north of Puu o Keokeo. After tethering the riding animals and walking across some ten alternations of rough aa and smooth pahoehoe, the aa making the most terrible footing on earth, there could be seen the line of rift cones, some 40 of them visible at one time, extending from near Puu o Keokeo northward. The source of the outbreak was revealed in panorama, consisting of a line of new gushing hillocks of slag, a true fissure eruption. Here great fountains were spouting continuously for a thousand feet like a wall of red flame, and in detail they were seen to be made of incandescent, light, crumbly material, yellow when it shot up, and red when it came down. Gas was rushing through a lava pool filling the rift, churning it to a foam with a noise like surf, and flinging up the foamy matter to solidify as it fell. Northward the smoking patches and driblet heaps became progressively smaller. This activity had all started by a simple splitting



Mauna Loa eruption of 1926, line of cones formed along rift, dying crater of main flow in foreground. Looking down mountain toward distant Puu o Keokeo on left. The flows poured off to the right. Taken May 4, 1926. Photo Jaggar.

open of the mountain flank along a new line within the belt of fracture generally known as the rift, and the splitting had progressed from the summit crater region downhill. The process had begun by strong earthquakes September 14 and 18, followed September 26 by a gush of smoky cauliflower clouds with chocolate-colored edges from the region immediately southwest of the summit crater of Mauna Loa. Two distinct columns of smoke developed side by side and a mile or so apart. The top of the jet reached 7,000 feet above its base, and with nightfall the cloud was illumined a bright orange-red. These gas jets waned so that by 10 p. m. only one fume jet could be seen, and by 3 a. m. the preliminary eruption was over.

The glow illumining the summit smoke in the first eruption was undoubtedly caused by a gush of frothy lava. There was then a lull from early morning of September 27 to 1:45 a. m. September 29, when moderate red glow and fume appeared over the southwest rift of Mauna Loa about the 8,000-foot level and both spread southward. This was the activity which quickly built up the line of pumice cones shown in the picture on Page One. There had evidently been a first release of gas from the expanding lava column up the central pipe, this in turn produced an expansive swelling that took two days to open the southwest rift, and thereafter the path of least resistance lay at the 8,000-foot locality and the outflow gathered volume there and maintained the release for several weeks. The eruption gradually dwindled in November. No sudden event was observed to mark its termination on Mauna Loa, but on Kilauea, where there had been continuous outflow in the big crater for many months, the lava suddenly subsided in Halemaumau on November 28.

An earlier published airplane picture (Volcano Letter No. 270, Page Three) showed well the straight lines of cones built up from 50 to 100 feet on the southwest rift of Mauna Loa in April, 1926, when there was another lava flow of the same quality as the one just described for 1919. In fact the photograph in question shows the line of cups within cones that had been built in 1919 about a half mile to the west of the new fissure that was opened in 1926. The same picture also shows in the foreground a short line of still older cones with their interior cup-craters lying to the east of the 1926 crack. The characteristic initial structure is an elliptical cone at each of the many openings along the crack, with an egg-shaped cup inside, and in many cases as the eruption dwindles there will be two cups where a revival of activity has made an inner cone at some larger spindle-shaped crater whence the activity had shifted elsewhere and returned during the progress of the eruption from many vents.

The photographs on Pages Two and Three show the line of cones made at the source of the 1926 eruption looking towards Puu o Keokeo and the older cones of that district, and an excellent airplane picture of the western flank of Mauna Loa above the forest line and below the rift belt exhibits the torrent of molten lava in the midst of a band of solidified aa. The source vent picture was taken May 4, 1926, just as the eruption ceased and shows the place where the final source fountain had been in the foreground, still fumy with sulphurous acid, with very hot air rushing up the cracks, a depression 5 to 10 feet deep floored with a swirl of lava. The flow picture was taken on the same day (April 18) that saw the destruction of the fishing village of Hoopuloa by the front of the flow at the sea shore 10 miles farther down the mountain (Page Four Volcano Letter 270). The surface of the golden torrent shows a dark line of crusts and rafts down the middle

and a tendency to form distributaries around islands, the rapid stream maintaining in general a middle position along the band of semicongealed black clinker produced by earlier overflows of its banks. At the top of the picture this band is seen to change to lighter colored lava under the fume and cloud of the source vent region, and this lightness is due to the presence of pahoehoe or smooth lava, with glistening surfaces on all the upper heaps within a half mile of the rift. This transition from pahoehoe to aa a short distance from the Mauna Loa source cracks is characteristic, and shows the results of stirring on a steeper slope as described in Volcano Letter No. 281.

We see then that the source vents for Mauna Loa flows create true fissure eruptions, with many cones and cups along miles of cracked mountain flank, and that a new eruption tends to start at the top of the rift belt and to split its way down the mountain to that place on the flank where the lava finds a path of least resistance for continuous flowing. Quite commonly the splitting of the crack extends below the place selected for final adjustment to outflow: this happened in 1919 and 1926 on Mauna Loa, and in 1920 on Kilauea. Thus the lowest opening on the crack is not the vent selected for most voluminous flowing, showing that the outpouring is not strictly hydrostatic, but is rather selective of that portion of the rift which may be opened widest by the swelling of the mountain.

T.A.J.

KILAUEA REPORT No. 959

WEEK ENDING JUNE 8, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

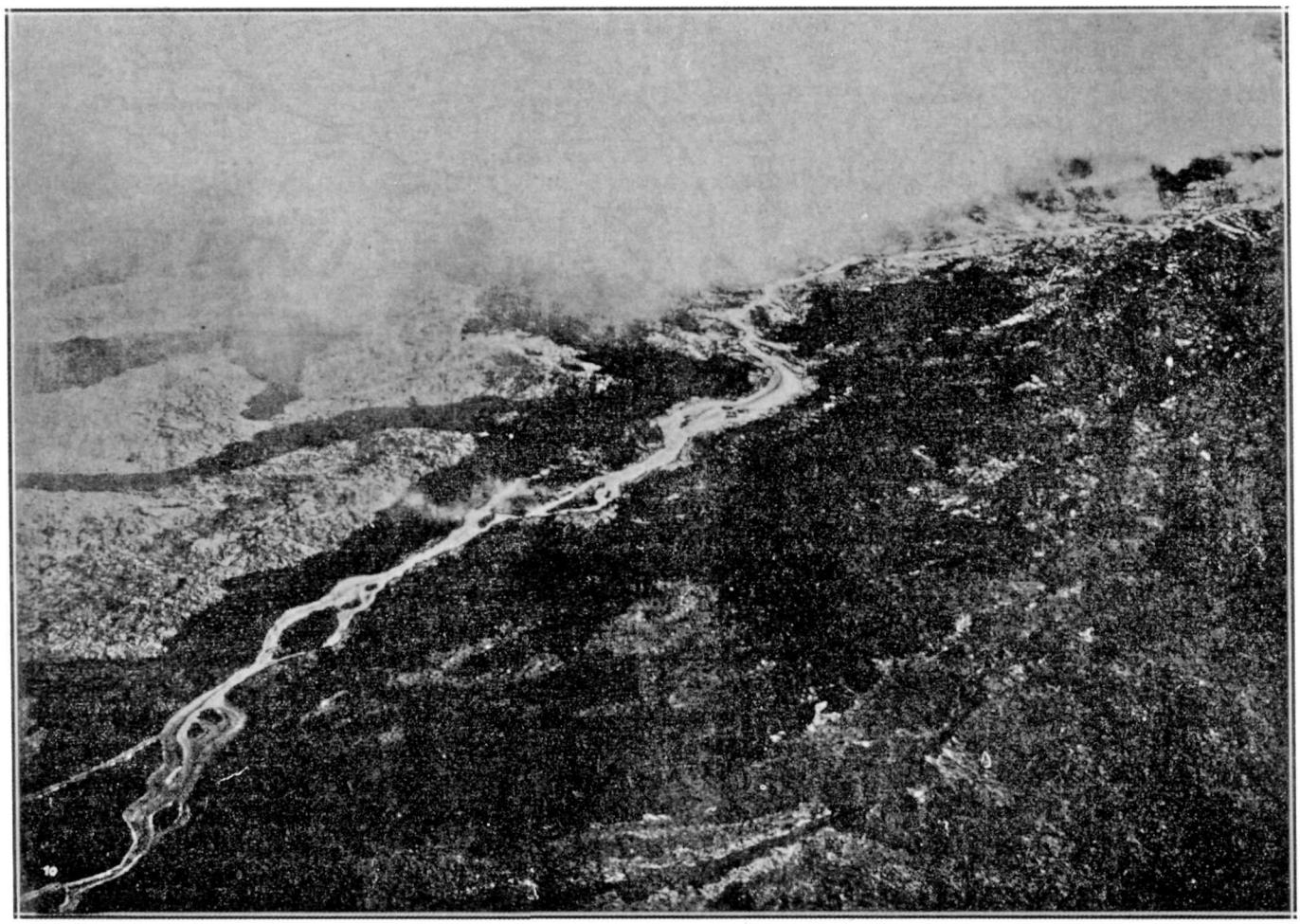
Halemaumau pit in Kilauea Crater remains quiet. At 11 a. m. June 5 no steam could be detected at any of the interior vents of the pit, though the vapor rising from cracks back of the west rim was as usual. On the morning of June 7 a little vapor could be detected at the south talus.

Ten local seismic disturbances were registered, of which six were short tremors lasting less than one minute, one was a very feeble seism, and three were feeble quakes. Two of these were felt on both east and west sides of the island, the times being 4:54 a. m. June 3, indicated distance from Kilauea 67 miles along with southeast tilt at the Observatory, and 6:32 p. m. June 4, probable distance 14 miles. The other was at 3:39 a. m. June 5, distance 28 miles. Tilt for the week was slight NE, and microseismic motion was slight.

MAY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

April 28-May 4	1.03 seconds	WSW
May 5-11	1.33 seconds	WSW
May 12-18	0.48 second	ENE
May 19-25	0.85 second	WNW
May 26-June 1	0.85 second	WSW



Airplane view of Hoopuloa lava flow of April 18, 1926, showing incandescent stream within aa fields at about 5,000-foot contour of mountain. Mauna Loa eruption of 1926 from southwest rift pouring westward above Puu o Keokeo. Transition pahoehoe to aa upper right. Photo Eleventh Photo Section, U. S. Army Air Service.



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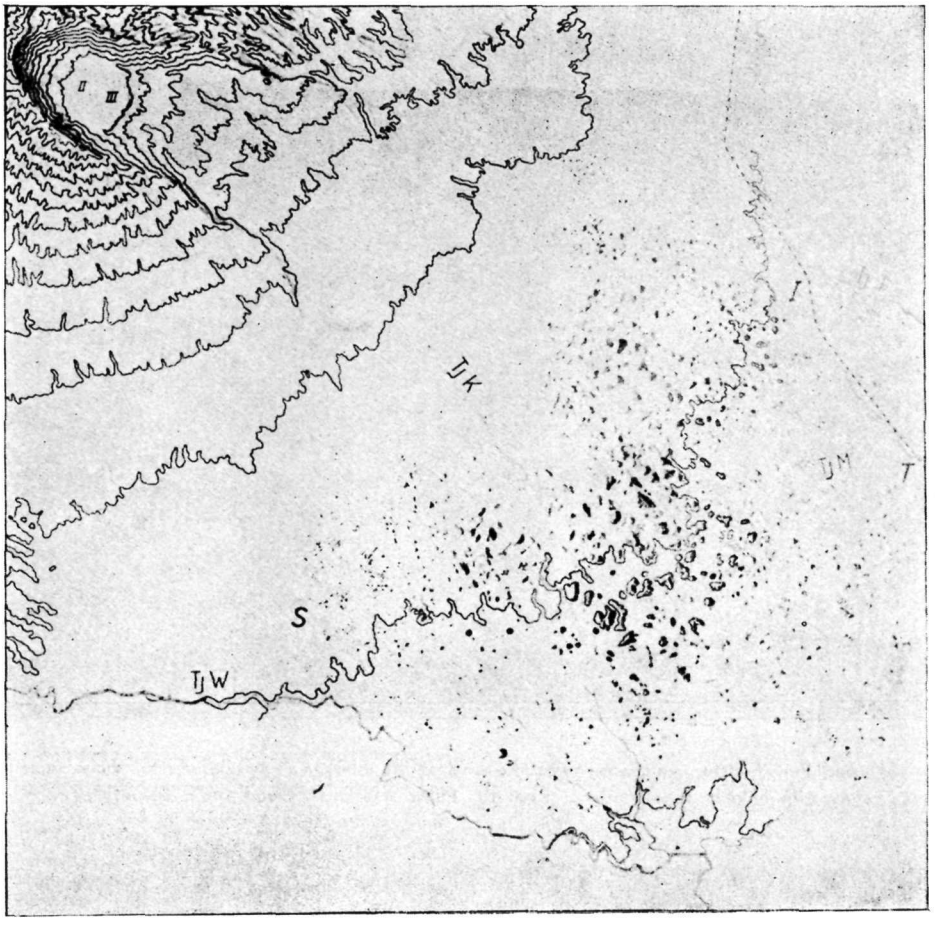
No. 286—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — June 19, 1930

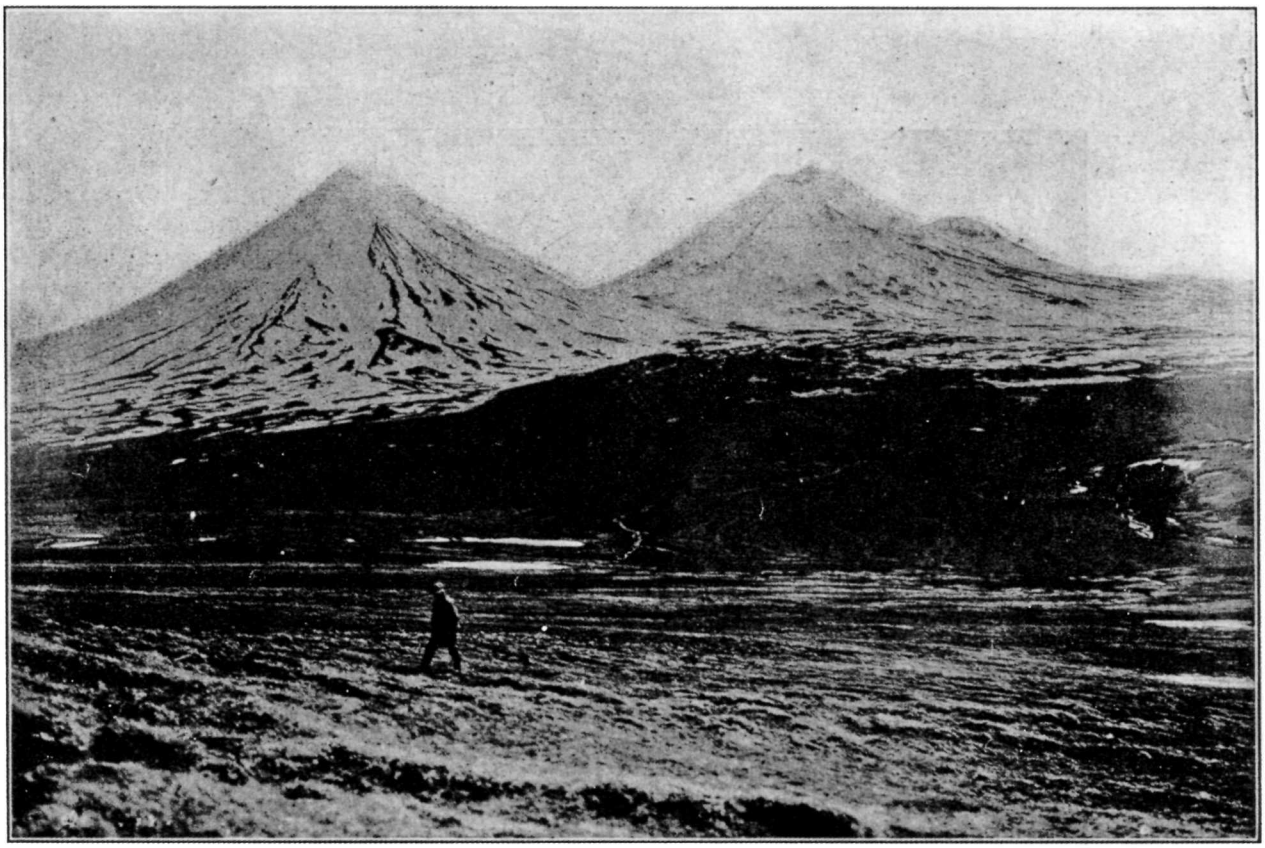


Map of southeast slope of Galounggoung Volcano in Java. The many hills indicated by mottling southeast. Crater valley at northwest is four miles long. Tj=streams, S=Singaparma, T=Tasik Malaja, I=Indihiang. May by Escher.

THE CRATER OF GALOUNGGOUNG

In west central Java the active volcano Galounggoung is a big cone 2,168 meters high with an amphitheater hollowed out of its eastern side, and from this amphitheater three streams drain off to the south in a flat country where many villages were devastated in a terrific eruption accompanied by mud floods in 1822. This flat country is covered by many hundreds of prehistoric small hills from 10 to 250 feet high. The map above shows the crater trenching the east-southeast flank of the cone, and the roman numerals I, II, and III at the head of the crater valley mark eruption centers. The principal historic eruptions were in 1822, 1894, and 1918, the last developing a lava dome below point III on the map. The first two eruptions were explosive and produced great floods in the rivers. In addition there was a landslip in 1868, just as there was in the same year on the southeastern flank of Mauna Loa in Hawaii. Indeed this amphitheater crater of Galounggoung is strongly suggestive of the gaps of Haleakala Crater, which open into valleys toward the sea, and of the Waipio, Mohakea, and Wood Valley embayments on the island of Hawaii. The hundreds of preristoric hillocks of Tasik Malaja bear some resemblance to some of the moraine-like hills on the north and west sides of Mauna Kea near the base of the mountain, these hills consisting of a jumble of mud and bowlders, possessing very irregular forms, and exhibiting no craters such as are characteristic of true cinder cones.

The places on the map of the Tasik Malaja hills marked Tj are streams, the hills are indicated by the mottling, and their disposition with the largest ones out in front of the crater valley certainly suggests a relationship between their origin and some ancient discharge from the valley. As Professor Palmer pointed out in his review of Escher's paper (Volcano Letter No. 253), 3,648 hills have been mapped, and the map here reproduced is taken from that paper, published by the Geological Society of Leiden in 1925.



Pavlof Volcano (right) and Pavlof Sister, volcanoes near the end of the Alaskan Peninsula. Pavlof shows summit crater and open valley with hillocks leading down from it. Photo National Geographic Society.

Each hill is composed of very fine material enclosing large blocks of andesite rock. The cubic content of all the hillocks taken together is about one twentieth of the material missing from the cone of Galounggoung at the great amphitheater. Underneath the hills, however, there is an underlying mixture of bowlders, gravel, and mud some 70 feet thick in the middle and thinning out toward the margin of the hilly area. If we add this under layer to the volume of the hills, we still fall far short of the volume lost from the big crater.

According to Escher the material of the hills had slid down from the crater in the condition of mud, probably from a crater lake. As a succession of eruptions had migrated from a summit crater to the southeast, it is probable that the crater lake broke through and caused a violent and watery landslide. "The hillocks represent the fixation of the last material of the slide, clots that remained standing higher, the principal mass having slowed down because of increasing bottom friction as it spread out fanwise and lowered, and as it lost part of its water." The finer mud and surface material flowed on down the slope, leaving the clots in relief where irregular clusters of bowlders clothed with mud made the remnant hills. The largest of these were in the middle of the landslide fan and opposite the middle of the crater valley. Taverne (Vulk. Med. No. 6, Mining Bureau of the Netherlands East Indies, Galounggoung and Telaga Bodas, Weltevreden 1924, page 29, and plate III) has reproduced an old map of Galounggoung after the eruption of October, 1822, and the area devastated and buried by this eruption corresponds closely with the area of the hills.

The following second review kindly sent us by Professor Palmer presents another explanation for the hills of Tasik Malaja. T.A.J.

THE BOWLDERY HILLS OF GALOUNGGOUNG

A paper by the eminent Dutch geologist, B. G. Escher, relating to the "Ten Thousand Hills of Tasik Malaja," was reviewed in the Volcano Letter for October 31, 1929 (No. 253). Escher considers these hillocks to be stranded masses of landslide material, the rest having swept on down the slope.

A short paper by Dr. F. X. Schaffer, head of the Division of Geology of the Naturhistorisches Museum in Vienna, has been received and suggests another origin for these hills ("Die Zehntausend Hugel von Tasikmalaja," Centralblatt f. Min. etc., 1926, pp. 207-209). Dr. Schaffer visited the region a year before read-

ing Escher's paper. At that time he was of the opinion, which he still holds, that the hillocks are man made. Most or many of the hillocks bear houses and friut trees. As dwelling sites they offer some protection from the numerous mosquitoes and rats which infest the rice fields at the bases of the hillocks. They offer some immunity from attack by hostile persons, and they insure dryness for the dwellings. They also offer places of refuge from the volcanic mud-flows that from time to time rush down the depressed sector of the volcano where they are to be found. The gently sloping, fan-shaped region built up by the mud-flows is very favorable for rice cultivation, which has undoubtedly been practiced from time immemorial. However, the preparation of the rice fields has involved the movement of great volumes of rock and earth in order to bring them to grade. In the process of clearing the land it would be probable that the people would make dumps of the bowlders and cobbles from the mud-flow material. Thus the dumps have become hillocks, and it was a simple matter to take advantage of the favorable characteristics of the hillocks that are favorable for house sites. The objection might be raised that the volume of man beings. This might be true of occidentals, but is not beyond the powers of the numerous and ant-like industrious Malays.
material moved is too great to be conceivable as the work of hu-

The reviewer has attempted to give Dr. Schaffer's views and nothing else on this occasion, which is what he attempted on the previous occasion for Professor Escher's paper. Schaffer concedes that the cores of the larger hillocks are not man-made. It is to be regretted that we have no information as to native legends of the origin of the hillocks. H.S.P.

SOME ANALOGOUS BOWLDER HILLOCKS

The foregoing discussions of bowldery hills in fan-like grouping in front of a crater valley in Java are too important to pass without some comment. This question of crater sinks merging into collapsed valleys has been splendidly reviewed and illustrated by Friedlaender, (Volcanological Review, Berlin, Vol. II, page 186, 1916, "On volcano fault-valleys," with maps of Bandaisan in Japan, of Hawaii, of Brava, San Thiago, and Fogo in the Cape Verdes, of Palma in the Canaries, of Stromboli in Italy, of Savaii and Tau in Samoa, and of Crater Lake in Oregon.) As mentioned in the last Volcano Letter, the Hawaiian volcanoes are breaking down by faulted sectors. When such downbreak is accompanied by explosion at the volcanic center, big downblasts, floods and landslips are common. The accompanying photograph of the north face of Pavlof (Page two) cones shows down-broken sectors, the right-hand peak, Pavlof proper, exhibiting an open A-shaped gash, clotted rocky hillocks of debris below it and under the crater, and a vast jumble of bowlders and wash spread out in a fan farther down the slope. This jumble contains hundreds of mounds like those described under Galounggoung. (See Nat. Geog. Mag. January 1929, pp. 130 and 134).

The most perfect parallel to the Galounggoung cluster of hills is to be found on the north slope of Bandaisan volcano in Japan, and these mounds were created by the explosion and landslip of the great eruption of July 15, 1888. They were described as follows (The Eruption of Bandai-san, by Sekiya and Kikuchi, Jour. Sci. Coll. Imp. Univ. Tokyo, Vol. III, Pt. 2, 1889, page 110, plates xv, xviii, xxi, xxii): Large and small conical mounds stand out from the surface of the debris in immense number. There are big bowlders, measuring from five to ten meters, carried along as part of the mud current, and thousands of mounds, large and small, have been formed on the vast sea of mud, standing out of the debris like so many miniature Fujiyamas. They consist of disintegrated crumbling rocks, and the refuse falling around their bases has assumed a conical shape by forming taluses around them.

The writer examined this field of landslip of Bandaisan in 1914, where a huge amphitheater was quarried out of the flank of the mountain by the eruption, making just such a map as that of Galounggoung on Page one. The hillocks are clustered fan-like amid the tumble of rubbish in front of the crater niche. There were scars on the sides of the valley devastated, 75 to 100 feet above the debris, showing how the mud and earth had sunk away from its highest level. This high level corresponded with the tops of the mounds. The mounds had mostly a hard bowldery core, and many of them stood as islands in the lake which the eruption had produced by damming. One hill sketched was a pyramid with four surfaces fallen away, its summit sharp, made of earth and stones. The explanation adopted by the writer was that the first rush of the landslide was a thick fan while the huge rocks were grinding up, then the vast amount of water acquired by the finer material made this finer stuff rush much farther as a mud flood, carrying smaller bowlders and bowlder clots, and spreading as a thinner layer. This outspreading of the lower fan drained down the deposit from the scar level to the final level, and the larger rock fragments in units and groups remained in relief, as mounds which resisted farther progress. This would leave the larger clots nearer the crater, the smaller ones farther away, and precisely that effect is shown by plate XV of Sekiya and Kikuchi, and by Escher's map on our Page one. There is every reason to suppose that Galounggoung has had the same type of eruptions as those of Bandai. In both cases the same expression is used by scientific observers, "thousands of conical mounds." Escher's explanation appears to the writer to be correct, and to account for the gradation in size, and the distribution relative to the crater, and the rocky cores, while Schaffer's observation concerns human selection after a cataclysm had created the hills. T.A.J.

KILAUEA REPORT No. 960

WEEK ENDING JUNE 15, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There are no changes in the crater of Kilauea, and only once during the week was a little sliding observed at the pit walls.

The seismographs at the Observatory have registered one slight earthquake, three very feeble local seisms, two of them accompanied by easterly tilt, and four tremors lasting each from one-half minute to one and one-quarter minutes. The slight earthquake was generally felt on the east side of the island at 12:25 a. m. June 14, the seismogram indicating distance of origin about 12 miles from Kilauea Observatory. The felt movement was prolonged and moderate at Kilauea, shorter and ending in a sharp jerk at Hilo. The vertical component was very pronounced on the Kilauea seismogram.

Tilt for the week was stationary, and microseismic motion was very slight.



Note on this map the horseshoe valley west of Pahala and the depressions northeast of Kohala summit, as well as Kilauea Crater, all amphitheaters similar to Galounggoung Crater.

THE VOLCANO LETTER

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The Volcano Letter

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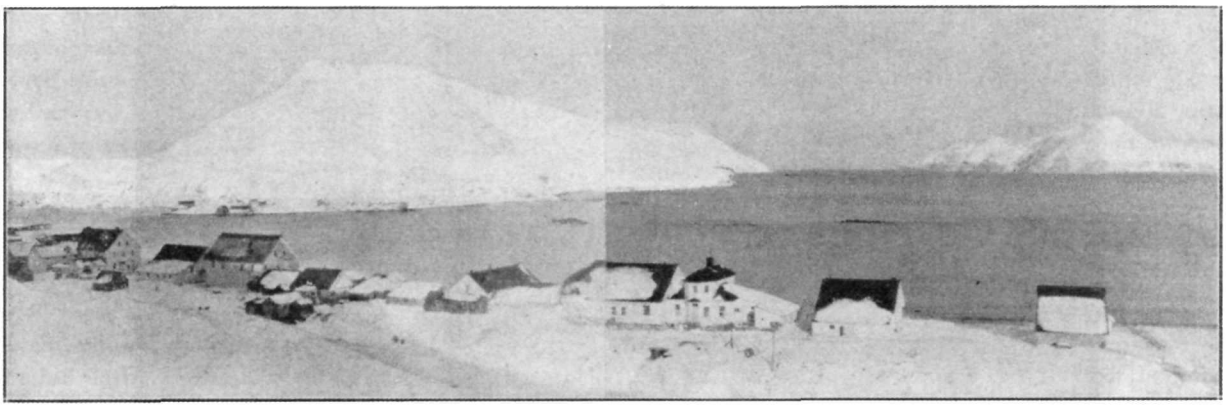
No. 287—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 26, 1930



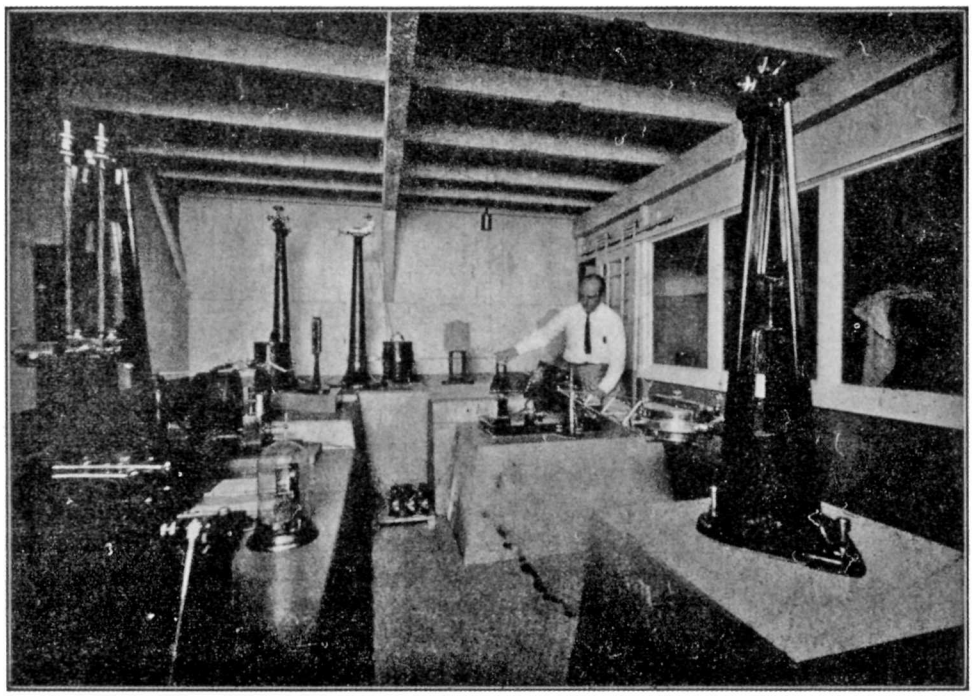
Unalaska harbor, in the Aleutian Islands, looking north in winter time, showing the village in foreground and on the left Amakmak Island, where are Dutch Harbor and the Naval Radio Station that houses the seismograph of the Volcanology Section, U. S. Geological Survey. Photograph by Yatchmeneff.

THE PULSE OF THE PACIFIC

How the seismograph works has been the subject of another number of the Volcano Letter (No. 268), and one of the first objects of investigation when the Hawaiian Volcano Observatory was started in 1912 was the pulse of the ground at an active volcano. For fifty years the Japanese have been taking the pulse beats of the earth crust in Japan, led first by John Milne, second by Professor Omori, and third by Dr. Imamura. All of these were stimulated by their researches to give attention to the active volcanoes of Japan, and recently the work has been narrowing down to what Imamura calls chronic earth tilting. The San Francisco earthquake of 1906 revealed a great rift extending for hundreds of miles, and the Coast Survey determined horizontal movement whereby the two sides of the rift shifted in opposite directions during the earthquake. Monuments have been set up to learn how much of such movement is chronic and continuous. The Carnegie Institution of Washington has set up sensitive instruments in southern California to learn how many small jarrings are associated with such faults. The Section of Volcanology of the Geological Survey has extended the Hawaiian work to Lassen Volcanic National Park in California and to Kodiak and Unalaska (see photographs Pages One and Three) in Alaska in order to take the pulse of new places. New Zealand and the Dutch East Indies are at work on the same problem.

All of this may be regarded as a big experiment requiring both time and space, the half century of time and for space the whole fiery circle of the Pacific, in order to find out, for local seismology, what movements of the ground are sufficiently continuous, chronic, or frequently repeated. One subject of local seismology at the volcano belts is to determine important cycles leading to recurrence of eruptions. For the geography or space side of the argument, the object is to determine what volcano or vent will erupt. For the places where volcanoes are not active, like Wellington or San Francisco, the object is to determine the earthquake danger, and what are the cycles in time for big earthquakes at the same place, and what are the places where the snapping of the earth's crust may progress through the ages from point to point, not accidentally, but because of some deep-seated law of which hitherto man was ignorant.

Thus in Hawaii the volcano observatory is seated on a comparatively simple structure, an island with three active volcanoes and two old ones. We have five active seismograph stations where pendulums register the tremblings, jolts, and tiltings of the ground and the lists exhibit thousands of earthquakes where in the year 1800 the only lists were in the memories of the natives or the log books of explorers. In 1800 there was an eruption with lava flows down the west side of Hualalai Volcano, and we know nothing of what spasms of earthquaking then preceded the bursting open of that dormant mountain. Ten years before Kilauea on the other side of the island had a bad explosive eruption with much shaking



An early photograph of seismograph cellar, Hawaiian Volcano Observatory, which is dug down to bedrock. The concrete tables hold the rigid posts on which pendulums are swung equipped with chronographs that register movements on the rock on smoked paper. Station near Volcano House, Kilauea Crater.

and an enormous sinking of the bottom of its crater. Here were two events in a decade and two volcanoes somehow related. Compare with this the decade 1924-1934. Kilauea in 1924 had an explosive eruption with much shaking and sinking of its crater. Hualalai in 1929 had two months of shaking in excess of anything experienced there for a centry. Here were the same two volcanoes somehow related, but this time harnessed with seismographs. The transference within six years of the underground activity from Kilauea to Hualalai hints at a repetition of 1790-1800. The seismographs and tilt machines and leveling instruments, as well as continuous notes on Mauna Loa and Kilauea, had proved a rise and fall of the east side of the island, accompanied by rise and fall of lava in both Mauna Loa and Kilauea, for the eleven years preceding 1924. We see from all these facts that the observatory notes of only 20 years of work have enabled the scientists to sketch out an important eleven-year cycle, and the adjustment of this cycle to past history enables them to sketch out an important forecast relating to the geography of adjacent volcanic craters. Underlying these researches is the pulse of the crust of the earth measured by recording pendulums, and these have been writing the autograph of the bedrock since the summer of 1912.

The cut on Page Two shows the seismograph cellar built on the bedrock under the Hawaiian Volcano Observatory back from the edge of Kilauea Crater on its northeast side. A number of iron posts are seen, bolted into the concrete. Heavy beams support the floor above, so that the building rests on the outer margins of the cellar, and the walking of people on the upper floor does not press down the floor of the cellar locally. This is important, for every time an observer enters the cellar to change the chronograph drums as shown in the picture, his weight in walking by a post is sufficient to swing the magnifying pens a half inch across the smoked paper. The instruments are very sensitive, and are designed to record on different chronographs strong motions and weak motions, up-and-down motions, east-west and north-south motions, and to distinguish between tiltings, tremblings, local earthquakes, and distant earthquakes. A local earthquake makes a quick motion, a distant earthquake makes a slow motion. With all of this goes continuous registration of time from a clock, and correction of the clock by wireless. With 15 or 20 local earthquakes

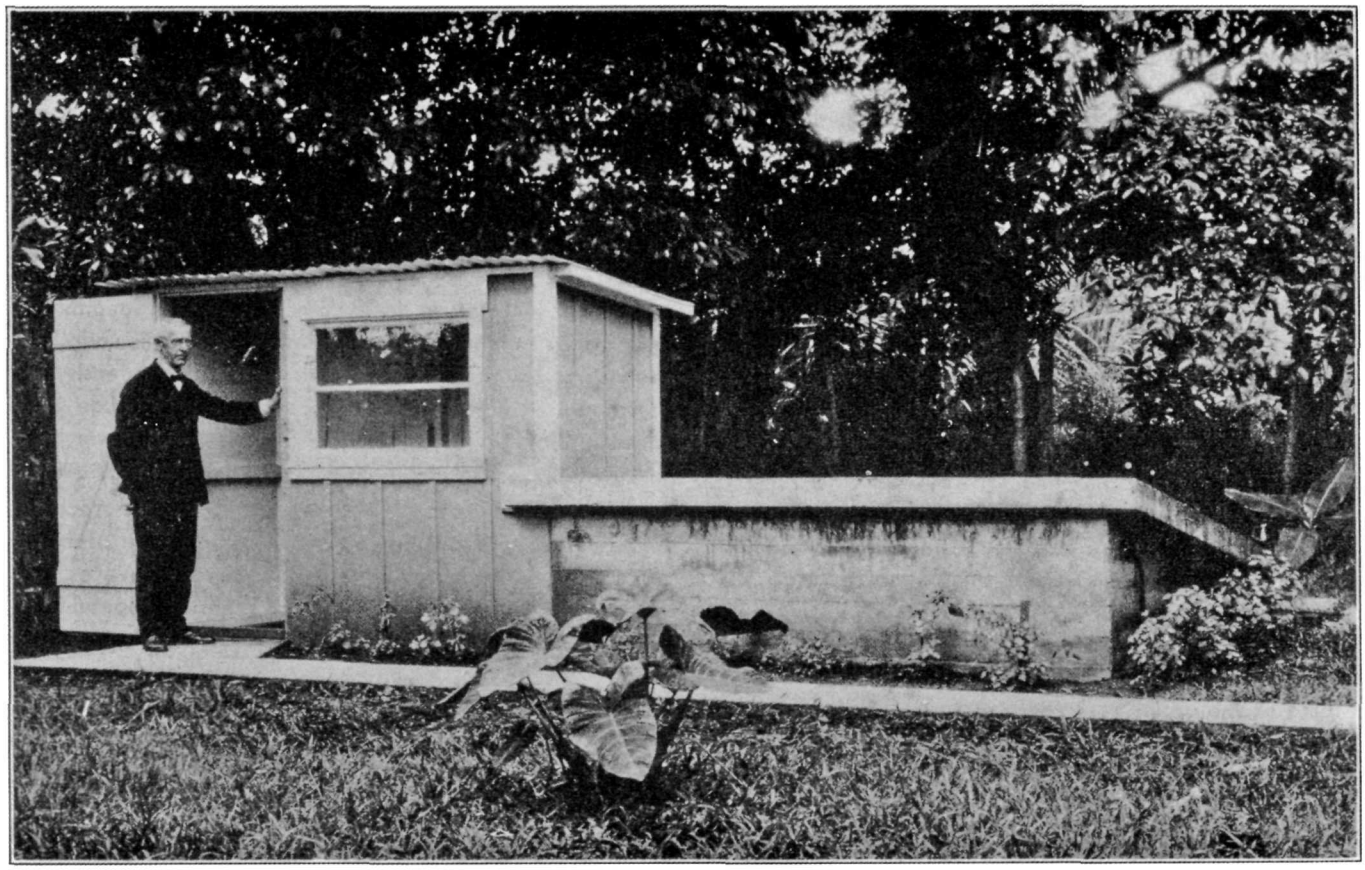
a week, numerous distant earthquakes throughout the year, small wave movements in the ground due to lava in the pit, the action of a storm, the pounding of a distant surf, or the passage of a steam roller: with hundreds of earthquakes when an eruption begins: with tilting and certain kinds of tremor always in progress; it will be seen that it requires experience to decide what seismograms to study, and where to place seismographs in order to cover geographical questions. As a matter of fact, the published seismograph records from volcano stations are unsatisfactory, because the volcano seismologists have too much to study.

It is popularly supposed that we look at a seismogram and predict an eruption. But neither eruptions nor big earthquakes herald themselves in this manner. The science of local seismometry is steadily working to narrow down all these many movements so as to reject the unimportant ones, and then to measure intensively, with distributed instruments, those chronic movements that are directly related to the lava underground. Japan and Hawaii have both concluded that chronic tilting or tipping of the ground goes with chronic rise and fall of the land. In Volcano Letters 264 and 283 we have shown how gradually Kilauea swells and how gradually the rim cracks of the pit spread open. From week to week we publish changes of tilt at the seismograph cellar, because big changes accompanied big risings and fallings of the lava. Imamura has shown that in Japan both volcanic eruptions and earthquakes are preceded by years of important tilting. Large earthquakes near volcanoes are proving themselves to be in a different class, involving deeper movements, than the small surface jarrings of an active lava period. Here there is a gradation that can only be explained by placing many seismographs in geometric relation to a single volcanic mountain. There is undoubtedly some relationship between numbers and intensity of earthquakes on the one hand, and the magnitude and direction of tilting on the other, but to discover this relationship a limited piece of ground must be studied.

The Hawaiian station is now at work on its records of 18 years with a view to narrowing down the problem of earth motion in relation to underground lava as applied to Kilauea Crater alone. The most hopeful line of attack appears to be the measurement of tilt at a number of stations all equipped with the same instrument, and a determination of policy and of instrument construction that will permit the operation of the system so as to eliminate earthquakes, tremors, temperatures,



Lassen Volcano Observatory at Mineral, California. This simple house in the forest is over a concrete cellar containing the seismographs of the Section of Volcanology, U. S. Geological Survey. R. H. Finch is in charge of the station, designed to study the seismic movements of Lassen Volcano.



Special seismograph cellar at St. Mary's School, Hilo, Hawaii, operated by Brother J. B. Albert for the Hawaiian Volcano Research Association. This houses a pair of Hawaiian-type seismographs made in the shop of the Kilauea Volcano Observatory. The records are compared with those of the crater, 30 miles away.

storms, and artificial disturbances, and a routine sufficiently simplified as to make possible the measurement for a term of years at reasonable expense. T.A.J.

KILAUEA REPORT No. 961
WEEK ENDING JUNE 22, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The Hawaiian volcanoes continue without action, and nothing has been observed in motion at Halemaumau pit of Kilauea Volcano except the sliding of a few rocks at 2:20 p. m. June 18 and at 10:25 a. m. June 20.

The seismographs at Kilauea recorded six very feeble local seisms, two of these indicating distances of origin 18 and 23 miles. Seven tremors were registered lasting from one-quarter to three-quarters minute each, and easterly tilt accompanied one of these and one of the above mentioned local seisms.

General tilt for the week was slight NNE, and microseismic motion was slight.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

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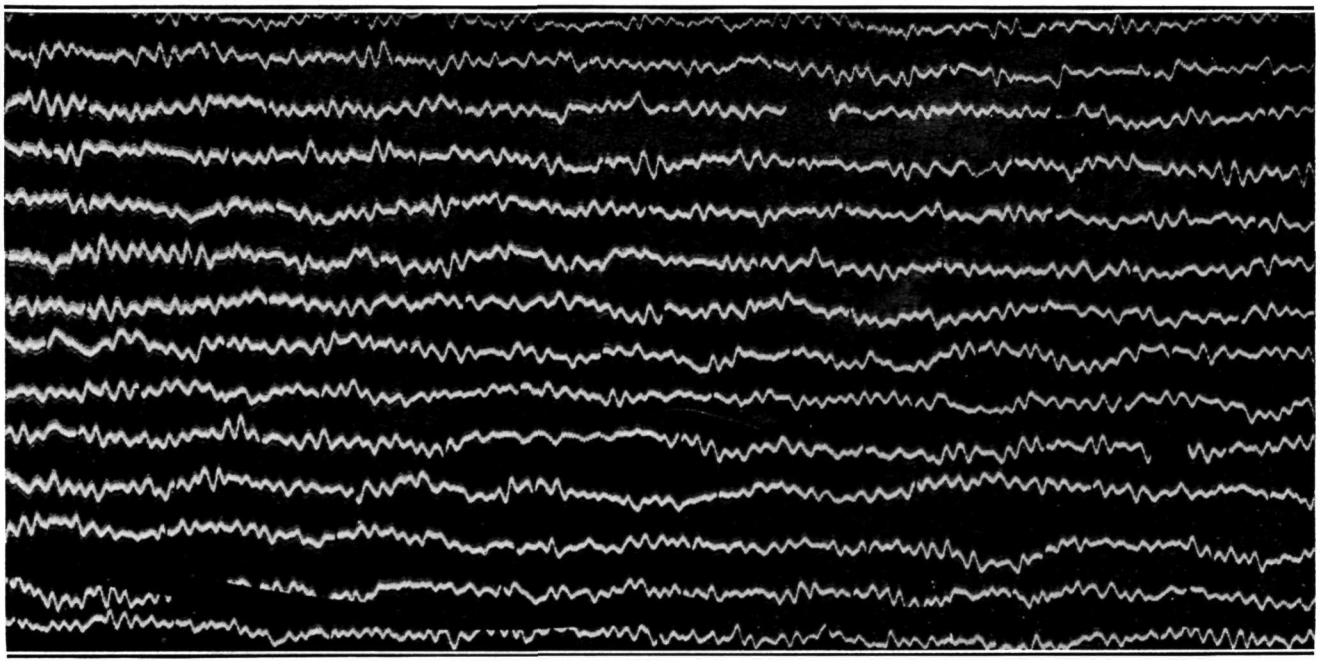
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 288—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 3, 1930



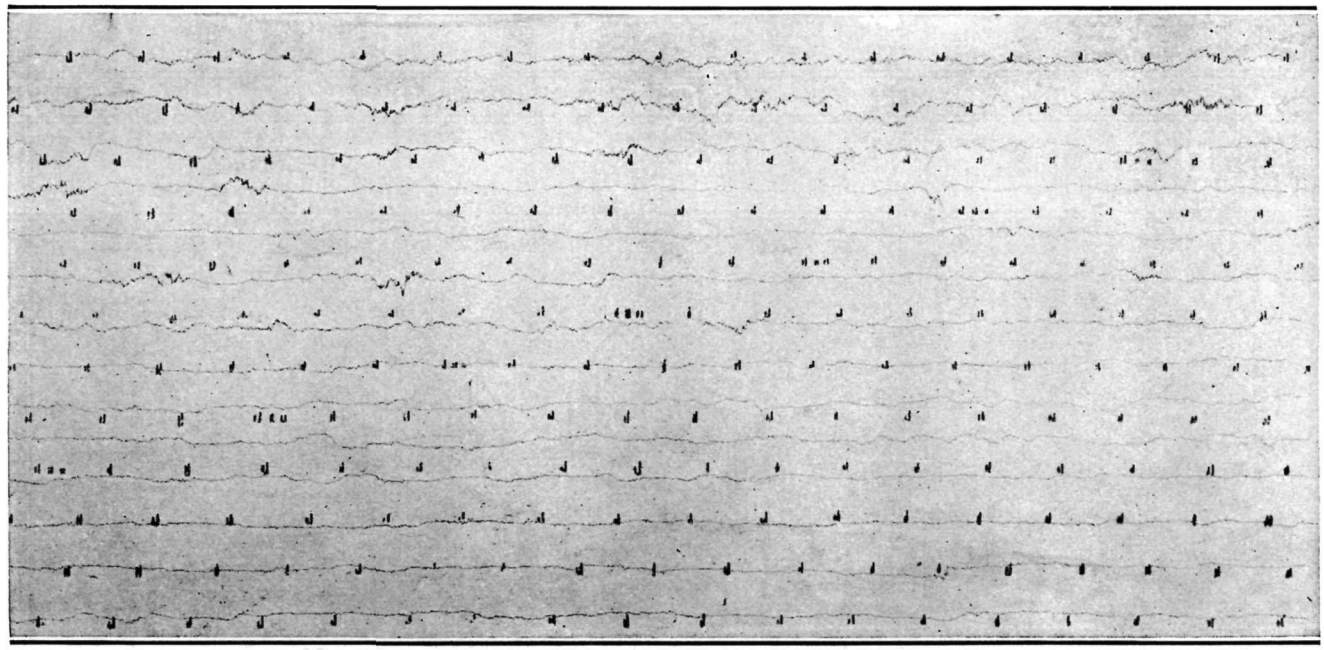
Seismogram, showing the lines written with a beam of light on a Kodak film in June, 1918, exhibiting microseisms as the principal wave movements. Minute marks are exhibited as gaps in the line. Registration of experimental seismograph pendulum of high magnification, Hawaiian Volcano Observatory.

SOME TECHNICALITIES OF VOLCANO STUDY

The reader of the bulletins and reports of the Hawaiian Volcano Observatory will be helped to understand the descriptions of the seismic movements at Kilauea, and of the rising and falling lava in the inner pit Halemaumau, and of the flowing of lava down slopes, if the observers at the stations of the Geological Survey will turn aside occasionally from technical description in order to explain the meaning of terms. Harmonic tremor, local seisms, avalanche vibrations, microseisms, streaming, fountaining, the wall crack and rim cracks are everyday structures, processes, and events at a volcano station equipped with seismographs. But the visiting traveler finds even such a simple word as "tilt" incomprehensible. He is not accustomed to a land which is tilting, and even if the house he lives in tilts back and forth between noon and midnight under the stress of the neighboring ocean tide and the weight of the changing water on the shore, he probably does not know it.

It has been the purpose of some recent numbers of the Volcano Letter to explain lava flows, rim cracks and crater slides, pahoehoe and aa, the bubbling, gushing, and cascading of lava, the swelling of the mountain, the seismogram of a distant earthquake as foretelling a tidal wave, the distinction between lava froth and lava paste, the working of a seismograph, and the heating of lava tunnels and wells by gas. Tilting or tipping of the ground was described last week in Volcano Letter No. 287 as an interesting chronic motion whereby a volcano is breathing through the weeks and months and its breast is accordingly rising and falling (Volcano Letter No. 264).

The present article is designed to show some seismograms and a diagram exhibiting movement of the ground in the shell of a mountain which is over a hot lava column. By lava column is meant an upright body of natural slag charged with gas in solution and occupying a natural shaft or well which goes down many miles and widens out in subterranean forms which it is the object of Volcanology to discover. Just as General Gorgas and Walter Reed discovered by experiment in Cuba that the mosquito carried yellow fever, so by experiment is it possible to show eventually that the lava under these great volcanic mountains swells out into a bulb, or a dome, or a lens, or a net of upright cracks. Experiment at the Kilauea Observatory has already shown that the mountain swells with rising lava and that the local ground always swells at the crack where rising lava is coming out. Leveling has shown that this swell extends down Kilauea Mountain to within 14 miles of Hilo, and that after the great collapse at the crater in 1924 there was subsidence of a foot or more at two stations in the National Park near Volcano House, and farther down the road very little effect. During the gradual rising of lava in Halemaumau from 1912 to 1921, the marked stations along the road



Seismogram printed directly from smoked paper, the quick tremors shown here and there being spasmodic volcanic vibrations. The slower waves are microseisms. Minute marks are dots. Hawaiian Volcano Observatory.

from Hilo to Kilauea showed in tenths of feet a rising approximately as follows:

Distance from Hilo Wharf			Change Between Levelings of 1912 and 1921		
10.9	Miles		+ 0.0	tenths	feet
14.1	"		+ 1.3	"	"
17.2	"		+ 2.4	"	"
20.4	"		+ 4.1	"	"
31.3	"	(Park entrance)	+ 8.1	"	"
32.5	"	(Volcano House)	+10.1	"	"

The graded increase of change in these figures as the crater is approached leaves little doubt of actual rising of the ground that has been discovered to a still greater degree close around and within the crater of Kilauea (Monthly Bull. Hawn. Volc. Obsy. Vol. XV No. 6, p. 40). The tilt measurements of a single year at the Observatory are shown in the diagram on Page Four as though the trace of a hanging fountain pen were enormously magnified. The bend July 8 coincided with an eruption.

There is suggestion that the underground lava rising in Kilauea Crater between 1912 and 1921 was spreading out underground as a wedge for 16 miles in the direction of Hilo. The implication is that the tipping up of the country over this wedge grows less and less so that 21 miles away it is zero. There is a quantity of other information derived from running levels in the direction of Pahala and across the Kau Desert. The placing of instruments in small chambers in the solid rock in many places that would measure this tipping from year to year would furnish evidence of the rate at which the changes in level take place and the times of sudden changes if any.

As explained in Volcano Letter No. 268, the seismograph may be made to measure several things. Here are some of the terms used: A microseism is a slow, wavy movement in the ground consuming about four seconds to each wave as shown in the optical seismogram on Page One. Each line there represents a part of a different hour, the minutes are marked by gaps in the lines, and the lines were written by a tiny spot of light on a moving Kodak film, the light beam being reflected from a little mirror oscillated by a pendulum, and the pendulum registered the movement of the ground. It will be seen that the wavy movement comes in spells which wax and wane every minute or two. Microseismic movement is common everywhere and is variously explained.

Volcanic tremor is shown in the seismogram on Page Two, where the lines were written by a scratching pen on smoked paper and the time marks for minutes are closer together and are made by little double dots from a mechanical marker. Many spasmodic groups of tremors are shown, much quicker than microseisms, and these are common at Kilauea when there is active lava in Halemaumau. Such was the case when this seismogram was made by a pendulum set up two miles away from the pit. A complete wave motion for this tremor occupies two tenths of a second. Sometimes the tremor becomes continuous and even, when it is spoken of as "harmonic," and this has been found to agree with times of fountaining lava in the pit.

Local seisms are merely local earthquakes and the ordinary ones registered on instruments at Kilauea are technically defined as very feeble (of which we have thousands), feeble, slight, and moderate. The first two are totally unfelt, but when an instrumental earthquake gets so big as to be "slight" it is usually felt by everybody. To those who do not understand technical grades of intensity, it is hard to understand how seismologists can say to each other, "Do you mean to say that earthquake was slight at Hilo? At Kilauea it was only feeble." In other words, slightness is stronger than feebleness. In the same way "moderateness" is quite big, dismantles the high magnification instruments by throwing the pens clear of the drum (see seismogram Page Three), and the shock is referred to by inexperienced people as "terrible" or "strong." It is not "strong" technically, because it does

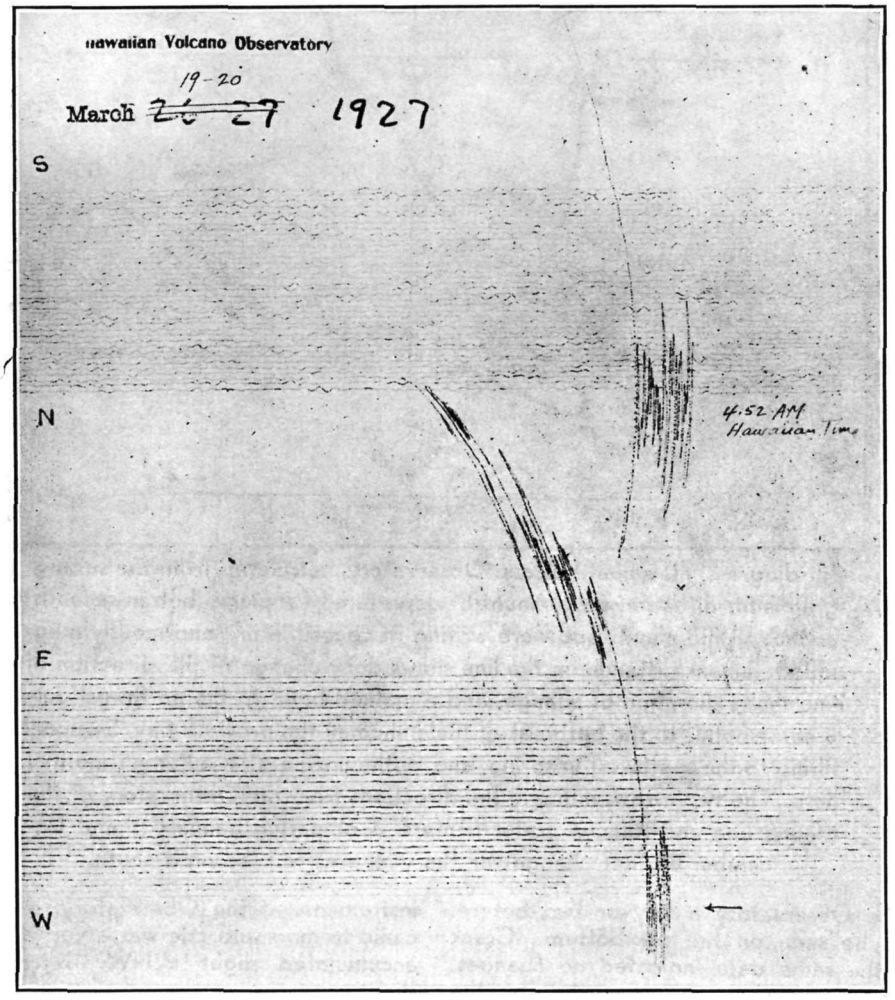
not knock over anything, and we have to reserve some words like strong, very strong, and disastrous for the grades of very big earthquakes.

The "indicated distance" for the moderate earthquake shown on Page Three is indicated by the duration in seconds of the preliminary motion. In the upper south-north band of lines, just to the left of "4:52 a. m.," there is registered a group of vibrations about an inch wide up and down and occupying a quarter inch in the direction of the lines. Then there comes a big sweeping movement where the pen goes off the paper. In the lower band of lines (east-west) the pen starts to go off sooner. The quarter inch corresponds to so many seconds of time of preliminary motion, or the first phase of the earthquake, and by Omori's formula for local earthquakes four seconds means 18 miles, eight seconds 37 miles, 12 seconds 55 miles, etc., of distance horizontally to the place on the earth (or on the map) which lies over the place underground which bumped or scraped or snapped. The place underground is called the center or origin, and the place above it the epicenter. Sometimes the ground at the instrument tips suddenly at the time of the earthquake and this widens or narrows the space between the lines on the seismogram, while gradual tilt of the ground widens or narrows the lines gradually (see seismogram Page Four, Volcano Letter No. 276). Avalanche vibrations are occasioned by the falling of great masses of rock from the crater walls (see Volcano Letter No. 269), and these write their records on the seismogram as quick waves gradually increasing to a maximum and then dying away. An earthquake is different, with a small preliminary, and then the sudden wide movement of the long waves, followed by gradual decline. T.A.J.

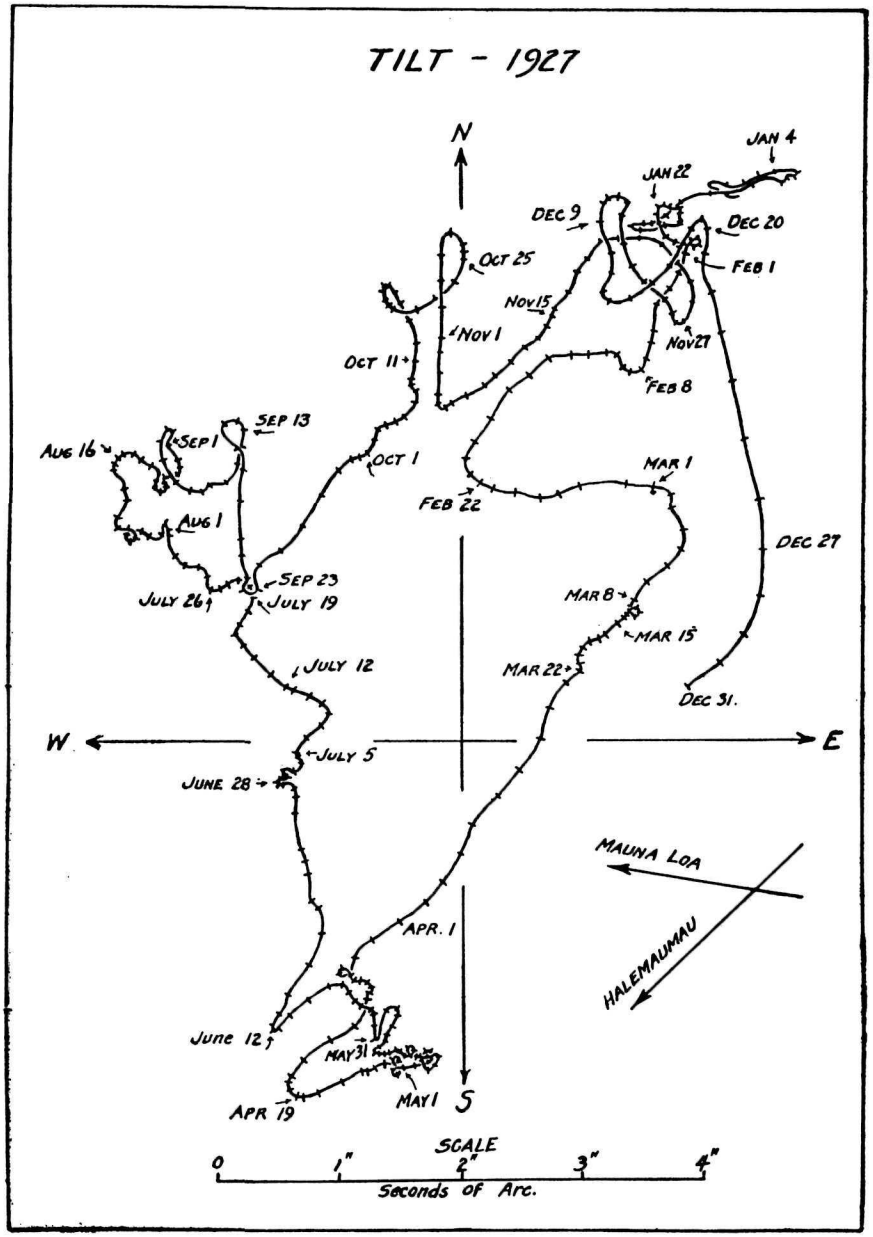
KILAUEA REPORT No. 962
WEEK ENDING JUNE 29, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Kilauea Volcano remains quiet and without visible changes. On June 28 a small scar at the top of the west Halemaumau wall appeared to mark the location of a



Seismogram showing two bands of lines registering horizontal motion, the upper south-north, the lower east-west, made on smoked paper originally, and showing a local earthquake 4:52 a. m. March 20, 1927, of moderate intensity. Shows preliminary tremor, and then the pens are flung off. Magnification about 100 times.



Tilt diagram, Hawaiian Volcano Observatory, calculated from the seismographs for direction and amount of departure of a plumb bob in seconds, as though the plumb bob were writing its record in ink, enormously magnified. Linear distance on the line shows daily change of tilt, direction of line shows direction of change, and a marked bend to the northwest July 8 corresponds to the outbreak of Halemaumau the previous day. Seasonal tilting to the southwest in spring, and to the northeast in autumn is normal here. The two arrows indicate the directions from the Observatory of the Mauna Loa and Kilauea crater centers. Comparing January 1 and December 31, net change for the year was four seconds south.

slide seen from the Observatory a day or two before. No steam was to be seen on the pit bottom. Crack measurements on the same date indicated no changes.

Only six seismic disturbances were recorded by the instruments at the Observatory, of which five were volcanic tremors and one was a very feeble local seism. Tilt accumulated slight WNW. Microseismic motion was slight.

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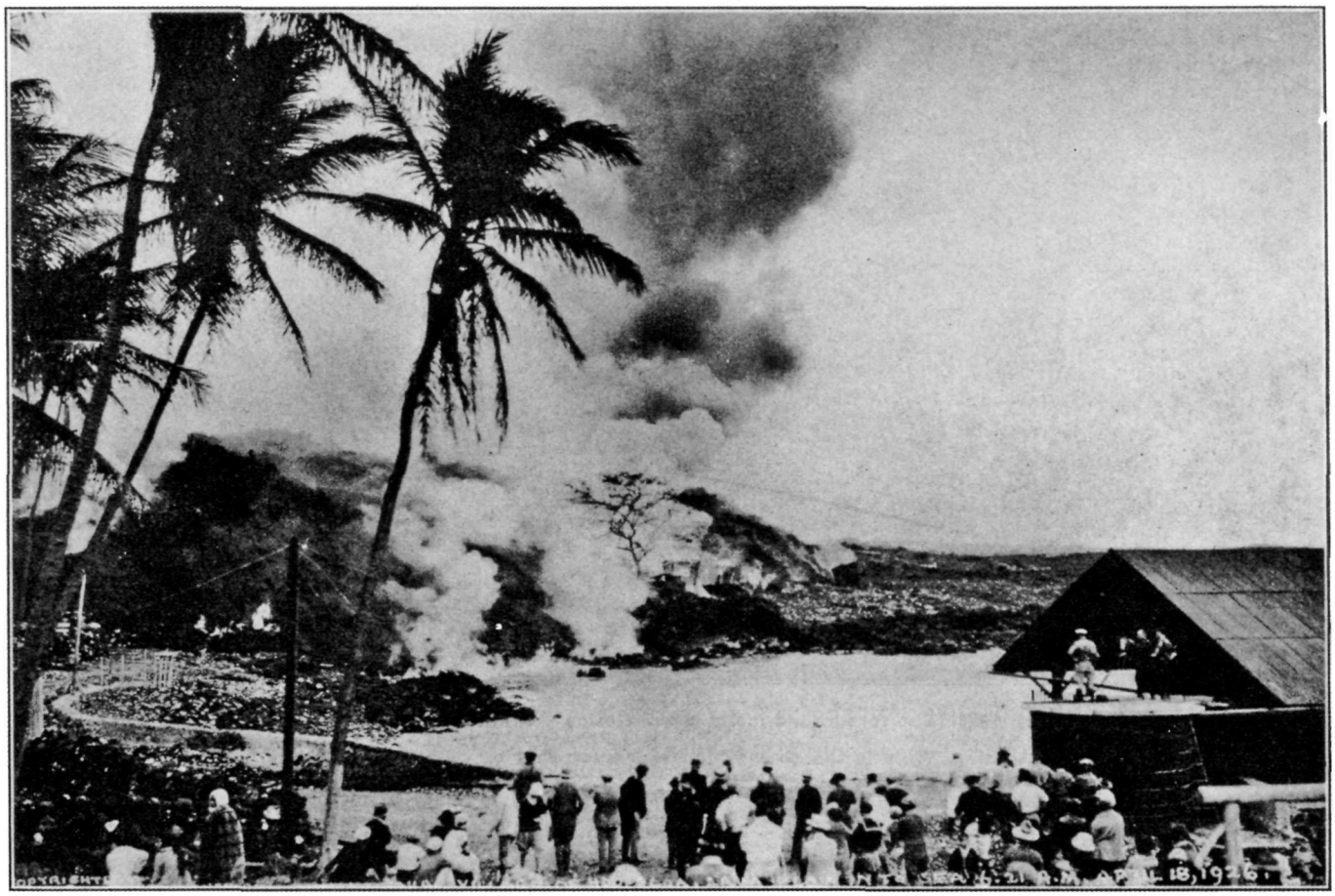
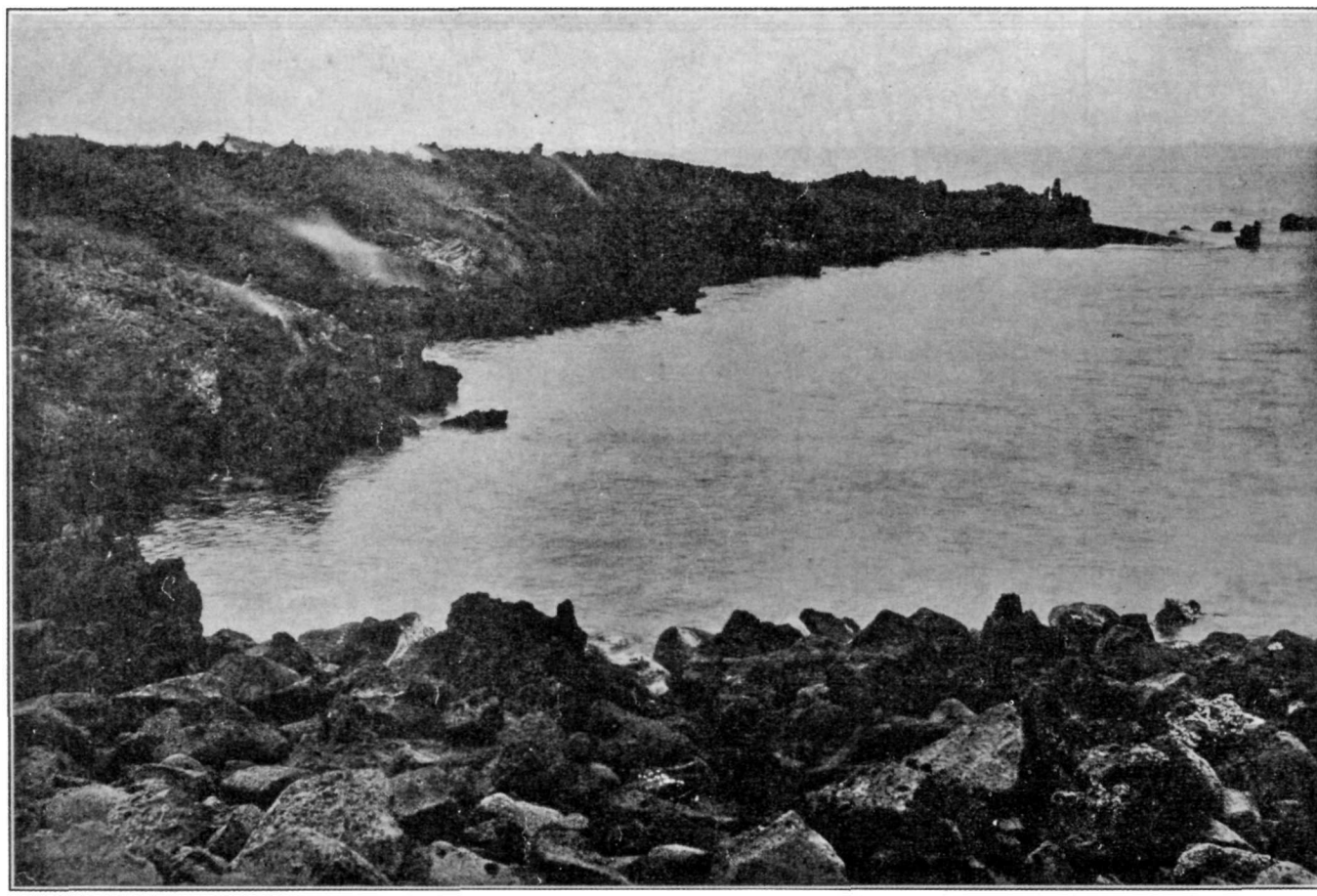
No. 289—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 10, 1930



Hoopuloa when the first buildings were burning and the lava front had just reached the sea, at 6:21 a. m. April 18, 1926, looking south. Photo Tai Sing Loo.

MARINE EROSION AT HOOPULOA FLOW

In 1926 during the month of May Mauna Loa produced one of its periodic displays with outpouring of molten lava, first from near the summit, then spreading down the southwest rift, and finally settling down to a steady flood of basalt from a vent at about the 8,000-foot level. This puddled on the flattish upland as usual for this district, the edge of the pool spilling in several directions before settling down to a final flow. The progressive feeling for an outlet in such a flow is partly conditioned by the tendency of the source crack or rift to open its way down the mountain. A vent is formed at a certain place on the crack, builds up a cone, overflows to the east, the cone-building clogs the hole, the crack opens a new vent farther down the mountain, and the escape of lava there is easier than at the first hole. The new cone overflows to the west, where the country is flatter, the slagheap backs up, the source is impeded, and a new place on the crack still farther down makes a freer outlet. In this way vent after vent is opened down the rift line. Finally a lower series of vents clog themselves and force the oncoming fluid from the depths to adopt one of its first openings a little farther uphill. The spouting melt is now dammed above and dammed below, and keeps flowing at one place. The flood



The site of Hoopuloa April 26, 1926. The foreground is old rock. Notice beginning of sand spit at point. The lava is still steaming. This is the cove which was later shut off. Photo Jaggar.

accordingly feels its way to the nearest declivity where finally it crushes a path for itself down a steeper grade through the forest, and this flow forms an adjusted canal through its own clinker fields to the ocean.

The flow of 1926 adopted this program, and the canal selected was a slight sag in the steep mountain slope of South Kona. This sag or valley, between old lava flows (see airplane pictures Volcano Letter No. 270, Page Four, and No. 285, Page Three) ended as is natural, in a shoreline indentation. This bay was where the fishermen naturally had chosen a landing for their canoes, here in some shelter had been built a wharf for the steamer landing, a beach had accumulated at the head of the bay, and dwellings had followed the demands of fishing and transportation. So this was the ancient fishing village of Hoopuloa, built to be sure on old and desolate rough lava flows, and only a short distance away from where in 1919 the Alika flow cascaded over the shore platform into the ocean, and made some short-lived tidal waves which wrought havoc at the Hoopuloa wharf. There was threat of danger, but why worry? There are lava flows everywhere.

The choice of a bay of the coast by men is also the choice of the fire goddess for good sledding on her lava. The aa flow of 1926 pushed right through the village ruthlessly, spared neither wharf nor dwellings, and nearly filled up the bay. There was left only a small cove at the northern quarter of the indentation where the wharf had been. Our pictures show the sequence of events.

At 6:21 a. m. April 18, 1926, we would have looked southward across Hoopuloa Bay (Page One), as the spectators and photographers in the foreground of the picture are doing, and we would have seen the crumbly incandescent front of the lava enveloping the village houses with flames, and just touching the water to start columns of white steam. The palms and the dock in the foreground are soon to be swallowed in molten rock. Jets of gravel will shoot up in zigzag trajactories, and the great steam-cloud will be blackened with exploded sand, while the heated

and poisoned sea-water will kill small fish by thousands.

Within twenty-four hours, by 9 a. m. of April 19, all motion in the flow at the sea front had stopped, and the new point of lava, thirty to forty feet high, extended out 300 feet. The photograph on Page Two, taken a week later, shows the old sea worn rocks in the foreground, and the new lava promontory still steaming. Not a single building was left of Hoopuloa village. The destruction could not have been more complete if it had been a deliberate engineering enterprise. Of the original harbor there was now only a small cove shown in the picture. A canoe reposed in this cove. A large beach had been formed by the sea on the flow itself. Some of this is shown at the tip of the cape. These new beaches were evidently growing very rapidly in several places.

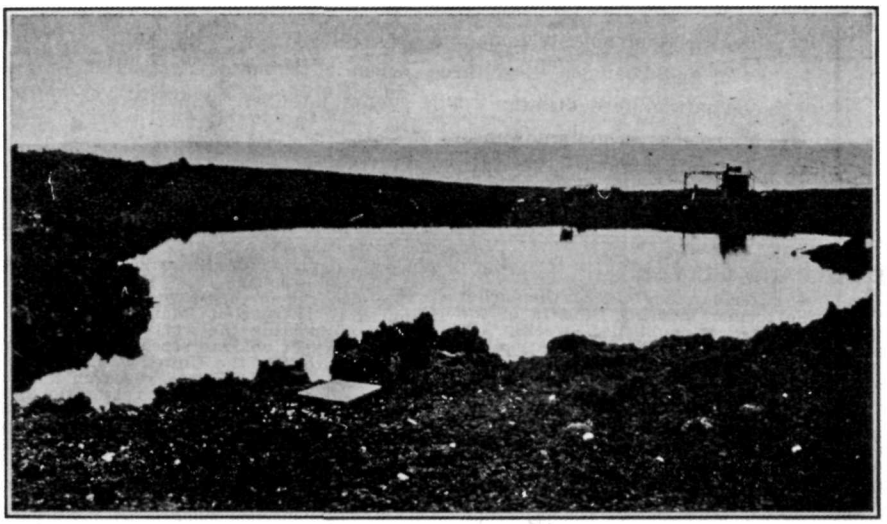
The hot gas rising, smelling strongly of ammonia and carbonaceous products, appeared to indicate that buried wood of the forest and the habitations was still smoldering under the flow. These smells were common at places remote from former habitations. When the large number of heavy sap-filled trees which the flow overwhelmed are taken into account, and when it is realized that they had no time to burn when they were smothered in the lava, it appears reasonable to suppose that all this carbonaceous matter may continue to burn slowly, with what oxygen it can get from the lava vesicles, for many months. This process will supply heat as well as gas, and the many explosions which are heard at old caverns when a flow is progressing through vegetation are occasioned by mixture of carbon monoxide, from the burnt wood, with air. Such explosions do not occur at the lava front when it advances over bare rock, where it has not travelled through vegetation.

Less than a year after this destruction of Hoopuloa even their little cove was denied the fishermen. The abundant loose material of triturated and tortured clinker that forms the upper surface of an aa flow, furnished a rich harvest to the mowing machine and reaper of the winter storms from the south in 1926-27. This building of beaches, so rapid within a month, created big sea-walls within the year and a barrier beach was thrown straight across the entrance to the cove, straightening up the entire shore-line. The cove became an enclosed fish-pond of the type prized for mullet storing by the Hawaiians, but all trace of a harbor was lost. The new beaches are of gravel and sand with steep fronts sloping rapidly into comparatively deep water (Pages Three and Four). The observation of this rapid shore process of erosion and filling acting on a fresh lava flow, suggests the possibility of interpreting the age of a past lava flow by the amount of wear of the stones and the arrangement of the beach fills. T.A.J.

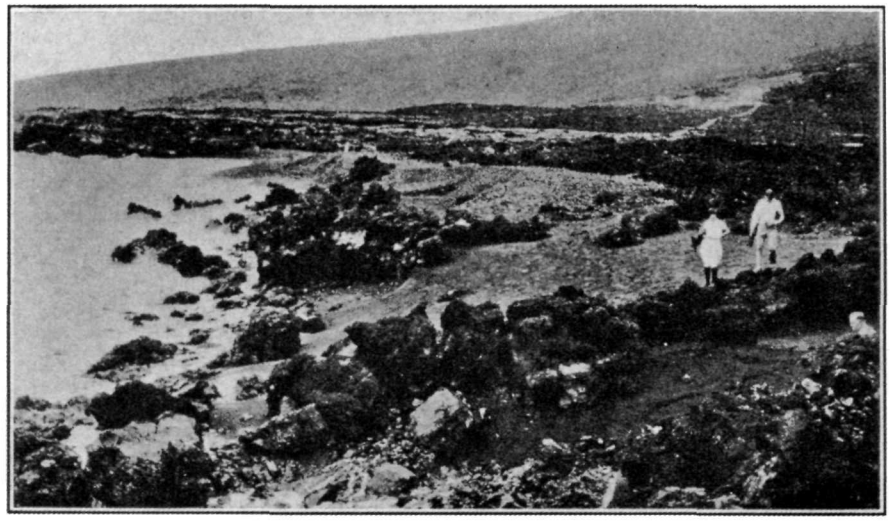
JUNE TILTING OF THE GROUND

At the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

June	2- 8	1.08	seconds NE.
"	9-15	0.48	second NW.
"	16-22	0.97	second NNW.
"	23-29	0.48	second N.



Looking west at Hoopuloa Cove converted by barrier into a fish pond. Hut is on the new beach ridge. Compare Page Two. Photo Godfrey.



May 29, 1927, shore wash of the new flow at Hoopuloa thirteen months after. Sea wall beaches built up from winter storms. Looking north, showing barrier beach that cut off Hoopuloa. Photo Godfrey.

KILAUEA REPORT No. 963

WEEK ENDING JULY 6, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Very few slides have occurred at Halemaumau during the week. White dust was twice seen rising on July 4. A little steam was observed on the south talus early in the week. The south sulphur area had a little whitish color.

The instruments remained very quiet seismically. The only disturbances were three volcanic tremors, each of *one-half minute duration. Tilt accumulated slight* WSW. Microseismic motion was slight.

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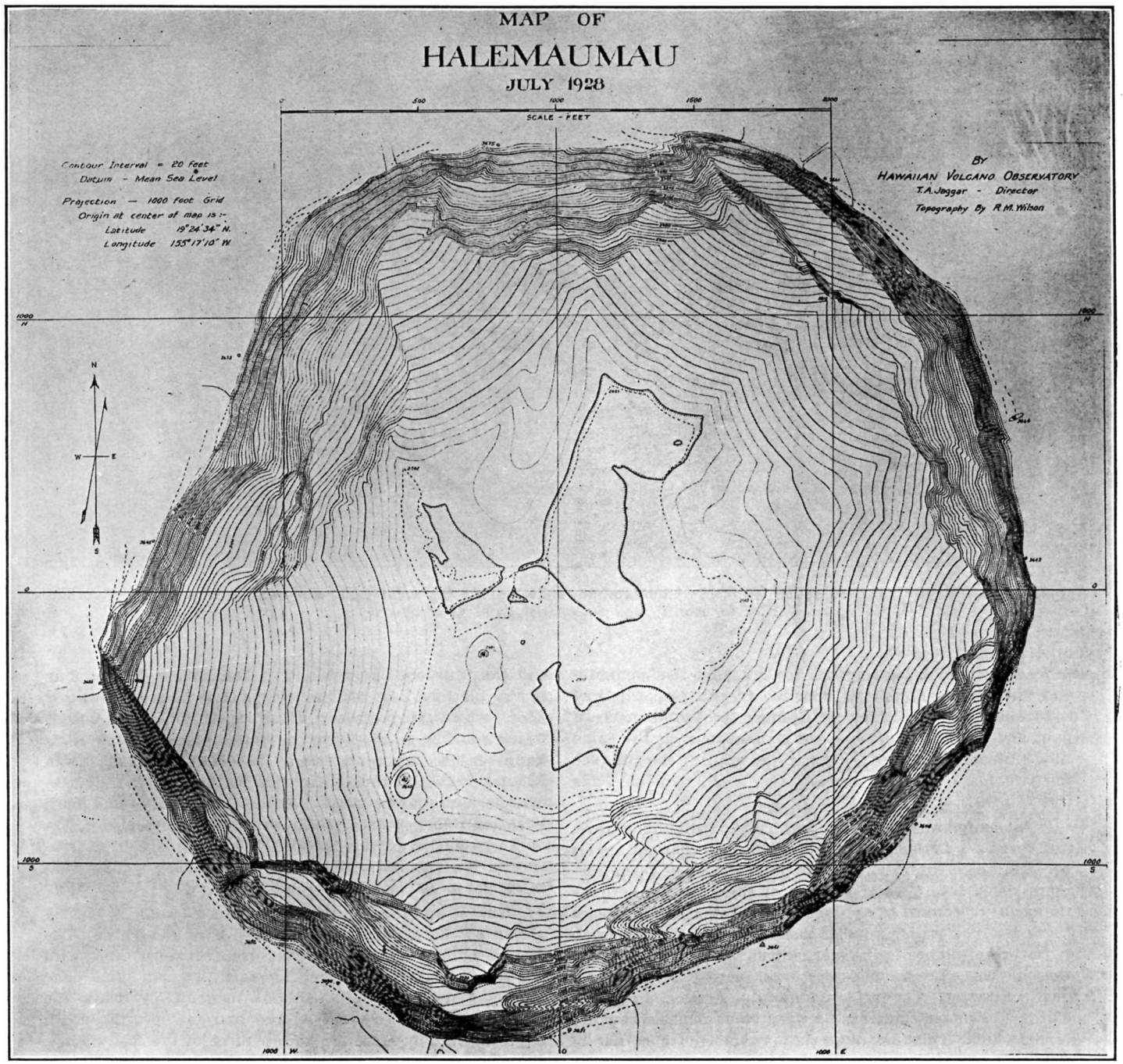
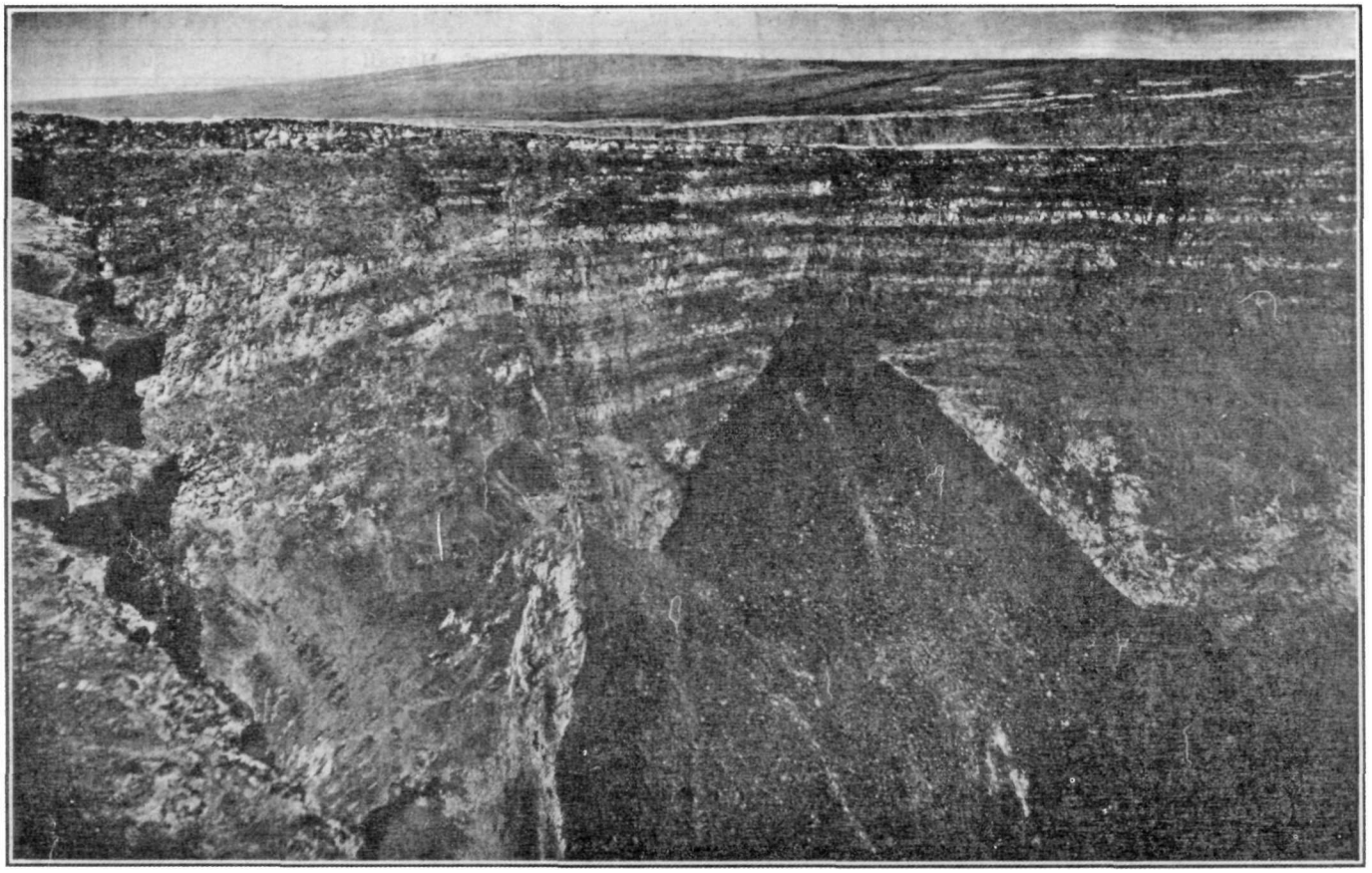


Map of Halemaumau, with twenty-foot contours, showing pentagonal form and star-shaped peaks of the big talus conoids at the five angles of the pentagon.

THE WALL PLANES OF HALEMAUMAU

There is much evidence in the manner of eruption of the lava pits of Hawaii to prove that these pits, although apparently circular, are really guided by definite upright planes. This applies equally to the large sink craters, like Kilauea and Mokuaweoweo, and to the small pits, such as Halemaumau or Makaopuhi. It is clear enough, from an inspection of the map, that the Chain of Craters extending to the southeast from Kilauea, is on a curved line, and this curved line must be guided by some geometrical echelon of cracks, if not a single crack. The outstanding event of the last twenty years at Halemaumau, which



Angle between southwest and south walls of Halemaumau showing the big west talus and Mauna Loa in the distance. Photo Wilson.

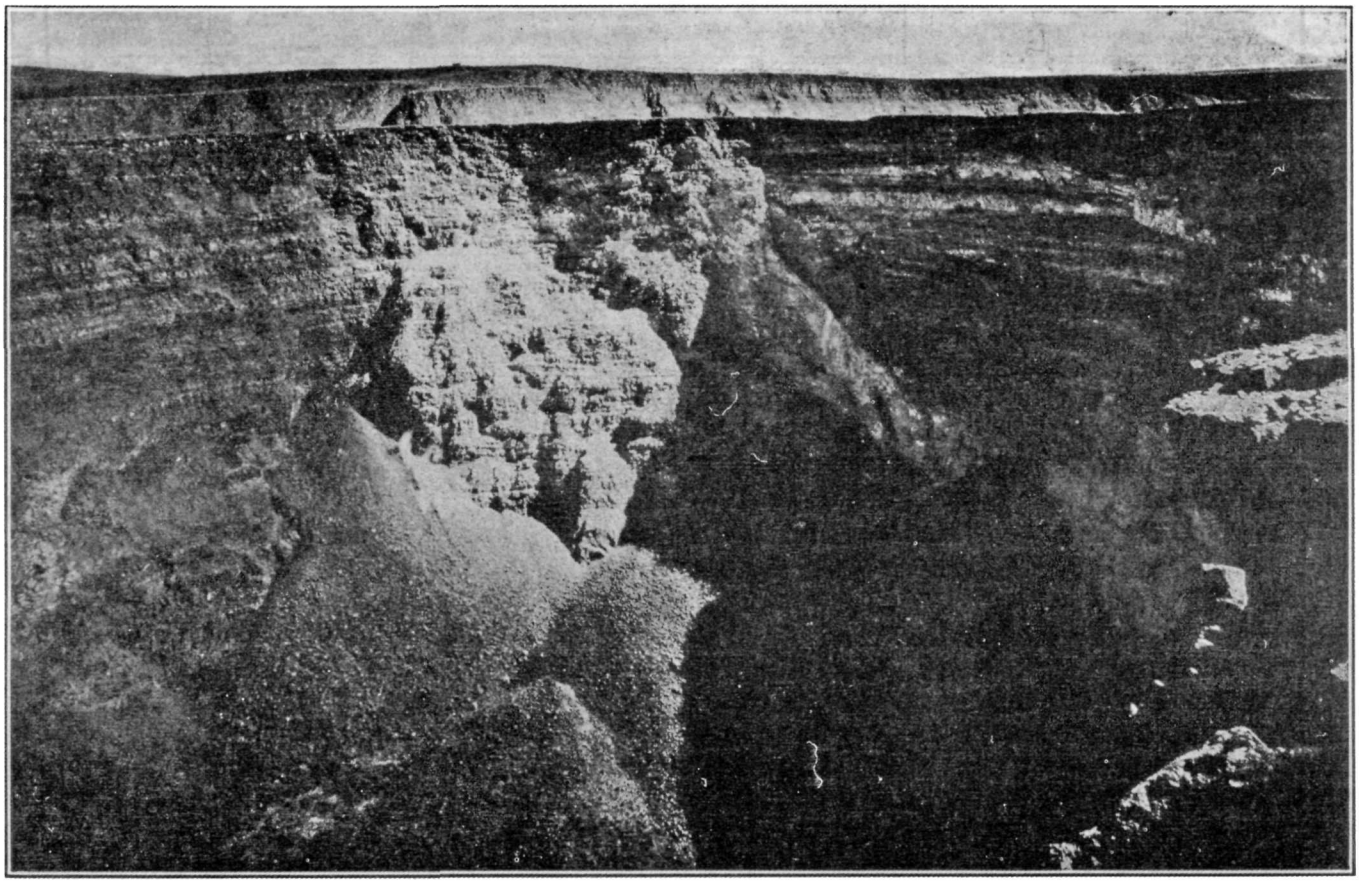
proved connection between a deep crack in the mountain and the opening of the pit, was the cracking open of the southwestern desert flank of Kilauea in 1919 to make a flow, and the visible drainage of Halemaumau at the same time through an upright crack in the wall of the pit (see the two black caverns in southwest wall, map on Page One above).

This map was made in July, 1928, with much care, and reveals a five-sided cauldron, with well marked angles between the five sides, and the light shade of open contours rising into a point at each of these angles indicate the peaks of conical talus slopes. In between these taluses there are rock walls. Four of these walls are fundamentally important planes in the mechanism which has generated the pit. These are the ones northeast, northwest, southeast and southwest. The fifth side is the north wall (Page Three), a remnant buttress between two gulches which are tending to join behind it at the extreme north corner of the map. That buttress has been undermined by avalanches right and left for years past, and threatens some day to fall into the pit and make a big avalanche, which would leave the pit four-sided.

If the reader will consult the outline map on Page Four, and there study the shape of Kilauea Crater, within the floor of which Halemaumau is an inner pit, he will find that the larger sink is also five-sided, with the two longer dominant walls northwest and southeast, and two shorter end walls northeast and southwest. Here also at the north there is a cross wall between the Volcano House and the Military Camp which is backed by the Sulphur Banks platform, an ancient remnant of a former crater floor, which if removed, along with the downfaulted Byron's Ledge, would leave the crater four-sided. Byron's Ledge is the triangular piece separating Kilauea from Kilauea Iki. It is thus clear that the outline of Halemaumau is a miniature of the outline of Kilauea, and both have their longer axes in a northeast-southwest direction on an extension of the 1920 rift. This rift is a deep fracture in the mountain, which has given vent to many lava flows off to the southwest.

The appearance of the Halemaumau walls is clearly shown by the photographs on Pages Two and Three. The picture on Page Two shows the great western talus with the western angle of the pit above it, a small talus cone adjoining it on the left, and this immediately below the rift caverns of 1919, and on the extreme left the south angle of the pit. Here are shown three of the wall planes, the ragged edge of the left hand foreground being part of the southeastern wall.

The picture on Page Three exhibits the north wall of the pit in bright sunlight, with a talus on each side of it, and this shows what is meant by referring to that wall as a lumpy buttress likely to fall away and leave a single angle behind it where the northeast and northwest walls meet. These two wall planes are shown right and left, the right hand one exhibiting the great white sill with a talus athwart it in the shadow, while in the foreground on the right is seen a craggy bit of the southeastern wall.



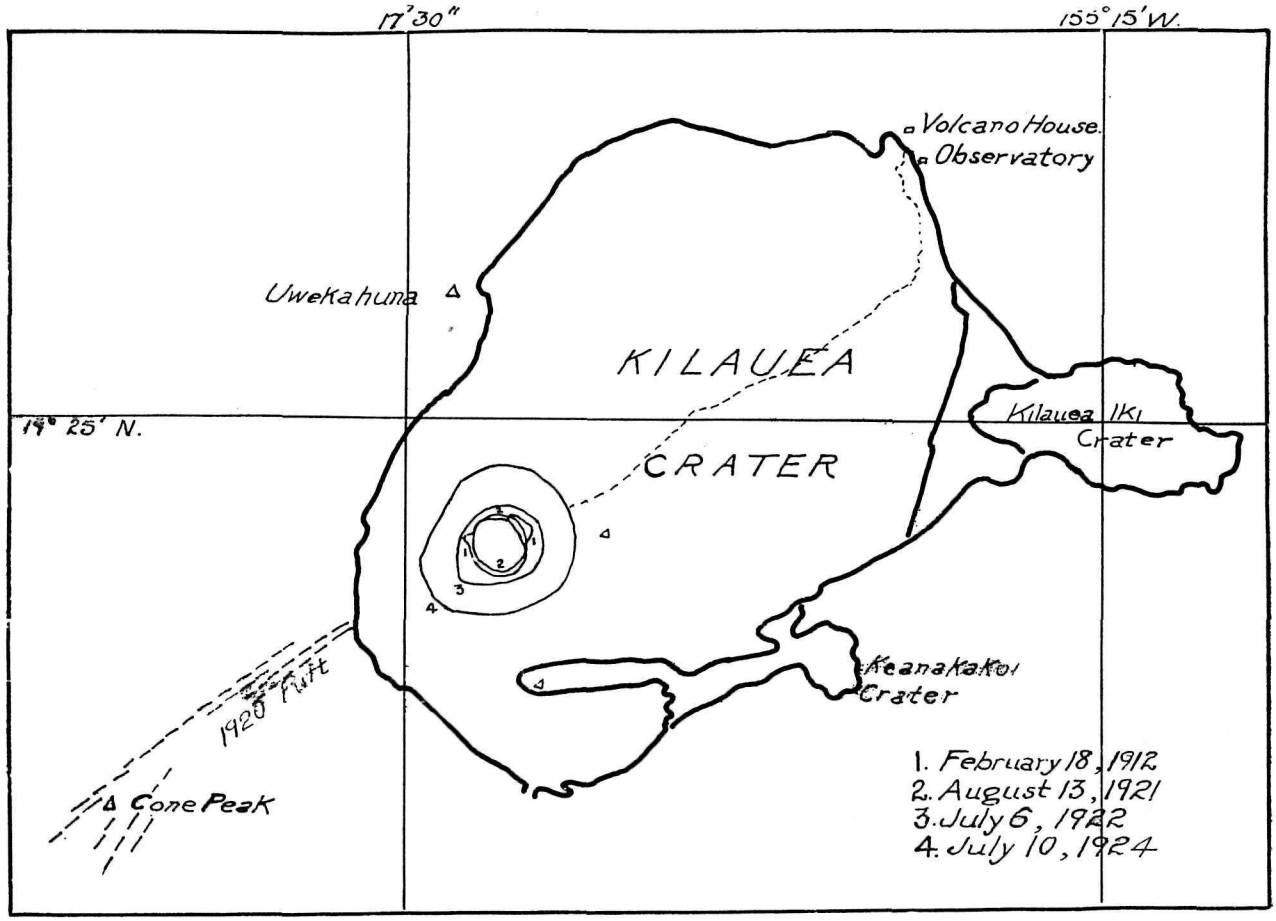
North wall of Halemaumau showing north and northwest taluses and protuberant buttress at north corner of the pit. Uwekahuna bluff in background. Photo Wilson.

Now if we go back to the map of Halemaumau, there will be seen across the bottom of the pit four small circles in a NE-SW line, which line if extended coincides with the rift tunnels at the southwest, and with a dyke or fissure filling which extends up and down the northeast wall (see upright line athwart the great sill on the right of the talus in the shadow in cut on Page Three). These bottom vents lay along the crack which opened in the bottom of Halemaumau July 7, 1927, the southern one building up into a big cone. A huge landslip from the north fell on the floor which was left January 11, 1928, and apparently cracked the floor in a semicircle around the lobate front of the landslip so as to let fresh lava ooze up and well out in a short-lived eruption. The fundamental crack of 1927 was approximately parallel to the northwest wall of the pit, and also to the northwest wall of Kilauea Crater. We may conclude from this that when Halemaumau revived after three years of repose, the deep rift which guided the revival was the great southwestern crack. And this great crack, in the original downbreak that formed Kilauea Crater, guided the production of the northwest and southeast walls of that crater.

The map on Page One shows that the northwest and southeast walls of Halemaumau have comparatively gentle slopes toward the center, and in plan they tend to converge toward the southwest. The northwest and southeast walls of Kilauea Crater (Page Four) also converge in plan toward the southwest. Apparently the great southwestern rift tends to have its cracks fan out or diverge in the direction of the rounded dome of the summit of the mountain and this is what has shaped the breaks which have determined the longer axis of both inner and outer craters.

All of the activities of rising lava in the pit since 1924 appear to have been controlled largely by the southwest rift. The big lava cone of July, 1924, was at the base of the western talus. The line of active vents of February, 1929, was at the base of the northwestern talus. The line of activity of July, 1929, was again at the base of the western talus. The surface fractures in each of these cases were doubtless determined by the breaking of the cake of lava left in each case at the bottom of the pit by the next preceding eruption. But there is no evidence in any of these outbreaks of lava that the northeast and southwest walls lay parallel to the crack which ruptured under the pit in order to permit the extrusion of lava.

The northeastern and southwestern wall planes of Halemaumau have very different quality from the walls of the pit which lead to the southwestern rift. They lie right athwart this rift and they are almost vertical down to the places where they join the talus. (See left wall, Page Two and right wall, Page Three). In plan these two steep walls also tend to converge, and this time it is to the southeast that the convergence points, which would take us to the Chain of Craters in Puna District off beyond Keanakakoi and Kilauea Iki. This is the second great flow rift of Kilauea mountain, and the two walls northeast and southwest of Kilauea Crater also trend in that direc-



Outline of Kilauea Crater and the stages in growth of Halemaumau pit as mapped on four different dates. Shows control of longer axis by southwest rift.

tion, as though the Chain of Craters rift tended to fan open into several major cracks as it approached Uwekahuna, the summit of the Kilauea dome (see Page Four).

If now we imagine the primitive Kilauea dome covered with lava flows from a summit well at the height of the top of Uwekahuna bluff and over the middle of Kilauea Crater, it appears likely that the flank of the mountain fractured and let out floods of lava southeast and southwest. When this period of big flooding ceased in prehistoric times, the top of the mountain tended to cave in about the meeting points of these two sets of rifts, each of which tended to finger apart and to cross each other at the summit region. This crossing of convergent southeast and southwest cracks determined the polygonal outline of Kilauea Crater as a sink, and it in turn determined the polygonal outline of its inner pit as a secondary sink.

T.A.J.

KILAUEA REPORT No. 964

WEEK ENDING JULY 13, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There are very few changes to be reported at Kilauea Volcano. The sulphur area on the south floor of Halemaumau remains whitish and appears to be spreading slightly. Steam vents within the pit remain inactive. On July 10 thin, light dust rose at 2:50 p. m. and at 3:25 p. m. Small rock slides at the north corner were observed July 11 and 12. The west wall has had additional dusting from small slides.

The seismographs recorded eight disturbances on the 7th, 8th, and 9th. Of these four were tremors of less than one minute each, and four were very feeble local seisms. Two of the latter showed distance phases of 14 and 18 miles from the Observatory. One was accompanied by tilt to the east. No disturbances were recorded after the 9th.

Tilt accumulated moderately NNE, with movement strongest to the north. Microseismic motion was slight.

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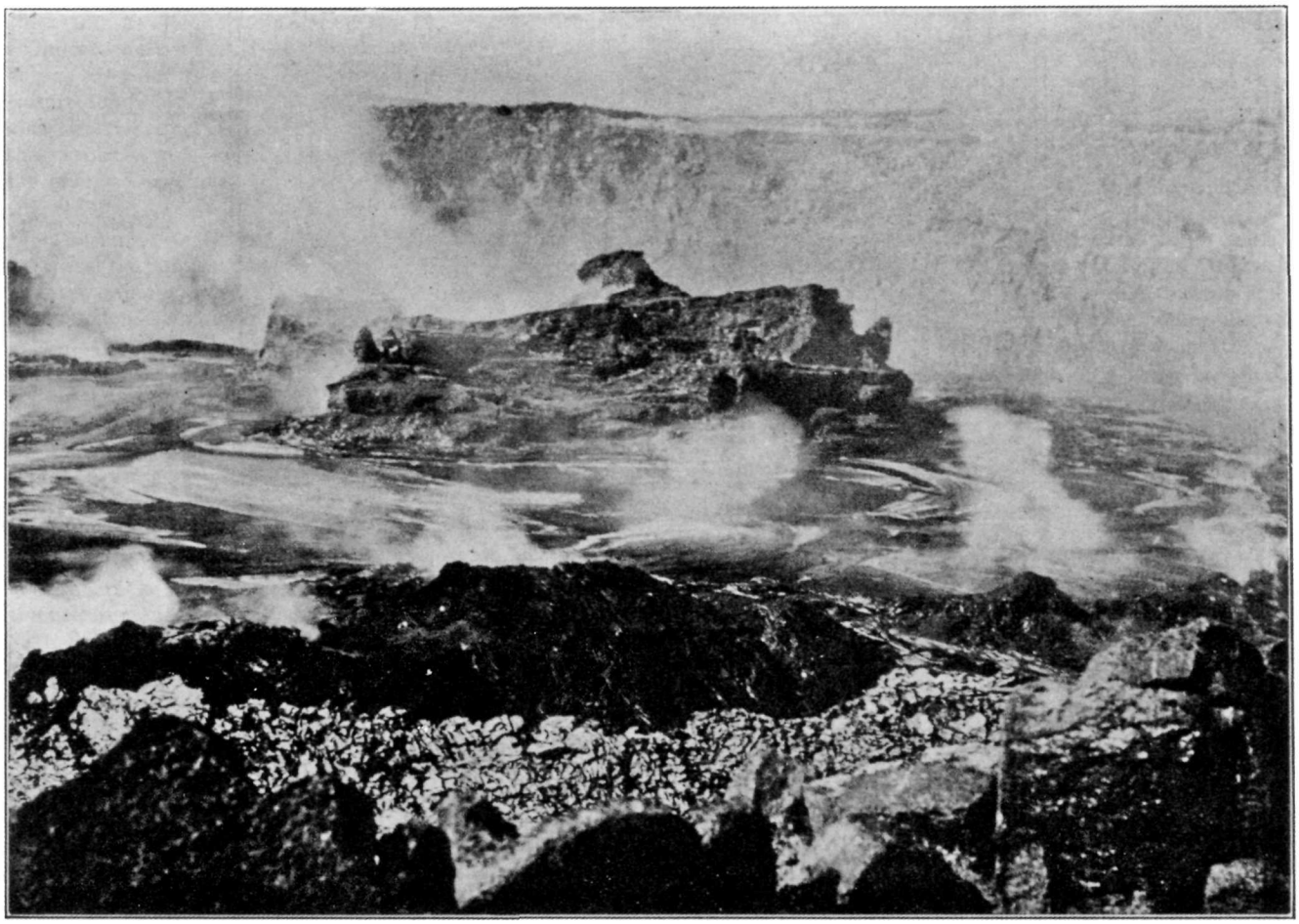
No 291—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 24, 1930



Rising lava lake and crag mass December 15, 1916, from northeast rim of Halemaumau. The several terraces on the crag mass are overflow benches which have slowly tipped up. A time of strong rising. Photo Jaggar.

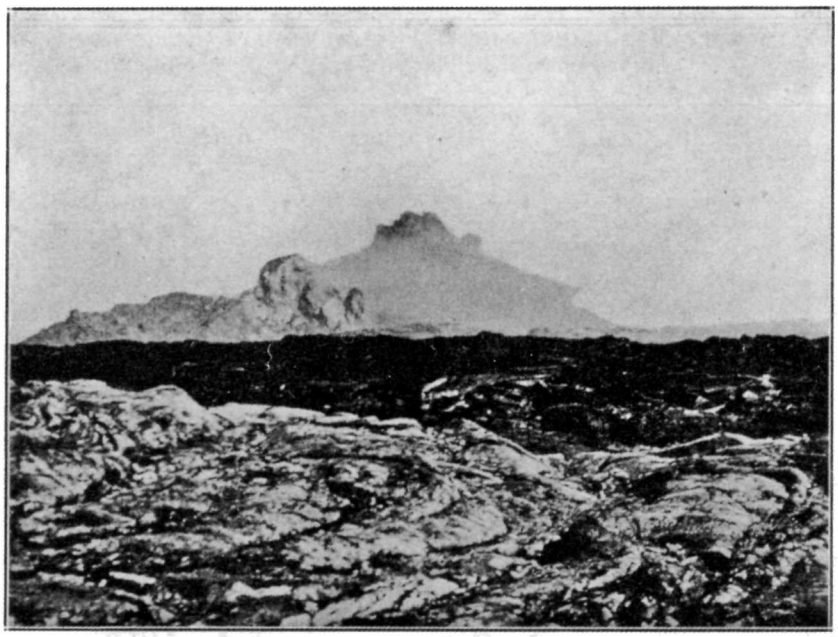
WHEN THE PIT LAVA RISES

To the observer on the brink of Halemaumau, that vast cauldron of the present day some 3,400 feet in diameter and 1,000 feet deep, the rising of the lava in the bottom is a very slow process. At present the bottom has shallowed more than 300 feet since June of 1924, but this has proceeded entirely by the building of layers in several eruptions in 1924, 1927, etc. The rising of the lava column in the bottom of Halemaumau becomes a continuous process very different from this piecemeal building of layers when the inpouring of the slag behaves as it did between 1914 and 1924. This was a real rise of the lava column, and the phenomena distinctive of rising lava are worth examining.

During the six years beginning with 1914 the top of the live lava in the bottom of Halemaumau pit rose gradually from a position 600 feet below the rim of the pit to the top, so that the rim was building up, lava flows occasionally poured over the rim, and other lava flows in great volume poured for months at a time up cracks a little way back of the rim. These last were just as much "overflows" as the spillings which crossed the actual rim of the pit. They equally were draining the pit lava, but by mechanism of internal expansion of lava gas which permits the fluid to well up small outlying cracks to higher levels than are occupied by the broad open effervescing lakes. The mechanism of lava overflow as contrasted with flank outflow has been reviewed in Volcano Letters Nos. 280 and 282.

The rate of rising during a big rising spell was thus approximately 100 feet per year, but this is merely the statistical result, for the actual risings were often much quicker, and the prolonged rising spell was interrupted by many sinkings of hundreds of feet, each occupying either a few days, a few weeks, or several months. Sudden subsidences of from 50 feet to 400 feet occurred repeatedly, and rapid risings averaging about 30 feet per month were common.

These risings of 30 feet per month were themselves



Halemaumau full of lava in September, 1918, showing lifted crags from the west. Observer is at level of pit rim. Looking across fresh flows dating from March, 1918. Photo Jaggar.

punctuated by risings and fallings of 10 or 15 feet from week to week, this being particularly noticeable at times when the curve of major rising tended to flatten out to a spell of relatively stationary lava preparatory for a temporary decline. The same thing was true of a stationary period at the end of a temporary decline, when the lava would fluctuate more from week to week than during a term of steady strong rising. There were times during the early years of work at the Observatory (and something of the same sort has been noticed for earthquake frequency during recent years) when the observers thought they detected a periodicity of three weeks in the fluctuations.

The most rapid rise ever recorded at the Observatory was during the month following November 28, 1919, when both liquid lava and crag lava rose 30 feet a day, making the crag lava into a ring-island as recorded in Volcano Letter No. 282. Excessively rapid rising of this sort is accompanied by unusually strong effervescence of gas, implying an exceptional release of pressure on the underlying magma. In this particular case, Mauna Loa had just finished an eruption, its underground lava had presumably sunk back into the depths, and this in connection with the Kilauea lava had released pressure by causing an enormously rapid subsidence of the Kilauea lava column of some 400 feet in two hours, which was immediately followed by the rapid rising above referred to. Such happenings as this lead to the inquiry, "What makes the lava column rise at all?" This in turn leads to a second query, "Is the sinking of lava an exact reversal of the process that makes it rise?"

These are very pregnant questions. What Dana called the "ascensive force" in lava has been a subject of much controversy and much doubt. This was because the early observers of the Mauna Loa lava fountains describe them as glistening jets like molten metal ejected hundreds of feet into the air, and these observers did not perceive that they were impelled by gases. They were looking for steam, the traditional gas of the Italian volcanoes, and when they saw no steam condense, they inferred that the spouting must be hydrostatic. To get hydrostatic spouting in a molten slag free from gas, on the top of Mauna Loa 13,000 feet above sea level, it was necessary to imagine expanding forces within the liquid itself, or else to imagine a pressure on the reservoir deep under the mountain such as might be produced if blocks of the earth's crust were settling on top of the liquid.

All of this presumed liquidity for the underground lava as a matter of course, and such an assumption created great difficulty if one attempted to connect Mauna Loa with Kilauea hydrostatically. If Kilauea were open at 3,500 feet elevation, necessarily it ought to drain Mauna Loa if the two were connected. Both were open at times and erupting together, yet Kilauea did no draining. Therefore, so ran the argument, the two are totaly unconnected. William Lowthian Green combated this, and insisted that the two show a sympathy of alternation of eruptions.

These difficulties disappear when lava is understood to be a dense glass at high temperature, with many times its volume of hydrogen, sulphur and carbon gases dissolved within it. Deep in the cracks under the mountains this glowing gas-charged glass is so compressed as to be almost a solid. In such condition it may be thought of as an enormously expansible and combustible paste. If Nature pulls apart the crack which it occupies, the gases puff it

up like beaten foam. If the gases thus by release of pressure unite in bubbles, they mix with air and burn. If they burn they heat the foam more than before and make the mass more liquid. Greater liquidity means more mobility and a foam pressure capable of opening cracks and doing work like a steam engine. But here we have rather a chemical engine, a multiple expansion engine and a heat engine all combined in one. This engine is dependent on Nature for cranking it, and for supplying the gas-charged glass, or "magma." Given an age-long supply of magma up the cracks, and a systematic self-starter which will pull the cracks apart once in so often, and volcanic eruptions will result.

The supply of magma in Hawaii and similar basaltic volcanoes is unquestionable; it builds new layers of land and new promontories in the sea, and swells up the islands by intrusion. It makes the island ridge bulker than it was before. Probably this is at the expense of the sea bottom round about, which may sink proportionately lower than it was before. If so, the magma is the matter of the primitive substratum of rock-forming glassy paste under the crust 30 miles down. It is eternally rising until the ridge of its own building becomes so massive that its weight balances the downsinking blocks of sea floor. Then and then only will volcanic eruption become "extinct."

After outpouring of lava ceases, intrusive irruption of lava in cracks and among strata may continue and swell the country and heat the springs, long after the volcanoes have ceased to give vent to lava. This continuity of internal activity ought to be measurable on the surface of the country, if we study changes of the plumb line, changes of elevation, relation of these to earthquakes, and changes of temperature and composition of hot springs. There is little sense in laboriously studying things like earthquakes and hot springs unless we study them IN RELATION to something. These time and change relations are worth while. There is no fixed observatory in the hot spring belt north of San Francisco to tell us how the ground changed its tilt, and how the ground-water changed its salt content, its temperatures, and its flow after the great earthquake of 1906.

But what is the systematic self-starter that makes lava rise? In 1924 in Hawaii the "eruption" came to an end. Lava immediately reappeared in the bottom of the pit. It froze there. In 1926 it reappeared in great force on the top of Mauna Loa. In 1927, 1928, and 1929 it reappeared mildly in Halemaumau. In the autumn of 1929 its intrusion shook up Hualalai. Perhaps after all nothing came to an "end." Perhaps after all the engine is always running and Nature puts her foot on the accelerator rather than on the self-starter. Her accelerator is any force that will pull the trigger to ease the pressure on the gas-charged paste.

There are the crust blocks of the sea bottom acted on by centrifugal force as the globe whirls. There are the changes in that force as the sun and moon make tides in the earth itself. There is the greater diameter of the equatorial protuberance of the globe, acted on angularly by these forces. There is the cracking down of the great Hawaiian ridge along its old fault or rift planes as the lava flows drain its reservoirs, or fracture it with steam blasts, or upset its water drainage, or settle its crater wedges, or weight down its flanks. The "yielding of the edifice," as an engineer would say, is probably the most potent control of the accelerator, and a cone would not build itself in a circle without a geometrical law of control of the vent by the arrangement of the structure. It is the final task of volcanology through the ages of man to discover this law.

T.A.J.



North rim of Halemaumau November 2, 1918, with floods of fresh lava pouring from an outside crack at a level higher than the lava lakes in the pit. These flows as shown were cascading inward to the pit on the right. Photo Jaggar.



Telephoto of Halemaumau May 9, 1919, from west bluff of Kilauea. Fresh overflows in foreground. The lava column was now topped with a swollen dome above rim of pit, punctured with lava lakes. Photo Jaggar.

KILAUEA REPORT No. 965

WEEK ENDING JULY 20, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Steam continues to be absent from the vents in Halemaumau pit. This may mean that the top of the Kilauea lava column lies close to the surface of the volcano edifice and thus dries up moisture seepage. Dry weather has been prevalent, however.

A large section of the east rim fell on July 15 at 10 a. m. This leaves the 14-ton bowlder of 1924 nearer the edge of the pit. Small rock falls on the north wall were noticed from time to time. Some slides southeast on July 19 were caused by visitors dropping rocks.

Thirteen seismic disturbances were recorded by the seismographs during the week, classified as follows: Six tremors, the longest having duration two and one-quarter minutes; six very feeble local seisms, two showing origin distance 23 miles from the Observatory and one showing 14 miles; and one teleseism which registered faintly at 12:41 p. m. July 14. No disturbance was perceptible.

The net accumulation of tilt was very slight SW. Microseismic motion was slight.

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The Volcano Letter

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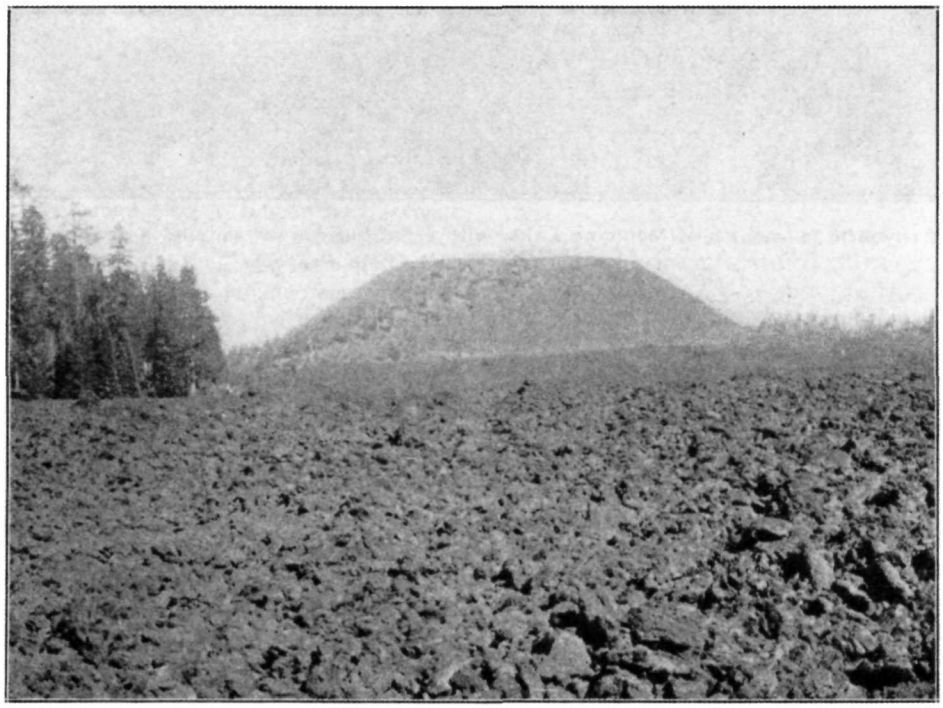


An aa flow of basaltic lava and the cinder cone associated with it called Burnt Lava Flow. Photo Powers.

THE GLASS MOUNTAINS OF NORTHERN CALIFORNIA

Among the legends of the Modoc Indians of northern California are stories of an ancient time when their hunting grounds trembled beneath their feet, when the silence of the forest was broken by strange thunder, and the mountains around their Medicine Lake were lighted up by unearthly fires. Today, the presence of a number of flows of fresh looking lava and mountains of pumice in this area suggests that the Indian legends describe the last activity of a small volcano. Medicine Lake, in the heart of this region of recent volcanic activity, is located north of Lassen Peak and about 30 miles east of Mount Shasta in northern California.

This interesting volcanic region may be easily reached by automobile from Shasta City, California. Since it lies within the boundaries of the National Forest Reserve, one must first obtain permission to build fires in the forest from the Forest Supervisor at Shasta City, who also makes sure that every automobile in the party is equipped with a shovel and an ax as a rough and ready fire control. This is a regulation passed for the protection of public property and is very rigidly enforced. On one occasion two prominent government officials were ordered out of the National Forest because they had failed to equip their car with an ax and shovel.

Leaving the Pacific Highway near the city, one passes over a long ridge built up by lava flows from Mount Shasta. The flows are of great age and their surface is mantled with a rich soil which supports a luxuriant growth of pine and fir. The road soon drops down into the valley of the McCloud River and passes through the flourishing little lumber town of McCloud.

A few miles beyond, the road becomes extremely dusty and many dead and dying trees are noticed in the forest. This is the country which was buried by a so-called mud flow from Mount Shasta in 1925. This mud flow was not of volcanic origin; in fact, quite in contrast, it was caused by a glacier on the high slope of the mountain. As the river of ice moved slowly down its valley, it ground up quantities of rock into a very fine powder called rock flour. At the lower end of the glacier, this rock flour piled up with unpowdered rocks and other debris to form a sort of dam called a terminal moraine. During a period of very hot weather in 1925, a great deal of the ice of



A flow of rhyolitic lava north of Medicine Lake, with a flat but rugged top and a nearly vertical flow front over 100 feet high. Photo Peacock.

the glacier was melted and this terminal moraine became so saturated with the water from the melting glacier that it became a huge pile of very slippery mud. It immediately began to slide and the slope of the valley was so steep that it became a veritable river of mud which flowed for several miles, burying the underbrush and piling up around the trunks of the forest trees in its path.

Soon after leaving the mud flow, the road begins a long, gradual climb up the gentle slopes of an old volcanic dome. This was built up by lava flows from a little satellitic vent on the eastern slope of the mighty volcano which formed Mount Shasta. After the lava stopped flowing from this little volcano, the top of the dome began to settle and a circle of cracks was formed around the summit. If this settling and cracking had continued it would have yielded a large crater in the top of the dome very comparable to the large crater on the top of Kilauea. However, the sinking of the top was interrupted by another outburst of lava which issued from a number of places along the circle of cracks around the top of the dome. These numerous small eruptions built up a circle of cinder and lava cones which formed a crown upon the top of the older volcano. Futhermore, the crown of small volcanoes formed the rim of a large basin-like depression, which was filled with water to form a large lake. The water for the lake was supplied by the melting of many small glaciers at the end of the Ice Age. Since that time, the supply of water by ordinary rain and snow fall has not been great enough to keep pace with the evaporation from the lake, and the original large lake gradually decreased in size until it became the present Medicine Lake. Thus it is that Medicine Lake is located on top of a volcano and yet is not a simple crater lake.

Long after the end of the Ice Age, the old volcano took a new lease on life and broke out with many small eruptions on its flanks and its top. Those from its top emitted lava and pumice of rhyolitic composition. They are very rich in silica and low in iron and magnesia, contrasted to a basalt which is low in silica and high in iron and magnesia. While all of these summit eruptions happened much more recently than did the main eruptions of the volcano, they did not all take place at the same time.

The earliest of the late flows came out of a crack in the top of the volcano just north of Medicine Lake and spread out over a square mile of the old lake bed. The lava was extremely viscous and spread somewhat after the fashion of very cold tar. As a consequence the outer edges of the flow were maintained as nearly vertical walls over 100 feet high. Since the lava cooled, the rock has been broken a good deal by freezing and thawing and by the prying action of the roots of trees which grew on the flow. These broken blocks have fallen to the foot of the flow front and form talus piles which hide much of the original steep wall of the flow. However, the slopes are much too steep for safe climbing, especially in view of the fact that the lava is almost like a glass and breaks into knife-edged fragments. The photograph on Page Two shows the edge of this flow. It also brings out the fact that the top of the flow is very rugged. Broadly viewed, the surface of the flow is quite as flat as the surface upon which it spread, but in detail it is made up of a maze of crags and depressions. During the movement of the lava, the upper parts of the flow cooled quickly into a thick crust, but the lava beneath was so viscous that it could not flow quietly beneath this crust as does the Hawaiian basalt in a pahoehoe flow. Therefore,the movement of the flowing lava continually shattered the frozen crust and carried the blocks along on the surface of the lava stream. These blocks were titled and jumbled together, and when the flow ceased its movement and all of the lava consolidated, the blocks were frozen in the top of the flow in every conceivable position. It is this haphazard chaos of broken blocks which makes the top of the flow so rugged.

In the last phase of the summit eruptions, which is probably the one described in the Indian legends, there were both flows of lava and ejections of pumice. At one locality west of Medicine Lake and just outside of the cones which form the crown of the mountain, the explosions were so violent that they built up a mountain of pumice about 800 feet high. This huge pumice cone is the white knoll in the right background of the picture on Page Three. It is formed entirely of white and grey pumice in pieces ranging in size from that of small peas to that of a man's head. All of it consists of volcanic glass blown so full of volcanic gas bubbles that even the largest pieces will float on water.

Two of the lava flows of this last eruption are of

enormous size and thickness and form what are called Big and Little Glass Mountains. Both mountains are almost entirely devoid of vegetation. Big Glass Mountain lies to the east of Medicine Lake and its lavas cover more than nine square miles and are piled up in the center to a height of about 1,000 feet. It is not easily accessible, but it is actually only a larger model of Little Glass Mountain which is passed by the road into the lake. Little Glass Mountain is made up entirely of volcanic glass with the chemical composition of a rhyolite. The outer edges of the flows are very similar in structure to the edge of the older flow shown in the photograph on Page Two. The broken edges of the glass from this flow are even sharper than those described before. The lava of the Little Glass Mountain flow has frozen in a great many different forms. Much of the top of the flow is really a froth of volcanic glass and looks very much like a rubber bath sponge except that it is made of glass. At the other extreme, much of it is a dense, black glass which is called obsidian. This is the material from which the Indians made many of their arrowheads and cutting implements. Then between the two extremes can be found all intermediate stages, from obsidian with a few large bubble holes to bath sponge stuff with streaks of solid obsidian drawn through it.

The frothy top of the flows have been thrown into waves and troughs by the movement of the flows so that the surface of the mountain when viewed from the forest lookout on Little Mount Hoffmann presents somewhat the appearance of a lake of froth with ripples roughly concentric about the center from which the flow issued. This phenomenon is poorly apparent in the photograph of Little Glass Mountain on Page Three.

The many small eruptions from the flanks of the old volcano yielded lava and cinders of basaltic composition, very similar to the lavas of Kilauea. Most of the flows are small and incline more to the aa than to the pahoehoe surface texture. Over each small vent from which a lava flow issued was built a cone of cinders and slag. The small vents were so numerous and so close together that large areas of the mountain flanks are covered with rough basaltic lava and dotted with cinder cones. This broad waste land on the north flank is called the Modoc Lava Beds and formed excellent hiding ground for the small band of Indians which resisted a large force of American troops in the Modoc Indian War.

One of the youngest flows of this basaltic lava with its associated cinder cone is called Burnt Lava Flow and is located on the southeast flank of the mountain. It is so young that it supports almost no vegetation as can be seen from the photograph on Page One. Mr. Finch and a party from the Lassen Volcano Observatory are planning to determine if possible the exact age of this flow. Its eruption probably occurred within the last 500 years, though it is actually older than the pumice eruptions from the top of the volcano near Medicine Lake since little pockets of the pumic can be found on the surface of Burnt Lava Flow. H.A.P.

KILAUEA REPORT No. 966

WEEK ENDING JULY 27, 1930

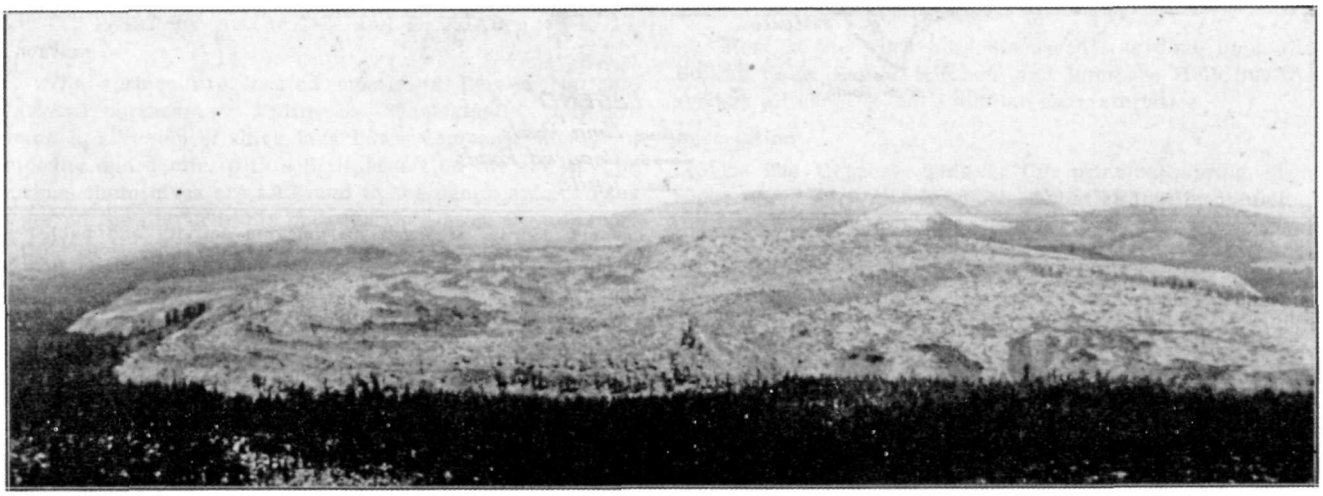
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On July 21, after week end rains, steam reappeared on the south talus in Halemaumau. Still more steam was noticeable in the pit during rain on July 26. A few wall slides occurred during the week, notably one at 5:50 p. m. July 25. There was no change at the 14-ton bowlder.

An earthquake at 1:53 p. m. July 22 was felt generally all over the island, especially in North Kona. Workmen at the halfway house on the Mauna Loa trail were severely jolted. No damage was reported, but the shock was alleged to have been the strongest since the Hualalai series of the previous autumn.

The instruments recorded a total of 10 seismic disturbances for the week. Four of these were short tremors, five were very feeble seisms, and one was a moderate shock felt as described above. Its epicenter appears to have been in the saddle between Hualalai, Mauna Kea, and Mauna Loa. Two of the very feeble seisms were also perceptible; one at 3:10 p. m. July 22 at Paauilo, and one at 3:54 p. m. July 27 at Kapapala Ranch, Kau.

Tilt for the week was slight ENE. Microseismic motion was slight.



A birdseye view of Little Glass Mountain, built up of flows of rhyolitic lava. A mountain of pumice appears in the right background. Photo Powers.



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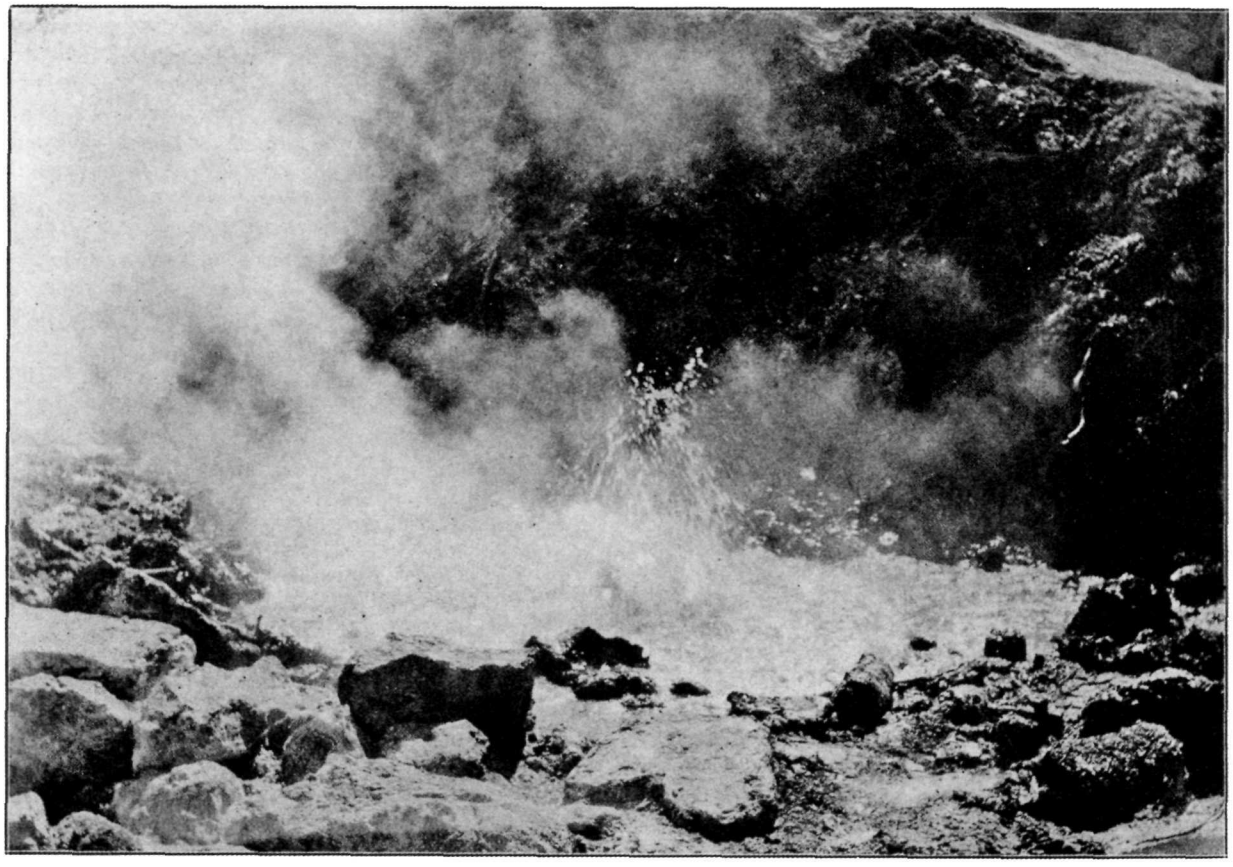


A pool of boiling, solfataric water in Devil's Kitchen, Lassen Volcanic National Park, California. Photo Huff.

HOT SPRING PHENOMENA OF LASSEN VOLCANIC NATIONAL PARK

(From "Volcanic Activity and Hot Springs of Lassen Peak," by Arthur Day and E. J. Allen.)

Location

The springs are located mostly in Lassen National Park in northeastern California. Geologically, they are found in a region of thick lava flows, composed mainly of andesite and dacite, with a little basalt on the edges. The springs themselves are all found in the dacite areas. They occur on the line of faults between the Sierra Nevadas and the Klamath mountains. For the most part they are found on normal faults.

Number

There are about eight groups at intervals of a few miles, their allignment suggesting that they follow two intersecting fissures, A. and B.

Fissure A:

1. Geyser springs.
2. Boiling Lake.
3. Drake Springs.
4. Devil's Kitchen.
5. Bumpass Hell.

Fissure B:

1. Mill Creek Springs.
2. Supan's Springs.
3. Morgan's Springs.

Most of the work here discussed was done upon the Boiling Lake, Devil's Kitchen, and Bumpass Hell, but the springs all seem to have similar characteristics.

Description

1. The Geyser: This is the principal spring of a group of three connecting pools, about 25 feet in diameter, the Geyser being the first. The temperature ranges from 20° C. to the boiling point, which is 94° C. Sometimes it spouts as high as eight feet, though it is often without action.

2. Boiling Lake: It has an oval basin of hot water. Its greatest diameter is 200 yards. The banks are steep for the most part, and it suggests its origin as the basin of an ancient crater. There is a small inlet of cold water at the south end, and a larger outlet of warm water at the north. Both of these become entirely dry in summer. Gas bubbles rise over the surface of the lake. The temperature is about 50° C. Much muddy sediment makes it appear shallow. Algae may be present. It is almost encircled by

a chain of small springs and mud spots, most of which are near the boiling point in temperature. Most of them are near the lake shore, but a few are farther up the slopes. The northern shore is red in color and composed of decomposed lava which has been dyed by iron oxides.

3. Drake's Springs: These are three-fourths of a mile north of the Boiling Lake. They differ in appearance from all of the others. They have a much lower temperature, the highest noted being 62°C. They are, probably because of this lower temperature, choked with bright green vegetation. They are all small, and the individual ones are not well marked. Their mineral content is similar to that in the other springs. but they contain no free acid, or H_2S.

4. Devil's Kitchen: Its site is a deep narrow valley, with a swift, cold stream, called Warner's Creek. The Kitchen, which is rather a flat area, is surrounded on nearly all sides by high steep walls. There is almost no sign of activity on these slopes, but there are many mud pots and hot springs upon the floor. There is no vegetation near them, but the area is forested elswhere. The temperature is about that of Boiling Lake, but the amount of the hot water indicates much greater thermal activity. The Devil's Kitchen also shows an area of precipitated sulphur, while there is almost no free sulphur at Boiling Lake. The Kitchen has many pools which are covered with pyrite as a thin scum, of dark material. The ground near Warner Creek is reduced by decomposition to a dangerous thin crust of earth over hot, sticky mud.

5. Bumpass Hell: This has a crater-shaped basin which is 500 by 1,400 feet in area. It is located high in the mountains, and has almost no vegetation. The thermal action is more concentrated, and the spectacle much more striking in appearance than the others. It contains many boiling fountains, sulphur springs, etc. The rocks are much decomposed at the surface, and the ground is undermined, and easily broken through. The pools are large in size and few in number. There is much free sulphur as a precipitate in some of the pools, and it is also found in needle crystals in many small fumaroles in the west. There are fewer mud pots here than in the Devil's Kitchen. The temperature is usually just below the boiling point, but one fumarole in 1916 gave a temperature of 117.5° C.

6. Supan's Springs: These cover a small area, and most closely resemble the Devil's Kitchen, but they are much smaller. The temperature range is like that of Bumpass Hell. There are many sulphates present, and previous to man's entrance much free sulphur, but this has much of it been removed, though there is apparently not enough present to pay the expenses of a real mine.

7. Morgan's Springs: These were not studied by this party, but the description of them has been taken from Waring. They occupy an area in a meadow, and are composed of quiet pools with a small flow, which are quite shallow and contain some algae, native sulphur, and deposits of calcium and silicon. There are also many chlorides present. The highest temperature is 95.6° C., thus showing the boiling point of springs at this altitude to be lower than that of the others.

Types of Springs

1. Hot Springs. The Lassen hot springs are of the solfataric type.

2. Mud pots. The characteristics of these are a limited water supply, large amount of heat, and no visible outlet. The mud itself may be the result of local chemical action, or may be transported.

3. Mud Volcano. This is caused by drying of mud pot to allow escaping steam to force out clods of mud which build up the cone.

Field Work

1. Maps were made.

2. Temperatures were measured by means of a thermometer in a brass cage. There was no great attempt at accuracy. Their findings showed that the variations in temperature were too great to be accounted for on the basis of change in barometric pressure.

3. Tests for H_2S with $Pb(C_2H_3O_2)_2$ paper showed that though H_2S was widely distributed, only small quantities were escaping from the springs. Also the rise of the gas was not uniform over the entire surface of a pool.

4. Rough litmus paper tests, later borne out by titrations in the laboratory, proved most of the springs to be either neutral, or slightly acid, only a very few being slightly alkaline.

5. Ferrous iron was also tested for at camp, and conclusions were that practically all the iron was in the ferrous form.

6. The amount of free acid was also determined in camp.

7. The water was then carefully bottled and sent to the laboratory.

Laboratory Conclusions

The water was found to consist of sulphates almost entirely, and to be practically free of Cl and Al. The Al present seemed to depend upon the acidity of the water, the greater the acidity the more Al. The springs had no ferric iron present at all, while Boiling Lake had no ferrous, being entirely ferric iron.

The volume of gases given off was found to be very small. The analysis showed the presence of CO_2, H_2S, CH_4, H_2, N_2, A, O_2, and the order of these as given indicates roughly the order of the amounts found.

Deposits of soluble salts are to be found about the springs at various times, though no one has been able to determine as yet just what causes them to appear and disappear when they do. These salts upon analysis gave tests for Al, Fe++, Mg, Na, K. and So_4 in all cases, and for these additional ones in some cases: Fe+++, Ti, Mn, Ca, Li, NH_4 H, S_5O_6. One case showed Cl. S was also usually present. (It is rather surprising that, if the statement that these springs showed the presence of NH_4 as salts is true, the gas analysis showed no NH_3 present in the water.)

Pyrites were found at Geyser, Boiling Lake, Devil's Kitchen, and Bumpass Hell. They were not looked for elsewhere.

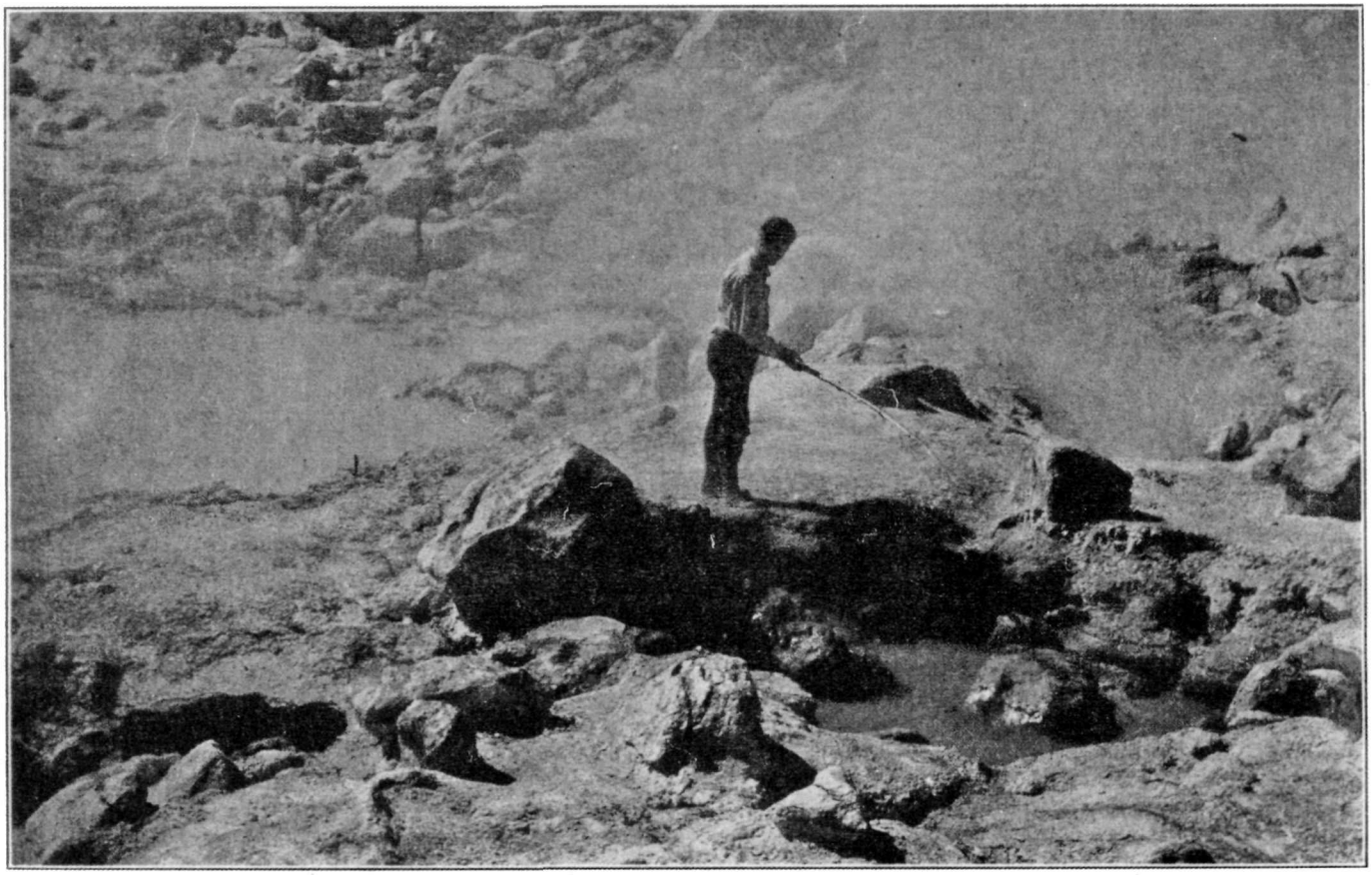
Chemical Effects

1. The formation of pyrite. Problematic, possibly from $FeSO_4$.

2. The formation of H_2SO_4. From S by oxidation. (Park—possibly from oxidation of pyrite.) (Bunsen—by oxidation of SO_2 and combination with water.) But this last would also produce H_2SO_3 and there is none at all present. There is evidence, however, that H_2S is directly changed to H_2SO_4.

Chemical Decomposition of Lavas

Silica is always the final residue. There are two types of reaction: (1) Those which produce kaolin and no $Al_2(SO_4)_3$; (2) those which produce silica and $Al_2(SO_4)_3$.



Method of taking pool temperatures by immersing thermometer in the scalding water. Pool at Bumpass Hell. Photo Finch, Lassen Volcano Observatory.

Pentathionate is probably the decomposition product of lava due to the action of SiO_2 and H_2S.

Original of Hot Springs and Their Relation to Igneous Activity

The heat supply must be great. Possible sources are:

1. Radioactivity. This has absolutely nothing to do with it since it was shown that the cold water in the Yellowstone was slightly more radioactive than the warm.

2. Chemical Processes. This is a minor factor, and the reactions are not rapid enough or extensive enough to yield either a heavily mineralized water or much heat.

3. Volcanic. Therefore since the other possibilities have been proved false, the only possible explanation is that of heating by means of magma. That this is the fact may be proved by the location of these springs along cracks or fissures, and the fact that gases are emitted.

Conclusion

The conclusions reached are that the springs are fed chiefly by surface water, derived from precipitation, and that another portion of the water rises in the form of very hot water or steam, from an underlying batholith, which mingles with the other and thus heats it. This shows the close relation of the hot springs to fumaroles, and explains both the variations in temperature of the water and in size, and appearance on the basis of the amount of precipitation.

Hazel G. Robinson.

JULY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

June 30-July 6	0.60 second	SW.
July 7-13	1.09 seconds	S.
July 14-20	0.36 second	NW.
July 21-27	0.48 second	NE.

KILAUEA REPORT No. 967

WEEK ENDING AUGUST 3, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

No changes were observed at Kilauea Volcano throughout the week. Steam was absent from the interior of Halemaumau except a little seen on the south talus at 2 p. m. August 1.

In addition to three very feeble seisms recorded by the seismographs were 10 minute volcanic tremors, three showing tilt to the east during registration.

Tilt for the week accumulated moderately NNE. Microseismic motion continues to be light.



THE VOLCANO LETTER

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Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

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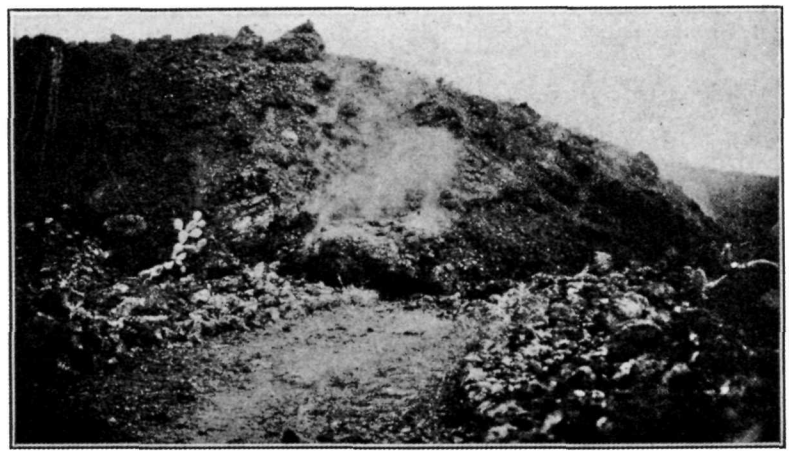
No. 294—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 14, 1930



Front of the 1926 flow of aa lava from Mauna Loa as it crossed the government road above Hoopuloa. The resemblance to a pile of huge cinders is shown well in this picture. Photo Boles.

A REVIEW OF THE AA-PAHOEHOE QUESTION

(By G. L. CHANG)

Most of the lava flows at the basaltic vents of Kilauea and Mauna Loa in Hawaii assume surface forms known commonly to us as "aa" or "block" lava and "pahoehoe" or "ropy" lava.

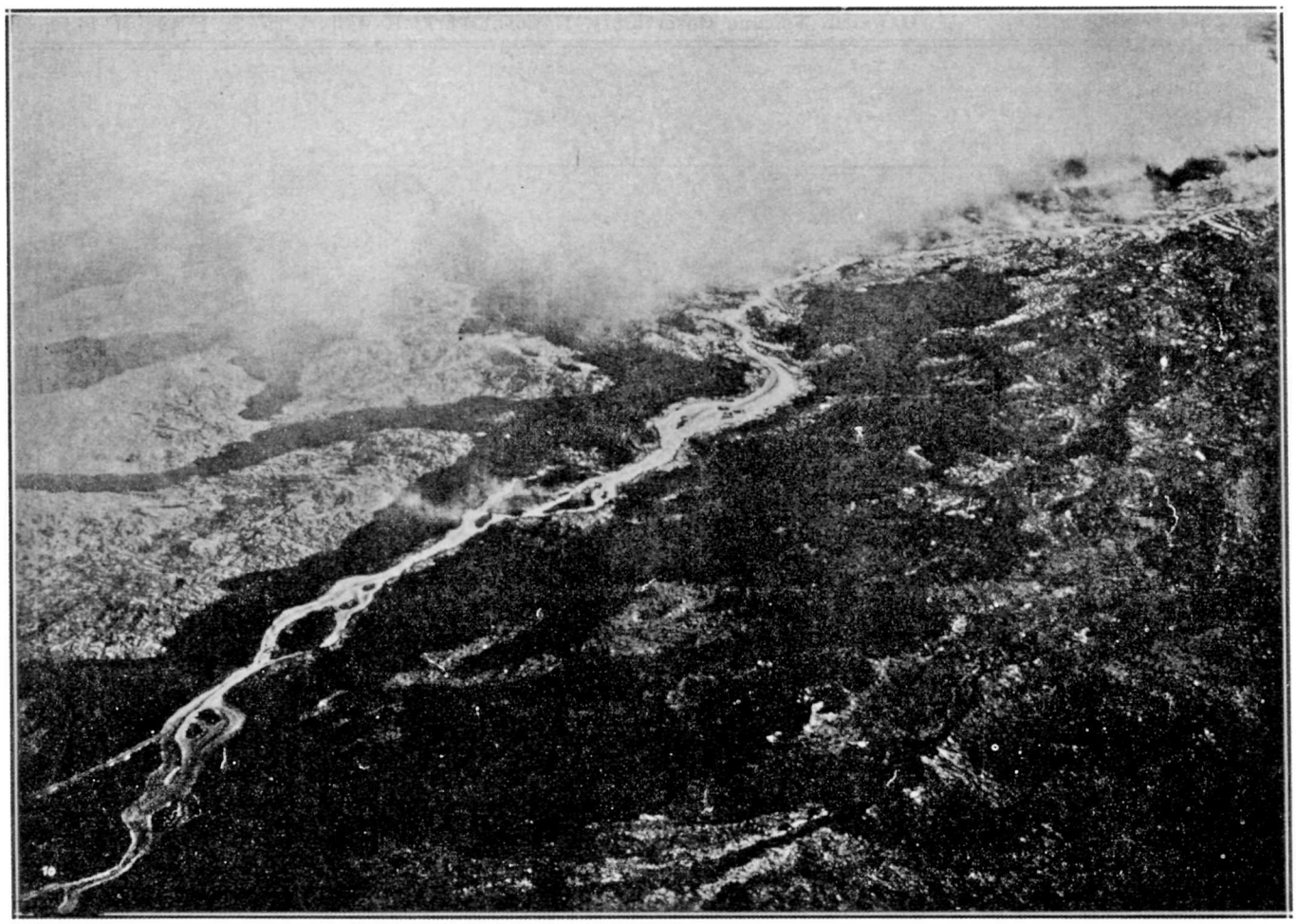
The rough aa surfaces are formed by material which is essentially crystalline, while the smoother pahoehoe surface is formed by a definite layer of glass. This glassy skin varies greatly in thickness; also in vesicularity it varies from a froth to an almost continuous solid. A surface that is not glassy is commonly more or less rough and aa-like, and not infrequently such surfaces are found in pahoehoe flows where cracking of the surface crusts has exposed crystallizing lava.

That there is no noteworthy difference chemically between aa and pahoehoe is generally accepted. The crystalline parts of a lava mass generally have a higher proportion of ferric oxide than the glassy ones, and the cause of the difference may be complex. A flow frequently starts as pahoehoe and changes to aa, but the reverse apparently never occurs, although in a great eruptive period like that of Mauna Loa in 1880 and 1881 the earlier discharges are dominantly aa and the later ones pahoehoe. In the transition zones the two forms are often intimately mixed, and, further more, hand specimens can be found having the glassy pahoehoe skin on one side and the rough features of aa on the other.

By several experiments it has been proven that the formation of aa is due to crystallization while the flow is in motion. When a given mass of lava has crystallized to the extent that it ceases to flow readily, and the forces acting on it are sufficient, it crumbles into loose blocks, some of which subsequently stick together giving the fantastic shapes so characteristic of aa. In the field, crystallization must frequently take place rapidly as the transition from a liquid stream to blocks of solid aa is often very short both in time and distance. However, if the flow is slower, allowing skins of chilled glass to form over the surface and if the force of the flowing lava is insufficient to break them, pahoehoe is formed.

The flank eruptions of Mauna Loa start with giant fountains which pour out enormous and rapid streams of lava. They may flow a short distance as pahoehoe, but usually soon change to aa. The Alika flow of 1919, which broke out from the southwestern flank of Mauna Loa at an elevation of about 8,000 feet, was fed by a series of fountains some 200 feet high, and the lava which cooled near the source was a glassy and frothy pahoehoe. Farther down, the lava flowed in a definite channel at a rapid rate, and where it crossed the government road in Kona 10 miles from the source it was still intensely hot and liquid. At times the stream rose and overflowed its banks and the resulting flood cooled as aa. Dr. Jaggar, who observed all this, said that at no time was there any tendency to form glassy pahoehoe skins. A thin section of some of the lava, collected where the main Kona road now crosses the flow, contains about 10 per cent of phenocrysts (large crystals), chiefly feldspar, enclosed in a matrix made up largely of glass (lava which has frozen too rapidly to crystallize). This composition indicates that comparatively little crystallization had actually taken place before the overflow.

It is in the declining phases of the Mauna Loa activity that most of the pahoehoe is formed. Crusts form over the lava until the stream of liquid lava flows continuously in tunnels and so may flow for long distances without los-



Airplane view of Hoopuloa flow of April 18, 1926, showing the incandescent lava stream flowing through a field of aa already frozen from the same flow. Transition from pahoehoe to aa lava is shown in the upper right. Photo Eleventh Photo Section, U. S. Army Air Service.

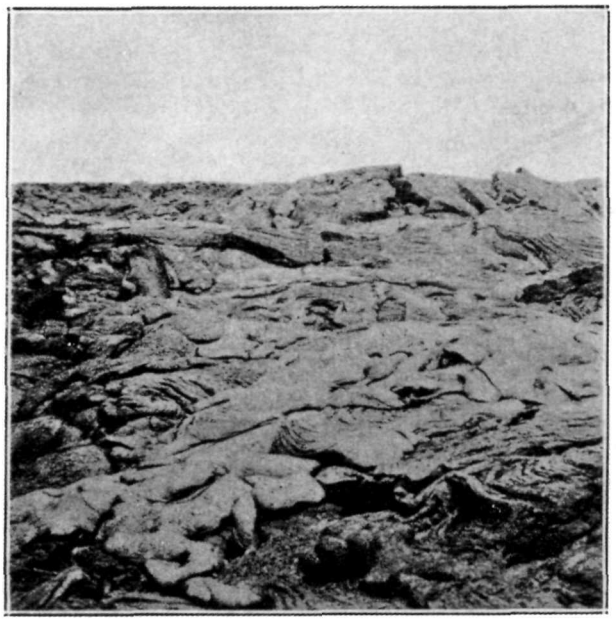
ing much heat. The flow advances by pushing out bright toes along the edges, which flow gently compared with a raging torrent like the Alika lava river.

In Kilauea crater there is little aa. Most of the overflows of Halemaumau have spread out over the gentle slope in large sluggish sheets or have been the thin shelly variety without any body. However Dr. Jaggar has observed several times that when the lakes in Halemaumau are drained, the bottom is covered with aa.

The eruptions from the flank of Kilauea in 1823 and 1840 appear to have been similar to the Mauna Loa outbreaks and much aa was produced. A significant feature of the 1823 flow is that the change from pahoehoe to aa took place just as the lava reached the edge of the gentle slope upon which it was discharged and started down a much steeper incline. An excellent record was kept of the 1920 flow which was probably the greatest discharge from Kilauea during historic time. The main activity took place some six miles southwest of Halemaumau where there was a rapid and voluminous flow which in a very few days travelled six miles. The extreme upper part of this was pahoehoe, but farther down it quickly changed to aa. Subsequently this vent poured out a series of short pahoehoe flows which built up a broad low dome. The summit crater behaved very much like Halemaumau with its bubbling and fountaining, and all of the flows from it were pahoehoe. Occasionally the flank of the slag heap was ruptured, discharging a mass of aa which resembled a landslide more than a flow.

An attempt was made to see what differences there are in the crystallinity of pahoehoe interiors and aa. Accordingly thin sections were made of representative types of lavas from the flows of 1868, 1887, 1880, 1881, 1907, 1919, and 1920. There was also a sample of aa from the bottom of Halemaumau which was exposed in May, 1917. This brief study indicated little tangible difference between the two.

It has been suggested that gases dissolved in the melt, of which water is the most abundant, are important agents in controlling crystallization and the formation of aa and pahoehoe, the theory being that aa is formed from lava containing and releasing the greater quantity of gas. Concerning this view, Dr. Jaggar said, "I know of no quantitative proof. Flames about aa are very apt to be due to



Toes of pahoehoe lava advancing slowly in the Mauna Iki flow of July 23, 1920. Kau Desert, near Kamakaia. Photo Jaggar.

burning vegetation. Pahoehoe crusts over so much that it confines its gas rather than gives it off. Pahoehoe pools remote from the source region often form blowing cones with flames at the orifices. Live streams of both pahoehoe and aa show bubbling, the former making blisters or small fountains, and the latter, occasional heavy, viscous bursts." In vesicularity, both aa and pahoehoe vary within wide limits, but the total volume of vesicles in aa is inclined to be less in a unit volume of rock than in pahoehoe, and the individual aa vesicles are inclined to be more irregular in both size and shape.

References

O. H. Emerson, The Formation of Aa and Pahoehoe, Am. Jour. Sci. 12, 1926, pp. 109-114.

H. S. Washington, The Formation of Aa and Pahoehoe, Am. Jour. Sci. 6, 1923, pp. 416.

T. A. Jaggar, Aphrolith and Dermolith, Jour. Wash. Acad. Sci. 7, 1917, pp. 277-281.

R. A. Daly, Igneous Rocks and their Origin, 1914, p. 290.

Monthly Bulletin of the Hawaiian Volcano Observatory, Oct. and Nov., 1919.

KILAUEA REPORT No. 968

WEEK ENDING AUGUST 10, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

To the casual observer, there have been no important changes in the appearance of Halemaumau during the week August 3 to August 10. Some new scars left by small rock slides were noticed on the north and east walls on August 5, and the steaming from the wall and talus cracks was slight during the early part of the week. During the heavy rain of the week-end intense steam clouds rose continually from the pit and from the cracks of the Kilauea floor.

However, the instrumental records show a number of interesting features. Two feeble earthquakes, one at 8:52 a. m. August 5 and one at 11:14 a. m. August 8, were felt in the National Park area. The center of the first was located 9 miles from the Observatory and that of the second was located at Kilauea. There were three very feeble shocks which were not felt in the Park timed as follows: 10:03 a. m. August 4 distance 14 miles, 3:09 p. m. August 8 distance not known, and 5:50 p. m. August 9 distance not known. There were several small tremors recorded (each lasting a fraction of a minute), with more of them showing on the two instruments close to Halemaumau than on the instrument at the Observatory which is nearly two miles from the pit. This would seem to mean that the feeble tremors had their origin in or under Halemaumau. They were recorded as follows:

Date	Observatory	Uwekahuna	Pit
August 4	1	2	2
August 5	0	7	5
August 6	2	2	2
August 7	0	1	0
August 8	0	5	2
August 9	2	4	3
August 10	0	0	1

Measurements of the tilting of the ground under the Observatory show that the average accumulation for the past week has been a slight tilt to the northeast. In other words, the rim of Kilauea crater under the Observatory has been tilted up and away from the pit, possibly by an increase of lava pressure under Halemaumau. Heretofore, the weekly tilt report has been taken from the difference in tilt between the last day of the current week and the last day of the preceeding week. From now on, the tilt report will express the difference in average accumulation of tilt between the current week and the preceeding week.

The small seismograph on the edge of Halemaumau indicates that the rim at that place has been tilted up and away from the pit. If one imagines a vertical wand standing on the edge of the pit, the tilting of the ground under it during the past week would have inclined the wand over 10 seconds of arc from the vertical position away from the pit. This is an extremely strong tilt and is much more than the Kilauea rim under the Observatory has been tilted during the same time.

Microseismic motion was strong from August 7 to August 10 accompanying the high wind and the heavy surf. This microseismic motion is a very slight vibration of the earth which causes the seismograph pens to write a wavy line, but is probably not caused by any volcanic forces.

The conclusion drawn from all this evidence is that lava pressure is increasing under Halemaumau. **It is impossible to say whether or not this will result in an eruption,** but it can be said confidently that conditions look more favorable now than at any time in the past several months.


NORTH KOHALA
SOUTH KOHALA
NORTH HAMAKUA
SOUTH HAMAKUA
NORTH HILO
SOUTH HILO
HILO
PUNA
KONA
SOUTH KONA
KAU
Island of
HAWAII
MAUNA KEA 13825
MAUNA LOA 13,675
MOKUAWEOWEO CRATER
KILAUEA CRATER
HAWAII NATIONAL PARK
KAU DESERT
Ranch
SUMMIT 5505
REST HOUSE 10,060
HALF WAY HOUSE
VOLCANO HOUSE
Military Camp
Bird Park
Tropical Jungle
Mountain View
Rainbow Falls
Boiling Pots
Onomea Arch
Akaka Falls
Laupahoehoe Peninsula
Honohina
Hakalau
Honomu
Papaikou
Pepeekeo
Ookala
Paauilo
Honohaa
Waimanu
Waipio Valley
Kukuihaile
Kawaihae
Puukohola
Puako
Kamuela
Parker Ranch
Kiholo
West Point
Kailua
Old Royal Fort
Rock Pictures
Kahaluu
Keauhou
Kainaliu
Kealakekua
Cook's Monument
Kealakekua Bay
Napoopoo
Honaunau
City of Refuge
Hookena
Kaohe
Pahoehoe
Aiikapapa
Hoopuloa
Punaluu
Honuapo
Kaalualu
Ka Lae
South Point
Kaiohinu
Kahuku Ranch
Pahala
Puu o Keokeo
Kapapala
Kapopala
Kamakaia
Keauhou
Wahaula
Heiau
Kaimu
Kalapana Cocoanut Grove
Cave of Refuge
Makaopuni
Lava Trees
Kehena
Kamailii
Opinikao
Pohoiki
Heiau
East Point
Hot Spring
Green Lake
Kapoho
Haena
Kaumana Caves
Puu Oo
Waiakea
Hilo
Kukuau
Pololu
Waimanu
Honokaa
Paauhau
Kohala
Summit
Mauna Kea
Mauna Loa
Flow 1843
Flow 1881
Flow 1887
Flow 1907
Flow 1919
Flow 1926
Flow 1868
Flow 1840
Flow 1855
Flow 1852
Flow 1801
Flow 1859
Flow 1880
Flow 1942
Flow 1935
Flow 1950
Flow 1960
Flow 1955
Flow 1901
Flow 1907
Flow 1926
Flow 1919
Flow 1887
Flow 1907
Flow 1926
Flow 1919
Flow 1887
Flow 1907
Flow 1926
Flow 1919
Flow 1887

The Volcano Letter

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No. 295—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 21, 1930



Dr. E. S. Shepherd and Alec Lancanster collecting gases with vacuum tubes from the edge of a lava lake in Halemaumau. From Journal of Geology, April-May, 1925.

COMPOSITION OF GASES OF KILAUEA

(A review by A. N. LIKE)

The search for the sources of energy back of volcanic phenomena requires not only a continuous observation of the physical activities of the volcano but also an examination of the material thrown out from the crater, i. e., lava in all its forms and gases. It is the latter with which we are concerned in this review. The gaseous emanations have necessarily attracted much attention.

The chief gas collections made at Kilauea in 1912 were from a flaming cone on the floor by Day and Shepherd. The somewhat crude apparatus used in this collection was a train of collecting tubes and pumps. On account of the condensation of water in the tubes, quantitative results could not be reported on the gas as a whole. In 1917, Shepherd endeavored to collect gases by thrusting vacuum tubes into flaming holes in the crust of the lava lake. The difficult part of such collecting is to get the gas in the tube sealed off without having the tube filled with air during the process. During 1918 and 1919, Dr. Jaggar made a number of gas collections from various sources at Kilauea with intent to discover not only the nature of the gases evolved but also the most favorable sources.

In 1912, the gases collected at Kilauea by Day and Shepherd had the following approximate average composition by volume for one thousand liters of gas:

H_2O	CO_2	SO_2	CO	H_2	S_2	N_2
.04	.25	.50	.02	.03	.02	.14

This collection by Day and Shepherd demonstrated the presence of the three combustible gases, CO, H_2, and S_2, and of the products of combustion, CO_2, and H_2S. There was an abundance of nitrogen in these collections.

The samples collected in 1917 gave the following analyses:

Table I, volume per cent at 1200° C.

Tube	CO_2	CO	H_2	N_2	A	SO_2	S_2	CL_2	H_2O
1	2.65	1.04	4.22	23.22	n.d.	0.16	0.70	n.d.	67.99
2	17.95	0.36	1.35	37.84	n.d.	3.51	5.49	n.d.	38.48
3	33.48	1.42	1.56	12.88	0.45	29.83	1.79	0.17	17.97
4	11.12	3.92	1.42	.....	0.51	.....	8.61	0.02	77.50
5	9.54	1.12	1.53	10.47	.....	9.90	2.72	.....	64.71
6	1.97	0.82	0.21	3.50	0.07	0.95	2.70	.....	89.77
7	17.25.	0.62	0.76	5.88	0.18	9.75	1.07	0.25	64.18
8	15.27	0.45	0.70	0.87	0.14	6.98	0.49	.....	75.08
9	8.32	0.82	1.82	8.92	0.29	16.80	2.49	1.01	59.97
10	1.54	0.43	0.37	2.44	0.39	.....	3.56	1.34	89.93
17 (°)	11.61	0.37	0.58	1.29	0.04	6.48	0.24	0.05	79.31

(°) Collected by T. A. Jaggar, March 17, 1919.

These analyses bring out certain relations. CO is usually present in less quantity than H_2. Next to H_2O, CO_2 is the chief constituent and often the rare gases (computed as argon) are no more than would be required on the assumption that the nitrogen came in as air. The chlorine content is surprisingly low. On the other hand, tube 4 shows over 7 per cent of sulphur which agrees with the observation that at times fountains break which set free violent brown fumes which look like sulphur vapor. The water is surprisingly high in all the samples and it is always present. Either we must allow some validity to the thesis that salt water diffuses through the earth's crust and reappears in the volcanoes, or admit a thesis by Dr. T. A. Jaggar that the combustible gases are burned at and below the lake surfaces by air carried down by sinking crusts, air sucked by fountaining, and oxygen diffusing into the lava as it rises in the conduit. These analyses



Direct photograph with a Wratten Panchromatic Plate of pale yellow-green flames about five inches long from a distance of five feet, August 23, 1918. Photo Jaggar.

indicate perhaps that all three of the processes postulated by Dr. Jaggar are active. Trapped air would call for a great deal more of nitrogen, but this does not apply to oxidation along the conduits or at the lake surface. Dr. Shepherd tends to accept the surface combustion as an important factor in the maintenance of the lake's heat supply. On the other hand, the great variations in composition of all samples collected lends support to Day's thesis that a part of the energy may be derived from the shifting of gas equilibria due to a lack of equilibrium among the gases rising in the magma.

Tube	CO_2	CO	H_2	N_2	A	SO_2	S	SO_3	CL_2	H_2O	A/AN
2	5.97	0.00	0.00	7.92	nd	4.76	0.00	2.41	4.08	75.00	0
3	6.63	0.22	0.15	2.37	0.56	3.23	0.00	5.51	1.11	80.31	0.191
4	6.79	0.14	0.17	2.33	0.00	1.38	0.15	3.43	0.62	84.98	0.000
6	0.87	0.16	0.07	20.01	0.00	0.01	0.00	0.13	0.03	78.71	0.000
8	47.68	1.46	0.48	2.41	0.14	11.15	0.04	0.42	0.04	36.18	0.054
10	16.41	0.11	0.10	15.03	0.21	13.57	0.05	3.56	0.03	50.88	0.013
11	20.93	0.59	0.32	4.13	0.31	11.42	0.25	0.55	0.00	61.56	0.039
12	1.42	0.05	0.08	0.68	0.05	0.51	0.07	0.00	0.03	97.09	0.068
13	16.96	0.58	0.96	3.35	0.66	7.91	0.09	2.46	0.10	67.52	0.139
14	14.81	0.47	0.17	2.91	0.00	3.65	0.10	1.03	0.00	76.84	0.000
15	11.53	0.13	0.10	6.20	0.16	6.14	0.03	1.70	0.10	73.89	0.025
16	18.03	0.56	0.67	3.11	0.08	8.53	0.15	2.53	0.08	66.25	0.025
17	11.61	0.37	0.58	1.29	0.04	6.48	0.24	0.00	0.05	79.31	0.030
18	17.55	0.74	0.83	4.50	0.12	10.81	0.22	3.22	0.13	61.88	0.026

Table II. Gases collected from Kilauea, 1919. Volume per cent at 1200° C.

A comparison of these figures with the Shepherd collection of 1917 and with the two gases from Mauna Loa shows a general agreement in major constituents, a general agreement in the degree of oxidation, and a lack of any uniformity in the quantities of the minor constituents. One can definitely say that there is no evidence of equilibrium obtained from among the various sources.

Summary

The analysis of some 25 samples of gas taken at Kilauea between 1912 and 1919 shows that:

1. The major emanation from this volcano is water (H_2O), the average of water in all analyses being about 70 per cent of the gas evolved.

2. Second in order of magnitude comes carbon dioxide (CO_2) with sulphur dioxide (SO_2) following in the third place.

3. Sulphur trioxide (SO_3) occurs in variable amounts. in one instance rising to five per cent, whereas, in the two samples from Mauna Loa, it reached the high value of near eight per cent

4. Sulphur, while usually small in quantity, sometimes makes up as much as eight per cent.

5. In general, the 1917 collection, obtained from passing crusts at the lake edge, contains higher amount of hydrogen and carbon monoxide than that of 1918-1919. The general inference is, however, that, quite regardless of the

source from which the gas is obtained. it reaches the surface almost completely burned or else is actively burning in the upper layer of the lake.

6. In general the ratio of argon to nitrogen is about three times as great as in atmospheric nitrogen.

7. Chlorine occurs in relatively small amount The presence of fluorine could not be tested satisfactorily in the volumes of gas which were analysed. In the 1912 collection there was evidence that fluorine was present in about twice the volume or amount of chlorine.

8. Hydrocarbons are apparently absent or else present in inappreciable amounts.

9. The water present may well be partly due to oxidation of evolved hydrogen, but such oxidation must occur in the body of the lake presumably near the surface. It does not seem probable that this combination could occur at the actual surface since any such quantities of hydrogen as would be implied by the great amount of water would certainly show marked explosion phenomena. Certainly the highly oxidized condition of these gases taken as they are from all sorts of promising sources argues strongly for the hypothesis that combustible gases are burned at and below the lake surface.

The outstanding fact about the samples of gases from Mauna Loa is the high degree of oxidation. Hydrogen is practically absent and carbon monoxide is nearly as minute in quantity. Certain unexplained eccentricities in the analytical data might indicate very small amounts of hydrocarbons but with such minute quantities, a definite decision is impossible In any case, everything that could oxidize has done so yet the amount of nitrogen is not excessive. Here, as in Kilauea gases, the amount of nitrogen is insufficient to account for the water present. Perhaps the next important fact is that SO_3 is present in relatively large amount and this accounts for difficulties both in breathing and smelling. It is common experience that SO_3 particles or even sulphuric acid particles are not easily removed from the air. Rare gases computed as argon are relatively high, and chlorine is notably lacking. On the whole the Mauna Loa gases seem to be like those from Kilauea.

References

T. A. Jaggar, Gases of Kilauea, Am. Jour .Sci. 44, 1917, pp. 161-168

E. S. Shepherd, Composition of Gases of Kilauea, Haw. Volc. Obs. Bull., vol. 7, No. 7, pp. 94-97.

E. S. Shepherd, Two Collections from Mauna Loa, Haw. Volc. Obs. Bull., vol. 8, No. 5, May 1920, pp. 65.

E. S. Shepherd, Kilauea Gases, 1910, Haw. Volc. Obs. Bull., vol. 9, No. 5, May 1921, pp. 83-88.

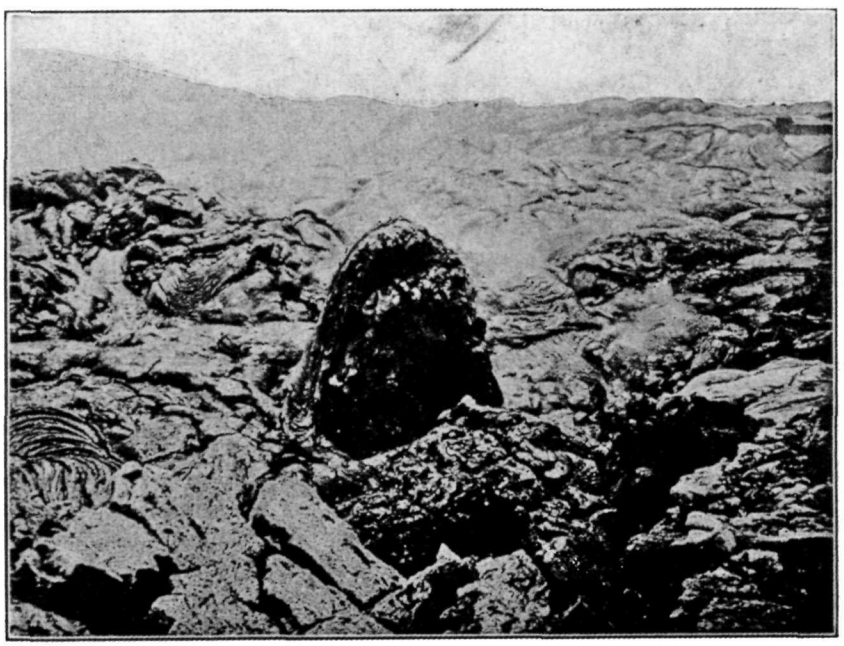
KILAUEA REPORT No. 969

WEEK ENDING AUGUST 17, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

On Monday and Tuesday of last week, during and immediately following the heavy rains, huge clouds of steam were rising from Halemaumau. They were so unusual in appearance that they formed the basis of a rumor circulated in Hilo to the effect that the pit was active again. By Wednesday, the steaming of the Halemaumau floor-cracks had ceased except in the small sulphur-stained area in the southwest part of the pit. Even these had stopped their steaming by Sunday. There has been no avalanching from the walls, and the weekly measurement of the cracks around the 14-ton bowlder showed that no movement has occurred at that point.

The average accumulation of tilt at the Observatory for the week was moderate to the S-SE, which would indicate a depression of the Kilauea wall toward the south.



Northwest cone from which gas was escaping under high pressure and burning as soon as it reached the air. The photograph on page two was taken on the side of this cone at 11 p. m. Photo Jaggar.

It was interesting to note that much southerly tilt was recorded on August 10, 11, and 12, during the heavy rain, but slight recovery to the north began on the 13th after the rain had stopped. Two very feeble quakes which seemed to center on Mauna Loa were accompanied by tilt to the east as if the ground at the Observatory had moved a little up and away from the center of the quakes. The ground under the instrument at Halemaumau sagged slightly toward the pit on Wednesday after the rain ceased, and has remained almost stationary for the rest of the week.

Three very feeble earthquakes, not felt in the National Park, were recorded as follows: August 14, 12:12 a. m. distance not known; August 16, 3:46 a. m. distance doubtfully 23 miles; and August 17, 7:30 p. m. distance doubtfully 55 miles. Small tremors lasting less than a minute have not been as numerous as during last week, but more of them still are recorded on the Pit and Uwekahuna instruments than on the one at the Observatory. Between 9:16 and 9:45 p. m., August 15, all three instruments recorded about twenty minutes of slight but continuous tremor. Microseisms, caused by the constant vibration of the earth, have been slight since August 11, which date seemed to mark the end of the heavy storm of last week-end.

It would seem from this information that the pressure under Halemaumau has moderated during this past week. The coincidence of the abrupt tilting to the south with the heavy rainfall suggests that the weight of the water added to the surface of the mountain may have caused the tilting, but this cannot be proved without a number of parallel cases to support it.

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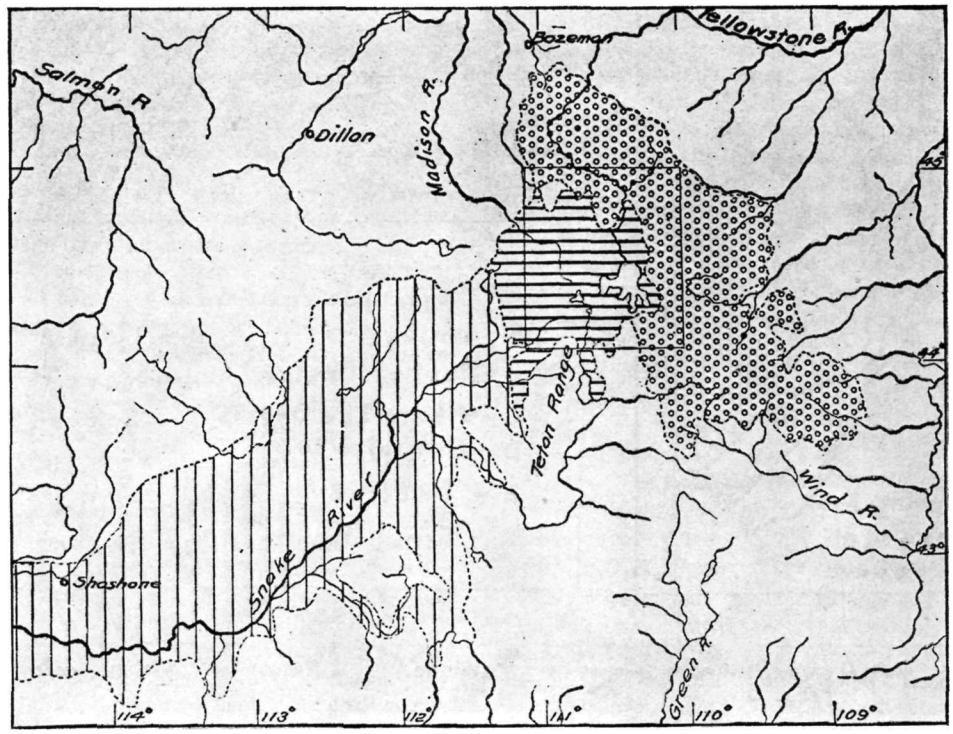
The Volcano Letter

296

Two dollars per year — Ten cents per copy

No. 296—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 28, 1930



Region of Shoshone and the Snake River Basalt (vertical lines) in relation to (Pliocene) Yellowstone Rhyolite (horizontal lines), and andesites of the early Tertiary (circles). Proc. Amer. Acad. Arts and Sci., June, 1911, p. 64

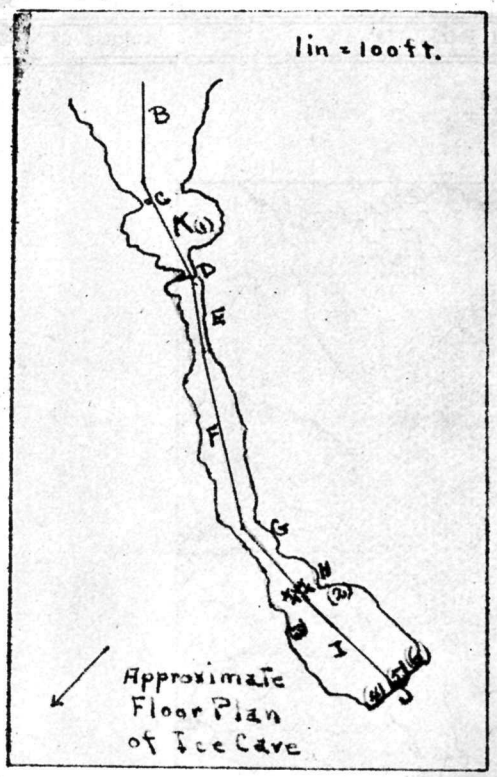
THE SHOSHONE ICE CAVE, IDAHO

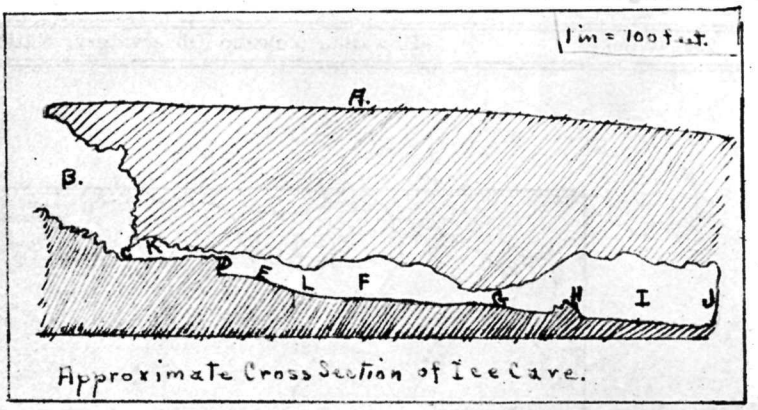
(By H. G. ROBINSON)

This ice cave is located in south central Idaho about thirty miles north of Shoshone, just off the state highway leading to Hailey. The entire region is underlain by Pleistocene lava, but in several places there are Recent lava flows. The most famous of these are the Craters of the Moon, which are located about eighty miles north of the Shoshone Cave. The cave is situated in another small Recent flow, the surface of which has been undermined by huge gas bubbles, which have subsequently caved in, leaving the otherwise fairly smooth surface of the flow broken by many crater-like depressions from one to two hundred feet in diameter. Several caves, or apparent remnants of the old tubes, lead off from these "craters," and one other of these besides the Ice Cave has ice in it near its entrance at certain times of the year, thus obtaining the name of Little Ice Cave.

The Shoshone Ice Cave opens at the bottom of the western end of one of these craters, and extends back in a southwesterly direction for four hundred feet, where it is abruptly terminated by a solid wall of ice. A study of the cave was made during the first part of 1930 in an attempt to determine the causes of the phenomenon.

The first visit was made Saturday, January 4. The weather was clear and cold. The temperature outside the cave was -7 degrees Centigrade (seven degrees below freezing). There was a fall of several inches of snow upon the ground. The party set iron stakes in the ice at various points, measuring the amount which protruded, in the hope of obtaining some idea of the amount of melting or freezing during the succeeding months. Measurements of the length and breadth of the cave were also made and heights were estimated. The party took several flashlight pictures also. There was much hoar frost on the ceilings and walls, and many ice stalactites and stalagmites might be observed. There was no water to be found upon the floor of the cave, but instead a sheet of solid ice, several inches thick, covered the entire floor between two points marked "C" and "J" on the diagram. This fact was noticed with great interest, since the local tradition is to the effect that "the ice melts in winter, and freezes in summer." This was proved untrue by the absence of water on the floor during this visit in the dead of winter—one of the very few, if not the only one, that has been made at that time of year. There were, however, two places near the rock pile marked "H" where a slight dripping from the ceiling was noticed, sufficient to make the ice somewhat slippery under foot.





Key

A - Surface
B - Part of "Crater"
C - Where Ice Begins
D - Abrupt Drop
E - Incline
F - First "Room"
G - Tunnel
H - Rock Pile
I - Second Room
J - Ice Wall
K - Entrance
L - Foot of Slide

	Temperatures in Degrees Farenheit.							Amount of Stake Protruding in Inches.					
Date	Outside	Entrance K	Foot of Ladder D	Foot of Slide L	Tunnel G	Rock Pile H	Ice Wall J	Entrance (1)	Left Floor (2)	Right Floor (3)	Right Wall (4)	Center (5)	Left Wall (6)
Jan. 4	13°	32°	35°	39°	34°	34°	34°	Flush	1¼"	1"	4⅞"	3¾"	1¾"
Feb. 15	50°	28°	30½°	33°	31½°	33⅜°	31°	¼"	1¾"	⅞"	2¼"	3¼"	1⅛"
Apr 6	78°	32½°	35°	—	—	34°	33½°	½"	1¾"	1½"	2¾"	Removed	2⅛"
May 18	80°	34°	35°	—	—	—	37°	⅜"	1⅜"	1¼"	Removed	"	2⅜"

A plan and section of the Shoshone Ice Cave (above) and the table of measurements showing changes of temperature and amount of melting ice. H. G. Robinson.

The second visit was made on Saturday, February 15, 1930. There was still much snow on the ground. The members of the party had to wade through knee-deep drifts in the "crater." The weather was clear but not as cold as on the last visit, the thermometer registering about 50 degrees Farenheit in the sunlight. Conditions at the entrance seemed much the same as on the last trip, despite the much warmer weather outside. But we had not gone far into the cave before we heard the sound of dripping water. Hurrying through the first cave, at the end of the tunnel which leads into the larger room we found several ice stalagmites from six inches to a foot in height on the floor of the tunnel. A little farther, at the rock pile "H," water was dripping steadily from above. and there was enough water on the floor to wet the feet and splash a little as we went through it. This was the same point at which the moisture was noticed on the last visit, but at this time it was much more abundant. At all other

parts of the cave the floor was solid ice as on the first visit.

More pictures were taken of the ice wall at the rear, and some excellent views of the stalagmites were obtained. On throwing the beams from our flashlights upon the roof we noticed much more crystallization there than on the first visit. In fact both the walls and roof were covered with the most glorious and fantastically shaped ice crystals. Several flashlight pictures were attempted but proved to be disappointments. It was not until a few months later when we got a portrait attachment for the camera that we were able to get anything like satisfactory pictures of these crystals, and even they do not do justice to the original.

The third visit was made on Sunday, April 6, 1930. The thermometer registered about 78 degrees F. The day was clear and hot. No icicles were seen on this trip. Stalagmites were still present and much crystallization on the roof. A new feature of this visit was the presence of great quantities of ice on the rocks outside the entrance between "C" and "B." This was not present on any of the previous visits, and is hard to explain since the ice-covered rocks were under the overhang of the "crater" wall where the drip from the melting snow could not have easily reached them. Patches of snow were seen occasionally. The dripping at the rock pile "H" had almost entirely ceased, the floor being only a little slippery from the presence of a thin film of water on the surface. The ice was everywhere as thick as usual, in fact, we have reason to believe that it was thicker than on our first visit. A newspaper brought in with the flashlight powder on the first trip had been left on the rock pile. This paper was now covered with ice to a depth of at least four inches, the ice undoubtedly having come from the freezing of the water which dripped in above the rock pile.

The fourth visit was made on Sunday, May 18, 1930. The weather was clear and quite warm. Upon this, the last visit, several more pictures were taken, in particular several of the crystals, with the portrait attachment, and one of a huge stalagmite at the top of the rock pile. There was still ice to be seen at the entrance outside, though it seemed to be melting rapidly. The crystals were not as perfect as on the previous visit, but some very fair pictures were obtained. There was no water at all in the bottom of the cave, though the ice was very slippery for an extensive area about the rock pile, and the rock pile itself was so slippery, being practically covered with ice, that it was almost impossible to climb it. Since there was no drip from above, this seemed to indicate a true thaw.

The accompanying table gives the temperatures of the cave as recorded on the several visits, and also the readings of the lengths of iron stakes projecting beyond the surface of the ice. It can be seen that no appreciable melting took place during the season observed. Also, though the temperatue of the cave varies, it is invariably colder right at the entrance than at any other point, even when thawing is apparently taking place as on May 18.

As a result of this study it is easy to understand the method by which the ice on the floor and sides of the cave is renewed. The water from the melting snow upon the surface of the ground seeps down into the cave, where the low temperature maintained by the wall of ice in the end causes it to freeze in the winter and spring. People who have been there in the early summer state that the floor of the cave is then covered with water, and that this water disappears later in the summer leaving the floor entirely dry during the late summer and early fall. This may be explained by the fact that early in the summer the level of the water table is high enough to prevent the water escaping, and as the water table lowers during the dry summer, the cave floor becomes dry. However, it is easy to see how this condition has led to the local tradition that "it melts in the winter and freezes in summer," since the first people to go there in the spring often find it full of water, which indicates thawing to them, and later the dryness makes them think it is freezing again. Though this study has outlined the cycle of the yearly accumulations, it has given us no clue to the method by which the great ice wall itself was formed, and that remains, at least for the present, a mystery and a matter for speculation.

KILAUEA REPORT No. 970

WEEK ENDING AUGUST 24, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

There have been no visible changes in the condition of Halemaumau during the week ending August 24. No avalanching from the walls of a magnitude sufficient to cause dust clouds has been noticed, though isolated rocks are still dropping from the rim almost continually. Steaming from the wall cracks and talus piles has been much less than usual, in fact, during two visits to the pit, no steam could be seen issuing from the cracks within the pit.

The number of earthquakes recorded is very small. One feeble shock which was felt only by a few parties in the National Park was registered at 10:43 a. m. August 21. The distance to its origin was measured as 8 miles. Three very feeble shocks which were not perceptible were registered at 7:47 p. m. August 21, 11:39 p. m., August 23, and 5:52 a. m. August 24. It was not possible to measure the distances from these records, but two of them were accompanied by tilt to the east. There were 25 records of small tremor of volcanic origin during the week. Most of these tremors lasted for less than a minute. but at 11:00 p. m. on August 22 a vibration started which continued for 18 minutes. The non-volcanic continuous vibration of the island has been slight during the entire week.

There was no significant tilting of the crater rim under the Observatory during the week. The tilt reading varied slightly from day to day and the average of the week compared to that of last week showed a slight accumulation to the southeast. The instrument at the pit recorded no conspicuous movement of the walls of Halemaumau.

The number of small tremors recorded is somewhat greater than the usual number for the past few months. The tilt record suggests that there has been no notable swelling or settling of the crater walls. It must be concluded from this that lava is neither rising nor falling at present.



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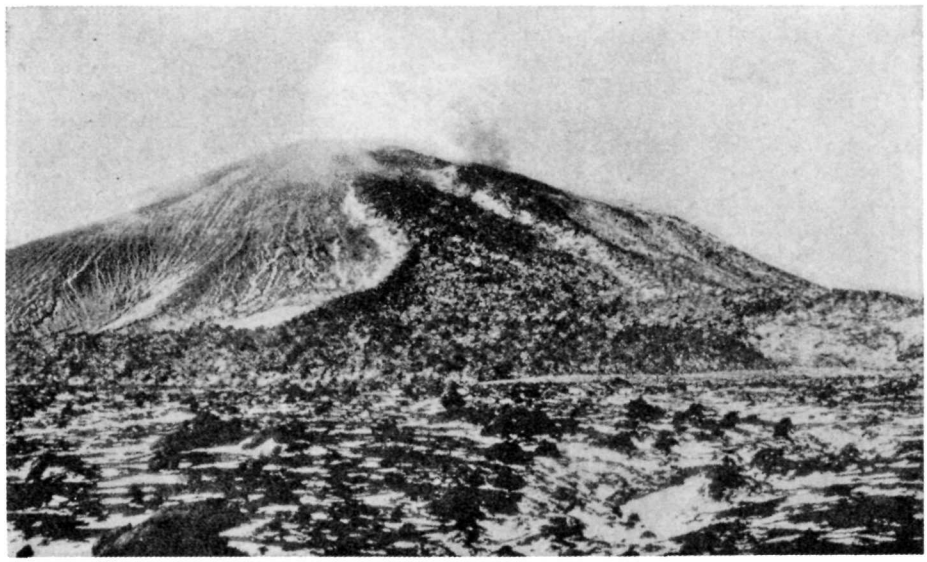
No. 297—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — September 4, 1930



View of the great aa lava flow of 1783 on the north side of Asama Volcano, Central Japan. Photo Omori, 1911, Bull. E. I. C., VI, No. 1, 1912.

ERUPTIONS OF ASAMA-YAMA, JAPAN IN 1873

(A Review by I. Toyama of part of "The Eruptions and Earthquakes of Asama-yama" by F. Omori, Bull. Imp. Earthquake Investigation Comm., 6, 1912.)

Date of Occurrence. The series of explosions of Asama-yama, in third year of Temmei (1783) ended in a tremendous catastrophe of August 5. It is a memorable circumstance that the great Calabrian earthquakes were recorded in the same year on February 5.

The frequency of the eruptions of Asama-yama is subject to an annual variation which indicates two maxima occurring respectively in April and August.

Weather at the time of Eruptions. It rained slightly in Yedo, the present Tokyo, on the 28th of July; in the province of Kotsuke which lies east of Asama, the weather was clear on July 31 and August 1, and fair on August 2 and 3. Considering all reports, the weather was dry and fair in the central part of Japan during the one week period before the main eruptive period, while on the 3rd, 4th, and 5th of August the weather was calm in the vicinity of the volcano. This shows that an area of high barometric pressure existed over Asama and the central part of Japan during the later part of the eruption. Immediately after the catastrophe, a strong cyclone swept across the country.

Course of the Eruptions. The eruptions which lasted for 88 days, began on May 9. On June 24 detonations like distant thunders began to occur at about 7:00 a. m. On the 25th, between 10 and noon, loud detonations were heard, accompanied by a strong explosion. The sounds also occurred the next day, June 26. between 4 and 6 p. m. The mountain then remained quiet for twenty days until July 16, when loud detonations occurred during that night and the night of the next day. After eight days, on the 25th, detonations continued from 8 a. m. to noon, although smoke emission was slight during the day. This marked the beginning of the last stage of the great eruption.

On the 26th of July, at 4 p. m., there were detonations accompanied by an explosion which threw out smoke toward the east. The detonation lasted until evening. On the 27th, when it rained heavily, there were detonations and emission of smoke toward the southeast at 4 p.m. Volcanic manifestations became greatly intensified in force on the 28th when, in fair weather, there occurred at noon a powerful explosion which was stronger than that of June 25th, and which threw out smoke toward the east. From this time, the effects of the eruptions could be felt in such distant places as Yedo, where ashes fell on July 28. The people of this region wondered why the houses and doors were shaken, although the ground and the water remained undisturbed.

On July 29th, burning began at 3 p. m. which continued until 5 p. m. On the 30th, the explosion which began at noon became excessively great between 2 and 8 p. m. and came to a temporary end at 4 a. m. July 31. The eruptive activity continued to increase during that day and on the following day.

On August 2, the weather was fair and clear. The eruption reached its maximum violence and the volcano emitted fire from 6 p. m. until midnight. A large quantity of stones and sand were thrown out and Maikake-yama, which was near by, was converted into a litteral sheet of fire. The eruption ceased for a short while in the morning of the 3rd of August and resumed its violence on the same day from 2 to 10 p. m., covering Kiba-yama, another nearby mountain, with red hot stones of different sizes.



Map of Central Japan, showing Asama Volcano in the shaded ellipse, which is the area of strong sound during the eruption of April 3, 1911. Wind direction is shown by arrows, and black dots indicate spots where detonations were heard. There was a zone of silence or sound shadow between the two shaded areas. From F. Omori, Bull. E. I. C. VI, No. 1, 1912.

On the 4th, explosions began with detonations at 8 a. m. and caused such an excessive fall of ashes between 1 and 4 p. m. that people as far distant as Fukaya in the province of Musashi had to use lanterns during the day to see their way through the darkness caused by the falling ashes and sand. On the 5th the weather was fair. Outbursts which began at 4 a. m. became extremely violent from 8 to 11 a. m. A little after 10 a. m. a huge mass of burnt rocks, lava and hot mud descended with deafening detonations from the crater and swept down the northern side of the mountain, rushing into the valley of Azuma-gawa.

The Course of the Eruptions in Four Stages.

First stage, commencement, May 9.
Second stage, outbursts, June 24 to 26.
Third stage, outbursts, July 16 to 17.
Fourth stage, outbursts, July 25 to August 5.

The Lava. The great lava flow of 1783 which forms an imposing spectacle on the northern flank of Asama-yama, descended into the Rokuriga-hara plain. The lava mass terminated in an abrupt manner, forming a slope of about 40 degrees which runs for a considerable distance. Its height varies from 30 to 50 meters. The area covered is somewhat of the shape of a triangle, 6 kilometers along the base of the flow.

The Great Volcanic Avalanche. The great torrent of volcanic material, which swept down the slope with a very high initial velocity, caused much damage and devastation in all the villages along the northern slopes and base of the Asama-yama and those along the Azuma-gawa. The principal course of the flow was along the deeply cut ravines that run from the foot of the mountain toward the north.

The volcanic avalanche blocked the flow of the Azuma-gawa for a while, producing a temporary decrease of water in the lower course of the river. At about 11 a. m. August 5th, the water broke forth through this newly formed dam of debris, and together with the steaming volcanic material, rushed down sweeping and carrying with it houses, furniture, and everything that blocked its way.

Ash and Smoke. Ash fell at Yedo, Choshi, Maebashi, and the surrounding regions during the morning of August 6. Mud rain fell in Karuizawa, Sakamoto, and Isobe on the fifth of August. In the city of Takasaki, 44 kilometers away from Asama-yama, ash accumulated to a thickness of 6 inches. The old and weakly built houses were crushed, and endangered the lives of the occupants.

The area covered by the fallen ash and stones measured about 220 kilometers long and 100 kilometers wide, or about 11,000 square kilometers. The thickness ranged from one to six inches, and taking the mean thickness as 2 inches, the quantity of fallen volcanic material will be about 0.9 cubic kilometer.

Conclusion. This great eruption of Asama-yama was not the beginning but the result of the outburst of the volcanic energy accumulated during the course of many years. The eruptions were caused by powerful underground explosive forces, that were suppressed until the last stage.

The shallowness of the crater caused the immensely large mass of molten and burning rocks and lava and mud to overflow and cause the dreadful volcanic avalanche. Had the crater been deeper and larger, the catastrophe and disaster caused by the eruption would not have been as severe nor as terrible.

KILAUEA REPORT No. 971

WEEK ENDING AUGUST 31, 1930

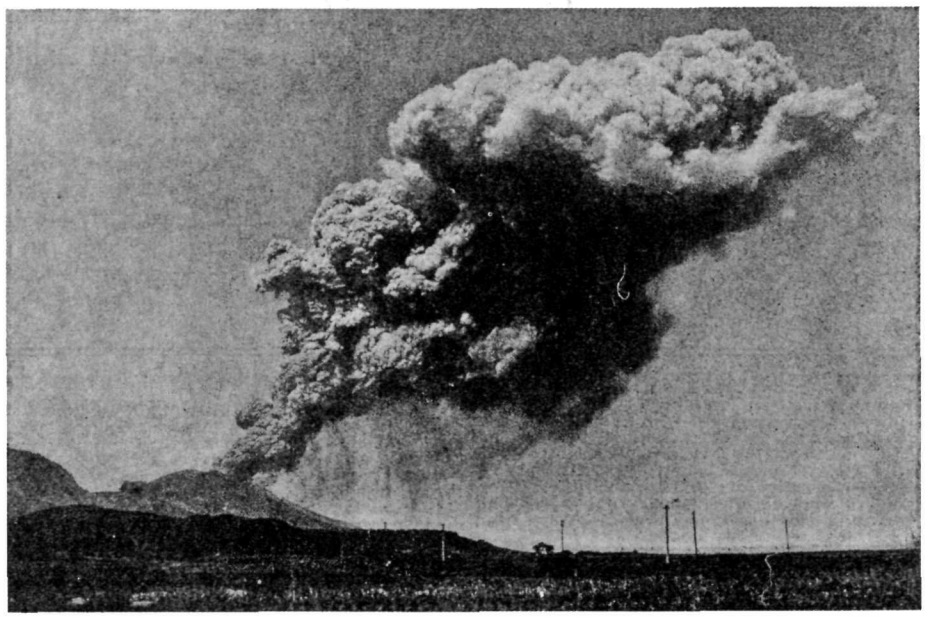
Section of Volcanology, U. S. Geological Survey
H. A. Powers. Temporarily in Charge

But one thing of interest has happened at Halemaumau during the week from August 24 to 31. On Saturday, August 30, about 3:30 p. m., a large slab of the wall between the 14 Ton Bowlder and the pit loosened itself and made an avalanche which was heard at the Military Camp over a mile from the pit. Other than this, the fire pit has been exceedingly quiet. The amount of steam from the wall and floor cracks has been variable but has averaged even less than usual. A number of small quakes were felt in Pahala and other nearby towns of the Kau district.

The seismographs at the Observatory registered five very feeble shocks as follows: August 26, 4:19 a. m., 5:01 a. m., 10:26 a. m., and 2:38 a. m.; and August 30, 8:54 a. m. distance 32 miles. Judging from all the available information, these quakes probably had their centers somewhere in the region of Puu o Keokeo. The instruments also recorded 31 very small tremors of less than a minute duration. Of these, 17 occurred on August 30 during the time that several avalanches were observed in the pit. Some of the tremors may have been caused by these rock slides. The continuous trembling of the earth (microseisms) which is probably not of volcanic origin has been very slight during the week.

Measurement of the tilting of the ground under the Observatory show that there has been a slight accumulation of tilt to the southwest. In other words, if one imagines a vertical wand placed on the ground at the Observatory, the tilt during the week would have inclined this wand a little bit toward the southwest. The ground at the edge of Halemaumau has shown a similar movement, which suggests that this tilting has not been caused by any changes of pressure under the fire pit.

It may be concluded that there has been no measureable change in the volcanic conditions at Halemaumau. However, slight movements of the flanks of Mauna Loa similar to a series which occurred last spring have been resumed.



A modern strong eruption of the Asama-yama, May 8, 1911, seen from Komoro looking northeast. Photo Uozu, from Bull. E. I. C. VI, No. 1, 1912.



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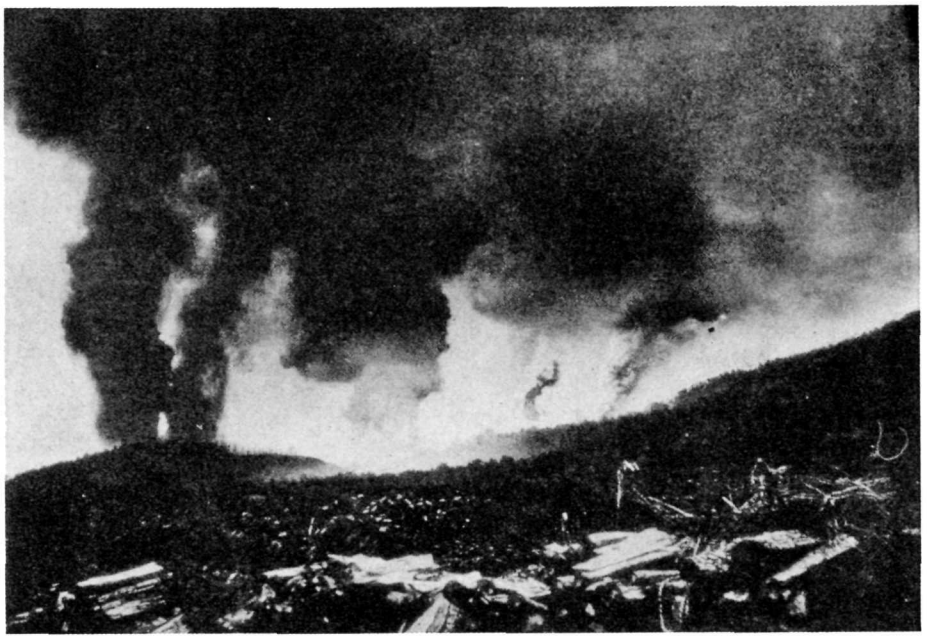


Eruption of the north flank of Usu Volcano in Hokkaido, north island of Japan, August 2, 1910. West Maruyama is the forested hill on the left. From Omori, Bull. E. I. C. vol. I, 1911.

ERUPTION OF USU VOLCANO IN 1910

(From Oinouye, "1910 Eruption of Mt. Usu," J. G, 25, 1917, pp. 258-88. Reviewed by K. Onishi.)

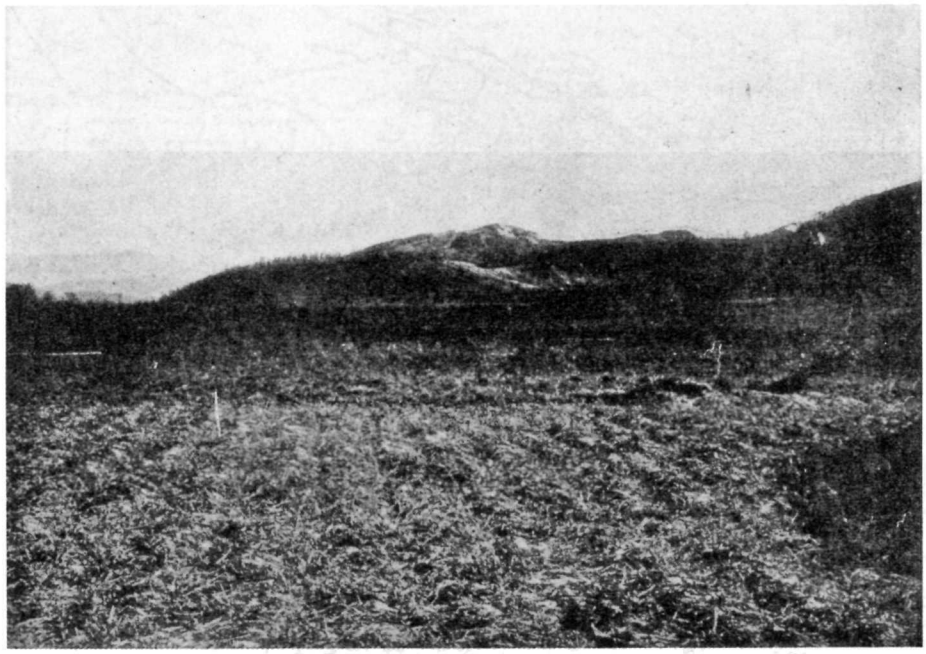
Mt. Usu, a volcano located in northern Japan on the island of Hokkaido, rises 736 meters above sea level and is approximately two kilometers in diameter. Two domes crown the top of the volcano, their names and elevations being O-usu and Ko-usu and 736 meters and 609 meters respectively. Since the craters resemble in shape the "usu," a Japanese mortar used in making "mochi" a kind of pounded rice cake for festivals, the people have named the two craters "usu" with the prefixes "O" and "Ko" to indicate the sizes, the former signifying big and the latter small. Hence O-usu is the larger of the two craters.

The clear and able report by Oinouye deals particularly with the interesting phases of the eruption. The author narrates in detail the following observations of the outbreak: earthquakes, mud cones, explosions and their processes, explosion craters, the changes in topography of the land, and the damage done by the overflow of mud and the scattering of ash and other material from the pits.

Prior to the eruption, four days to be exact, frequent earthquakes had disturbed the people. The occurrence of these undulations of the earth's crust grew more numerous as the days passed after the first shock. On July 23, 1910, 110 shocks were recorded, about 350 on the following day, and 163 on July 25, the day of the first outbreak. Two violent shocks, one on July 24 at 4:30 p. m. and the other on the following day at 5:00 p. m., thoroughly alarmed the people. The results of the quakes were some fissures made on the west side of the volcano almost parallel to the coast line. These varied in width from 3 cm. to 40cm. There also resulted two faults going in an east and west direction on the western foot of the mountain.

Another result of the quakes was the formation of mud cones on the flat land north of the volcano. The first resulted from the severe shock of July 24. The cones were formed of mud and sand, well stratified and flat and conical in shape and ranging from 6cm. to 3 meters in diameter and from 3cm. to 60 cm. in height. The water level in the neighboring wells rose and the volume of the water was doubled. Several new springs were formed but the water everywhere was turbid and dirty.

The first explosion took place on July 25 at ten o'clock in the evening from the northwest slope of the main volcano. Red hot bombs were thrown into the air. July 26



View from the same point as Figure 1 taken on November 9, 1910. The "New Mountain" is shown elevated back of the right shoulder of West Maruyama. From Omori, Bull. E. I. C. vol. I, 1911.

witnessed the explosion accompanied by black and white smoke that rose to a height of 700 meters. July 28 was a dreary day with two explosions, rain, thunder, intense lightning, huge columns of dense smoke, and low roaring noises contributing to the general atmosphere of gloom.

The explosions were quite remarkable. A cannon-like sound announced the arrival, a "V" shaped vent opened the path, and a procession headed by black smoke, sand, and ashes came into view. This material helped to form the cones, each requiring a day or a week to complete one, the time depending on the amount of matter ejected and the size of the vent.

During the period of greatest activity. from July 25 to August 2, fifteen new craters were formed, the number increasing to 45 for the ten weeks of the eruption. These craters were grouped into two groups of 16 and 29 lying in two parallel lines. The distance between the two lines of vents was about 800 meters. All of these craters emitted quantities of black smoke, ash, sand, and bombs. Five of them spit mud and hot water as well. The greatest distance to which the ash was carried was 44 km. In places the land was covered to a depth of 30 cm. A mud flow to the lake at the foot of the mountain measured 200 meters in width, 500 meters in length and 1.5 meters in thickness.

The chemical composition of the mud flows, the sand of the seashore, and the substance in the mud cones was practically identical, showing evidence that all the material came from the same source, a brown pumice at the base of Mt. Usu.

Bombs hurled into the air produced a sound like a firecracker when they were struck in midair by other ascending bombs. They were basaltic in composition, dark grey, porous, somewhat round, and not more than 25 cm. in diameter. An abundance of pores filled with ash and sand on the exterior of the bombs was contrasted with a scarcity of pores in the interior.

The topography of the land was changed materially. The water in Lake Toya rose 30 cm. on the north margin of the lake and the slope of the south shore tilted to 30 degrees from the original 5 degrees. Before the eruption, Nishimaruyama could be seen from the village of Nishikohan, but after the activity of the volcano, the view was obstructed by the so-called "New Mountain." The maximum height of this newly constructed ground is 120 meters.

Professor Omori is of the opinion that an intrusion of lava in the form of a dome or spine caused the elevation of this new mountain. Sato believes the intrusion to be a laccolith. Oinouye, the author of this article, thinks that the uplifting of the new land was caused by a plug which was intruded in the midst of the activity, the intrusion being materially helped by the faulting of the land.

The damages incurred included the destruction of a fine forest on the slope of the mountain, and the burial of houses and farm lands within a radius of two kilometers.

Many houses suffered cracks in the walls and a number were completely destroyed.

TILTING OF THE GROUND IN AUGUST

A graph showing the tilting of the ground from day to day is plotted at the end of each month. The position of the tilt recorder with respect to an assumed fixed point in space is read each day. However, these daily tilt readings are affected to a certain extent by causes other than true volcanic tilt such as rapid temperature changes, heavy rainfall, and slight instrumental errors. To eliminate as many as possible of these outside influences, the curve showing the daily tilting is "smoothed" by computing "overlapping seven day means." This means that the tilt reading plotted on the graph for each day is actually the average of seven days, ie. the three days preceeding and the three days following the day in question. This smoothed curve thus shows a truer picture of the tilting of the ground as caused by volcanic forces of comparatively long duration. The curve obtained by this method of plotting may be figuratively described as being the curve traced by a wand placed rigidly in a vertical position in the earth at the observatory, with the upper tip of the wand writing the curve on a piece of paper held above it in a fixed position in space. As the earth tilts, the wand is tipped from its vertical position and the tip of the wand writes a curved line on the paper. The net change in position of the top of this wand for each week in August is expressed in a compass direction and angular degrees of arc in the following table. For example, from July 28 to August 3 the wand had tipped through 0.96 seconds of arc in a northeasterly direction.

July 28-Aug. 3	N.E.	0.96	sec. of arc.
Aug. 4-Aug. 10	S.S.E.	0.87	" "
Aug. 11-Aug. 17	S.E.	1.45	" "
Aug. 18-Aug. 24	S.E.	0.72	" "
Aug. 25-Aug. 31	S.W.	1.45	" "

KILAUEA REPORT No. 972

WEEK ENDING SEPTEMBER 7, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers. Temporarily in Charge

The famed 14 Ton Bowlder has advanced one more step on its journey back into Halemaumau. The sliver of th rim which supports the bowlder has slipped downward until the top of the bowlder is several feet below the level of the solid rim behind it. This slipping occurred during a spell of almost continuous avalanching which began about noon on Thursday, September 4, and stopped sometime Saturday evening, September 6. Most of the larger avalanches, however, fell from the northeast part of the rim a considerable distance from the 14 Ton rock. Aside from this, at the risk of being very monotonous, it must be reported that little excitement has happened at Halemaumau.

National Park Rangers have reported that two avalanches have fallen from the walls of Kilauea Iki during the past ten days. It is entirely possible that these resulted from blasting which has been done in the course of the construction of a new trail into this crater.

Six very feeble quakes, probably originating in the Puu o Keokeo area, have been recorded during the week as follows: Sept. 1, 7:41 a. m.; Sept. 3, 6:45 a. m.; Sept. 4, 8:34 p. m.; Sept. 5, 3:17 a. m.; Sept. 6, 6:28 a. m., distance questionably 20 miles; and Sept. 6, 6:51 a. m. Twenty-six small tremors were recorded on the Observatory instrument. The larger number of these occurred during the spell of avalanching and probably are records of these rock falls. Microseismic motion was slight during the entire week.

Tilting, both of the Kilauea rim and of the Halemaumau rim, was slight to the southwest.

It must be concluded that pressure under Halemaumau is decreasing from the maximum attained during the second week in August. There is no evidence as yet that lava pressure is building up under Puu o Keokeo even though there have been a number of recent quakes which seemed to center in that region.





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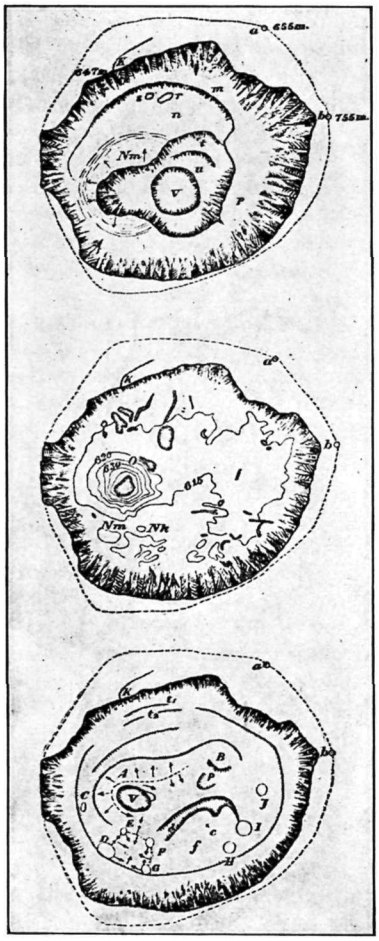
No. 299—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 18, 1930



Mihara Crater in the summer of 1907. Diameter 825 meters E-W. (Nakamura)

The same crater, January 1, 1913. (Okamura)

The same, 1916, showing block lava, terraces, spatter cones, ditches, pits, and fuming holes. (Tsuboi)

STRUCTURE AND ACTIVITY OF OSHIMA VOLCANO

(Review by Y. Yamamoto of "Volcano Oshima, Idzu," Seitaro Tsuboi, J. C. S., Imperial Univ. of Tokyo, Vol. 43, 1920.)

Geographic Sketch. Oshima is the largest number of a group of volcanic islands off the Idzu peninsula, and lies in the sea of Sagami about 110 km. southwest of Tokyo. The island itself is a gigantic lava and ash volcano with an elevation of 755 m. above sea level. It consists of a central cone called Miharayama, with an active crater at its summit. The outer slopes of the insular volcano vary greatly in different directions. On the western side the slope is regular and makes a fine concave curve. On the eastern side it is abnormal, varying from 15 to less than 5 degrees, and continuing from the summit half way down, until on approaching the shore, it becomes suddenly as steep as 40 degrees. The relief of the cone surface is further diversified by a number of parasitic knobs on its flanks, but as a whole, the shape of the island is that of a cone, and its outline viewed from a distance conveys a strong impression of the volcanic origin of the island.

Structural Outline. The volcano is a composite stratified one consisting of double cones—a somma and a central one—and is built up of numerous layers alternately accumulated of lava and fragments of basaltic nature. The somma has several satellitic bodies. On the flanks of the main body of the somma there are eight parasitic knobs. The top of the somma is truncated with a ring-wall that surrounds a huge oval caldera. The wall is not completely closed but there are two gaps, a greater one on the northeastern and a smaller one on the southwestern side. The active central cone, Miharayama, stands in the caldera, and its volcanic products not only cover the ground within the encircling wall but have also spread down to the sea shore through the gaps in the wall.

The Central Cone. The central cone, Miharayama, which is a perfectly preserved undissected heap, stands somewhat to the south of the center of the caldera. The cone is very simple in its structure, being composed of superfluent lavas and ejecta, the alternately accumulated layers of which may be well observed on the inner wall of the summit. The volcanic products of the central cone, both lavas and ejecta, not only fill the caldera but are also spread down to the sea shore through the northeastern and southwestern gaps of the ring-wall of the somma. Especially on the



Geologic map of Oshima Volcano in Sagami Bay near Yo kohama, with profiles N-S and E-W. After Tsuboi, Jour. Col. Sci. Tok. 43, 1920.

eastern part of the island, the products of the central cone are so distributed over the surface of the somma body as to conceal its original slope. The present crater seems to have attained its size in 1684 according to historic records. The features of the inside of the crater are always changing. It is habitual that when the volcanism displays its full energy, lava fills the crater, and on declining, the layer of lava depresses more and more due to its own weight, leaving the peripheral parts in the form of terraces.

The Meiji-Taisho eruption (1912-14) began with the outpouring of lava from the vent. During this interval, the extrusion of lava took place intermittently, five times, of which the second and fourth can be considered as the after effects of the first and third respectively. In the first period during March-June 1912, the lava reached a level of 62 meters below Kawajiri, burying half of Naumann's cone and forming a new Nakamura's cone. The second eruption in July was the squeezing out of a new molten lava due to the depression of the lava layer at the crater bottom and resulted in the breaking up of Nakamura's cone. In the third activity, September-October 1912, the extrusion of the lava took place from a new vent at the western part of the crater bottom and was accompanied by the formation of a new spatter cone, Omori's cone, around the vent.

The whole crater is at present in a state of deep tranquility. No motion is seen and no sound is heard to cause any uneasiness. Activity is only indicated by fumes with a faint peculiar choking odour of sulphur dioxide. The fumes rise calmly at varying places from pits and clefts of the elevations on the crater bottom and from cracks and fissures traversing the lava which fills the crater floor, depositing sulphur in a yellow crust on any objects.

Volcanic Activity in Historic Times. The first eruption ever recorded in Japanese chronology took place on November 29, 684 A. D. Several authors are of the opinion that the area now occupied by the villages of Motomura and Nomashi was formed by this eruption. During the period from the eighth to the eleventh century there was no eruption at all. In the twelfth century, on November 18, 1112, there was one eruption. Two eruptions took place during the fifteenth century. In the seventeenth century there were four eruptions. There was one eruption in the eighteenth century in the years 1777-78. This eruption of the An-ei era was the most violent one ever recorded in the history of the volcanic activity of Oshima. Five eruptions were recorded in the nineteenth century. The last one of this period which occurred in 1876-77, was a rather violent eruption. The activity lasted forty days. Lava was poured out in the crater of Miharayama but it did not run over the brim of the crater. The eruption of 1912-14 lasted for two years and three months. During this eruption, lavas were extruded in five periods with short intervals of quiet between spasms of activity. They did not run over the brim of the Miharayama crater, but they changed the state of the inside of the crater. The activity in the month of October in 1915 continued about twenty days but ceased without having poured out any lava.

KILEAUEA REPORT NO. 973

WEEK ENDING SEPTEMBER 14, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

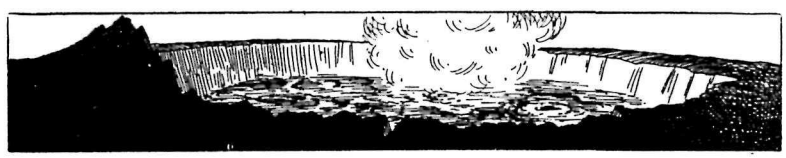
The 14 Ton Bowlder fell to the bottom of Halemaumau during the evening of September 10. No one was present to watch the manner of its going, but a little news was yielded by the seismogram from the pit instrument. About 9:30 p. m. a landslide initiated a series of fourteen different slides large enough to record on the instrument. Two of the largest occurred at 10:30 p. m. It is probable that the 14 Ton Bowlder was carried in by one of these two. A section of the rim over fifty feet long and thirty feet wide dropped in during these avalanches. As a rough estimate, over 65,000 tons of rock fell from the wall of the pit.

Aside from the series just mentioned, there has been little avalanching during the week, and the steaming from the cracks in the pit has been slight except during one half day of rain.

Only one very feeble earthquake was recorded on the instrument at the Observatory on September 11 at 11:39 p. m. A total of 46 small tremors were registered during the week, of which a small number are probably avalanche records. Microseisms have been slight during the entire week.

The average tilt for the week showed a slight gain to the north at the Observatory. A careful analysis of the records suggests that the tilting is being influenced more by Mauna Loa than by Halemaumau. The tilt seems to be a series of small movements to and from Mauna Loa, and gives no evidence of increasing pressure under that mountain.

Again it must be concluded that things are very quiet at Halemaumau ,and that nothing of obvious consequence is happening at Mauna Loa.





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No. 300—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 25, 1930



Tower of the stone church of Sataputu, Savaii, all that remains to mark the site of a village buried under thirty feet of lava. There is subsidence around the tower, probably due to fluid lava entering the building below. After Tempest Anderson, Q.J.G.S. London, 1910.

ERUPTION OF MATAVANU, SAMOAN ISLANDS, 1905-10.

(Review by L. Smith. Reference: The Volcano of Matavanu in Savaii, Tempest Anderson, Quart. Jour. Geol. Soc., 66, 1910, pp. 621-639.)

Before the eruption of 1905, a sort of elevated plain surrounded by mountains stood where the crater of Matavanu is now. A deep valley extended from near this place down to the sea. On the western side of its coast were the villages of Saleaula, Salago, and Toapaipai. Farther to the east of Toapaipai was a stretch of "iron-bound" coast, or a coast made of old lava not protected by an encircling coral reef. Still farther east were the villages of Malaeola and Sataputu. These were on a part of the coast protected by coral reefs.

The eruption began August 4, 1905 with an explosive phase, sending forth mostly solid ejecta which did not cover an extensive space.

September 2 to September 4 saw molten lava pouring out and extending for a distance of two miles.

October 28 found the lava at Saleaula, and on November 3, this lava-stream was a quarter of a mile across. The side of the crater fell out and from the collapsed part a flood of lava issued.

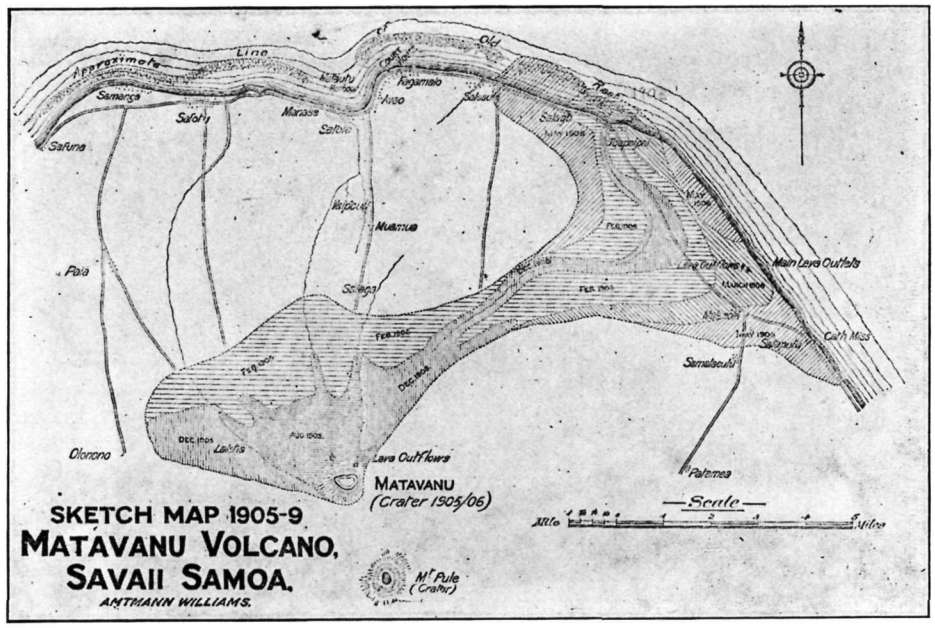
The lava reached the sea at Toapaipai on December 7, filling up the lagoon between the shore and the coral reef, then taking a westward turn along the reef, leaving untouched a part of the lagoon which was not filled up until later.

From January 28, 1906 to the middle of February, there was a great increase of activity. The lava extended along the coast from Salago to Saleaula, filling the space between the shore and the reef. Farther east, half the town of Malaeola was destroyed.

The lava ceased running in the swamp behind Saleaula on March 3, 1906. Near the coast about half the town of Saleaula had been destroyed. The lava filled up the space between the shore and the reef at Saleaula and extended westward, blocking up one of the entrances to the lagoon. The lagoon between the shore and the reef was not filled up until later.

On March 6, 1906, the lava extended eastward along the coast to two hundred yards from Sataputu which was destroyed somewhat later. Where the coast was "iron-bound" its formation was little changed for the lava flowed directly over the sea cliff into deep water.

Around the first of September, 1906, the lava-flows near



Map of the northeast side of Savaii Island showing the region of the crater and lava flows (shaded) of 1905-9 of Matavanu Volcano. After Tempest Anderson.

the sea coast extended eastwards, overwhelming the village of Sataputu, filling up the lagoon which was thirty feet deep in places, and pushing the coast-line seawards about 3000 feet. The total length of sea-front covered at different times by the lava was nearly nine miles.

It was noted on August 7, 1908, that the lava continued to run strongly into the sea, making its course mainly in the direction of that district where Toapaipai formerly stood.

A visitor to Savaii in the year 1910 or thereabouts would have seen a crater, 2000 feet high, surmounted by a canopy of white steam shaped a little like a pine tree, often breaking into cauliflower lobes, rising to a height of 8000 to 10,000 feet. Great fields of black lava, whose rough and irregular surface had large areas of both the aa and pahoehoe variety, comprised a considerable area around the cone, but on its southern and eastern sides their journey has been checked by hills. They are greater toward the west and north where they have filled the upper parts of several valleys. In the northeast, toward the sea, is the most extensive field of the fresh lava.

Of course, all vegetation overwhelmed by the lava was killed, but much more damage was done by the "Ua Sami," or poisonous gases, discharged from the crater or formed by the action of the hot lava on the sea water. Descending the crater from the west, the destruction of trees was complete, and for a distance of nearly two and a half miles, their bleached skeletons alone were left. It was only in a few sheltered places that the low undergrowth was beginning to return from the old roots. The towers and other parts of two churches are nearly all that remains of the villages of Saleaula and Sataputu.

The bottom of the crater is oval, entirely occupied by a lake of liquid lava, all in rapid motion and of such fluidity that it continually beats in surging waves against the wall. The lava is at a brilliant white heat with a darker scum continually forming on the surface, especially when the trade wind blows strongly on it. These pieces of scum break up and flow down to the north-eastern end of the crater where they disappear along with the liquid lava down a tunnel about 30 feet at the foot of the cliff. The surface of the cone is composed mostly of a series of flows of basaltic lava, and a number of bombs or ejected blocks of lava of similar character are scattered over the surface.

KILAUEA REPORT NO. 974

WEEK ENDING SEPTEMBER 21, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

A large part of the badly cracked section of the southeast rim, near the old site of the 14 Ton Bowlder, has fallen into the pit. Starting last Sunday, September 14, the

avalanching was almost continuous until daylight the morning of Thursday, September 18. Between midnight and 4:30 a. m. of the 18th, a number of very heavy slides formed the climax to the series and produced the most visible changes in the rim. The edge of Halemaumau moved back about fifty feet through a distance of more than one hundred feet as a result of the avalanching.

Other than this sliding from the wall, there have been no events of interest at the fire-pit. Steaming has been very light and none of the earthquakes of the week has had its origin under Halemaumau.

The seismograph at the Observatory registered five very feeble earthquakes during the week, one of them on September 20 being felt in Kau. The times of the shocks were: September 15, 7:27 a. m.; September 18, 2:50 a. m. and 4:14 a. m.; September 20, 5:24 a. m.; and September 21, 6:08 p. m., distance 28 miles. During the spell of avalanching, 36 small tremors were recorded at the Observatory, while the pit instrument showed a total of 90 small shocks caused by the rock slides. During the last three days of the week, 13 tremors registered on the Observatory instrument of which none seems to be due to avalanching. The ordinary microseismic trembling of the ground which is thought to be of non-volcanic origin was slight for the week.

The tilt of the Kilauea rim under the Observatory gained slightly to the southeast, and the rim of Halemaumau showed the same amount and direction of movement. The daily tilt diagram shows continued small movement back and forth from the south ridge of Mauna Loa, but no gain of pressure under that mountain is indicated. Kilauea does not seem to be affecting the tilt to any appreciable extent at this time.

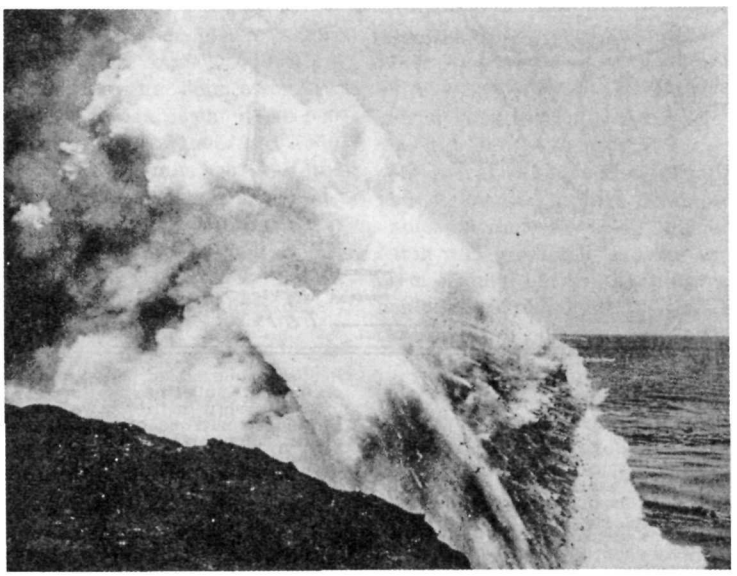
LAVA "SQUEEZE-UPS"

The Sunset Crater Lava flow, northeast of Flagstaff, Arizona, not only presents the most recent evidence of volcanic action in the San Francisco Mountain area but also contains a curious phenomena on the surface of the flow. These are fissures filled with basalt which have been given the name of "anosma," or "squeeze-ups." Through the middle of the main flow from Sunset Crater is a fissure, varying in width from a few feet to seventy feet, and a mile and a quarter in length. Through this fissure, basalt, apparently in a plastic condition, has been squeezed, under pressure, several feet into the air. The sides of the protruding basalt tongue are grooved conforming to the walls of the fissure, and slickenside surfaces are usually present. In the wider fissures, the more plastic inner layers of the mass have slid over the outer less plastic plates so that we get a condition of a series of vertical layers pushed into the air.

That the mass was plastic like stiff clay is evident from the rough surface of the sides of the mass that have been in contact with the walls, a condition often seen in the moulding of bricks. Further, the plates of basalt, as they have been thrust into the air, have bent under their own weight to form graceful arches in some places.

Besides the long squeeze-up, others are known of which many are less than 100 feet long. Most of these squeeze-ups are found on or near the edge of the main lava flow and form the source of smaller secondary flows. These secondary flows must have been more or less contemporaneous for in many cases they have coalesced.

It is thought that the formation of the squeeze-ups is related to the fact that the lava is contained in an intercone basin, a basin with no outlet surrounded by cinder cones. Into this basin, lava has poured from a vent near the high side of the basin. The remains of numerous fumeroles and the altered condition of much of the surface of the primary flow indicate that the main flow was deep and long in cooling. The squeeze-ups, in some way, seem to be associated with this condition.—HAROLD S. COLTON.



Lava of Matavanu entering the sea through a tunnel near Toapaipai. Fragments are being thrown up, each with a trail of steam, by the force of the explosions which occur when the lava enters the water. Photo Allen, after Tempest Anderson.



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The Volcano Letter

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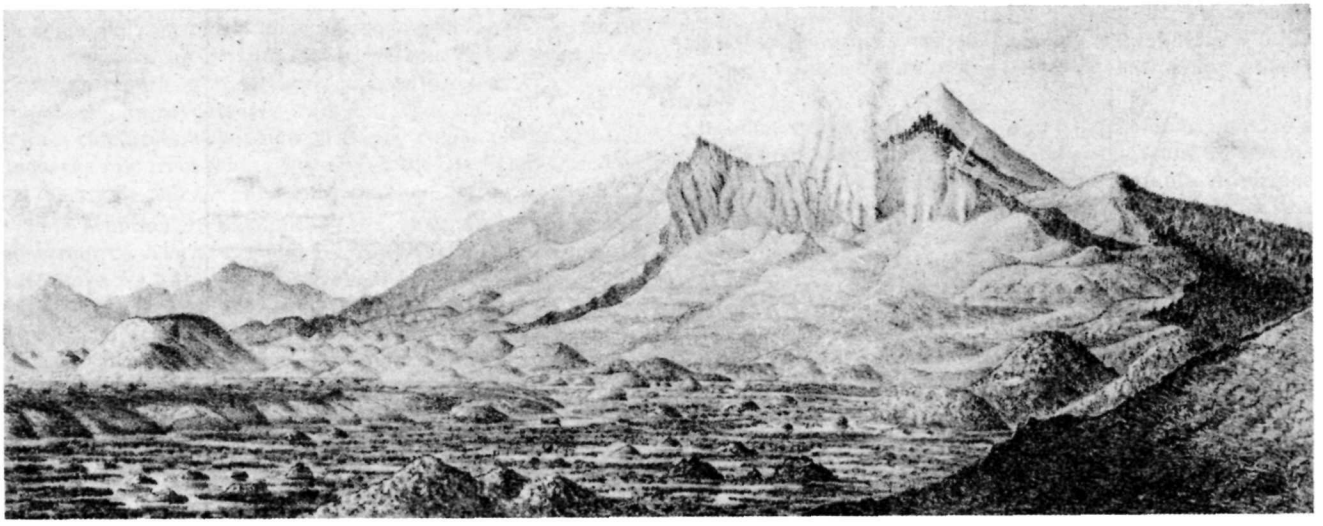
No. 301—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — October 2, 1930.



Crater of Bandai-san three weeks after eruption, looking south, showing the many conical mounds, similar to Galounggung (Vol. Letter No. 286). Bare hillsides on the right were scored by the mud torrent. After Sekiya and Kikuchi.

THE ERUPTION OF BANDAI-SAN, CENTRAL JAPAN, 1888.

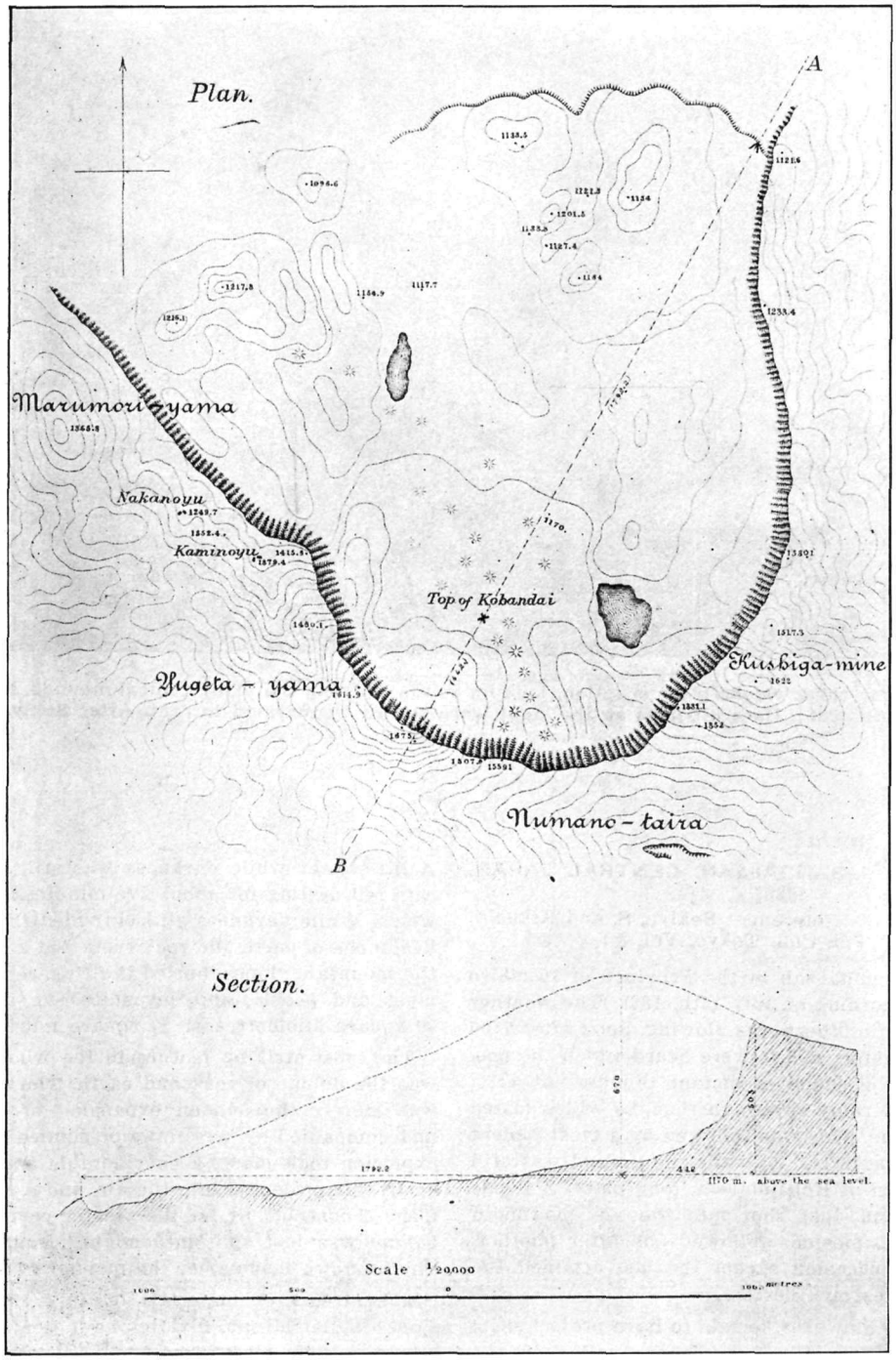
(Reviewed by L. K. Fo. Reference: Sekiya, S. and Kikuchi, Y.. Jour. Sci. Coll. Tokyo, Vol. 3.)

The eruption of Bandai-san in the Province of Iwashiro took place on the morning of July 15th, 1888. The weather was clear and a gentle breeze was blowing. Soon after 7:00 o'clock, curious rumbling noises were heard which the people thought to be the sound of distant thunder. At 7:30, there occurred a tolerably severe earthquake which lasted more than 20 seconds. This was followed by a most violent shaking of the ground. At 7:45, while the ground was still heaving, the eruption of Kobandai-san took place. A dense column of steam and dust shot into the air, making a tremendous noise. Explosions followed one after another, the steam on each occasion except the last attained the height of 1280 metres or 4200 feet.

The last explosion, however, is said to have projected its discharge almost horizontally towards the valley on the north. It is probable, from the topography and form of the crater, that previous discharges were also more or less inclined to the vertical in a northerly direction. The main eruptions lasted for a minute or more and were accompanied by thundering sounds which continued for nearly two hours. Meanwhile the dust and steam rapidly ascended and spread into a great cloud like an open umbrella in shape. At the immediate foot of the mountain there was a rain of hot scalding ashes, accompanied by pitchy darkness. A little later while darkness was still great, a shower of rain fell, lasting for about five minutes. The rain was quite warm. While darkness still shrouded the region, a mighty avalanche of earth and rock rushed at a terrific speed down the mountain slopes, buried the Nagase Valley with its villages and people, and devastated an area of more than 70 square kilometres or 27 square miles.

The most striking feature in the whole of this eruption was the deluge of rock and earth. The destructive agency was merely the sudden expansion of imprisoned steam, unaccompanied by lava flows or pumice ejection. When the explosion took place, a considerable amount of rocks and earth was projected into the air, and a part diffused in the form of dust, but by far the greater part of the bulk of Kobandai was just split into mighty fragments which were thrown down much after the manner of a land-slip.

The stream of materials of July 15th, ran down the slopes of Bandai-san, dividing as it went into two principal branches. The main branch flowed northward. Kobandai sloped on the north towards Nagase Valley in an unbroken descent, and as the mountain burst on this side, the debris dashed with great violence down this northern slope in the direction of Hibara, 9 km. away. One part of the rock torrent actually ran up the valley, toward the source of the River Nagase, burying on its way the three hamlets of Akimoto, Hosono, and Osuzawa. A part, however, ran down the valley reaching Kawakami spa and submerging it to a depth of probably more than 40 metres. The other and



Plan and profile of Bandai-san as destroy ed by the steam blast eruption of July 15 1888. Heights given in meters, dotted lin e shows former profile. After Sekiya and Kikuchi.

much smaller branch took quite a different route making an angle of 120 degrees with the main stream.

The combined volume of these two great streams entirely covered an area of 27 square miles with a solid sea of mud and rock, beneath which were buried all features of the landscape together with cattle, people, and all other living things.

The mud current also carried along numerous big boulders, some of them measuring from 5 metres to 10 metres each way.

The explosions were accompanied by terrible wind blasts. In some exposed parts, houses were levelled to the ground and trees torn up by their roots. Marumori-yama, situated near the mouth of the crater, and fully exposed, received the most severe damage. This hill was formerly covered with a thick forest, but now presents a melancholy appearance, the few trees which were left standing being as naked as telegraph poles.

This eruption of Bandai-san was more destructive than constructive. The materials which had accumulated in past ages gave way and were thrown down from a higher to a lower level in less than an hour in a gigantic landslide. The loss of property is said to have been immensely great. There is absolutely no hope of recovering or reclaiming the buried land.

Formation of new lakes due to the damming up of the river Nagase by the shattered mountain was also a striking effect of the eruption. There were four lakes formed in this manner, called Osuzawa, Hibara, Onogawa, and Nakatsu. Fifteen days after the eruption, the village of Onogawa was covered with water from the gradual accumulations in these lakes.

Out of the total of 461 dead, only 116 bodies were recovered, the rest remaining buried under the mud from the avalanche. Seventy individuals were injured by the hurricane of hot ashes and falling stones.

TEMPERATURE OF STEAMING CRACKS

The steaming cracks on the rim and floor of Kilauea Crater are, at present, the most visible indications of the presence of latent volcanic forces. They inspire numerous questions and are worthy of considerable study. Where does the steam come from? Are all of the cracks of the same temperature? Does the weather have any effect on the amount and temperature of the steam? These and many other questions of a like nature easily come to mind.

Since the beginning of the constant observation of the volcano, some notice has been taken of the steaming cracks. Measurements of temperature both at the surface and in holes bored beneath the surface have been made at a number of different times since 1912. At the present time, a daily record is being kept of the temperature and behavior of three accessible steaming cracks.

In February and March, 1912, a comprehensive survey was made of the temperature of steaming cracks in the entire crater area. The results of this survey are reproduced here in the following table:

Locality	No. of Cracks	Maxima	Minima.
Sulphur Banks	6	95.5 C. (204 F.)	66.0 C. (151 F.)
North edge Kilauea	2	70.0 C. (158 F.)	55.0 C. (131 F.)
Steaming Cliff	13	80.5 C. (177 F.)	47.8 C. (118 F.)
Observatory	2	59.0 C. (138 F.)	25.5 C. (78 F.)
North floor Kilauea	11	89.0 C. (192 F.)	36.7 C. (98 F.)
Northeast floor Kilauea	5	81.7 C. (179 F.)	57.8 C. (136 F.)
East floor Kilauea	7	84.0 C. (183 F.)	39.0 C. (102 F.)
Southeast floor Kilauea	7	94.5 C. (202 F.)	43.4 C. (110 F.)
South floor Kilauea	2	73.3 C. (164 F.)	66.6 C. (152 F.)
Around Halemaumau	6	145.5 C. (294 F.)	64.0 C. (147 F.)

The table does not include the Postal Rift which maintained temperatures varying around 320 C. (608 F.) for a number of years before it was buried beneath a flow of lava in 1919.

In June 1922, a hole was bored in the Sulphur Bank to a depth of 50 feet, and the temperature was found to be consistently about 96.0 C. at the bottom of the hole. A surface reading in one of the steaming cracks was made at the same time which showed a temperature of 95.5 C., identical with the maximum temperature of these cracks in 1912.

At the same time, temperatures of about 65.0 C. (149 F.) were measured at the bottom of an eighty-foot hole drilled in the south floor of Kilauea Crater. A surface crack gave off steam at a temperature of 55 C. Two cracks measured in this area in 1912 had temperatures of 73.3 C. and 66.6 C.

In January 1925, temperatures were recorded from cracks on the rim of Halemaumau as follows: west rim, 75 C. (167 F.); southwest rim, 86 C. (187 F.); south rim, 72 C. (162 F.); and southeast rim, 76 C. (169 F.). These temperatures taken when there was no lava in the pit contrast with those of 1912, taken when lava was present, which showed a maximum of 145.5 C. and a minimum of 64.0 C. Two cracks on the south floor of Kilauea showed temperatures, in 1925, of 87 C. (189 F.) and 90 C. (194 F.).

A reading of 66.4 C. was obtained from the bottom of the eighty-foot hole in January 1926, and the steaming crack near the hole showed 57 C. These compare with 65.0 C. and 55.0 C. for the two localities in 1922.

Three generalizations are obvious from these earlier records. First, the temperature of the steaming cracks in the vicinity of Kilauea varies over a wide range. Second, three individual "hot spots" show very little change over a period of several years. Third, the temperature shows no definite relation to the presence of lava.

Since May 1930, a continuous record has been kept of the temperature of a narrow steam crack about one hundred yards south of Halemaumau. During May the temperature averaged about 71 C. (160 F.); during June, 70.5 C; during July, 70.0 C.; and during August, 69.5 C. (157 F.). For comparison with the curve of variation of the temperature of the steam crack, records have been kept of the daily rainfall, daily average air temperature, daily range of air temperature, daily barometric pressure, daily wind condition, and air temperature at time of reading the steam temperature. The results obtained so far seem to indicate that the temperature of the steam from the crack does not depend on any one of these outside influences.

In an effort to test this information more fully, daily records have been started on two more steaming cracks, one about 100 feet south of Halemaumau, and one on the Steaming Cliff on the northeast Kilauea rim. It is hoped that comparison of all of these records will permit some definite conclusions as to the origin and control of the temperatures of the steaming cracks.—H.A.P.

KILAUEA REPORT No. 975

WEEK ENDING SEPTEMBER 28, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

There have been very few avalanches, and steaming from the cracks in the crater has been very light during the past week. Sunday evening, September 28, at 8:35, a few people in the National Park felt an earthquake which was also reported as felt in Kona.

Between September 22 and September 27, four very feeble quakes were recorded on the Observatory seismographs as follows: September 23, 5:09 p. m. distance 37 miles; September 24, 4:16 a. m. and 9:03 a. m.; September 25, 7:55 a. m. None of these was felt in the Park. At 8:35 p. m., September 28, a quake of moderate intensity dismantled (this means that a small safety device is disconnected which prevents serious damage to the writing pens) all of the instruments at the Observatory and was followed by a number of feeble and very feeble shocks as follows: 8:59 p. m. very feeble, 9:05 p. m. feeble, 9:08 p. m. very feeble, 9:13 p. m. very feeble, and 10:56 p. m. feeble.

The moderate shock at 8:35 gave some interesting but puzzling records. On several of the instruments, the distance to its center was measured as 12 miles, while on the others its distance was 20 miles. It had a strong vertical movement, yet it was felt as a very gentle rocking motion by a very few people. The best guess which can be made from the conflicting records is that the quake had its origin at great depth under the island and cannot be assigned definitely to either volcano.

Twenty-three short tremors, probably of volcanic origin were recorded during the week, and the non-volcanic microseismic trembling was somewhat stronger in the middle of the week.

The tilt for the week still seems to be controlled more by the southern part of the main Mauna Loa rift than by Kilauea. The ground at the Observatory was tilted moderately to the northeast.

The deep seated earthquake probably indicates deep movement of lava, but it is too soon to tell whether the lava is rising into one of the volcanoes.

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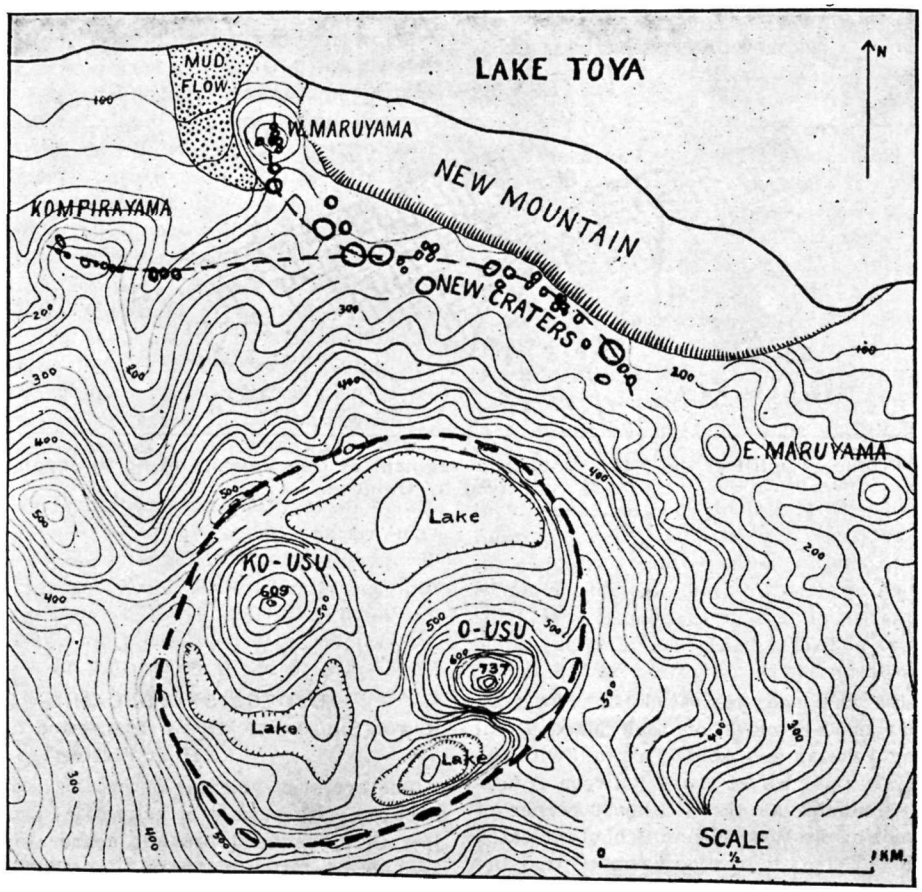


Map showing old somma ring and domes of Usu, the line of active craters of 1910, and the uplifted segment which makes the "New Mountain" escarpment. After Daly.

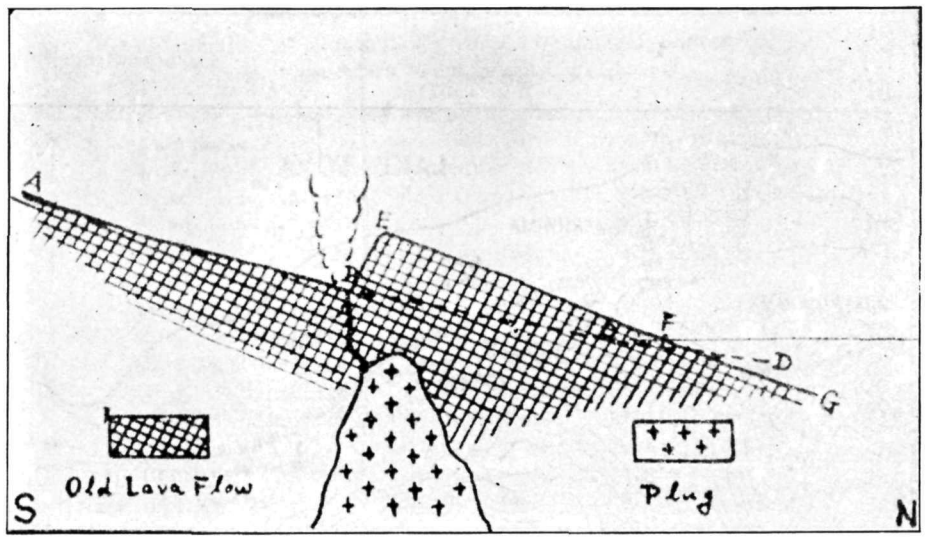
CHANGES OF ELEVATION AT USU VOLCANO, JAPAN

(Review by D. Malone of the paper by F. Omori, Bull. I. E. I. C., 5, 1913)

The volcanic outbursts in 1910 of the Usu-san volcano were followed by the formation of the "New Mountain." The elevation phenomenon was not confined to Usu-san but in November, 1910, in the town of Auta on the southwest base of Usu-san, a fence surrounding a field which had been level was at the time invisible from one side to the other. The Military Survey Department, in 1911 and 1912 undertook the determination of the heights of the first order benchmarks on the lines of precise-levelling running along the northeast coast of Volcano Bay and along the western foot of Usu-san.

In the summer of 1911, the height was examined along the Volcano Bay coast from the vicinity of the town of Benbe southeast to Abuta-Tokatan, then along the southwestern base of Usu-san to Tokotan on the Toya Lake and then to Muko-Toya along the western coast of Toya Lake. The total distance was about 25 km. In the summer of 1912, the measurement was repeated, being further extended 12 km. southeast along the coast of the bay to the town of Nishi-Monbets which is about 8 km. southeast of the central crater of Usu-san.

As may be expected from the proximity to the site of the "New Mountain," the benchmark at Tokatan was elevated 2.4244 meters, while benchmark Number 6596, situated midway between Toya Lake and Volcano Bay, was elevated 1.1601 m. At Abuta-Tokotan, on the coast of Volcano Bay, the elevation was 0.358 m., although the distance from New Mountain is 6 km. On the other hand, the benchmark No. 6597, not far from 6598 (at Tokatan), suffered a depression of 0.0739 m. while Nos. 7192 and 6599, at the distance of 2 km. to the northwest of Abuta-Tokotan and



Profile of uplift of the "New Mountain" segment at Usu Volcano in north Japan, as conceived by Ouinoue.

Tokotan respectively, were each depressed about 0.022 m. It will be seen that marked elevation took place at all benchmarks between Tokotan and Abuta-Tokotan, with the exception of No. 6597, and also at those between Abuta-Tokotan and Nishi-Monbets. As the southeast corner of the lake shore in front of the West Kohan School indicated an upheaval of some 1.333 m., it may be assumed that the whole mountain mass of the Usu-san and its base suffered an elevation, doubtlessly extending some distance beneath Toya Lake.

A comparison of the heights of the different benchmarks determined in 1911 with those again determined in 1912 shows that a sort of a level adjustment was going on both in the upheaval and the depression regions to no small degree. It may be seen that the three benchmarks Nos. 6596, 6598, and 6597 (the first two of which had been elevated by the greatest amount of 1.16 and 2.4244 m.) now indicated depressions of 18.4 to 29.2 millimeters. On the contrary, the three others, Nos. 7192, 6599, and 6600, which had been depressed by the maximum amount of 22 mm. were now raised to the amount of 2.0 to 3.1 mm. The ratios of the downward and the upward restitutions were thus greater than the former. It is likely that the process of the level fluctuatio ncontinues for many a year to come or at least as land as the volcano is in more or less active condition.

The problem of level change in volcanic districts forms an exceedingly interesting branch of geophysical research. Seismologically it is exceedingly desireable to investigate the changes in level which may take place in districts belonging to active earth-quake zones, previous to the occurence of destructive disturbances.

CYCLES OF VOLCANIC ACTIVITY

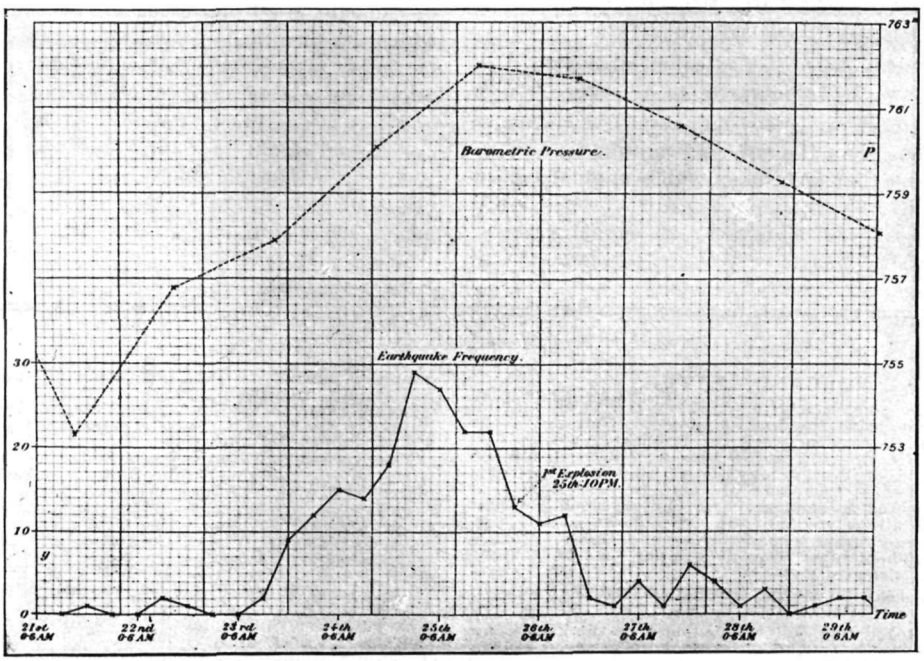
K. von Sapper, pp. 270-74. Translated from the German by H. C. Flattery.

The cycles of volcanic outbreaks and their possible connections with cosmic or terrestrial occurences are a subject that has been brought nearer to a solution by the keeping of statistics. Above all, a connection with sunspots has been accepted. J. Jensen finally came to the conclusion, through various experiments, that the greater frequency of outbreaks occurred simultaneously with the maxima and minima of sunspot coverage. Later W. Koppen, who has gone over this field again, found by studying the outbreak statistics of E. Kluge and de Marchi that the outbreaks were most frequent at the time of sunspot minima and most rare at the time of maxima. However, the record of outbreaks of K. Schneider gave a greater number of outbreaks for the time of maxima than for the time of minima. On account of these contradictory results, I have tried to examine my material with this in view: are the periods noticeable for the whole earth, or does an increase in certain districts equalize to some extent the decrease in others? For this purpose I have determined year by year the number of known activity units, and for the smoothing of the curve, I have, in each instance, considered the preceeding and the following figure at its weighted value—b equal ¼ (a plus 2b plus c). I ignored the continuously active volcanoes as they do not influence the curve. The southern hemisphere, on account of the greater number of continuously active volcanoes, is ahead of the northern hemisphere in general frequency of activity. But it shows a lower frequency figure, if one disregards the continuously active volcanoes, which is in keeping with its smaller

land surface. Only seldom does the southern hemisphere gain a preponderance. The beginning of the list is in the year 1749 as only from this time on is the sunspot curve known through observation. The absolute number of outbreak units is continually getting higher, the nearer we approach the present time. This can be explained through better reporting and the addition of new volcanic districts. The frequency curve plainly shows a number of periods. They are not of equal duration, but vary from six to twelve years. Very often they approach the duration of sunspot periods, so it is not remarkable that several times a high frequency of outbreaks coincided with sunspot minima and at other times with maxima. According to my figures there were seventeen frequency periods from 1749 to 1914. During the same time there were only fifteen sunspot periods. This shows that a fundamental connection cannot be established between the two. Nevertheless. a certain relation is not out of the question for it is noticeable that during a time of the pronounced flattening of the sunspot curve (1798-1825) the frequency curve too is less sharply defined. Gigantic outbreaks sometimes correspond with a high, and sometimes with a low point of the curve, or even in between, so that no particular regularity can be read from this material for the occurence of great volcanic catastrophes.

Even though the sunspot theory may fail to be proved, positive causes of terrestrial or astronomic nature may yet be found in the course of time for the periodical volcanic outbreaks. Perrey and Falb (during the second half of the 19th century) believed to be able to predict the earthquakes and volcanic outbreaks under the supposition that there was a flow of the molten liquid of the earth's core. This theory has now been abandoned, but there is still much speculation as to the influence of the constellations of sun, moon, and planets on these phenomena.

F. A. Perrett came to the conviction, after careful observation of the activity of various Italian craters, that the position of the moon and also the sun to each other and to the earth has a decided influence on volcanic activity. Perret took into consideration the distance of the moon from the earth, the quadratures and syzygien, and the changes of the declination of sun and moon. He found fortnightly and half yearly maxima. The first show a stronger swing. H. O. Wood, who was at the Kilauea Volcano Observatory from 1912-1917, criticised Perrett's curve, because it showed the fortnightly amplitude as greater than the half yearly one. He emphasized the great value of declination. The observations at Kilauea showed that high lava levels and strong surface activity occurred at solstice, low lava level and little activity at equinox. T. A. Jaggar, who has had charge of the Kilauea Observatory since 1917, calls attention to the fact that from 1911-1913 the lava measurements may have corresponded with these data, but not so from 1914-1918. He shows that occassionally solstice and equinox have high lava levels, but at other times they may be accompanied by low lava levels. He found that on the average the lava in Kilauea had a tendency to rise in April-May and October-November, and to fall in July-August and January-February. From these various views one might well draw the conclusion that the observations have not been recorded for a sufficient length of time to show reliable results. H. O. Woods pointed out that in a cycle of 18.6 years the moon exerts an increased influence on the earth. This is caused by the regression of the occuring moon (nutation) while the change of breadth of the same is completed in



Curve showing the rise of barometric pressure and of earthquake frequency just before the first explosion at Usu eruption. After Omori.

a seven year cycle. It is remarkable that the multiplication of these two periods is about 130 years. Half of this is 65 years. Woods notes that Omori, in examining the eruption history of Asama-yama, finds the mean interval to be 63.5 years and in doubling it, 127 years. Dr. Jaggar prophesied in 1918 that in 1920 (the 130th year after the great eruption of Kilauea) another such eruption would take place. In fact, great lava flows occurred in this year and the explosive outbreak repeated itself in 1924. As such successes lead us to hope that through the careful collection of observations of all kinds and through the consideration of the outbreak history of the various volcanoes it may yet be possible to shed light on the causes and the origin of these eruptions.

For a long time one has tried to connect eruptions not only with astronomic events but one has also thought of the possibility that atmospheric influences, above all heavy rainfall, at least in case of explosively active volcanoes, might be the cause of eruptions.

Systematic observations were first made by G. de Lorenzo at Mt. Vesuvius. He found that heavy precipitations increased the activity of this fire mountain. F. Stell-Starrabba extended the observations to Etna and later on to Japanese volcanoes on information furnished by H. Tanakadate's paper "On the Activity of Japanese Volcanoes from January 1914 to August 1924." Lately the work referring to Japanese volcanoes was continued, using Karl Sapper's catalogue of the historical volcanic eruptions. This gave information on volcanic outbreaks since earliest times. Both sources showed the coinciding of rainy and eruption times. In looking over the entire eruption activity, the maximum seems to be delayed several months, during the short period from 1914 to 1924. This retardation is explained, according to Starrabba, by the fact that the general eruption list shows only major eruptions while in Tanakadate's compilation, even less important manifestations of activity are recorded.

KILAUEA REPORT NO. 976

WEED ENDING OCTOBER 5, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

On Monday and Tuesday a few dust clouds were caused by small avalanches from the walls of the pit. Since then it has been so rainy that any slides which might have occurred did not raise clouds of dust. The heavy rains which began on Wednesday, October 1, and have continued all week have caused an excessive amount of steaming from Halemaumau. A number of times, large cauliflower steam clouds have given a perfect imitation of eruption clouds.

One feeble earthquake was recorded on October 1 at 7·14 a. m. with a distance to its origin of 28 miles, and three very feeble shocks were recorded as follows: September 29, 12:31 a. m.; October 1, 1:05 p. m.; and October 5, 10:51 a. m. Twenty-five small tremors registered on the Observatory instrument during the first four days of the week, and three were recorded on October 5, the last day of the week. On two days there were neither tremors nor quakes. The microseisms, which indicate the non-volcanic trembling of the ground, were slight during the early part of the week but increased to moderate intensity over the week-end.

The Kona and Hilo records of the earthquake of September 28 give additional evidence which shows that the quake had its origin at great depth under the crater, Mokuaweoweo, on the main Mauna Loa rift line. Late reports also show that the quake was felt by some people in all parts of the island.

During the past week the ground under the Observatory has titled moderately in a south south-west direction. Unfortunately, the heavy rainfall of the latter part of the week has caused some tipping to the south, which tends to obscure the significance of the tilt record so far as volcanic pressure is concerned. Only one thing is certain, that is, if any excessive change of pressure had followed the deep seated quake of September 28, it would surely have made itself evident in the tilt record in spite of the obscuring outside influences.

TILTING OF THE GROUND FOR SEPTEMBER

The general movement of the ground under the Observatory during the month of September was a slight tilting back and forth along a northeast-southwest direction. The net amount of tilting for each week, taken from the curve which is smoothed by calculating progressive seven-day means, is given in the following table:

September	1— 7	N. E.	.97	seconds	of	arc
"	8—14	N. E.	1.20	"	"	"
"	15—21	S. S. W.	.90	"	"	"
"	22—28	N. N. E.	1.33	"	"	"

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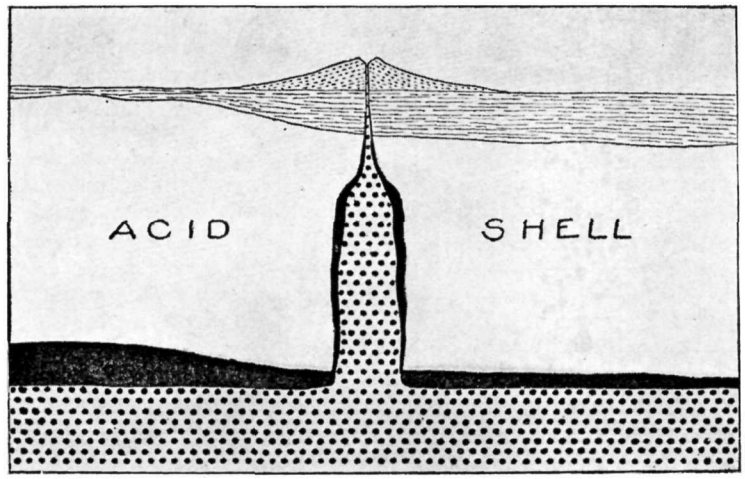
No. 303—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — October 16, 1930



Diagramatic section through the earth's crust showing sediments under a volcano, siliceous (acid) shell, black solidified layer of basalt, dotted liquid basalt of the substratum partly crystallized on the walls of the fissure leading to the volcano. The volcanic cone is represented as 5 km. in height. After Daly.

JOLY'S THEORY OF SURFACE CHANGES OF THE EARTH

(Reviewed by M. Gauntlett. The appendix of "Surface History of the Earth" by John B. Joly.)

After a sinking of the earth's crust with inflowing of the seas over the land masses, sedimentation takes place and then a gradual rising of the continental blocks again. Before the final climax of the renewed rising, floods of basalt arise and flow out through the cracks in the earth's surface. The geosynclines, or places which have received the most sedimentation, are lifted up to form mountain ranges. These periods of great crustal movement, or Revolutions, have occurred about four times, the last ushering in the present geologic age with the rising of the Eurasian chains.

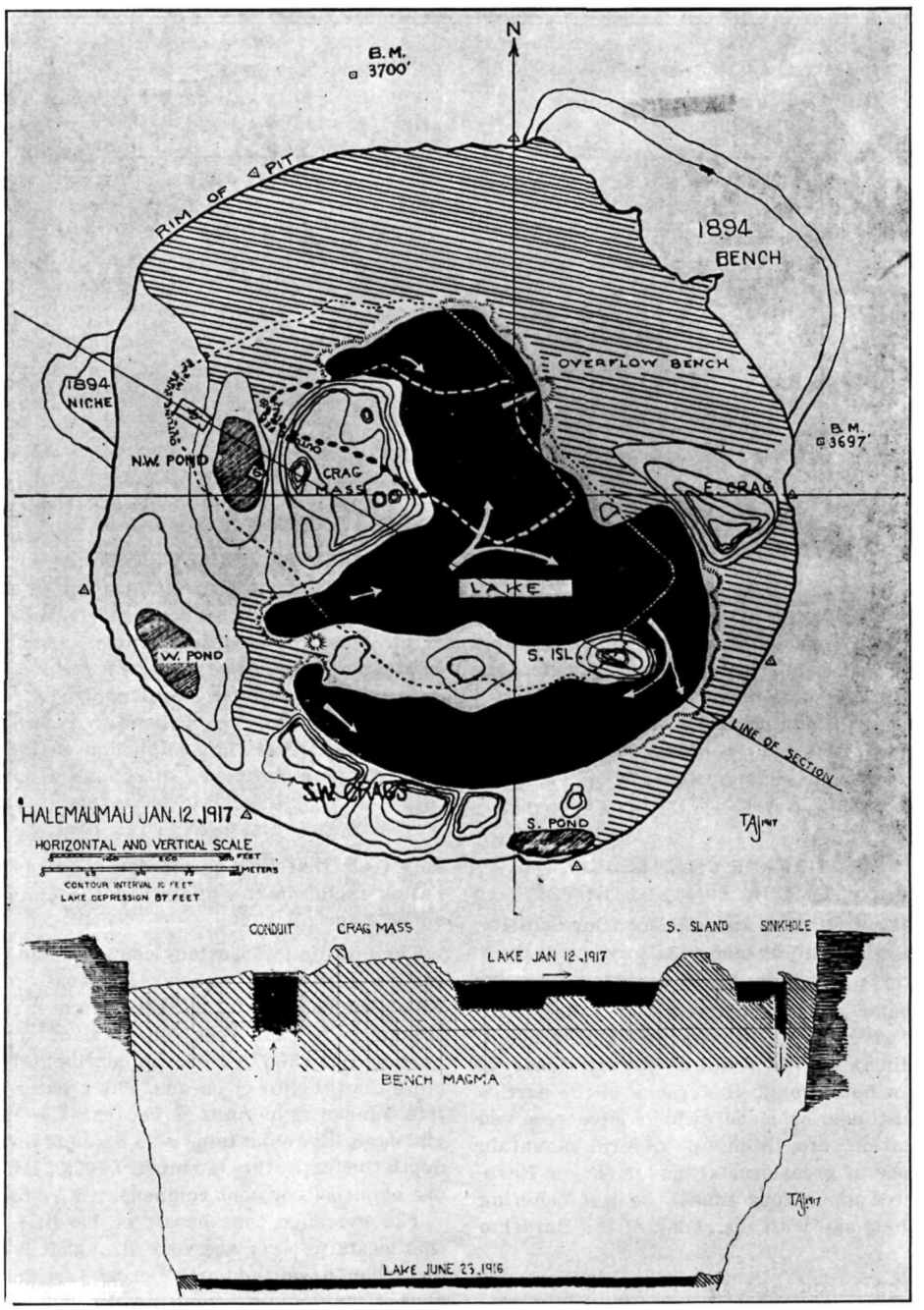
In the article, the origin and interrelations of these events, the sinking and rising of continental blocks, is traced in reference to: (1) the existence of a general basaltic magma-ocean or isostatic layer in which the continents float and upon which the oceans rest; (2) the presence of a certain amount of radioactive materials throughout this magma-ocean; (3) the maintainence both in past and present of isostatic equilibrium of the land masses; (4) certain forces acting on the earth's surface crust.

The general distribution in the rocks of energy-producing or radioactive elements was demonstrated by Lord Rayleigh about twenty-two years ago. This shows that there is everywhere in the rocks a perpetual source of heat which is unfailing whether the heat is accumulating or escaping. More thermal energy was evolved in past ages. Joly feels that this accumulated energy has been a dominating factor in the history of the changes of the earth's surface for all time.

The question of isostacy connoted the existence near the earth's surface of a layer of dense, plastic material in which the continental masses of lighter rock float and upon which the oceans rest. The law of compensation works here to a marked degree, the continental masses displacing more than the lower oceans. The greater mass of the mountain ranges is permitted because the lighter rock which makes up the mountains also extends downward to a great depth beneath the mountains. The Himalaya mountains are about 80 per cent compensated by this method.

The evidence that basalt or basaltic magma composes this isostatic layer are very strong. It is found that during disturbances on the earth's crust vast amounts of intensely heated, fluid basalt come up through the fissures. Basalt has a very high density. It is the most prevalent effusive rock on the globe. The oceanic islands are predominantly basaltic. Experimentally it has been found that basalt directly underlies the oceans. Joly designates the continents as a granitic scum which has separated out. The continents float in this underlying magma layer and the oceans rest upon it as oil on water.

From astronomical study and seismology it is found that at present this substratum must be solid and behave as an elastic solid towards rapidly changing physical forces. However, it is in the solid state very near its melting point, and in the past it has been in the fluid state just above its melting point. Now heat is being generated by



Pit plan and profile of Halemaumau. Shows in profile the bench magma shaded) as a narrow rim in June, 1916, and as the principal fill of the pit in January, 1917. Map shows lake, crags and western source wells. After Jaggar, A. J. S., Sept. 17, 1917, p. 168.

radioactive elements, and heat from a solid is given off only by slow conductivity, so heat is accumulating since it has no rapid means of escaping. It will take some 30 million years for enough heat to accumulate to change the basaltic magma back into the liquid state.

When this takes place there will be an uprising of the entire earth's crust due to the expansion of the basalt during melting which is 11 to 12 per cent, but there will be a sinking of the continental blocks because of the decrease of density of the basalt during melting. After liquifaction is complete, the rate of loss of heat is enormous due to the convection currents in the liquid mass. The heat will be lost mostly through the ocean floor. The loss of heat causes the magma to solidify again and the entire sur-

face of the earth sinks again with the continents rising due to the change in density of the supporting magma-layer. This is a cycle which occupies from forty to sixty-five million years as well as may be judged with the scarcity of known facts.

It is quite probable that, during this time of liquifaction, there are great tides in the magma and the continents shift with the ocean in respect to the deep lava.

In the formation of mountain ranges, Joly holds to the theory that the folding and over-thrusting of the layers of sediments are done long before the mountains are elevated. The sedimentation in large geosynclines, or troughs, forces these areas to bear down much more heavily into the superheated isostatic layer beneath, and later, when the horizontal mountain-making forces come into action, they do not push the mountains up but rather further down. The mountains do not rise until solidification of the underlying magma increases its density and the forces tending toward compensation become great enough to force the whole crushed mass of sediments upward as elevated mountain ranges. This elevation is due to vertical forces and not horizontal as has been stressed in earlier theories of mountain building. The energy comes from the expanded magma and is traceable to the accumulated radioactive heat.

According to astronomers this liquid layer of basalt has tides and the tidal movements greatly exceed in energy those of an ocean of water. There arises a west-to-east pressure transmitted from the rotating earth in opposition to the lunar and solar gravitational forces. This acts on the submerged westerly coasts of the continents. It is a fact that all of the great lava flows have occurred on the western sides of the mountain ranges and continents. The magma expanding about ten per cent would increase the equatorial width of the Pacific about thirty miles and that of the Atlantic eleven miles. The approximated thickness of the ocean floor would be twenty miles in twenty-five million years, and the thickness in inter-revolutionary times would be fifteen miles. During the period of thermal dissipation it will be attacked by super-heated currents and greatly reduced in thickness by melting of the bottom. It will rupture along the coasts of the continents, and the fractures will be filled rapidly by congealing basalt, forced in under pressure. During this time the heat is being dissipated and the ocean floor again thickens and strengthens. Then, when this thickened and enlarged oceanic crust sinks due to the cooling of the underlying magma layer it pushes against the coasts of the continents and causes buckling.

Earth movements and volcanism must result from this breaking down of solid to liquid. Also it is difficult to separate horizontal and vertical movements because of the tensional properties of the rocks and the fact that molten lava fills all cracks preventing return to the original dimensions. The vertical oscillatory movements become a source of ever-extending lateral pressures.

The relative amounts of land and water are explained by thermal equilibrium. If the temperature becomes too great, the continental rocks liquify and either rise vertically in great intrusive bodies called batholiths or expand laterally until the thermal equilibrium is reached again.

By the theory as represented many great facts of earthly tectonics are explained. Such cyclic changes not only arise consistently and naturally, but it may be said inevitably from the conditions present. "The events of the past cease to be mysterious, but become the natural outcome of the physical structure of the earth's surface."

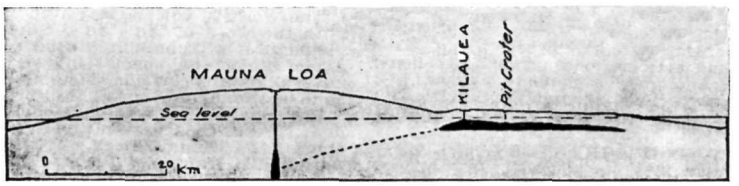
TILT AND RAINFALL

In Kilauea Report No. 969, August 17, the remark was made that abrupt tilting of the ground to the south was coincident with a period of heavy rains in the region around Kilauea crater. Additional data have thrown more light on this occurrence.

On several different occasions during the past few months, rainfall has been so heavy that streams of water have formed numerous short-lived water falls over the walls of the crater, and the crater floor has been dotted with countless pools of standing water which last for several hours after the rain ceases. One of these water-catching basins is located about 30 feet south of the building which houses the Halemaumau seismograph, and during the heavy rains it holds a pool of water perhaps 20 feet in diameter and one foot deep on the average. Thus approximately 4000 pounds of load are added to the surface of the ground just south of the seismograph.

The observer at the pit has noticed that this small basin has been filled on five different occasions, and, at each time, the seismograph has registered abnormal tilt to the south.

Date	Amount of tilt	Duration of abnormal tilting
Aug. 10, 1930	S—1.2 sec. of arc	4 hours
Aug. 11,	S—1.1 " " "	3 "
Sept. 10,	S—3.1 " " "	5 "
Sept. 19,	S—0.3 " " "	2 "
Oct. 8,	S—3.0 " " "	5 "



Profile of Mauna Loa and Kilauea after Daly, imagining Kilauea fed from a remnant lenticular intrusion. Daly, Proc. Am. Acad., June, 1911.

The exact amount and duration of these rains is unknown, so that a quantitative correlation between rainfall and tilt of this instrument cannot be made. However, observations have been sufficient to make certain that these short periods of abnormal southern tilting of the Halemaumau seismograph are coincident with the heavy rains which form the pool of water just south of the instrument pier.

The heavy rains at the pit on August 10 and 11 were a phase of a very heavy general rain which affected the whole area. During the three days, August 10, 11, and 12 about 12.5 inches of rain were recorded at the Observatory. On these same three days, the Observatory seismograph showed an abrupt tilt to the south which amounted to 3.5 seconds of arc. The other three instances of sharp tilt at the Halemaumau instrument were not coincident with any unusual rainfall or tilt at the Observatory. However, during the three days, October 3, 4, and 5, about 6.8 inches of rain fell at the Observatory, and a rather abrupt tilt to the south of 1.2 seconds of arc was recorded. These two instances from the Observatory are not sufficient basis for any generalizations on the correlation of rainfall with the general tilting of the Kilauea rim. It is evident, however, that abnormal tilt may be shown on the Observatory instruments which does not affect the Halemaumau station, and vice versa.

In an article appearing in the Bulletin of the Seismological Society of America in March, 1929, T. A. Jaggar and R. H. Finch discuss the relation of regional tilting to regional rainfall distribution. They point out that the northeast slopes of Kilauea receive many times as much load from rainfall as do the southwest slopes of the mountain. They conclude that "such a loading might be expected to give a northeasterly tilt at the Observatory. There is, (judging from their study of a three-year record) however, practically no correlation between tilt and rainfall, either daily or seasonal.—If the winter irregularities (in the tilt curve) were due to rainfall, we would expect that in 1918, the wettest year, the winter curves would be more irregular than for 1919, the driest year, but such is not the case."

The local instances cited in the present article do not affect, in any way, this conclusion on regional rainfall and tilting. They indicate simply that local loading of the surface may cause a temporary local bending of the lava structure of sufficient magnitude to show up as abnormal tilting on the seismograph records.

KILAUEA REPORT No. 977

WEEK ENDING OCTOBER 12, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

There have been no conspicuous avalanches from the walls of Halemaumau during the week. Large steam clouds have accompanied or followed several heavy showers, and on the evenings of Oct. 8 and 9 very striking cauliflower clouds rose over the pit. The wind was light enough so that they were not blown away immediately upon their formation.

At 12:04 a. m., Hawaiian Standard time, October 8, the instruments recorded a very small disturbance which was caused by a distant earthquake. The record is so poor that it is impossible to estimate either the distance or probable direction to the source of this teleseism.

Three very feeble earthquakes of local origin were recorded as follows: October 8, 8:16 p. m., and 10:30 p. m., no distance determined; and October 9, 7:46 a. m., distance to origin 35 miles. A total of 17 small tremors occurred during the week. This is the smallest number of these tremors recorded since the week ending August 17, 1930. The microseismic, or non-volcanic trembling decreased the early part of the week and has remained slight to the present.

The week's average of the tilt record shows that the ground under the Observatory has been tilted slightly to the northeast. The southwest rift of Mauna Loa still seems to be controlling the tilt movements, but there has been no notable increase or decrease of pressure to suggest movement of lava on a large scale since the deep earthquake of September 28.

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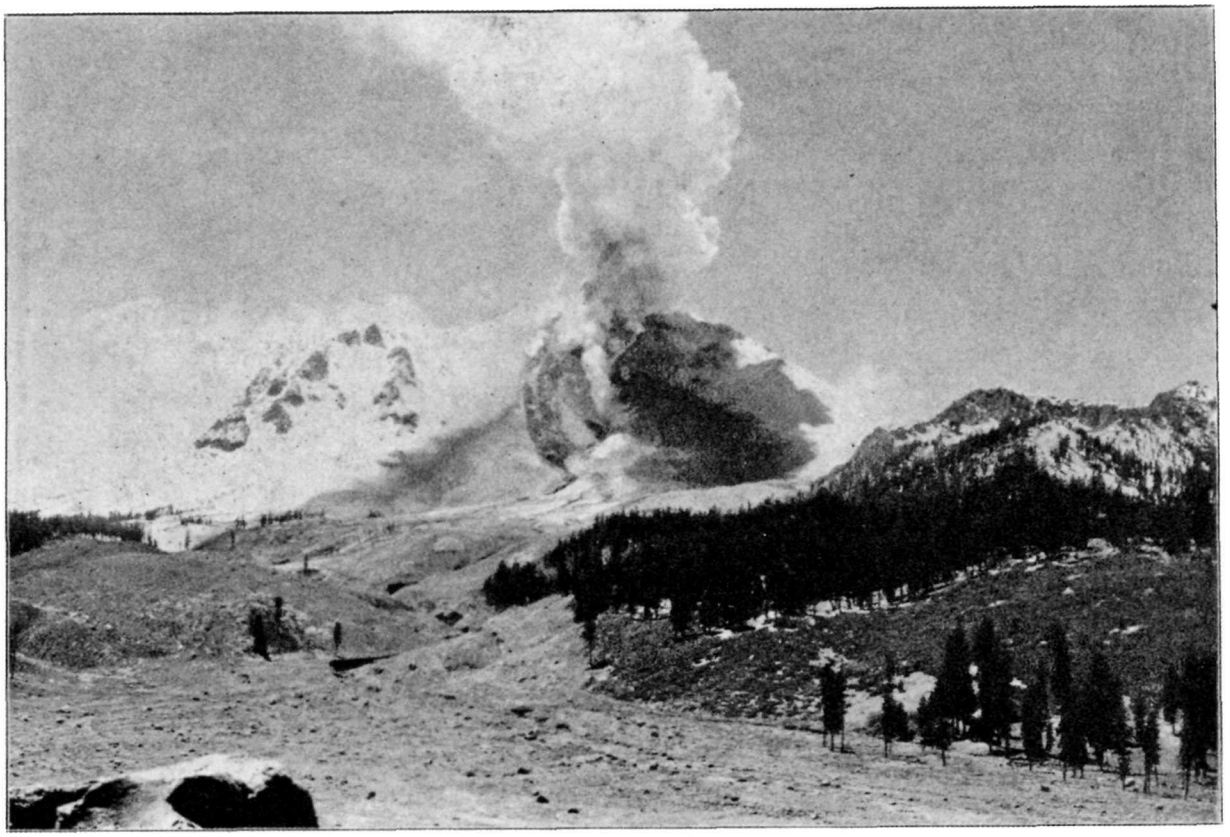
No. 304—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | October 23, 1930



One of the explosive eruptions of Mt. Lassen as seen from the northeast. The explosion is from the newly formed gash crater. The snow to the left of the crater is grey from the falling ash. Photo by B. F. Loomis.

ACTIVITY OF LASSEN PEAK, CALIFORNIA, UP TO 1915

By H. C. HANNA

References: Popular Science Monthly, March 1915, Professor Holway. Lassen Peak Folio, U. S. Geologic Atlas, Folio 15. U. S. Dept. of Interior Bulletin, June 1 to Sept. 15.

It is almost certain that no white man had ever witnessed an eruption of a volcano in the State of California until May 30, 1914. On that date Lassen Peak, a well known volcanic cone about seventy-five miles southeast of Mt. Shasta, suddenly burst into explosive action. During the six months that had elapsed when Professor Holway presented his article there had been an average of one eruption every three days, and no indication at that time that the activity had ceased.

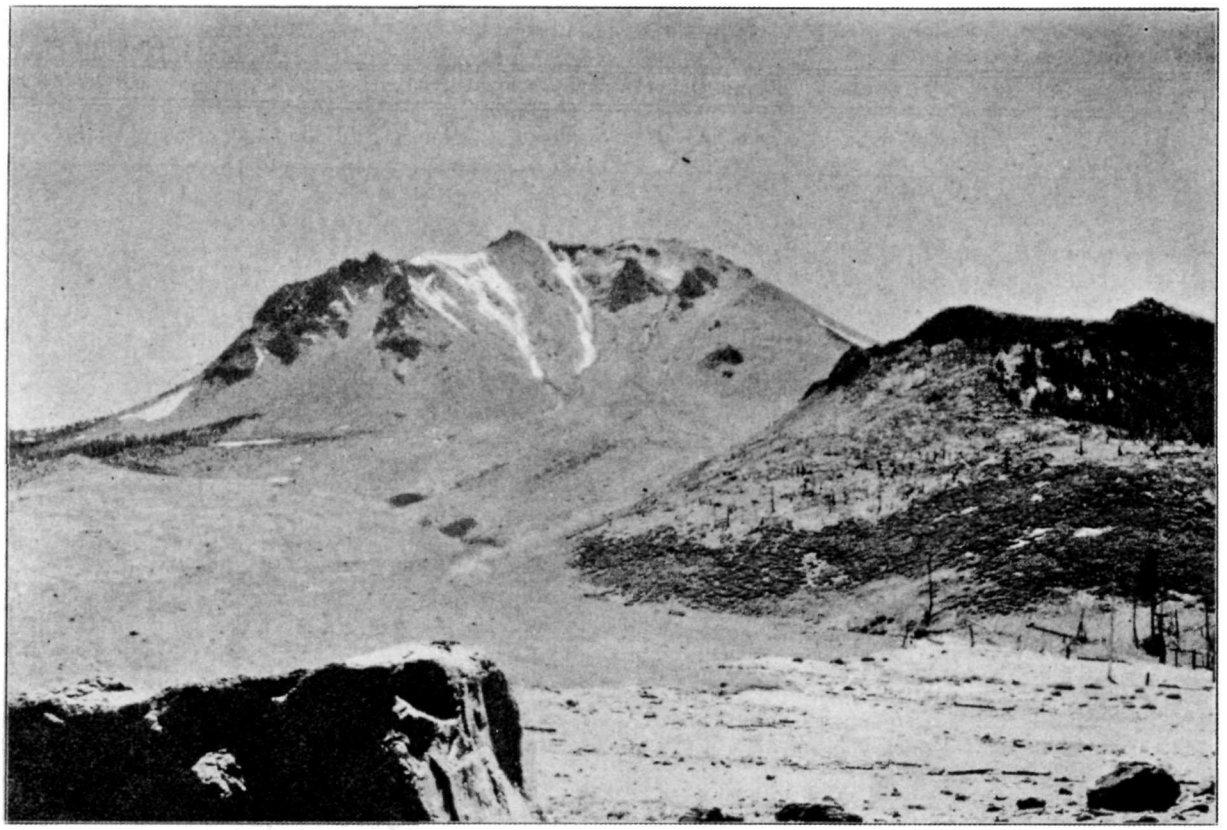
A natural curiosity exists concerning the event that took place in view of probable developments of the future. Was this activity a sign of rejuvenation of a long quiescent volcano? Will this volcano again erupt lava?

Lassen Peak is located in the extreme southeastern corner of Shasta County, nearly two hundred miles from San Francisco. It lies on the southern tip of the great Tertiary lava field, some 250,000 square miles in extent, which covers not only northeastern California, but parts of Oregon, Washington, Idaho, and Nevada as well. Lassen marks the southern end of the Cascade Range and is the last of a series of volcanoes of which Rainier, Adams, Hood, Three Sisters, Pit, Mazama, and Shasta are familiar examples. South of this mountain range are the Sierra Nevada Mountains which were caused more by great faulting and uplift than by volcanic accumulation.

Until this recent outbreak (1914), Lassen Peak belonged to the class of doubtfully extinct volcanoes. As shown by the following statement, Diller did not consider the volcano extinct: "That volcanic activity is not yet extinct in Lassen Peak is shown by the presence of numerous solfataras and hot springs. At Bumpass' Hell, near the southern base of the peak, there are boiling mud pools and vigorous solfataric action."

Previous to the eruption of 1914, there have been several accounts of eruptions reported by the Indians who claim to have witnessed them shortly before the coming of the white settlers. Following is a report of Dr. J. W. Hudson of Akiak, California.

"I was in that region in 1904 collecting for the Field Museum of Natural History, Chicago, and heard much of



Lassen volcano in the summer of 1924 after all eruptions had ceased. Most of the light colored material on the flanks of the volcano and in the foreground is powered rock which was erupted during the activity of 1914 and 1915. Photo by B. F. Loomis.

Lassen Butte. An old Indian told me that when a child, an earthquake occurred at Lassen one summer day. The sun rose, but finally faded to the darkest night——. In many localities along the Pit River watershed, I heard similar reports amongst the aged Indians. The name of this volcano in Palinikau tongue is "Am bliikai," ie. "Mountain-ripped-apart."

Prompt investigation of the first eruption is due to the fortunate fact that the mountain is included in Lassen Peak National Forest, and that the U. S. Forest Service had built a fire look-out station on the topmost crag of Lassen Peak itself. When the eruption began in 1914, the lookout stations had not yet been occupied for the summer season. It can be seen that the interests of the forestry service made the activity on Lassen almost immediately investigatable.

The following is a report made by W. J. Rushing of the Forestry Service:

"Such wild stories are being circulated concerning Mt. Lassen that I am sending you the results of our observations to date. Saturday, May 30, the first outbreak occurred at 5 p. m. This was witnessed by Bert McKenzie of Chester who was looking directly at it when it occurred. Ranger Abbey investigated it on Sunday, May 31, finding a hole 25 by 40 feet in size and of unknown depth. Sand, rocks as large as a sack of flour, and mud were ejected. The heavier material was thrown over an area 300 feet across, while the ash was scattered over an area a quarter of a mile across. No molten material was thrown out. At 8:05 a. m., June 1, a second outburst occurred, throwing out large quantities of the same sort of material. Boulders weighing a ton were ejected. The vent was enlarged to 60 by 275 feet. On June 8, heavier volumes of steam were noted, and at night, another eruption took place, throwing out more ashes and fine material.

"Heavy volumes of steam are coming out of the vent today. We have watched it carefully, and at no time have we been able to see any flame or indication of fire. The vent is about one quarter of a mile from the fire look-out house, and if it continues eastward, as it has so far, it will finally break out on the east side."

Mr. Macomber, a member of the Forest Service spent the night of June 4 at the fire lookout house and reports: "The crater measured 275 feet long. It was then in a pause between explosions. Cracks appeared in the ground and sulphur smoke was rising from them. The walls of the crater were perpendicular and about 60 or 70 feet in height. In the center of the crater floor there appeared a pile of rocks."

On June 14, there occurred the heaviest eruption up to this time, and it was from this explosion that the only injuries during the whole six months period were incurred.

Mr. B. F. Loomis gives a brief summary of the experiences of the party that was caught by this eruption:

"Mr. Phelps party reached the rim of the old crater and sat down to rest a short time, watching the smoke from the crater, when the eruption began. Without any warning or explosion that could be heard, a huge column of black

smoke shot upward with a roar, such as would be caused by a rushing mighty wind, and in an instant the air was filled with smoke, ashes and flying rocks from the crater. They all ran for their lives. Mr. Phelps hid under an overhanging rock, which sheltered him from the rocks which brushed past him as they fell. Lance Graham was a few feet away and was struck by a flying rock, which cut a great gash in his shoulder, piercing the thoracic cavity, and broke his collar bone. He was left on the mountain as dead for a time, but was then removed with great difficulty. He is now recovered. Another of their party ran down the mountain and coming to a snow drift, slid down the mountain like a shot. The cloud of smoke kept pace with him and when he reached the bottom of the snow drift, he found a clump of bushes and diving into it, buried his face in the snow to keep out the blinding smoke and ashes. The smoke is described as causing the blackest darkness, black as the darkest night."

Volcanic dust or ash from the different eruptions has been reported as falling from ten to twenty miles from the peak, the amount and direction varying with the wind. The limits of the heavier falls of ash were within a circle of less than a mile. The direction of the dust outbursts varied, irregular streaks of ash such as that of June 26 showing minor outshoots of dust in various directions. Exaggerated reports of the distance to which stones were thrown were based on the distance they were found on the outer slopes of the old crater. To avoid mistaking such stones for those thrown out by the eruptions, careful search was made on level patches of the old snow so located that it was impossible for stones to roll down on to them. Wherever such places were found, there was no evidence that ejected stones fell at a much greater distance than to the lookout house, and certainly no further than one-half mile from the crater.

The winter's snow had largely disappeared and near the top of the mountain snow was to be found only in patches and beneath a covering of ashes. These areas appeared black in contrast with the light grey of the greater part of the mountain crest due to the presence of dust. This dust was so fine that it was easily moved by the wind and at times a strong gust would send immense clouds into the air, thus giving the appearance of an eruption which would fool observers at a distance and to these probably were due the many false reports about new eruptions that never existed.

During the month of August there were eight eruptions, fewer than either of the preceeding months. Seven out of eight of these threw dust as high as 10,000 feet and were considered quite severe. The record for September showed 17 eruptions, the largest number for any of the six months covered in this report. During this month there was an enlargement of the crater and new vents were opened.

The most remarkable change in the crater (new on the northeast side) occurred in September. The inner vent was 900 feet in length. The severity of these September eruptions is confirmed more or less by the fact that the lookout house there was completely demolished on the 29th of September. The forest lookout on Turner Mountain reported having seen red hot stones ejected. This was confirmed by other observers who claim to have seen flames. This, therefore, is the only observation during these eruptions that indicates such temperatures as molen lava.

The records of October and November are incomplete due to the severe storms in the vicinity which prevented observations. However, these two months are credited with 16 eruptions which shows that the volcano was by no means becoming quiet. Later in January 1915, the San Francisco Chronicle reported an eruption from a new crater on the east as equal to any that had gone on before. The article also stated that no one had visited the volcano for a period of three months.

Mr. Rushing in a letter to the author made some observations during November and states that the eruptions could be classed as medium. He gives a suggestion that this fact may be explained by the fact that a new vent had been opened at a lower level. A comparison of distant observations from the north and from the south would be necessary to test the correctness of Rushing's supposition.

The action of the "smoke" from Lassen is well described by Prof. C. F. Shaw who says:

"The smoke rolled up until practically the entire height of 12,000 feet was reached before any change in its form occurred, when just below the top of the column there was a tendency to stratification and a layer extended out toward the south and toward the north. When this appeared, the smoke column began to lean toward the north and, from our point of vision apparently toward the northeast, distortion took place with the inclination of the column, the upper part spreading out into streamers. As soon as the inclination of the smoke column became very plain, we could readily distinguish indications of falling material. The lower two-thirds of the column seemed to be dropping some material that was falling in a slightly oblique line, the obliqueness pointing back toward the mountain peak. As the eruption continued and the smoke column blew out more toward the north, the streaked condition indicating falling material become more and more apparent, but as the light was failing it became rather hard to distinguish the exact outlines of the lower portion of the column." c

The falling matter must have been the stones and coarser material in distinction to fine ash forming the top of the column of "smoke." Professor Shaw's observation is the only one received by the author that indicates the height to which the heavier fragments were thrown. His statement indicated a total height for coarser material of 8,000 feet.

All of the observers agree that there was no molten lava ejected. Samples of the ash were submitted to Professor A. S. Eakle of the University of California and his report states that the ejected material was composed entirely of fragments and dust particles formed by the shattering of the old volcanic rock which makes up Lassen Peak. The activity, accordingly, must have been all steam explosion, with no eruption of new lava to the end of 1914. (A plug of new lava did make its appearance in the crater of Lassen at a later date).

KILAUEA REPORT No. 978

WEEK ENDING OCTOBER 19, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

The early part of the week passed with no happenings of interest at the Volcano. About noon on Saturday, October 18, several medium-sized avalanches fell from the north wall of the pit, and small slides were noticed occasionally on Sunday. Steaming from the wall and floor cracks was very light during the entire week.

At 8:25 a. m., October 20, a moderate earthquake dismantled all of the instruments at the Observatory. The quake was felt over the entire island, with localities on the slopes of Kilauea receiving the strongest shock. This evidence corroborated the data from the seismograms which indicated that the center of the quake was under Kilauea crater. It is not yet possible to form an intelligent opinion as to whether or not this shock is the forerunner of an appearance of lava in Halemaumau.

There were two quakes of very feeble intensity during the week, recorded as follows: October 13, 4:12 a. m., and October 17, 7:31 p. m. Neither of them has been reported as felt anywhere on the island. Seventeen tiny tremors which may have been of volcanic origin registered on the seismograph at the Observatory. The non-volcanic trembling of the island which is reported as microseismic motion was slight throughout the week.

The average of the week's tilt recorded shows that the northeast rim of Kilauea has been tipped moderately (about 1.5 seconds of arc) in a north-northeast direction, ie. away from the pit. Tilting in this azimuth has usually been associated with changes of pressure under Kilauea crater, and the tipping away from the pit is considered as an indication of increase of volcanic pressure. The earthquake of Monday morning was accompanied by a sudden tilt of nearly 1.5 sec. of arc in the same direction, suggesting that the quake was associated with upward pressure under Kilauea.

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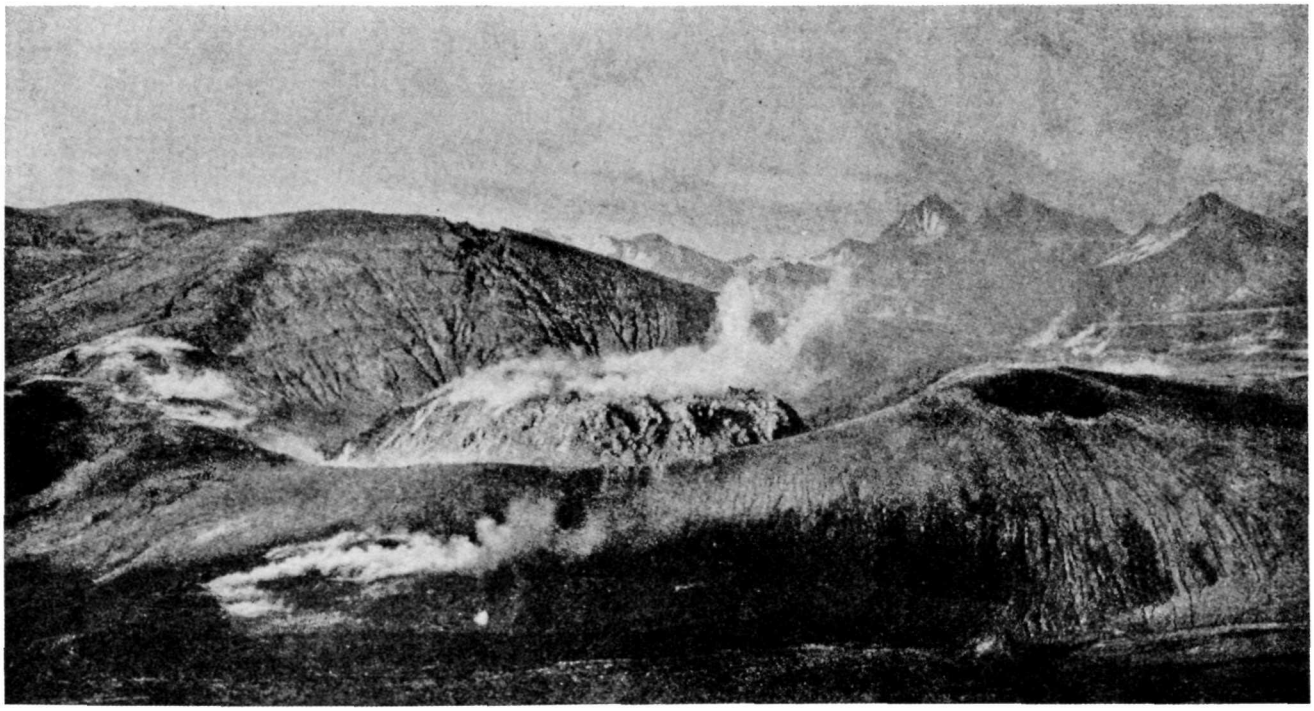
No. 305—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | October 30, 1930



Novarupta Dome, of siliceous lava, from the southwest, showing parts of the Valley of Ten Thousand Smokes beyond. Photo, National Geographic Society, 1919, from Katmai Series, No. 1.

THE ERUPTION OF KATMAI, ALASKA, 1912

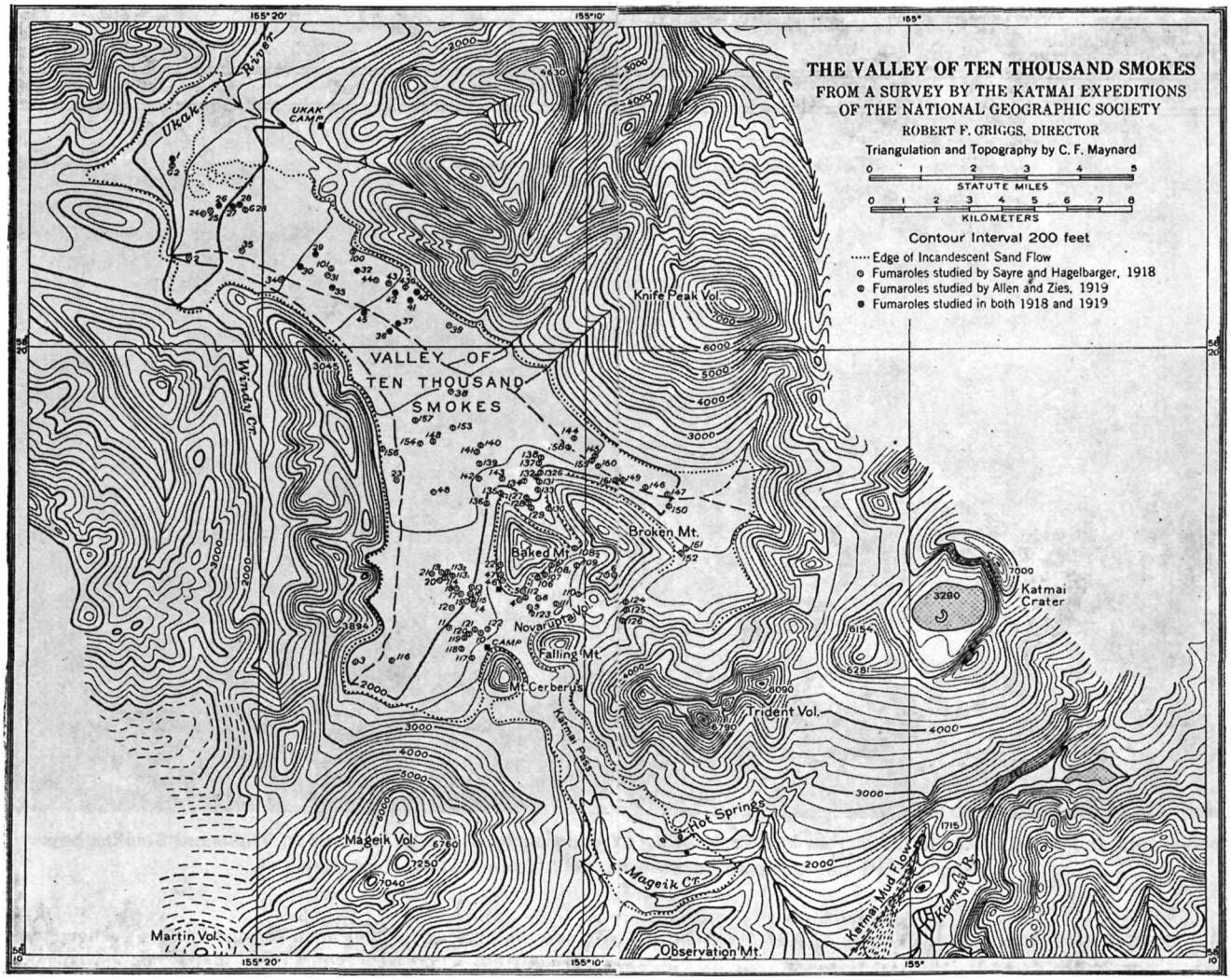
By H. Okimura. Reference: Robert F. Griggs, National Geographic, September 1921, pp. 219-292.

The explosion of Katmai Volcano in Alaska in June 1912 is ranked among the twelve greatest historic eruptions of the world. It is easy to see the justification of giving this rank when it is shown that as a result of this eruption, a town a hundred miles away was buried under a foot of ashes; that so loud were the concussions that the comments of people at a distance of 750 miles were excited; and that the quantity of dust thrown into the upper atmosphere was such that the intensity of the sunlight was diminished for many months throughout the northern hemisphere. The eruption giving rise to the Valley of Ten Thousand Smokes was a sequel to eruptions from the floor of valleys at a considerable distance from Katmai as shown by the fact that the stratified ashes from Katmai everywhere lie on top of the deposits of this earlier phase of eruption.

Lack of any eye-witnesses and any recorded happening resembling this sort of eruption made difficult the interpretation of the events of this great explosion. True, there was one, "American Pete" as he was called, who had witnessed the occurrence but aside from stating that it was dark and hot ashes fell, the only eye-witness could not much enlighten the explorers. The host of small volcanoes or vents which burst forth destroying the once beautiful green valley, presented a feature unusual in volcanic phenomena, for here no dormant vents had awakenend, but volcanoes had been formed in areas where none had existed. The new volcanoes, made simply of holes blown through the floor of the valley, began to thrown out ash and pumice in enormous quantities soon after their formation.

It is believed that in addition to myriads of fumaroles, hundreds of vents must have been belching forth incandescent material in veritable torrents of fire. Quantities of red-hot solids and liquids, sands and stones, masses of fluid or semi-fluid lava rushed out of the vents and poured out on the ground to roll down the slope and consume everything along its path. It is also believed that had one been able to witness the scene, there would have been seen many separate volcanoes each pouring forth its own mass and giving rise to great black clouds to a considerable height in ever-expanding convolutions. The smoke, instead of deriving its source from the mass of incandescent material around the vent, originated from the gases that boiled out of the semi-molten lava. The quantity of gas given off was so great as to be able to puff up the lava into pumice and entirely disrupt it by the expansive force of escaping gas.

The valley was overgrown to an altitude of 1500 feet by a dense forest and except for the ancient lava flow the rocks of the valley are not volcanic, consisting of sand and shale full of fossils of marine shell-fish of Jurassic age. Long before fires that consumed the surrounding vegetation had time to run their course, the mass of incandescent fragments accumulating round the separate vents coalesced until they covered the whole area of the valley,



Map showing Katmai crater on the east, Novarupta Dome in the middle, and the pumice-filled Valley at the left. From National Geographic Society, Katmai Series, No 1.

converting it into a single fiery torrent of red-hot sand and rock which began to roll down the valley under gravity for seventeen miles and even at that distance the heat was so intense as to reduce every stick it touched to charcoal. This fiery mass is not comparable to ordinary lava, although undoubtedly a liquid in the beginning, it did not remain so, for the escaping gas converted it to solid fragments suspended by the enormous quantities of gas given off.

The main arm is toward Naknek Lake for seventeen miles while another completely encircles Broken Mountains. The greatest length is twenty miles while the greatest breadth is nine miles, the total area covered being 53 square miles. The magnitude of the operation by which it was produced could be conceived if it is said that the sand flow is equivalent to the output of all the stone crushers in the United States for a period of 100 years.

The highest temperature was 645 degrees Centigrade and a stick thrust into the hole was changed to glowing coal within a few seconds. Big fumaroles furnished any degree of heat that might be needed for cooking, while snowdrifts behind the tents gave water and provided refrigeration. The steam from the fumaroles was highly charged with either hydrochloric or hydrofluoric acid which ate the rope to pieces and made holes in aluminum pots. Bacon was fried in no time, while corn bread was baked satisfactorily in Nature's oven.

In some places, columns of very hot steam came out under considerable pressure. The emerging gas came with such a rush that when a cup of water was poured over it, the water was vaporized before it had a chance to touch the bottom and a hat thrown in was tossed up thirty inches in the air.

Although the explorers had been able to get a fair idea of the "Smokes" themselves, they had no adequate conception of the marvelous coloration of the valley. One of the men who had lived on the brink of the Grand Canyon was impressed with the striking colors which were altogether different from those of the Canyon. The colors of the Canyon being remarkable at a distance, the coloration is produced entirely by the wonderful atmosphere and brilliant light which floods its recess. The colors of the valley are more brilliant when seen at close range, but at a distance they are grayish or brownish due to the fact that all the colors of the spectrum, being present close together, blend into a neutral color. In some places con-

siderable areas are leached out to a gleaming white by the acid fumes, while in some places pure yellow sulphur overlies other colors, and in still other spots where the ground is not too hot a bright green color is produced by the growing algae.

LASSEN REPORT No. 26

Lassen Volcano Observatory.
R. H. Finch, Associate Volcanologist.

During the summer of 1930 the National Park Service built a modern fire lookout building on the summit of Mt. Harkness, 8,039 feet above sea level. The United States Geological Survey installed seismographs in the basement of the building on August 21, 1930.

Eighty-eight tremors were recorded during the month that the seismographs were in operation. In addition to these tremors, there were, on many days, more or less slight continuous vibrations with a period of two seconds. This continuous shaking was stronger in the north-south direction than in the east-west. This type of vibration appears to be peculiar to the mountain top.

The entire mountain top is shaken by strong winds and the seismographs show a very irregular record on windy days. Puffs and gusts of wind produce records of tremor with considerable amplitude.

Good records were written of the southern California earthquake of August 30, 1930. The record of the Eureka, Cal., shake of August 23, 1930 was larger than that written by the instruments at Mineral. Several of the shakes that were recorded at Harkness were not recorded at Mineral.

Some time during July, the "Big Steamer" or uppermost large vent in the Supan Solfatara increased in activity and scattered mud for a distance of forty feet around the vent.

What was hitherto a large steam vent in the southeastern end of the Devil's Kitchen is now a boiling pool about 10 feet across. It boils constantly raising the main body of water to a height of four or five feet and occasional jets reach a height of 10 feet.

The Boiling Lake was the lowest during the summer of 1930 that it has been for several years.—R.H.F.

KILAUEA REPORT No. 979

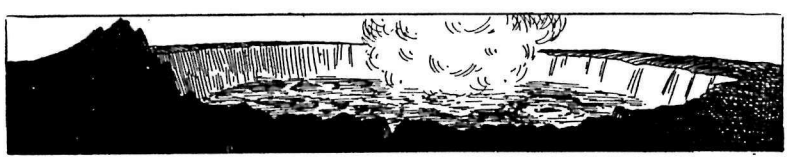
WEEK ENDING OCTOBER 26, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

A few avalanches in Halemaumau occurred simultaneously with the earthquake on Monday morning, October 20, which are thought to have been started by the quake. Since that time, no rock falls of noticeable size have been seen. The steaming of the wall and floor cracks has been very light except for short periods during rains.

The seismographs at the Observatory registered very slight traces of a distant earthquake on October 24. The record started at 9:55 a. m., Hawaiian Standard time. Only two local shocks were recorded during the week, the one moderate earthquake at 8:25 a. m. October 20, and one very feeble shock at 6:27 p. m. October 24. Fifty-seven very small tremors registered on the seismographs during the week, and the microseismic trembling of the island increased a moderate amount the later part of the week accompanying the few days of high wind and heavy surf.

During the earthquake of Monday morning, the ground under the Observatory was tilted to the north-northwest (errouneously stated last week as north-northeast). But since the quake, there has been practically no tilting of the ground as registered by the instruments. It would appear that the increasing pressure which caused the northeasterly tilting last week had culminated in the big quake. It will be interesting to see whether the first major change of pressure after this temporary standstill will be a decrease or a further increase.





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The Volcano Letter

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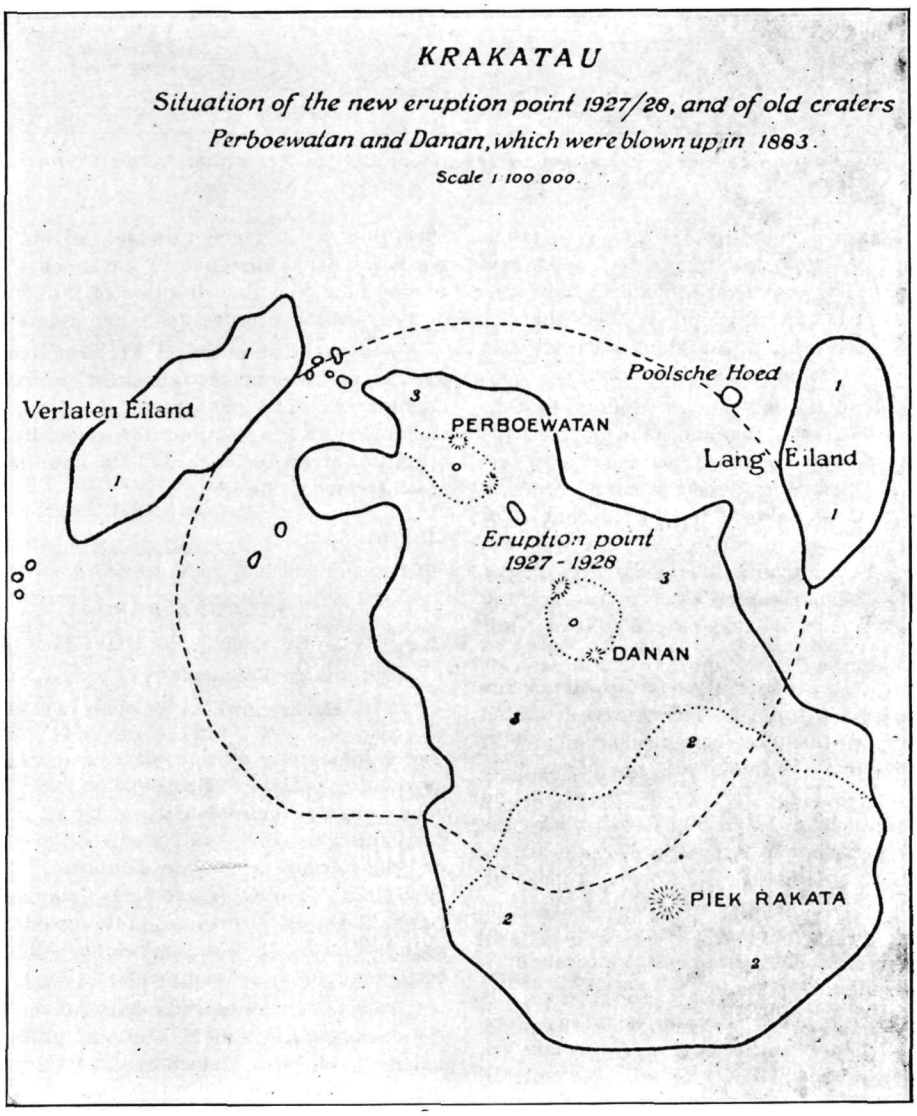
No. 306—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — November 6, 1930



Arrangement of the three craters Perboewatan, Danan, and Rakata of Krakatoa in 1883. The area enclosed within the heavy broken line is that region which was engulfed in the 1883 eruption. The location of the 1927-28 activity also shown. After Stehn.

THE ERUPTION OF KRAKATOA, 1883

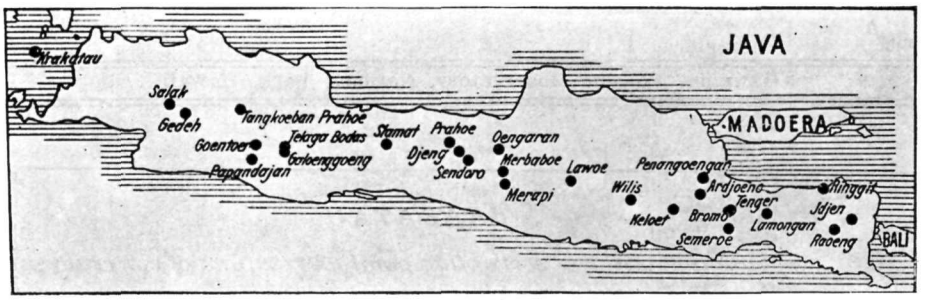
Review by R. A. Miyake of the Report of the Krakatoa Committee of the Royal Society.

Krakatoa is only a fragment of a great crater-ring rising out of the Sunda Strait, which separates Java from Sumatra. Along the line of this Strait we have evidence of a transverse fissure crossing the main fissure nearly at right angles. Upon this transverse fissure, a number of volcanoes have been built, namely: Pajung, in Java, with a height of 1,500 feet; the cone of Princes Island, 1,450 feet; Krakatoa, 2,623 feet; Sebesi, 2,285 feet; and Rajah Basai, in Sumatra, 4,308 feet.

In spite of the significance of its position at the point of intersection of these two great lines of volcanic fissure, Krakatoa had, until the year 1883, attracted but little attention.

On the afternoon of the 26th of August, and through the succeeding night and day till the early morning of the 28th of August, it was evident that the long-continued moderate eruptions (Strombolian stage) which had for some months been growing in intensity, had passed into the paroxysmal (Vesuvian) stage.

About 1:00 p. m. on August 26, the detonations caused by the explosions attained such violence as to be heard at Batavia and Brutenzorg, about 100 English miles away.



Distribution of active volcanoes in Java from Bali to Krakatoa. After Stehn.

One hour later, Captain Thomson of the Medea, then sailing at a point 76 miles east-northeast of Krakatoa, saw "a black mass rising up like a smoke in clouds" to an altitude which has been estimated as being no less than 17 miles. The great detonations at this time were said to be taking place at intervals of about ten minutes.

By 3:00 p. m. the explosions had so increased that their sound was heard at Bandong and other places 150 miles distant, and by 5:00 p. m. they had become so tremendous that they were heard all over the island of Java. The noise is described as being like the discharge of artillery close at hand, causing rattling of the windows and shaking of pictures and other objects hanging on the walls. Nearly all observers agree that there was nothing in the nature of earth-quake shocks, but only strong air-vibrations.

At 7:00 p. m., when the dense vapor and dust-clouds brought on early darkness, the whole scene was lighted up from time to time by the electrical discharge, and at one time the cloud above the mountain presented "the appearance of an immense pine tree, with the stem and branches formed with volcanic lightning." The air was loaded with excessively fine ashes, and there was a strong sulphurous smell. The steamer G. G. Loudon passed to the northwest and west of the volcano within a distance of 20 or 30 miles. It was seen to be "casting forth enormous columns of smoke" and the vessel passed through "a rain of ashes and small bits of stone."

The explosive bursts of vapor beginning on the afternoon of Sunday and continuing at intervals of ten minutes, increased in violence and rapidity, and from sunset till midnight there was an almost continuous roar which moderated somewhat towards early morning.

The constant augmentation of tension beneath Krakatoa in the end gave rise to a series of tremendous explosions on a far grander scale than those resulting directly from the influx of the sea-water into the vent; the four principal of these occurred at 5:30, 6:44, 10:20 and 10:52 Krakatoa time on the morning of August 27. Of these, the third occurring shortly after ten was by far the most violent, and was productive of the most wide-spread results.

After the great outbursts of the early morning of the 27th, it appears that there was a lull for a time inasmuch as no explosions were heard at Brutenzorg during the afternoon. At 7:00 p. m. the explosions began again, increasing in violence until 10:00 or 11:00 p. m., when they again declined and finally ceased to be heard at 2:30 a. m. on Tuesday, the 28th of August.

The soundings of the ocean bottom around the volcano after the eruption showed that a great depression or fissure had been formed, which extended eastward from Krakatoa for a distance of seven or eight miles, and extended nearly in the direction of the great line of volcanic activity which crosses Java and Sumatra.

The greatest outburst of Krakatoa in 1883 was the excessively violent though short paroxysm with which it terminated. The phenomena displayed during this eruption are to be accounted for, according to Judd, by the situation of the volcano and its liability to great inrushes of water from the sea.

KILAUEA REPORT No. 980

WEEK ENDING NOVEMBER 2, 1930

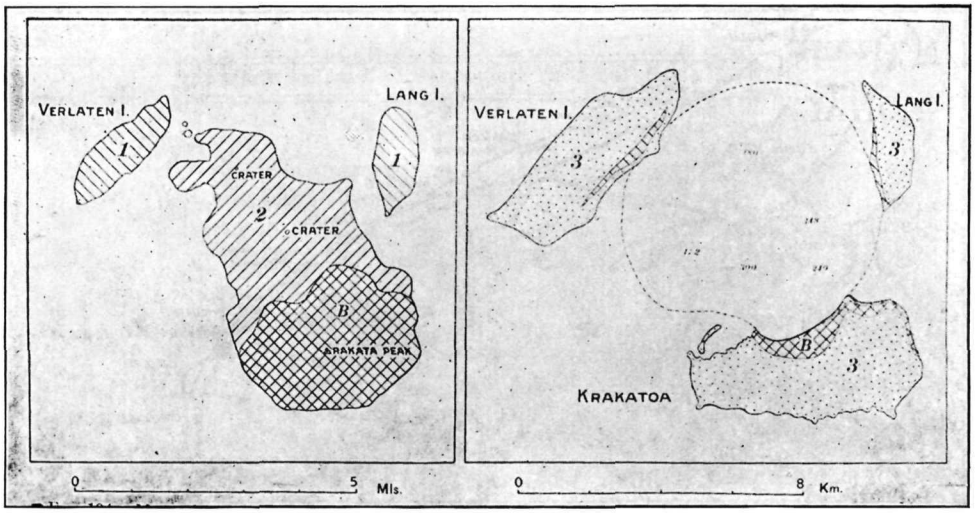
Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge.

Halemaumau still persists in showing no signs of reawakening activity. Even avalanching from the walls has been conspicuously absent during the past week, and the dry, sunny weather has permitted the steam from the wall and floor cracks almost to disappear. A slight earthquake on Friday evening was felt by many people in the National Park, and by some of the residents of Hilo. Probably it was felt in Kau and Kona, but was not sufficiently disturbing to cause comment.

The instruments recorded this quake at 6:23 p. m., October 31, as a shock of slight intensity. The distance to its origin was determined as 32 miles, which would place it as a Mauna Loa disturbance. Three very feeble quakes were also recorded by the Observatory seismograph as follows: October 28, 4:19 a. m.; October 29, 1:35 p. m.; and October 31, 7:41 p. m. None of these has been reported as felt, and the records were not clear enough to establish the distance to any of their origins. Small tremors which may have been of volcanic origin were more numerous this week, the instrument having recorded 42 of them in the seven days. Non-volcanic trembling of the island was slight during much of the week, but increased slightly with the strong winds of the week-end.

The average of the tilt readings for the week shows a very slight increase in a north-northwest direction. However, an analysis of the daily readings of tilt shows that there has been no consistent directional movement which would be the case if there had been a definite change in pressure conditions under either volcano. This makes the second week of apparent stagnation since the Kilauea earthquake of October 20. Some change, either an increase or a relaxation of pressure, may be expected during the coming week.



Plan of Krakatoa volcano before and after the great explosive eruption of 1883. After Daly.

THE ERUPTIONS OF CINDER CONE, LASSEN VOLCANIC NATIONAL PARK, CALIFORNIA

The existing knowledge of the eruptions of Cinder Cone, a small basaltic volcano near Lassen Peak, and descriptions and theories as to the origin of its rather remarkable lava are very well summarized in a recent paper by R. H. Finch and C. A. Anderson, "The quartz basalt eruptions of Cinder Cone, Lassen Volcanic National Park, California," University of California Publications in Geology, Vol. 19, No. 10, 1930, pp 245-273. The general descriptions of the eruptions is of considerable general interest inasmuch as the last lava flow from this vent is found to be one of the most recent flows in North America.

The first account of activity of Cinder Cone is a paper, published in 1874, by H. A. Harkness, "A recent volcano in Plumas County." He quoted statements from a number of independent observers which establish the fact that lights were seen in the Cinder Cone area on many different nights during the winter of 1850-51. Also two prospectors reported passing by an active volcano and hot rock in that region in the summer of 1851. On the strength of these reports and his own observation a little later, Harkness attributed all of the cinders and lava of Cinder Cone to activity in the winter of 1850-51.

J. S. Diller of the United States Geological Survey described a detailed investigation of Cinder Cone in several papers which appeared between 1890 and 1900. Diller showed that the volcanic features of this area are the product of two main periods of activity with a considerable time interval between. He showed that trees about 200 years old were growing near the old cinder cone, but that the more recent second period of activity might have occurred at some late date, though prior to 1840. He dismissed the Harkness evidence as in adequate proof of an eruption in 1850-51.

A. L. Day and E. T. Allen of the Geophysical Laboratory at Washington studied Cinder Cone in connection with their work on the Lassen Peak eruptions, and published their findings in 1925. They accepted Diller's idea of two periods of activity, but showed that a tree over 200 years old was growing at the edge of the younger flow. This new evidence was advanced against both Harkness' and Diller's dating of the late activity.

In 1927, R. H. Finch issued a preliminary statement to the effect that the later "flow" actually was made up of two or three flows of different age and that the youngest of these might be of very recent date.

In the same summer, A. E. Jones made a reconnaissance study of the magnetic properties of the flows at Cinder Cone. He found lava flows of at least five different ages; the three oldest belong to Diller's early activity, and the two youngest flows, to the late activity. The youngest flow was given an approximate date of 1846, and the oldest flow was dated about 500 A. D.

Finch and Anderson add a number of facts to this previously existing information. They show that the main cinder cone is the product of several different eruptions of pyroclastic material, probably separated by considerable intervals of time. Further several small cinder cones are found in different parts of the lava field, indicating that a number of vents were involved in the eruptive activity of the region.

They give a detailed discussion of the latest flow of black lava which is easily distinguished from the older flows by its fresh black color and its unweathered surface. This latest flow lies entirely on top of the older flows from Cinder Cone so that its hot margins never had an opportunity to destroy the vegetation which grows at the edges of the whole lava field. In view of this fact, the evidence offered by Day and Allen and by Diller to prove that the lava must be over 200 years old is not applicable to the youngest flow. Therefore Finch and Anderson conclude that this flow was formed by activity in the winter of 1850-51.—H. A. P.

TILTING OF THE GROUND DURING OCTOBER

A review of the tilt record for the month of October shows several features of interest. During the first few days of the month there was an extremely heavy rainfall at the Volcano. Accompanying this heavy rain, and perhaps caused by it, the ground tilted considerably to the south. Beginning about October 7, the ground tilted steadily and strongly in a north-northeast direction, which is up and away from the active center of Kilauea. Tilting in this direction has been found usually to accompany an increase of lava pressure in this volcano. This phase of the tilting was culminated by the earthquake of October 20 which produced a sudden tilt to the northwest. Since that date, there has been no consistent tilting of the ground, but only a very small amount of apparently aimless wandering. A tabulation of the amount and direction of tilt by weeks is as follows:

Sept. 20—Oct.	5	1.7	sec.	of	arc	—S.
Oct. 6—Oct.	12	1.3	"	"	"	—N.N.E.
Oct. 13—Oct.	19	3.1	"	"	"	—N.N.E.
Oct. 20—Oct.	26	1.1	"	"	"	—N.



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307

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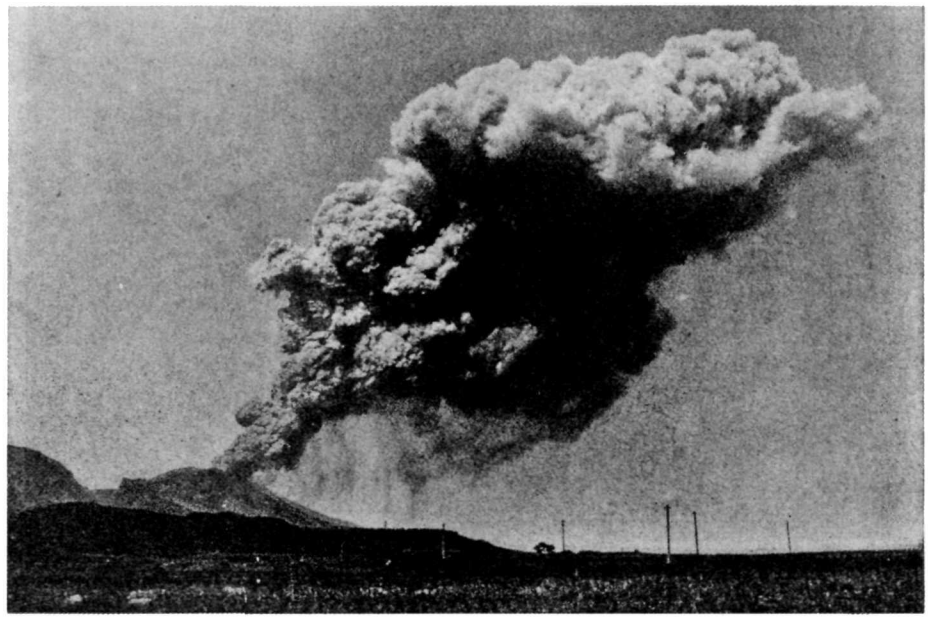
No. 307—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — November 13, 1930



An explosive eruption from Asama-yama in 1911. Much greater eruptions of this type from this volcano, Bandai-san, Krakatoa, Katmai, and others have thrown huge quantities of fine dust into the upper layers of the earth's atmosphere, creating a universal haze which affects the temperatures of the surface of the earth. Photo Uozo.

EFFECT OF VOLCANIC DUST ON EARTH TEMPERATURES

By H. C. HANNA

In June 1912, C. O. Abbot of the U. S. Geological Survey was in Algeria making measurements on the quantity of heat coming to the earth from the sun. At the same time, F. E. Fowle of the Geological Survey was engaged in making similar measurements at Mount Wilson in California.

At Bassou, Algeria, during Abbot's observations of June 19, 1912, he noticed streaks of dust lying along the horizon. These were joined by others and in a few days the sky appeared "mackereled" although no clouds were present. Finally the phenomenon became so marked that any observations were discontinued. On June 29, the whole sky was filled with haze which continually became worse until the expedition departed on September 10.

Thinking that this was merely a local condition, Abbot returned to the United States to learn of the eruption of Mt. Katmai in Alaska. He also found from reports of the Weather Bureau and European journals that these same atmospheric conditions had been noticed elsewhere.

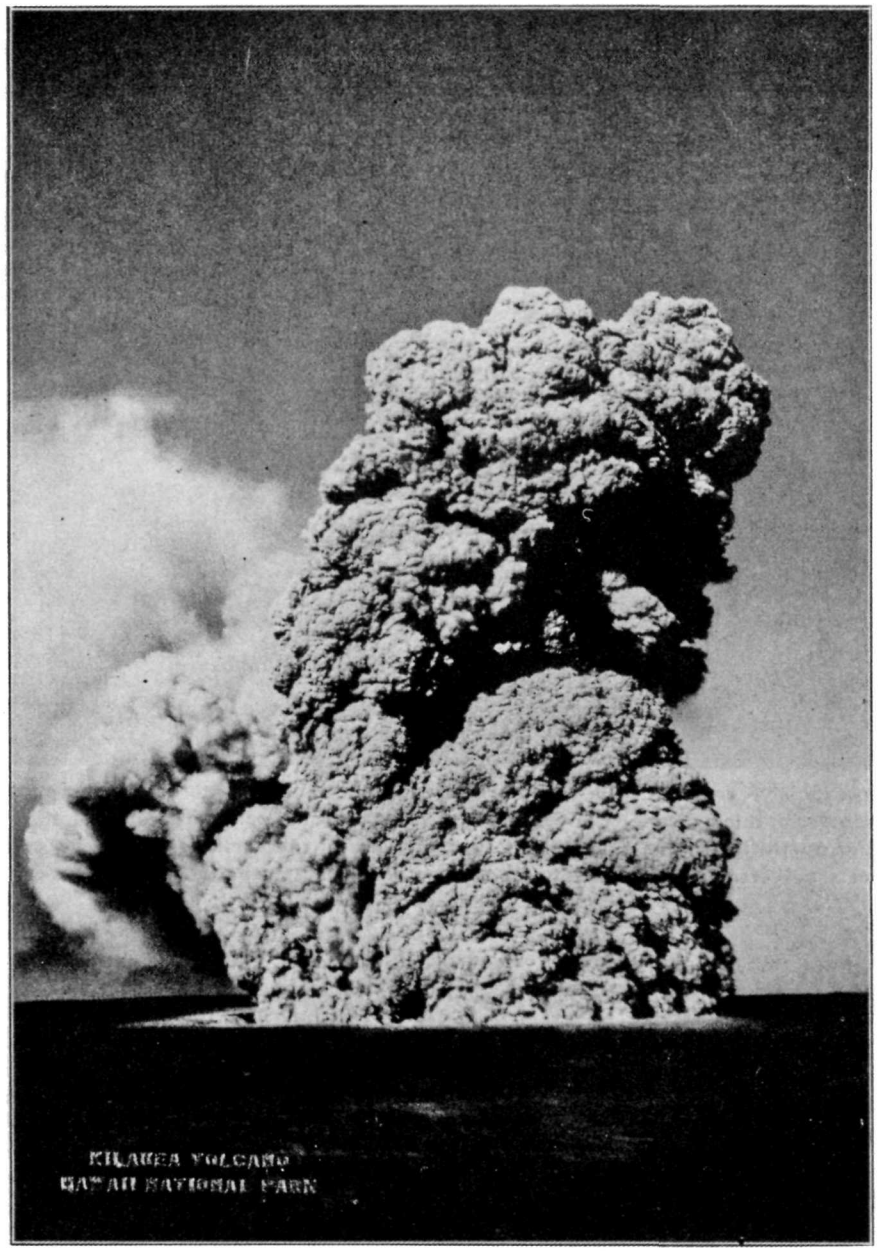
This effect was naturally assumed to have been caused by the Katmai eruption, and immediately estimates were made to discover the speed with which the dust reached certain distant points. Roughly the dust had moved at a rate of 40 miles per hour toward Washington; 25 miles per hour toward Basson; and 3 miles per hour toward Mt. Wilson. The small average speed toward Mt. Wilson probably is to be accounted for by the fact that it is more nearly south of Katmai and the high velocity winds follow a general course from east to west.

The nature of the observations made and the apparatus used should be considered; first, the pyrheliometer was used to measure the heating effect of the sun at the earth's surface; and second, the spectro bolometer, a device of Langley, was used to observe the excessively minute heating effects of the rays of different color in the solar spectrum. Using a thin, blackened thermometer, the heat produced by each ray of the spectrum from the ultraviolet to far beyond the red was measured.

Measurements were made at intervals of several hours. Then knowing the angular distance of the sun from the horizon at each time of observation, the thickness of the layer of atmosphere traversed by the solar beam was computed. After this it was possible to determine how much greater the heat intensity of the rays would have been had the observations been made outside of the earth's atmosphere—"for instance on the moon." Then it was possible to determine how much the ray of each part of the spectrum had been diminished by passing through the dust-laden atmosphere on its way to the earth's surface.

From these measurements it is shown that the haziness of the atmosphere during the summer of 1912 produced a very marked decrease in the direct solar radiation for all parts of the spectrum which reached nearly 20 per cent of the total heat at high sun.

There was naturally an increased brightness of the sky for this loss of heat in 1912. This was due to the



One of the explosions from Halemaumau in 1924. The Hawaiian volcanoes are not in the habit of erupting with a violence sufficient to throw dust into the uuper atmosphere.

reflection of the sun's rays from the dust in the air, thus making the sky bright as do the particles of dust in a room reveal the path of a sunbeam in it. One can easily see that since the light of the sky and the loss of heat by reflection into space both depend on the presence of the particles of dust in the atmosphere, an increase of the dust must make the sky brighter and the loss to space of sun heat greater.

In the main it is this that interested the observers for they wished to inquire how much heat was lost to the earth by the reflection of the atmosphere, owing to the dust which came from Katmai volcano. Abbot and Fowle constructed a formula involving the following factors: (A) is the direct solar beam; (B) is the skylight; (C) the rays absorbed by atmospheric water; (D) rays reflected into space from upper atmosphere; and (E) heat of solar beam outside the earth's atmosphere, approximately the sum of A, B, C, and D.

Measurements of (A), the direct sun rays, and (C), the absorbtion by water and other atmospheric vapors, are made each day. Abbot built an apparatus to measure (B), the direct light of the sky. Knowing, then, the value of (E), (D) could be found readily by subtracting from (E) the sum of (A), (B), and (C).

Following this proceedure, the results obtained at Bassou on the 5th, 6th, and 7th of September, 1912, were as follows, stated in calories per square centimeter per minute:

(A) Heating effect of direct beam of zenith sun	1.250
(B) Heating effect of entire sky	.245
(C) Heating effect of rays absorbed by atmospheric vapors	.175
Total of (A), (B), and (C)	1.670
(E) Heating effect of sun outside earth's atmosphere	1.950
(D) Heat lost by reflection from dust in atmosphere	0.280

Thus 0.280 calories per square centimeter per minute represents the heat reflected to the atmosphere in 1912. In previous years, it was found from experiments at Mount Wilson and Mount Whitney that this heat reflection was less than .050 calories. From these results, Abbot draws the following conclusion: "I am of the opinion that the difference between these results of 1912 at Bassou and those of earlier years at Mt. Wilson and Mt. Whitney (about 0.200 calory) represents approximately the radiation reflected away to space by the volcanic dust of 1912, or, in other words, the loss of heat available to warm the earth which we must attribute to the great haziness which prevailed in 1912. Hence I conclude that the dust of Katmai diminished the heat available to warm the earth in the north temperate zone about ten per cent during the summer of 1912. In accordance with the laws of heat and radiation, this might produce a fall of seven degrees Centigrade in the temperature of the earth as a whole if it were effective for a long enough period of time."

The question naturally arises as to whether volcanoes can really produce such world wide haze. Going back to the records of times of the great volcanic actions of the last 150 years, we have the eruption of Asama-yama, Japan, in the year 1783. In the same year occurred another extraordinary eruption, that of Skaptar Jokul in Iceland which took place on June 8 and 18th.

Arago records dry fogs in the upper atmosphere on about the same date at places distant from each other such as Paris and Avignon, Turin and Padua. It extended from the north coast of Africa to Scandinavia and lasted more than a month. In Languedoc, its density was such that the sun was not visible until it had reached a position 17 degrees above the horizon, and at the time of new moons the nights were so bright that small print could be read even at midnight.

In 1815 occurred the eruption of Mayou in the Philippine Isuands and on April 7 to 12, 1815, the eruption of Tamboro Sumbawa. For three days there was absolute darkness for a distance of 300 miles. Then came the long twilights and sunsets for which the year of 1815 is so notable in Europe.

Hecla and Vesuvius erupted in 1845 and 1846, and Merapi in 1872. In 1883 occurred the eruptions of Krakatoa and St. Augustine in Alaska. The extraordinary atmospheric phenomena which followed these remarkable volcanic eruptions were so in relation of effects to causes that there can be no doubt as to the reasonableness of ascribing the haze of the summer of 1912 to the volcanic eruption in Alaska.

Very great departures from the usual intensities of solar radiation occurred from 1803 to 1807, 1888 to 1893, and from 1902 to 1904. We have only to look back to the history of such volcanic eruptions as Wulano and Mayon in 1888, Meharaizan in 1889, Mt. Zoo in 1890, Bandaisan and Etna in 1892, Pelee and Santa Maria in 1902, Colnira in 1903 to see that the decrease in solar radiation over these periods had much volcanic action to cause it

Abbot assembled data on recorded temperatures during the year 1912 which show that the surface of the earth was appreciably cooled, especially in the high mountain regions, by the haze from the explosion of June 1912.

He studied the temperature departures for Pic-du-Midi, Puy-de-Dome, and Lchneekoppe for the years 1882 to 1884 inclusive to determine the effect of the Krakatoa eruption. These results, however, were not so satisfactory, although, at some of the stations, daily temperature depressions were found beginning in September 1883. He says:

"The fact is that the temperature of the earth is a function of so many variable quantities that general or cosmical effects are often greatly obscured by local ones. Studies, however, are being made by several authors to detect if there is a periodicity of terrestrial temperature corresponding in time to the sun-spot cycle of about 11 years. It has been found that there is indeed an increased temperature at times of minimum sun-spots. This increase of temperature is greater than would be caused directly by darkening of the sun by sun-spots, so that it seems that there is accompanying the spots, some secondary influence affecting terrestrial temperatures."

These fluctuations in temperature not being accounted for by the variation of sun-spots, Abbot and Fowle have endeavored to see whether a combination of the effect of the sun-spot cycle with the effect of volcanic haze will produce a more exact correspondence between the cosmical phenomena and the temperature curve of the earth's surface.

Their work gives a set of curves comprising the sun-spot curve from 1880 to 1909, the curve of departures from the mean temperatures at 15 stations in the United States and a similar curve of departures for the world. These three curves show, quoting Abbot, "a considerable degree of correspondence yet it is not hard to see that there is also much discordance." This diagram tends to lead to the conviction that terrestrial temperature varies in accordance with fluctuations in the number of sun-spots and, in addition, that the intensity of the sun's direct radiation as measured at the earth's surface is much modified by such terrestrial phenomena as the dust of volcanic eruptions.

Humphreys follows a line of reasoning similar to the above writers though he carries his conclusions farther. The main differences between his views and those of Ellsworth Huntington (another student of the subject) are that (1) he regards variations in solar activity as of negligable importance so far as our present knowledge is concerned and (2) he strongly emphasizes the importance of volcanic dust. In his own words,

"Variations in the average temperature of the atmosphere depend jointly upon volcanic eruptions through the action of dust on radiation and upon sun spot members, through, presumably, some intermediate action they have upon the atmosphere.—Hence, as there appear to have been several periods of great volcanic activity in the past with intervening periods of quiesence, it is inferred that volcanic dust in the upper atmosphere was at least an important factor in some, if not all, the great universal climatic changes."

Huntington does not agree entirely with Abbot, Fowle, or Humphreys. After a lengthy discussion of facts, he

concludes that the variations in the sun are the main factor in modifying terrestrial temperature, but their effect may be much modified by the presence of volcanic dust in the atmosphere.

It is thought that if volcanic explosions continue active through a more or less long geologic time they could alone, or in part, cause cold or even glacial climate. We should, therefore, expect an extremely cold climate at the end of a mountain-making era during the "critical periods." Huntington points out that we have had ice ages at the close of the Paleozoic and Cenoxoic eras, but that the close of the Mesozoic (an era of extreme mountain making and volcanic activity in North America) did not result in a glacial but only a slightly cooled climate. There is also evidence that volcanism was renewed in the Cordillera of North America throughout much of the Eocene, and yet there was no glacial climate at the end of this time. In the same way there was a marked temperature decline at the close of the Cenozoic in the Pleistocene. Equally extensive movements were going on in Europe in the rise of the European Alps and earlier movements did not affect the climate.

It seems however, although there is some difference of opinion among the authorities on the importance of volcanic dust, that the most logical conclusion to draw from these discussions is that volcanic dust in the isothermal regions of the atmosphere has caused serious effects upon the temperature of the sun's rays at the surface of the earth.

References

National Geographic Magazine, February 1913, an article by C. O. Abbot.

Physics of the Atmosphere, by W. J. Humphreys.

Climatic Factor, Ellsworth Huntington, 1914.

KILAUEA REPORT No. 981

WEEK ENDING NOVEMBER 9, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge.

Halemaumau is still remarkably quiet. Steaming has been almost nil during the daylight hours of the week. A rather striking cumulus cloud was noticed above the pit the evening of November 4 which was formed when the column of warm air rising from the pit was interrupted by a layer of cold air blowing across the summit of Kilauea. No avalanches in the pit have been noticed or reported.

The seismographs recorded only one very feeble earthquake on November 9 at 5:14 a. m. The distance to its center could not be determined. Forty-four small tremors registered during the week and the non-volcanic microseisms have been of moderate size accompanying the rather heavy surfs which have been pounding on the coasts of the island.

The average of the week's tilt record shows a very slight tilt to the northeast, up and away from the crater. However, there has been no marked change in the tilting of the rim which would indicate a change of pressure conditions under the volcano.

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The Volcano Letter

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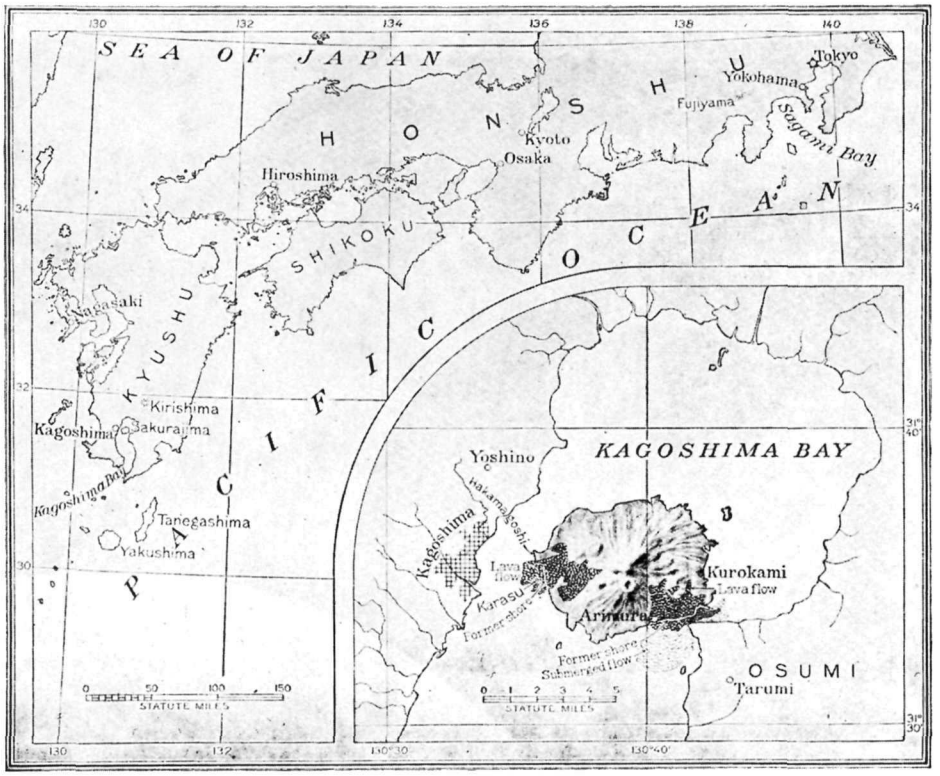
No. 308—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — November 21, 1930



Map of southern Japan and of Kagoshima Bay, showing Sakurajima and its 1914 lava flows. From National Geographic Magazine, April 1924.

ERUPTION OF SAKURAJIMA, 1914

Review by K. Onishi of F. Omori's article in the Bull. of the Imperial Earthquake Investigation Committee, Vol. VIII, No. 1, Sept. 1914.

Sakurajima volcano forms a small island in Kagoshima Bay on Kyushu, the southermost island of Japan proper. It is located on the great Kyushu rift, a crack which runs in a southeasterly direction from Japan to the Bonin Islands. The volcano has two high peaks, Minamidake and Kitadake, and a parasitic cone on the eastern flank called Nabeyama. A number of hot springs rise from its slopes. At the time of the eruption, the population of the island exceeded 23,500.

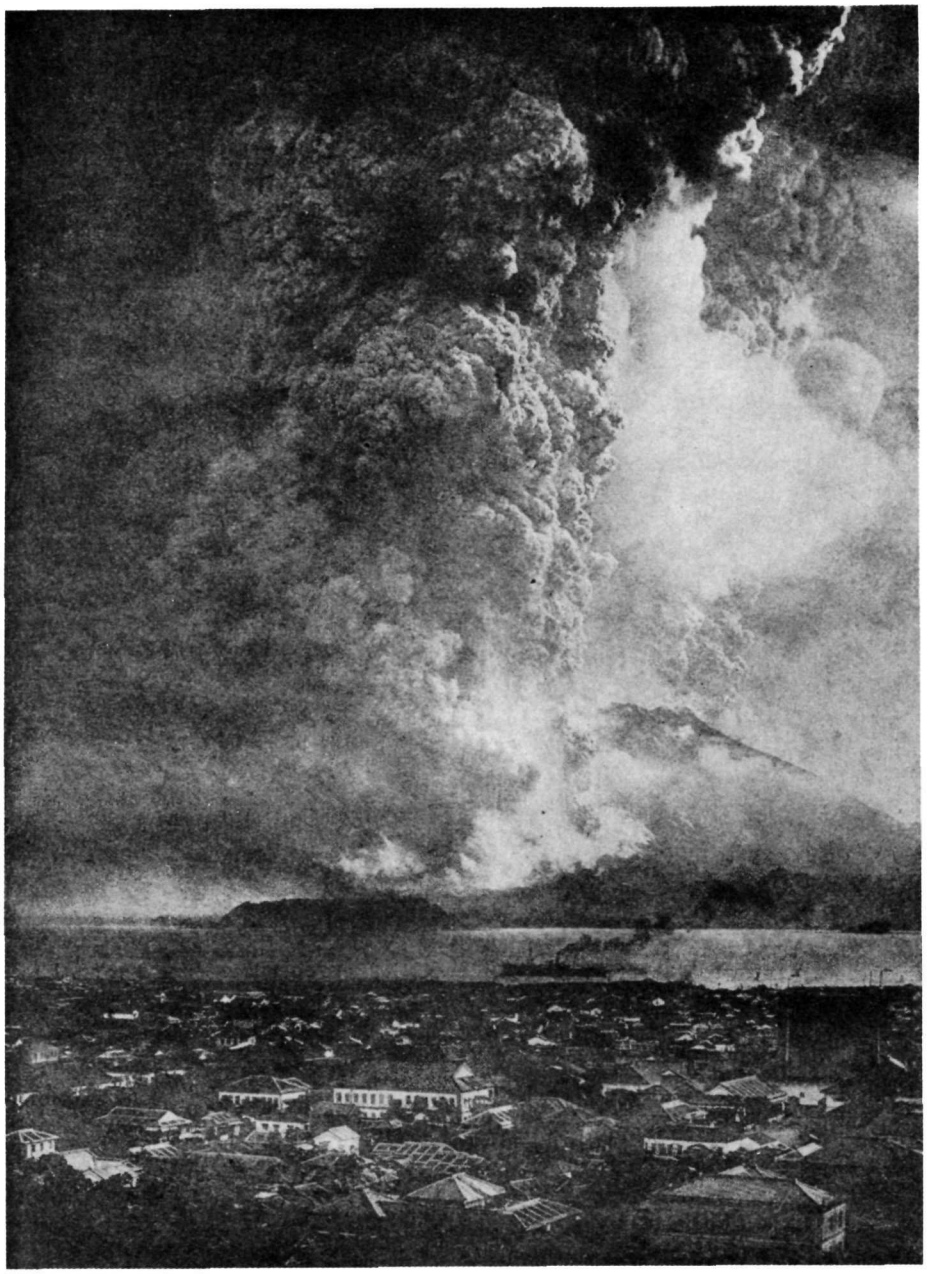
Investigations of the occurence of volcanic activity seem to point to a cycle of about 130 years in the Japanese volcanoes. In the years 1777-92, about 130 years previous to the year 1914, Oshima, Sakurajima, and Asama-yama had had tremendous outbreaks. Since Asama-yama, in 1908, and Oshima, in 1912, had produced numerous earthquakes and lava flows, Sakurajima was expected to follow suit not long after. Kirishima-yama, some 45 km. to the north of Sakurajima, finally burst out in November and December of 1913, and Sakurajima followed with an eruption two months later.

Warnings that Sakurajima was ripe for an eruption came in the forms of smoke, earthquakes, and an increased flow of water from the springs on the mountain. On the island, earthquakes were felt from the night of January 10, while the city of Kagoshima (on the shore of Kagoshima Bay) was mostly unaware of them until early in the morning of January 11. The frequency of the shocks increased with the progress of time, the greatest hourly numbers 28 and 27 being reached resepectively at eight to nine p. m. on the eleventh and three to four a. m. on the twelfth. As many as 66 shocks in one hour were felt on Sakurajima.

Early the morning of the 12th, the people noticed that water with a high temperature had started to issue from a number of places, and more could be seen bubbling up through the sea. On the opposite end of the island, the volume of water from the natural cold springs increased considerably while many wells had their water levels raised two to three feet.

At 8:00 a. m. on the 12th, a column of white smoke was seen rising from the top of Minamidake. Earlier in the morning, observers from Kagoshima had noticed slender filaments of white vapor above the mists that shrouded the mountain. Two hours after the smoke from Minamidake was seen, the first eruption occurred.

The unmistakable signs of the approaching disaster were sufficient to alarm the inhabitants who immediately began to desert their homes and seek refuge in Kagoshima



The eruption of Sakurajima on January 12, 1914 as seen from the heights back of Kagoshima. The peak is clear and the smoke and ashes are rising from rifts on the near and far sides of the cone. After Omori.

and the neighboring villages. The evacuation of the island was so exceptionally well handled that the whole population of over 23,500 was safe from harm when the final break came.

The first outburst came from the western side of the mountain facing Kagoshima about 500 meters up the slope, at 10:00 a. m. July 12. An interval of some 10 minutes followed when the east side of the island burst open with huge columns of smoke which rose to a vertical height of over 20,000 feet above sea level. This explosion completely enveloped the island in a mass of white and black smoke within a few hours.

On the evening of the first day of the outbreak, at 6:30, a strong quake took place. After this shock, the hot lava became stronger, reaching its maximum between 11:00 p. m. of the 12th and 5:00 a. m. of the 13th. After ten o'clock of the morning of the 13th, the violence of the explosions gradually decreased.

On the eastern and western sides of Sakurajima were formed seven small craters from which issued a lava of very high viscosity. The stream on the west reached the sea on the 16th, averaging 45 meters per hour during the first two and a half days. The lava continued to flow into the sea until it had invaded about two and one half square kilometers of former sea-bottom. The flow on the eastern (Nabayama) side was much faster, the lava finally blocking the narrow strait and joining the island to Osumi, intensity of the volcanic noises and the projection of red converting Sakurajima into a peninsula.

The total area covered by the western flow amounted

to 8.33 sq. km., while the eastern portion covered approximately 15.41 sq. km. The estimated total volume of lava that was ejected was 1.6 cu. km., the western half contributing .33 cu. km. and the remaining 1.27 cu. km. being the contribution of the eastern flow.

The showers of hot pumiceous lava fragments and ashes did considerable damage to the whole island, the villages of Koike and Akobaru on the west and Kurokami being especially hard hit. The ash precipitation was slight in Kagoshima (about 3mm, deep) whereas the northern and central parts of Osumi on the opposite shore of the bay received from 3 inches in places to over 3 feet. The total amount of pumice and ashes which fell has been estimated to be in the neighborhood of .62 cu. km. or 40 per cent of the total volume of the lava output.

The total amount of material exuded from Sakurajima is thus 2.2 cu. km. which is equivalent to one twelfth of the volume of the whole mountain.

The strong quake of January 12 must have been one of very deep origin and not a shock immediately connected with the eruption, because the intensity of motion was nowhere in Kyushu excessively severe. It was probably caused by the stress accumulation along the whole volcanic chain in southern Kyushu. This quake took the only lives which were lost in the activity, 19 persons being killed.

Considerable excitement prevailed in Kagoshima during the course of the eruption. The fear of asphyxiation by the poisonous volcanic gases was reason enough for immediate evacuation. Rumors of a huge tidal wave helped to aggravate the fears of the nearly panic stricken people. The only real source of danger came from the one great earthquake. This quake was registered on very distant seismographs in Europe and America.

ACTIVITY OF A CALIFORNIA VOLCANO IN 1786.

The following quotation was brought to the attention of the writer by Dr. Max Ferrand, Director of Research of the Huntington Library and Art Gallery.

La Perouse, in voyaging along the California coast in 1786 witnessed a volcanic eruption, and the location given on his map is roughly in the Lassen region. A direct quotation from his observations is as follows:

> " . . . . our latitude, observed at noon, was 40° 48′ 30″ north; our longtitude, according to the timekeeper, was 126° 59′ 45″ west. I continued my course to near the land, from which, at night-fall, I was only four leagues distant. We there perceived a volcano on the top of a mountain, which bore east of us; its flame was very lively, but a thick fog soon deprived us of this sight. . . . '"

As Mt. Shasta might be visible from a ship at sea in the position given, it, as well as Lassen Peak, should be considered as a possible source of the witnessed eruption. Both peaks would be nearly east from the stated latitude. If the eruption were from Lassen, nothing but an explosion cloud would have been visible. Considerable volcanic activity occurred at the summit of Mt. Shasta since the time of general glaciation, and nothing on the peak at present indicates the impossibility of there having a minor eruption in 1786. R. H. Finch.

LASSEN REPORT No. 27

Lassen Volcano Observatory

R. H. Finch, Associate Volcanologist

The western half of the Lassen edifice was shaken by a series of earthquakes on October 29, 1930. The shocks were strongly felt at Redding on the west and as far southeast as Mineral. The distance to the origin of the shakes from Mineral as determined by the seismograph of the Lassen Volcano Observatory was 27 miles, which makes the seat of the shaking to the northwest of Lassen Peak, or in the vicinity of Millville. Press reports indicate that the shake were stronger at Millville than elsewhere.

The series was ushered in by a very small and not generally felt shake at 4:10 a. m. The plainly felt shakes occurred at 4:34 a. m., 11:48 a.m., and 8:28 p. m. A light roar accompanied the shaking at many places.

On the 29th of April, 1930, a shake that was much stronger than any of the recent series occurred in the same region.

KILAUEA REPORT No. 982

WEEK ENDING NOVEMBER 16, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge.

Steam has risen from the floor of Halemaumau and the amount of visible steam from the wall and floor cracks of Kilauea has increased several times during the heavy rains of the week. A few rocks have been heard tumbling from the walls of the pit, but there have been no avalanches large enough to attract attention.

A distant earthquake wrote a very small record on the seismogram at 8:57 a. m., November 12. There were ten local shocks of very feeble intensity timed as follows: November 11, 11:26 a. m.; November 12, 5:38 p. m.; November 13, 8:50 a. m. distance 22 miles, and 10:11 p. m.; November 14, 2:57 a. m., and 1:30 p. m.; November 15, 6:57 a. m.; November 16, 3:52 a. m. center in Halemaumau, 1:34 p. m., and 7:55 p. m. The Observatory seismograph on the rim of Kilauea crater also recorded 48 small tremors, of which 30 occurred during the last four days of the week. During these same days, the instrument at Halemaumau recorded 42 tremors. Many of them were stronger at the pit than on the Kilauea rim, suggesting that they had their origin in Halemaumau. The non-volcanic trembling of the island was moderately strong during most of the week.

The average tilt for the week showed a slight movement in an east-northeast direction, all of which was gained through a marked tilting of the Kilauea rim up and away from the pit during the last four days. During this same period, the Halemaumau seismograph indicated that the rim of the pit was also tilting up and away from its center.

The latter half of this week showed the first definite change of conditions from the "stagnation" which has existed since the earthquake of October 20. The tilt change and the increase of tremors suggest an increase of pressure and movement of lava under Kilauea.



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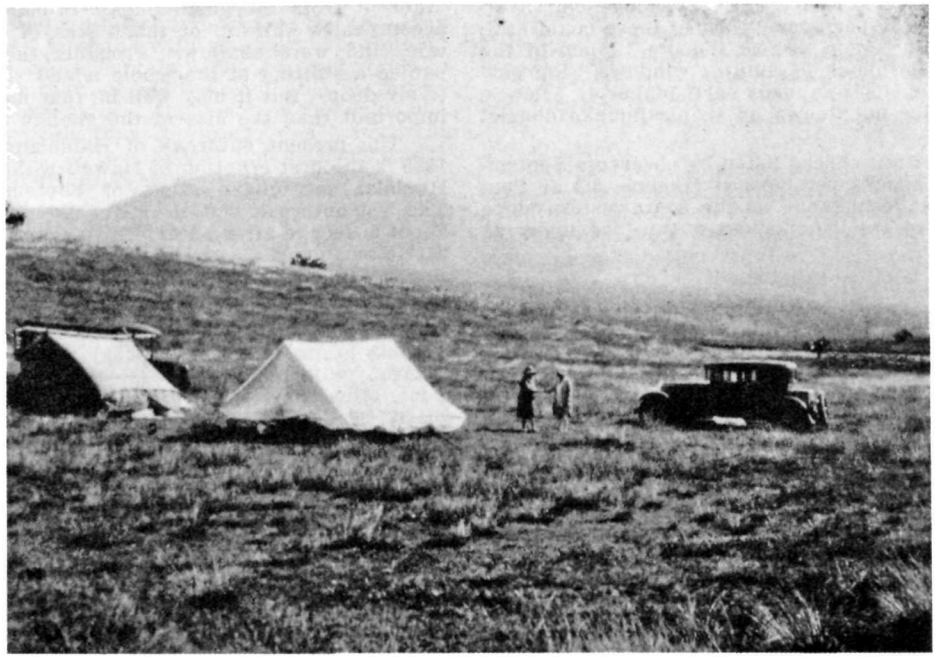

Camp of ranch people at Puu Anahulu during the earthquakes of October, 1929. Looking toward Puuwaawaa from the northwest, with Hualalai volcano in the haze at the right. Photo Jaggar.

THE HUALALAI EARTHQUAKE CRISIS OF 1929

What Happened

During the week ending September 18, 1929, the seismographs at Kilauea Volcano. at Hilo and at Kealakekua on Hawaii island registered nothing remarkable. Then came a really tremendous swarm of earthquakes in North Kona on and near Hualalai volcano. Sudden shaking began September 19 and continued, racking the countryside, reaching culmination in big earthquakes September 25 and October 5, and destroying hundreds of thousands of dollars worth of property in houses, walls, tanks, stone fences and roadways. No volcano eruption followed on Hawaii until now, November 19, 1930, when lava returns quietly into the bottom of Halemaumau pit of Kilauea volcano, on the opposite side of the island from Hualalai.

The spasms of earthquake September 20 and 21, 1929 were at intervals of several hours. Then the intervals shortened and the spasms lengthened in duration. The area of felt earthquakes extended itself. Maximum motion was within a circle of 35 miles radius around the summit of Hualalai. The force of shaking increased. The strongest motion and greatest destruction was near Puuwaawaa. The highest frequency of shakes was on the southwest flank of Hualalai. Rumbling was heard there but not at Puuwaawaa.

At Kilauea 221 shocks were recorded for the week ending September 25, as compared with only 9 for the previous week. As to epicenters or places of origin measured from the seismograms by the distances from the instrument station indicated by formula: at the Kilauea Observatory, for four weeks to October 16, the successive average weekly distances of epicenters were 23, 28, 35 and 44 miles. This looked like a progression of underground jolts from about Mauna Loa to about Hualalai.

Big earthquakes of Grade IX Rossi-Forel occurred at Puuwaawaa September 25 and October 5. These were felt throughout the Hawaiian Islands.

Airplane inspection of all the craters revealed no eruption of lava. The shaking continued for a month but gradually quieted down in November.

Statistical Data

At Kilauea the weekly frequency of shocks as indicated by numbers of earthquakes counted on the seismograms, beginning with the week ending September 25, was as follows for four weeks: 221, 244, 129, and 97. The maximum was thus the week ending October 2, between the two strong earthquakes. The frequency and intensity varied together. The Kilauea total of shocks to October 16 was 691, many of them felt.

For the four days between the two greater earthquakes different places with seismometric instruments registered the following numbers of shocks:

	Oct. 1	Oct. 2	Oct. 3	Oct. 4
Kilauea	19	13	15	18
Hilo	38	26	13	74
Kealakekua	155	110	96	138
Puuwaawaa	241	117	97	114

The frequency increases just before the big shock of October 5. The geographical gradation is not wholly accordant with distance form Hualalai. Thus Hilo has more shocks than Kilauea, yet is farther from Hualalai.

The instrumental record of decline in frequency was as follows:

	Oct. 8	Oct. 9	Oct. 10	Oct. 11	Oct. 12
Kilauea	16	15	14	10	9
Kealakekua	94	61	42	41	43
Puuwaawaa	387	353	235	203	139

This is reasonably consistent as a decline with the passage of time, and as showing geographical decrease of numbers with distance from the center.

The shock recorder at Puuwaawaa of the type described in Scientific American for November, 1929, with magnification x25. registered numbers of shocks as follows during the first part of the time of maximum frequency:

September 26	599	shocks
September 27	541	"
September 28	400	"
September 29	334	"
September 30	321	"
October 1	241	"

The computed instrumental total for the central region for 26 days from Sept. 21 to Oct. was 6211 shocks. This averages 239 per day or 10 per hour. Most of these could have been detected by a person at rest indoors. Much of the time there was continuous jiggling of windows. Puuwaawaa registered nine times as many earthquakes as Kilauea. And that in a place not known as an earthquake district before this year.

The average of felt shocks listed by observers September 23-24 was 2.2 shocks per hour at Huehue, 3.3 at Puuwaawaa. and 6.0 at Honokahau on the southwestern slope of Hualalai. Observers listed about a third as many as the shock recorder.

Theoretical

The big earthquakes of September 25 and October 5 showed no preliminary tremor on seismographs forty and sixty miles apart. Both Hilo and Kealakekua in Kona behaved as though they were right over the center of the earthquake. So did Kilauea. In this they behaved quite differently from their registration of the ordinary earthquakes of the period, these always showing a preliminary tremor accordant with the theoretical distance of the focus or origin.

The absence of preliminary tremor is usually explained on the ground that these greater earthquakes are very deep. If such jolting is profound in origin, it may shake the whole of a small area like the island of Hawaii equally.

But even if the earthquake were a hundred miles underground the horizontal impulses at the pendulums of Kealakekua, Hilo and Kilauea would have been sufficient to exhibit **something** of the preliminary if the compressional waves had been present. There was no slightest trace of them, unless they were so enormous that they themselves dismantled the seismographs. This is improbable, by analogy with other records of earthquakes of like intensity, showing preliminaries, which have clearly registered with small ampltiude before the long waves dismantle the instrument. The pens at places sixty miles apart simply shot off the drums at the first impulse. Meanwhile the Honolulu seismograph registered a preliminary accordant with the distance of Hawaii.

If this failure to record preliminaries were due to depth of focus, the depth would have to be several hundred miles, and even in that case a vertical component instrument ought to register an excellent preliminary, characteristic of compressional elastic waves arriving vertically. There is no suggestion that such waves were present. Even a horizontal pendulum would give some thickening of the line.

There is another possibility. If hot magma were present under Kilauea. Mauna Loa and Hualalai equally, like a vast cake of dough, with localized injections of its substance as protuberances with each mountain, it is conceivable that the protuberance under Hualalai moved to make the localized earthquakes; and that the larger mass shifted the whole island shell for the greater and more generalized shocks.

Comparison with 1868

The 1868 cataclysm on Hawaii was a parallel to this. A new series of eruptions at the southwest was then begun, unheard of before. A great earthquake swarm began on the south flank of Mauna Loa culminating in a terrific shock.

On March 9 of 1868 there was an earthquake in Kona. On March 27 in Kau quaking became continuous and the next day there was a big shock of Grade IX. On April 2 came the big earthquake of Grade X, making a landslip back of Pahala, a tidal wave along the Honuapo shore, and bringing about the immediate collapse of very active lava in Kilauea Crater. April 6 the south rift of Mauna Loa vomited lava to the sea, the eruption lasting six days. Other big shocks occurred and a lot of aftershocks.

This combination of clustered quakes, big shocks and lava outpouring in a new district suggests that the underground shift of magma from the old northern district made the mountain labor. The same thing is suggested in 1929. There is a shift of activity from south to north. Recent Mauna Loa flows have all been in Kau. The Hualalai earthquake swarms were quite like those of Kau in 1868. But lava outbreak has not yet occurred on Hualalai. Presumably lava intrusion did occur.

In both 1868 and 1929 there were big shocks that were different from the small ones. Probably the small ones accompanied shifting of the blocks of the smaller mountain, and were shallow. Probably the big ones accompanied a shifting of the whole island shall and were relatively deep. But it may well be that mere depth was less important than the size of the shell which was shifted.

The present outbreak of Halemaumau November 19, 1930 is the first eruption in Hawaii which has followed the Hualalai earthquake crisis of September-October, 1929. The last outbreak known at Hualalai volcano was in 1801, about a decade after an explosive eruption which occurred at Halemaumau. A decade after our last explosive eruption of Halemaumau will be 1934. Is the present return of lava in Halemaumau preparing for a new activity on the north or northwest sides of Mauna Loa or Hualalai?

T.A.J.

THE CURRENT ACTIVITY IN HALEMAUMAU

Lava came back in Halemaumau at 1:29 p. m.. Wednesday, November 19. It broke through first in two fountains about one hundred yards out in the pit floor in front of the horn between the two grotto niches of 1929. According to Craik. of the National Park, the floor started to swell rapidly under this spot, then huge blocks of the old crust were thrown into the air by the first gush of fountaining lava. Craik immediately left to spread the news so he did not see the next fountains break through. When next seen half an hour later, lava was spouting perhaps fifty feet high from these two fountains; from twenty to fifty feet high from seven fountains closely grouped near the edge of the 1929 flow about half way between the old 1927 cone and the sulphur stain on the south edge of the pit floor; and about 150 to 200 feet high from a main fountain through the sulphur stained patch about 100 feet out in the 1929 floor from the edge of the south talus. The whole southwest corner of the old floor soon was covered by flows from all of the fountains, but the main flood came from the large fountain and spread rapidly out to the center of the floor.

By 4:00 p. m., the old cone peak of 1927 had disappeared in the south cove, and the main flow had reached a point three fourths of the way across the old floor. New lava covered about half of the area of the 1929 floor at this time. One fountain had disappeared from the south-southwest group leaving six small ones together, also the two near the 1929 grotto, and the main fountain. The small ones showed about their original strength, but the large one had increased so that it was throwing slag over 200 feet into the air. A crack opened along the contact of the northern small 1929 grotto and the talus behind it. and it was soon filled with a small ooze of glowing lava. All of the fountaining activity was still concentrated in the southwest part of the 1929 floor.

As the depth of the lava around the fountains increased, some of the smaller ones were drowned, so that by 6:00 p. m. only two remained of the original group of seven. The two near the 1929 grotto had built up spatter cones through which they only occasionally were able to spout visible spray. The main fountain had become more constant, and was throwing slag steadily to heights of about 100 feet. The main flow was still very strong, but was beginning to pile up on top of itself rather than spread farther over the old floor.

The main fountain was slowly building a crescent shaped grotto on its south side which had reached a height of about forty feet by 8:00 p. m. At this time only one fountain remained of the original cluster of seven. and the two near the 1929 grotto broke through their "hoods" only at long intervals. The activity of the main fountain remained constant throughout the evening. The big flow was definitely building a rampart over which small flows were cascading to the lower level of the floor. The main overflow seemed to concentrate on the northwest and the southeast sides of the lake near the main feeding fountain,

with only an occasional flow over the northeast wall most distant from the fountain. The situation did not change materially during the rest of the night.

At 7:00 a. m., November 20, the vigor of the main fountain had not changed, but the smaller ones showed only an occasional spurt. They continued to smoke vigorously. The main flow from the big fountain was feeding a well defined lava-lake which covered approximately 25 acres, a little over one million square feet, of the 1929 lava floor and was oblong in shape with the long axis running northeast from the main fountain. The greatest overflow still took place near the fountain over both the northwest and the southeast ramparts. The level of the lake had been rising more rapidly than the grotto was being built by the main fountain so that it was not as conspicuous as it had been during the previous evening.

A measurement at the end of the first 24 hours, 1:30 p. m. November 20, showed that the surface of the lake at the big fountain was 90 feet above the level of the old floor at that point. The surface of the lake still sloped away considerably to the rampart walls so that there was a constant but slow movement of the cracking crust away from the big fountain. Overflows from the lake had covered about ten acres (435.000 square feet) of the old floor, so that flows and lake of new lava together covered an approximate area of 35 acres. The big fountain continued its steady spouting, throwing slag from 60 to 100 feet in the air. The two fountains near the 1929 grotto still smoked but no fountaining was visible. The one isolated small one had built a cowlshaped hood with the opening to the northwest so that its spray could not be seen from the main observation point.

It was reported that nine noisy explosions occurred at regular intervals of a few seconds about 11:00 a. m. No unusual behavior was noticed in the fountain but the sound seemed to have come from the large fountain.

Shortly after noon, a large stream of lava began to cascade over the southeast lake rampart and flowed toward the base of the east talus. It kept up a steady flow till after 6:00 p. m. and gradually formed a secondary lake between the talus pile and the main lake-rampart. Secondary flows from this small lake poured out along the flat between the east talus and the old pressure ridge and by 8:00 p. m. had covered the rest of the 1929 floor in this part of the pit. More overflows from the northeast end of the lake occurred during the late afternoon and evening, and slowly crept toward the north and northeast talus. By midnight November 20, only a few acres of the north part of the old floor remained visible.

This steady fountaining and overflowing from the main lake characterized the activity during the next morning, November 21. A second lake rampart had been built up inside of the northeast end of the lake during the night. Its location probably was determined by the position of a number of pressure ridges and domes in the old floor which may have obstructed the free flow of new lava and piled up blocks of the new crust. This inner rampart was built to a point at which the surface of the inner lake was very nearly level. As a consequence the migration of the cracking lake crust became so slow that it was not noticeable to the eye.

At the end of 48 hours of flow, 1:30 p. m. November 21, the surface of the lake at the fountain was 100 feet above the old floor, and the whole lake averaged a depth of almost 100 feet. It covered an area of about 15 acres (about 650,000 square feet). The overflows had encroached on the talus walls on the south side of the pit behind the big fountain, and had nearly covered the old 1929 lava floor. Thus the total area covered by new lava was about 50 acres (over two million square feet).

The main fountain began to show a tendency to break into two separate fountains of about equal size and a third one of small size and irregular frequency. The vigor of the fountaining appeared to remain the same. The activity of the afternoon and evening continued after the fashion of the previous day, with most of the overflow occurring on the northwest and the southeast sides of the lava-lake.

About 11:30 p. m. of November 21, a large cascade broke over the rampart at the far northeast end of the lake. It was falling down a steep incline of nearly fifty feet so gained in size very rapidly. Within fifteen minutes it had become the most spectacular feature of the eruption to date. It yielded a flow of such velocity that no crust had a chance to form, so that more than five acres was soon covered with the glowing red lava.

This river was still flowing the forenoon of November 22, but had split into two main branches, one of which was flooding the low area toward the northeast talus and one was pouring new lava into the depression at the foot of the northwest cliff.

Spouting from the small south-southwest fountain was no longer visible, but it and the two near the 1929 grotto still emitted a continuous volume of fumes. The large fountain continued its constant activity but the amount of lava taken from the lake by the three main overflow channels equalled the amount fed in by the fountain so that the level of the lake became fairly constant at 90 feet above the old floor.

During the evening of November 22, the spouting of the big fountain became slightly irregular. For a period of several minutes it would spout huge fans of slag over 300 feet in the air, and then it would relax for a time and resemble a bubbling mass of porridge. In these periods of relative calm, it could be seen that as many as seven separate spots were bubbling, which united in the larger spurts to give the appearance of one huge fountain. Overflow still continued from all three sides of the lake,, first one side showing the most active flow and and then another. The same general condition held during the night and all of the next day, Sunday, November 23. H.A.P.

SEISMIC FEATURES OF THE ERUPTION

The seismic events leading up to the eruption of lava in Halemaumau were not unusual but are none the less of interest. On November 13, the seismograph on the rim of the pit began to register a definite tilting of the rim up and away from the pit. It also recorded many small tremors which were not of sufficient strength to influence the instruments at the Observatory on the rim of Kilauea crater. These facts supplied the information that lava was moving and pressure was increasing under the volcano.

During the six days previous to the appearance of the lava, the rim of Halemaumau pit was tilted upward and outward through 10 seconds of arc. Half of this accumulated slowly, while the balance of 5 seconds of tilting took place in an interval of one hour and fifteen minutes immediately preceeding the gush of lava. As soon as the outlet to the surface was gained, the lifting force of the rising lava was lost and the pit rim tilted back through 7.5 seconds of arc during the first 18 hours of lava activity. Since then, equilibrium has been maintained and the tilting of the pit rim has been negligible.

On the morning of November 19, the pit seismograph recorded a series of 18 small shocks which culminated in a very feeble quake at 11:06 a. m. There was a slight tilting of the rim in toward the pit accompanying this quake. A series of 30 small shocks followed in rapid succession, many of them producing a little inward tilting. At 11:42 a. m., a quake of feeble intensity occurred under Halemaumau, causing a slight sudden inward tilt of the rim. During the next half hour eight small tremors were recorded, but no tilting took place. Then, between 12:15 and 1:29 p. m., 35 small shocks occurred and at the same time the rim of the pit was tilted up and outward through 5 seconds of arc.

Continuous tremor began at 1:29 p. m. and gradually increased for nine minutes. Then, at 1:38 p. m., the amplitude of the tremor suddenly increased. This sudden increase may mark the breaking of the lava through the bottom of the pit and the beginning of surface fountaining. The tremor continued with a constant intensity till about 4:00 p. m. when it gradually moderated until 7:00 p. m. From that time on it has continued evenly, except for an occasional more violent burst of a few moments duration. H.A.P.

KILAUEA REPORT No. 983

WEEK ENDING NOVEMBER 23, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

Lava appeared in Halemaumau at 1:29 p. m. November 19. It broke through in three fountain groups, two of small size which disappeared during the first two days, the third remaining as the main fountain which is still spouting vigorously. Lava from the fountains spread rapidly

over half of the 1929 floor in the first four hours. Then a central lake of molten lava was formed which is being fed by the main fountain. The lake rapidly built its ramparts upward until a depth of molten lava of about 90 feet was reached. This depth has been maintained, with overflow on three sides of the lake removing the new lava as rapidly as it is supplied. These overflows have completely covered the old floor of the pit and are encroaching on the surrounding talus piles.

During the two and one half days of the week preceding the appearance of lava on November 19, the Observatory seismographs recorded seven very feeble earthquakes: November 17, 2:29 a. m., 2:56 a.m., centering in Halemaumau, 8:11 p. m., and 8:19 p. m.; November 18, 5:47 a. m. distance to center 4 miles; and November 19, 8:13 a. m. and 11:06 a. m. One quake of feeble intensity, felt at Uwekahuna, was recorded at 11:42 a. m., November 19, with a distance of 4 miles to its origin. One very feeble shock was recorded after the eruption started, i. e. at 7:34 p. m., November 19. There were thus nine earthquakes for the week at the Observatory. A total of 24 short tremors were recorded before the lava broke out, and 17 minutes of continuous tremor registered during November 18. Continuous tremor caused by the fountaining of lava is accompanying the eruption. The non-volcanic microseisms were slight during the entire week.

The average tflt for the week shows a slight westward tilting of the Kilauea rim compared to last week. Some southward tilting has accompanied the flow of lava as the lifting force of the lava is lost by its access to the surface.



The Volcano Letter

310

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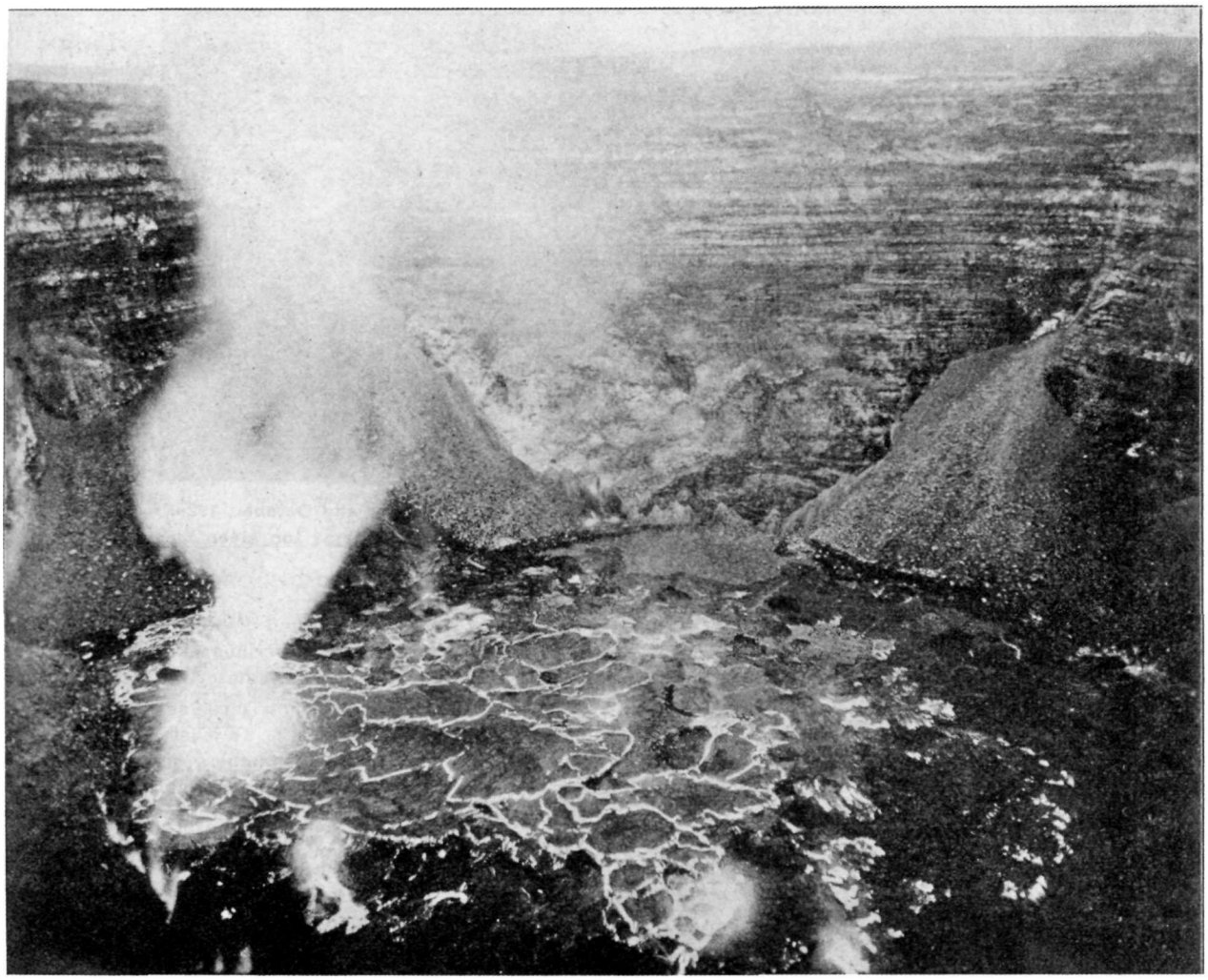

New lava in Halemaumau November 20, 1930. Photo Maehara.

HUALALAI EARTHQUAKE CRISIS
(Continued)

The earthquake crisis of 1929 on Hawaii, as described statistically in Volcano Letter No. 309, produced two earthquakes of grade IX Rossi-Forel. Grade ten is the intensity of a great disaster like those of San Francisco and Tokyo. Nine is disastrous; there are many grades of quick jerking between nine and ten, as represented by the earthquakes of history, some of them slow with wide amplitude and fatal continuity, others very sudden and quick with terrible results on weak structures. The greater earthquakes of the Hawaiian crisis were always led up to by numbers of minor ones, and by more or less continuous tremor which culminated from time to time in increasing numbers of large shocks, which happened both before and after the major ones. The earthquakes of this crisis were very impressive in demonstrating to an observer the difference between experiencing a large earthquake in a house or on the ground out of doors. In a house with an iron roof the rattle of the roofing, of the furniture, of the doors and windows, and the creaking of the timbers all made the quaking perceptible to the ear. Also the artificial structure acted as an inverted pendulum and magnified the motion. The writer was kindly permitted to dwell at Puuwaawaa Ranch House during the period of greater shaking, and to make experimental tests of earthquakes indoors and out. Shocks that were considered strong indoors, with much preparatory rattling leading up to a culminating jolt, were wholly imperceptible to an observer standing on the grassy lawn outside, except for a slight upward thudding sensation at the moment of the final jolt. Meanwhile the outdoor observer, with his feet planted firmly on the sod, could hear the roof of the house roar, and feel nothing during the rattling stages.

An interesting experience during the greater earthquake of 6:20 p. m. September 25, 1929, demonstrated that even a disastrous earthquake in a wooden house might go unperceived in an automobile in motion. This earthquake was so strong that it seriously damaged the Kealakekua



King residence, Honokahau, after the earthquakes of September and October, 1929. The retaining wall of the terrace was shaken down, being built at too steep an angle. Photo Jaggar.

seismograph, stone walls were thrown down, furniture was displaced and overturned, some buildings were moved, landslips were produced on steep slopes, masonry was cracked, and some water tanks burst. The road fills on steep hillsides were generally cracked and in many cases retaining walls on the downhill slope collapsed. The damage was enhanced by the weakening effect of the hundreds of large and small earthquakes, mostly with vibration from the mountain outward which preceded the larger shock for six days. These had loosened foundations, cracked the soil, and by minor damage had weakened structures through much swaying. The writer in his car was driving northward through Honokahau along the government road north of Holualoa and turned into a private driveway to stop for a moment at a residence there. He had felt nothing. The big earthquake had happened a few minutes before, and he found the house in a turmoil, with furniture overturned and strong aftershocks still in progress. It was demonstrated later, when many people left their houses and slept in their automobiles, that a modern car is an admirable earthquake-proof building. Even at rest a sedan on springs and rubber tires produced almost no sensation to the occupants, while adjacent homes were rattling and roaring with the aftershocks.

Prior to the big shock of October 5, 1929, there was a marked lull in frequency during the daylight hours, the big earthquake coming at 9:22 p. m. The effects of this shock were stronger than those of September 25, and the damage to buildings was extended northward into Kohala. Conspicuous effects were the cracking of road fills in new places, the overthrowing of embankments at the tips of road spurs, and the sliding downhill of rocks and vegetation on cliffs.

The intensity relations, obtained by counting the numbers of strongish shocks, indicate that these clustered around September 26 and October 5. There were about 200 earthquakes recorded as sharp between September 19 and October 5 in the North Kona region. September 23 at Puuwaawaa there were nine, September 24, twenty-six, with one in the morning described as the strongest yet, and the next morning came one described as still stronger.

The following figures show three series about the frequency maxima, September 26, October 5, and October 8. The lists show computed numbers of earthquakes as registered instrumentally at Puuwaawaa, and in each case the figures rise to a maximum on the date above mentioned, and decline afterwards.

First Series		Second Series		Third Series	
Sept. 21	39	Oct. 3	97	Oct. 7	136
" 22	237	" 4	114	" 8	387
" 23	258	" 5	141	" 9	353
" 24	432	" 6	89	" 10	235
" 25	513			" 11	203
" 26	599				
" 27	541				
" 28	400				

In the first and second series, the dates September 25 and October 5, both in the evening, were the occasions of great earthquakes. For the third series there were one strong and five moderate quakes October 8, one strong and one moderate October 9, two strong October 10, and one moderate October 11. There was an increase in numbers of strongish shocks October 14-15 accompanying a slight increase in frequency. It is worthy of note in the above second series that the total frequency on either side of the day of the biggest shock (Oct. 5) is much less than the daily frequency of the earlier and later periods.

There is reproduced on the last page the photograph of a model of Hualalai Volcano by kind permission of Mr. W. T. Pope of Honolulu. The scale of the photograph is approximately four miles to the inch. The model shows the linear character of the belt of cones that constitutes the summit ridge of Hualalai, and the trace of an old sink crater at its summit. The two recent lava flows indicated on Hualalai are both believed to date from 1800-1801. The fluted cone at the northeast is Puuwaawaa; and the hill north of it Puu Anahulu is made of very old basaltic

rocks extending in a curved ridge southward through Puuwaawaa, as though the latter were a parasitic cone built on the edge of part of an old sink crater. The 1859 flow from Mauna Loa is shown at the northeast. The regions tremendously shaken in 1929 lay on the north and south slopes of the Hualalai ridge, and it may be seen from this model that these two regions are symmetrically balanced about a volcanic fissure. It seems reasonable, therefore, that the disturbance was due to intrusion.

It may be remarked that this region and these earthquakes of 1929 were the theme for the story recently published, "Lava" by Armine von Tempsky. T.A.J.

LASSEN REPORT No. 28

Lassen Volcano Observatory
R. H. Finch, Associate Volcanologist

On November 3 and 4, 1930 a spasm of small earthquakes were recorded on the seismographs at Mineral. The shaking began at 11:39 a. m. November 3, and when the trembling ceased at 3:31 a. m. November 4, ten shakes had been registered. None was reported felt though three showed an intensity well within the range of perceptibility. The indicated distance to origin was 11 miles or nearly equal to the distance between Mineral and Lassen Peak.

TILTING OF THE GROUND DURING NOVEMBER

The following presents a record of the tilting of the ground at the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, showing the net amount for each week computed from the daily seismograms obtained by platting a curve which is smoothed by overlapping progressive seven-day means. As shown in Volcano Letters 302 and 306, the tilting of the ground in September and October was generally northeastward, as is usual for the autumn season. Therefore the tilt to the southwest for the week of the outbreak of Halemaumau (November 19) may have been stimulated by the release of gas and the inward dip of the country resulting therefrom.

Oct. 27-Nov. 2	0.72 second	N.
Nov. 3 - 9	0.48 second	S.
Nov. 10-16	1.57 seconds	NE.
Nov. 17-23	1.20 seconds	SW.

KILAUEA REPORT No. 984

WEEK ENDING NOVEMBER 30 ,1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

The pouring in of basaltic lava at the bottom of Halemaumau pit has continued during the week. On November 24 the fountain was building outer spatter ramparts on the side of the lake preparatory to formation of a spatter cone. The lake lava showed pahoehoe skins which wrinkled like satin. Festooned pahoehoe flows poured voluminously to the northeast and northwest. Small typical aa streams were sluggishly pushing out from the floor slag heaps in two places. The great delta-like fronts of the flows against the talus were half aa carrying pahoehoe crusts. Such crusts were cracking and sinking at the edge of the lake and elsewhere as the liquid lava welled up and weighted down the hardened surfaces.

Measurements made the floor 2,200 feet long south to north by 1,800 feet wide. The lake was one-fifth as large as the floor. The total area of new lava was 55 acres, covering the 1929 bottom 15 feet deep about the edges and 90 feet deep at the lake. The lake was thus at the top of a heap 100 feet high.

The same type of activity continued during the week, the heat diminished, the fountain enclosed itself with a spatter dome more than 100 feet high, the overflows of the lake rim dwindled, and the glow of the outer slopes of the slag heap became less. Sulphur stain increased along a steaming crack at the southeast edge of the floor.

The Observatory seismographs registered feebly two teleseisms at 9:22 p. m. November 27 and 11:23 a. m. November 30. There were no local earthquakes. Volcanic tremor was harmonic and continuous throughout the week, with a spasm at 5:56 a. m. November 29 accompanied by easterly tilt, and another spasm at 6:55 a. m. November 29. The tremor was weaker November 30. Tilt was very slight to the southeast, and microseismic motion was slight but somewhat increased November 26-28.



Collapse of partitions in cellar of Puuwaawaa Ranch House resulting from earthquake damage October 5, 1929. Note the wooden posts diagonally braced and footed in concrete, which saved the house when the cellar walls gave way.



Model of Hualalai Volcano, 1930, by Willis T. Pope Summit 8,251 feet. Shows trace of old sink crater and NW-SE summit rift marked by cones. Distance from Kailua bay to Keauhou in southwest corner six miles.

THE VOLCANO LETTER

The Volcano Letter combines, after January 1, 1930, the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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The Volcano Letter

311

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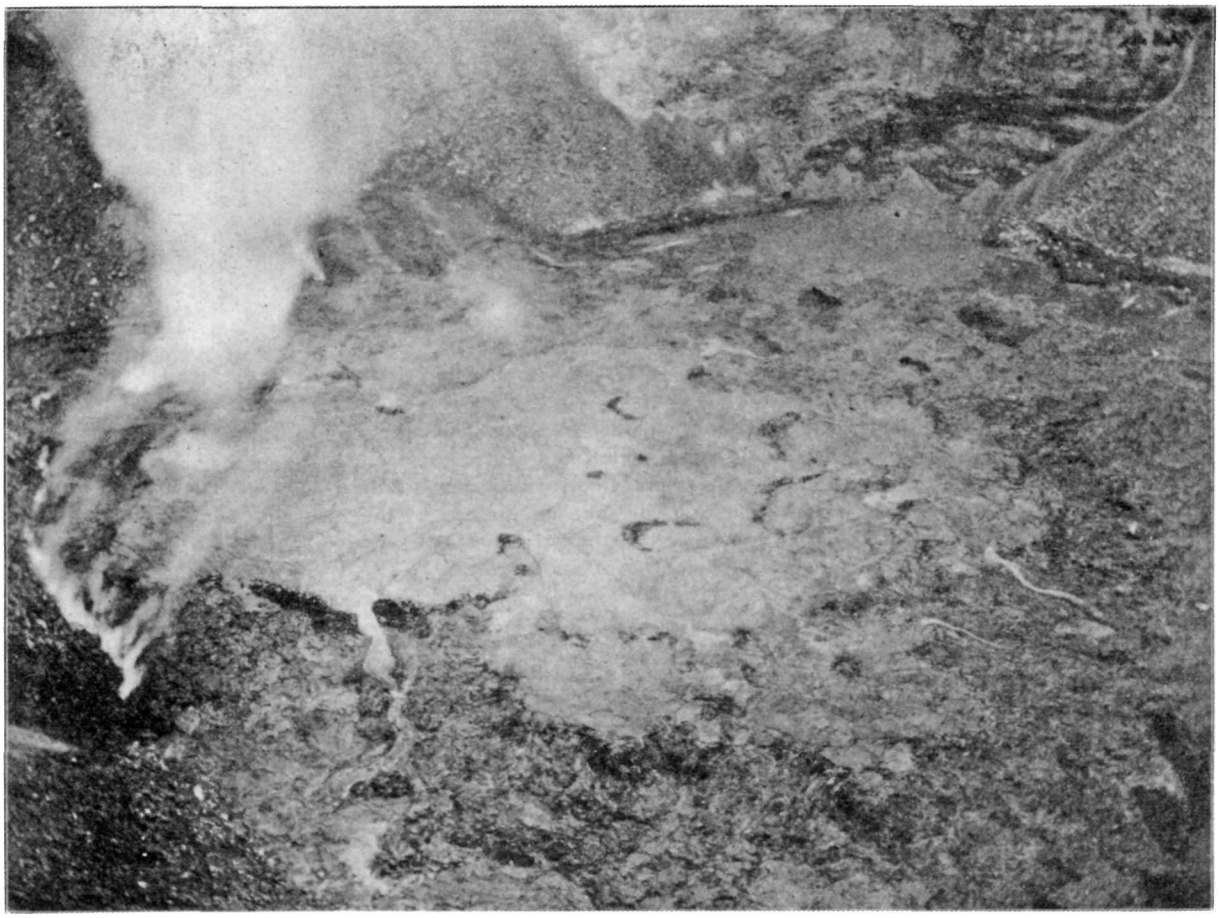
No. 311—Weekly Hawaiian Volcano Observatory, National Park, Hawaii December 11, 1930



Floor of Halemaumau from the east at 3 p. m. November 20, 1930. Shows the smooth lake area, the sulphur-stained crack with line of steam jets at the left, the fountain and its rampart under the large fume column, the 1929 lava heap against the talus at the back and numerous pahoehoe overflows from the terraced lake. Photo Powers

JOURNAL OF HALEMAUMAU ERUPTION 1930

As the eruption of lava in the bottom of Halemaumau pit of Kilauea Volcano came to an end so far as appearances go about noon December 7, 1930, it is appropriate here to show some pictures of special features and to review the daily sequence of events.

November 13. Pit seismograph recorded tilting of the ground away from the pit and many small tremors.

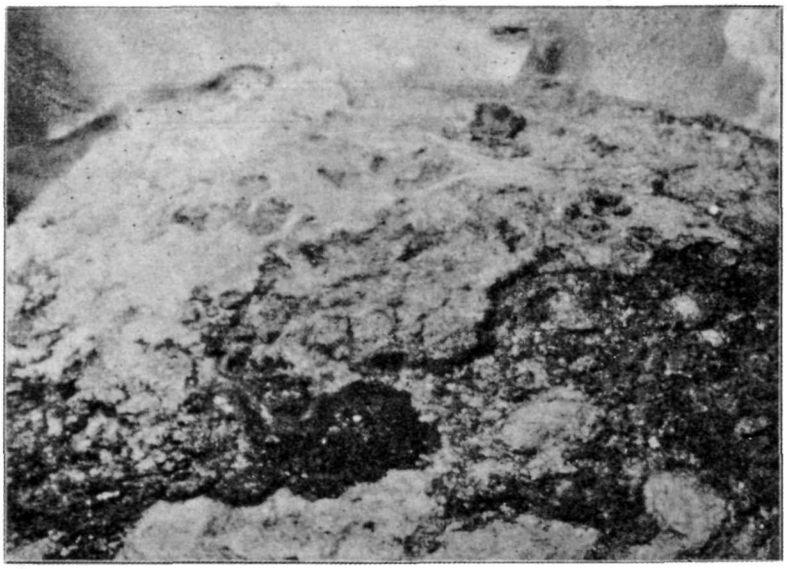
November 19. Tilt away from pit at 12:15 p. m. had accumulated to five seconds of arc. Then for an hour and a quarter 35 small earthquakes were registered and rim of pit tilted up and out five seconds more. This had been preceded in the forenoon by 57 small jarrings with slight tilting of the pit inward. This became continuous tremor after 1:29 p. m., becoming stronger at 1:38 p. m. moderating from 4 to 7 p. m., and thereafter continuing throughout the eruption, which had started with gushing of lava and gas at 1:29 p. m. Thereafter during the first 18 hours of lava activity the release of gas and escape of lava caused the pit rim to tilt back toward the center through 7.5 seconds of arc.

The lava broke its way up through the 1929 floor in the southwestern part of the pit. The floor swelled, broke, and the gush of lava carried up blocks of rock. Then seven fountains broke out southeast and finally a big fountain developed 100 feet from the south talus. The first fountains were 20 to 50 feet high, the big one was sometimes 200 feet high. The flood of lava spread over the 1929 floor and the smaller fountains dwindled. Oozing lava broke out back of the 1929 cone at the west. These events suggested that the new lava welled up through the 1929 paste, still hot under its thick crust.

The main fountain built a crescent grotto 40 feet high by 8 p. m., and the western fountains covered themselves with hoods. The outspreading flow began to pile up a slag heap with overflows northwest and southeast. Ramparts formed around a pool on the top of the heap.

November 20. At 1:30 p. m. the slag heap was 90 feet high, there was slow movement of crusting lava away from the big fountain, which now spurted from 60 to 100 feet into the air. The hooded vents of first action were smoking. About 12:30 p. m. a large flow cascaded over the southeast lake rampart and continued until the evening. By 8 p. m. most of the eastern remnant of the 1929 floor was covered, other flows crept toward the north, and by midnight only a little of the old floor was still uncovered.

November 21. The single large fountain continued its



Southwest corner of floor November 24, 1930, showing at the back the fume from the fountain vents which had sealed themselves, the 1929 heap at the right and the increasingly smooth lava from the border region in the foreground to the lake on the top of the heap. The small dark colored flow is the northeastern brown aa stream of November 24. Photo Powers.

activity and an inner lake rampart outlined an inner pond of lava with slow moving crust, the outer coves of the northern extension of the lake appearing like terraces at a lower level. At 1:30 p. m. the new lava covered 2,000,000 square feet and the lake was about 100 feet above the 1929 floor under it. The lake covered 650,000 square feet. The fountain was breaking up into two or three jets. At 11:30 p. m. a large cascade broke over the rampart at the northeast and produced a flow of such velocity that no crust had a chance to form so that 5 acres was soon covered with glowing lava.

November 22... In forenoon the northern stream on the floor was flooding in two branches northeast and northwest. The drainage of the lake and the settling of the slag heap had lowered the lake level 10 feet while the margins of the floor were building up against the border talus of the pit. The fountain had become a group of spraying jets of the Mauna Loa type. The lake was oval feeding a flow which poured downhill spreading like a delta northward in the forenoon, and to the WNW in the evening. The flows were pahoehoe above and half aa below with a coke-like appearance. The fountains were quiet, but sometimes made a surf-like noise and puffed up brown fume, spurting up from 50 to 100 feet. The fragments were light pumice, for they floated down slowly, and much of this material along with Pele's hair fell to leeward of the pit. In evening glow edges appeared under the western lake rampart. Lava toes pushed out at the edge of the floor all along its western edge. There were three or more crust islands in the lake and irregular elevations in the lava slope west of the lake. Some 1929 lumps and terraces were detectable at the north side of the bottom. Smell of sulphur dioxide rose with the fountain gas.

November 23. The fume from the pit rose in a transparent brown veil these days, with a moisture cumulus above varying at different times and sometimes disappearing. The fume was blue in reflected light. A brown trail of smoke spread westward and northward over the valley between Mauna Loa and Kilauea. The glow at night over the pit was sometimes yellow, and at other times rosy. Large crowds of people visited Halemaumau.

At 9 a. m. the fountains continued with a deep rumble and occasional very high spurts. A scar up the west wall of the pit had been left by avalanches of November 20-21. The grotto at the fountain caved in continuously. Overflows from the lake poured south as well as north and northwest, the last appearing as a big stream. A protruding spur extended the slag heap of the lake toward the northeast, where chasms were caving in leaving red-hot aa walls, and lava trickles pushed out at the edge of the floor. The floor edge was building up so as to touch the WNW, S, and SE walls between the taluses. Bright yellow sulphur stain extended along a steaming crack at the edge of the floor nearest to the fountain to the south of the lake. Bluish-white salt appeared at seven steaming cracks in the slag heap to the NW and NE. Pumice of mossy green apparance lay on the backslope of the fountaining grotto.

At 5 p. m. the northwest stream had crusted, leaving V-shaped bright areas. The lake was covered with bright lines in flow pattern without apparent motion. The fountain showed none of the inrush and foundering of crusts toward its center characteristic of the old Kilauea fountains. The puddle around the fountain was thinly liquid on the side toward the grotto, but otherwise the jets seemed to rise from stiff quickly congealed material, sometimes flinging fragments in a high spire apparently 150 feet into the air. The glow of the crack pattern in the aa slag heap to the northeast was different from the lake. An aa flow from it to the northeast talus was like a forked coral or fungus with a herring-bone pattern which remained glowing like a coal quite different from the festoons of pahoehoe. The whole floor looked rigid but very bright, a fan of flows with two outstretched arms enclosing a dark space. The foundering blocks of the rampart next to the fountain rolled over and grounded on a shallow bottom. The dark areas of the floor were W and S and N.

November 24. Measurements at noon made the lake 90 feet above the former bottom and 435,600 square feet in area. The outlying slag heap was 40 feet deep, covering 1,306,800 square feet. The edge flows averaged 15 feet thick, covering 653,400 square feet. The total volume was estimated at 93,000,000 cubic feet. The diameters of whole floor were 2,200 by 1,700 feet.

At 10 a. m. two sloping ramparts outside of the fountain marked its enclosure by a cone. The lava was changing to true pahoehoe with spatter of glistening black glass. The lake was covered with pahoehoe festoons, but on the outer slag heap northeast and west two short brown typical aa flows emerged from cracks. Otherwise the pahoehoe overflows from the lake turned into large semi-aa areas at the edge of the floor NE and NW. The continuous fountaining of the active center was more suggestive of

1917 Kilauea activity than anything yet seen. All the 1929 floor was now covered except the big west spatter heap. At 5 p. m. the glow pattern was darker than before owing to the pahoehoe skins. The rampart around the fountain was closing in to a horseshoe and the overflows were dwindling.

November 25. Activity was more sluggish, flows were shorter. and the edge of the floor was building up.

November 26. The fountaining niche was becoming a cone, there was fresh lava along the east and northeast edge of the floor and also against the south wall of the pit. A new overflow from the lake poured NW.

November 28. The fountain had spells of high spurting and other times of unusual quiet. Flowing was weaker. The fountain cone was growing.

November 29. Weakening action continued. Fumes were strong. Eastern lobe of floor had raised 50 feet while the lake level remained the same; an intervening point stood 64 feet above the 1929 floor. The horseshoe cone around the fountain stood 75 feet above the lake with an opening toward the west and a frothing pool which cascaded steeply through the opening to the lake of cloverleaf shape. The cone had an outer crescent ridge at the south. There was glow around edges of the floor, strong at the NE and weak at the W and N. A flow broke out through a crust on the northeast side of the fountain cone. A dull flow pattern extended from the lake across the northeast floor, but outside pahoehoe flows had ceased. The glow and fume were lessening.

November 30. The fountaining cone was now the main feature. The heat at the edge of the pit had greatly diminished. There was festooned skin streaming across the lake. The edge of the floor had risen all around and the steaming sulphur crack southeast had increased in sulphur deposits. The cascade poured out of the cone growing weaker and crusting over, and the top of the cone caved in. The border lava was rising around the 1929 heap at the west.

December 3. After two weeks of action the area of the top of the slag heap containing lake and fountaining cone was roughly 500 by 800 feet. The cone was about 75 feet high and 200 feet in diameter at the base. The entire new bottom area was leaf-shaped 2,300 feet long by 1,700 feet wide and covered 62 acres or 2,710,000 square feet. The deepest fill was 175 feet at the top of the cone, or 100 feet at the lake level. The shallowest fill over the 1929 floor at the north side of the bottom was 50 feet. The volume of molten lava was 229,000,000 cubic feet which had come in during the first three days of the eruption at the rate of 25,000,000 cubic feet per day, and the last 11 days at 14,000,000 cubic feet per day. The process had been first piling up the center, and then spreading out at the edges. The weight of new lava was slightly more than 15,000,000 tons.

KILAUEA REPORT No. 985

WEEK ENDING DECEMBER 7, 1930

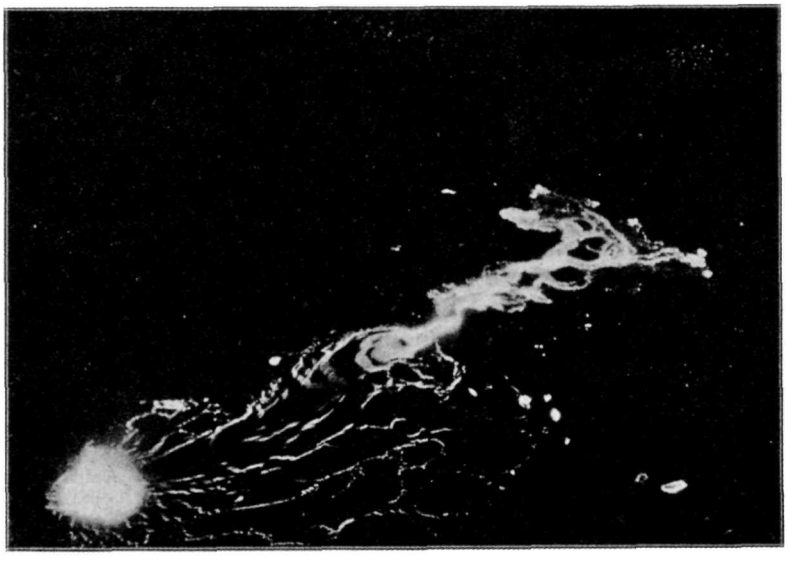
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

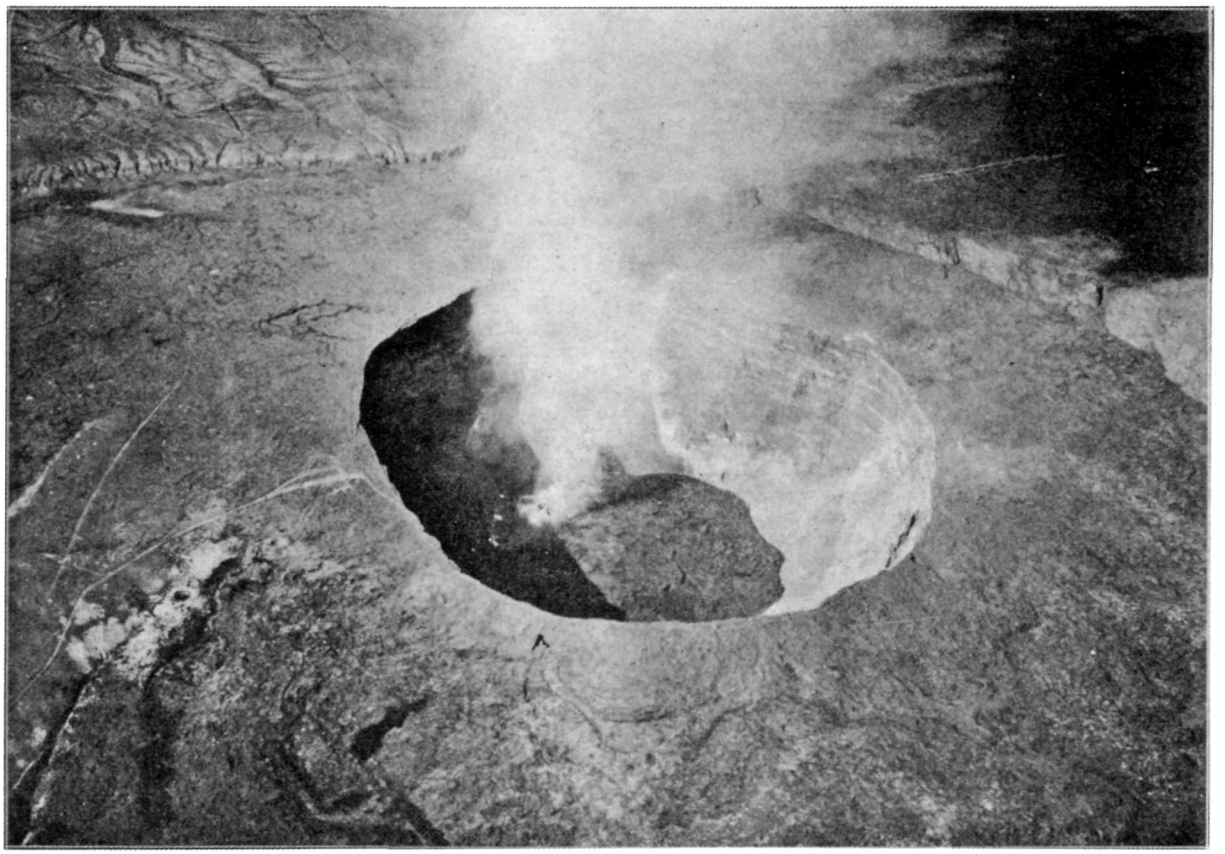
On December 1 the fountain in a cone of lava at the bottom of Halemaumau about 900 feet down was spouting variably. Its cone had grown big and the cascade down its side tended to crust over. The spectacular activity of the week came at times when the crust over the lake broke up and a rapid seething of glowing lava extended itself all over the surface along with sinking of the crust blocks. This process at intervals of from three-quarters of an hour to two hours continued until the evening of December 6, with increasing intervals. December 2 a stream from the big cone poured in a loop northward across the lake. December 3 a flow was building up the south edge of the floor. December 4 the cone was breaking down the edges of its cup. The break-up spells of the lake crust were brilliant accompanied with crackling noise. Bright yellow sulphur made a spicy smell at the southeast edge of the floor. The cascade from the fountaining cone renewed itself and poured flows over the lake crust. The fountain occasionally revived to high spurts. Then it dwindled to mere bubbling last seen the morning of December 7, and about noon that day all action ceased.

Volcanic tremor at the Observatory seismographs gradually weakened and stopped about 3:30 a. m. December 7. Two very feeble local earthquakes occurred December 1, one of these 8:55 p. m. indicated origin distance 32 miles and was felt from Hilo to Kona. Spasmodic tremors occurred four times December 4 to 7. Microseismic motion was moderate and tilting of the ground was moderate NE.

The action of tilting and trembling on the Halemaumau seismograph showed none of the sudden phenomena accompanying the end of the eruption which were observed when the lava ceased action in February, 1929. Strong trembling ended about 8 p. m. December 6, but minor tremor gradually dying away continued on December 7. At the end of that day it was nearly gone. There was no pronounced tilt of any kind. The effect is as though the lava pressure were still there without evident fountaining.



Night view of eruption November 21 at 11:30 p. m. This shows the spectacular cascade over the rampart, the bright line pattern of the lake, and the streaming away from the fountain. Photo Powers.



Halemaumau from the air at 9:30 a. m. November 25 showing the new fill in action burying up the talus slopes. The crescent at the base of the great western talus is the 1929 lava heap. Note the concentric cracks close to the rim of the pit showing how perfectly the caving tends to maintain a circle. All of the layers shown in the walls poured out during the 19th century. This picture shows that the floor of Kilauea crater is a dome. Photo by 11th Photo Section, Air Corps, U. S. Army.

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The Volcano Letter

312

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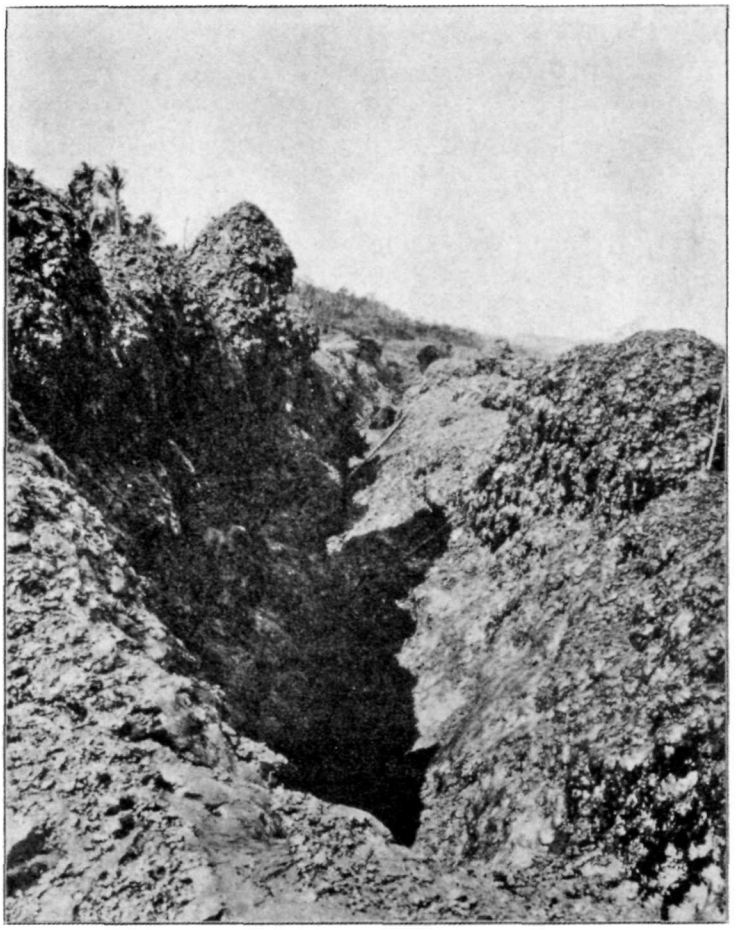
No. 312—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — December 18, 1930



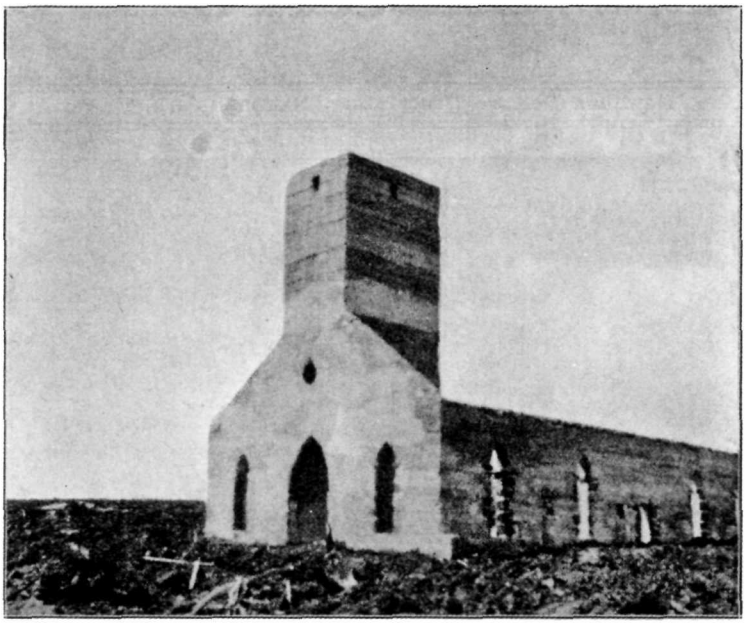
The great lava rift 30 feet deep back of Futu on the northwest side of Niuafoou Island, source of the destructive flows of 1929. The lava floods poured down to the right, and on the left are the unijured cocoanut palms of the ring ridge. There are spatter heaps on both sides of the chasm. Photo looking south September, 1930, by Jaggar.

THE ISLAND VOLCANO NIUAFOOU

Niuafoou, an active volcanic island belonging to Tonga, was described in Volcano Letter No. 265 in connection with the eruption of lava that poured out on the west side of the island and destroyed the village Futu July 25. 1929. The writer was privileged to visit the island as a member of the joint eclipse expeditions of the United States Naval Observatory and the New Zealand government from August to October, 1930.

Niuafoou is a splendid example of a crater ring, with lake in the crater, crowning a 6,000-foot volcano, most of which is below the level of the sea. It stands on the northeastern corner of the submerged portion of the Australian continent between Samoa and Fiji. It is an inhabited island, a paradise of cocoanut palms, the soil wholly volcanic, and lies 15½ degrees south of the equator. It is almost a perfect ring five miles across. The lake inside the ring is three miles across, of brackish water, surrounded by a ridge 600 feet high, with cliffs facing the lake and a gentler slope outside. It has islands and is much like Crater Lake in Oregon. Outside of the ring ridge there is a wider lava platform with cliffs facing the ocean. It is on this platform most of the people live in nine villages traversed by lovely avenues amid coconuts, ironwoods, mangoes, and other tropical trees and shrubs, and the usual pandanus near the shore. Copra is the principal crop, but there is much planting of yam, taro, papaia, sweet potato, bananas, melons, and manioc.

Seven villages are a short distance inland from the shore, two are on the ocean, one was destroyed by lava in 1853, one by hurricane in 1909, and Futu by lava in 1929. Futu is at the west, where the eruptions of the 19th century had created a lava desert with eruptions creeping northward. There are no lava flows about the crater lake, but here in 1814 and 1886 there were steam-blast eruptions which piled up sand islands and peninsulas, strewed the island with heavy blankets of dust and sand, and broke down the coconut trees with plastered mud that destroyed the crops and occasioned much suffering. About 1840, 1853, 1867, 1912, and 1929 the lava eruptions broke out along cracks trending chiefly north and south at the base of the ring ridge on the west side of the island and sending short flows for from half mile to a mile into the ocean. The 1853 eruption broke up through the center of the village Ahau and killed half the inhabitants. In 1929 the natives of



Church of the Marist Catholic Mission at Futu, a stone structure which was surrounded by aa lava and burned out July 25, 1929, and all the village houses around it were buried. Only a cross in the graveyard was left standing intact. Photo Jaggar.

Futu saw the fiery cracking of the flank of the hills in the distance, and fled to the heights in time to save themselves. But the northern half of their cluster of warehouses, churches, and habitations was buried under aa lava. They removed to a new village near Angaha on the north shore.

A remarkable adaptation of natural history to the uses of warm volcanic sand is the malau bird, a unique inhabitant of this island. At several places around the lake, and especially where the afternoon sun heats the explosion-made sand hills of 1886 this bird dwells amid the ironwoods and other growth. It is a small bush hen of the tribe Megapodius, meaning "big footed," which has another representative in Australia. It has large, yellow legs and claws adapted for digging in the sand. Its body is black, its head small and scrawny, and its size that of a small Leghorn hen. It whistles like a quail.

The malau hen digs a hole three to five feet deep in the sand slope, lays her egg in the bottom, scratches her way out filling the hole behind her with sand, and Nature does the rest. The sun heats the sand to from 85° to 95° F. Different hens reoccupy the same holes over and over again, even though the natives dig up the eggs for food. When a more fortunate egg hatches, the young bird digs its way out and is said to fly at once. The egg is long and pink, as big as a goose egg.

The people of Niuafoou are Polynesians with a civilzation much like that of Samoa, and they are strictly governed by a high chief, a magistrate, and police service representing the Queen of Tonga. There are usually seven or eight white people at Angaha, the principal port, where a rough landing may be made with boats. The people are completely Christianized, members of three denominations, are constant church attendants and lovers of religious music. The population is about 1,100, there are several motor cars, and the trails are broad and kept in good condition. Every man has his plantation, the people are splendid physical specimens, they are fond of tennis, cricket, croquet, boxing and swimming, and are very hospitable and friendly. They are not afraid of sharks, and meet the mail boat with swimmers. Hence the name "Tin Can Island."

The geology of Niuafoou indicates that it is the peak of a big lava dome under the sea, and thus it represents a more advanced stage of the same kind of volcano growth as White Island in New Zealand, or Falcon Island (Volcano Letter No. 265) farther south in the Tonga group. The central crater has been engulfing its walls along with explosive eruptions in recent geological ages. The lava plug under the crater tends periodically to erupt around its edges, or along the 'wall-crack" as we say at Kilauea, but the fractured caldera rim makes it easier to find a fissure up a crack in the outer lava platform than in the crater lake. Once in a long period, just as at Kilauea, the lava pressure is relieved and the plug lowers, letting in water and making a steam-blast eruption through the crater lake. The known last interval between these steam eruptions for Niuafoou was 72 years, whereas for Kilauea it was 134 years.

The ring ridge is made up of lava layers alternating with ash dipping a little more steeply away from the center than the heavy lava layers shown at the foot of the cliffs around the crater lake. The history, therefore, implies a lava dome below, becoming an alternation of lava and explosive eruptions in the later stages.

The eruption of 1929 was typical of all the western lava eruptions. The lava is a feldspar basalt similar to those of Hawaii except that olivine is not conspicuous. The southwestern desert of Niuafoou is what Kahuku and the Kau Desert are to Hawaii. In 1929 the old NNW-trending rifts of 1853 and 1912 at the inner border of the southwestern lava platform of the ring island were suddenly extended northward with an unheralded splitting of the mountain athwart its flank. Fiery slag shot up the crack without warning except for a few tremors. The frothy outflow swept west down to the sea. This happened about 4 a. m. July 25 by Tongan time, almost exactly 24 hours before a similar lava eruption occurred in Halemaumau pit.

The rifts in Niuafoou propagated themselves northward in overlapping gashes. These gashes showed such sympathy with the wall-cracks of the caldera as to indicate that if the intervening ring ridge broke down, the lava source cracks would promote the natural enlargement of the crater lake basin. The lava floods were pahoehoe above and aa near the sea. A dozen of them reached the water with islands of untouched forest in between. The length of the active spouting belt was approximately three miles. About 4,000 acres of coconut plantations were destroyed and traders' property estimated at $10,000. The eruption lasted only a little over a day.

The action was quite like the Kilauea flows of 1920 and 1923, fountains shooting up 20 to 50 feet, making Pele's hair and glassy needles, and building, as shown in the photographs herewith, long spatter ridges along straight chasms, fields of pahoehoe and aa, multitudes of coconut tree molds, and sand heaps along the sea front which were later converted into beaches. There was a little steam-blast action at the southern end of the rift belt, flinging up pieces of coral along with clinker. There were burning hydrogen and other gases at the vents making secondary glazes of many colors.

The straight wall of vents along the source crack was frequently double with heaps of glistening slag on both sides of the crack except where a torrent had maintained a flow gap. Steam still rises back of Futu and deposits sulphur and sulphates. The lava heaps there are 6 to 20 feet high above the former surface of the country, the visible V-shaped chasm in places is 30 feet deep, and collapse has revealed a cross section of old lava and ash beds where the original slope was rent asunder when the rift opened.

The explosive eruption of 1886 was a great event in the history of Niuafoou. It ranks the volcano in Class II among about 43 of its kind including Vesuvius. There was no direct loss of life owing to the good fortune, probably due to the trade wind, which forced the great cauliflower clouds of debris westward over the lake so that only 2½ feet of ash fell on the settlements. An earthquake gently swayed the island at 7 p. m. August 31, 1886, and shocks continued until midnight causing great alarm. Then with detonation a "rocket" ascended from the lake 3,000 feet, the shaking ceased, violent lightning storms developed striking the trees in many places, and big steam-blast vents piled up sand hills and shut off lagoons about an engulfment notch that was formed in the rim of the caldera on the northeast side of the lake. On the leeward side the deposits on the ring ridge were 20 feet deep. The material was broken fragments of rock, pumice, sand, and fine dust. The hills of this next to the lake are 200 to 400 feet high. The eruption lasted 18 days. It was accompanied by subsidence of border benches of the caldera. The Tarawera eruption in New Zealand happened only two months before, in June, 1886, was similarly explosive, and on the same line as the Tonga islands to the south. Here was another of the many cases of volcanic sympathy hundreds of miles apart where the same rift in the earth's crust is concerned. Falcon Island and submarine eruptions in Tonga were in action in 1927 and 1928, this activity continued into 1929 and so was sympathetic with Niuafoou in that year. Similarly Falcon Island had begun eruption in October, 1885, preceding Niuafoou in 1886.

The writer carried a shock-recorder this year to Niuafoou and set it up in a quiet place on concrete, and operated it in September and October. The records in 1930, 13 months after the activity of 1929, were singularly free from earthquakes, none was felt by any member of the expedition from August 19 to October 22, and earthquakes were not reported by the natives. They did, however, report underground rumbling in the lava belt October 3, and 9 small shocks during 4 minutes following 6:38 p. m. that day were registered on the shock-recorder. Felt earthquakes had been more numerous during the last half of 1929 and were reported as late as January, 1930, but thereafter seismic quiet ensued. T.A.J.

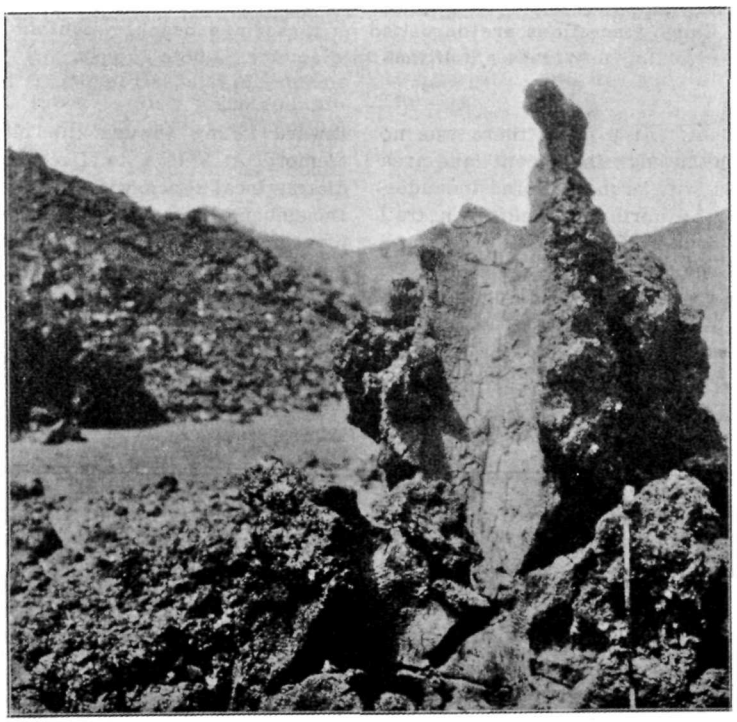
KILAUEA REPORT No. 986

WEEK ENDING DECEMBER 14, 1930

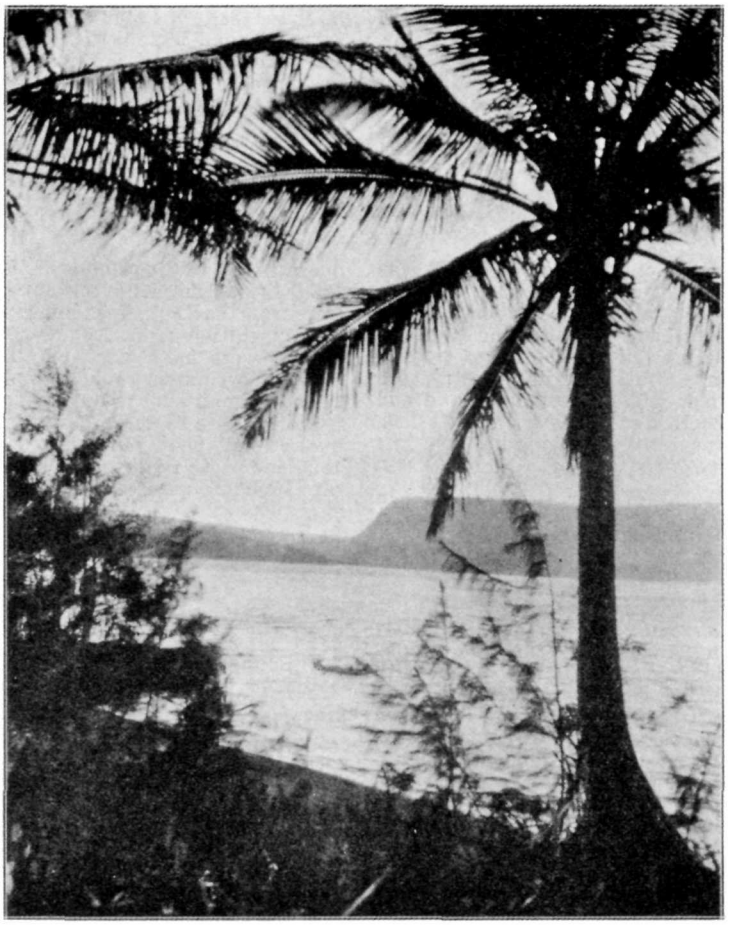
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

The week at Halemaumau pit following the recent lava eruption in the bottom of this inner cauldron of Kilauea Crater has produced no new visible activity, but the glow of the hot basaltic fill may still be seen in cracks through the floor, and the bluish fume continues to rise around the vents and at the sulphurous wall-crack at the southeast.

On Monday December 8 there was abundant fume rising from the pit as seen in the afternoon light when the sun is on far side of the vapor as seen from the Observatory. With the sun behind the observer in the morning



Interior of a coconut tree mold showing the bark pattern made by the pahoehoe lava of 1929 on Niuafoou. Thousands of coconut trees were molded so as to leave groves of stone trees 5 to 13 feet high. Photo Jaggar.



Glimpse of the crater lake of Niuafoou from the largest island, showing the eastern ring ridge in the distance, the ironwoods and coconuts on the island, and the black sand beach. Singular limey concretions are deposited on these lake beaches, containing tiny crabs a half inch in diameter. Photo Jaggar.

light the fume is less evident. At 8 p. m. there was no glow over the pit, but from the edge the recent lake area was seen to be well marked with orange-colored incandescent cracks. One spot at the northwest emitted a trail of light as though from an open grotto. There were small glow spots at the edge of the floor, N, NE, SW, and W. There was no noise. Fume rose from the side of the fountain cone, the southwest side of the floor, and at the bright yellow sulphur SE. December 13 there appeared to be settling of the lake area. Glow in cracks was still visible at night.

The pit seismograph December 8 showed no sign of inward tilting toward the pit and recorded spasms of tremor. At 3:45 a. m. December 13 it recorded an immediately local shock with tilt away from pit. At 5:07 a. m. December 14 a tremor at the Observatory was accompanied by east tilt. The Observatory instruments registered three very feeble local earthquakes for the week, one at 6:18 p. m. December 13 with origin 9 miles away. Four spells of continuous tremor occurred and 29 spasdomic tremors, probably a continuation of eruption tremor. Microseismic motion was moderate on the 8th and otherwise slight. Tilt was very slight north. The evidence suggests continued lava pressure upward.

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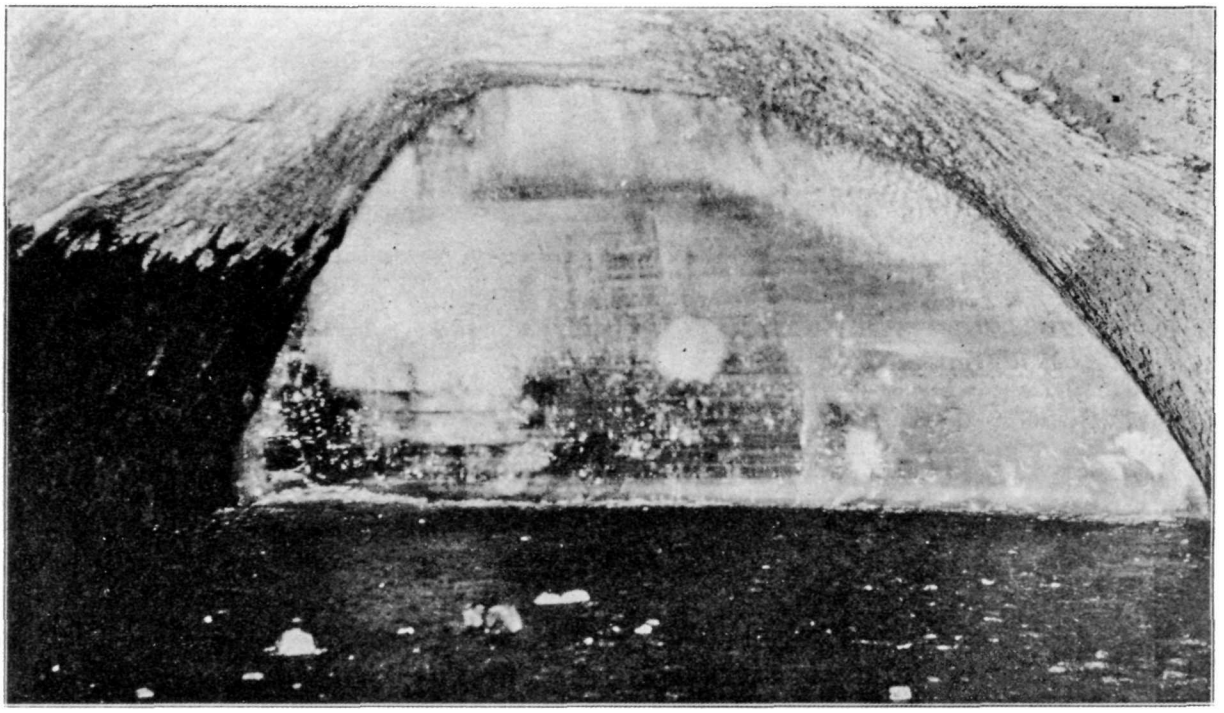


Flash light photograph of ice wall 30 feet high and 40 feet wide at inner end of Shoshone Ice Cave. Note horizontal stratification, ice floor, and ice crystals on roof and on the face of the ice wall. Photo February 15. 1930, by Bruns.

NOTE BY THE EDITOR

The following paper may be prefaced by a brief summary of the ice cavern situation. This lava tube in recent basalt is 30 miles north of Shoshone in Idaho. It is 80 miles south of the Craters of the Moon National Monument. It is a pahoehoe flow with tubes leading from collapse-basins. Several of them foster ground ice in roof crystals, stalactites and stalagmites, and floor coatings.

The ice cave is 400 feet long in a southwesterly direction from one of the sinks, where it starts 100 feet below the level of the country, and progresses underground downward in steps at a flat angle. The inner part is floored with several inches of ice, the roof variously develops hoar frost and ice crystals, there is a rock pile 80 feet from the inner end, and at the end the cavern is abruptly terminated by a wall of solid ice. This wall of ice is 30 feet high, according to Miss Robinson's diagram (Volcano Letter No. 296), 40 feet wide. and its middle is 100 feet underground. There is a drop with a ladder 50 feet from the entrance. The coldest air temperature was always found just inside the entrance chamber, about 32° F. The innermost chamber was usually 2 to 5 degrees higher. On summer visits there was some water on floor and water drip. Accumulation of ice 4 inches deep went on between two visits of February and April, over paper which had been left.

It may be mentioned that the excessive radiation of solar heat at night, with rapid evaporation if the nights are dry, in contrast to solar melting of ground ice from snow in cracks and chasms daytimes, would be assisted by convection in a cavern system. The finding of the lowest temperature at the narrow entrance, the highest part of the floor of the cave, implies a rush of cold air confined in the narrow passage from within outward. This was found in daytime when the outside air was at 80° F. This shows that an ice box circulation is maintained with seepage of air from outside refrigerated along the same passages that bring down the water in daytime. Probably the night reaction freezes this new water at a lower level, and possibly the convectional circulation. aided by evaporation chilling, becomes stagnant or changes direction. It seems certain that the ice wall is fed by an unseen ground ice reservoir, operated by some such mechanism, and it would be interesting to know what air currents are present, night and day. T.A.J.

THE SHOSHONE ICE CAVE, IDAHO

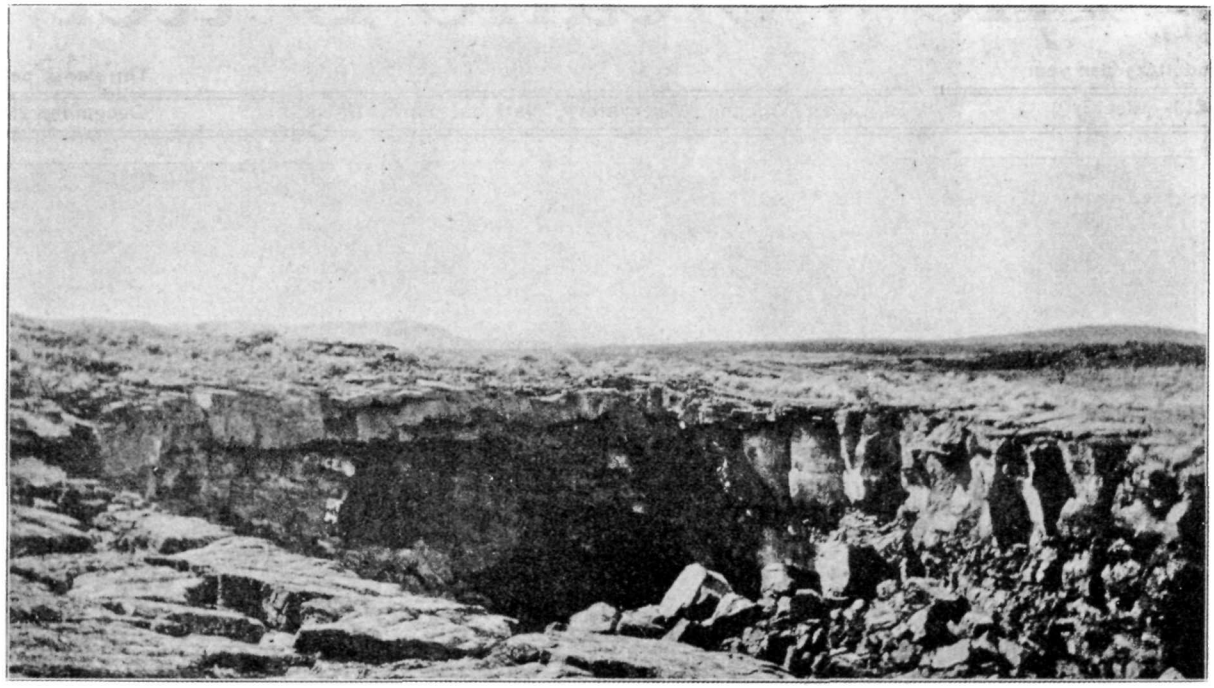
(Second Paper)

By H. G. ROBINSON

In the Volcano Letter for August 28, 1930, this ice cave was described briefly, and an account was given of a series of visits paid to it in the early part of 1930. Since then another trip has been made which resulted in the discovery of several additional facts.

This last visit was made on Sunday, September 7, 1930. The outside temperature was approximately 80° F. The day was clear and hot. In the outermost entrance cave, the ceiling was very damp, and water was constantly dripping. Deep in the cracks which crossed the roof at intervals could still be seen slushy ice crystals. Since there had been no rain for a long while, the water must have come from the melting of those crystals deep in the wall. The floor was still covered with ice, but on top of this ice was a thin film of water which in places measured as deep as half an inch. At the sides of the entrance cave, where the ceiling is very low, formerly there had been thick deposits of clear ice.

It was at once apparent that much melting had taken place at these points, and the ice which remained was no longer clear but looked much like slushy snow. As we approached the ladder we noticed water-cut channels in the ice of the floor, through which small streams of water were running rapidly toward the ladder. They formed a very considerable water-fall just behind and beside the ladder. Right at the foot of the ladder was a depression in the floor ice, worn by the constant stream of visitors usual in the summer time. This depression was filled with



Outer sink and entrance to Shoshone Ice Cave. Photo May 18, 1930 by Bruns.

water. But the floor elsewhere, between this point and the rock pile, was dry.

In view of the amount of water constantly pouring over the edge by the ladder, this indicates rapid freezing conditions in the cave. The floor, previously of clear ice, was now covered with a thin film of ice crystals which sparkled faintly in the flashlight. As we neared the rock pile, a slight film of water was again noticeable. It was not more than a quarter of an inch deep, except in depressions apparently caused by the drip of water from the ceiling, or by melting about some foreign object. Just the other side of the rock pile the drip from above was again noticeable. The stalagmites had in all cases melted away until only slight humps could be distinguished.

Over the rock pile the ice which had been clear enough to enable us to read the newspaper a few months ago was now crocked like old china, forming a mottled pattern all over the surface. It was thinner than before also, for the paper, one which was left behind by accident in January and noticed in April, covered to a depth of about six inches with crystal-clear ice, was now only a few inches below the surface. Nowhere was the ice as slippery as it had been on the previous trip.

The ice wall at the rear was much the same as usual, except that a large part of the wall near the bottom had been dug away, apparently with a pick-ax. Like all other such efforts made in the past, it proved useless, and rather worse than useless, since it revealed no end to the wall and helped to destroy a thing of beauty. We found also that all of the iron stakes driven in at various places to aid us in measurement of the ice thickness had been removed, except those on the right and left floors which were so well concealed as to be unseen by the average sightseers.

There were no ice crystals at all on the ceiling of the entrance cave. At the foot of the ladder the roof was covered with ice which had lost its crystalline form, having apparently melted and refrozen into clear ice drops. Farther back in the cave the percentage of real ice crystals increased, and their presence was noticed much farther back than on any previous visit. It was also noticed that they were much more abundant and extended farther back on the left, or inside, curve of the wall than on the right.

The temperature of the cave at the foot of the ladder was almost exactly freezing. This fact explains the freezing of the water flowing in from the entrance cave, and the reformation of the drops of ice from the crystals on the ceiling. However, the crocked condition of the ice at the rock pile, the original melting of the crystals, and the slushy, snowlike appearance of the ice at the entrance, certainly indicate that considerable thawing had taken place during the summer months.

On this visit a survey of the ground above the cave was attempted by a rough estimate of distances and compass readings. At the point where we believed the underground rock pile to be the ground surface was much disturbed, being composed mainly of loosely piled chunks of lava rock which left many cracks, crevices, and holes leading downward. Though there was a party in the cave at the time, no sound of their voices or other noise could be heard at this place, thus showing that though these cracks are extensive, they do not form any open channel into the cave. Just the same, a network of cracks leading into the cave is almost certain, and the outer loose rock would form, of course. an excellent reservoir for snow, which on being melted by the sun's rays would find its way into the cave below, thus forming the persisent drip at the inner rock pile.

Farther on outside, at the place where the ice wall starts underneath, a sharp V-shaped depression cuts across the surface at right angles to the general direction of the cave. This depression is about 20 feet across and about 50 feet long. It looked as though support had been withdrawn from beneath a crack at right angles to the cave direction, thus causing the two sides to slope in gently toward it. However, no opening could be detected at this point.

On following across country the line of the cave still farther, a very small cave was located. In the eastern wall of this nearest the ice cave were several very small tunnels leading downward and eastward. From these there came drafts of very cold air. By much effort Mr. Bruns, our photographer, wriggled into one of them for some little distance, but saw no ice. However, several other small caves in the vicinity had a little ice in their far recesses. The discovery of these other caves, with their possible connection with the ice cave on the other side of the ice wall, together with the very small opening of the ice cave itself to the exterior, makes one wonder whether the original formation of the ice wall might not be explained by the hour-glass theory advocated by Balch, although the fact that the ice wall is now entirely solid makes the theory of little value in explaining present conditions.

The absence of all ice crystals in the roof in the dead of winter and their appearance later in the spring may be accounted for as a phenomenon of condensation. The cool moisture-laden air of the cave coming in contact with the roof, which has been warmed both by penetration of the

sun's rays and by convectional circulation, deposits moisture on the roof where it immediately freezes into crystals. This will of course take place only when the cave air is cooler than the outside air.

As a result of this study, the method by which the ice on the floor is renewed is plain. Its source is ground water from snow and rain, and the presence of the ice wall itself is at least one factor in maintaining a freezing temperature. And yet air currents must play a considerable part, too, since the table of temperatures indicates that the coolest place is always just at the foot of the ladder. From a study of the stake measurements a constant very slow melting may be observed during the interval of study, which is what one would expect.

Though the cave has been observed during the greater part of a year's cycle, the seasonal changes of the local accumulations being roughly recorded, still the phenomenon of the ice wall is not yet explained, and the only conclusion is that detailed and careful study is needed before it can be. Such study might prove to be profitable in opening up new possibilities in refrigeration.

KILAUEA REPORT No. 987

WEEK ENDING DECEMBER 21, 1930

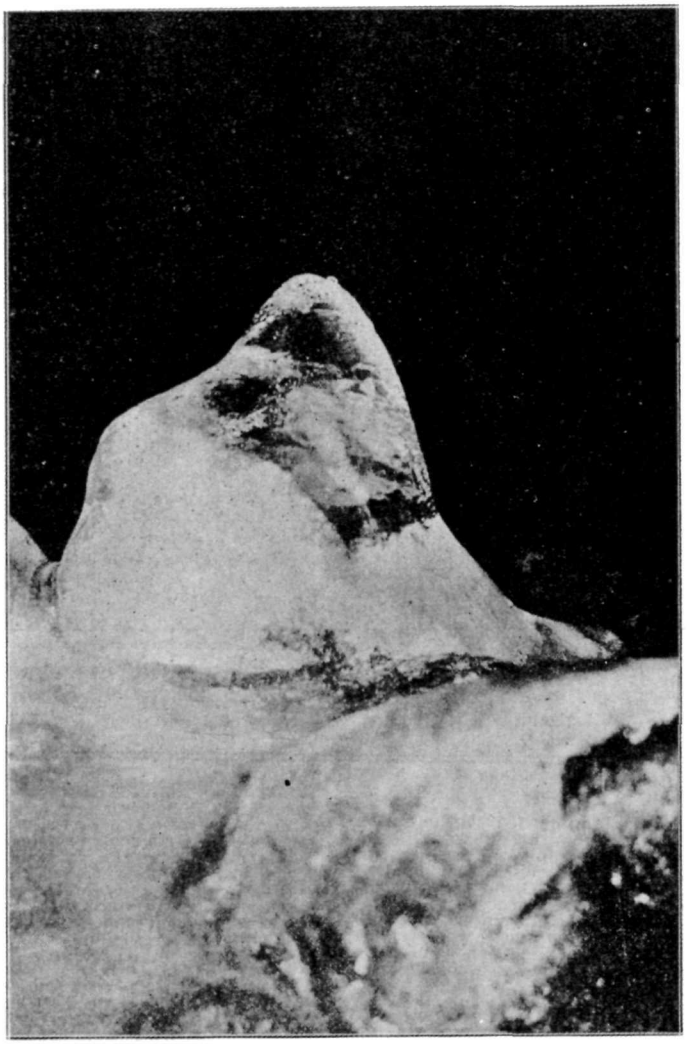
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The fuming from the new lava fill in Halemaumau has been somewhat less during this past week, but has been constantly noticeable. The fume cloud has been added to by clouds of steam on several rainy days. There has been no further slumping of the surface of the new lava, though a few more fragments from the rim of the spatter cone have collapsed. A feeble earthquake was felt by several persons in the National Park at 4:24 a. m. Saturday, December 20.

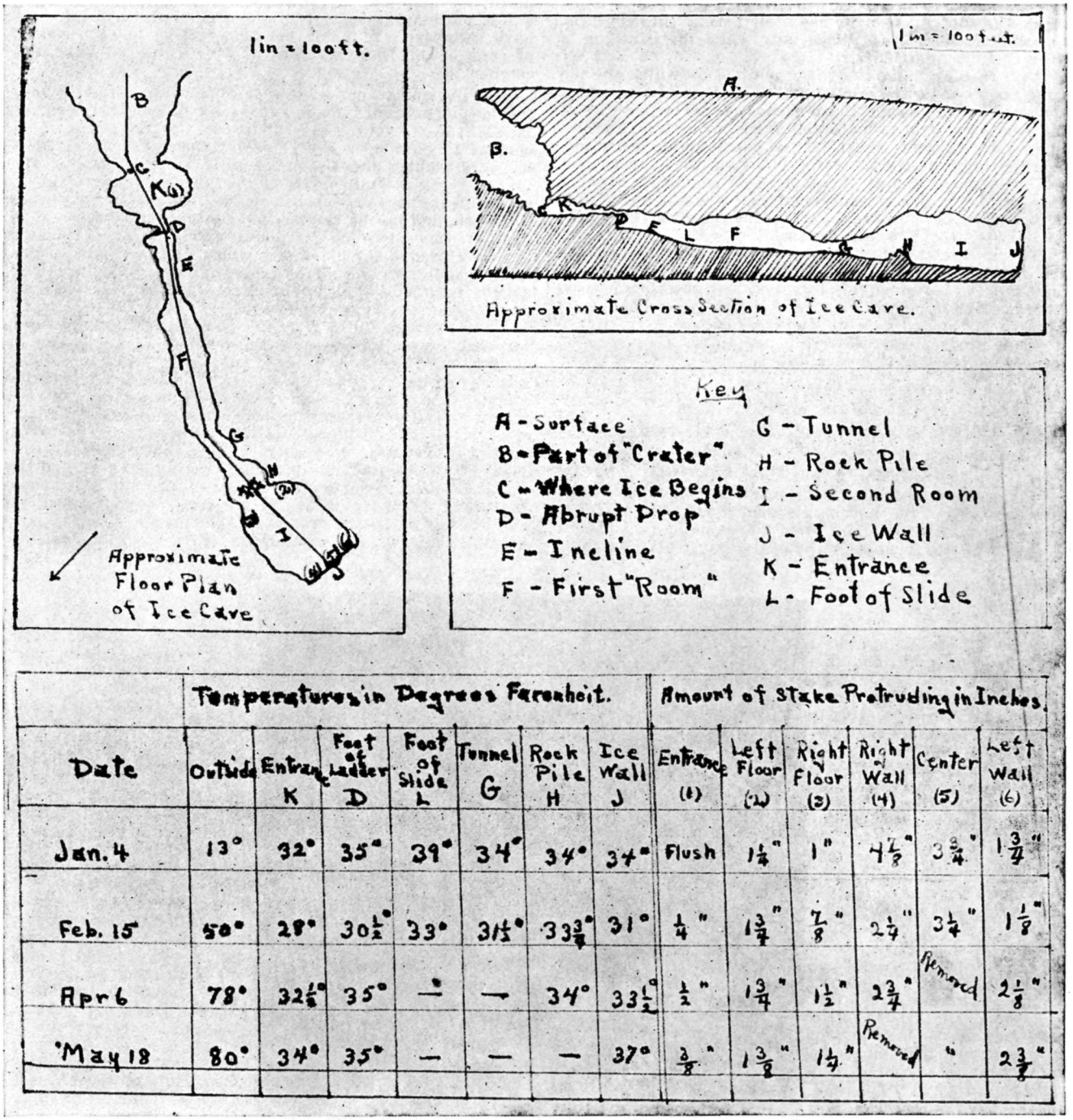
The seismographs at the Observatory recorded 3 very feeble shocks and 1 feeble quake as follows: December 17, 12:21 a. m., very feeble, distance to origin 9 miles; December 18, 8:49 p. m., very feeble; December 19, 11:42 p. m., very feeble; and December 20, 4:24 a. m., feeble, distance to origin 4 miles, felt in the National Park. Thirty-six small tremors of volcanic origin were registered during the week, and during the last 3 days there has been a good deal of tiny spasdomic tremor which appears volcanic but may be due to the strong winds of that period. The non-volcanic swaying of the island indicated by the microseisms has been slight to moderate during the week accompanying the trade-wind storm.

The average tilt of the Kilauea rim under the Observatory has been slight NE, up and away from the center of the crater. During the same time, the rim of Halemaumau has been tilted upward and outward by a slightly greater amount. A notable tilting of the rim upward and outward from the pit accompanied the Kilauea quake of Saturday.

The normal tilting of the Kilauea rim is to the northeast at this season of the year, but the fact that the instrument on the edge of Halemaumau shows tilting toward the southeast at the same time indicates that at least some of the tilt is due to volcanic pressure under Kilauea. If the tilt was entirely due to the seasonal effect, both instruments should show simultaneous tilt to the northeast.



Giant stalagmite of ice two feet high on the rock pile inside of Shoshone Ice Cave. Photo. May 18, 1930, by Bruns.



	Temperatures in Degrees Farenheit.							Amount of Stake Protruding in Inches.					
Date	Outside	Entrance K	Foot of Ladder D	Foot of Slide L	Tunnel G	Rock Pile H	Ice Wall J	Entrance (1)	Left Floor (2)	Right Floor (3)	Right Wall (4)	Center (5)	Left Wall (6)
Jan. 4	13°	32°	35°	39°	34°	34°	34°	Flush	1¼"	1"	4⅞"	3¾"	1¾"
Feb. 15	50°	28°	30½°	33°	31½°	33⅜°	31°	¼"	1¾"	⅞"	2¼"	3¼"	1⅛"
Apr 6	78°	32½°	35°	—	—	34°	33½°	½"	1¾"	1½"	2¾"	Removed	2⅛"
May 18	80°	34°	35°	—	—	—	37°	⅜"	1⅜"	1⅞"	Removed	"	2⅜"

Plan and section of Shoshone Ice Cave. Scale reduced here to ⅞ inch to 100 feet. Statistics of earlier visits in 1930. By H. G. Robinson.

THE VOLCANO LETTER

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Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

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The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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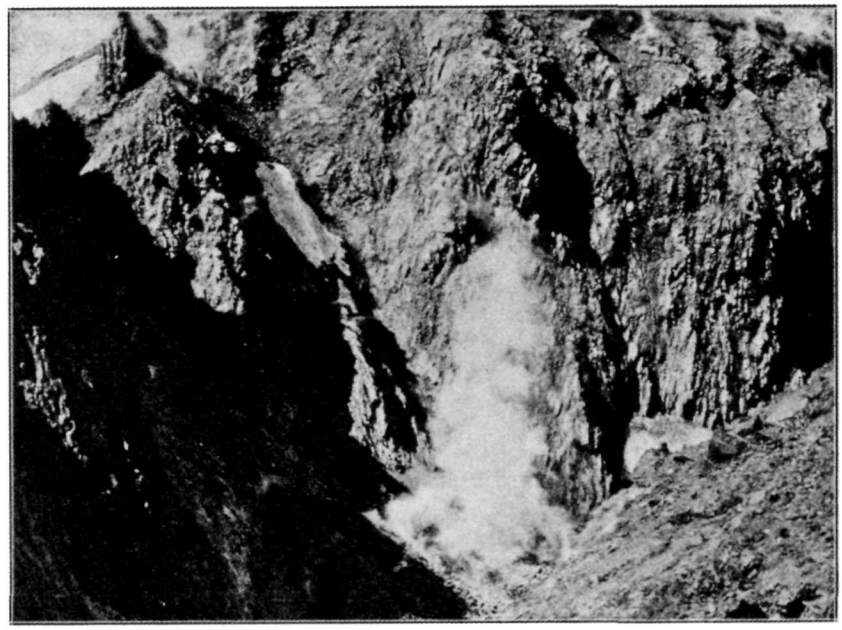
The Volcano Letter

314

Two dollars per year — Ten cents per copy

No. 314—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — January 1, 1931



One of Dr. Stone's photographs made during his ascent of Calbuco January 19, 1930, a year after the eruption described by Dr. Reichert on January 6, 1929. This is looking down into the new crater of the volcano, from the north side of the summit, showing thick white fume issuing from the bottom.

1929 ERUPTION OF CALBUCO, CHILE

By Dr. Federico Reichert

(Translated by J. B. Stone from Riel y Fomento, No. 87, July 1929).

It was in the afternoon of the 5th of January, 1929, when, accompanied by a friend, I undertook to climb the peak Derrumbo situated to the south of Lake Todos los Santos, a body of water well known to those making the trip between Bariloche and Puerto Montt. On the accompanying map of the Pacific Ocean these places may be found just where the longshore islands begin on the west side of South America, in the great valley of Chile, about 600 miles south of Valparaiso.

The prospect for the projected climb was very favorable. The sky was completely clear. The sun was brilliant and the calm absolute. Only the barometer marked an extraordinary and inexplicable minimum. In spite of this abnormal low pressure we resolved to begin the trip, and were able to climb that afternoon to an altitude of approximately 1,200 meters, where we stopped and were overtaken by night.

At about 2 o'clock of the following morning we were awakened by a strange noise and, on looking toward the horizon, we saw a thick mass of clouds, which was approaching rapidly from the west. The rarefaction of the atmosphere was clearly manifested. We supposed that a storm was approaching, a phenomenon often occurring in these regions. The stars still shone. Believing that it was a temporary atmospheric disturbance, we decided to wait until the clouds should discharge themselves, and then continue the interrupted ascent.

But this plan was rudely changed at 5 a. m. when we saw that the clouds were taking forms ever more curious and strange, and were approaching our position like phantasms, threatening to envelop the whole neighborhood and the summit of the peak we were trying to scale. At the same time there was heard a distant detonation different from the report of thunder, and the sky darkened thickly. We thought it would rain, but it did not do so. We decided then to abandon our plan and to return to the shore of the lake, where we had left a boat tied. This we did.

After setting out downhill and about 7 a. m., we found ourselves faced by a strange condition. At first we had the sensation that it was raining, but very quickly found we were mistaken. We looked up and verified the fact that it was a volcanic eruption, which in my judgment proceeded from the mountain Calbuco, situated some fifteen or twenty kilometers distant from the spot, and the only volcano at that time characterized by periodic activity in this region.

Little by little the sky was darkening more. The south



Overturned trees in the valley of Rio Caliente half buried in ash and swept by the blast that had rushed out from the eruption of Calbuco. Just such effects were found on the west side of Sakurajima in 1914. Photo Stone.

cove of Lake Todos los Santos was wrapped in an impenetrable blackness. Only in the north there were seen patches of faint light which quickly disappeared. At 9 a. m. we reached our moored boat. Meanwhile volcanic ash fell intermittently. We embarked at once bound for the south corner of the lake to seek refuge. We rode ten minutes and found ourselves in the dark, as in the middle of a starless night. Something marvelous! In the north, too, were extinguished the little lights gleaming until then in the bosom of the cloud masses. Under such conditions like blind men we kept on rowing anxious to gain the shore.

Ordinarily this could be done in 20 minutes, but now we rowed madly for two hours and a half. We seemed to navigate in a vacuum. The rain of ash bathed our bodies and faces and hindered our looking upward. The situation became complicated a little later by another pheonomenon no less strange. We were wrapped in the "fire of Saint Elmo" produced by the high electric tension. From our clothes and flesh we gave off sparks, and our heads seemed to be surrounded with aureoles. Suddenly the lightning flashed, followed immediately by thunder. The light of the celestial dischange, however, was not bright enough to tear the curtain of ash and nocturnal darkness which covered everything. Simultaneously the discharges from our bodies stopped and we found ourselves again in a chaos. We went on for a stretch and the phenomenon of the "fires" was repeated.

Without warning we reached the shore. To orient ourselves we lit matches and debarked not without difficulty. We were absolutely ignorant of the point where we had arrived. At last at 11:30 a. m. the sky began to clear and we distinguished smokily some outlines of the vicinity. To our surprise we found that we were scarcely 100 meters from the place where we had set out.

The spectacle which presented itself to our gaze was breath-taking. All the landscape, usually so magnificent, was covered by the gray colors of mourning. The fresh green forest had disappeared under cloaks of volcanic ash. The panorama was like a desert. The summits of the mountains Osorno, Puntiagudo, and Tronador, so majestic, had also received the rain of ash from the volcano. The snowy whiteness of their snow-clad peaks was now blackened. Carried by the blast from Calbuco the ash had traveled to the end of the state railways of Argentina, covering all the region of Lakes, Gutierrez and Mascardi of the Argentine Southern National Park. An area consequently of thousands of square kilometers.

Our expedition had aspects, therefore, that were unexpectedly dramatic, but it served for scientific observations. We analyzed the ash which had encircled us for so many hours, to see if it contained fertilizing substances. From this study we can say that it has a specific gravity of 2.66, and that the average thickness of the blanket was 1.5 centimeters. Thus every square meter of surface received about 40 kilograms of ash, contributing lime and phosphoric acid in appreciable quantities. For the 40 kilograms of crude ash will eventually add to every square meter of ground 740 grams of lime and 84 grams of phosphoric acid in the form of easily assimilable compounds.

(Dr. Stone points out that no rain fell at Calbuco for two weeks after this eruption, confirming Finch's conclusion (Amer. Jour. Sci. Feb. 1930) that steam from volcanoes is not the cause of accompanying showers, which depend rather on atmospheric humidity.)

VOLCANOES AND VOLCANOLOGY IN KAMCHATKA

The following is summarized from an interesting letter sent by Dr. P. T. Novograblenof, Director of the Kamchatka Museum, Petropaulovsk, Kamchatka, U. S. S. R.

Writing May 5, 1930, he states that in September, 1929, a great eruption began of Gorely Volcano, a peak 1,830 meters high lying 85 kilometers southwest from Petropaulovsk. The eruption reached its maximum December 30-January 2, and ended in March, 1930, lasting nearly seven months. Gorely, like most of the Kamchatka volcanoes or "sopka" as they are called there, is in uninhabited country. The result of this eruption was that a large area of southern Kamchatka was covered with ash. This is not to be confused with Gareloi of the Aleutian Islands.

Kluchevskaya Volcano, the Vesuvius of Kamchatka, was in a severely active condition throughout the whole of 1929. There were, however, no considerable earthquakes at Petropaulovsk. There are 18 active volcanoes in the peninsula and one in eastern Kamchatka. In the beginning of 1930 the massive northerly volcano Shiveluch, 3,291 meters high, began to throw up clouds of ash and lapilli. It is not known whether there were lava flows.

The Academy of Sciences of U. S. S. R. proposes to establish two volcano observatories in Kamchatka, one near Avachinsky Volcano, the other near Kluchevskaya. The Geological Committee of the Union has informed the Kamchatka Scientific Society that a volcanological expedition is being sent to Kamchatka under Professor A. N. Zavaritsky for exploring Avanchinsky Volcano (elevation 2,720 m.) and Koriatsky (3,462 m.), both these cones being near Petropaulovsk. This expedition will work for two years. It will be the second volcano expedition sent to Kamchatka. as the first one under Conradi and Kehll worked there in 1908-10. T.A.J.

KILAUEA REPORT No. 988

WEEK ENDING DECEMBER 28, 1930

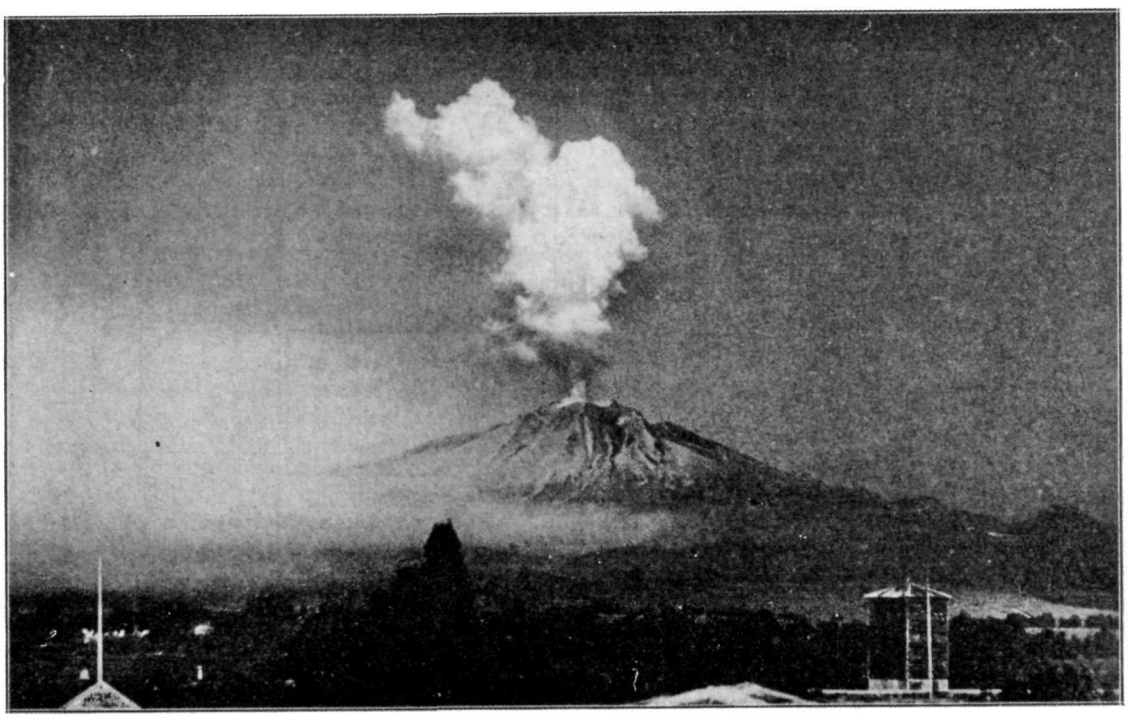
Section of Volcanology. U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

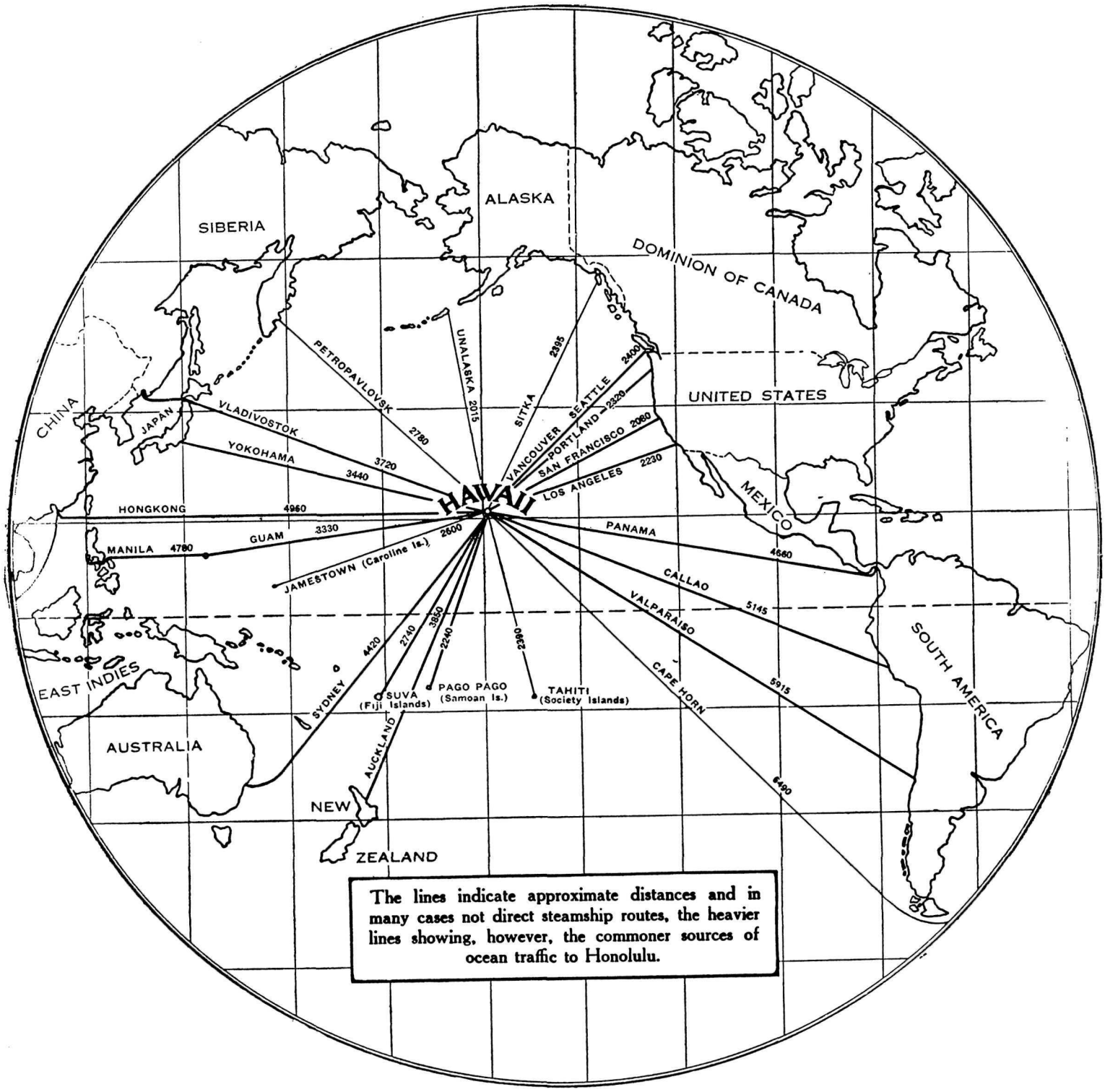
The situation at Halemaumau pit after the recent eruption of lava which filled the bottom and ceased activity December 7, 1930, still suggests continued upward pressure of the lava without sufficient gas potential to make it break out with visible lava flowing. This is indicated by tilt eastward at the pit seismograph and northward at the Observatory instruments, both of these directions implying a tipping away from the volcanic center; also bluish sulphur fume continues to rise.

December 24 the fume had greatly diminished in quantity as seen at 9:15 a. m. when one looked down at the side of the new cone and the sulphur crack at the southeast edge of the new floor. The lava December 26 seemed to have settled and cracked a little at the aa area. The pit seismograph showed tilt away from the center. December 28 at 4 p. m. fresh red debris was conspicuous on the north and east taluses. The pit as seen from a distance showed faint blue fume rising, otherwise was clear. This was identified as coming actively from the base of the outer ridge around the new lava cone, from the southern end of the sulphur crack, and from whitish spots at the southwest. The lava lake area has slumped as much as would be expected from loss of gas in the underlying lava pool.

The seismographs have registered 42 tremors, two of them continuous for several minutes, and two accompanied by easterly tilt. One feeble earthquake was registered at 12:55 a. m. December 25. Tilt at the Observatory was moderate north and microseismic motion was slight.



The eruption of Calbuco January 6, 1929, looking east from Puerto Varas on the morning of the day described by Dr. Reichert. Puerto Varas is on the railway at the south end of Lake Llanquihue, and the pall of ash is here shown at the north in the direction of Lake Todos los Santos. Photo Karl.



This map of the Pacific Ocean shows one radius leading to Petropaulovsk 2,780 nautical miles from Honolulu, and another to Valparaiso which is 600 miles north of Calbuco Volcano. Niuafoou, described in Volcano Letter No. 312, is midway between Suva and Pago Pago.

The Volcano Letter

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No. 315—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — January 8, 1931



The eruption in Halemaumau November 19, 1930, at about 5 p. m. The smaller fountains directly in front of the large talus in the center background, and the main fountain to the left, are pouring out lava which is rapidly spreading over the old floor formed in July, 1929. Photo Maehara.

LAVA IN HALEMAUMAU SINCE MAY. 1924

It may be of interest at this time to review briefly the stages of the volcanic activity of Halemaumau since the great explosive eruption and collapse of May, 1924.

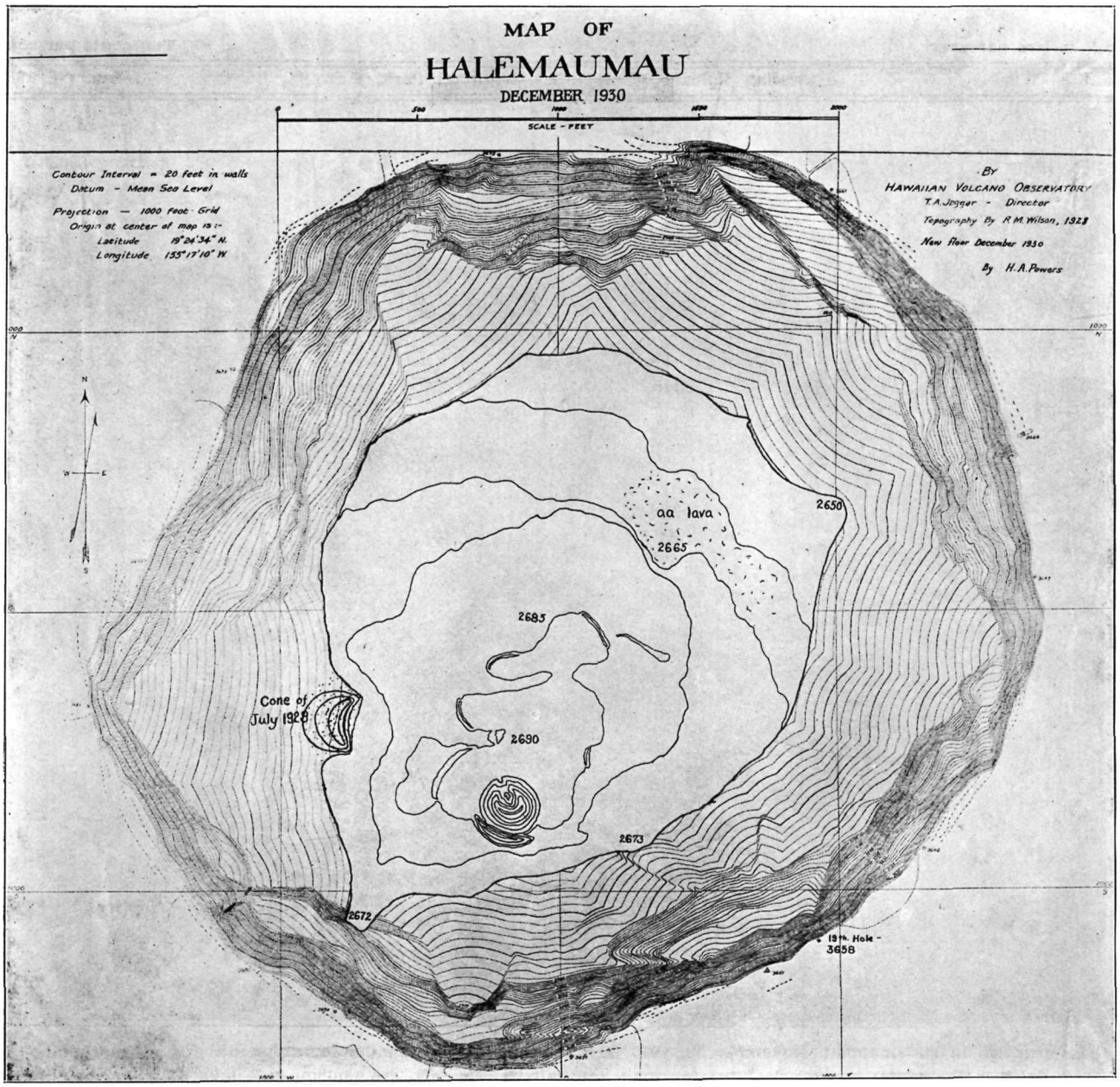
At the end of this explosive phase, no live lava was visible in the pit. Its appearance may be described by quoting from the Monthly Bulletin of the Hawaiian Volcano Observatory for July, 1924:

"The cauldron left by the May eruption was at the upper rim by measurements platted early in July, 3,400 feet long northeast-southwest by 3,000 feet wide. It remained an irregular oval with edges that had gone back about equally in all directions. The lowest part of the bottom flat was towards the north apporximately 1.335 feet below a datum station on the eastern rim. This bottom area was diamond-shaped and gravelly, of dimensions 1,000 by 700 feet. . . . . The site of the center of the new pit was indentical with the old Halemaumau, which had merely been enlarged and deepened."

Shortly after 1 o'clock on the afternoon of July 19, 1924. live lava appeared in the new pit, breaking out in a source fountain through the west talus at a point about 125 feet higher than the bottom of the pit. The lava flowed from the source fountain down the talus slope and then outward over the floor of the pit. This activity continued 10 days, until July 29. The new lava floor built by this eruption was 1,100 feet long by 800 feet wide. The center of the floor had piled up some 25 feet higher than the margins to a point 1,305 feet below the station on the east rim or about 2,390 feet above sea level. Thus the new lava floor was 35 feet thick in the center over the lowest point of the old rock floor.

Lava did not reappear in the pit until July 7, 1927, almost exactly three years later, but during all of this interval the pit was being enlarged by cracking and avalanching of the rim.

About 1 o'clock the morning of July 7, 1927, lava broke out in four fountains aligned along the edge of the 1924 lava floor at the base of the southwest talus. The southern-



Map of Halemaumau revised to show the shape and elevation of the 1930 lava floor.

most fountain broke through the talus above its base in the manner of the 1924 fountain. This eruption came to an end on July 19, after 12 days of moderate but continuous activity. The new floor formed by the lava which poured over the bottom of the pit was 1,700 feet long and about 1,400 feet wide at its greatest dimensions, with its long axis lying in a northeast-southwest direction. It covered a space of approximately 30 acres. An average elevation of the center of the floor was 2,515 feet above sea level. Thus somewhat over 100 feet of new lava had been deposited on top of the old floor by this eruption.

The last of the year (1927) was marked by a series of very heavy avalanches. After one enormous slide from the north wall of the pit, live lava oozed out from several cracks in the floor at the edge of the avalanche debris. No fountaining accompanied this gush of lava, and many other facts seemed to indicate that the activity was no more than a squeezing-up by pressure of remnant liquid lava from the July eruption. This gush of lava took place on January 11, 1928.

The collapse of the rim of the pit by avalanching continued with some violence during the early months of 1928. In the summer of 1928 a survey of the pit by Mr. Wilson showed that it had changed somewhat in shape since the summer of 1924. Quoting from the Volcano Letter No. 184: "In its (the pit's) present condition it is almost circular in shape, though the northeast-southwest diameter is slightly greater. Its diameters are 3,240 by 2,980 feet. The perimeter is 1.96 miles. The depth of the lowest part of the floor below the average rim elevation is 1,170 feet. The area of exposed lava floor and the cones with their spatter is now about 19 acres. The horizontally projected area of all the taluses is 87 acres, and the area of the horizontal projection of all the walls is 81 acres; the slope areas are of course much greater. This makes the total area of the pit 187 acres.

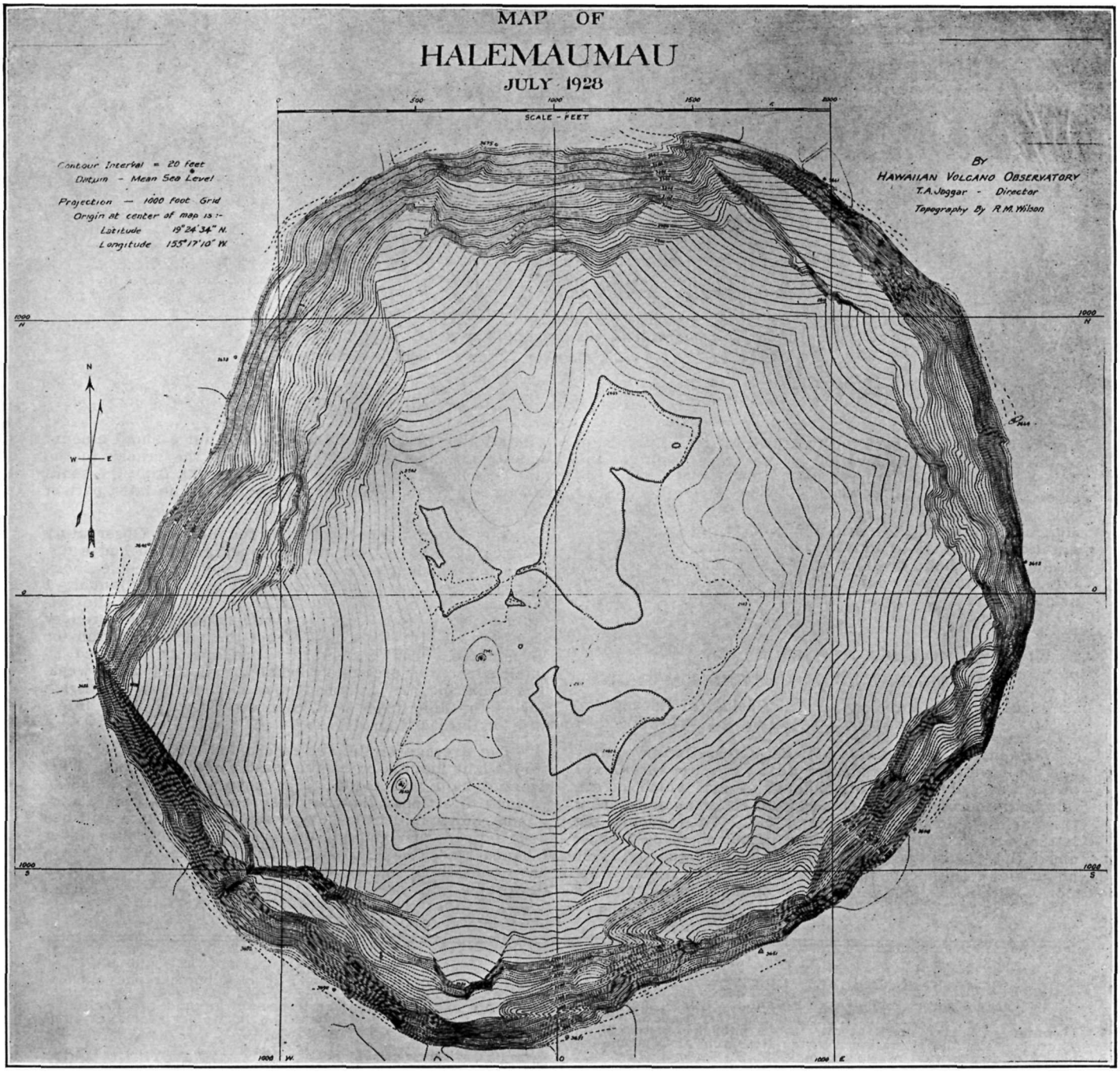
Lava reappeared in the pit at 12:45 a. m. February 20, 1929, and the fountaining occurred along a thousand-foot rift in the old floor trending N. 63° E. about 270 feet out from and parallel to the northwest edge of the floor. The activity continued until 1:15 p. m. February 21, about 36 hours. The new lava spread completely over the old floor and extended itself up on the bounding talus slopes.

At the end of the eruption the new lava fill had an average diameter of 1,600 feet and covered 40.5 acres. After solidification of the new fill, the surface averaged 45 feet above the average surface of 1927 lava.

After a much shorter period of repose. fountaining lava again appeared in the bottom of the pit about 6 a. m. July 25, 1929, the source fountains breaking through the southwest edge of the old floor near the big talus very close to the center of the 1927 fountaining area. Lava flowed from the source fountains until 7:42 p. m. July 28. During the first 24 hours the lava rose 44 feet above the level of the old floor. At the end of 48 hours, the depth had increased to 77 feet, and on the morning of the fourth day, July 28, the pit had been filled 88 feet. The maximum elevation of the surface of new lava was reached at the end of 85 hours activity, 94 feet above the old floor and 2,640 feet above sea level. Withdrawal of some molten lava, and shrinkage due to crystallization. caused some collapse of the surface of the new lava after the eruption stopped. The final cooled fill of new lava had a surface area of 55 acres and an average depth of 55 feet. The average elevation of its surface was 2,600 feet above sea level.

The recent activity, November 19 to December 7, 1930, has been the longest of this series of intermittent eruptions, and it has also brought a much greater amount of lava into the bottom of the pit. The new floor formed during this activity covers 62 acres and has an average depth of about 70 feet. It was estimated that somewhat over 15.000,000 tons or about 229,000,000 cubic feet of new lava is contained in this fill. The surface of the new fill varies from 2,650 to 2,690 feet above sea level.

In the six years from 1924 to 1930 the dimensions of the flat bottom of the pit have been increased from 1,000



Map of Halemaumau as drawn in 1928, showing the elevation s and shape of the floor of lava formed by the 1927 eruption.



New National Park Service lookout house on Mount Harkness, California. The Lassen Volcano Observatory has installed a two-component seismograph in the basement of this building. (See Volcano Letter No. 305, October 30, 1930.) Photo Finch

by 700 feet to 2,200 by 1,700 feet by the rise of the level of the lava fill. The elevation of the lowest point of the bottom has changed from 2,360 to 2,650 feet above sea level, giving a lava fill of 290 feet. Thus a total volume of over 463,000,000 cubic feet of lava has been poured into Halemaumau by the five eruptions which have a combined duration of 46 days of activity. In a circular pit 1,000 feet in diameter, about the size of Halemaumau before 1920, this volume of lava would make a column about 600 feet deep. H.A.P.

KILAUEA REPORT No. 989

WEEK ENDING JANUARY 4, 1931

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

The strong trade winds blowing across the dry crater and the edge of the Kau Desert during the first three days of the week whipped up huge clouds of dust which gave a fair imitation of the dust clouds from Halemaumau during the explosive eruptions of May, 1924. Then during the latter part of the week, beautiful cumulus clouds formed above the pit at night which lacked only the glow on their under side to duplicate the steam cloud of the recent eruption. Within the pit the emission of blue fume from the fountain site has ceased entirely, and but a small amount of steam is now being given off from the cracks in the new lava floor. Steaming was fairly strong from the south talus and the big southwest talus during the later part of the week.

One feeble quake was recorded on the Observatory seismographs at 4:01 p. m. December 30 which had a distance to its origin of 9 miles; and one very feeble shock was registered on January 4 at 9:33 p. m. On January 1 the seismograph was disturbed at 11:39 p. m. by the preliminary wave from a distant earthquake, and the stronger shock waves from this quake kept the pens in motion for 55 minutes. The Observatory instruments recorded 56 small tremors of probable volcanic origin during the week. The non-volcanic microseismic motion was moderate during the first three days, then dwindled to slight intensity for the last four days.

The average of the tilt record for the week shows a very slight inclination to the west since last week. This average gain was made up of several slight tiltings in various directions, showing that no single strong factor is controlling the tilt at the present time. There still has been no sign of a notable decrease in the pressure under Kilauea since the end of the last eruption which would have been indicated by a notable tilting of the ground in toward the pit.

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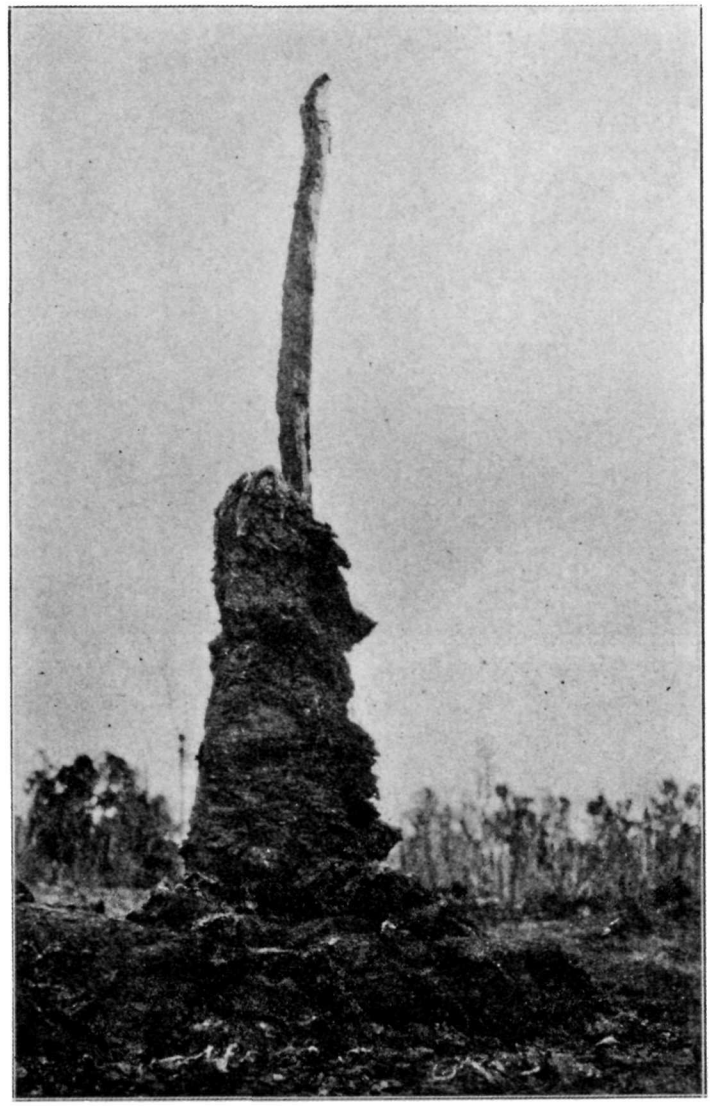
The Volcano Letter

316

Two dollars per year **Ten cents per copy**

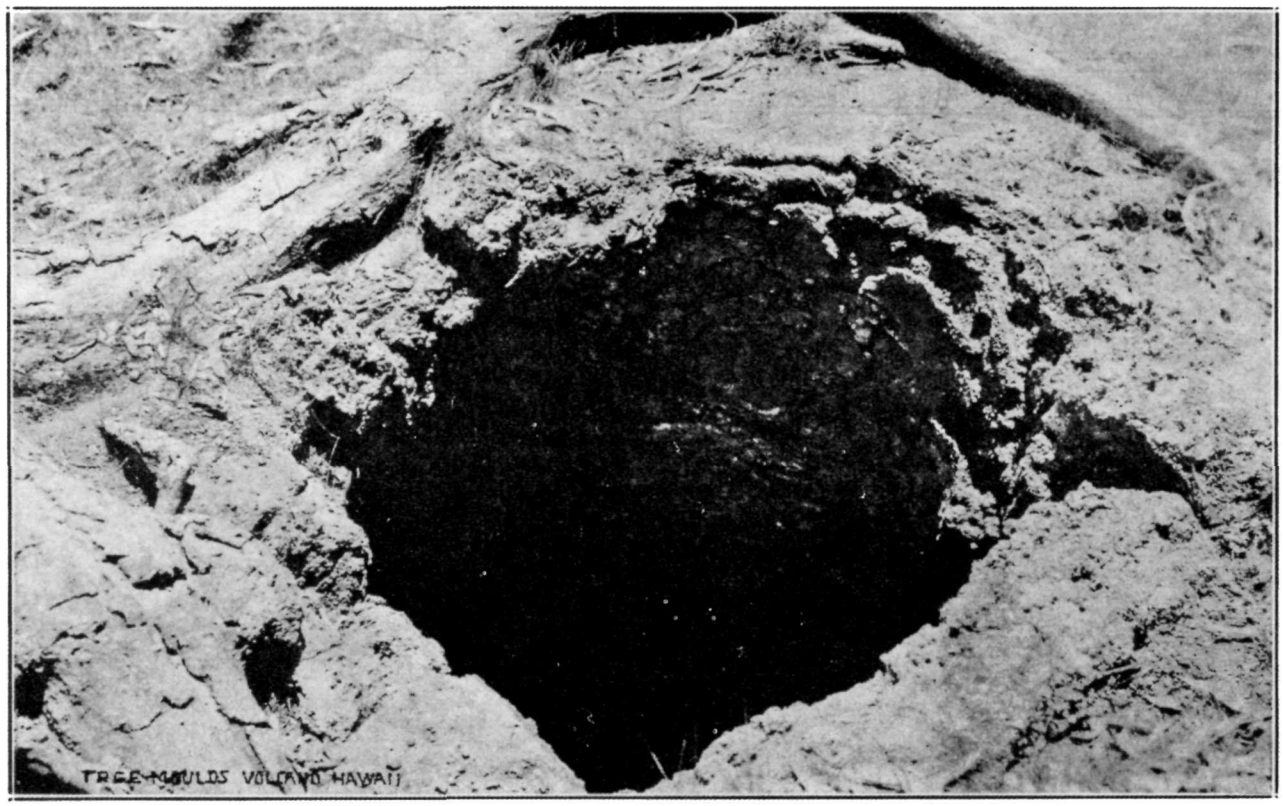
No. 316—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 15, 1931



Lava tree with wooden trunk still standing in it, formed by flow enwrapping the base of tree from left to right and then lowering. 1923 flow from Kilauea, Chain of Craters Road. Photo Boles.

LAVA TREE CASTS AND TREE MOLDS

Lava trees, Figure 1, and tree molds, Figure 2, are very much the same thing, but the one stands in relief, while the other is left a hole in the ground. To understand these tree molds we must remember that lava is very stiff and plastic when it is flowing, like molasses candy, and that contact with any cool substance like wood may, it is true, set fire to the substance, but none the less the lava will instantly congeal. It is really a glass, and molten glass solidifies very quickly. When the wood which is surrounded by lava flames up and burns away, the glass mold may retain very perfectly the pattern of the bark (see Volcano Letter No. 212, Page Three). Both lava trees and tree-molds contain cavities where the wood has burned out. There is a possible third type which would be formed where fresh lava filled up one of these cavities and made a true cast or stone tree by utilizing the natural mold created by the earlier lava flow. A fourth type was described by Mr. Bartrum in Monthly Bulletin of the Hawaiian Volcano Observatory for July, 1925. Here in the North Auckland district of New Zealand a carbonized tree trunk had been trapped by very liquid lava, by shrinkage radial cracks had developed the ring structure and radiation



Tree cast making a well three feet across, with bark pattern molded on the walls. Roots of a modern tree shown above. Here the lava surrounded a tree that burned out. Golf links at Kilauea Volcano. Photo Kanemori.

structure of the wood, the molten glass had penetrated these cracks forming lamellae of finely vesicular basalt in a sort of honeycomb preserving the texture of the original tree. Some of the partitions are no thicker than a sheet of paper.

Both lava trees and tree-mold wells are formed when a fluid lava flow invades a tree-covered area. The lava is chilled upon surrounding a tree and solidifies. If the flow is one of great fluidity, the level of the lava surface is apt to lower greatly after the source of supply has given out. This is because the flowing does not cease, out from under the high crust first attained. Consequently this flood level of the lava in the forest leaves its mark on all the trees, and its mark is nothing less than a casing or shell around each trunk. The original crust over the flow as a whole sinks much lower than the level where it stood when the hot lava was impeded by the forest. The outer edges of the flow during the closing stages sent out tongues which drained away the under substance. Hence the casts of trees, or better the frozen shell of lava around trees, remain to mark the original height of the flow.

Figure 3 shows the southern edge of the floor of Kilauea Crater in March, 1921, where the level of the lava was adjusted after the source fountain ceased action. No trees were present, but the lava plaster on the cliff marks the height of the flood when the fill was made. The cliff is composed of old horizontally bedded ash layers. At the foot is seen the downward broken or slumped field of lava, robbed of its under substance by outflow from under the crust.

If a flow is not so fluid and there is no way for the lava to escape around the edges, the surface does not lower so much after activity at the source has ceased, and instead of a plastered rock tree above the surface, there may be left merely a well or hole in the rock, molding the tree that has burned or rotted away after being surrounded by the melt. Figure 1 shows the wooden bole of the tree still standing in the embrace of the plastered layers of lava which are wrapped around its base.

Occasionally tall lava trees are found on hillsides for which fantastic explanations have been offered. It must be remembered that a grove of trees is a substantial and resistant object in a landscape. A lava flow is a sluggish mass of porridge which will pile up against such an obstruction. This is illustrated by Figure 4 where the obstruction was a cone on the southwest slope of Kilauea. The flow of 1823 plastered the slope of the cone to a considerable height as the flood divided around it. The cone is about 30 feet high and if trees had existed at its base so as to be trapped in the lava, these might have been molded and stand as monoliths today of considerable elevation, while but a few feet away other trees might have escaped uninjured.

Tree casts and molds are found in many places. In the Craters of the Moon National Monument in Idaho there are excellent examples. In the "Burnt Lava Flow" south of Glass Mountain in northern California there are several tree casts. most of which were pushed over by later flows. These casts of woody matter by lava are not confined to recent volcanic activity. for they are found preserved in ancient volcanic strata.

The tree molds near the golf links at Kilauea Volcano are wells lined with a selvage of glassy lava which often preserves the pattern of the bark of the koa trees which were molded by an ancient Kilauea flow. These wells where the tree has burned out are from 6 inches to 6 feet in diameter and from 3 to 12 feet deep. The ground round about is covered with ash soil, and this somewhat obscures the real significance of these molds. This ash was the fallen volcanic dust of the explosive eruption of Kilauea in 1790. Where the original lava shells around the trees stood slightly in relief in these places, the ash drifted over the country in sufficient volume to fill up the ground around the tree casts, but not sufficient to fill up the holes themselves. Therefore the shells do not appear to stand up, but are preserved merely as pits in the ground modelled after the original single, double, or triple trees whose roots were far below where the tourist stands today. On the nearby slopes of Mauna Loa there are some of these tree molds shaped like a trough, where the lava trapped a fallen or recumbent tree, and the divergent roots at the end are now marked by divergent tubes where the roots were modelled in stone and then burned away to ashes.

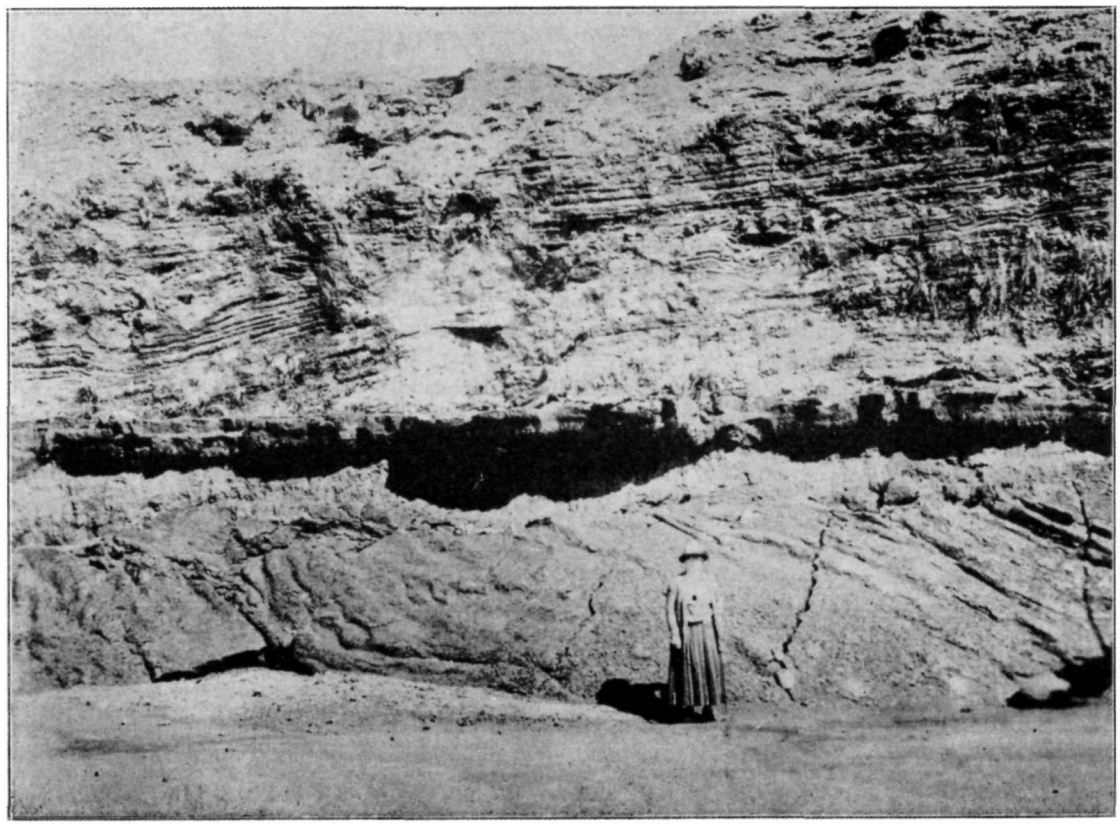
R H.F.

TILTING OF THE GROUND FOR DECEMBER

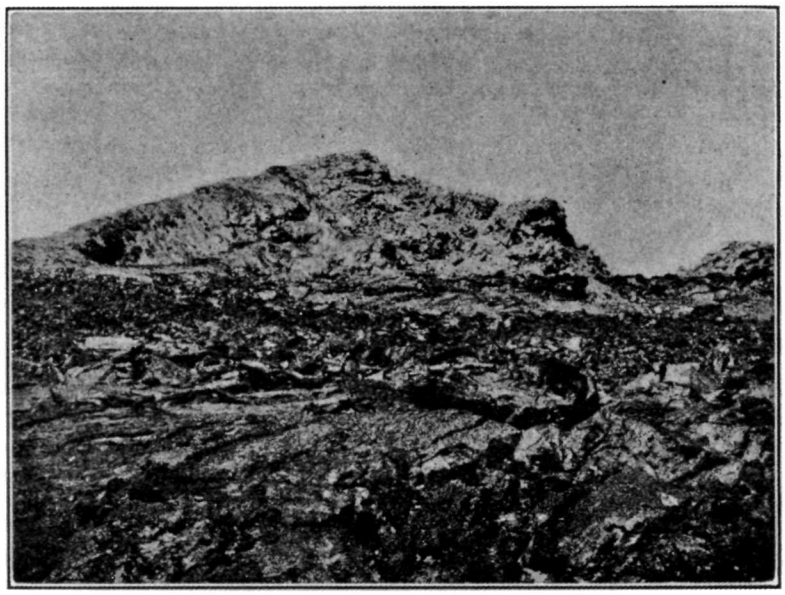
The tilting movement of the ground under the Hawaiian Volcano Observatory during the month of December, 1930, and following the eruption of lava in the bottom of Halemaumau pit beginning November 19 and ending December 7, has amounted to more than 5 seconds of arc in a northeasterly direction. This is a tilt away from the pit and it will be seen that it increased during the eruption and increased greatly the second week after the eruption. While still being northerly the tilt had a westward trend during the last week of December. The suggestion is strong that the upward pressure of the lava continued after the visible outflow ceased. There has been nothing around Halemaumau as yet to indicate that the lava column is lowering.

The following figures show the net amount of tilt on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping progressive seven-day averages.

November 24-30	1.2 seconds	NNE
December 1-7	1.8 seconds	NNE
December 8-14	0.2 second	NNE
December 15-21	2.5 seconds	NE
December 22-28	1.2 seconds	WNW



Lava bench at base of ash cliff, south bay of Kilauea Crater. The 1921 flow slumped after rising to the level of this bench, as the feeding source had become inactive. Photo Finch.



Lava plastered cone where the 1823 Keaiwa flow from Kilauea piled up on the hillside and then lowered. Photo Emerson.

KILAUEA REPORT No. 990

WEEK ENDING JANUARY 11, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

There have been no changes at Halemaumau during the week. Steam is as usual at the vapor vents. No renewal of fume has occurred.

The instruments at the Observatory recorded a total of 28 seismic disturbances. Of these 25 were tremors and 3 were very feeble local earthquakes, all unfelt. One shock occurred at 6:27 p. m. January 6 with indicated distance 18 miles; another was at 7:38 p. m. January 7, indicated distance 37 miles.

Tilt for the week accumulated moderately strong SSW, a change from the prevailing northerly direction during previous weeks. Microseismic motion was stronger than normal, probably due to high winds at the end of the week.

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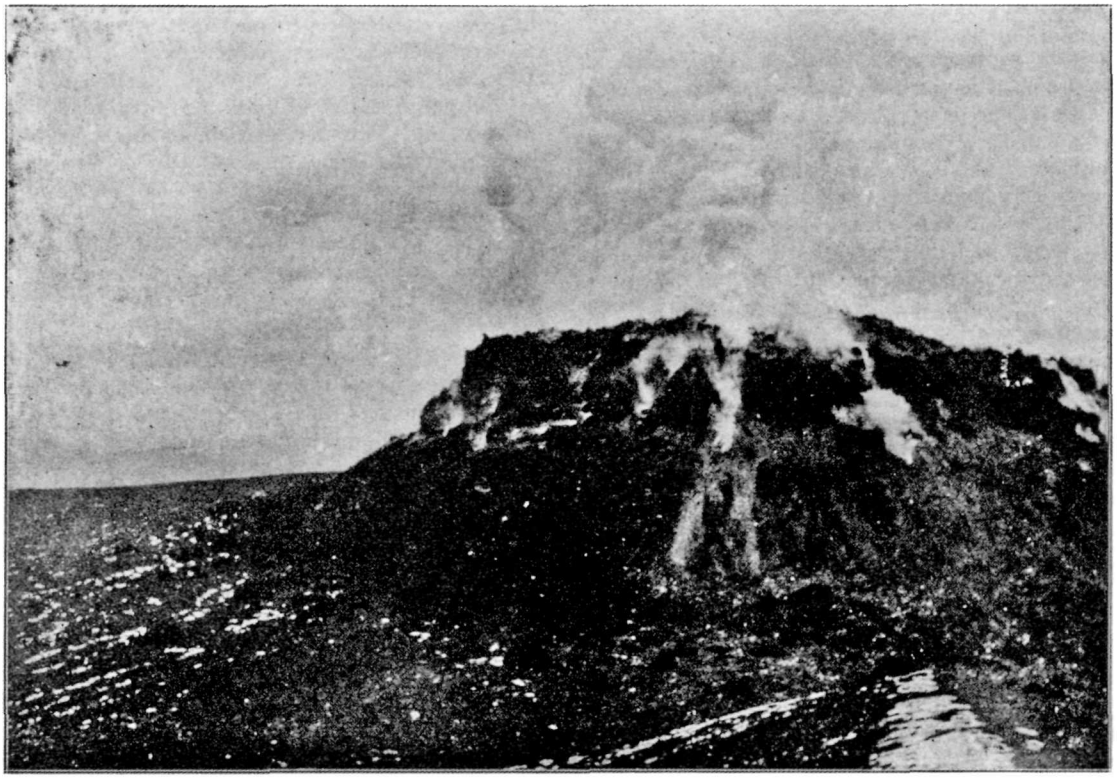
The Volcano Letter

317

Two dollars per year — Ten cents per copy

No. 317—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — January 22, 1931



Lava dome of Tarumai Volcano in Hokkaido, the north island of Japan, two hours after the eruption of October 30, 1926. The dome was formed in 1909, but was rent asunder by a new gas eruption in 1926. Photo K. Shibahara.

THE LAVA DOME ERUPTION OF TARUMAI

In Volcano Letter No. 276 an airplane photograph of 1926 was shown exhibiting a new gas outbreak through the crater dome of Tarumai Volcano in Hokkaido, the north island of Japan. Tarumai is 3,300 feet high amid the forests and lakes of the "Canadian" wilderness of Japan. The map on Page Three shows the four islands of Japan and the black lines represent the arcuate rifts in the crust of the earth along which are grouped the belts of active volcanoes. The southwestern curved line follows the arc of the Riu Kiu islands, which passes through Sakurajima Volcano in the southernmost bay of Kiushu (Volcano Letter No. 308). This ends with subordinate offshoots in the west end of Japan proper, and then comes the arc of that island, with eastern and western belts of volcanoes at the north. These belts converge at Yakedake Volcano (Y in cut), and there meet the great arc extending to the south which passes through Asama Volcano in central Japan. (Volcano Letter No. 297) Fujiyama, (F in cut), Oshima in Sagami Bay southwest of Tokyo (T in cut, see Volcano Letter No. 299), and the Ogasawara volcano islands and the Bonin group far to the south in the direction of Guam. Another bend starts a new arc in western Hokkaido and this extends outside of the map to the northeast along the line of the Kurile island volcanoes which lead in turn to a new arc in Kamchatka. Tarumai is at the southwestern end of the black line marking the Kurile arc, and not far east from Usu Volcano, described in Volcano Letters 298 and 302. (See Simotomai, Zeitchr. fur Erdkunde zu Berlin, No. 9, 1912).

The eruption which lifted the crater floor of Tarumai and converted it into a lava dome occurred in the spring of 1909, and the writer was privileged to make the ascent of the mountain and study the dome while it was still hot and steaming on May 9 of that year. He carried with him a Bristol pyrometer for measuring high temperatures in the cracks of the lava dome. He was accompanied by Professors Oinoue, Sato, and H. Tanakadate, who furnished valuable photographs and information. He stayed at the sawmill and match factory in the forest at the base of the mountain, operated by Mr. Haruta, who had watched the activity from its beginning.

We arrived by rail May 8th at Nishitap near the south shore of Hokkaido, and walked two miles across open flats to the mill which is on a brawling trout stream. The valley is enclosed by a marked marine terrace at least 200 feet above sea level. In the afternoon the clouds rose and showed the east rampart of Tarumai to be saddle-shaped, with pure white steam clouds rising behind it. The mill is 7 miles from the crater, and its function is to make thin strips of pine for match boxes.

At 6:30 a. m. we started on foot through the woods for the mountain, and after leaving the forest crossed several step-like ridges at the base of the outer cone, these being followed by a 35° slope of pumice and cinder which made laborious climbing. Arrived at the high rim of the outer crater we were surrounded by clouds, but saw a great fallen block of andesite in the inner crater. In the afternoon the summit cleared and the huge lava dome was revealed 1500 by 1800 feet in diameters and 600 feet high above its visible base. There was an inner crater pit 2200 by 1300 feet in diameters, and the dome of the new lava was west of the center of this inner crater with its talus overlapping the crater edge on the southwest. The whole surface of the dome was pinnacled with many small pillars rising all over it. These dimensions were from a survey by Oinoue of April 23 and there had been some changes during the fortnight succeeding. The picture on Page One shows the general aspect of the dome, but with much more talus than was present at first. The writer had studied the dome of Bogoslof in 1907, and was impressed by the greater height and steepness of the Tarumai dome, and the protruding crags of hot lava.

At the north where the lava dome was rounded and did not overlap the rim of the inner crater, no falling of rocks was observed, but at the south the dome was very steep and overlapped the rim, there were great fallen blocks at its base, and Dr. Oinoue reported he had seen a block 30 feet in diameter come down. Several rocks were heard falling. At a sulphur patch amid the cracked andesite of the dome, a maximum temperature of 457° C. was measured, while the steam temperature gave 430° when the terminal did not touch the rock.

The history of the eruption was as follows: On the night of January 11, 1909, a column of fire rose over the crater, in the night of January 22 ash fell on the snow at the mill, in the morning of February 6 there was an ash fall and smoke was visible over the mountain, and at 3 p. m. February 10 sounds were heard twice, much steam arose, and ash fell. At 1 p. m. February 18 much steam was visible, and on March 3 rumbling noises were heard three times by the miller Haruta. In the morning of March 30th detonations began at 7:18 a. m., rumbling continued for an hour, stones fell the size of peas, and the smoke from the crater rose in a very slender whitish column which later became darker. After an hour the activity diminished, and in the afternoon the eruption ceased.

April 12 at 11:40 p. m. came loud rumbling and lightnings, at a place two and a half miles from the crater stones fell 5 to 7 inches in diameter, and an earthquake occurred lasting two minutes. April 15 and 17 the column of brown smoke was seen at Sapporo in central Hokkaido. Close at hand strong rumblings, smoke, and glow were perceived, and April 18 with southerly wind the ash fell to leeward 25 to 30 miles away. The cauliflower clouds rising above the mountain assumed wonderful spiral form. There was no life lost in the eruption. The glow increased and the explosive activity dwindled to steam jets April 22.

April 23 Oinoue climbed the mountain, found the steaming dome, and made photographs and sketches. The dome had first been noticed by a fisherman on Lake Shikots on April 20 and had developed at some time after the explosions of April 12 and 17. On April 4 the inner crater pit had been 200 feet deep, floored with gravel, the floor sloping gently toward the north, and steaming chiefly around the west and southwest borders. The pit had shown lava sheets in its wall. There was a small depression in the northern part of the bottom. The lava dome had come up through this bottom. Mr. Oinoue observed glow in the crevices of the dome. Several cracks were found in the rim of the inner crater near the edge of the dome. Rocks were constantly falling off the western side from the many pinnacles of this rude aa of andesite lava, of which the dome was formed. When a huge block fell away from the upper part of the dome a glowing spot was left where it broke off.

On May 1 a sketch from the western mountain showed increased talus all around the dome, except on the northeast side where the jagged rock ledge extended all the way to the base. The profile had become flatter on top, but still showed pinnacles, and an inner comb or fin rose slightly above the flat top. There were many immense fallen blocks, but the slides of rock matter were small and few.

When I saw the dome on May 9 the sulphur-coated blocks of rock near the level of the edge of the crater on the south side of the dome averaged 2 to 3 feet in diameter and the odor was of sulphur dioxide. Quiet steam was rising. There was an area of sulphur stains 30 feet across. The wind was from the south, and a faint crackling was audible in the hot rocks.

The following notes on temperature of crevices in the dome, made with the thermo-couple, indicate the heat at this time:

(1) The base-metal couple was inserted without touching the rock one foot into a cavity nine inches in diameter full of rising steam. The terminal was at least three inches from the rock in four directions. Temperature 430° C.

(2) A narrow steaming fissure was measured, the terminals touching the rock, and inserted 24 inches from the outer surface. Temperature 450° C.

(3) A big wedge-shaped cavity was measured, under a large bowlder, with a very large opening on the outside. Temperature 390° C.

(4) A small cavity, lower down the slope under No. 2 above, received the terminals 12 inches inside laid against the rock. Temperature 457° C.

(5) A small cavity 6 inches across the mouth, admitted the terminal for a distance of 4 feet. Temperature 398° C.

(6) A small area of secondary solfataric action, stained rocks across an area 7 feet in diameter, a 2-inch fissure among the fragments, the terminal inserted one foot. Temperature 200° C.

This volcano is famous for the large amount of pumice which it has ejected. It has an outer ring wall like Somma at Vesuvius. There was a faintly defined inner cone surrounding the inner pit. In July of 1739 the mountain rumbled and emitted fire, volcanic ash fell heavily during two or three days and nights, all this being preceded by a

shock of earthquake. In 1804-17 there was a great eruption of fire, sand, and ash, many lives were lost and some people were wounded, and the emission of smoke continued for 40 years. (This record is somewhat doubted.) December 25, 1871, Tarumai vomited sand and ash for three days and two nights; this destroyed a small cone on top, left a cavity 100 meters deep with a small pond in the bottom, and changed the summit in other respects. February 8, 1874, there was another eruption lasting three days with a revival February 16. Ash fell in Sapporo November 5, 1883, from another eruption, and there were two other outbreaks during that decade. There was unusual black smoke August 17, 1894, and thereafter there was always steam at the crater until the big eruption of 1909. T.A.J.

KILAUEA REPORT No. 991

WEEK ENDING JANUARY 18, 1931

Section of Volcanology, U. S. Geological Survey

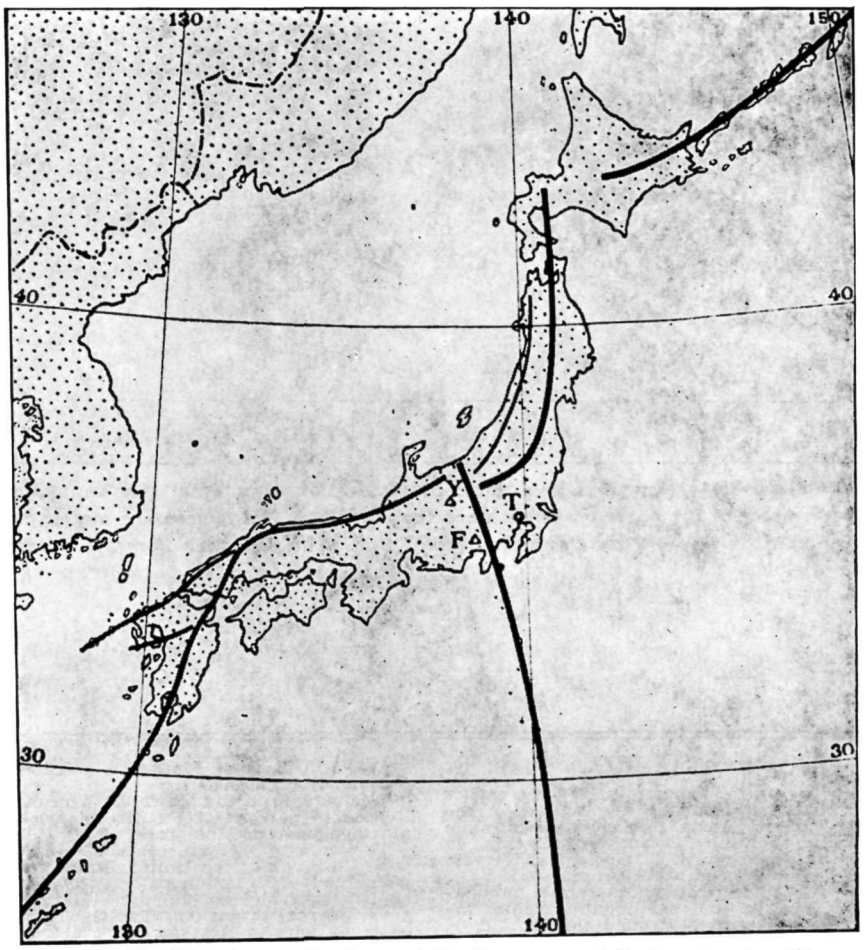
T. A. Jaggar. Volcanologist in Charge

Few notable changes have occurred at Halemaumau during the week. Fume remains absent at the 1930 vents. There are many scattered sulphur areas with whitish coatings, but the main area southeast is bright yellow. On the 14th steam was strong on the south talus.

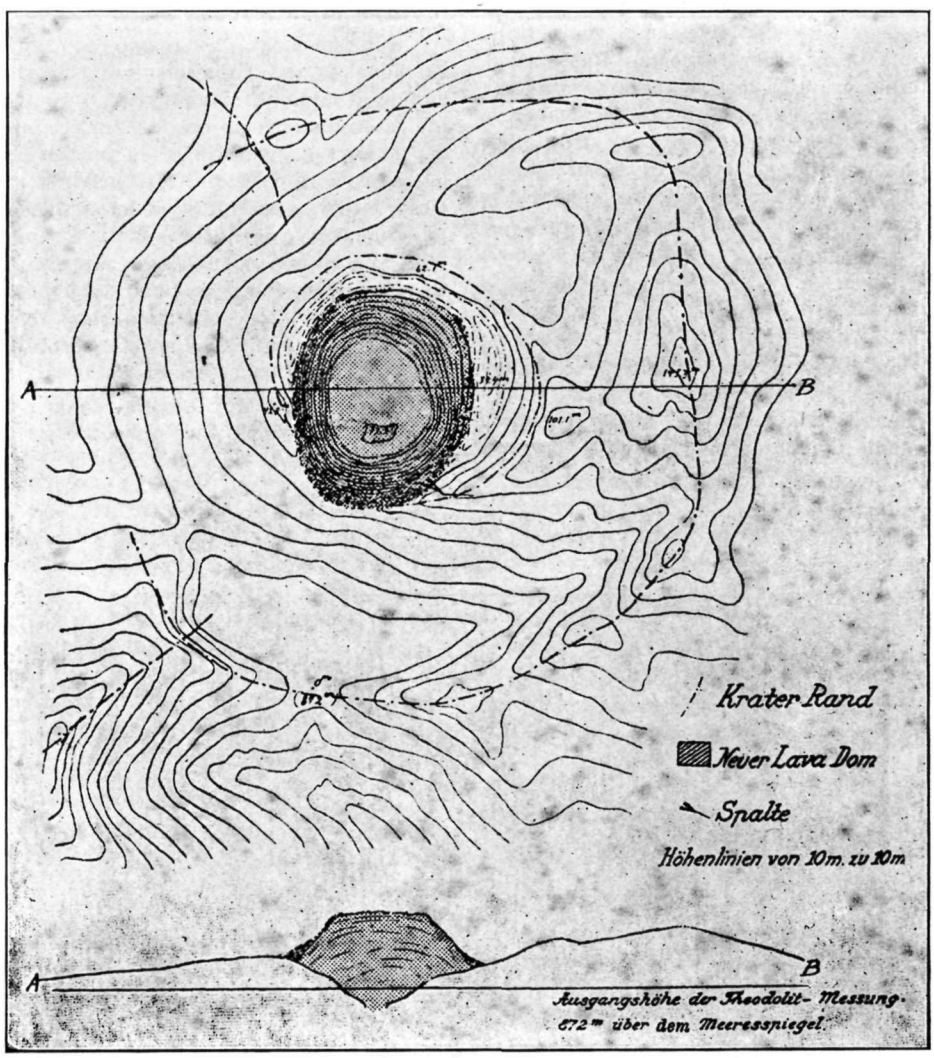
Thick dust clouds over the region southwest of the fire pit, caused by extremely high trade gales, gave rise to rumor of an eruption January 12.

The seismographs registered 29 local tremors and earthquakes and 2 teleseisms during the seven-day period ending at midnight January 18. Two of the first group had indicated distance to origin 18 miles, and another (3:03 a. m. January 12) was reported felt in Hilo. A local earthquake at 8:44 p. m. the 16th originated 30 miles from the Observatory, apparently under the center of the island. It was felt generally, and was more perceptible in Hilo and Hamakua districts than elsewhere. The first of the two teleseisms registered 3:31 p. m. to 4:04 p. m. the 14th; its indicated distance was about 6,000 km. ESE (Oaxaca, Mexico). The second recorded feebly 4:40 p. m. the 16th, duration 21 minutes.

The direction of tilt again changed, accumulating slight NNE. Microseisms were moderate at the beginning of the week, decreasing to slight.



Map of Riu Kiu, Japan, Bonin, and Kurile arcs and their volcanic rifts.
T=Tokyo, F=Fujiyama, Y=Yakedake. After Omori.



Map and profile of Tarumai lava dome of 1909, after Simotomai (H. Tanakadate). The diameter of the outer crater is more than a mile. The figures are meters above the contour line 872 m. Contour interval 10m. The new lava dome is shaded

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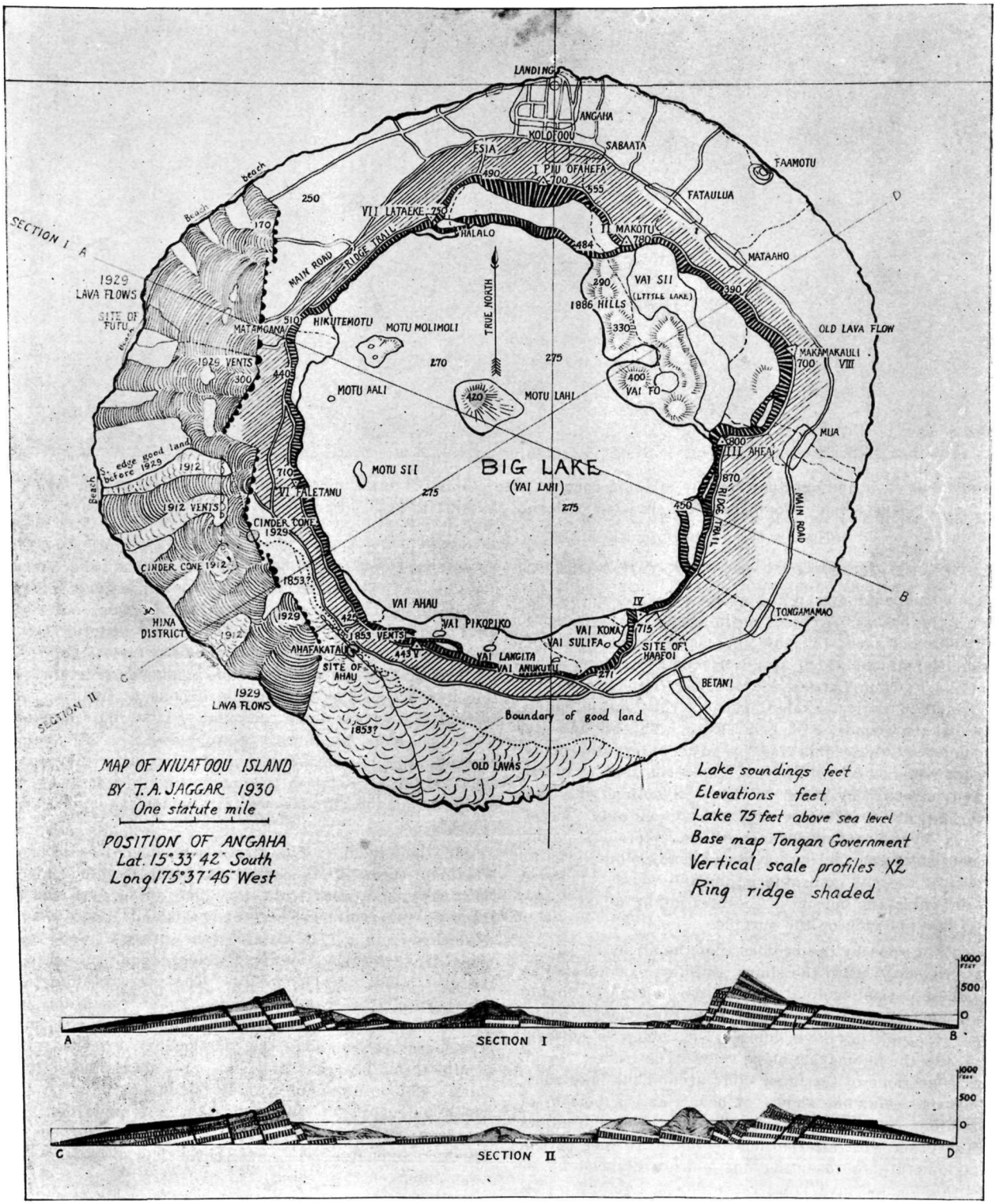
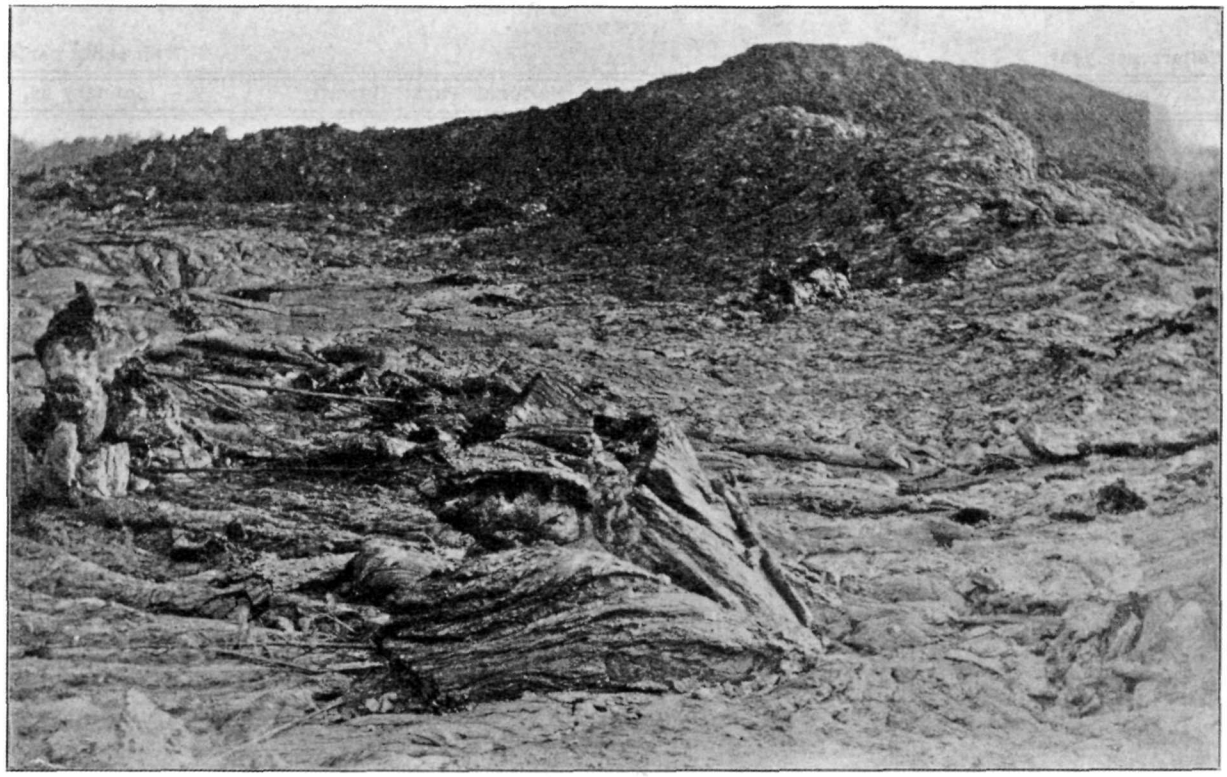
No. 318—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 29, 1931



Volcanologic map of Niuafoou Volcano, a ring island in the Pacific Ocean visited by the U. S. Naval Observatory Eclipse Expedition in 1930. Shows profile structure sections, the positions of the villages, roads and trails, and the lake soundings and land elevations in feet. Survey by T. A. Jaggar.



Pahoehoe lava and spatter ridge, with some coconut tree molds of 1912, photographed in 1913 when the lava was fresh. Compare 1929 eruption Volcano Letter No. 312. Photo from Captain Crawford.

GEOLOGY AND GEOGRAPHY OF NIUAFOOU VOCANO

The accompanying map and profiles were made by the writer on the basis of a recent outline map of the Tongan government and serve to show the perfect ring shape of the island Niuafoou, which as described in previous numbers of the Volcano Letter (265 and 312) is a prosperous copra island in the triangular space of the South Pacific Ocean between Samoa, Fiji, and Vavau. The big lake in Niuafoou is a crater sink fed by rain water and made somewhat brackish by hot volcanic gas springs, by evaporation, and probably by more or less connection with sea water. The lake is 275 feet deep and stands only 75 feet above sea level, so that 200 feet of its waters are below the ocean level, and that in a porous basaltic dome greatly cracked. As there is no drainage, and salt water is heavier than rain water, the bottom of the lake might be salt without that fact showing on the surface.

It will be seen by the profiles that the structure of the island, here shown with the slopes and dips exaggerated to double their normal inclination, and the heights to double the true elevation with reference to the horizontal scale, is that of a very flat lava dome. The island is entirely basaltic and the submarine slope seaward is from 4° to 7°. The cross sections of the inner cliffs around the lake show very massive columnar sheets of basalt at the bottom of deep sections 600 feet thick. The upper ring ridge shows mixed eruption with alternations of about 20 feet of ash and agglomerate representing one phase, followed by 20 feet of thin-bedded lava flows representing another phase. These upper beds have dips of from 13° to 18°, whereas the lava layers seen in the sea cliffs of the border platform dip radially away from the center at from 4° to 8°.

This implies that the lower dome of Niuafoou was built up of heavy sheets of liquid basalt, and that the development of explosive eruption was a later feature recorded chiefly in the upper layers. The angle between outer platform and ring ridge is accented by the modern flows of lava which have come up concentric fractures as shown in the profile, but this angle is also produced structurally by the presence of the steeper mixed cone of the ring ridge resting on an older dome pediment of lava, like the present Vesuvian cone. This angle is probably a belt of weakness concentric to the crater lake, as indicated by the western 1929 fractures shown on the map with lines of black half-domes along the rift fissures from which the flows poured to the sea.

In the ejecta of the two most modern eruptions of Niuafoou, those of 1912 and 1929, both of which emerged through what appear to be tension fractures of northerly trend on the southwest side of the island, pieces of coral were thrown up. This ejection was during a minor steam-blast phase at one locality ("cinder cone" on map), all the rest being pure lava flow. The coral fragments are mixed with dike rocks and lava clinker, at cinder cones containing unusually deep circular pits along the line of lava source vents, and at the 1929 locality three-quarters of a mile from the sea. Ash and sand accumulated to leeward. This ejection of coral fragments recalls Vesuvius, which flings up limestone, and the 1823 explosions along the lava rift near the sea at Kilauea. The coral at Niuafoou indicates that coral rock exists under the southwest slope of the island, though there is no coral reef around the island at the present day. Coral does not occur in the explosive fragments of the 1886 hills, produced by the big eruption of that year northeast of the lake. There may have been a fringing reef at some inactive stage when

the island was smaller. The elevations of the two vents where the coral fragments were found are approximately 150 and 200 feet above sea level.

The cross section of the island shows an outer lava slope all around, (black in the profiles) the ring ridge, the inner cliff, three platforms of explosive materials making islands and sandy hills at the lake level, and the lake bottom. The latter is probably floored with down-sunken blocks of the former cone, overlaid by explosive fragments and sand. This material is shown in heaps in the sections. The outer lava slope at the west and south is modern. It will be seen that each of the three inner lake shore lowlands, including the islands as attached to the northwestern one, is backed by a notching outward of the ring of cliffs. Each of these lowlands stands for an explosive eruption, the northwestern one prehistoric, the southern one probably 1814, and the northeastern one 1886. These steam blasts probably represented subsidences of the lava column at the end of a cycle of upward pressure and outflow. Ground water entered the void, the retreat of the lava into the depths being along the wall-crack of the more or less circular plug under the lake, steam blast shot up and loosened fault blocks, and the sinking of these notched the ring of cliffs outward. The biggest notch is that back of the 1886 hills.

The modern lava flows of the last century started at the south and extended the process of opening fissures northward up the west side of the island. The mechanism of breakage of the cone appears to be by lava flows outside the ring ridge and engulfment eruptions of steam inside of it. There are no fresh lava flows on the lake side of the ring ridge. There are only minor evidences, as cited above, of steam-blast cinder cones on the ocean side of the ring ridge. The cycle at Kilauea appears to involve shorter pulsations of lava flow at 11-year intervals, and a longer cycle of six or twelve of these (66 or 132 years). This longer cycle may culminate in explosion, which means lava subsidence. Something of the same sort exists at Niuafoou.

Summarizing the list of eruptions of Niuafoou we find known outbreaks in 1814 (steam blast), 1853 and 1867 (lava flows), 1886-87 (steam blast), 1912 and 1929 (lava flows). Apparently the 1814 eruption was a steam-blast phenomenon, and it seems likely that its center was at Vai Kona, on the south side of the lake, for there are still warm gases there smelling of hydrogen sulphide, depositing alum, and bubbling up through lagoon waters. Like the Kilauea eruptions of 1790 and 1924, the years 1814 and 1886 may mark the opposite ends of one supercycle, in which case the next explosive eruption for Niuafoou might be expected 72 years after 1886, or about 1958.

It will be seen that the doubt about lava flows on Niuafoou (Thomson, N. Z. Jour. Sci. Tech. 1926, p. 369) is definitely dismissed. The modern lava flows of 1853 and 1867 were at the south (see map), 1912 farther north, and 1929 much farther north. Naturally the clustered settlement at Angaha is anxious about the next eruption, which is likely to extend the concentric fractures around the northwest side of the island in the direction of the villages. The explosive eruption of 1886 notched the rim of the big crater outward where that rim was highest, and therefore heaviest (over 800 feet above sea level). It followed lava flows of the 19th century on exactly the opposite side of the island. If this mechanism maintains a balance of concentric breakage about a cone, it is logical for the explosive eruption about 1958 to follow after flank outflows on the opposite side of the volcano. The highest and heaviest rim of the caldera next to be expected to subside in a steam-blast eruption is southeast (870 feet high). The flank outflows then to be expected between now and 1958 will be at the northwest. As the maximum lava gushing of 1929 was west-northwest, and the trend of a century appears to be extension of cracks northward, there appears to be every reason to expect the next lava eruption to invade the lands west of Angaha.

Sapper (Vulkankunde, p. 336) cites a doubtful date 1840 for a Niuafoou eruption. Supposing this to have been a lava flow, there were six volcanic events in the 115 years following 1814, with intervals respectively:

After 1814 explosive eruption: 26, 13, 14, 19, years
After 1886 explosive eruption: 26, 17, ? ? years

It thus appears that an extra long interval may follow an explosive eruption, and this is true of other volcanoes. The average interval otherwise for Niuafoou by this table is 16 years. This would place the next probable lava flow following 1929 about the year 1945. If the eruption is normal it will fracture open a fissure about a mile long, and if it should start at the big steam vent back of Futu, and spread a mile to the northeast, it would do no damage to Esia, nor to Angaha, but it would be much too close for safety. The next eruption after that is likely to be ejection of steam and ash about 1958, possibly at the Ahea ridge, with damage like that of 1886. The records are very imperfect and it should be understood that there is a range of from three to five years on each side of the year mentioned for the expectancy based on statistics.

These forecasts are not accurate, for our knowledge of the 19th century is very imperfect. They are merely suggestive experiments in volcanologic reasoning, based on such imperfect data as those figures by which the 1924 explosive eruption of Kilauea was forecast on historical data in 1918, with an error of four years (Bull. Hawn. Volc. Obsy., Jan. 1918, p. 17). They may rightly be used by those governing Niuafoou as stating facts based on past statistics. T.A.J.

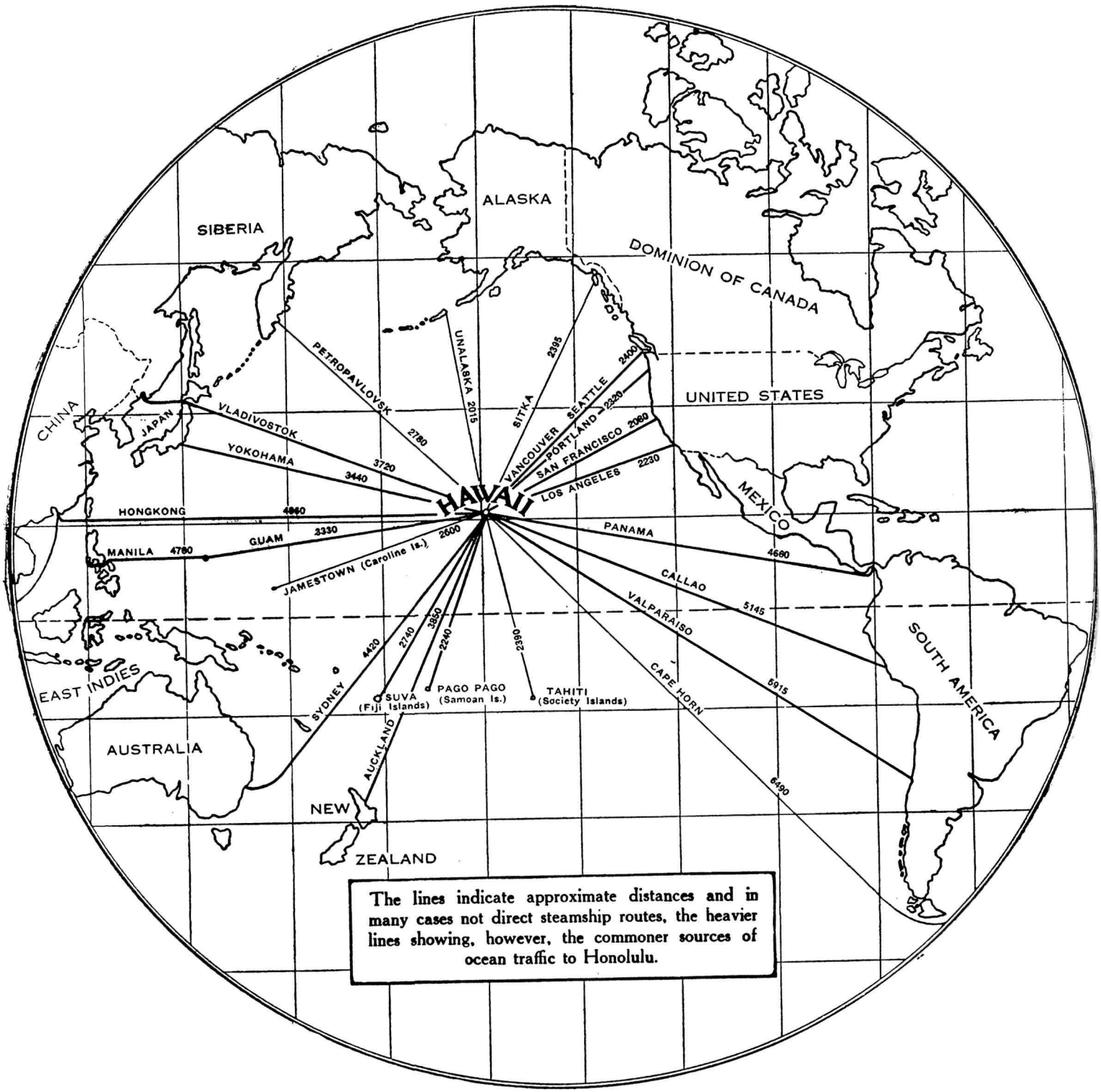
KILAUEA REPORT No. 992

WEEK ENDING JANUARY 25, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

On January 19 no changes were observed at Helamaumau and steam rose from the south talus as usual. The pit seismograph indicates that conditions are quiet. A little dust rose from the north rim of the pit at 3:45 p. m. January 22. This was seen to have been a slide at the north talus and on January 24 a little fume rose at the southeastern sulphur crack and the pit seismograph showed a few volcanic tremors.

The Observatory seismographs for the week ending midnight January 25 registered 30 tremors, one of which lasted two minutes. Fourteen very feeble local earthquakes occurred, three of them on January 25 indicating origin about 30 miles from the station. Tilting of the ground was slight to the WSW, and microseismic motion was slight.



Map of the Pacific Ocean. Niuafoou is between Pago Pago and Suva.

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The Volcano Letter

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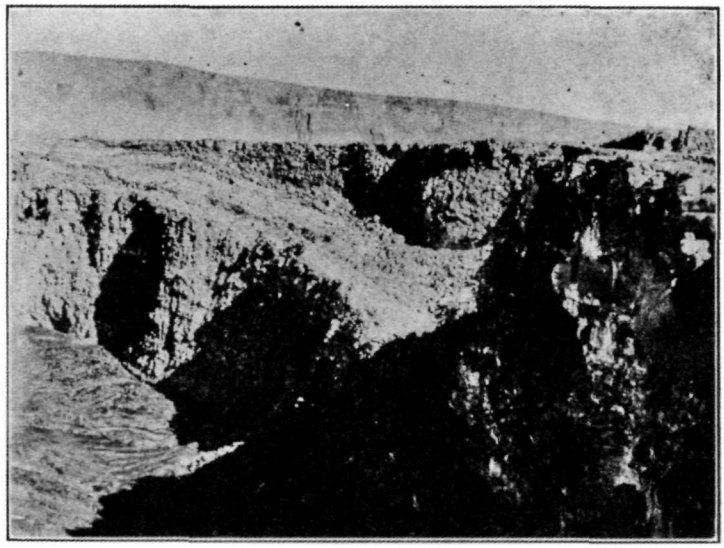
No. 319—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 5, 1931



Halemaumau looking north from the southeast rim December 15, 1916, showing the northeastern inner shelf which had been left for *many years as a feature of the pit rim by the collapse of* 1894. The pit circle measured only 1300 by 1400 feet at this time. The inner lava is seen below, and in the background is Uwekahuna bluff of Kilauea Crater. Photo Jaggar.

TWENTY YEARS OF HAWAIIAN ERUPTIONS

The Hawaiian Volcano Observatory, which was first financed in 1909 and began research in the summer of 1911, has observed about twenty important crises in the three volcanoes Kilauea, Mauna Loa, and Hualalai in the course of twenty years. This means an average of one a year, and with each new event the public is apt to forget the vastly important and exciting events that went before. Therefore very briefly we recount here the sequence.

Kilauea Activity of 1909-13

After the southwestern Mauna Loa flow of 1907, lava rose and fell in Halemaumau pit, then much smaller than at present, at depths 200 to 300 feet below the rim. In 1910 and 1912 three remarkable risings occurred with hundreds of roaring liquid lava fountains. Then came subsidence with much smoke, the lava 600 feet down, from May 1913 to May 1914.

Mauna Loa Summit Eruption 1914

Slowly the melt rose with glowing trickles, sputter, and fume in Halemaumau. In November 1914 Mokuaweoweo, the summit crater of Mauna Loa, suddenly split athwart its bottom and gave vent for two months to high spurting fountain jets of frothy lava, which flowed in the crater only, and became dormant.

Kilauea's Rising 1914-16

Halemaumau now began a cycle of steadily increasing inflow of lava, which was destined to last for 10 years. There was sinking just after the Mauna Loa event, then the upbuilding of a lake in the Kilauea pit, with overflow floor, crags and islands.

Southwest Flow Mauna Loa 1916

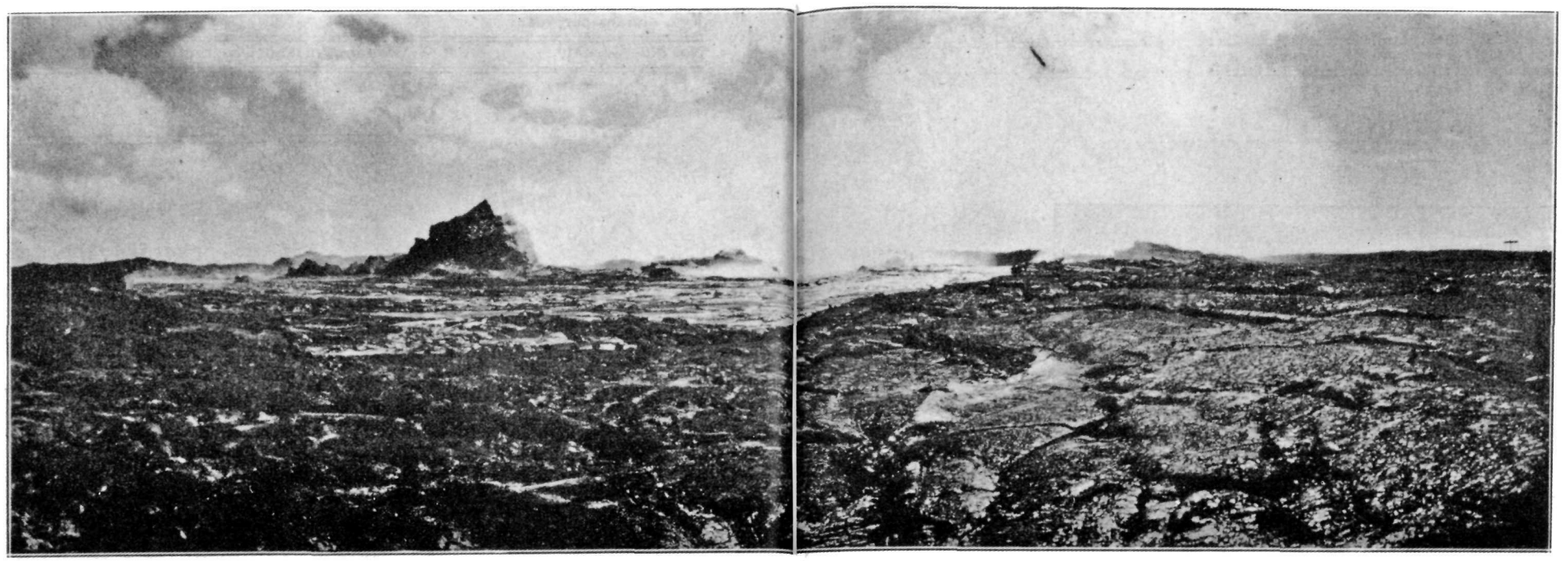
With an astonishingly beautiful mushroom of fume that shot up from about the 10,000-foot level southwest on Mauna Loa May 19, 1916, a new lava flow began making short streams of aa into the forest of Kahuku and Honomalino. This never reached the road and ceased about June 5.

Kilauea Subsidence and Recovery 1916-18

On the same day the lava of Halemaumau, which had just shown a spurt of rising, with the Mauna Loa eruption, sank nearly 400 feet in 24 hours with a magnificient display of red-hot avalanches tumbling into the void 673 feet deep. Immediately lava boiled up in the bottom, and with chiefly rising tendency built up lakes, platforms and crags to the point of overflowing the rim of Halemaumau in February 1918.

Overflows Into Kilauea Crater 1918-19

These two years exhibited the lava in Halemaumau with huge craggy peaks of uplifted floor between the lakes, and whenever there was overflow, reactions of subsidence followed. Overflowing was continuous for seven months in 1919, flooding the Kilauea floor north.



Halemaumau brim full of lava December 31, 1920. This photograph shows the whole pit im with the enclosed liquid lava lake and a high crag standing in its midst, looking toward the south. Where the photographer was standing would now be about 600 fe inside the north rim of the present pit, and 30 feet up in the air. Photo Jaggar.

Alika Flow Mauna Loa 1919: peak of the Cycle 1913-1924

Kilauea flows spurted when Mauna Loa erupted again September-November, 1919, beginning with gushing near Mauna Loa summit southwest. The Mauna Loa flows came out about the 8000-foot level above Puu o Keokeo and poured to the sea at Alika in south Kona.

Kilauea Grand Subsidence 1919

About when Mauna Loa ceased action, Halemaumau, when full to the top, on November 28, 1919 suddenly withdrew its lava column like a piston into a cyclinder 400 feet in an hour. The lava lowered farther for a few hours, immediately recovered, then rose 30 feet a day.

Kau Desert Outflow Kilauea 1919-20

Halemaumau lava rose to the top again December 15, 1919, flooded the southwestern Kilauea floor, burst open the mountain in the Kau desert 6 miles away, and during the next 8 months built the slagheap hill there Mauna Iki, making aa and pahoehoe flows five miles long. Lava in Halemaumau lowered.

Kilauea's Great Overflows March 1921

From 320 feet below rim Halemaumau executed a tremendous rise again for its inner lava lakes between October 1920 and March 1921. There was increasing effervescence, gigantic fountains spouted up in myriads, crags, floors, lakes and wells rose en masse, and the pit overflowed to the Kilauea floor in three great floodings with 5 overflows at one time on March 18, 1921. A small flow went out through the southern Kilauea wall to the desert.

Chain of Craters Outbreak from Kilauea 1922

Kilauea lava subsided three times, with intervening rises, during 1921-22, the last being the greatest engulfment of the Halemaumau walls which had yet occurred in this century. This in May 13-27, 1922, enlarged the pit from a diameter of 1400 feet to 2000 feet. Then May 28-29 came short-lived outflow in Makaopuhi and Napau pits in Puna 9 miles from Halemaumau.

Second Chain of Craters Outflow 1923

Kilauea pit was dormant until lava burst from the talus and began to fill Halemaumau July 17 and September 2, 1922. Then came pulsations of rising to a point 127 feet below rim July 4, 1923, followed by another big subsidence in August and an outflow up a long crack in the forest near Chain of Craters trail west of Makaopuhi. This is the flow shown to tourists where the vent is still hot and lava spatter clings to the trees.

Great Rise and Collapse of Kilauea 1923-24

These oscillations of rising and sinking at Halemaumau, with outflow somewhere down the mountain, reached a grand climax in 1924. This was the end of the eleven-year cycle, and this cycle was the end of an 134-year super-cycle. In the pit greatly enlarged by numerous collapses, the lava rose to within 121 feet of the rim January 27, 1924, making the largest continuous sea of lava ever measured by the Observatory. Then it lowered to dormancy February 15-21, 1924, left a collapsed tumble with a glowing hole about 400 feet down, leading to a demonstration on the eastern or Puna rift of Kilauea Mountain.

Kapoho Coast Subsidence April 1924

This eastern rift crack extends beyond the Chain of Craters through the forest to be crowned with a line of clinker cones 30 miles east of Kilauea. Here at Kapoho April 21, 1929, began continuous shaking, then extensive cracks opened with settling of the country along a four-mile strip to the coast. There was possibly slight increase of steam there at the always steaming Puulena pit craters. No heat was detected in 20 new chasms. The country sank 11 feet, at the ocean a new salt water lagoon extended 200 feet inland, and coconut trees stood in eight feet of water.

Kilauea Explosive Eruption 1924

The series of subsidences in Halemaumau was now breaking down the mountain, the lava retreated into a deep void, and immediately after the eastern rift subsidence Halemaumau pit began to cave in with increasing avalanches beginning April 28, 1924. Through the cloud of rising dust steam blasts began to fling up rocks May 11, this accentuated the collapse of the funnel and the breaking down of the walls, and a grand climax of explosive eruption was reached May 18. The steam blasts came in pulsations like geyser eruptions every few hours. One man was killed through being too venturesome. The pit was enlarged from 2000 feet to 3500 feet diameter and was left 1300 feet deep. Red-hot walls were revealed below. Steam blasts ended May 27.

Return of Lava July 1924

Except for avalanches Kilauea was dormant until July 19, 1924, when frothy pumiceous lava shot up through the talus of the bottom of Halemaumau with much burning gas, made torrents of melt into the cup of debris at the bottom of the pit, and kept up the action gradually declining for two weeks. This was followed by prolonged dormancy at Kilauea for three years. T.A.J.

(To be continued)

KILAUEA REPORT No. 993

WEEK ENDING FEBRUARY 1, 1931

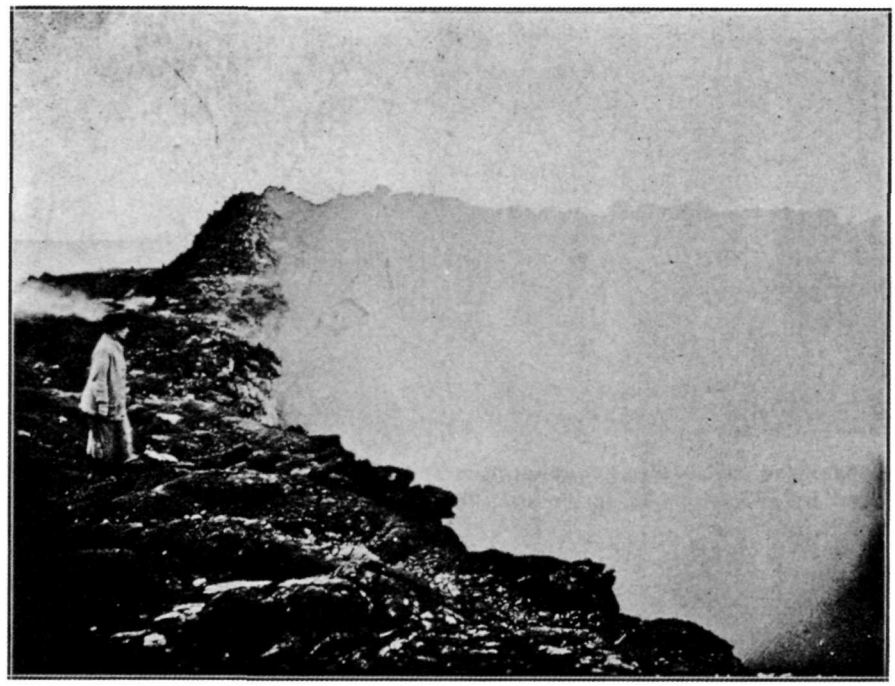
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

The week was notable on Hawaii for two felt earthquakes noticed generally all over the island suggesting origins under Mauna Loa. These in sequence upon the similar earthquake of January 16, which by careful analysis showed signs of originating deep under the northeastern slope of Mauna Loa, make the watching of that mountain for possible volcanic activity a matter of interest in the near future.

During the prolonged slight earthquake of 11:39 p. m. January 29 rocks were heard falling in the direction of Halemaumau. Prior to that time there were no changes at the pit, but the seismograph there had recorded a few slow-period tremors. At 9:30 a. m. January 30 a few rocks fell from the north wall of the pit where there was a small red scar from earlier falls. The steaming at the south talus was slight and no fume was detected at the sulphur crack south.

The seismographs at the Observatory registered 1 slight earthquake January 29, 11:39 p. m., 1 classed as feeble 11:56 a. m. February 1, the former showing distance 14 miles, the latter 55 miles. Very feeble shocks were registered to the number of 26 as well as 39 tremors. Ten of the minor shocks indicated distances around 30 miles, as in the case of the earthquake of January 16. The increase of total frequency over the preceding week is from 44 to 67 disturbances. Microseismic motion for the week changed from moderate to very slight. Tilting of the ground was strong to the east.



Halemaumau on the forenoon of November 28, 1919, just after the early morning subsidence which had lowered lakes and crags like a piston drawn into a cylinder. The previous evening the lava had been up to the level of the rim shown so that one could walk out on the inner floor. Ridge in background was the pressure rim crushed up during the previous year. Photo Jaggar.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian *Volcano Research Association and is leased and operated by the* United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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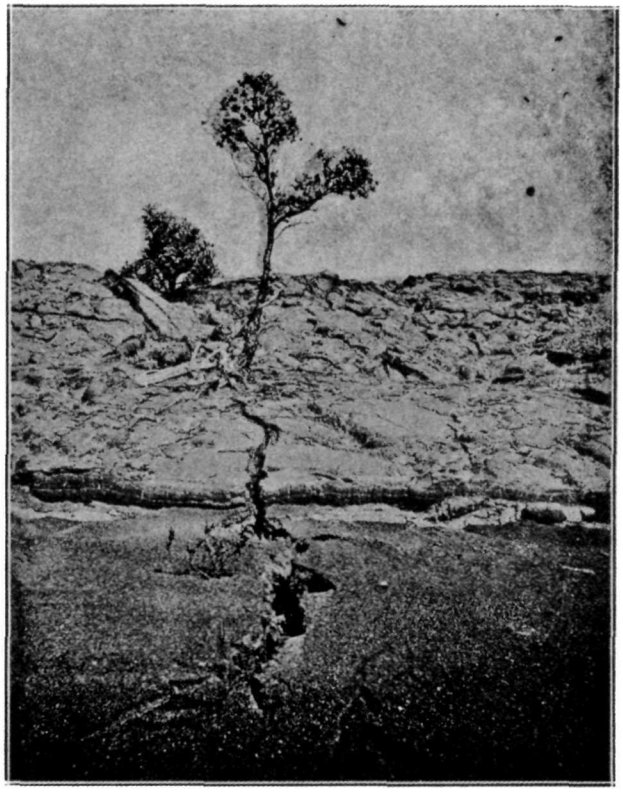


How the old lava mountain of the Kau Desert split open December 22, 1919 through sand and rock and the roots of a tree, in order to give vent to the lava which later piled up into Mauna Iki.

TWENTY YEARS OF HAWAIIAN ERUPTIONS

(Continued)

Hoopuloa Lava Flow Mauna Loa 1926

While Kilauea remained dormant, Mauna Loa on April 10, 1926, opened its southwestern rift about 3 a. m., with lava splitting its way upward and gushing at first just outside of the summit crater. Frothy pahoehoe flows from this summit source poured several miles southward. Then at about 8,000 feet elevation and east of the Alika source cones of 1919 three cups opened along the southwestern rift of Mauna Loa, a big brown fume column shot up, and lava flows started along the rift 15 miles southwest of the Mauna Loa summit. The flood of slag spread both east and west from the rift crack, the western flow finally taking control, pouring down through the forest in South Kona, crossing the main road at 12:22 p. m. April 16, pooling back of Hoopuloa village at the coast as a mass of heavy aa, and completely burying the village, wharf, and harbor between 4 and 9 a. m. April 18.

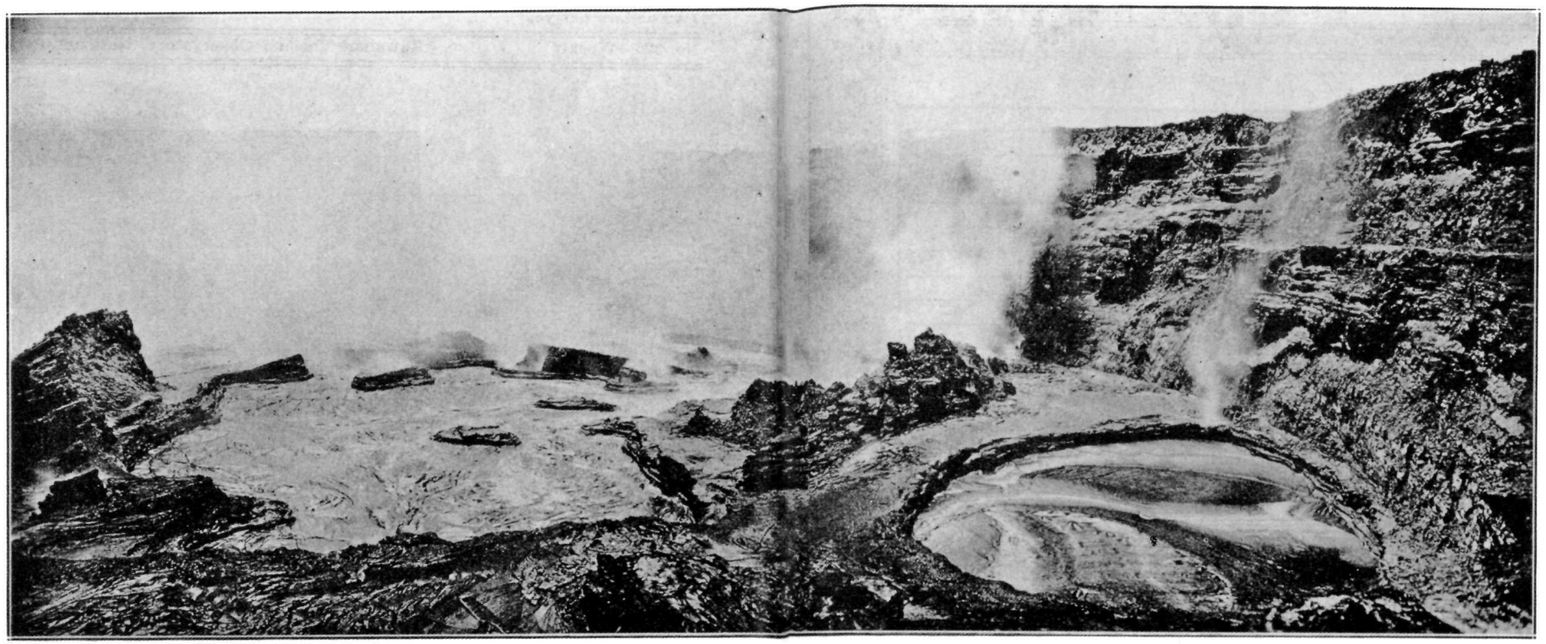
The source region on top of the southwest ridge of Mauna Loa had developed a line of activity along the rift five miles long with cones and fountains 50 to 100 feet high, the activity progressing along the crack from above downward, and settling down to steady flow at one of the lower cones. Flowing stopped at the Hoopuloa shore April 19, but continued in new streams in the upper Honomalino forest until April 30, when the eruption ceased. There were swarms of earthquakes during and after the outbreak, the frequency diminishing after April 17.

Return of Lava Kilauea July 1927

Halemaumau remained dormant until July 7, 1927, when lava returned to the bottom of the pit, declining in activity to dormancy July 20. The spraying fountains of pumiceous lava attracted attention by their illumination at 1 a. m., and were found to be in a line of four vents trending northeast-southwest across the lava floor of 1924. The persistent vent which became the main source of the bottom fill originated up the southwestern talus and built a pumice cone. About 100 feet of new lava was deposited over an area in the bottom of the pit 1700 feet long northeast-southwest by 1400 feet wide.

Return of Lava Kilauea January 1928

After a series of heavy avalanches in Halemaumau culminating in a monstrous one which caused the north-



Halemaumau Pit during its recovery September 7, 1920, showing the rising pahoehoe liquid lava of the lakes making overflow platforms as the lake lava gained upon the crags. Taken from an inner shelf looking south.

western talus to develop into a landslip over the lava floor at 12:26 a. m. January 11, 1928, glow suddenly appeared at the pit coincident with this landslip. New lava had spouted up cracks in the 1927 floor which was brightly incandescent at first, but the rosy over the pit disappeared in 20 minutes. By 1 a. m. the glowing areas indicated cooling flows with a hint of blue flame at a northern cone vent, but there was no observable motion. Slides from the walls continued on all sides. There was no fountaining seen, but no observer was present during the first half hour.

This upflow was believed at the time to be the result of loading down the crust of July 1927, and squeezing up the lava that remained still fluid below. This explanation is doubtful as the frequency of volcanic earthquakes had been unusual for two months, and an eruption was expected.

Return of Lava Kilauea February 1929

Halemaumau was dormant until February 20, 1929, when inflow of lava in the bottom of the pit lasted a day and a half. This was heralded by a striking record of tilt with small earthquakes at the pit seismograph. The ground suddenly tilted away from the pit, and at the end of the eruption tilted back again. Again the outbreak was just after midnight, in the early morning hours of February 20 along a fracture in a straight line across the northwestern side of the bottom lava in Halemaumau. As the landslip of January 1928 had diminished the size of the cup of talus, the new fill, only 45 feet deep, was smaller than that of 1927, measuring only 1600 feet in diameter. The action was marked by a line of continuous fountains with a big fountain of the Mauna Loa type shooting up frothy lava 200 feet at the north end of the live crack, and making a streaming with bright line pattern out into the lake which covered the bottom. There was a steady roar, blue fume arose, while pumice and Pele's needles fell outside of the pit. There was almost no avalanching. The northern fountain built up a pumice and lava heap from which cascades poured down, and this broke down to an "arm-chair niche" at the end.

Return of Lava Kilauea July 1929

After a shorter period of dormancy Halemaumau again produced a spurting eruption in its bottom lasting three days July 25-28, 1929, so as to diminish the depth of the pit by another layer of lava 55 feet deep. This left Halemaumau approximately 1,000 feet deep. Again the outbreak was in the early morning. The time was about 4:35 a. m. as shown by sudden tilt and earthquakes. The center of activity was a fracture through the western talus tangential to the bottom plug. Big fountains spouted up there, and the seismograph at the pit showed inward tilt toward the center on the first day, followed by outward tilt thereafter. In all these short eruptions of lava in Halemaumau a characteristic harmonic tremor of the ground was registered at the Observatory during the days of actual fountaining, and was absent before and afterwards. At the end of July there remained visible glow from cracks in the floor for a few days, as usual with these eruptions, but none of these outbreaks left hissing gas or other signs of continued activity. The eruption stopped abruptly and the new lava solidified.

Hualalai Earthquake Crisis Autumn 1929

Suddenly small earthquakes began to be felt in North Kona near Hualalai Volcano September 19, 1929, though Kilauea remained dormant, and no volcanic activity appeared elsewhere. Puuwaawaa, a large cone on the north flank of Hualalai, became the center of maximum motion. Large destructive earthquakes about Grade IX Rossi-Forel occurred September 25 and October 5. Six thousand two hundred eleven earthquakes were registered in Kona between September 21 and October 16. Great damage was done though no lives were lost: houses, roads, stone fences, fills, tanks, and masonry of every description were broken. Exerything indicated that this seismic spasm was connected with volcanic movement of lava underground tending to shift from the Mauna Loa region to the Hualalai region. An Hualalai outbreak was expected, for this volcano had been active in 1800. No lava flow came and the seismic movements gradually died away in November.

Return of Lava Kilauea November 1930

Another eruption began in the bottom of Halemaumau at 1:29 p. m. November 19, 1930, and this proved to be the longest of this series of intermittent eruptions, bringing also a much greater amount of lava into the bottom of the pit. The activity lasted until December 7 and added a layer to the bottom averaging 70 feet deep. The bottom floor was greatly enlarged to become a leaf-shaped structure 2200 feet long northeast-southwest by 1700 feet wide with a large source cone near its southern margin. The remnant half cone of July 1929 still persists at the base of the western talus.

The new lava fountains broke through the floor in front of the grotto niches of 1929 and several fountains developed, one dominating the others as usual, and this in the region of the south edge of the 1929 floor. Here there were developed spraying jets 100 feet or more high, pumice and Pele's hair fell outside of the pit, a crescent heap was built around the south side of the fountain and this gradually enlarged to become a big cone more than 100 feet high. A lake was developed north of the source cone with changing ramparts around its margin, and this at the top of a slag heap which constituted the entire fill of 1930. From the lake the slag heap sloped down in all directions, steeply at the south and more gradually at the north. The activity developed streaming across the lake from the source cone, and trickling flows now here, now there, from the lake out to the margin of the fill. The decline of activity was gradual, and the region of lake and source cone was left thicker and higher than the border fill. Halemaumau was now 930 feet deep, and at the top 3400 feet long by 3000 feet wide. T.A.J.

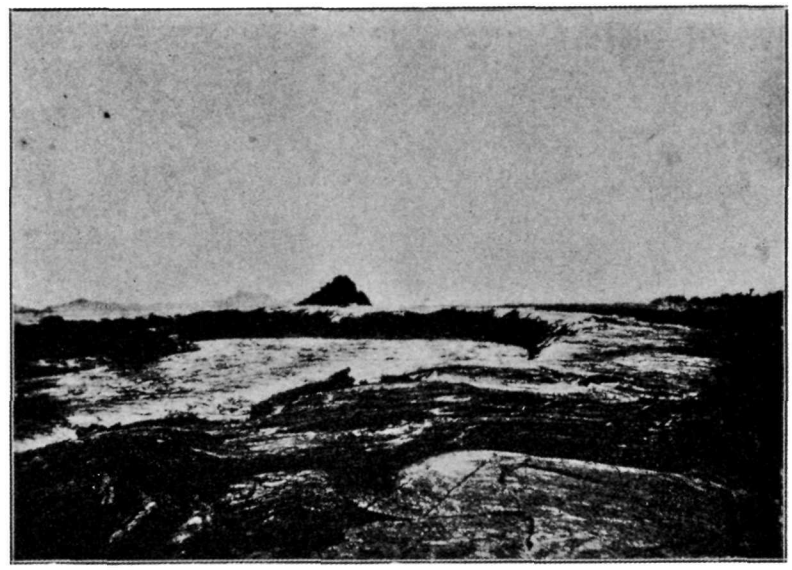
KILAUEA REPORT No. 994

WEEK ENDING FEBRUARY 8, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

Conditions at Halemaumau remained without change during the week. A few quick-period tremors recorded on the pit seismograph early in the week.



Upper part of one of the flows from Mauna Iki January 9, 1920, showing a bend in the lava stream, placidly flowing along like a river. This lava had come out of the same crack shown on Page One, and six miles away was draining the pit shown on Pages 2-3. Photos Jaggar.

Fourteen local disturbances and one distant shock were recorded on the instruments at the Observatory, the former classified as follows: 11 tremors, 2 very feeble seisms, and 1 feeble seism. The feeble shock occurred at 7:10 p. m. February 4 and had an indicated distance of 23 miles from the Observatory. It was felt at Kapapala, Hilo, and vicinities.

The teleseism, which began recording at 12:27 p. m. February 2, had an indicated distance of 8,040 kilometers; direction as determined by the record of the vertical component was south-southwest (New Zealand disaster).

Tilt for the week accumulated strong northwest Microseismic motion mas slight.

THE VOLCANO LETTER

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter Dillingham, Vice-Presidents; L. Tenny Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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The Volcano Letter

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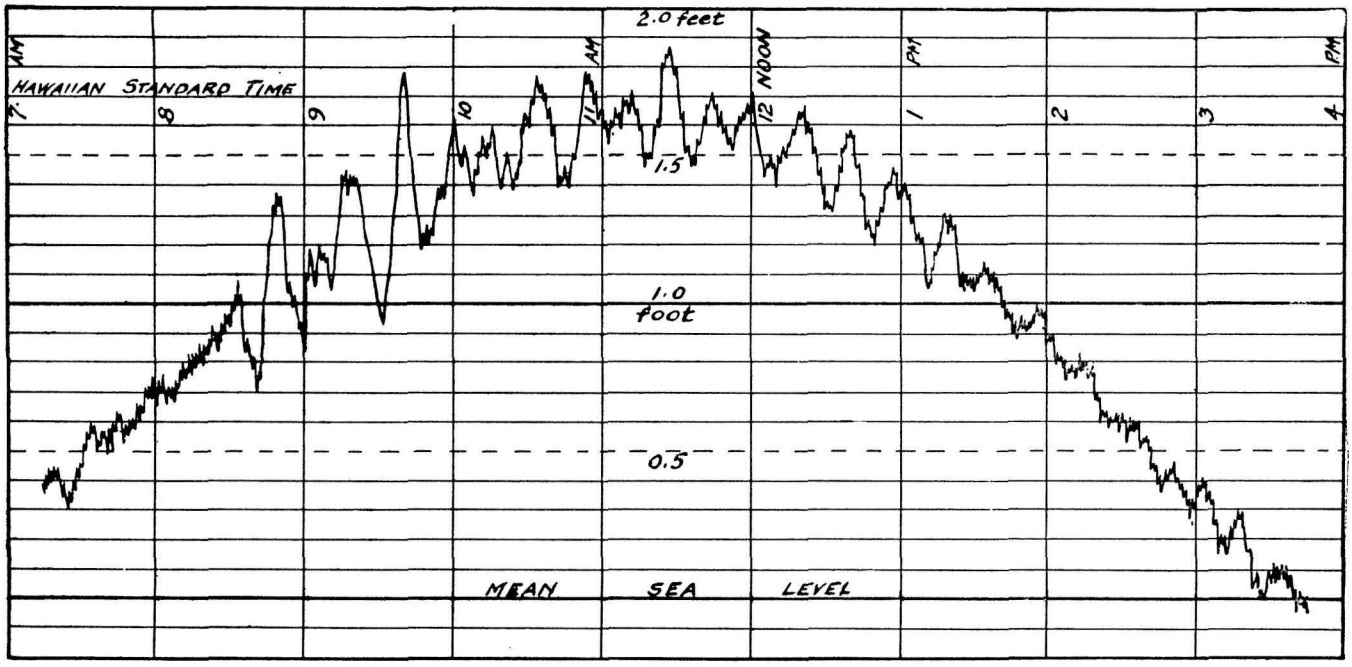
No. 321—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 19, 1931



TIDAL WAVE, NOVEMBER 4 1927
HILO, HAWAII.

Tide gauge record showing the beginning of an earthquake wave series at 8:30 a. m. with maximum range of about a foot, from an earthquake under the sea off the coast of California November 4, 1927. This earthquake was 3,925 km. from Hilo, and the sea wave traveled 7.8 statute miles per minute, The quake was felt in California and on a ship at sea.

HAWAIIAN DAMAGE FROM TIDAL WAVES

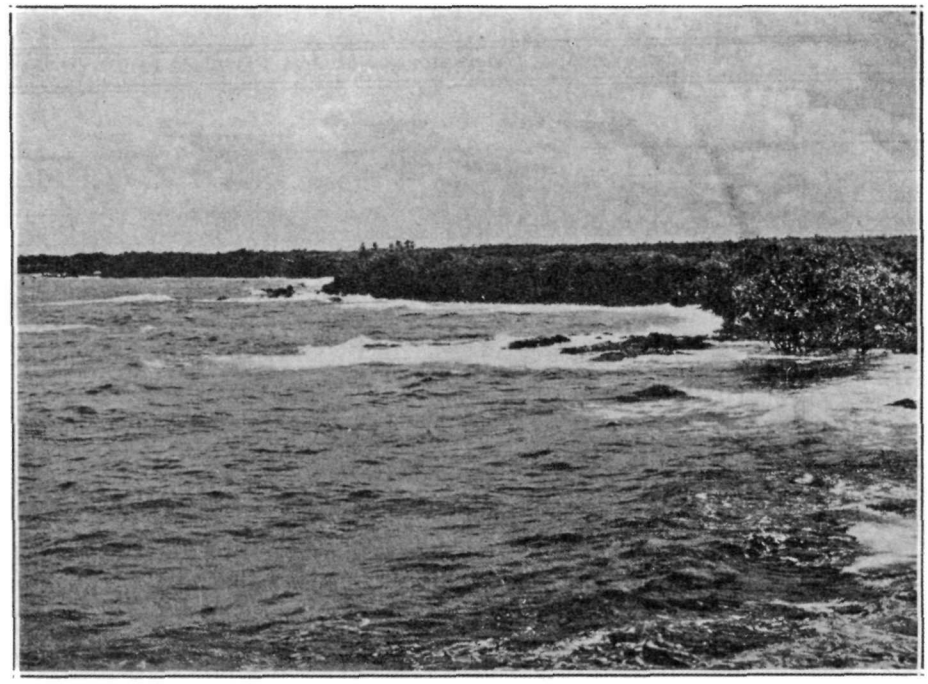
In Volcano Letter No. 274 the general conditions, under which a "tsunami" or earthquake wave is generated by a seismic movement of the sea bottom, are reviewed. These are commonly called tidal waves, a name protested by geologists, but after all not wholly inappropriate, for tides do enter into resonance with the harmonic oscillations of water that make catastrophes popularly called tidal waves. Moreover not all such damaging movements are due to earthquakes, as this piling-up of rhythms to make flood on a shelving shore may be due to landslip, to volcanic engulfment under the sea, to submarine lava flow, or to hurricane. In the earthquake wave proper, a sea-bottom shift like the dropping of a fault block of earth crust sends an impulse across the deep ocean, the trough or crest of which travels from 300 to 500 miles an hour, and so is quite comparable to the travel of the crest of the tide actuated by the pull of the moon. We have proved here in Hawaii that two tremendous deep-sea earthquakes off the Aleutian Islands in one case made disaster in Kahului and Hilo, in the other did not. Both made measurable waves, but probably the one augmented a tide, and the other was in some way compensated by a tide.

Facts about tsunami in Hawaii may be found in the well known books of Brigham, 1866 (Mem. Bost. Soc. Nat. Hist., Vol. I, pt. 3), Hitchcock, Hawaii and Its Volcanoes (Honolulu, 1911), and Brigham, Kilauea and Mauna Loa (Bishop Museum 1909).

In May 1819 the ocean was seen to recede in Hawaii and executed about 13 oscillations before it came to rest again.

On November 7, 1837, a big earthquake off the Chile coast made a disastrous wave about the shores of the Pacific Ocean which was described by Coan as arriving at Hilo so as to cause retirement of the sea about 7 p. m. The surge returned in a few moments "breaking on the beach with a noise like thunder." Lowlands were submerged. Houses were swept away. People were left struggling in th water. The sea remained high for 15 minutes. Then a series of oscillations occurred, the water moving slowly out and in again. There was a meeting of the natives on the shore at the time, and the flood caused great consternation, the people shouting to find their lost relatives and rushing about in panic. An English whaler which was anchored in the bay lowered boats for relief. Canoes were all washed out to sea. The water ran past the ship with an eight-knot current, and soundings were reduced from five to three and a half fathoms, so that much of the bay was dry.

At Kahului in Maui the water retired widening the beach 120 feet so that the delighted natives ran out on the reefs that were left bare in order to pick up stranded fish. But they were terrified to see a wall of water returning



Lowered shore line with drowned pandanus trees where the coast subsided east of Kapoho in Puna April 23, 1924. The land back from the shore was cracked for a distance of four miles, and these events preceded by a fortnight the collapse of Halemaumau 30 miles to the west. This coast subsided in 1868 also, when a wave disaster was produced. Photo Emerson.

which engulfed them and the village. As they were good swimmers only two lives were lost. The back-and-forth disturbance of the water continued for more than 24 hours.

At Honolulu this 1837 tsunami lowered the water eight feet so as to leave the reef dry; returned slowly in 28 minutes; then fell six feet again; and the ebb and flow continued at intervals of about 28 minutes. The third of the flood-water spells reached about four inches above high water mark.

The next account is of a retirement of the waters at Honolulu May 17, 1841, at 5:20 p. m., when the ebb was sudden, leaving the reef bare, and the movement occurred twice in 40 minutes. This earthquake wave was especially sudden at Lahaina in its sucking down of the sea level, and it was reported as affecting the coast of Kamchatka also.

The year 1868 produced two disastrous tsunami on the island of Hawaii, the first accompanying the terrific local earthquake in Kau in April 2, the second from a submarine shock off Arica, Peru, August 13.

The local disaster of April 2, 1868, made a wave on the shore all the way from Kahuku to Kapoho, swept away the houses on the Puna shore, the Pahala shore, and the Honuapo shore, and with the earthquake the Puna coast subsided from four to seven feet. At Punaluu the stone church, the wooden houses, and all the coconut trees except two were washed down. Floating rubbish was driven inland "about a quarter of a mile," and large bowlders were washed in at Pohoiki. On the whole coast 108 houses were destroyed and 46 persons perished by the sea wave. At Hilo the sea receded horizontally 150 feet and when it returned rose about 10 feet above high-water mark.

The big Pacific wave of August 13, 1868, from near Peru, reached Hilo in about 14 hours, traveled about 350 miles per hour, and was reportedd to have been marked on a coconut tree somewhere near the present railway station as reaching 15 feet above ordinary low water and 5 feet above the ground. Hilo is 5,460 miles from Peru. At windward Maui the flood of this tsunami was reported 12 feet high. The damage was of the usual sort and must have been considerable in Waiakea and Kahului. The records of it are probably to be found in the newspapers of the time.

On August 27, 1872, just after a remarkable lava outbreak had begun in the summit crater of Mauna Loa which was destined to last some years, a small tsunami occurred at Hilo during calm weather, the water rising four feet, then six minutes later three feet, and diminishing for about 14 oscillations. The short period of this water wave, six minutes as contrasted with 20 to 30 minutes for the ones of distant origin, makes it likely to have been a local disturbance on the sea floor.

The earthquake wave of 1877 was the most disastrous on record for Hilo and closely resembled that of 1837. Like that one and the one of August 1868, it originated off the coast of South America between Chile and Peru in the evening of May 9, 1877, and reached Hilo at 4 a. m. May 10. At 5 a. m. it penetrated the shops on Front Street at a height reported by Luther Severance 12 feet 3 inches above ordinary low water. Every house within 100 yards of the water was swept away in Waiakea. Five lives were lost, seven persons were injured, 163 were left destitute, and 17 horses and mules were drowned. A vessel which had been anchored in four fathoms of water found itself on the

ground. The rise and fall of the waters continued all day. At 7 a. m. one complete swing from low to high was measured 14 feet vertically. The sea swept completely over Coconut Island. Thirty-seven dwellings were destroyed and 17 badly wrecked. Lumber was washed away to the value of several thousand dollars, and the total damage was estimated at $13,000.

There have been several small local waves doing some damage in Hawaii, occasioned by submarine volcanic disturbances, of which the wave at Hoopuloa in 1919, at the time of the nearby Alika lava flow into the sea, is typical. There was a succession of short period shallow tidal waves ranging from 3 to 14 feet in height, with maximum nearest to the flow delta on the third day of the eruption. The Hoopuloa wharf was flooded.

On February 3, 1923, a destructive tidal wave at Kahului in Maui and at Hilo occurred about seven hours after a big earthquake under the Gulf of Alaska, 2,500 miles away. In Honolulu the waters receded revealing the reefs for 20 minutes and then there were in-and-out surges at intervals of 15 to 20 minutes. In Hilo sampans in the Wailoa River were smashed over the railroad bridge, the bridge was destroyed, a man was killed, and the railroad embankment between Hilo and Kuhio Wharf was washed down and houses and wharves were upset. The major wave was the third of the series and was said to pile up more than 20 feet in the funnel of the bay at Waiakea.

We have mentioned pronounced damage in 1837, twice in 1868, again in 1877, and 1923 in Hilo, say five times in the century or an average of once in 20 years, mostly waves from Alaska or South America. One great disaster in Puna and Kau was due to a local submarine disturbance. Nine measured large or small waves between 1918 and 1929 on the Hawaii coast have been discussed in publications of the Hawaiian Volcano Observatory, and only since 1927 have we operated the Hilo tide gauge. Probably waves occur to the number of more than one a year, disregarding the question of damage. There is no record yet of serious tidal wave damage in Honolulu, but waves from the west and northwest have recorded as strongly on the Honolulu tide gauge as on the Hilo gauge. T.A.J.

TILTING OF THE GROUND FOR JANUARY

The following figures show the net amount of tilt per week at the Observatory on the northeast rim of Kilauea crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

December 29-January 4	0.97 seconds	W
January 5-11	0.96 seconds	S
January 12-18	0.91 seconds	WNW
January 19-25	1.33 seconds	WSW
January 26-February 1	1.33 seconds	ENE

KILAUEA REPORT No. 995

WEEK ENDING FEBRUARY 15, 1931

Section of Volcanology, U. S. Geological Survey

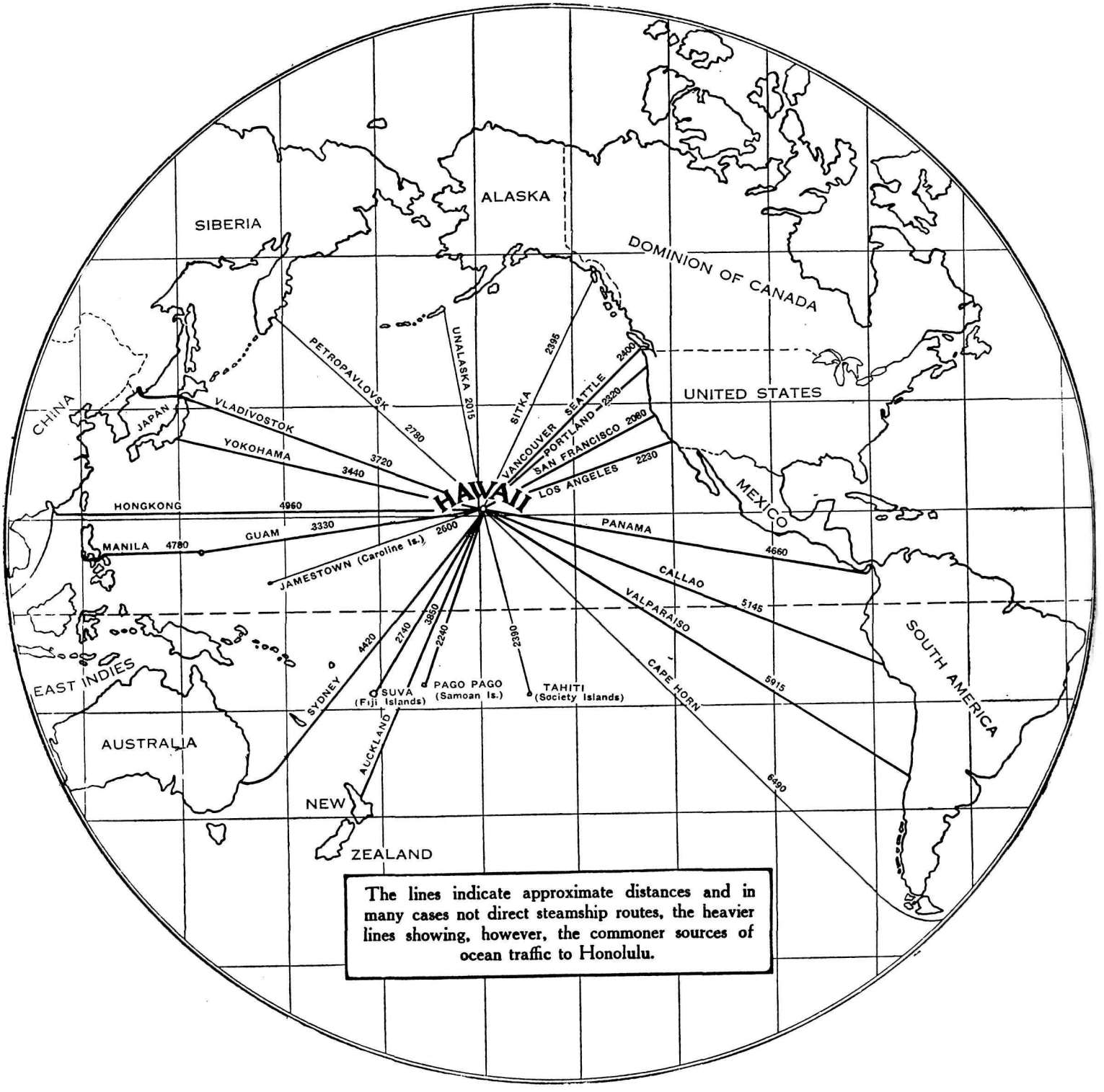
T. A. Jaggar. Volcanologist in Charge

The island of Hawaii is at present very quiet and practically no changes have occurred during the week at Halemaumau pit of Kilauea Volcano. Measurement of cracks at the edge of the pit on February 10 revealed a very slight widening. There is but little steam on the south talus and a few rocks have slid down to the edge of the lava floor at the south.

Only two very feeble local earthquakes were registered at the Observatory, of which one at 4:51 a. m. February 11 indicated distance of origin 28 miles. In addition 12 tremors were recorded. Tilting of the ground was slight NNW, and microseismic motion was very slight.



Detail of lowered shore line of 1924 near east point of Hawaii showing new lagoon of salt water over 12 feet deep with submerged coconut palms. Photo Emerson.



Map of Pacific Ocean. Submarine earthquakes making destructive tidal waves in Hawaii originate generally in the northeastern semi-circle of the ocean from Kamchatka to South America.

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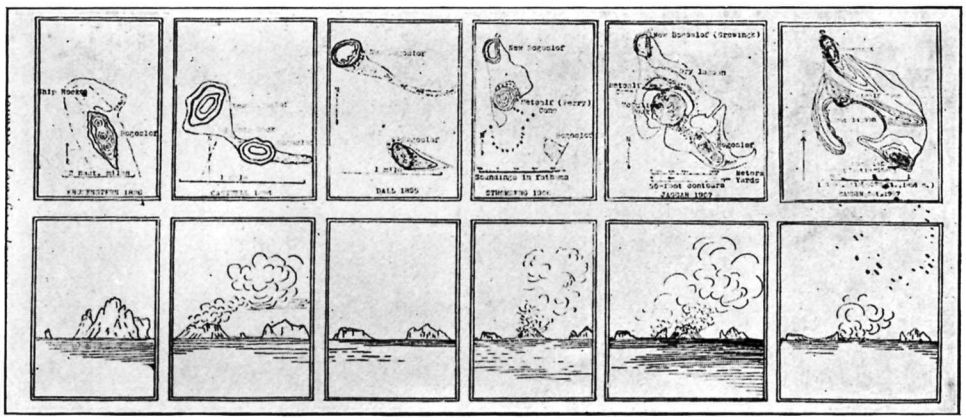
The Volcano Letter

322

Two dollars per year — Ten cents per copy

No. 322—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 26, 1931



Sketch maps and profiles of Bogoslof of dates from left to right as follows: (1) Krusenstern 1826, (2) Cantwell 1884, (3) Dall 1895, (4) Stromberg 1906, (5) Jaggar 1907, (6) Camden October 1907. These show the gradual growth of the island, and the lower cut in each case is the view from the south.

EVOLUTION OF BOGOSLOF VOLCANO

The scientific investigation of our vast American domain of active volcanoes in the Aleutian Islands and the Alaskan Peninsula is the largest task before the Section of Volcanology of the Geological Survey. Gradual advancement of this work is provided for by act of Congress, and during the coming summer Akutan Volcano, which has exhibited frequent activity, will be investigated. Akutan is next to the east of Unalaska (see map Page Four), and just to the northwest of Unlaska Bogoslof has been building up during the last 150 years by processes of squeezing up of lava domes similar to that of Tarumai Volcano (Volcano Letter No. 317).

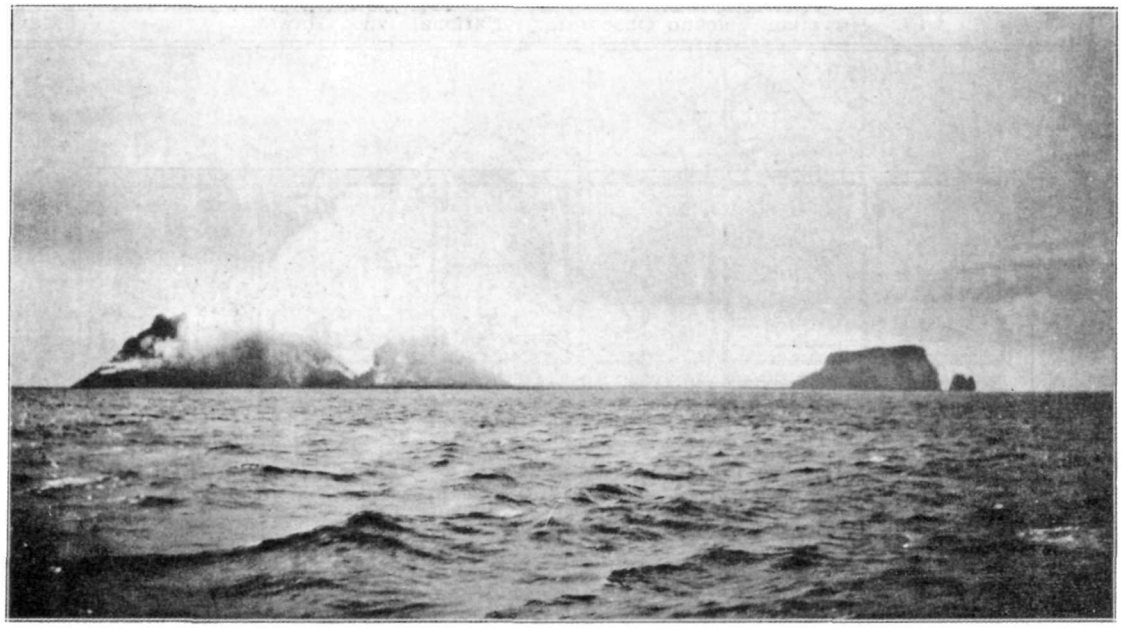
The gradual enlargement of Bogoslof island from 1826 to 1907 is shown in the succession of maps and sketches illustrated on Page One. Bogoslof is a big cone on the sea floor like Falcon Island and Niuafoou in Tonga, but only the tip of it is building above the waves. Under the ocean it is 6,000 feet high. The group of rocks that make the islet have been enlarging by alternations of rising lava and explosive steam jets, the former making domes, and the latter spreading gravel.

Ship Rock was first noticed by sailor men in 1768. Bogoslof proper or Castle Rock was thrown up in 1796. Grewingk or New Bogoslof rose about 1884 and the older Ship Rock was demolished, but Castle Rock still remained in 1891. In 1896 and 1899 there were two islands with water between. In May 1906 the "Albatross" reported a new volcano Metcalf Cone midway between Castle Rock and Grewingk, and attached by an isthmus to the latter. The cutter "Perry" in July 1906 reported 40 feet of water between the new dome and Castle Rock.

In July and August 1907 the writer visited the islands. A new cone McCulloch Peak had risen south of Metcalf Cone and adjacent to it. Metcalf had split in two showing an andesite horn rising through the split cone. This closely resembled the Pelee spine of Martinique. The rock was hornblende augite andesite with inclusions of sulphides and of diorite, some forms resembling pumice. There were also horn-like processes projecting from the summit of McCulloch dome, which was approximately 450 feet high above the sea. The channel between the islands was entirely filled so that Castle Rock, McCulloch, Metcalf, and Grewingk formed a single island a mile and a half long. McCulloch Peak was nearly surrounded by a steaming salt-water lagoon at about 90° F. and was itself steaming quietly. The following describes the adventures of the writer's party from the schooner "Lydia" of the Technology Expedition (Technology Review Vol. X, No. 1, 1908):

"Wednesday August 7, 1907. At 8 a. m. Bogoslof was in full view ahead, the weather fair, a steady southwest wind blowing. It was determined to land two dories and have the vessel stand off, while three or four hours if possible were spent in examination of the island. (The photograph on Page Two was made from the "Lydia" at this time looking west, and corresponds to the next to the last map of the series on Page One.)"

"The landing was made at 10:30 a. m. Hundreds of immense sea lions, bellowing with voices that well justify their name, swam within a stone's throw of the dories, when they would raise themselves high in the water, stare at the boat, and then plunge frantically beneath the waves. When we landed on the beach, most of the animals there had floundered into the water; but one immense bull re-



The northern hills and connecting sand bars of Bogoslof Island, looking west August 7, 1907, showing McCulloch dome on the left, Metcalf half-dome, and Grewingk. Castle Rock is out of the picture at the left. Photo Jaggar.

mained, apparently asleep. One of the party ran toward him with a camera, the monster awoke, and with awkward gait flopped down into the sea.

"The hours spent on Bogoslof were the most interesting of the whole expedition. The rocky cliffs are covered with millions of birds, their eggs and their chicks, chiefly murres and herring gulls. On startling them from the face of the cliff of Castle Rock, the swarm of winged creatures literally darkened the air. To members of the party climbing among the rocks the stench from offal and decayed eggs was intense. The island exhibited four rocky hills 350 to 500 feet high, Castle Rock peaked and prominent at the southeast, McCulloch dome circular and steaming actively in the middle, Metcalf crag half destroyed and adjacent to McCulloch on its north side, and Grewingk a flat table rock at the northwest end of the group. These were all connected by continuous gravel and sand strips where a year before there had been a broad channel and seven fathoms of water about the site of McCulloch dome."

"Around the base of McCulloch hill was a lagoon of hot salt water steaming quietly and yellow with iron stained mud. This hill was 450 feet high at the time of our visit, conical in outline by reason of the talus slopes, and showing great lumps or horns of what appeared to be ledge rock jutting out from the upper slopes, while the slide-rock slope of bowlders all around the base was straight in profile standing at 30 degrees. The entire mass was steaming from many fissures, and in places there were bright yellow sulphur coatings at the steam vents."

"Metcalf hill was a half-cone with its south side broken down where an explosion had destroyed it prior to the beginning of the welling up of the McCulloch lava. This rupture left Metcalf with a vertical precipice on the side opposite the remnant of its cone slope still steaming on the north side. Neither Grewingk at the north nor Castle Rock at the south was volcanically active at the time of this visit. The steep cliff of Metcalf revealed in cross section up its middle a great horn of congealed lava, which had risen into the midst of the cone with a smooth curved surface toward the west, and at the top a broken vertical surface toward the east. Seen from the north, this horn looked like a shark's fin or a parrot's beak; seen from the west like the horn of a rhinoceros."

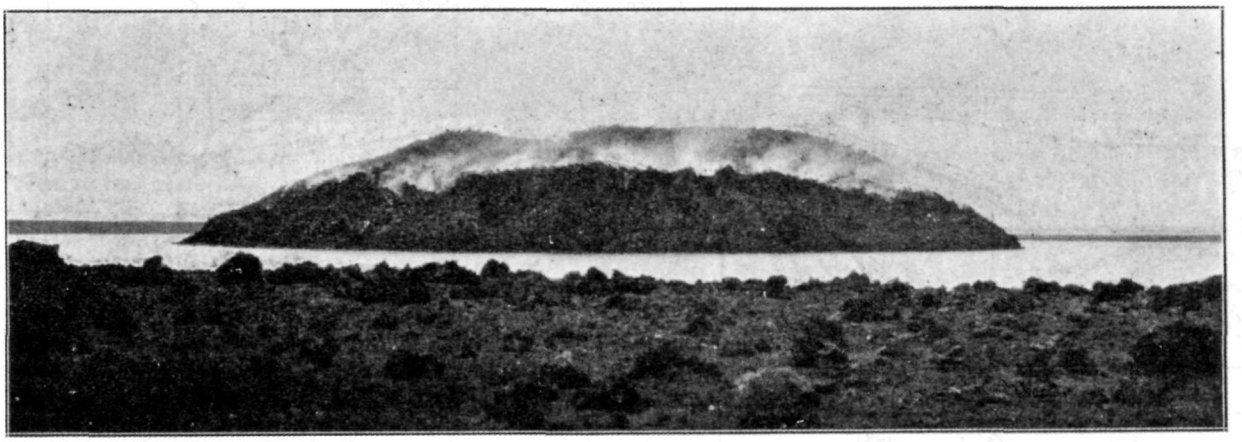
"McCulloch and Metcalf domes were both products of the slow pushing up from beneath the waves of a mass of refractory lava, semi-solid, crusting and breaking into blocks as it rose, with only the central portions retaining a semblance of fluidity. The horns were doubtless such central portions. The same mechanism produced the extraordinary spine which rose 1,000 feet above the dome of Mont Pelee in Martinique in 1902."

"Between 1891 and 1895 Grewingk had changed its form from a large irregular cone to a small flat-topped table. I believe this change was due (1) to its being leveled by the waves and covered with beach deposits, and (2) to its being subsequently uplifted. Beach bowlders and sands could now be seen in 1907 on its flat top and in section at the edge of the top of the cliffs. An extraordinary feature of the rocky wall of Castle Rock was a sea cave at the north end surmounting a rock bench or platform 25 feet above the ocean level. This notch and floor had evidently been made by the surf, but the present surf was beating the strand at a much lower level. On comparison with photographs of 1906, a year before, it

was found that the uplift of 25 feet had taken place during the last year, for those photographs showed the same rock bench and cave at sea level. Evidently Castle Rock had been rising slowly during eight months, while the lava pressure under McCulloch hill was heaping up that dome over 400 feet, with a base measuring 2,000 feet across at the beach level. The effects of mass uplift were in evidence all over the island. While a half plastic lava was pushing up rapidly in the middle cone, the adjacent, older, hard rock summits of the submarine mountain were slowly heaved up."

"On September 1, 1907, after we had left the islands, a steam blast and an engulfment destroyed McCulloch hill, sand and dust fell 100 miles to the eastward, and a visit by the Coast Guard cutter in October 1907 revealed a watery lagoon at the south base of the Metcalf remnant, McCulloch dome was gone, and all of the rocks were shrouded in a heavy mantle of volcanic debris."

There was probably another explosion lowering the remains of Metcalf hill in 1908, leaving a bay surrounded by beaches between Castle Rock and Grewingk, and in September 1909 two small lava islands arose here, a new lagoon was formed shut off from the sea, and these in June 1910 had united into a single lava hill standing 178 feet above the sea. A true crater was opened by explosion in this hill September 18, 1910, which ceased fuming in 1914. This Tahoma hill, as it was called, had been eroded away in 1922 and a channel was again opened between Castle Rock and Grewingk so that a boat could sail through. Grewingk had diminished in size and Castle Rock was changed to two rocky horns with a big accumulation of sand and gravel piled round about which trailed off into a long sand spit at the north. In July 1926 an explosive eruption heralded new activity, another occurred in December, and then a new lava dome piled itself up in the middle region within a warm salt-water lagoon at 70° F. completely shut off from the ocean by a ring of sand and bombs, and gravel heaps connecting Castle Rock and Grewingk as before. Since that time the island has quieted down. T.A.J.



New lava heap of Bogoslof Volcano about June 28, 1928, looking southwest showing warm salt lagoon and ring of explosion debris in about the same location as the active domes of 1907. Photo Wheeler.

KILAUEA REPORT No. 996

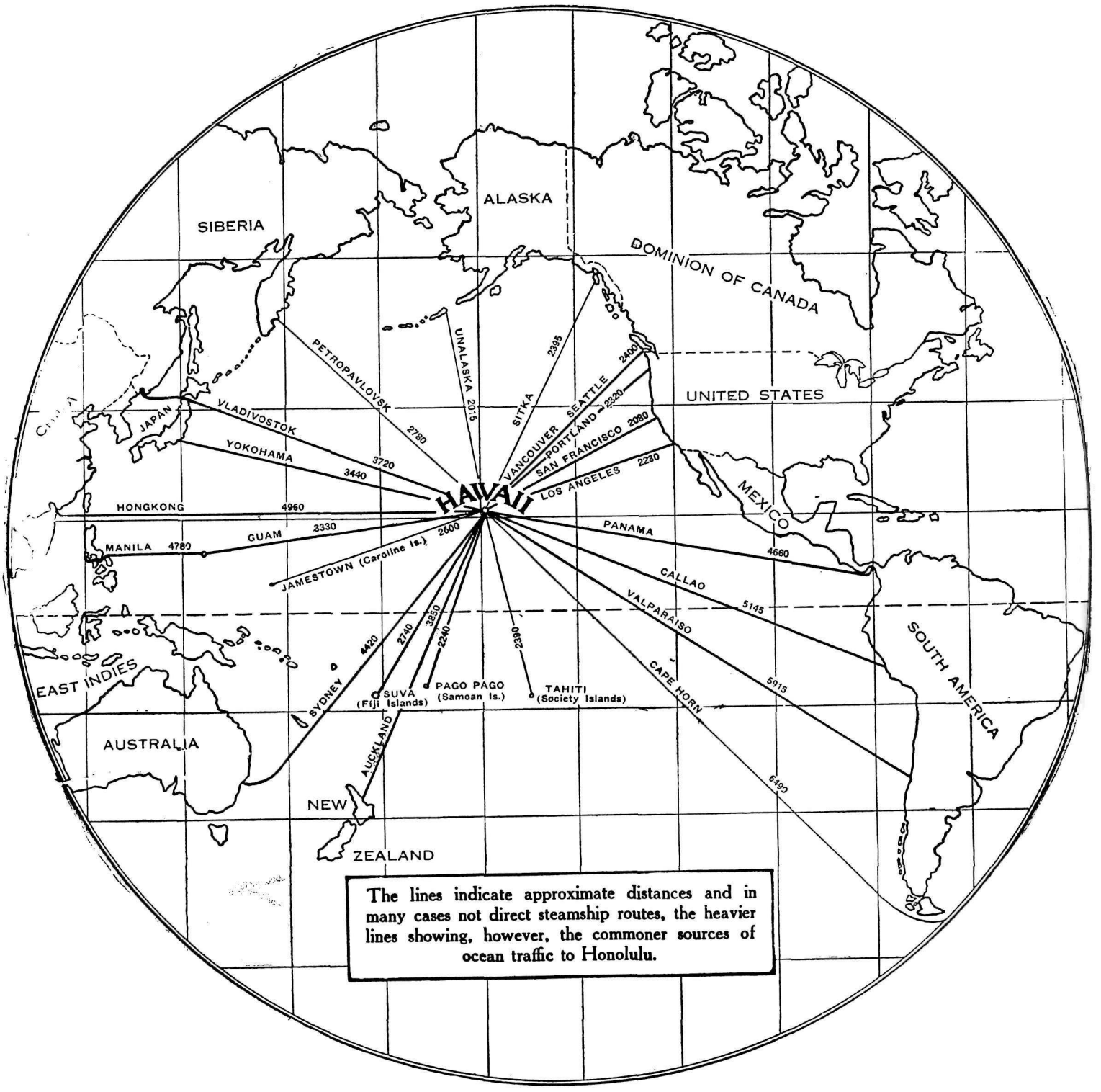
WEEK ENDING FEBRUARY 22, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains very quiet, there is only slight steaming on the south talus, and dust was noticed from slides at the north wall of the pit about 3:10 p. m. February 19.

Eighteen tremors and one very feeble local earthquake were registered at the Observatory during the week, the earthquake at 12:56 a. m. February 20 indicating distance of origin nine miles. Another at 12:26 a. m. February 21 was only a tremor at Kilauea but was felt as a single bumping jolt at Kealakekua in Kona accompanied by a slight noise.

Tilting of the ground was moderate to the southwest at Kilauea, and microseismic motion was slight.



Map of the Pacific Ocean showing position of Unalaska southwest of Alaska in the Aleutian Islands. Bogoslof is 40 miles northwest of Unalaska.

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The Volcano Letter

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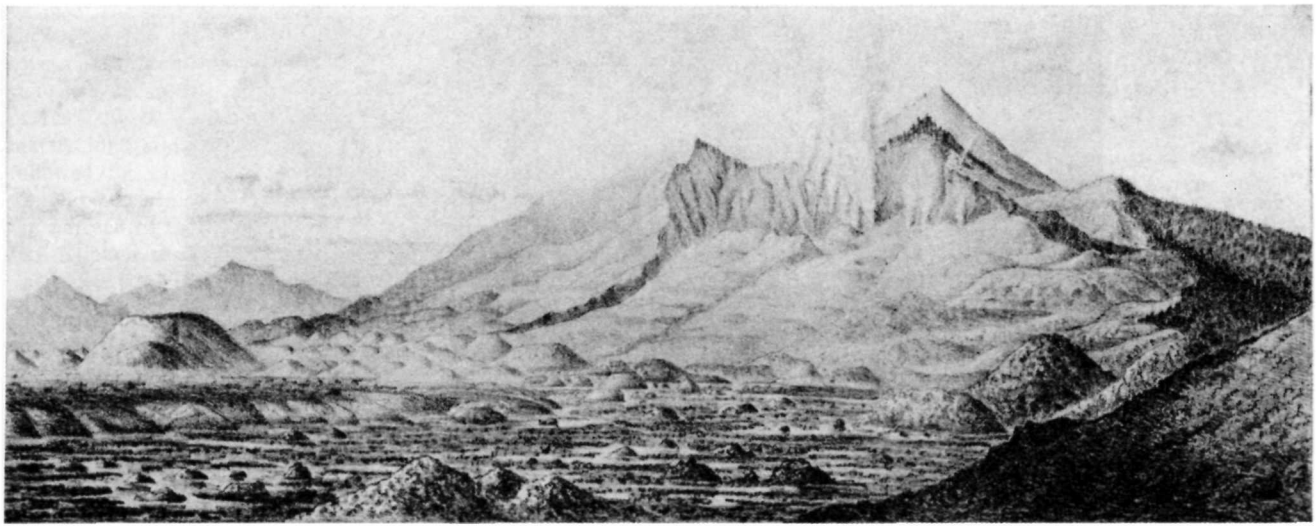
No. 323—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 5, 1931



Crater of Bandaisan after eruption of 1888 showing the steaming cleft in the mountainside, bare hillsides that were scored by the terrific avalanche, and mounds left by settlement of the debris. After Sekiya and Kikuchi.

JAPANESE VOLCANOES ARRANGED IN SERIES

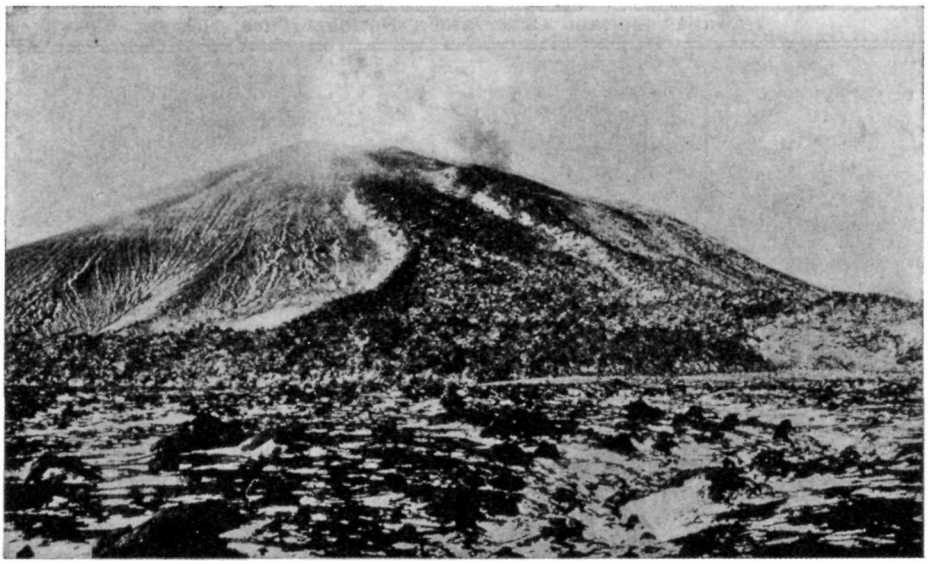
In order to classify volcanoes intelligently it is necessary to know the deeper mechanism that gave birth to the crater or mound or mountain. In Volcano Letter No. 164 was reviewed the classification given by Sapper, (1) Hawaiian liquid lava flow, (2) liquid lava combined with steam jet as at Stromboli, (3) stiffer lava combined with steam and black dust as at Vulcano, (4) stiff lava plug combined with Vulcanian paroxysms of steam and dust as at Pelee in Martinique, and (5) steam explosion alone throwing up fragments of old rock as at Bandaisan in Japan. These are usually described as (1) Hawaiian, (2) Strombolian, (3) Vulcanian, (4) Pelean, and (5) Bandaian. Numerous unhappy Greek words have been invented by Schneider and others, which unfortunately some Japanese geologists are repeating, but clear descriptive language is best in the present stage of the science.

A recent essay by H. Tanakadate (Eruptive Types of Japanese Volcanoes in recent Years, Proc. Fourth Pac. Sci. Cong., Java, 1929, p. 621) is a sound attempt to arrange the eruptions of Japan in series. The author uses some technical terms which would much better be replaced by plain language. He distinguishes eleven types as follows:

Bandaisan	1. Sudden explosion without lava.
Shiretoko	2. Sulphur eruptions.
Kusatsu-shirane	3. Crater lake eruptions.
Tokachidake	4. Explosive avalanches with explosive lava.
Ususan	5. Swelling mountain with explosive lava.
Tarumai	6. Explosive jets and rising plug.
Asama	7. Aa lava in crater with explosive jets.
Sakurajima	8. Ruptured mountain flank with aa outflow.
Oshima	9. Fluctuating crater lava and flows.
Minami-iwo-shima	10. Submarine eruptions.
Hakone	11. Subterranean lava movement making earthquakes.

(1) **Bandaisan** in interior central Japan had some solfataras on top of one of its peaks, elevation 1840 meters. July 15, 1888, subterranean roaring began at 7 a. m. and three-quarters of an hour later a gigantic steam blast rushed out at these solfataras and engulfed or threw out about half of this particular peak, avalanching 1700 million cubic meters of rock down the northern foot of the mountain, leaving a horseshoe crater 1 km. wide, 400 m. deep, and open to the north like a quarry with rushing steam in its bottom. The process dammed a river and made a lake. If there were fragments of new lava, they were in small amount.

(2) **Sulphur eruption.** In the eastern part of Hokkaido, the north island of Japan, Shiretoko-Iwo-san is a volcano of active solfataras where sulphur was mined. August 9, 1889, at 1 p. m. an explosion in a solfatara threw out sulphur both as blocks and liquid, forming a craterlet 40 m. long. The activity decreased at the end of two weeks, leaving a lake of boiling water, but sulphur production augmented. The next year on June 15, boiling water was thrown out. The accumulating and melting of sulphur coupled with geyser action influence such eruptions; the liquifaction temperature of sulphur is 114.5° C.



North side of Asama Volcano, central Japan, showing the great aa lava flow of 1783 and the fuming crater in the background. After Omori.

(3) **Crater lake eruptions.** Kusatsu-Shirane is a volcano 2,162 meters high in central Japan with three circular crater lakes and hot gases, amid sulphur mines. In July 1897 there were earth tremblings, a steam blast occurred in the middle of the largest lake and continued to mid-August. There were similar outbursts in 1900, 1902, and often between 1905 and 1925. Such eruptions in crater lakes are not rare in Japan. An explosive paroxysm of subterranean gas burst through Noboribetsu crater lake in southeast Hokkaido in the spring of 1927. The lake shows a temperature of 50° C. on the surface and 133° C. at the bottom. This place contains melted sulphur.

(4) **Explosive avalanches.** Tokachidake is a volcano in central Hokkaido 2,077 meters high with fumaroles so active that sulphur could be extracted from the fume by condensing it. Explosions began December 23, 1925, and culminated in two blasts May 24, 1926, upsetting the western half of a solfataric hill and causing it to avalanche down so as to leave a crater 130 by 300 meters and 50 meters deep. On May 25 a new sudden explosion threw up fresh lava and was accompanied by an earthquake, the scoriae falling on the avalanche debris. The activity waned except for renewed explosions September 8 and 10 ejecting high-temperature ash. Asosan in Kyushu and Kirishima are similar volcanoes beginning eruption by ejection of old rocks, ending with red-hot scoriae, this last phase continuing for a long time and declining gradually.

(5) **Swelling mountain.** Usu Volcano of elevation 725 meters in southern Hokkaido lies between the sea and a volcanic depression containing Lake Toya. After numerous earthquakes in 1910 it cracked along its flank for three kilometers, developed 45 explosive craterlets, and lifted a hill 700 meters long and 200 meters wide to a height of 100 meters (Volcano Letter No. 302). The lapilli thrown out were of new lava, and it is conceived that an intrusive mass of magma was pushing its way like a lens outward and upward, and by occasional recession permitting ground water to fill voids and turn to steam.

(6) **Rising plug.** The activity of Tarumai was described in Volcano Letter No. 317. This volcano also is in Hokkaido, is 1023 meters high, and after 15 years repose sent up a steam blast in 1909 with increasing violence for three months accompanied by the rise of 20,000 cubic meters of lava that formed a dome. This dome was quite like the andesite domes of Bogoslof, described in the last Volcano Letter (No. 322). The dome was 134 meters high, and several explosive outbursts have traversed it since April, 1917.

(7) **Lava in crater and gas blasts.** Asama Volcano in central Japan is the type, a big cone 2,542 meters high, much like Vesuvius, and in 1783 one of the greatest eruptions in the history of Japan spread volcanic detritus and ashes over a large area, followed by an aa lava flow. In recent years, between 1910 and 1915, and again 1919-23, the crater bottom welled up slowly by accumulation of new lava and there were repeated explosive eruptions proportional in frequency to the pulsations of rising of the lava. After big eruptions the bottom lava sank. There was a new eruption in September 1929.

(8) **Lava outflow from mountain flank.** Sakurajima is the type, described in Volcano Letter No. 308. This volcano is a peninsula in Kagoshima Bay at the south end of Japan and stands 1,060 meters high. It was shaken by earthquakes for two days in January 1914, then great cauliflower clouds arose, and two stiff, blocky lava flows of andesite poured from newly formed craterlets on both sides of the mountain. The volume of lava was estimated at 1.56 cu. km., the explosive materials 0.62 cu. km., and the area covered with lava 23.73 sq. km. The lava flowed for several months and the effusion ended gradually with weak explosions in the craterlets.

(9) **Crater lava and flows.** The volcano Miharayama,

755 meters high, constitutes the island of Oshima in Sagami Bay southwest of Yokohama. It had eruptions from 1912 to 1923 just before the Tokyo earthquake. In 1912 explosions of incandescent scoriae began in the central crater, in April it was filled with lava, in July its central part lowered 30 meters, in September pahoehoe lava poured up filling the crater by mid-October, fed by a cone of scoriae just as at Vesuvius at present. Then the lava field sank, on May 15, 1923 a Strombolian steam eruption occurred; thereafter the crater bottom rose and this was followed by a sinking and active border fissures in 1915. Lava eruptions were repeated in 1919, 1920, and 1923. In January of 1923 the lava field in the crater rose, with a cone 40 meters high standing upon it. Then there was a lowering, followed by the Tokyo earthquakes which had some of their epicenters close to Oshima. As shown by the changing pattern of the pit, the lava activity of Mihara is more like Kilauea than most Japanese volcanoes.

(10) **Submarine eruption.** In the ocean to the south of Oshima extends a line of volcanic islands. At Minami-Iwoshima a small island was built up after detonations and uprush of fume for 20 days in 1904. This was December 5, and in February 1905 the circumference was 5 km. and height 150 m. The cone was crowned with a crater of 120 m. diameter. It was eroded away soon after June 1905. In 1911 the water there was 400 m. deep, but on January 25 after two days of explosions a new cone arose, similar to the former one, and this had disappeared by June 1915. There were other eruptions along this line of the Ogasawara islands, making banks of pumice in 1906 and 1915.

(11) **Volcanic intrusion.** As a last stage in manifestation of magmatic energy, the Hakone Volcano, 1,439 meters high, near the beautiful lake of the Miyanoshita district so much visited by tourists, has been the scene of many earthquakes. Disastrous ones have occurred in the last few weeks. They were numerous in 1917, and also this district was terribly shaken by the great Tokyo earthquake of 1923. It lies on the Fuijyama volcanic zone. The earthquakes at Hualalai in Hawaii in 1929 marked another case of volcanic energy underground.

Professor Tanakadate shows analyses of lava from all these volcanoes, with silica increasing from No. 9 to No. 1, alumina decreasing, and decrease also in iron, magnesia, and lime. In other words the series is more basic the greater the fluidity of the lava. T.A.J.

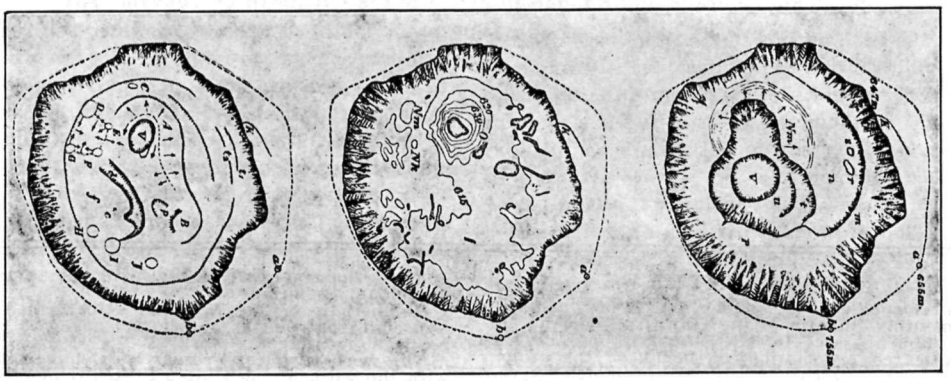
KILAUEA REPORT No. 997

WEEK ENDING MARCH 1, 1931

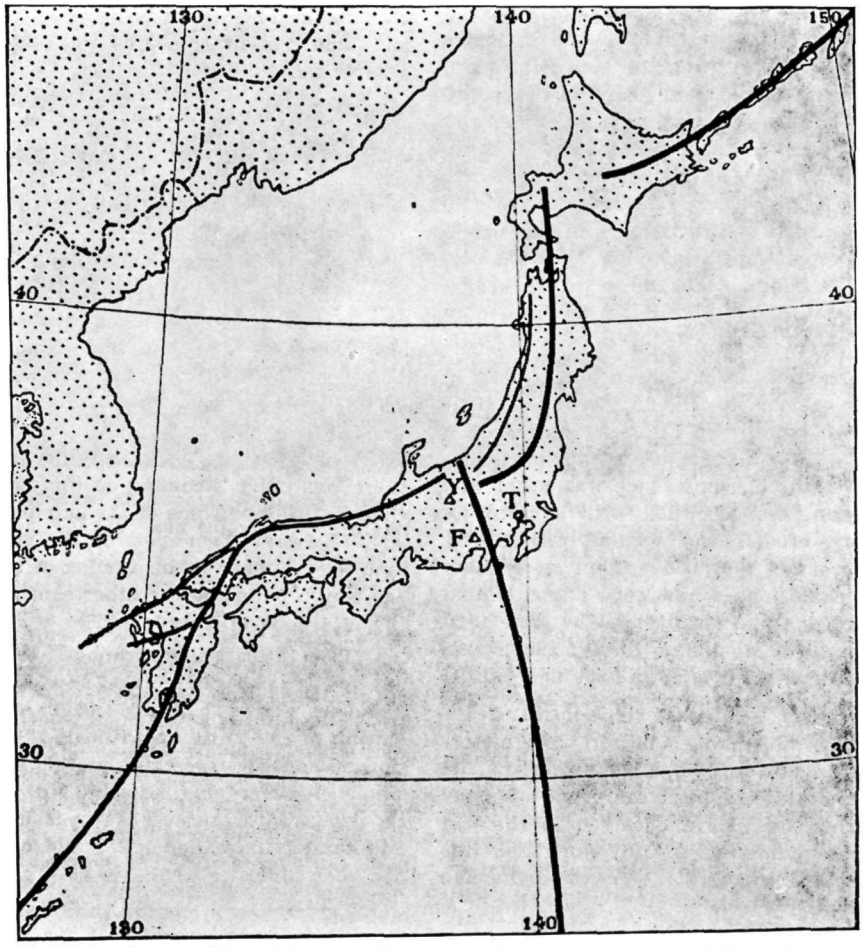
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

On February 23, 1931, no changes were observed at the pit Halemaumau of Kilauea Crater, the pit seismograph showed no tremors, and the tilting of the ground at the pit since the activity of November 1930 has been very gradually away from the center. It has never shown backward tilting toward the center such as would happen if the lava column subsided. On February 26 after heavy rain there was much steaming on the new crater floor near the cone of 1930 and some of the sulphur spots were somewhat washed away. Two spots on the northwestern part of the new floor appear to be fuming with blue sulphur smoke, the one in puffs and the other continuous, first observed on the afternoon of February 25.

Observatory seismographs have registered 25 tremors, one feeble local earthquake, and two very feeble ones, the distances shown being 9 and 11 miles from the station. Tilting of the ground was moderate to the south, a direction seasonally expectable at this time of the year. As a whole however this seasonal tilt has been delayed, as though upward pressure away from the volcano had been maintained here since December. Microseismic motion has been almost absent.



Three maps of the crater pit of Mihara Volcano in Sagami Bay near Tokyo. North is at the right. Right-hand sketch is the summer of 1907, in the middle is shown the condition of January 1, 1913, and on the left the block lava, terraces, spatter cones, ditches, pits, and fuming holes of 1916. After Tsuboi.



Map of volcanic rifts of Japan with Tokyo (T) and Fujiyama (F). The rift extending southeast underlies from north to south Asama, Hakone, Oshima, and Minami-Iwo-shima. The rift at the left underlies Sakurajima and Aso-san. The rift at the extreme northeast underlies Usu, Tarumai, Tokachi, and Shiretoko. Shirane and Bandaisan are over the rift north of Tokoyo. After Omori.

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The Volcano Letter

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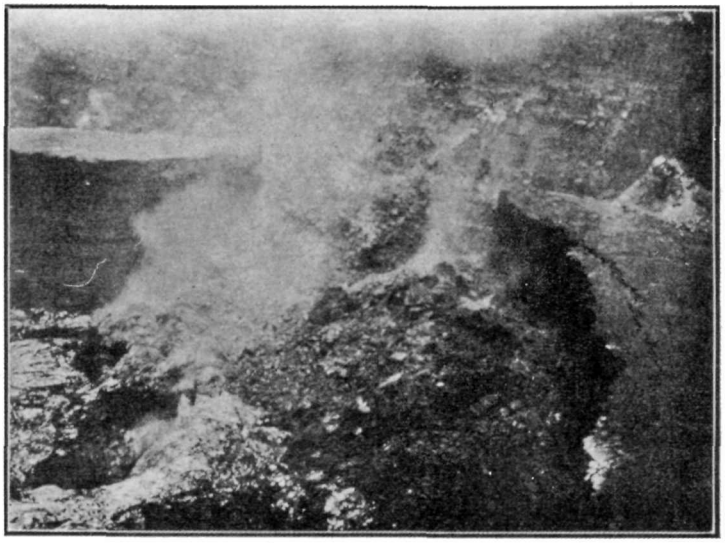
No. 324—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 12, 1931



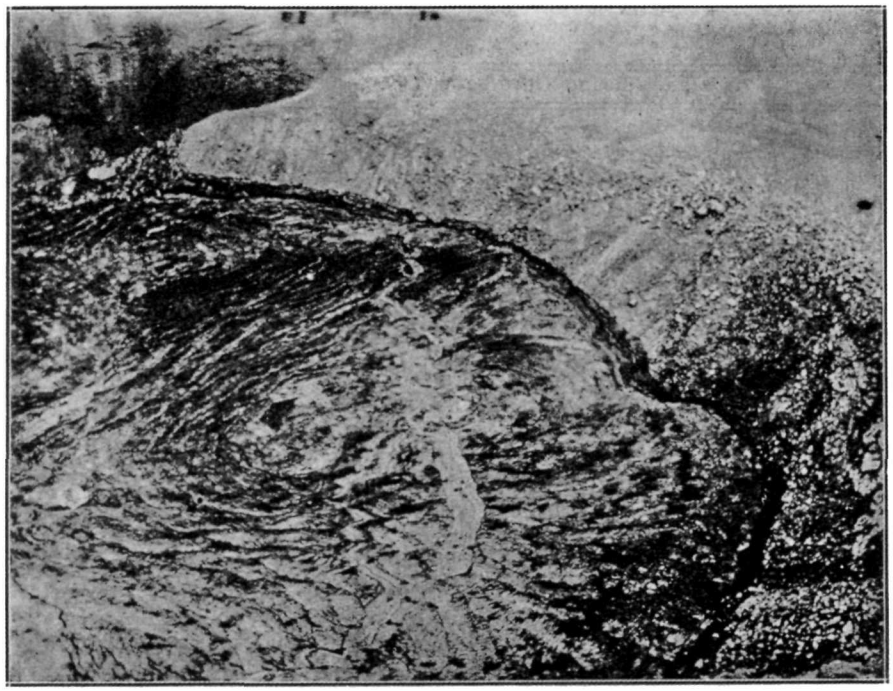
Looking down into the pit about noon on the day of the great subsidence of June 5, 1916. The east bench had collapsed, and a small island was shown to have a large extension of its mass under the lake which toppled over sideways as the lake sank. This is shown on the left. Bench cracking on the right.

WHEN THE PIT LAVA SINKS

In another number of the Volcano Letter (No. 291) the flooding action of boiling slag rising into Halemaumau pit was reviewed. Gas effervescence was shown to be the impelling agent. The question was asked, "Is the sinking of lava a reversal of the process that makes it rise?" The rising process is dependent on expansion and combustion of gases in the slag, a foaming up along with extra heating. It was shown that the foaming depends on release of pressure that otherwise confines gas in solution. Deep pressure is maintained by the weight of the accumulated mountains of lava, and these in turn are supported by blocks of the crust of the earth believed to rest on a substratum of basalt. Release of pressure is attained by periodic or occasional yielding of fault blocks of the mountain, or yielding of the crust blocks of the globe. The mountain is a strained heap of lava we call a volcano. The straining of the crust of the earth is complicated with the trigger-pulling forces of the tides, the atmosphere, and of the sun, moon, and earth.

When the lava subsides in Halemaumau pit, there are several explanations, and they may all apply at different times. If the slag loses its gas the remaining glass shrinks, and if the glass crystallizes underground, it shrinks still more. It changes from a foam to a rock. If a flank of the mountain opens a deep crevasse, or a fault block thousands of feet deep slips a little toward the sea, the lava which has been standing in the pit may drain away into an underground fissure. If a crust block of the earth hundreds of miles long and 30 miles deep moves ever so slightly by some tidal breathing of the globe, with its equatorial protuberance, its northing and southing of the sun, its fluctuations of the moon, its approach and recession to the sun in its orbit, and with the possible but unsolved mysterious relations of sunspot periods to magnetism and gravitation, it is likely that an increased pressure on the substratum would quickly show itself by a lessening of gas at the relatively tiny lava column represented by the pit.

The loss of gas and reestablishment of deep pressure to make the lava column recede should be gradual. The opening of the mountain to drain the lava into a crack, or through a fissure out to a submarine lava flow should be rapid. The diminution of gas, followed at other times by its increase, owing to astronomical controls, should be periodic and rythmical. The actual movements of the lava column when it subsides have suggested all three of these processes at different times; in 1912 there were striking quarter-yearly changes from high to low as though equinox and solstice were in control. Again and again a period of about three weeks has been observed from one sinking spell to the next. Earthquake frequency has shown a similar periodicity. From 1914 to 1917 during general rising of the lava there was a systematic series of risings and fallings with each complete wave about eight months long, each rising higher than the one before, and each sudden sinking lower than the one before. There were similar movements punctuated by sudden sinkings between 1917 and 1924. And in 1919 a critical investigation gave evidence of a daily tide in the lava.



New pool of lava in the bottom of Halemaumau November 30, 1919, after subsidence, looking southeast. The lake was rising very rapidly and the talus at the right turned out to be a ring crag of the bench magma which has subsided November 28, developing within two weeks into the ring island (Volcano Letter No. 282).

The sudden sinkings are accompanied by marked increase in numbers of local earthquakes. Four specially conspicuous ones were in 1916, 1919, 1922, and 1924. The first two were immediately after a lava flow from Mauna Loa, as though the sinking back of the lava in that volcano tended to drain Kilauea. The last two accompanied times when Kilauea itself tended to make lava flows, in 1922 a visible outpouring at the chain of craters, in 1924 a probable outpouring under the sea to the east. We may conclude that sudden subsidences justify the suspicion that the mountain mass has opened somewhere and created a true hydrostatic drainage of the lava. The seismical proof of this is illuminating. Earthquakes are few during the rising. They come in swarms during the sinking and in 1916 they showed Mauna Loa distances on the seismograms in May, and much shorter distances as though Kilauea Mountain were breaking on June 5.

On May 21 and thereafter, 1916, lava flows broke out on the southwest rift of Mauna Loa preceded by an explosion of gas and foamy lava high up the mountain May 19. The flows ceased about June 1. Kilauea lava had been rising vigorously for three months until May 25, when it was 265 feet below the rim of the pit. It then turned and lowered a little, and fluctuated until June 5. There was a ring-shaped lake with two islands within a black ledge of overflow. On June 5 the lake started to lower along with the islands, red-hot falls of bench matter from the black ledge crumbled and flowed into taluses around the receding pool of liquid, and finally terrific avalanches of old wall material made purple, white, brown, and black cauliflowers of dust that boiled up from the funnel below. The depression of the lake was 302 feet June 4, 340 feet 8:30 a. m., 380 feet 10:30 a. m., 540 feet 3 p. m., June 5, and 673 feet at noon June 6. There were occasional perceptible earthquakes, but a remarkable feature of the whole cataclysm was the rigidity of the upper walls.

In October 1919 Mauna Loa gave vent to the Alika flow southwest. Some time in November the flowing stopped. On November 28 a sudden, quiet drop of the Kilauea lava column took place amounting to at least 600 feet in a single morning. The subsidence was accompanied by almost continuous light local quaking of the ground, again with distances of origin shown on the seismograms much shorter than those which had indicated a distance of 35 miles or more for the earthquakes of Mauna Loa a month previously. It was as though the sinking back under Mauna Loa had brought the full force of the lava column to bear upon splitting open Kilauea, and then after filling the split by drainage, the lava column began to rise under Kilauea. The same thing had happened in 1916, for a very rapid Kilauea rise had followed the June subsidence. Now in December 1919 the rising in Halemaumau amounted to 30 feet a day after the drop of 600 feet mentioned above. This continued until in mid-December the rising wedge split the mountain clear to the surface, and the Kau Desert flow of Kilauea built up the slag heap Mauna Iki.

The 1922 subsidence in Halemaumau was so exactly parallel in its happenings to these two subsidences which had accompanied the termination of Mauna Loa eruptions, and the occasion of the subsidence was so clearly a Kilauea outflow accompanying a splitting open of the deep mountain mass, as to contstitute a proof that the connection between Mauna Loa and Kilauea need no longer be doubted. With each flow from Mauna Loa, the Halemaumau

subsidence followed; with each flow from Kilauea, the Halemaumau subsidence preceded.

The liquid lava May 13, 1922, was less than 50 feet below the rim of Halemaumau. By May 21 the lake level had dropped 300 feet with a steady but majestic sinking carrying down peaked crags, lava lakes, and adjacent floors. Avalanches from crags and walls were numerous. Swarms of earthquakes were registered by the seismographs. On May 26 began spells of general caving in of the pit wall, sending up cauliflower clouds of brown and salmon color, and making a thunderous roar. This continued for two days, and the pit was greatly enlarged. A swaying earthquake about 8 p. m. May 28 heralded the appearance of bright glow over Makaopuhi Crater nine miles away in Puna. A crack in the side of this pit, on the Chain of Craters rift line leading from Kilauea, was vomiting up the lava stolen from Halemaumau by the splitting open of the mountain along the rift. Cascades poured from the top of the talus in Makaopuhi and made a pool in the bottom. This flowing dwindled, but a new eruption broke out in Napau Crater farther east and in the upland beyond for two days, showing that the rift was splitting open eastward.

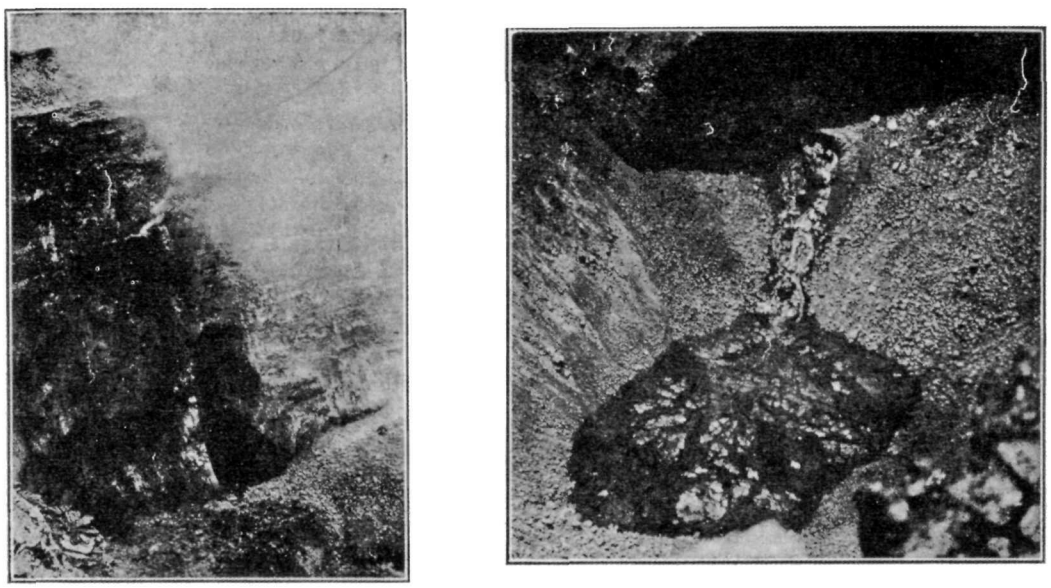
This underground wound healed, the lava rose in Halemaumau, and again it lowered suddenly and split the eastern rift with outflow in the forest near Makaopuhi in August 1923. Then the rift healed again and by January 1924 an enormous lake of liquid lava filled Halemaumau pit, now 2,000 feet across, to within 121 feet of the rim. Here were pulsations year by year, of this wedging agent, the basalt of the crustal substratum, welling up into the pit, and then splitting open the eastern rift, after the work for the cycle was finished in building at the higher rifts of Kahuku on Mauna Loa, and of the Kau Desert on Kilauea. The final splitting open of the eastern rift was exhibited by cracks in the ground and swarms of earthquakes at Kapoho on the extreme eastern point of the island in April 1924, after the lava in Halemaumau had sunk more than 300 feet.

Then came the grand crash of lava subsidence and engulfment of the walls of Halemaumau in May of 1924, with every episode closely parallel to what had happened in 1922 and 1923 except that the outflowing lava on the rift did not appear above sea level. There could be no question but that it did flow out a few miles beyond the east point of the island under the deep cold water of the Pacific. Each incident of breakage of the island mass 1919, 1920, 1922, 1923, and April 1924 had been farther downhill, and eastward from Mauna Loa to the sea. The swarms of earthquakes and their distances on the seismograms plainly told the story of the splitting open of the eastern rift in the depths of the mountain mass. There was added the episode of steam explosion, (the great cataclysm of 1924), then the lava rose and appeared 1300 feet down Halemaumau in July 1924, and the system entered into repose. T.A.J.

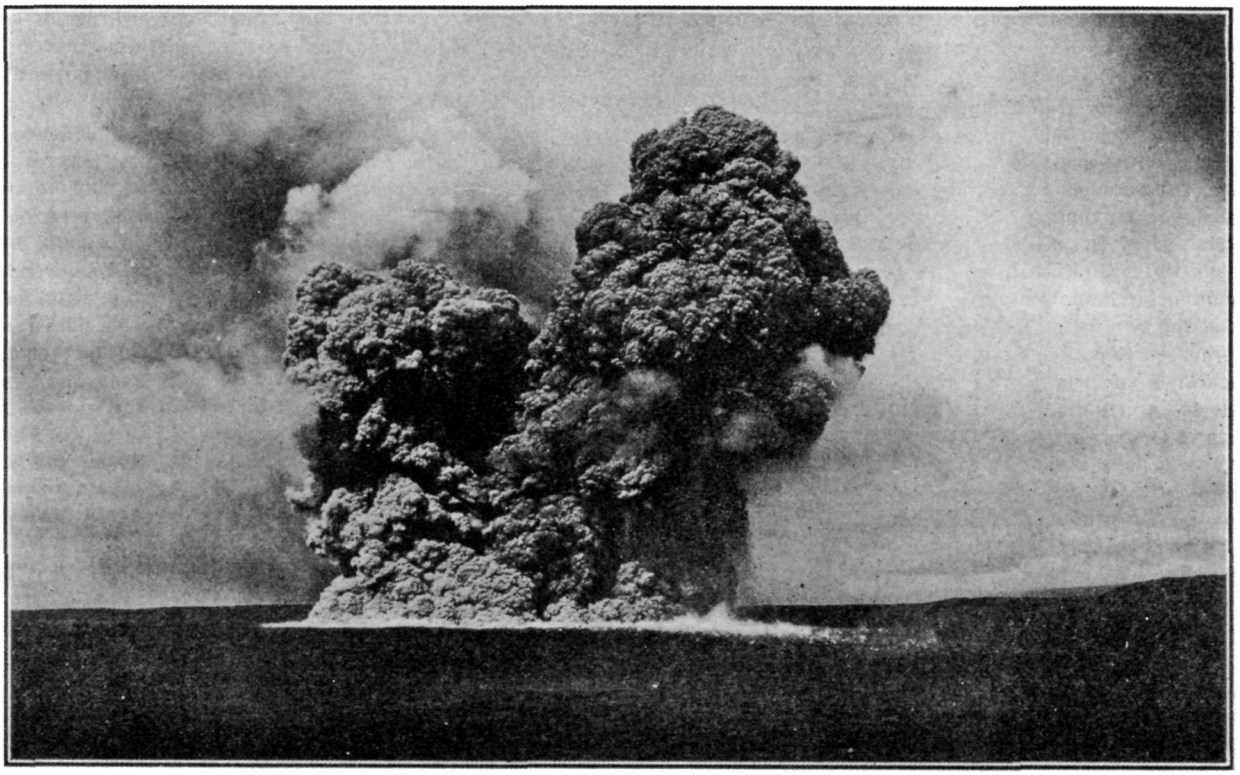
TILTING OF THE GROUND FOR FEBRUARY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

February 2-8	0.36 second	ESE
February 9-15	1.21 seconds	WNW
Feburary 16-22	1.31 seconds	SSW
February 23-March 1	1.74 seconds	SSW



The left-hand cut shows southwest wall of Halemaumau May 25, 1922, when the great subsidence had revealed a tunnel on the Kau Desert rift line through which the lava had flowed in 1920. The right-hand picture is the bottom of Halemaumau July 17, 1922, when the lava returned through a cup at the top of the talus slope pooling in the bottom. Photos Jaggar.



Halemaumau from Volcano House, 8:15 a. m. May 22, 1924, showing cauliflower cloud of one of the paroxysms of explosion and engulfment with bowlders bombarding the Kilauea floor. Photo Tai Sing Loo.

KILAUEA REPORT No. 998

WEEK ENDING MARCH 8, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Very slight fuming continues in the bottom of Halemaumau. New debris material was seen at the southeast edge of the floor on March 2, and on the 7th rocks were heard falling from the north rim. The pit is otherwise quiet.

A total of 19 seismic disturbances were recorded on the instruments of the Observatory during the week, as follows: 16 short tremors; 2 very feeble seisms, one at 9:04 a. m. March 7 originating 32 miles from the station; 1 slight shock at 6:53 a. m. March 8, 30 miles distant, felt in Hilo.

Tilt for the week accumulated slight NW. Microseismic motion was slight.

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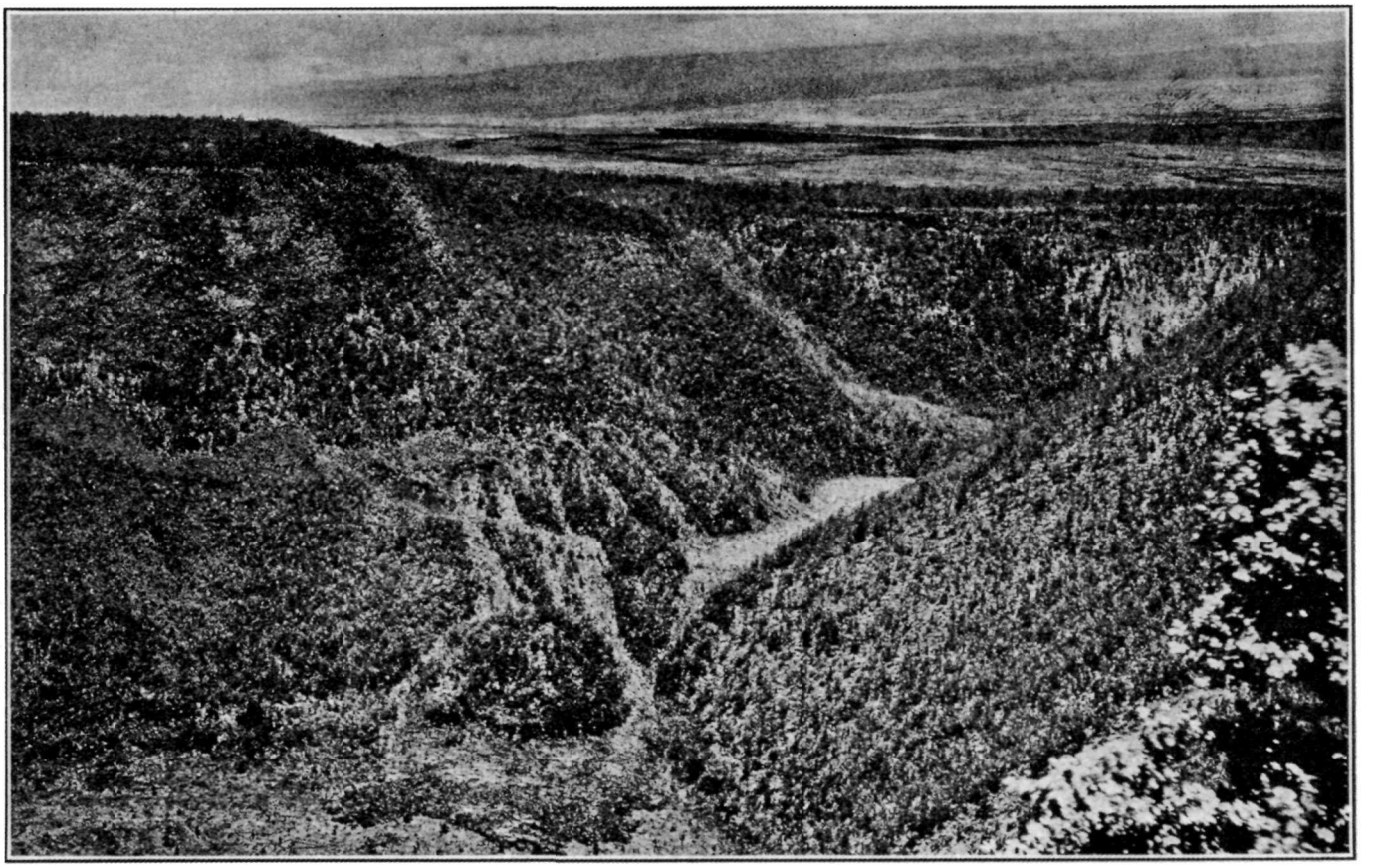
No. 325—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 19, 1931



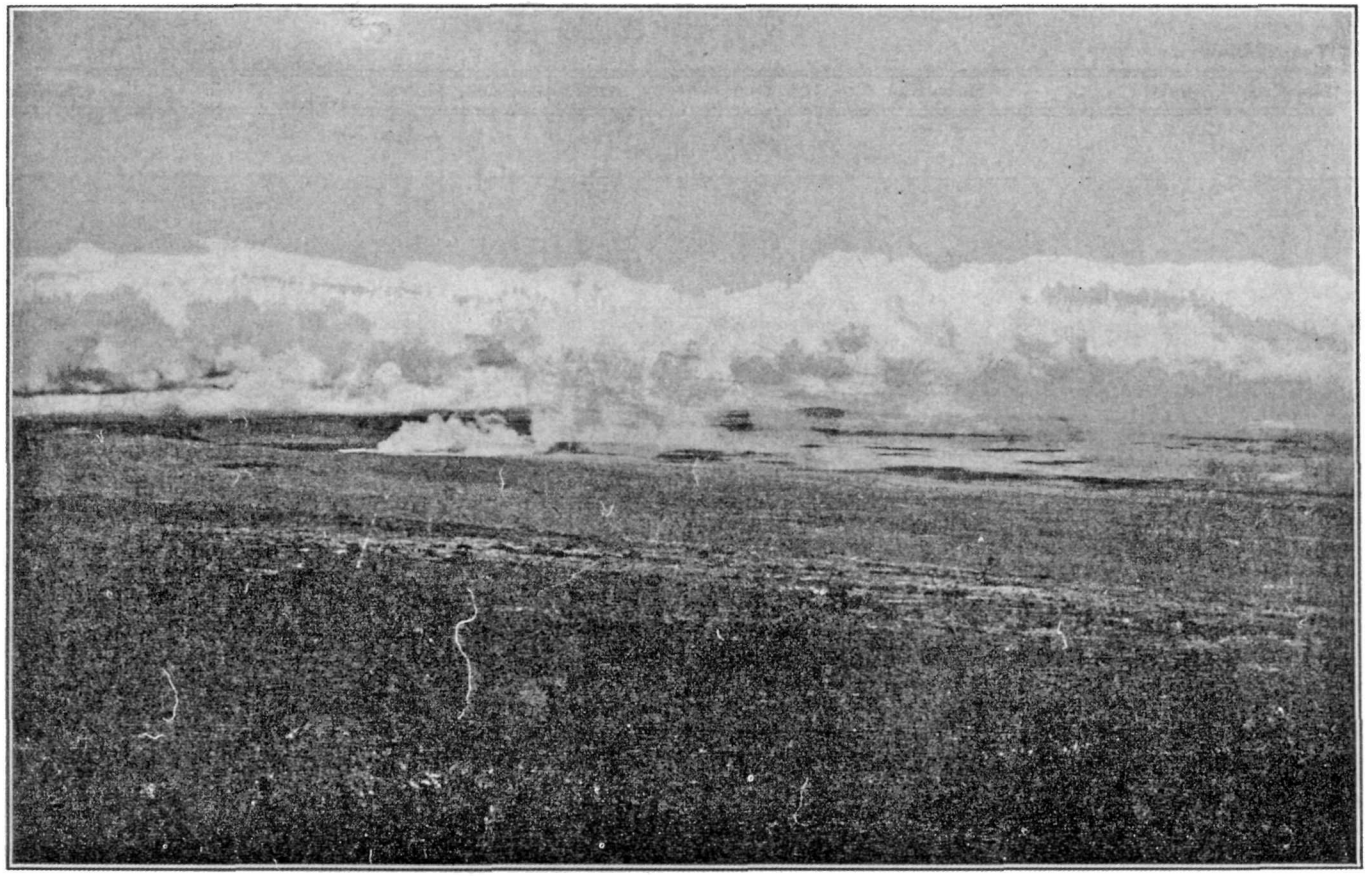
Looking across Kilauea Iki and Kilauea craters. The 1832 flow broke out on the ledge between the two. The 1868 flow made the frozen cascades shown. Photo Wilson.

THE HAWAIIAN VOLCANIC CYCLE

The summary of 20 years of Hawaiian eruptions in Volcano Letters Nos. 319 and 320, and the account last week (Volcano Letter No. 324) of the somewhat systematic repeated sinkings of the lava in Halemaumau pit from 1916 to 1924, naturally suggest to the reader the inquiry, "What can be made out of the sequence to suggest a definite cycle of accumulation and release of lava gas?"

William Lowthian Green (Vestiges of the Molten Globe, Honolulu, 1887), and more recently Wood (On Cyclical Variations in Eruption at Kilauea, Second Report of the Hawaiian Volcano Observatory, Cambridge, Mass., 1917), have commented on possible periodicities of 7 years, 9 years, 18.6 years, 65 years, and 130 years, and Wood has also suggested a semi-annual variation, or a possible variation during a term of about 14 months. Astronomical causes have been suggested. The possibility of a 9-year period, or roughly a decade, involving both Mauna Loa and Kilauea, became more and more plain after the Hawaiian Volcano Observatory was founded. The history of a century and a quarter from the end of the 18th century to 1925 strongly suggested a long term between explosive eruptions, here recorded about 1790 and in 1924, and a maximum volume of lava flowing (1855) in the middle of the term.

When we talk about cycles it is well to have a definite idea of what we mean. What was said in Volcano Letter No. 324 of the weight of the mountain bearing on one body of lava, of the weight of crust blocks of the earth bearing on a substratum of lava, and of the globe as a whole warping under the pull of the sun and moon, involves at least three possible units of volume to heave and sink, to be compressed and be released, and so to produce three different orders of magnitude of eruptive cycles at the same group of vents. It is thus entirely possible at the Hawaiian volcanic system, involving both Mauna Loa and Kilauea, to have a shorter cycle of puffs of the engine, so to speak, about 11 years long; and this superimposed upon a much longer cycle about 132 years long, at the end of which the engine opens its safety valve and produces a prolonged steam blast. Just this, to put the matter in round numbers, is the theory of cycles on which we are working at present, and if it is true, then the 12 episodes of 11 years each from 1792 to 1924 should approximately cover twelve similar eruptive periods of Mauna Loa and



Looking down on Kilauea, with Halemaumau smoking from 7000 feet elevation on Mauna Loa. Photo. Wood.

Kilauea combined. And if the 132-year cycle is itself made up of prolonged accumulation and release, then its first half for 66 years might well be expected to show increasing lava flow with perhaps some logical geographical sequence from Kilauea to Mauna Loa, and its last half should show decreasing lava flow with a progress to lower levels from the top of Mauna Loa downward past Kilauea to the east. It is also conceivable that the quarter period of 33 years may have some significance, for it happens that 1823, 1855, and 1894 produced extraordinary crises of eruption, the first and last on Kilauea, and the middle one on Mauna Loa.

Now let us examine the individual eleven-year cycles:

For the cycle 1781-1792 we know only that a lava flow in Puna east of Kilauea is reported for 1788, and that a major steam-blast eruption killing natives occurred at Kilauea about 1789-90, marking the end of one of our assumed supercycles approximately 132 years long. We thus begin a new supercycle.

The cycle 1792-1803 (end of each year named) involves report of a Puna lava flow 1793, and the very exceptional events which occurred on the west side of the island, lava flows from Hualalai Volcano in 1800 and 1801, the former at Huehue and the latter at Kaupulehu.

The cycle 1803-1814 we know nothing about, except that mariners reported fume continuing at Hualalai, and it is even said that fume was seen near Molokini west of Haleakala. Kilauea was presumably piling lava into its crater.

The cycle 1814-1825 was certainly a time of construction by lava up-building in Kilauea Crater, for the early missionaries after 1823 found a black ledge around the crater not covered with the debris of 1790. Therefore this was post-1790 lava. The year 1923 produced a tremendous breakdown in Kilauea, with the Keaiwa flow into the ocean below Pahala and low crater levels for two years thereafter.

The cycle 1825-1836 was a time of great activity and rising in Kilauea, a remarkable eruption on Byron's Ledge with lava flowing into Kilauea Iki and over the cliff into Kilauea Crater in 1832, a flow for three weeks on the top of Mauna Loa the same year, and a Halemaumau breakdown followed by recovery. Here is our first mention of Mauna Loa since 1790, and it will be seen that for 40 years the outpouring of lava had been from low levels in Kilauea and Hualalai.

The cycle 1836-1847 begins with Kilauea dull and unmentioned, then follows a rising to "terrific" effervescence there in 1840 and a breakdown with outflow far to the east in Puna, the lava reaching the sea at Nanawale. Kilauea pit recovered but slightly when Mauna Loa again took part, making a big northern flow piling a huge volume of lava in the saddle between Mauna Loa and Mauna Kea.

The cycle 1847-1858 involves the most tremendous flooding of lava which occurred in the nineteenth century. There were over 400 days of lava flow from Mauna Loa between 1851 and 1855. This was led up to by a dome forming over Halemaumau 1848, fluctuations of Kilauea activity until 1854, excessive flooding of Kilauea Crater in 1855, and lowering thereafter. Mauna Loa had outbreaks in 1849, 1851, 1852, and 1855, the last flowing for 13 months toward Hilo.

The cycle 1858-1869 is the beginning of the decline, showing 307 days of flowing lava, but is still characterized by enormous flooding from Mauna Loa. Kilauea was quiet, but Mauna Loa in 1859 made a big flow for seven months into the ocean in North Kona. Then Kilauea revived, the lava in Halemaumau rose and overflowed, the summit crater of Mauna Loa broke out for four months 1865-66, and in 1868 came a startling crisis with flows into Kilauea Iki, a world-shaking earthquake, a big breakdown of the

Kilauea floor, and outflows for the first time from the southwest flank of Mauna Loa, with a small outflow southwest from Kilauea. These events were accompanied by landslips, tidal waves, and shore lowering.

The cycle 1869-1880 was distinguished by great flooding of Mokuaweoweo, the summit crater of Mauna Loa, at the very top of the volcanic system. Kilauea recovered to low levels, then Mokuaweoweo was reported active in 1871, 1872, 1873, 1874, 1875, and 1876. Kilauea came to an overflowing with great activity in 1874, broke down and recovered in 1875, fluctuated and erupted at the small pit Keanakakoi in 1877. In that year Mauna Loa produced a submarine eruption in Kealakekua Bay on the west side of Hawaii. Then Kilauea built up crags and lakes and overflows with a collapse in 1879 followed by recovery.

The cycle 1880-1891 like the preceding produced more than 200 days of lava flowing, with Kilauea hard at work building up its floor until 1886, when it reached a crisis of breakdown. Mauna Loa in 1880-1881 produced the great flow that almost destroyed Hilo. Again in 1887 Mauna Loa had a short-lived but voluminous southern flow, Kilauea recovered and reached a breakdown in 1891.

The cycle 1891-1902 was distinguished by a great decline in numbers of flow days (only 37), yet there was activity in Mokuaweoweo in 1892 and 1896 and a northern flow from Mauna Loa in 1899. Kilauea increased its crateral activity to immense floods in 1894, when it broke down completely and remained dormant or very dull for 13 years. There is good reason to think that Kilauea had an outflow under the ocean.

The cycle 1902-1913 was marked by summit crater activity of Mauna Loa in 1903 and a flow to the southwest in 1907, only 28 flow days in all. Kilauea revived in 1905, reached very high effervescence in 1910 and 1912, and then lowered to a dormant year.

The last cycle 1913-1924 had somewhat higher flow duration, 71 days, and was the concluding cycle of the supercycle that led to the Kilauea explosive eruption of 1924. The lava pressure was marked by a steady climb of the lava in Kilauea fire pit from 1914 to 1919, and a pulsating subsidence with outflow from 1919 to 1924. Meanwhile Mauna Loa was active on the summit in 1914, and on the southwest flank with increasing floods in 1916 and 1919, but all small as compared with 1855. Kilauea exhibited increasing breakdowns until the grand crisis of 1924 when the east point of the island sank, Halemaumau exploded and probably there was submarine outflow. T.A.J.

KILAUEA REPORT No. 999

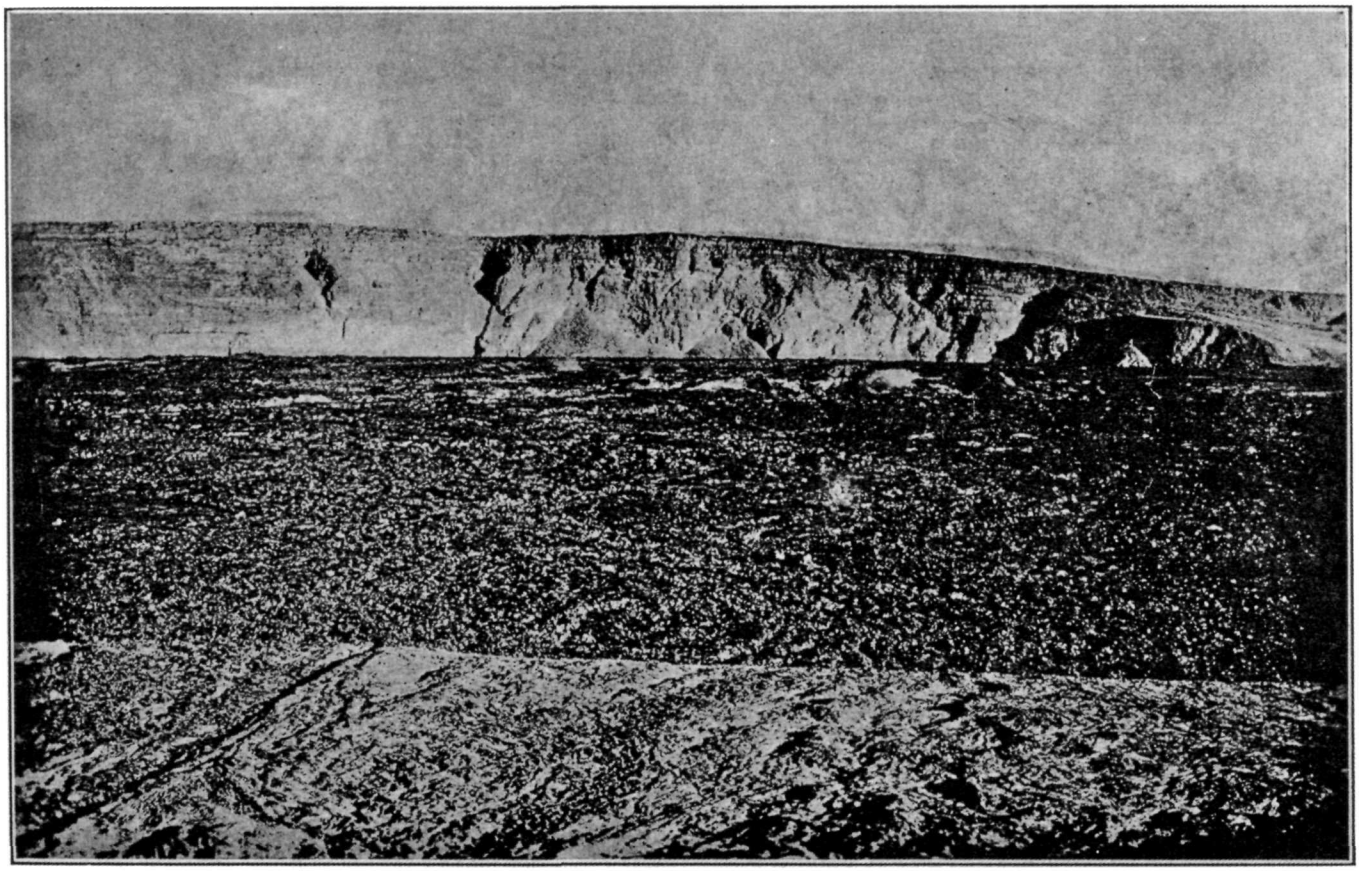
WEEK ENDING MARCH 15, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The only noteworthy features of Halemaumau pit in Kilauea Crater which suggest any change are sulphur spots north and west of the cone that was left standing on the lava floor of 1930. These spots on March 12 were observed to be fuming steadily. A small slide was observed at the southwest. The seismograph at Halemaumau indicated rather rapid tilting of the ground away from the pit between February 28 and March 3, and a gradual accumulation of tilt away from the pit at other times.

The Observatory seismographs registered 34 tremors during the week and 3 very feeble local seisms, one of these at 4:43 a. m. March 14 being accompanied with tilt to the southeast. Tilting of the ground was otherwise moderate SSW, and microseismic motion was very slight. The fluctuation of tilting within a few days was strongly marked during the first half of March.



West wall and floor of Mokuaweoweo, the summit crater of Mauna Loa. Photographed 1915 by Wood.



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The Volcano Letter

326

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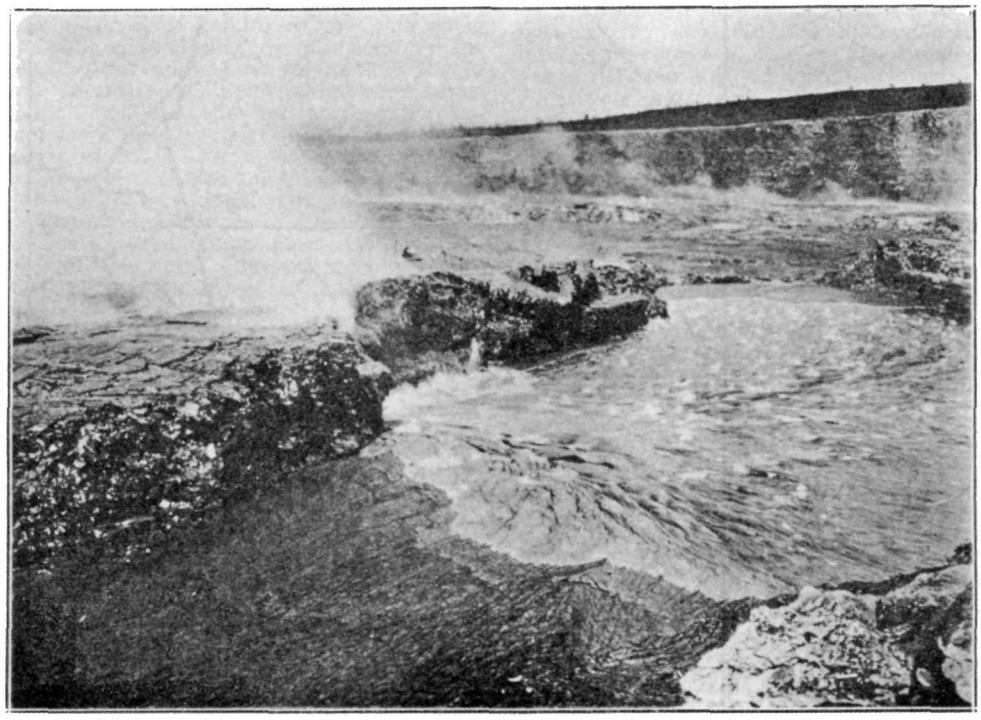
No. 326—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 26, 1931



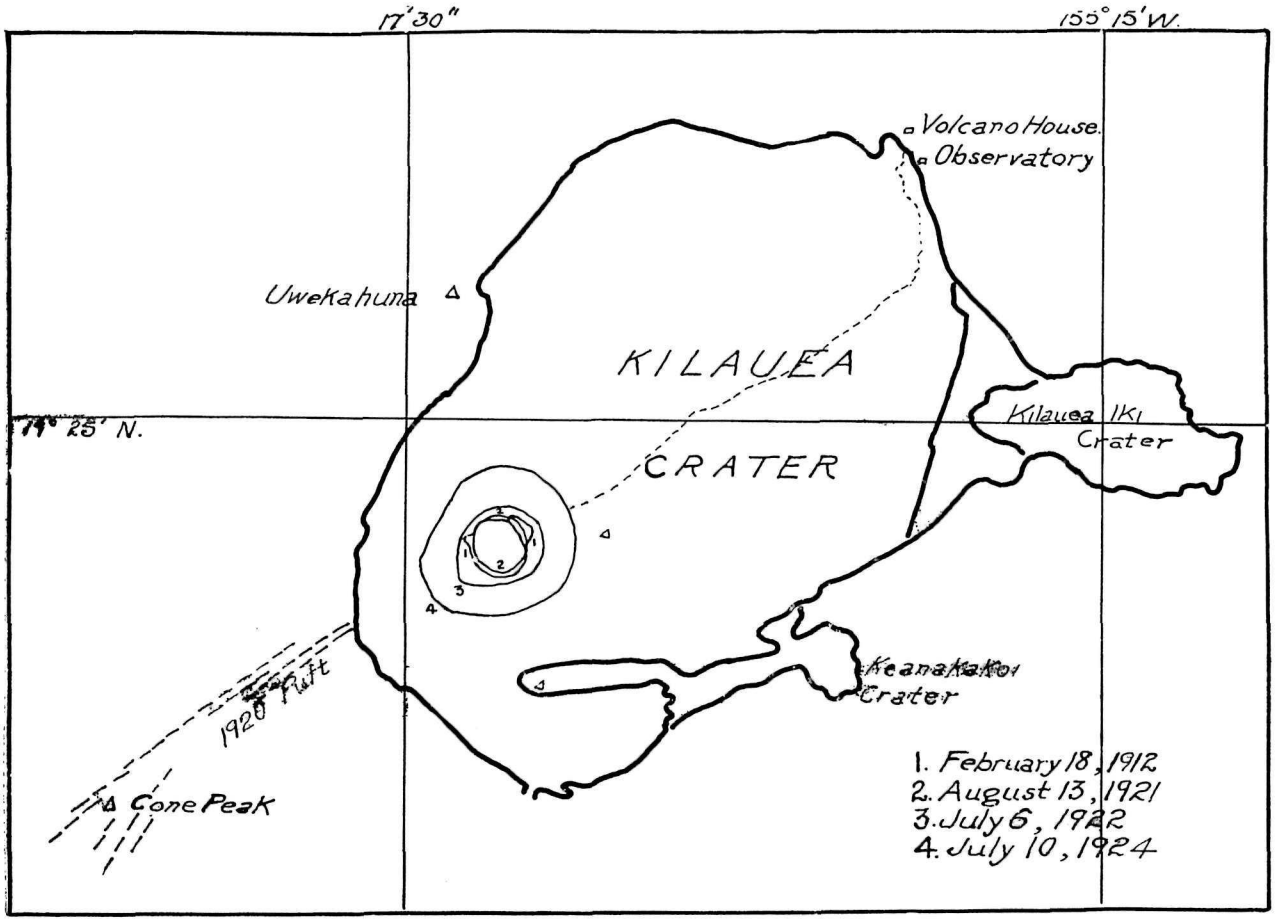
A high level in the cycle. Looking northwest across Halemaumau January 23, 1921, showing the rush of surface currents of bubbling lava into a grotto. Shows the fuming surface of the half solidified lava column, and in the background the Halemaumau wall and the Kilauea wall. Photo Jaggar.

VOLCANIC CYCLES AND SUNSPOTS

In the Volcano Letter Nos. 172 and 302, some notes are presented concerning a general similarity between curves of frequency of sunspots and of frequency of volcanic eruptions. Students of this subject who have taken the volcanic eruptions of the whole earth have published contradictory results, some finding more eruptions and some finding less eruptions for the time of sunspot maxima. Sapper found that gigantic volcanic explosions sometimes correspond with either high or low numbers of sunspots, but his curve shows a number of good correspondences between eruption frequency maxima and sunspot minima. For the period between 1790 and 1825, when sunspots were notably infrequent, volcanic eruptions were unusually inconspicuous.

Confusion in attempting to compare statistics is bound to result if such a word as "eruption" remains undefined. To take the great lava-flooding cycle of Kilauea 1913-1924 as an example, the peak of the lava pressure was 1919 when both Mauna Loa and Kilauea were vomiting floods of slag. This was also a time near sunspot maximum of frequency. To the layman, however, or to the ordinary geological traveler, the crisis of "eruption" was 1924 when Kilauea made tremendous steam explosions. And this was the time of sunspot minima. Which was the "eruption" of the decade for the statistician of the textbooks?

This leads us to examine critically the list of eleven-year cycles for Hawaii cited in last week's Volcano Letter, and to ask, "What are the distinguishing features of a cycle?" Probably Mercalli in his Italian book on "Active Volcanoes," and with his many years of experience as an observer of Vesuvius, hit the nail on the head when he said that the most distinctive feature of a volcanic cycle is the short repose period at its end. And this repose is often initiated by explosion, so as to be called "eruption" popularly. It is only on volcanoes such as Vesuvius and Kilauea, where the magma is visible most of the time, that these repose periods become striking. It is only when we can see the repose period in contrast to a high pressure period that has preceded, that we recognize its existence. If the high pressure has asserted itself by intrusion under a dormant volcano, seemingly always in repose except for a sudden explosion which goes unexplained, nobody will know about it. There may be a tide of flux and flow in the underground magma which has lifted the mountain and let it down again, but nobody has measured it. The sudden explosion may be the let down, as it certainly was at Kilauea in 1924. It is clear that even for the well recorded



Map showing successive outlines of Halemaumau pit in the southwest part of Kilauea Crater during a cycle. (1) Pit of 1912 with niches northeast and west. (2) Smaller pit of 1921 after nine years of building up. (3) Larger pit of 1922 after the first big collapse. (4) Very large pit of 1924 after steam-blast eruption and breakdown.

century of Hawaiian events, the only cycles that will bear intimate analysis are the recent ones where the descriptions are full.

The first reason for adopting eleven years is that this figure exactly fits the carefully observed cycle between two times of complete repose in 1913 and 1924 at Kilauea. The second reason for approving eleven years is by trial and error; if we apply nine, ten, twelve, or thirteen years as possible cycles for the events between 1790, the last great explosive eruption, and 1924, the newest one, none fits so well the division based on recorded repose periods as the number eleven. The third reason for approving eleven years as a cycle is that if we divide the 134 years from 1790 to 1924 into twelve cycles, we get 11.1 years as the average for each cycle, and each group of about three cycles leads to an unusually big crisis of lava breakdown or subsidence. And a reason for taking an interest in the sunspot analogy is that 11.1 years have been found by astronomers to stand for the average interval between sunspot maxima.

If we take the cycles at Kilauea and Mauna Loa immediately preceding the 1913-1924 period, we find 1902-1913 beginning and ending with complete repose, exhibiting Mauna Loa lava first in the summit crater and four years later pouring out of the south flank, and Kilauea lava rising to repeated maxima with effervescence and then sinking away. We find 1891-1902 beginning and ending with complete repose, exhibiting Mauna Loa lava twice in the summit crater and fianlly pouring out of the north flank, and Kilauea lava rising to a tremendous maximum so as to break the mountain and drain off. We find 1880-1891 following a repose in 1879 and leading to one at the end, exhibiting Mauna Loa lava twice in the summit crater and then pouring out of both the north and the south flanks in discharges six years apart; Kilauea builds up its floor with one of the greatest pressures of its history and then executes a series of breakdowns. These histories accord with the eleven-year cycle as a time of stress followed by a time of release, and with the conception that this cycle commonly involves both Mauna Loa and Kilauea as outlets for the same lava column. The details of sequence vary to such extent as the breakage of the island varies in yielding to the internal stress. The remarkable feature of these histories is that in spite of the incompleteness of the observations, there is such striking accord in showing two repose periods separated by an intervening high pressure period for both Mauna Loa and Kilauea.

Now when it comes to sunspots, let us keep in mind Mercalli's principle that the breakdown, whether it be explosive and conspicuous or not, begins a repose period, and the short repose or low period is the important punctuation mark in the cycle. The following two tables serve to compare low level quiet times in Hawaii with years of minimum numbers of sunspots:

Low Levels Hawaiian Lava		Sunspot Minima
1924	End of supercycle	1924
1913	Quiet year	1913
1902	Quiet year	1901
1891	Kilauea breakdown preceding great drainage of 1894	1889
1880	Follows Kilauea breakdown, starts Mauna Loa floods	1878
1869	Follows big breakdown both mountains	1867
1858	Quiet year following greatest lava floods of history	1856

1847	Quiet year	1843
1836	No mention in records, therefore quiet	1833
1825	Quiet year after great drainage of Kilauea 1823	1822
1814	Unknown	1810
1803	Quiet time following Hualalai outflows	1797
1792	*Repose following supercycles crisis of 1790*	Declining Sunspots

In these tables the Kilauea years are at arbitrary regular eleven-year intervals beginning at 1924 and going backward, and it will be seen that for this century the intervals between sunspot minima where notably longer than eleven years. In most cases if the actual years given in the sunspot column had been taken for the Hawaiian low levels, they would have been as near to the lava breakdowns as the years given in the Hawaiian column, but some of them would have preceded the breakdown instead of following it. If the observational data for Hawaii in the early years were as good as in the later ones, the bends of the Hawaiian curve might match many of the sunspotless years more perfectly. But the volcano record is very imperfect. What this shows is that the repose periods are remarkably systematic.

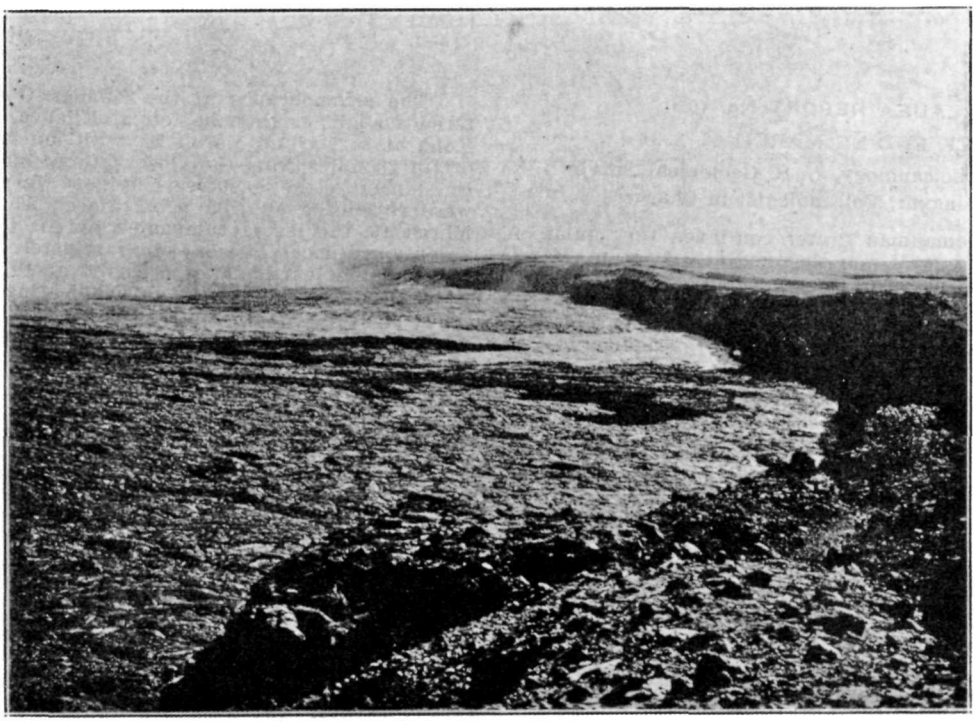
When it comes to the sunspot maxima, we find them in the midst of the Hawaiian periods of lava pressure, when within a cycle both Mauna Loa and Kilauea were flooding:

High Pressure Hawaiian Lava		Sunspot Maxima
1917-20	Kilauea and Mauna Loa flooding	1918
1903-07	Two flows Mauna Loa and Kilauea rising	1905
1892-99	Three flows Mauna Loa, Kilauea 1894 maximum	1893
1881-87	Kilauea and Mauna Loa big floods	1884
1869-77	Kilauea rising, continuous summit eruption Mauna Loa	1870
1859-68	Three flows Mauna Loa, Kilauea rising, overflowing	1859
1851-55	Mauna Loa maximum, Kilauea maximum	1848
1836-47	Kilauea flood 1840, Mauna Loa flood 1843	1837
1825-36	Kilauea and Mauna Loa floods 1832	1828
1814-25	Kilauea flood 1823, Mauna Loa unknown	1816
1803-14	Unkown, but Hualalai floods 1800-01	1804
1788-93	Probable Kilauea floods preceding 1790 explosions, and two flows reported in Puna	1787

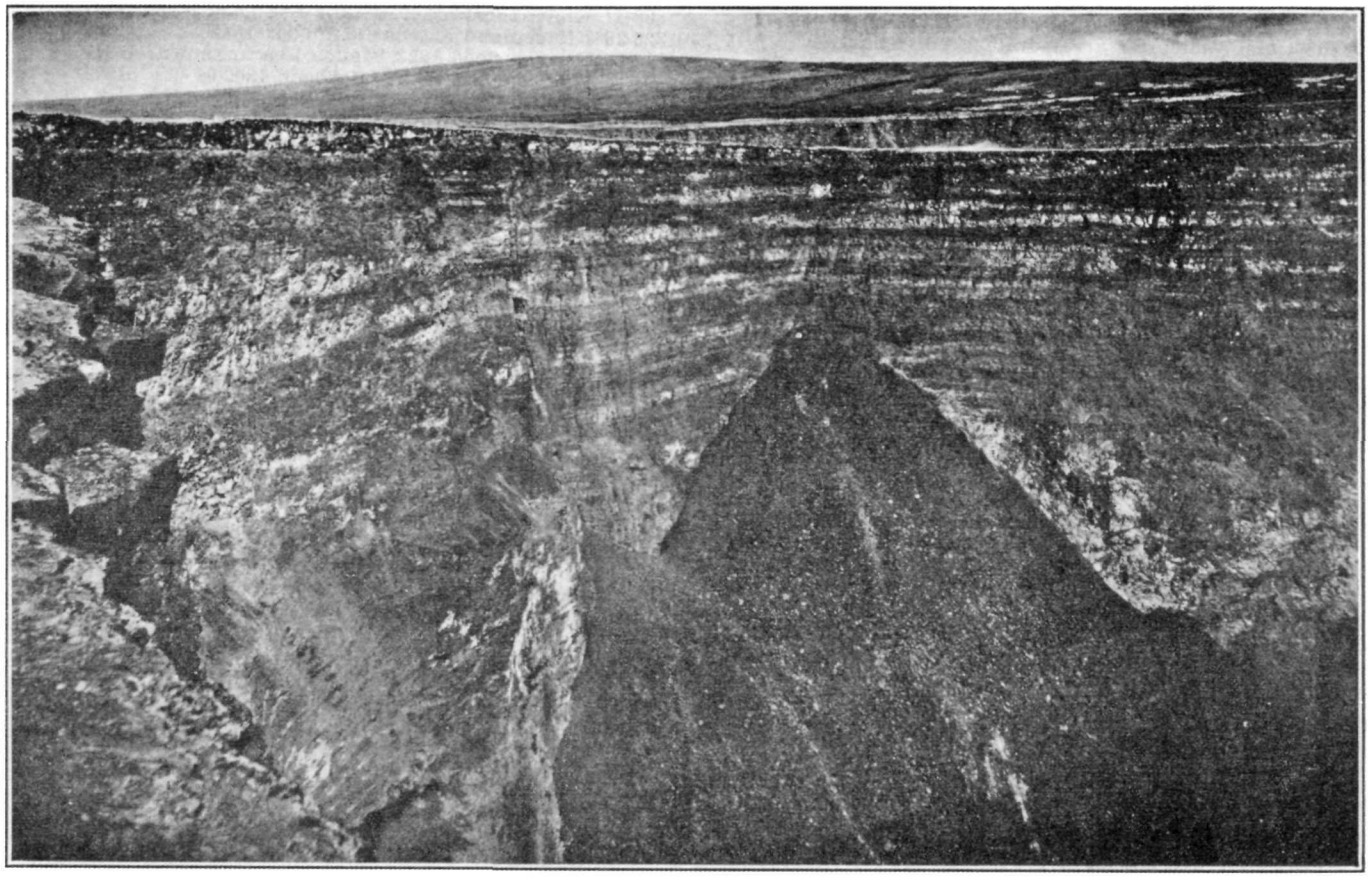
The sunspot maximum exhibited a very long interval between 1787 and 1804, and this was a turning point from high numbers to low numbers of sunspots for the maximum years. It was also the turning point at Kilauea for the supercycle that ended with the explosive eruption of 1790.

Referring to the low numbers of sunspots for some sunspot cycles and high numbers for others, the Humphreys curve (Sapper, Vulkankunde, page 272) shows low values 1790-1820, increasing values 1820-30, very high values 1830-80, declining vaules 1880-1920. The Hawaiian number of flow days roughly figured from existing descriptions was very few 1790-1820, about seven 1820-30, 132 1832-43, 411 1852-55, and then for six eruptive periods from 1859 to 1923 the figures 307, 207, 247, 37, 28, and 71. In other words the flooding of lava in Hawaii to the high maximum in the middle of the supercycle about the year 1855 corresponded to the higher maxima of sunspots in the nineteenth century.

If the reader asks why sunspots should have anything to do with volcanoes, the answer is that nobody knows. Times of maximum sunspots affect radio reception on the earth, magnetism on the earth, and auroras in the arctic regions. Sunspots are accompanied by gigantic eruptions of gas on the sun and colossal electrical phenomena in the solar system. If earth magnetism and electricity are in some way associated with gravity, volcanism may be affected. If heat by the earth's radio-activity affects volcanism, the sun may in turn affect the earth's radiations. Finally, if volcanic emanations on the earth are a last remnant of solar processes here, those processes by unknown means may be sympathetic with the sun. T.A.J.



Looking toward Kau Desert from high bluff west of Kilauea Crater January 3, 1921, when the white glistening flows from Halemaumau were filling the southwest corner of the crater. A maximum of flooding. Photo Jaggar.



Looking west across the vast void of Halemaumau in 1928, after the breakdown of 1924 was complete, showing the distant wall of Kilauea Crater beyond the Halemaumau wall, and still farther away the snake-like flow of 1881 on the smooth dome of Mauna Loa. Photo Wilson.

KILAUEA REPORT No. 1000

WEEK ENDING MARCH 22, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The pit Halemaumau Crater continues very quiet. A slide on the north wall was observed at 3:10 p. m. March 18. Fuming was observed at the two recently developed sulphurous spots on the north side of the 1930 floor the forenoon of March 19, and some rocks were heard falling on the north wall. The pit seismograph indicated two very small tremors about March 15.

The seismographs at the Kilauea Observatory registered a slight earthquake felt at Kilauea, at Hilo, and in Kona at 5:29 p. m. March 20, with indicated distance of origin 28 miles from the Observatory, and strong enough to dismantle the east-west stylus. Very feeble shocks were registered at 3:09 p. m. March 20 and 6:57 a. m. March 16, the last accompanied by tilt to the southeast. Twenty-two local tremors were registered. Weakly recorded distant earthquakes occurred at 10:47 p. m. March 17, at 9:56 a. m. March 18, this indicating a probable distance of origin of 800 miles; and at 8:08 p. m. March 18. Microseismic motion was slight with some increase March 19-20, and tilting of the ground was slight SW.

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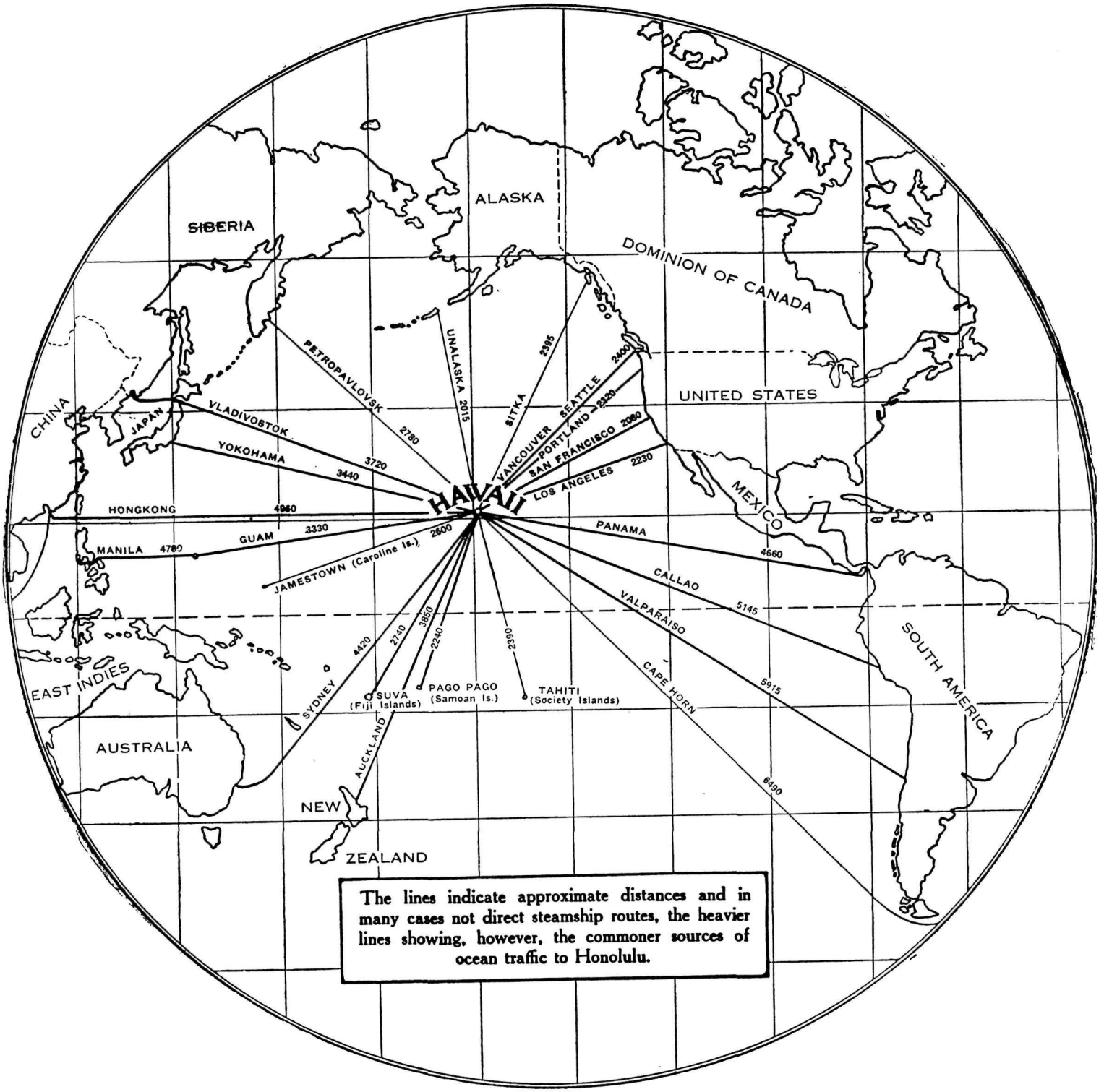


Map of the Pacific Ocean showing New Zealand at the southwest. Hawke's Bay is at the southeastern end of the North Island. Napier is at the southwestern end of Hawke's Bay. This is the eastern border of a continental mass which falls off to deep water east of New Zealand.

GREAT NAPIER EARTHQUAKE NEW ZEALAND

On Frebruary 3, 1931, at 10:47 a. m. local time, a terrific earthquake occurred destroying the cities Napier and Hastings at the southwest end of Hawke's Bay, an indentation in the middle of the southeastern end of the North Island of New Zealand. This had been registered perfectly on the seismographs at the Hawaiian Volcano Observatory with indicated distance 8,040 km. SSW., which checks satisfactorily with the New Zealand location.

Seimographs at the Dominion Observatory in Wellington show that 588 shocks originating in the Hawke's Bay district occurred during February, the after-shocks diminishing more quickly than those recorded after the Murchison earthquake in 1929. For the first day following the initial mark of the heavy shock 151 earthquakes were registered in 24 hours. Most of the after-shocks were not felt in Wellington, but the large shock was.

Hawke's Bay is 60 miles southeast of the Taupo volcanic belt and lies on the NE-SW mountain axis of New Zealand well to the east of the belt which was stricken at Murchison in the north end of the South Island June 17, 1929. In fact that Murchison fault belt if projected to the northeast would have passed through the Taupo volcanic belt. The New Zealand Herald reports official and other investigations about February 21 as follows:

Napier and Hastings are at the southwest end of Hawke's Bay, Mohaka is in the middle of the long curve of the bay, Wairoa is at the north, Mahia is at the northern peninsula enclosing the bay, Gisborne is farther north, and Morere hot springs lie in between. Waipukurau lies farther southwest than Napier. Remarkable changes in configuration were found on the coast near Mohaka in the middle of the bay. Here the coast line has taken a new contour and owing to its uplift, residents state that one may now travel dryshod along a new, wide, sandy beach as far as Napier, a feat that would have been impossible before even at lowest tide. The upheavals, however, have seriously affected only a narrow strip of coastal land around the bay. Wairoa was much less seriously afflicted than Hastings and Napier.

The land was most shattered along cliffs and hills between Napier and Mohaka. Inland a short distance no trace is found of the crumbled hilltops with deeply fissured sides which are conspicucous at the shore. In some of the gorges, however, loose hillsides have fallen away, just as did the Bluff Hill at Napier. In these places the road is blocked or annihilated. Alluvial formations in rivers have subsided and cracked, and this is what happened to the embankment road at Napier.

At Mohaka there is evidence of a strong upthrust. The correspondent felt an earthquake while there, giving the sensation of somebody tapping upward beneath the earth's crust with a huge hammer, and workmen said that was how all the shakes had felt around Mohaka. There was direct evidence of an upward and downward movement. In the hills above the Maori village the floor of an entire valley has sunk at least 50 feet in a crumpled mass. Many of the ridges for miles around resembled newly made fillings, while the main road has disappeared entirely for about half a mile. The most remarkable evidence of the tremendous forces brought into play is seen near the mouth of the Mohaka River. Within a distance of about five miles three new peninsulas have been thrown out from the shore, and there has been a general rise in the level of the beach. Where the river enters the sea a bluff has been shaken down into a heap of dust and clay bowlders.

A huge area of the sea is discolored with the discharge from the river which, after the middle of February, began to overflow a huge landslip dam which had blocked it for about 10 miles inland. Northward there juts out a promontory of what was formerly about 200 acres of pasture, and southward a bluff lies in ruins on one of the longest peninsulas formed by the upheaval. There are several of these upheavals along the coast. On the bluff in question about 160 acres of land were lost, and plants which originally grew just above the water level at the foot of the cliffs, were subsequently found growing near the top of the landslip. This indicates that the hills were thrown out from the base dropping down a block of the back land, and carrying beach shingle, sand, and driftwood up so as to overlap the sunken land behind. A big fish was found 50 feet above the water, shells and flotsam can be seen at a height of about 70 feet on the new ground, and this earth is so convulsed and contorted that the journey over it is like climbing in a miniature mountain range.

Homesteads and farm buildings all along the coast suffered severely, but the effects on buldings diminish rapidly toward the north and toward the interior Aftershocks were common and residents say they were accompanied by booming noises among the hills. They sound like heavy objects dropping. While there are blockages in the rivers, most of them are open except in the case of the uplift of the coast above noted. When rain comes the whole country will be subject to tremendous surface changes.

An investigation by the Geological Survey reports that the main fracture lies east of Napier, passing through the principal earthquake centers under the sea in Hawke's Bay as determined by the seismographs. There is a pro-unounced uplift of the sea floor and of the coast west of the fracture line. "So many factors influence the height of the tide that it is difficult to determine a change of a few feet in the level of a coast. No change was detected at the mouth of the Ngaururoro River. At Napier the uplift was about six feet decreasing southward. At Petane just to the north of Napier it is six to eight feet, and at Whakaari still farther north, perhaps seven feet. The harbormaster at Wairora is sure there has been no change in level there. These scanty observations make it appear that the coast has arched gently on a northeast line, the crest of the arch being north of Napier. Assuming that the amount of coastal uplift is a measure of the violence of the earthquake, the center of the disturbance was some miles northeast of Napier below the floor of Hawkes Bay."

Napier suffered greater damage than Hastings, Hastings more than Waipawa, and Waipawa more than Wairoa. The report states that fissures in alluvium were remarkably abundant along rivers and in localities where there was no lateral support for filled-in material. In places the ground had stretched 12 feet in a few score yards, water and sewer pipes having been disrupted, and dwellings greatly damaged. The West Shore causeway built across a mud flat area had spread and the roadway split and collapsed through lack of lateral support. The banks of the chief tidal channel had closed in on a bridge, forcing the top of one set of piles from under the ends of the girders supporting a span of the bridge. At many points along the coast shingle beaches had slumped either toward the sea or backward toward the lagoon behind them, and the surfaces were ridged by a series of parallel steps and trenches.

The displacement of alluvium narrowed the river channels, and raised their beds, making it likely that their discharging capacity during floods will be seriously dimin-

ished. During the earthquakes large quantities of water, sand, and silt issued from fissures in the ground. The origin was a water-saturated sand layer below the surface. Land slides were not nearly so prominent as they were in the Murchison district in 1929, where the hills were steeper and the climate wetter. Their distribution showed that they depended largely on local conditions ranging in quality from vast landslips involving many millions of yards of rock to mere downward creep of the soil mantle on the hills. Pressure ridges appear to mark the surface trace of an important earth fracture through the Poukawa Valley extending northeast about six miles. The ground northwest of the fracture is fissured and swollen and that on the southeast side unaffected. It appears probable that the earth block on the northwest side moved. The movement was toward the east. Probably it follows a weak layer interbedded with the strong limestone bands. Probably also, movement occurred along several weak layers. This suggests that the movement was distributed over a zone several miles wide.

An investigation by a government vessel taking soundings for three days north from Napier indicated that the bed of the roadstead had risen in parts from six feet to seven feet, but in places the soundings gave the same depth of water as is shown on the charts. Nothing less than 33 feet of water was found from two miles off shore to half a mile from the breakwater at Napier, the sounding being on the line of beacons leading to the roadstead. The investigations show that the anchorage in the roadstead is just as safe for shipping as it was before the earthquake.

With reference to earthquake-proof construction, the following quotations from a sensible article by Archdeacon K. E. MacLean are pertinent quite as much to other places as to New Zealand. The Archdeacon asks whether sufferers by the earthquake need believe that the disaster was a divine punishment. He cites the case of a man who gets sunstroke by going out without his hat. We are sorry for him, but we say bluntly, "It was his own fault."

"To be quite honest is not our position much the same? We know what earthquakes are. We know a good deal about how and why they happen. We know there are faults in the earth's surface and that the countries near those faults are liable to earthquakes. We know—we always have known—that New Zealand is one of these countries, and that a bad earthquake might come at any time. Yet we came knowing this and lived here and shrugged our shoulders about earthquakes."

"Our fathers, who remembered the earthquake in Wellington in 1855, warned us against brick houses and high chimneys, but the years went by and more and more brick houses and tall chimneys were built, and the years went on and they stood. It was quite possible to build earthquake-proof houses in wood or brick, or concrete, but it was expensive, and we wanted money for other things. It was quite possible to build chimneys in ordinary houses which had not got a tight collar of wood around them at the flashing, but we did not bother."

"It was quite possible to follow sound principles of construction in building shops and offices, but no one cared and no one asked for it. So up went the flimsy, showy walls and the heavy copings. It is not the fault of anyone in particular. Architects, builders, and workmen just shared the common mind and built their own houses in just the same way that they built houses for other people. We are all in this together. It was public opinion that it did not matter."

"Two years ago the Murchison earthquake happened and we said, or nearly all of us said, 'Poor beggars! Come and live in Hawke's Bay and be safe.' And we went on living happily in the death trap we had built. Then, on February 3, the earth wriggled for a minute. The fault settled down a bit more. Who caused the death and suffering? Only if we face this honestly shall we live more wisely in the future."

This wise comment applies equally to all lands around and in the Pacific Ocean. T.A.J.

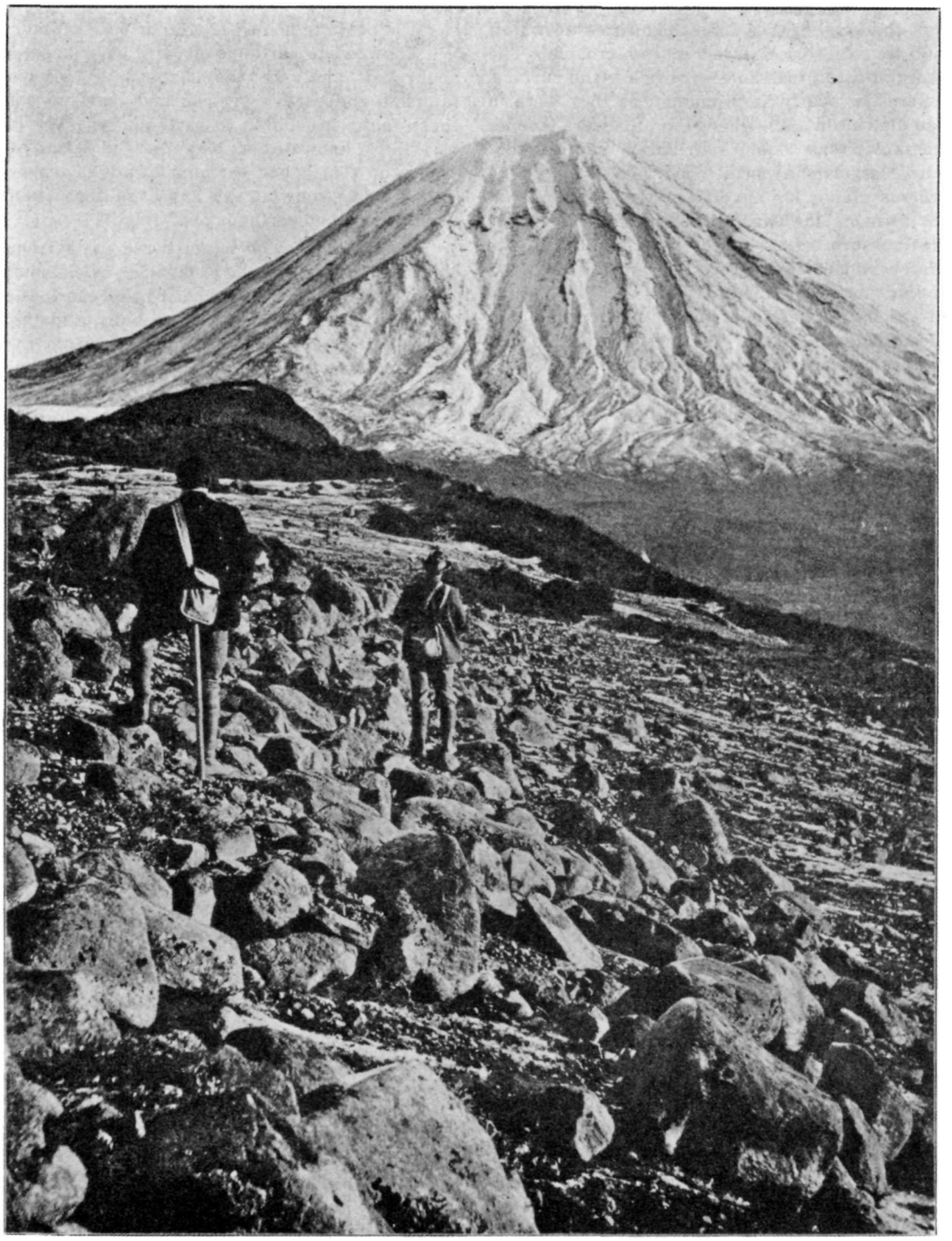
KILAUEA REPORT No. 1C01

WEEK ENDING MARCH 29, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

No significant changes have happened at the Hawaiian volcanoes and the fire pit at Kilauea is quiet. Thirty tremors were registered on the seismographs of the Observatory at Kilauea and three very feeble local seisms, one of these at 7 p. m. March 25 indicating origin distance 28 miles, and cne at 8:11 a. m. March 29 a distance of five miles. A tremor at 9:05 p. m. March 27 lasted eight minutes. A strong distant earthquake began at 2:21 a. m. March 28 local time (10 hours, 30 minutes slower than Greenwich) and indicated origin distance 8,830 km., apparently WSW. from station, which would locate it near the west end of New Guinea or the eastern part of the Dutch East Indies.

Tilting of the ground was moderate to the south, and microseismic motion was slight for the week.



Ngauruhoe Volcano in the Taupo belt of the central part of the North Island of New Zealand. This shows the volcano as seen in winter from the east, marking the line of active volcanoes which lie 60 miles northwest from Napier.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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The Volcano Letter

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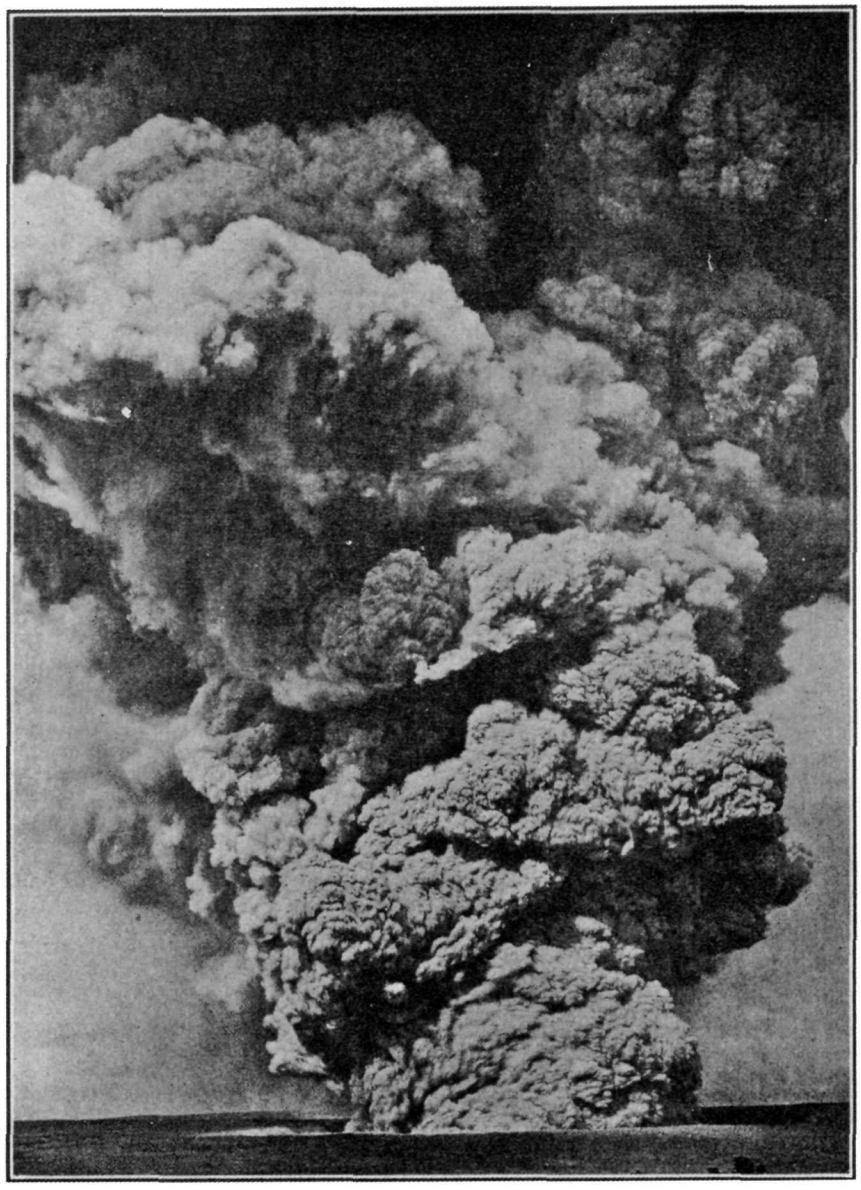


Steam-blast eruption at Halemaumau pit about 8:30 a. m. May 22, 1924, showing tendency to spiral vortex and dark electrical cloud forming above. Photo Tai Sing Loo.

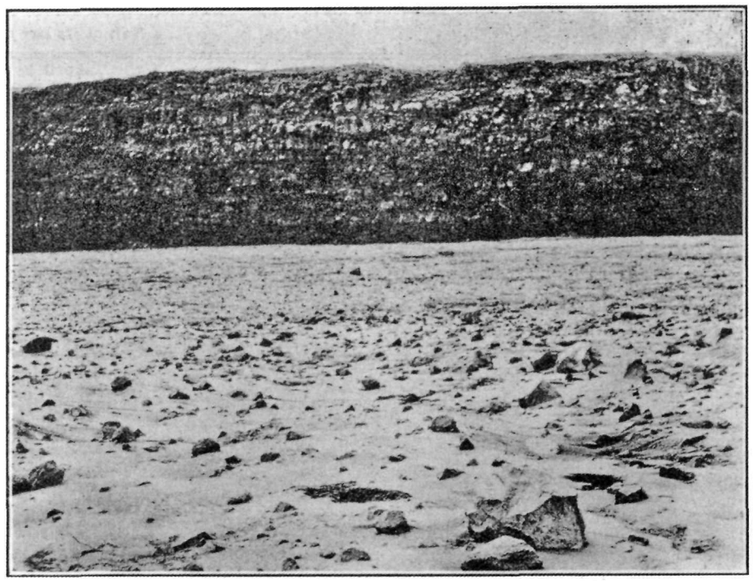
THE GREAT ERUPTION OF KILAUEA IN 1924

Much has been said in recent numbers of the Volcano Letter about the supercycle of 134 years which ended in the tremendous steam-blast eruption of Kilauea in the month of May 1924. The present covering of gravel and bowlders on the lava around the sides of Halemaumau was all thrown out during those three weeks in a series of violent upward jets of steam charged with rocks and sand, something which none of the present generation had ever seen in Hawaii. A much bigger ejection of this kind happened about 1790, and in 1823 there were steam jets that threw up gravel in the lava-flow crack east of Pahala. There are some fragmental stones evidently thrown out explosively around the crater Mokuaweoweo on top of Mauna Loa: no one knows their date.

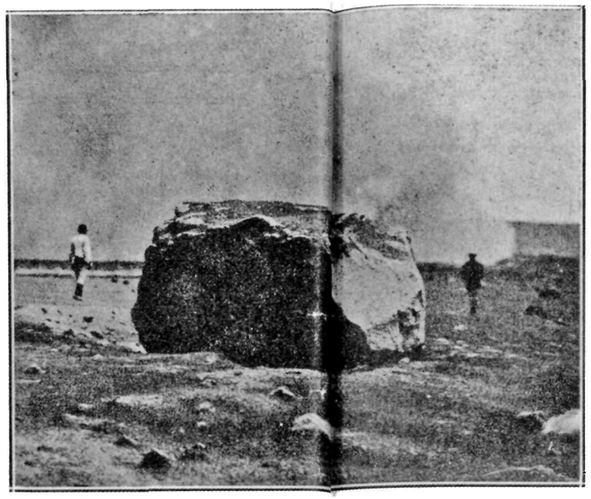
The sequence of events in 1924 was like what had happened in May 1922, when there had been:

(1) Sinking of the lava column.
(2) Great enlargement of Halemaumau pit with avalanches.
(3) Cracking open of the Puna rift to the east.
(4) Southerly tilt and many earthquakes at Kilauea.
(5) Cauliflower dust clouds rising.

What was different in 1924 was the subsidence farther away along the Puna rift (and no lava flow such as had broken out at Makaopuhi in 1922), this occurring in April of 1924 at the east point of the island with lowering of a big block of country, spreading open of cracks, and sinking of longshore vegetation below sea level. Then after the cauliflower clouds had been rising for several days from



Kilauea floor west from Halemaumau May 31, 1924. Shows bowlders and ash covering the lava surface. Photo Emerson.



Eight-ton bowlder thrown 3500 feet southeast from Halemaumau May 18, 1924. Photo Ai Sing Loo.

huge avalanches tumbling into Halemaumau early in May, people began to notice a booming concussion in their ears, and stones began to be flung up and out, instead of merely falling down and in. The so-called eruption was therefore a gradual growth beginning the end of April with a collapsing bottom of the pit that was not at all unusual, producing ejection of rocks first on the night of May 10-11 that was very unusual indeed, and then exhibiting a series of violent steam blasts, at intervals of several hours, for 10 days following May 13. This crumbled away the edge of the pit so that the former rim migrated back on all sides for 700 feet, as the geyser-like steam blasts accompanied gigantic engulfment of the walls of the shaft. May 24th was the last peak of explosive intensity, and thereafter the new type of activity waned and ended about May 28, with avalanches and earthquakes all that remained, these dwindling during June.

The summary of the 1924 sequence was then as follows:

(1) Sinking of the lava column in March.
(2) Cracking open of the Puna rift far to the east April 22.
(3) Subsidence of a fault block at Kapoho in Puna.
(4) Southerly tilt and increasing earthquakes at Kilauea.
(5) Great enlargement of Halemaumau pit in May.
(6) Avalanches at Halemaumau making cauliflower clouds.
(7) Same cauliflower clouds containing steam blasts upward, May 11.
(8) Engulfment of pit walls in May.
(9) Steam-blast spasms two hours apart May 13, thereafter less often.
(10) Ejection of stones, maximum May 19.
(11) Duration explosive spasms, maximum seven. hours May 19.
(12) Electric storms maximum May 17-19.
(13) Felt earthquakes maximum May 22.
(14) Total earthquake frequency maximum May 24.
(15) Cessation of steam-blast phase May 28.
(16) Glowing intrusive body exposed in pit wall June 12.
(17) Adustment of pit walls June-July.
(18) Liquid lava in pit bottom July 19-31.

The diagram on Page Four shows how these various features waxed and waned between May 10 and May 27, the numbers of explosive spasms taking the lead at the beginning of the eruption and the numbers and intensity of earthquakes dominating the situation at the end of the eruption, when the other features were declining. The conspicuous mud rains accompanied electric storms of the period between May 15 and May 19. The caving-in of the rim of the pit began at the southwest where lay the Kau Desert rift of 1920, and where the enlargement had taken place in 1922. Then the breaking-in of the rim followed around the circle to the south, southeast, northeast, and north until the breakdown was balanced by collapse at the northwest. Then there was more collapsing all around the previous outline of the pit. The greatest engulfment was accomplished during the times of maximum steam blast, maximum duration of spasms, and maximum intensity of earthquakes. The greatest break-down of the walls observed took place May 21-22 when there were incessant avalanches. These were the two days following the explosive maxima.

To give the reader an idea of what happened we may quote from the journal of the Observatory a few items of May 17-18: "A station was occupied during the night May 16-17 on the gravel spit southwest of Keanakakoi. There were explosions at 1:20 and 1:27 a. m., a continuous roar from 2 a. m. on, an avalanche cloud at 2:28 a. m., increased roar 3:19 a. m., and at 3:20 a. m. the noise increased, an explosion occurred, a few red-hot rocks were thrown out southeast from the pit, and one minute later a few came out from the east side. At 3:32 a. m. the cloud had become enormous, the roar was continuous, pisolitic mud began to fall, and at 3:35 flashes were seen in the cloud over the pit. At 3:42 there was a roar lasting four seconds accompanied by a slight earthquake, and by now the cloud had spread out like a fan over almost the entire sky."

This sort of record was maintained for many days at the Observatory, and the seismographs showed tilts, prolonged tremblings, and numerous earthquakes, and required incessant attention restoring the pens to the drums. During the month ended May 31, 1924, 3,961 local earthquakes were registered, the maximum being 467 in 24 hours on May 24. Harmonic tremor appeared on the seismograms April 19, becoming moderate to strong after May 6, and decreasing May 16 so as to become very slight before the maximum of explosive activity was reached May 19. Probably the harmonic tremor was due to lava surging, which had receded to such great depths by May 17 that it did not register. In 1924 the tilting of the ground at the Observatory in a south and southwesterly direction amounted to 88 seconds of arc between January and June, 58 seconds of this was during May, and the most rapid tilting took place just preceding, during, and immediately following the great engulfments and steam blasts. There was no good correlation between the number of earthquakes and the explosion days, true earthquakes increased on days when the steam blasts were inactive, but a peculiar shaking accompanied the explosions which gave long drawn out seismograms that built up gradually, without a preliminary tremor like a true earthquake, continuing for half a minute or so, with a period of 0.5 second, and then died away gradually.

Continuing the journal of May 17: "The pit was visited after 9 a. m. and found greatly enlarged so that rim had gone back 200 feet. Depth appeared over 1,000 feet, bottom was flat and covered with talus material, steam was rising without pressure and creeping across the floor irregularly in small continuous cottony clouds. The upper walls of the pit appeared to slope inward at 60°, approaching verticality farther down, so that the avalanches had a free fall to land with a tremendous crash at the bottom. Often the rocks fell with a pattering sound. The cracks across road 2,000 feet southeast of Halemaumau had widened and there were numerous other cracks between there and the pit. The Kilauea floor near the pit was now covered with bowlders in large numbers, locally extending a half mile from the pit and in places there was at least one fallen fragment for every square foot. Some bowlders weighed several thousand pounds."

"At noon came one of the impressive explosions, causing great consternation among visitors. At 12:02 p. m. came a roaring noise and a big dust cloud, accompanied by a moderate earthquake. At 12:32 p. m. there was a roar with sharp crashing noise lasting 50 seconds, and a very heavy black cauliflower cloud rose, much bigger than the one of the early morning hours. At 12:35 p. m. 15 explosive outbursts rose in the course of 11 minutes, accompanied by continuous roaring, and loud crashes of thunder made frequent lightning flashes very low over the Observatory. Showers of rocks were heard falling heavily. At 12:45 p. m. dust and sand fell for 25 minutes. A visit to the pit after this explosion showed newly fallen hot dust in a thick layer near the rim of the pit which had singed the grass farther away. The only gas noticed in the steam exhaled was a small amount of sulphur dioxide."

"May 18. At 11:07 a. m. began a great culminating explosion with tremendous dust cloud and ejected rocks. At 11:09 there was a second explosion plastering the area northeast of the pit with hot sand for several hundred yards. At 11:20 a. m. there was a steady loud roar and a fall of pisolitic mud at the Observatory. There was an Observatory party near the pit, and during the barrage of 11:09 a. m. Mr. Truman Taylor was fatally stricken down by bowlders and sand on the Kilauea floor about 1,800 feet southeast of Halemaumau. He was rescued, but died after being removed to a hospital. The observers were on the sand flat farther to the southeast and when sitting on the ground one could feel numerous quakes and a rumbling was heard. At the 11:09 explosion came a wave of increased air pressure that was painful to the ear drums. One of the rocks weighing over 300 pounds landed on the 1921 lava of the south embayment of Kilauea Crater, and another bowlder weighing eight tons feil at the landing field, made a deep impact cavity, and broke, the fragments bouncing and partially burying themselves on the side remote from the trajectory. An intense electrical storm followed."

T.A.J.



Rill-marked new ash May 29, 1924, south margin of Kilauea Crater. This ash lay over the country like drifted snow, and the rain gullies trench through to the old ash of 1790. Photo Emerson.

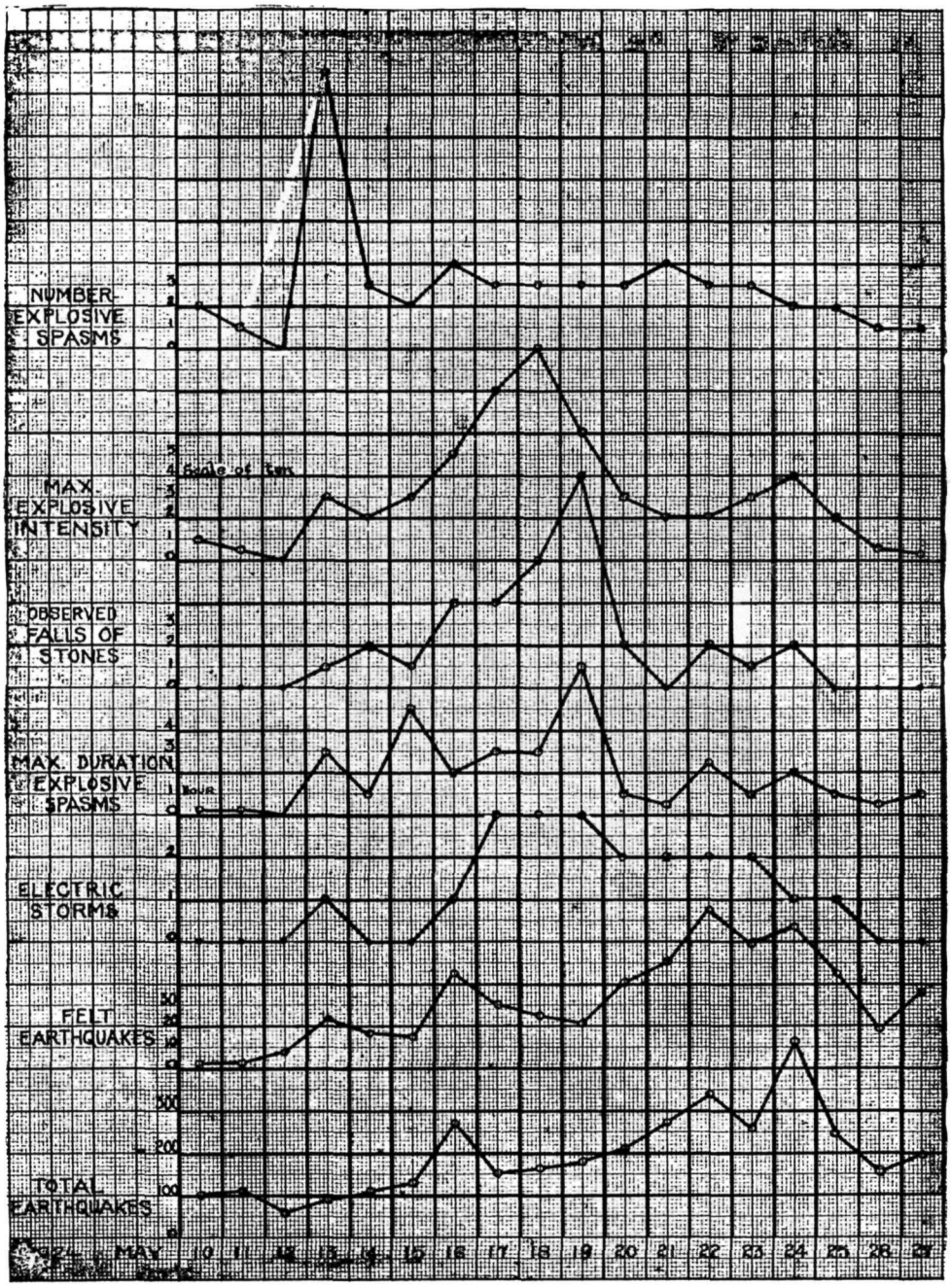


Diagram showing curves of measured activities taken from the tabular summary of the Kilauea steam-blast eruptions May 10-27, 1924.

KILAUEA REPORT No. 1002

WEEK ENDING APRIL 5, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Kilauea remains inactive and without noteworthy changes at the lava pit Halemaumau. There is still steady fume from vents near the north-central part of the pit floor. Steaming has lessened on the south talus.

A peculiar slow-period tremor recorded with more or less regularity on the pit seismograph 4 to 10 a. m. April 2 and again April 4. These were also noted on the instruments at Uwekahuna and the Observatory.

The seismographs at the Observatory recorded an increased number of disturbances during the week. There were 57 tremors, including 5 minutes of continuous tremor April 3 and 20 minutes of continuous tremor April 4; and there were 3 very feeble seisms, and 1 feeble shock occurring at 12:20 p. m. April 4. Phases of the last indicated 32 miles distance to origin. In addition on April 5 a very weak teleseism recorded at 8:30 p. m.

Tilt for the week was moderate to the south. Microseismic motion was moderate March 30 and 31 and at other times slight.

The Volcano Letter

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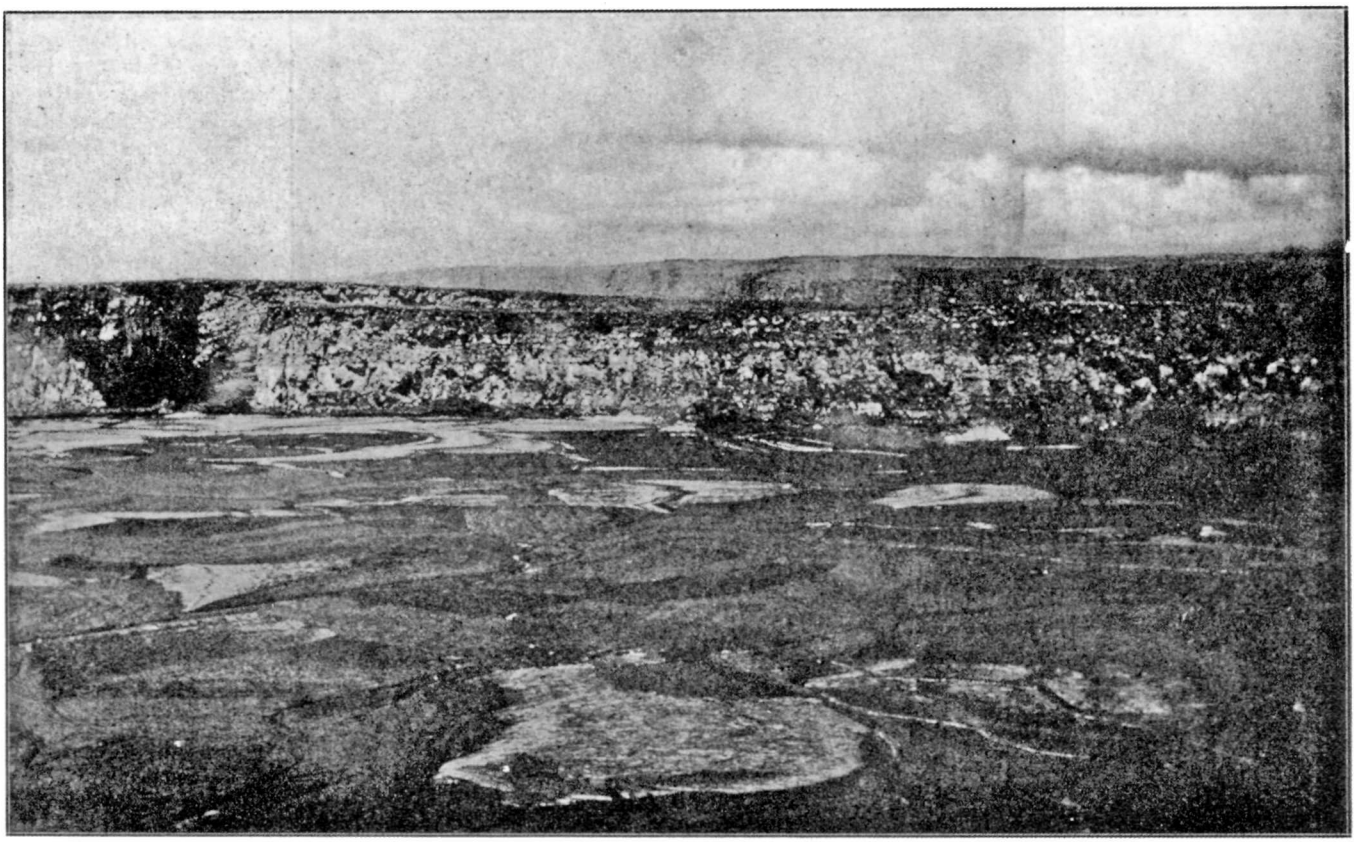


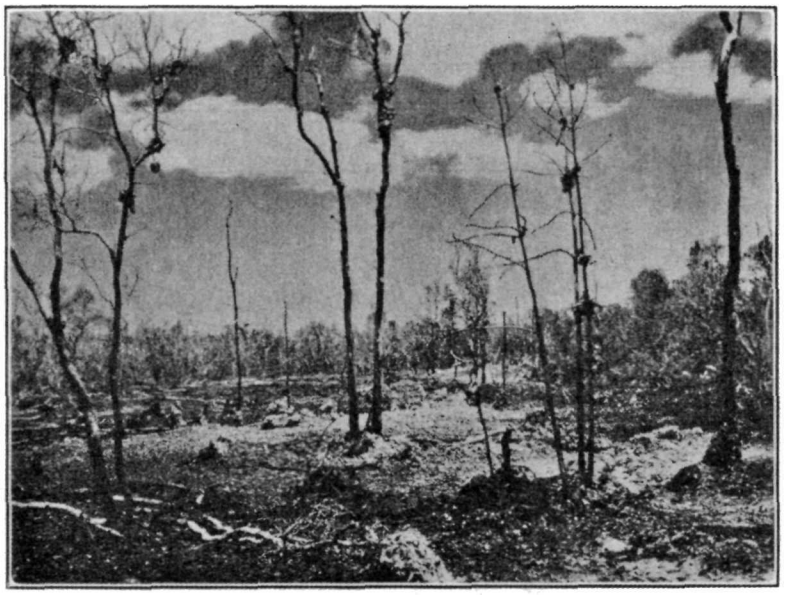
Halemaumau from the northeast rim, June 30, 1923, when t he lava was liquid from cliff to cliff 129 feet below the edge. Photo Jaggar.

EVENTS PRECEDING THE GREAT ERUPTION 1924

As the steam-blast eruptions of Kilauea in May 1924 represented the end of the supercycle of 134 years and of the last of the 12 eleven-year cycles with its peculiar terminal characteristics, it is profitable to inquire what prophetic occurrences filled the years just preceding the eruption. For the similar eruption of 1790 we have only the hint in the tradition of the natives that there was a lava flow in Puna off to the east of Kilauea about 1788.

Until 1921 when in March there was a maximum of overflow from the actual lip of Halemaumau pit inside of Kilauea Crater, no very marked breakdown of the rim of Halemaumau had occurred, the pit outline enclosing the overflowing lava column was about as small as it had been in 1919, and the only outflow from the flank of Kilauea Mountain had been the Kau Desert activity of 1920. After the 1921 overflows the lava of Halemaumau subsided twice moderately with recovery of the lava following the sinking. Thus it may be said that until May 1922, or just two years before the great steam-blast eruptions, the only events that predicted those eruptions were (1) the supposition of a supercycle about 132 years long after 1790; (2) the general decline in volume of Hawaiian flows for the last half of the supercycle after 1855; (3) the down-hill progress of flank outflows from Mokuaweoweo 1914, to Puu o Keokeo 1916 and 1919, and then to Kau Desert 1919-20; this outflow from the flank of Kilauea was a suspicious new feature.

We read in the journal of the Observatory May 13, 1922, "This day was the end of the prolonged rise." The liquid lava had risen to a point 49 feet below the rim, fountaining and splashing activity varied, outer pools of lava between inner crags and the rim of Halemaumau often overflowed their banks, flames were abundant, and an oven cone on a crack outside of Halemaumau in the floor of Kilauea Crater showed glowing slag about 50 feet down. Then in the third week of May the rising which had started in November 1921 ceased, and by May 21 the lake level had dropped 300 feet steadily and majestically, the crag peaks between the pools maintaining their identity as they went down. Avalanches from crags and walls were numerous. There followed swarms of earthquakes, many of them perceptible over the island of Hawaii. The shelf of new lava caved away, making glowing avalanches. The crags and lava lakes were enveloped in debris slopes. Avalanches increased and sent up cauliflower clouds of dust. On May 26 this made a thunderous roar heard many miles away, the rim of the pit was generally carried away, and at the southwest the collapsed rift made a smoking



The Chain of Craters rift of August 25, 1923, with lava spatter in the trees and sulphur along the flow-crack in the forest. Locality west of Makaopuhi. Photo Emerson.

canyon extending Halemaumau 500 feet in that direction. The pit was enlarged from an oval of maximum diameter about 1,400 feet to an irregular cavity 2,000 feet long by 1,500 feet wide. By May 31 the top of the lava column had subsided at least 1,000 feet and the vacant cauldron was floored with debris 861 feet down. At 8 p. m. May 28 lava fountains broke out on the side of Makaopuhi Crater (end of Chain of Craters Road) along the rift east, and it was evident that the great eastern rift was receiving the underground drainage from Halemaumau and vomiting up a little of it in these local eruptions. This outflow was all at lower level than the Kau Desert outflows of 1920. In the map on Page Four Makaopuhi is near the letter "P" of Puna.

The lava column was executing pulsations of subsidence, but the mountain edifice had not yet yielded sufficiently to let the lava of Halemaumau escape under the ocean to the east. Superficially the lava crust solidified in Makaopuhi and Napau, in July and September of 1922 the liquid slag burst through the talus slopes of Halemaumau and started to fill the bottom of that pit, and pulsations of rising followed so that at the end of June 1923 a sea of lava with a narrow shelf around its border extended from cliff to cliff only 129 feet below the edge of Halemaumau. The sequence of events always suggests that the basaltic melt has an unconquerable gas potential actuating it, but the pressure of the big mountain slabs, now yielding a little to the gas expansion, and now again reasserting itself under gravitation, controls what the gas in solution can do. According as the edifice breaks down or splits apart in spasms through the ages, the so-called eruptions of lava break out or fill the pits as directed by the yielding of the mountain slabs. A glance at the map of Kilauea shows that it consists of a series of big slabs on the southeastern slope of Mauna Loa which have been slipping seaward for ages.

On August 24, 1923, the lava in Halemaumau was still high, only 220 feet down, but a subsidence had begun. Local earthquakes became numerous, by August 26 the bottom of the pit was full of enormous jagged and tilted blocks and hardly any fire was visible except where lava was streaming out of a crack at the southeast. By August 28 Halemaumau was floored with a tumbled mass of broken blocks 564 feet down, and a new crack in the Chain of Craters country was spouting lava and sending up white fumes full of poisonous sulphur vapors. This was in the forest west of Makaopuhi, and the photograph on Page Two shows the sulphurous stain along the flow-crack and the lava spatter in the trees. The belt of cracks extended north and south for a width of 500 feet and a length about 2,000 feet. Patches of sluggish pahoehoe developed at both ends of the crack belt, round holes were produced along the rift lined with new lava, small cones and innumerable tree molds were formed, and patches of sulphur appeared in certain places. In September the lava reasserted itself in the bottom of Halemaumau and began to rise. The oozing up of lava near Makaopuhi lasted only a few days, the visible steam there continued for months, and hot vapor along the crack developed blue-green algae, these hot places still persisting in 1931.

Again there was revival in Halemaumau, and again the great sea of lava was only 121 feet below the rim of the pit on January 27, 1924. This was followed by the same kind of lowering which had occurred in August of 1923, leaving in February and March a collapsed tumble of debris with a glowing hole about 400 feet down.

The event of April 21 at Kapoho near the east point of the island of Hawaii was unprecedented for the present generation of men. Prolonged, mild quaking began, there were several hundred shocks for three days, the ground cracked open in several directions, cracks from six inches to nine feet across yawned athwart the roads with a gradual process of opening, and the principal movement proved to consist in a lowering of the fault-block south of the Kula cliff shown in the photograph on Page Three. This was an old fault-scrap facing southward. The block which moved was about four miles long east and west, by a mile wide north and south, and it apparently hinged

about the cracked zone on its south side near Kapoho village, and lowered the most along the Kula cliff on its north side, where the ground at the foot of the cliff gently dropped in the course of a few hours from 9 to 13 feet. This movement extended all the way to the sea at the east, with gaping cracks along the line of the cliff, and the lowering at sea level made new salt water lagoons and drowned the longshore vegetation. There was not a single big earthquake in the whole series of shocks. The fault block moved almost as though it were plastic. Houses and tanks which stood at a quarry against the fault cliff were lowered bodily and remained erect. Releveling of the ground showed a new profile 9 feet lower than before south of the quarry, and one foot lower than before at Kapoho station.

This April crisis at the east was the last premonitory happening before the Kilauea steam-blast eruption. It was led up to by earthquakes along the eastern rift which seemed to indicate that the lava was splitting its way in that direction. When the great crash came in Halemaumau in May, the supposition appeared to be justified that the lava escaped under the ocean to the east. The diagram at the top of Page Four exhibits one of the characteristic lava pulsations that led up to the great engulfment. T.A.J.

TILTING OF THE GROUND FOR MARCH

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the dirction given.

March 2-8	0.7 second	SSW
March 9-15	2.5 seconds	SW
March 16-22	1.0 second	S
March 23-29	1.9 seconds	SSW
March 30-April 5	1.1 seconds	E

KILAUEA REPORT No. 1003

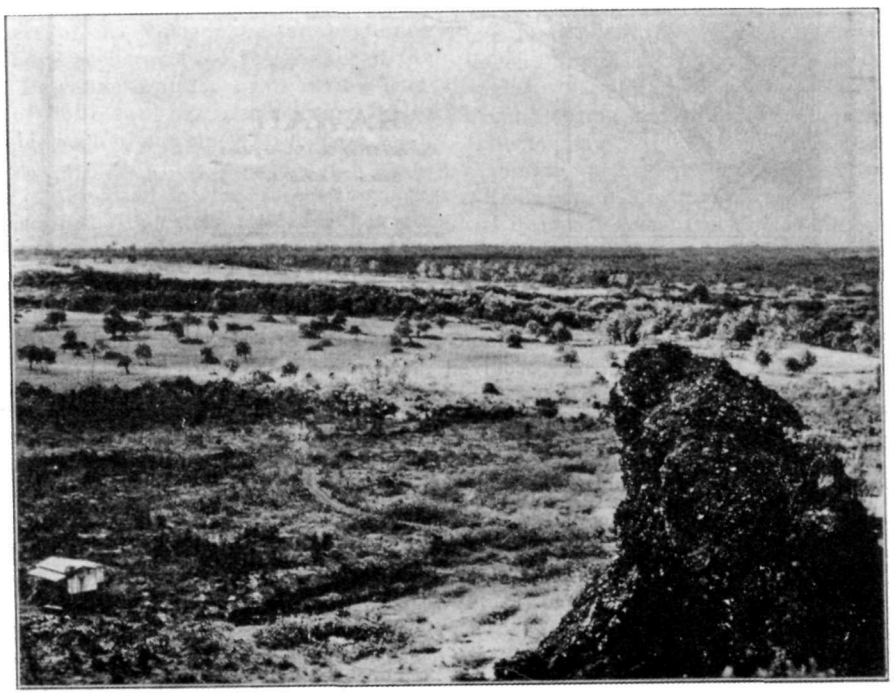
WEEK ENDING APRIL 12, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

On April 7 at 3:30 p. m. no changes were observed at Halemaumau pit, no tremors were recorded on the pit seismograph, and there was a little steam on the south talus. On April 8 at 2:40 p. m. a small avalanche caused dust to rise from the pit. A little fume still rises from the sulphur spots, and the western of these is brighter yellow than the others. On April 11 at 10 a. m. the 1930 cone at the top of the new lava heap of last November had caved in a little at its upper edge. The pit seismograph indicated a sudden tilt away from the center between the 7th and 9th of April.

The Observatory seismographs indicated 17 tremors for the week ending at midnight April 17, two of these on April 10 being continuous for periods of 2.5 minutes and 7 minutes, respectively. *Tilting of the ground* was very slight NNE, and microseismic motion very slight.



Kula fault of April, 1924, near Kapoho, east point of Hawaii. The foreground dropped about 10 feet, the country was seamed with cracks, and scores of earthquakes occurred. Photo Emerson.

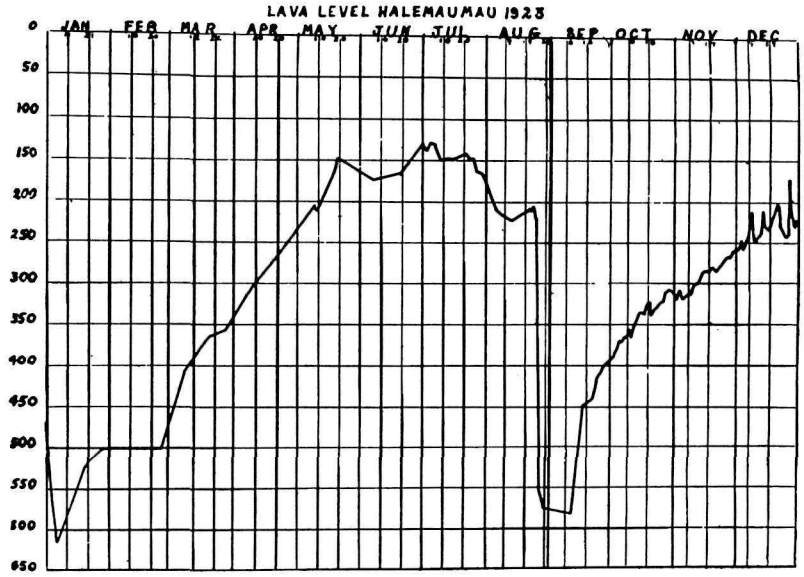
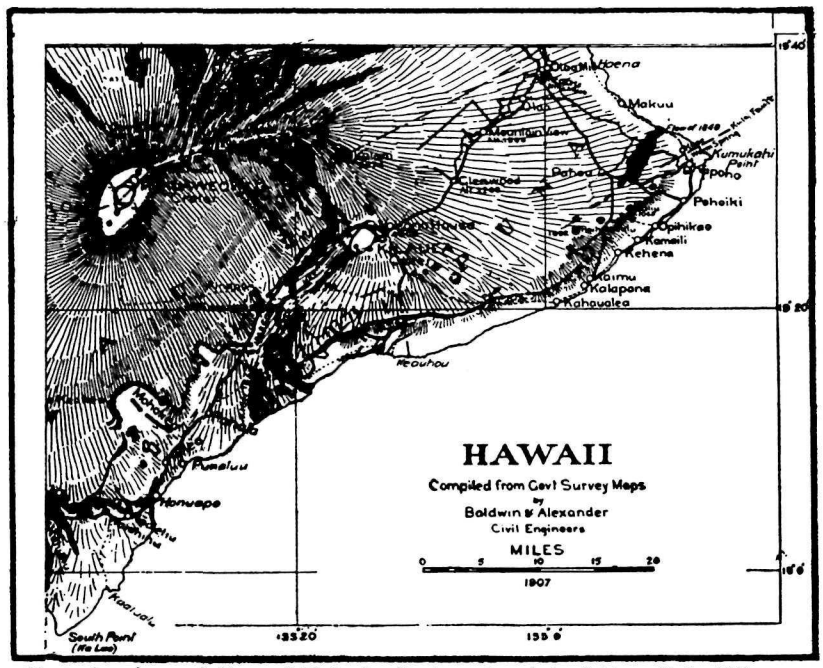


Diagram showing depression in feet of lava level below rim of Halemaumau during 1923. Shows sudden depression to 575 feet before the Chain of Craters outflow.



Map showing relation of Kula fault at east point of Hawaii to Kilauea and Mauna Loa. Here occurred the depression of April 1924.

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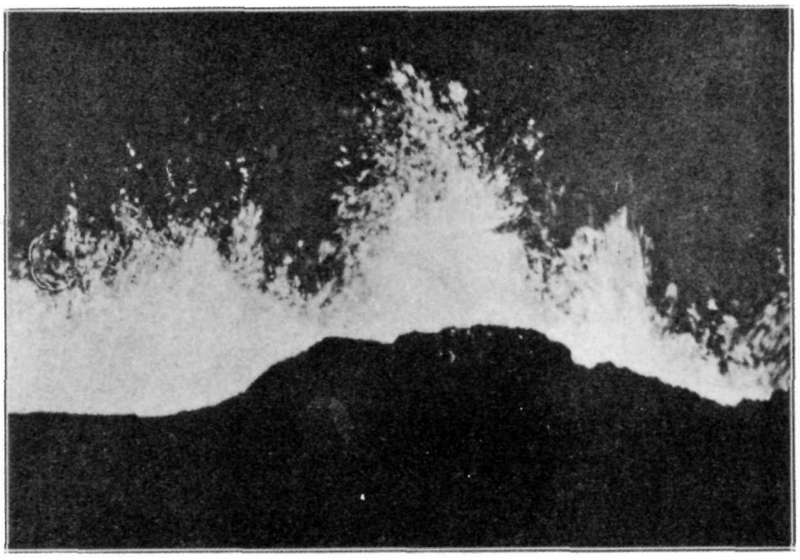
The Volcano Letter

330

Two dollars per year — Ten cents per copy

No. 330—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 23, 1931

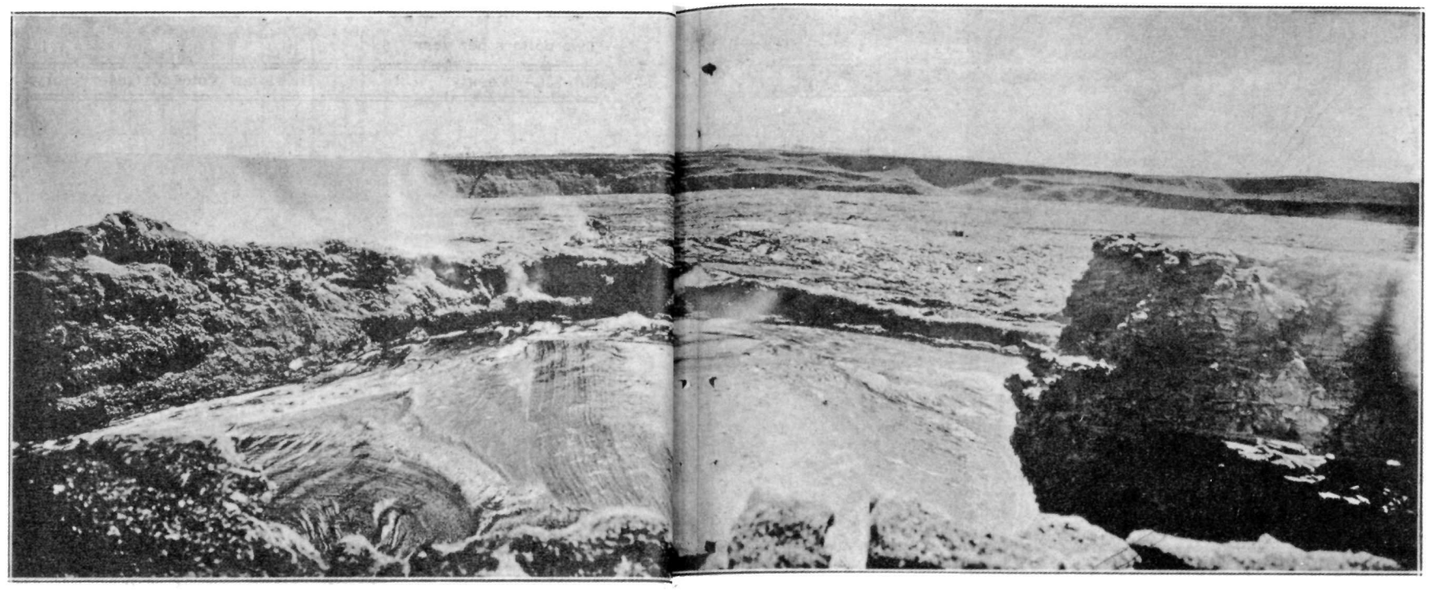


Source fountains of the main lake in the rift crack of the Alika flow, October 1, 1919, SW flank of Mauna Loa, 7000 feet elevation. Photographed by T. A. Jaggar 600 feet away, at night. "The great fountains 200-300 feet high were spouting continuously along the fissure for a thousand feet of length like a wall of red flames. In detail they were made of incandescent, light, crumbly material, yellow when it shot up, red when it came down. The noise was a roar like surf."

THE PEAK OF THE VOLCANIC CYCLE

In recent numbers of the Volcano Letter, beginning with No. 319, there have been reviewed the events of the last twenty years of Hawaiian eruptions, this review leading to a discussion of the eleven-year cycle from 1913 to 1924 as a type of twelve such cycles since 1790. Last week we discussed prophetic events which preceded the great steam-blast eruption of 1924, and in No. 328 that remarkable eruption was described. Pulsatory risings of about a year each followed by collapse and flank outflow were the features forecasting the grand crisis, and that crisis itself was an unusual collapse over lava that receded deeply. The immediate recovery of the lava and its appearance in the bottom of Halemaumau in high spouting fountains within two months after the time when the steam blasts ceased inaugurated a new cycle. We are living in the midst of that cycle, now characterized by small manifestations of spouting lava in 1924, 1926, 1927, 1928, 1929 (twice), and 1930. The 1926 happening began at the very top of Mauna Loa, so that the conclusion seems justified that the gas energy within the underground lava itself was not exhausted in 1924. Within two months hot and very vigorous lava was spouting in the Kilauea pit, and within two years it was bursting out through cracks 13,000 feet above the sea in Mauna Loa. What was exhausted, then, was the patience of the mountain in consenting to yield, now here, now there, more and more until 1919-21 when both Mauna Loa and Kilauea were inflated and let the lava squirt up through cracks. Then the great mountain blocks had been so uplifted and loosened that they even let the lava ooze out under the ocean somewhere east of Puna in 1924 about May and June, when the ground water flowed into the chamber under Halemaumau, and the steam puffed up like a freight engine. But the coldness of the Pacific conquered the submarine oozing slag, the frothing melt backed up into the Halemaumau conduit and reappeared in July 1924, the mountain blocks settled down hard owing to what had been withdrawn, and to their enormous weight, and the gas in the deeper magma was no longer able to lift them. The weight control of gravitation had again asserted itself.

This weight control of gravitation in a volcanic mountain, or better in a volcanic island consisting of several mountains, is like the spring control of a safety valve on an engine, opening only when the internal lava pressure has passed a certain minimum. The internal pressure under the volcanic island may be thought of as accumulating at a steady rate through the ages. The island safety valve has two or three openings, Mauna Loa, Kilauea, and Hualalai, with a heavy shell over cracked blocks determined in weight by the accumulation of the ages. This weight accumulation is operating against the pressure accumulation. Once in eleven years the underground lava gradually and irresistibly forces itself up into cracks under the several openings and extends out along the rift belts that break up the mountains into blocks. How this hot matter grades down into a pudding having horizontal extension we do not know. There may be subordinate puddings under each volcano dome led up to by old cracks extending down into bigger and deeper puddings representing



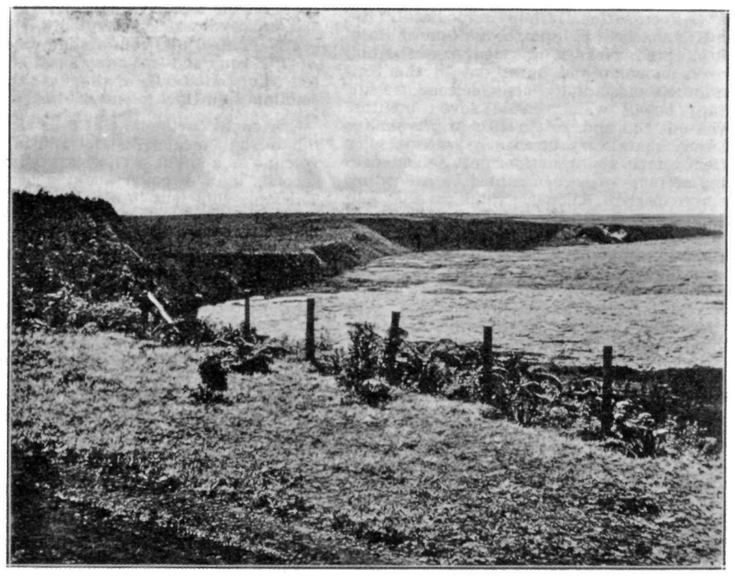
May 10, 1919 looking NE. across main lava lake in Halemaumau from the t[op] of the dome of live lava, when the eastern edge of the pit was completely overflowed and indistinguishable. The photographer was thus standing on the top of [mov]ing lava column. Edge of pit underlies small cone in background. Benches right and left are live lava, wholly inside the pit. Central part of lav[a] me was at this time 87 feet above what had been hitherto the edge of the pit.

ancestral domes. The height and size of the mountain puddings inside the island, and their supply of gas from the larger and deeper pudding, are what determines whether Mauna Loa or Kilauea shall erupt. If the weight control of Kilauea, the lower mountain, relative to its private pudding, is greater than that of Mauna Loa relative to its higher and larger internal pudding, it will be the higher mountain Mauna Loa which erupts. The yielding of each particular edifice relative to its internal lava expansion is what determines eruption. For the lava is not to be thought of as a rising liquid, but rather as a local expanding body of paste full of frothing gas.

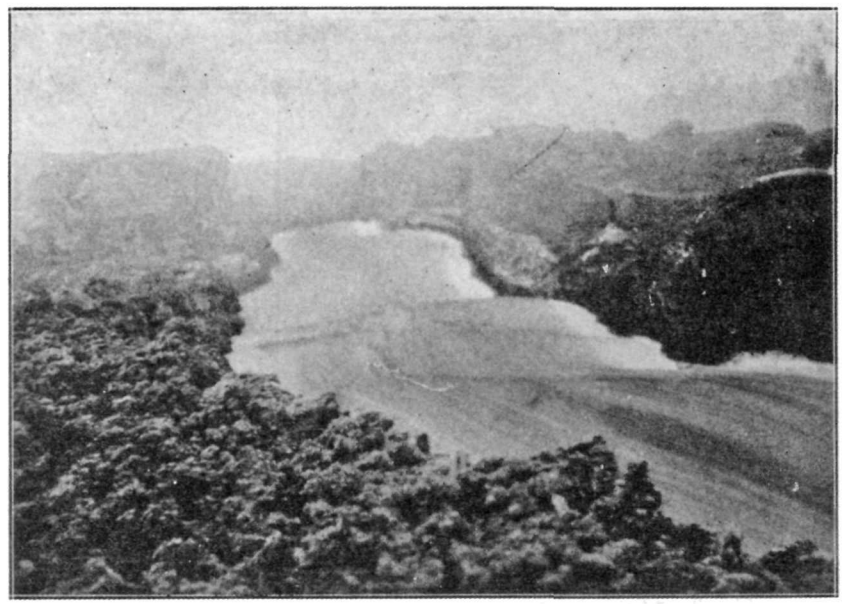
The yielding of the edifice needs clear definition. If a mountain block merely lifts on the flank of a pudding of underground slag, it does not weigh any less, and moreover solid basalt is heavier than pasty lava. Therefore what happens is an arching up or a tilting of blocks, and if new lava from below inserts itself into a mosaic of blocks up vertical cracks, it must spread the mountain apart horizontally. The eleven-year yielding is merely an average resultant of arching and tilting of blocks, swelling and penetrating of the lava, permission by the blocks to be pushed sidewise, slipping downward of those blocks which are on the slope toward the sea, breaking open of cracks at the surface to release pressure and start foaming in some parts of the lava, letting out of a large volume of paste, and re-assertion of weight to restrain the foaming by new flows on the upland or settling of crater fills. By "blocks" are here meant the big slices of mountain shell that lie between the important fault-rifts. These shells are miles wide and tens of miles long.

As there are big blocks of rock in this sense between the flow rifts of Kilauea and those of Mauna Loa which tip and squeeze the Kilauea pudding when Mauna Loa outflows come to an end, having lifted the shells and released the Halemaumau lava while the Mauna Loa flows were in action, it is easy to understand underground connection between the two volcanoes such as was described in the subsidences at Kilauea of 1914, 1916, and 1919 (Volcano Letter No. 324). Each of these sinkings came just at the end of a Mauna Loa flow period. Each Muna Loa flow period was accompanied by a gradual gushing of lava and rising in the Halemaumau pit of Kilauea.

The peak of the volcanic cycle 1913-24, measured by internal pressure, was the intense gushing of lava over the Kilauea floor from Halemaumau pit, full to overflowing in October-November 1919. During this same time Mauna Loa was giving vent to the Alika flow. Throughout 1919 this flooding of the Kilauea Crater floor had been going on, with very slight ups and downs in the central pit, but from the very day when Mauna Loa broke out at the end of September, the Kilauea flooding increased. The process that led up to the nearly continuous overflowing of Halemaumau had been a very strong rising of lava in the pit at an increasingly rapid rate after the subsidence which had followed the 1916 outbreak of Mauna Loa. The year 1917 was intensely spectacular at Halemaumau, the observers could walk down on the lava floor surrounding the liquid lakes, and many experiments were made of taking temperature, collecting the gases, and sounding the slag pools with steel pipes. The year 1918 began a series of overflows of Halemaumau, first in one direction, then in another, from the lip of the pit, so that by 1919 the overflowing was virtually continuous. This all culminated in the Mauna Loa eruption of the autumn, which came to an end gradually, and at no very definite date, some time in November. It is impossible to name the day when such an eruption comes to an end, for the lava is flowing in tunnels beneath surface shells of hardened slag, the rift-source region is usually crusted over and may show glowing cracks for



November 30, 1919 looking south from Observatory across Kilauea crater. The light colored nearer part of the crater floor is the fresh, then-glowing frontal portion of the live overflows from Halemaumau which had been pouring forth for seven months. The flows went west, north and bent east, filling the north corner of Kilauea crater 60 feet deep. Photos Jaggar.



Middle stream of the Alika flow of 1919 early in October at road crossing in South Kona, showing the standing waves of rushing golden melt travelling eleven miles per hour. This stream was forty feet wide, within fields of consolidation of its own aa overflooding. These fields also moved, but very slowly. Mauna Loa flow, elevation 1570 feet above sealevel.

weeks, and there is no evidence left of any particularly sudden down-sinking at the source cone of the flow. Possibly some such reaction would be seen there if there were inhabitants.

At Kilauea, however, as has been often described in these pages, a remarkable, quiet, and sudden sinking 600 feet of the entire lava column in Halemaumau pit occurred November 28, 1919, as though it were a definite reaction from the Mauna Loa cessation. Then immediately the violently foaming Kilauea lava rose in the bottom of Halemaumau pit until in three weeks it was nearly at the top, then in three weeks more it had burst out in the Kau Desert southwest of Kilauea, and a long series of flank outflows of Kilauea began which lasted seven months. This, however, was not the end, for in 1920-21, December to March, there were again very intense overflowings of Halemaumau, after temporary reactions of subsidence. The March gushing of 1921 was accompanied by a flooding of the entire southern part of Kilauea Crater, so that one flow passed through a gap in the sand hills which bound the crater on that side. The fountaining was so violent that forty-pound blocks of crust were flung up into the whirlwinds over the fountains and dropped 300 feet away. Halemaumau was a surface saucer full of rushing, golden melt, building up a big spatter rampart at one side, with islands out in the middle. Then there came moderate subsidences, followed by the big ones of 1922 and 1924.

T.A.J.

KILAUEA REPORT No. 1004

WEEK ENDING APRIL 19, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit in Kilauea Crater the only change observed on the forenoon of April 13 was that the sulphur spots on the new lava floor of 1930 seemed brighter yellow. The weather was dry and no steam was observed on the south talus. Dust from a slide rose at the pit at 3:30 p. m. April 13, and at 10:30 a. m. April 17 a fairly large avalanche fell from the middle of the wall above the northeast talus, sending up a thick cloud of dust.

A slight earthquake at 5:58 a. m. April 17 was strongly felt in the Volcano District and in Hilo, observed near the volcano as a slight preliminary bump followed in about two seconds by a stronger shaking occupying several seconds. This was sufficient to alarm a dog and in the region three miles toward Hilo from Kilauea the motion appeared to be northeastward. The Observatory seismograph indicated distance of origin 14 miles. Another feeble earthquake felt locally indicated distance of origin 23 miles, at 10:09 a. m. April 16. In all the Observatory instruments registered 26 local disturbances, of which six were very feeble seisms and 18 were tremors. A very feeble shock at 10:23 a. m. April 14 indicated origin distance 12 miles. Tilt for the week was slight WNW, and microseismic motion was slight.

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No. 331—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | April 30, 1931



Northeastern corner of Halemaumau pit showing lava overflows, from northern and eastern sides of the lake, uniting to fill the wall-valley depression. Lava lake outside of picture at the left.

RISING OF PIT LAVA KILAUEA 1917

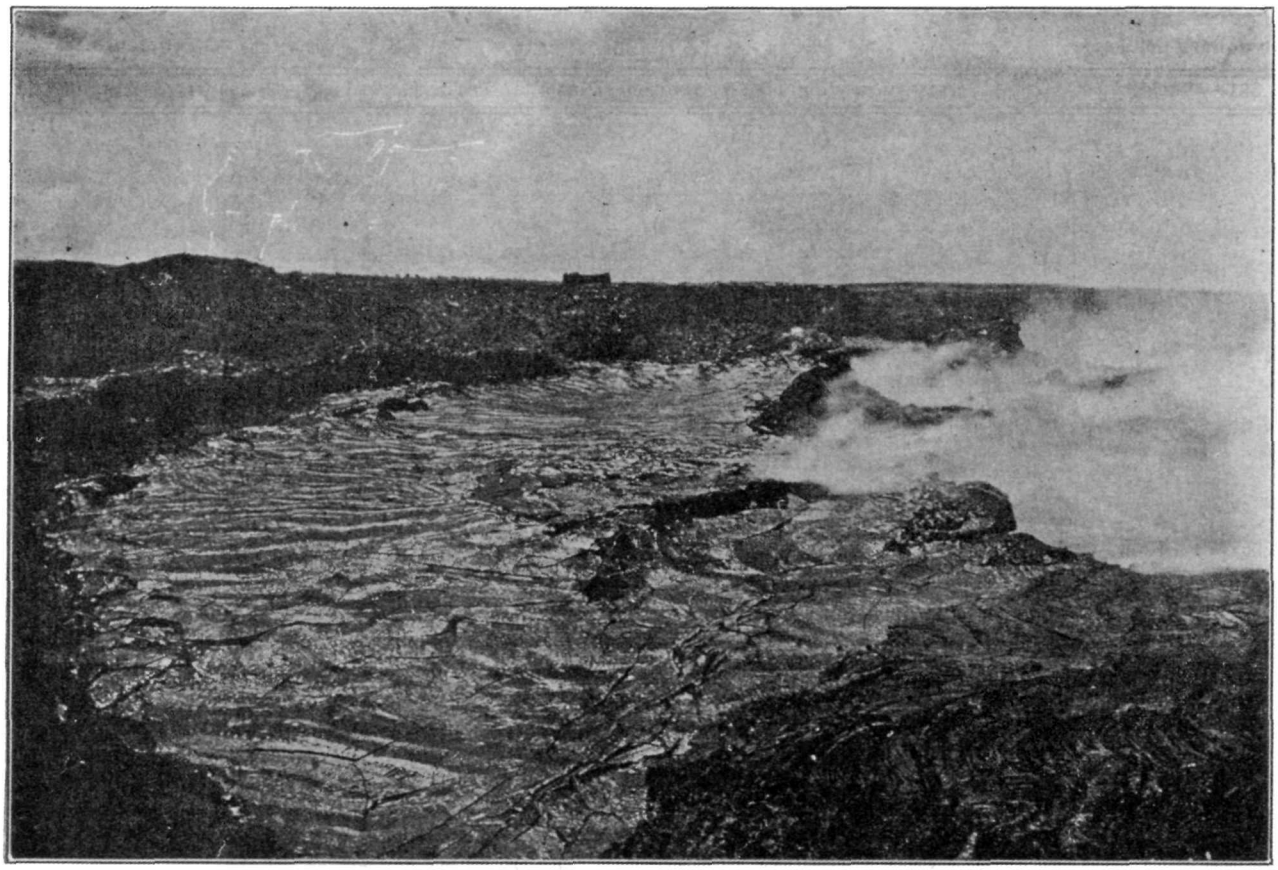
The first half of the cycle 1913-1924 was characterized by increasingly rapid rising. This showed itself by three, progressively more voluminous, lava ejections from Mauna Loa, and by a general rising of lava in Halemaumau pit, the inner well of Kilauea Crater. In order to understand the detail of the processes involved in the spectacular overflows of the inner lava lakes of Halemaumau pit, alternating with recessions of the lava from month to month, we here present a map and some photographs to exhibit the relation of the bench magma to the liquid lava. This is one of the hardest subjects for an outsider to understand.

The outline map of Halemaumau on Page Four has below it a true scale structure section showing what we saw and measured at the Observatory January 12, 1917, when with transit we went from one trig station to the next, as indicated by the little triangles around the rim of the pit. At the bottom of the structure section there is indicated a true scale extension downward of the pit profile as it was June 23, 1916, just after the liquid lava had come back vigorously, following the subsidence of June 5, which was described in Volcano Letter No. 324. The liquid lava at that time had filled a saucer in broken rocks, and then made its own spatter bench around the edges. The shape then of the liquid shown in black if we filled in the bottom would be that of the contents of a saucer, and as the lava was fed upward through small holes in the talus below, the only wells extending downward would be those holes, and everywhere else the liquid would be streaming over a hardened shell of its own glassy substance which had congealed against the cold broken rocks beneath it. The bench around the edges, then, was nothing more than the border expression of the hardened bottom lava.

What happened thereafter when the lava rose 500 feet filling the pit nearly to the top? The supply of liquid lava up the wells carries a certain amount of gas in vesicles which is reacting to keep it hot, but the air above, the sides of the pit, and its own congealed bottom lining are all tending to freeze the hot froth. The heat energy available can keep a saucerful liquid and streaming, the saucer in question being roughly of the size of the first pool. The rest that congeals under the pool is like the lava fields, that congeal on either side of a small medial stream, in a Mauna Loa flow. The congealing may be only partial so that this semicongealed substance is still mobile, and the upright wells are maintained through it. The rising then resolves itself into an uprush of the liquid froth through the wells, an overflow in pulsations of the liquid in the top saucer, and such additions of gas and heat to the under substance, as will cause it to swell or tumesce, under the hardened shells of overflow, that form the benches or platforms around the lava lake, or lakes.

If now we examine the map and section of January 1917, we see the main lava lake in black streaming from three coves at the west, and back of these, two source ponds, which are over wells. At the north, and at the south, there are overflow benches, the northern ones wide, and the southern ones narrow. There is a small wall pond at the south. There is a big crag-mass between the northwest pond and the lake which exhibited a tendency to rise gradually, as the tip of a northwestern sector of overflow shells. There is another such crag at the east, and a more complicated group of them making a peninsula, and southward tilted hills of uplifted overflow lava, at the southwest. At the southeast there is a line of big spatter grottoes along the edge of the lake, with inflowing liquid lava, as indicated by the white arrows. There is the same thing at the northeast. During subsidences these were revealed to be cascades into sinkhole wells, and the bottom of the lake of liquid was revealed to be a paste only 45 feet below the overflow bench.

This paste, under the shells of overflow, and under the crags created by the swelling up from day to day of the shells of overflow, is the substance spoken of as bench



Depressed northeastern floor of overflow in Halemaumau pit May 16, 1917, from north station, to be compared with elevated floor northwest shown on Page Three. These illustrate the balance whereby the weighted side of the floor goes down and the other side comes up creating a tabular crag of bench magma. The lava lake is in the fume at the right.

magma, and this semicongealed substance rises and falls from week to week as constituting the greater part of the lava column, apart from the mere wells, as shown in the section under the map. The depression of the lava at this time was 87 feet below the southeast trig station, and the bench marks (B.M.) east and north of the pit on the floor of Kilauea Crater stood at elevations 3,697 feet and 3,700 feet respectively above sea level.

The Journal of December 30, 1916, says: "The lava lake is a very different object from the elliptical pool of last June. It appears like a mighty river of fire amid hills and tilted crags, shaped in general like a "W." Roundish coves are bordered by high ramparts built up by overflow and by splashing fountains which have constructed huge domes, with glowing grottoes inside. Back of these ramparts, the overflow surface slopes back to the walls of the pit, so that the lake is really at the top of a low, flat, inner cone. Higher than these floors on three sides of the lake, but wholly within the pit, are craggy hills benched and fissured, which stand from 40 to 80 feet above the liquid lava."

"Other irregularities which add interest to the scene are high, flaming and puffing chimneys, outlying ponds of lava, and driblet cones built up over fissures in the floor. Following all the bends the lake is fully 1,800 feet long, with channels varying in width from 50 to 200 feet. The scene is magnificent from any side of the pit, and there is hardly any obstructing fume."

On April 6, 1917 we find the statement, "The rising of the crags is symmetrical about a central point in the pit, where the three arms of the lake lie at about 120° to each other. The sectors of bench, between these arms, are sinking around the circumference of the pit, and lifting their convergent points near the center. The marginal sinking is started by weight of the overflows, and increased by weight of debris fallen from the outer walls. As a result the south island peninsula, the crag-mass, and the east island are now all rising, and the floors are sinking. The inner bench confining the lake is therefore highest near the center of the pit. As usual the northwest and west ponds are the conduits of uprising liquid lava."

The beautiful symmetry of tumescence or swelling in the center, overflow of the lakes to weight down the wall valley around the edges, and up-tilting of the crag sectors to rise highest in the center, has appeared again and again, during the measurements conducted by the Observatory, so that the sectors of shell may be thought of as eternally overturning, away from the center of the pit. No solidified lava, except possibly light pumice, is capable of floating on liquid lava. The solidified crags, however, in some sense do float upon the bench magma paste beneath, or are of almost the same specific gravity, but this paste is not liquid lava. In addition to the circular symmetry, however, there would often develop a bilateral symmetry as shown on the map, whereby the three source wells are in the southwest half of the pit, and this southwest half was uplifted; whereas in general the northeast half was covered with overflows and tended to subside, except for the temporary east crag, which afterwards became overwhelmed and sank down.

The picture on Page One gives a clear idea of the northeast quadrant of the pit being filled by lava overflows from the lake in May 1917, the observation hut of the Observatory, and the old horse corral, showing in the background. This heavy flow is weighting down the wall valley, and tending to lift up the crag shown on the left-hand side of the photograph. If now we turn to the photo-

graphs on Pages Two and Three, we see a very striking illustration, on May 16, 1917, of a downweighted northeastern overflow bench (Page Two) which by a series of floods from the lake had subsided. This is looking from the north station straight southeast across the northeast overflow bench. The photograph on Page Three is looking from the same place straight southwest, across a new elevated northwest table crag, which for many days was in process of mass uplift. The following are Journal quotations from the history of this uplift.

"On May 12, 1917, the lakes had risen from 11 a. m. to 12:30 p. m., the main lake much faster than the southeast pool so that the northwest cove and the southwest shore were overflowing. The west cone was gushing incandescent lava and the crags had continued to rise. The tabular northwest crag was rising strongly while the north chasm was sinking. This was shown by a cracked ridge of fresh flow lava, lifted on the side of the crag, and though only two days old it showed a vertical displacement of about six feet from its original position. On May 25 the northwest table crag showed an extraordinary uplift of 15 feet since the previous day, carrying with it a bench of fresh flows around its base on the east and north. Instead of *tilting, this tabular mass is rising bodily owing to inflow* beneath it of pasty bench magma impelled by the weight of lava floods much larger than it in area in the lake basin itself and on the floors northeast and northwest. On May 28 a sudden readjustment of the bench magma was accompanied by a brilliant flare with opening of crevasses into which perhaps the lake magma flowed so as to lower it temporarily while the central crags were uplifted. The east crag rose bodily 10 feet, and the northwest tabular crag was now above the rim of the pit. The large crag-mass rose so much with westward tilt that its northeast peak suddenly became its summit, whereas only that morning the middle peak had been the highest. The spatter markings along its base on the lake side were fully 40 feet high."

The northwest table here referred to, and shown on Page Three, occupied what in January was the north-northwest overflow bench, between lake and rim of pit (map Page Four). The photographs on Pages Two and Three were taken from the trig station, on north rim of pit, south of the letter "N". The balance between the rising crags and the weighted portions of the pit floor might be called "isostatic," but not because the crags are lighter. T.A.J.

KILAUEA REPORT No. 1005

WEEK ENDING APRIL 26, 1931

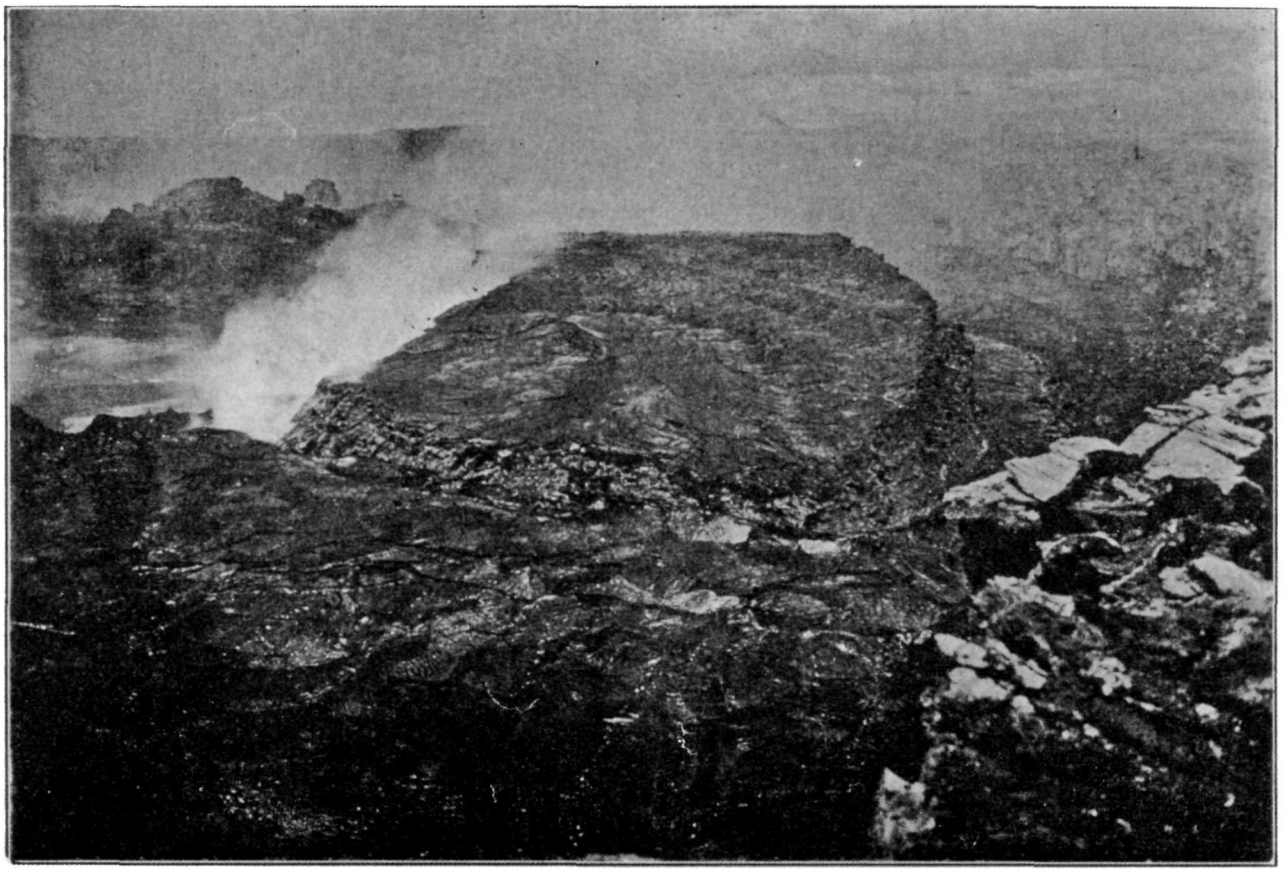
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Practically no changes have occurred at Halemaumau during the week ended at midnight April 26. Fume continues to escape steadily from the sulphur area north of the 1930 cone, which area is bright yellow. The instrument at the pit showed no volcanic tremors.

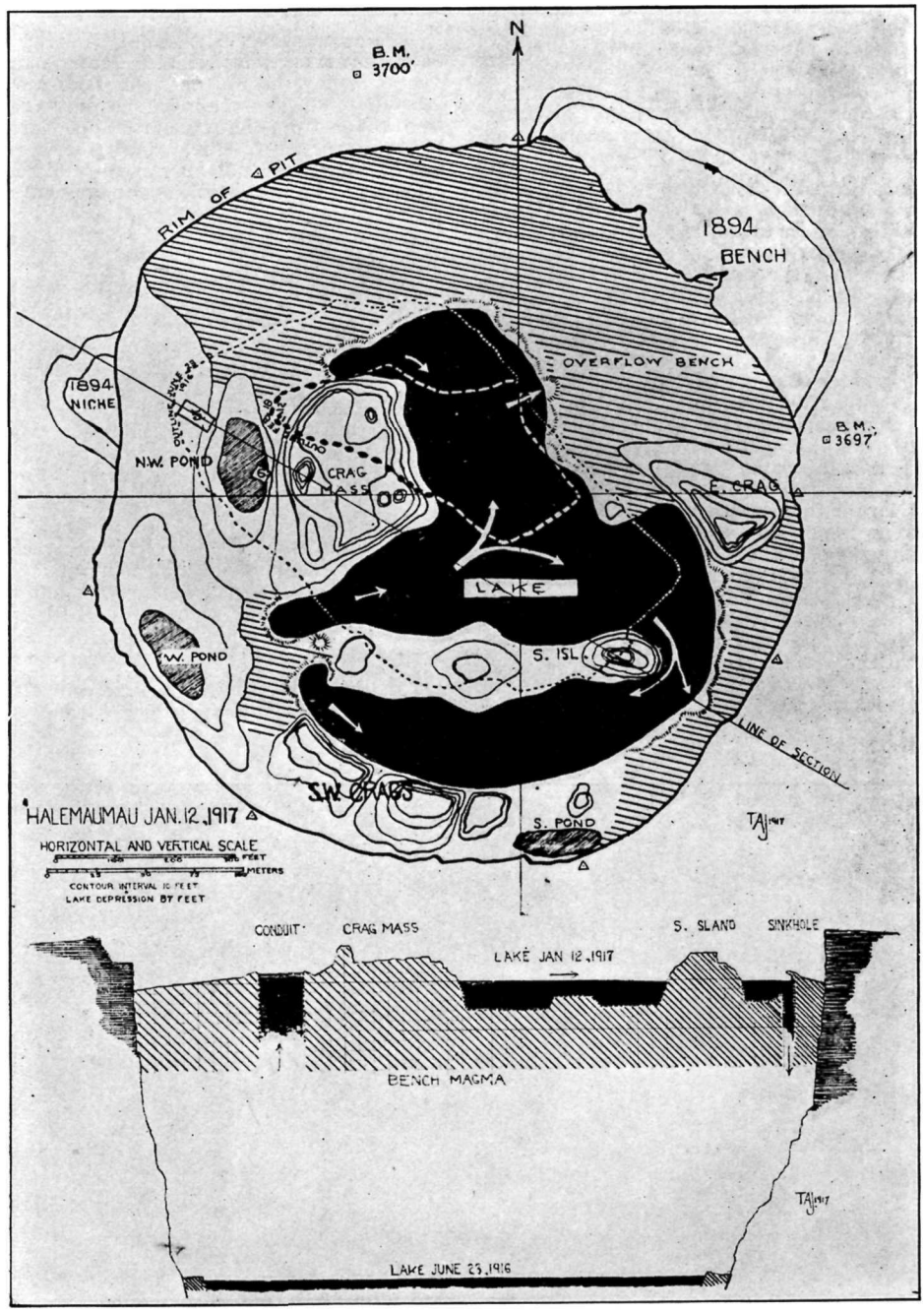
A total of 27 seismic disturbances were registered at the Observatory. Of this number were 23 brief tremors, three very feeble shocks, and one distant earthquake. The last recorded on April 24 for 10.5 minutes following 7:03 a. m. One of the very feeble shocks, at 11:25 p. m. April 25, indicated 25 miles distance to origin and was accompanied by tilt to the north; it was not reported felt.

Tilt was moderate WSW. Microseismic motion increased on April 21 from slight to moderate.



Elevated northwest table crag May 16, 1917, from north station, showing a block of bench magma in process of rising bodily by tumescence, or by the flowing in of paste beneath it, so that in two weeks its top was above the rim of the pit. This side of the floor rose, while the portion shown on Page Two was overflowed and subsided.

Photos Jaggar.



Plan and profile of Halemaumau pit January 12, 1917, when the great rise was in progress. Dotted outlines in map show progress of the rising and enlarging February 18, 1912, and June 23, 1916. Lower profile in section shows lake of June 23, 1916, in contrast to great development of bench magma, at higher level, six months later. Liquid lava black, source ponds shaded. Lake level 87 feet below southeast trig station. Crags with ten-foot contours.

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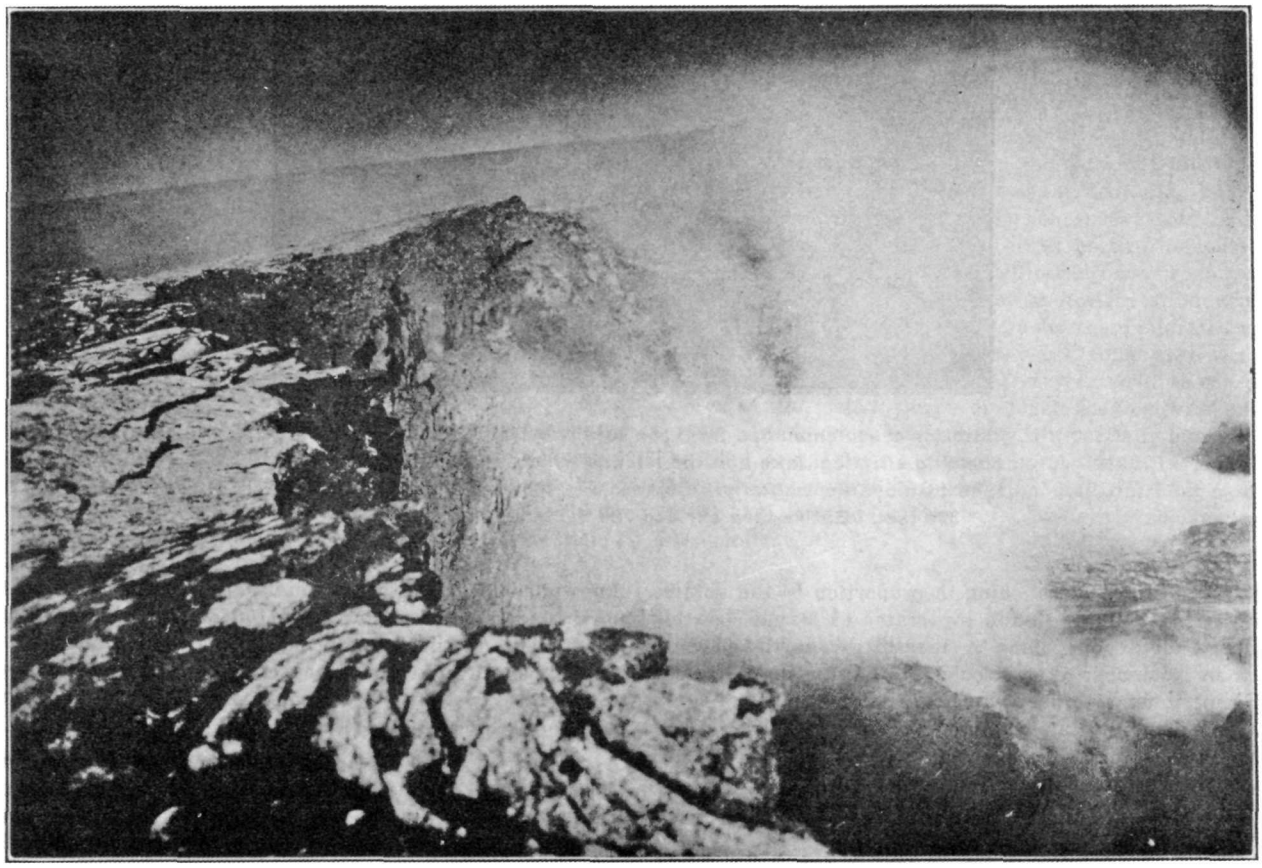
No. 332—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 7, 1931



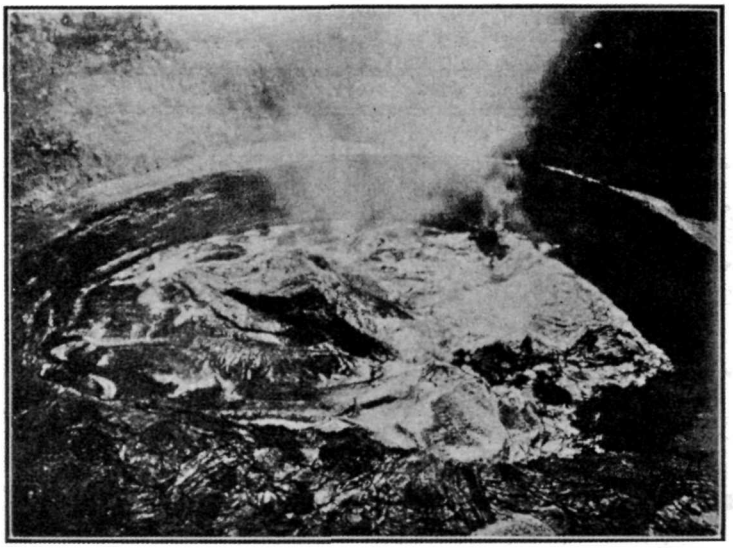
West rim of Halemaumau showing smoky conditions which were prevalent during the early years of the volcanic cycle 1913-1924. Taken from the south edge of the pit looking toward the region of the western source ponds, October 24, 1916.

BEGINNING OF THE VOLCANIC CYCLE

After reviewing twenty years of Hawaiian eruptions (Volcano Letters Nos. 319 and 320) and showing that the last cycle was 1913-24, we have recently described some details of this cycle, beginning at the end and going backwards. (Great Eruption 1924, No. 328, events preceding it, No. 329, Peak of Cycle, No. 330, rising of 1917, No. 331.) The beginning of the cycle was accompanied by two outbreaks of Mauna Loa in 1914 and 1916, and we have already described the remarkable subsidence of the latter year in Halemaumau (Volcano Letter No. 324). We have reason now in the cycle that began with influx of new lava in the bottom of Halemaumau July 1924, to make comparisons with the beginnings of the next preceding cycle. This might tell us something prophetic. But in doing so we must remember that 1913-24 ended with a gigantic collapse of about seven thousand million cubic feet of broken rock that fell down the Halemaumau shaft. This material is in the Halemaumau shaft now. No such fall of material occurred in 1913. At that time there was a solidified crust of live lava 600 feet down and the preceding cycle had been marked by slow risings with activity around the 300-foot level, and several sudden sinkings to depths not usually greater than 600 feet. Around the 300-foot depression level the lava column, therefore, of both bench lava and lake lava, was highly mobile, with an open shaft below into which it could sink. Now in 1931 the lava column 900 feet down is a pile of crusted layers, each not more than 60 feet thick, heaped up in five different years, and all comparatively stiff as a cake resting on top of the rock fill of 1924.

Such is the difference between the beginning of a new eleven-year cycle following the close of a supercycle, and the beginning of an eleven-year cycle which has many decades of mobility behind it. It is natural, therefore, that to some extent the years 1924-27 should be different in action from the years 1913-16. Both these periods, however, have been marked by gradual and somewhat intermittent rising of lava in the bottom of Halemaumau pit and by one or more outbreaks of frothy lava at the summit of Mauna Loa with eventual drainage in a Mauna Loa lava flow on the southwest flank of that mountain.

From May 1913 until just a year thereafter the lava lay 600 feet down in Halemaumau pit with great volumes of fume and steam making the bottom invisible. Slowly the lava rose in 1914, building spatter cones with glowing



Interior of Halemaumau from the southwest at 9 a. m. June 5, 1916, showing elliptical lake and the islands which on one occasion were seen to move horizontally. Depression of bench 253 feet, of lake 300 feet. Entire lava surface 780 by 675 feet in diameters.

trickles, the fume diminishing in proportion to the volume of lava fountaining. In the top crater of Mauna Loa big fountains burst out along a lengthwise north-and-south crack in November 1914, flooded the bottom of the crater and kept it up vigorously until the beginning of January 1915, the lava in Halemaumau meanwhile rising. There was no lateral outflow from Mauna Loa. When the summit activity of this big mountain ceased, Kilauea lava went down in Halemaumau 175 feet, but not very suddenly. This was the first of the occasions, that came under the observation of the Observatory, when in both rising and sinking, Kilauea showed sympathy with Mauna Loa.

The year 1915 produced a rising of lava in Halemaumau to a higher point than had been reached in 1914, and the peak of the rising in September was at the depression level 360 feet below rim of pit.

This September of 1915 produced a crisis of subsidence accompanied by many small earthquakes whereby the lava receded, the marginal bench cracked funnelwise and caved in, and the entire lava column lowered so as to leave a surging, liquid puddle in the bottom, destroying the integrity of the partially congealed saucer of bench magma. This saucer had consisted of four things: (1) The old slide-rock slopes of 1913, (2) the new liquid lava, (3) the overflow products of the lake, forming a bench, and (4) the partially congealed bottom material of the lake sometimes seen as shoals and islands. The measurements proved conclusively that these islands were part of the lake bottom and were not floating. The temperature of the liquid lava was proved quite incapable of melting the old slide-rock slopes of 1913. If we picture a cross-section of the top of the lava column at this time, we must imagine a stiff paste rising with the old talus breccia cemented in it, with a ring platform carried on its crest, the whole somewhat cylindrical in shape, and a shallow inside cup containing the lava lake fed by a well leading downward through the midst of the column of stiffer lava. Up the feeding well was coming the hot gas froth, which broke through the crust of the lake periodically about once a minute in what was known as "Old Faithful" fountain. This froth imported new fundamental magma from the depths, heated by gas reactions, and thereby this material was liquified and vesiculated to a fluid condition very different from the fundamental magma deep down under pressure, where it is presumably stiff, rigid, and heavy.

The September lowering was from depression 360 feet to depression 480 feet. The subsidence was like the one that had followed the Mauna Loa eruption in January of the preceding winter, but there was greater lowering in just such proportion as there had been greater clearing out of the throat below. The talus fragments had in a measure been appropriated as part of the bench magma column. This column had risen from a narrower throat below to a wider funnel above. Consequently with the uplift liquid lava occupies the ring channel and discharges through a border well into the upper saucer. By this process with every pronounced rising the throat is cleared bigger, and the pulsations of subsidence are permitted to go deeper. The lava entering loses its gas, becomes heavier and pours downward in some sinkhole wells, and the "Old Faithful" central well may reverse its flow and become a sinkhole at times.

The curve of rising and falling showed sudden drops in January of 1915, September 1915, and June 1916, each drop being bigger than the one preceding. As the first and the third of these followed the recession of lava into Mauna Loa after an outflow there, it appears altogether probable that the middle one of September stood for the same process. That is, lava rising into cracks under the center of the island, then escaping laterally by extending the cracks farther, thereby lowering its hydrostatic level, while Halemaumau as a gauge off to one side recorded the movement.

In early autumn of 1915 the circulation developed fiery cascades pouring into eastern coves and into a small outlying east pond connected by a tunnel with the main lake. At the west end was a source pond of rising lava, whence the lava streamed eastward to splashing border grottoes. Rising of liquid overflowed the floors around the lake after

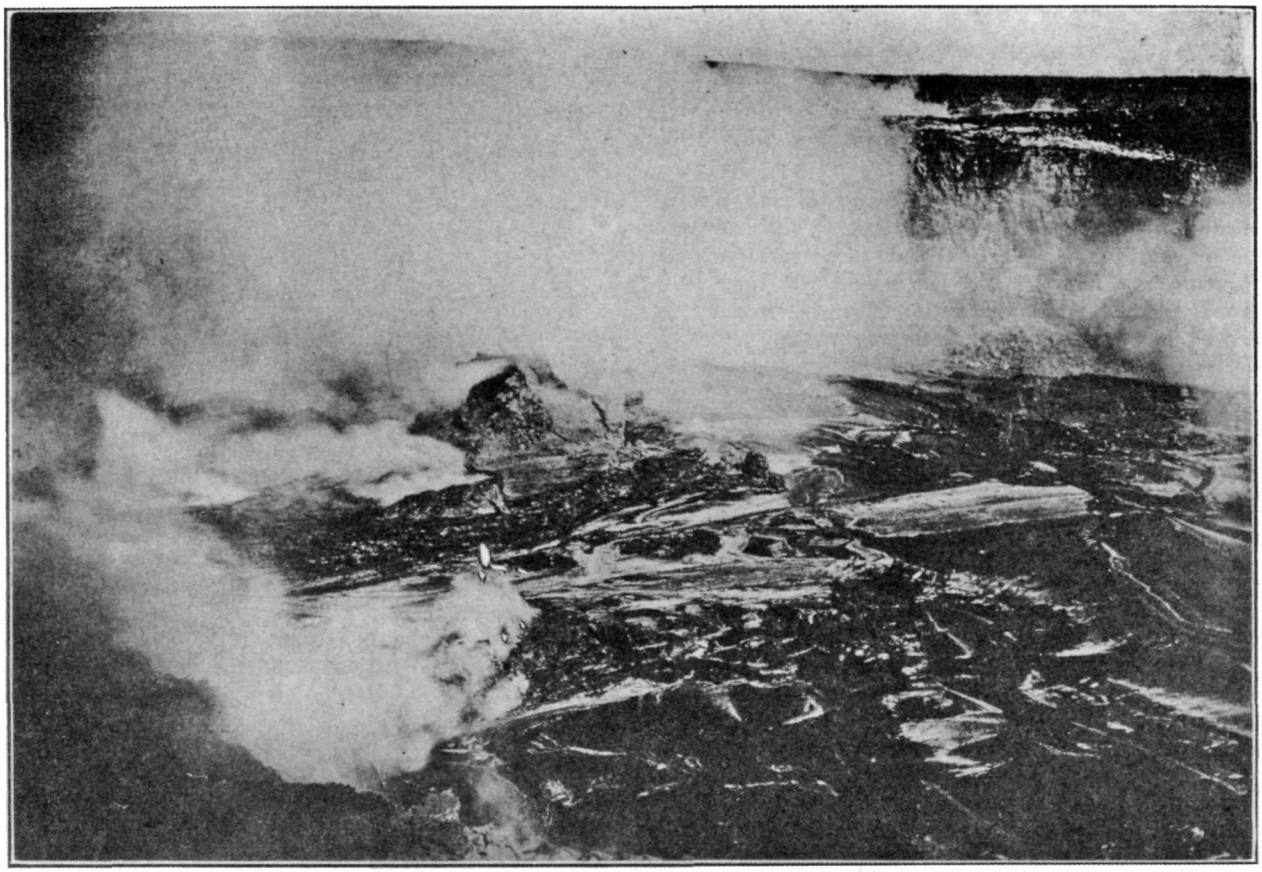
October, and the floors as part of the fabric of the bench magma showed tendency to lift and tilt away from the lake while heavy floods weighted the margins of the floor so that the crags became escarpments with steep faces toward the center of the pit.

Watching the action of the upward pouring slag in Halemaumau pit in 1915-16 led to a fruitful conception to the effect that a lava lake in a pit is nothing more than what would be a flow if it were on a monutain side. In a pit, however, there comes about heat conservation and long preserved internal glow of the bench magma which is different from the overflow fields of the mountain flank. As the front can go nowhere, being confined in a pit, we get a side vent or well, several tunnels as crusts form, and an overturning circulation due to upflow of the light and gassy, downflow of the heavier gas-free fluid. The resemblance of the lake in 1915 to a lobate flow from west to east across the bottom of the pit was striking. The spring of 1916 developed tremendous overflows of the lake which poured between two broken halves of a crag seen gradually to split in two. The overflow on the bench duly became a pool with definite rounded shape in plan, until finally it appeared that the lake had changed its outline, and had developed a big extension. The temperature of the rising melt is not high enough to fuse the banks, but the gases and their reactions are what produce melting. When a mixture of gas and slag comes up rapidly, it enlarges the wells and lakes partly by gas-melting, partly by convectional erosion, and largely by determining the boundary change between two viscosities, that of the more liquid gas-charged lava, and that of the stiffer relatively gas-free paste.

From January to May 1916 the lava of Halemaumau rose rapidly so that the overflow of the floor, and the breakage of the bench magma column below developed in April a big S-shaped lake, then two crags became islands, and lastly the rising lake developed elliptical form around them. Finally the island crags exhibited horizontal movement, which is rare in Halemaumau. One of them migrated north bodily with rotation around its west point as a vertical axis. As the rate of rising was very rapid it seems probable that the island blocks of bench magma were undermined so as to execute a rotatory tilt, partially buoyed, and breaking away from a narrow stem. May 19 came the southwestern Mauna Loa eruption, and on June 5, after Mauna Loa ceased action, came the great subsidence in Halemaumau. T.A.J.



The western source pond filling the wall valley under the northwestern cliff in Halemaumau August 23, 1916, after recovery from the great subsidence. This shows a typical source well and the process by which crags of bench magma were tilted up.



Halemaumau from the south-southwest when the lava bottom was 225 feet below rim, fume was diminishing, lava was flooding, and benches and crags were being elevated bodily around the lava lakes. Photos Jaggar.

KILAUEA REPORT No. 1006

WEEK ENDING MAY 3, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Conditions at Kilauea remain with little change. Fuming is steady at the yellow sulphur area north of the 1930 cone. A few falls of rock and dust from slides were noted at the north wall on April 27. On this date a southerly wind storm doing much damage in Kau District blew thick dust clouds from the desert over Kilauea Crater in the early forenoon.

Cracks paralleling the southeast rim of Halemaumau were measured on the 27th. Nearly all the marked points showed widening, the greatest being 1 7/16 inches at a place in the roped-off area near the tourist shelter.

A total of 39 seismic disturbances were recorded on the instruments at the Observatory, viz: 33 tremors, 4 very feeble seisms, and 2 feeble seisms, all local to the island of Hawaii. The greatest number of disturbances in one day was 11 on April 27. One very feeble shock at 12:18 p. m. April 28 was felt at the Observatory as a sudden jerk, the record indicating a close origin.

Tilt for the week was moderate SW. Microseismic motion was slight.

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No. 333—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 14, 1931

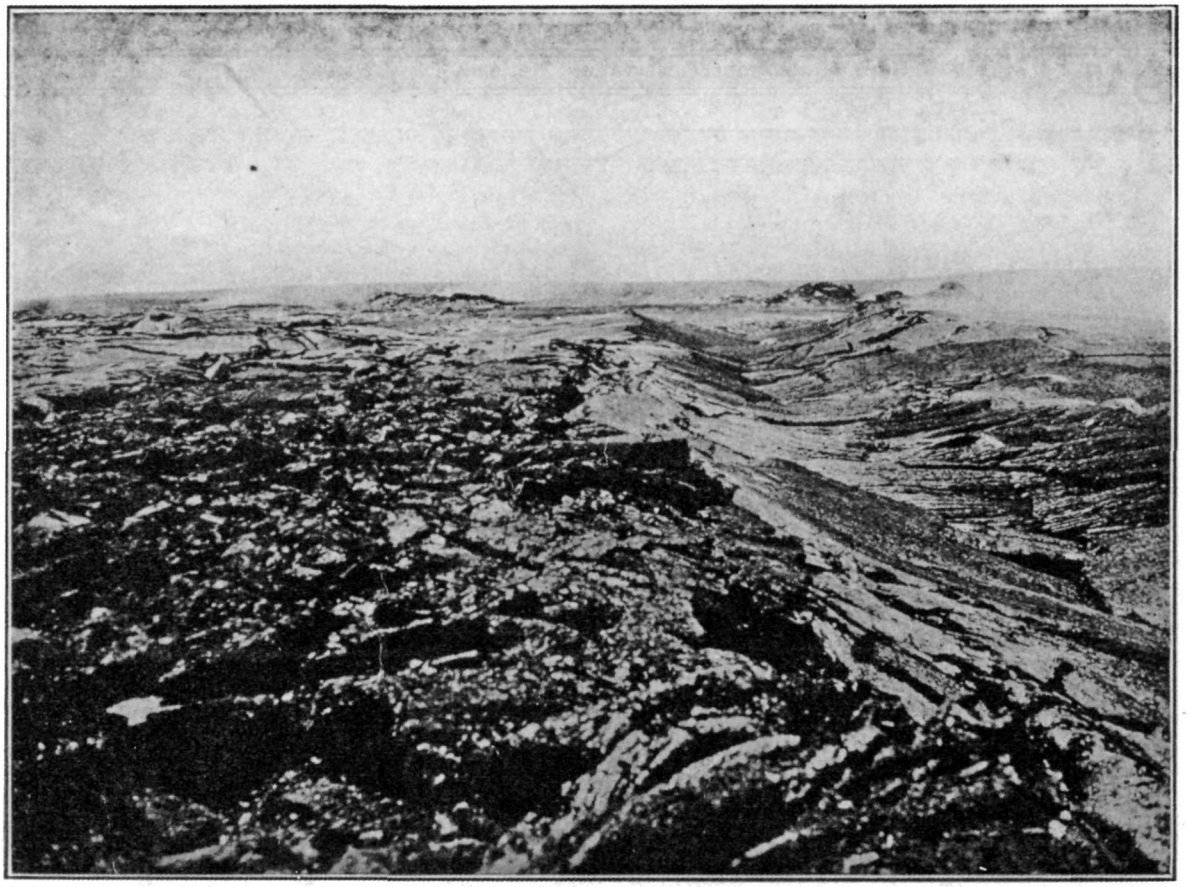


South rim of Halemaumau February 3, 1919, when it had begun to swell faintly, and on the right are seen live flows pouring along the wall crack from a small cone inside the pit. The live lava column of the pit is on the right. This margin of the pit was thrust up as the great pressure ridge February 25 and later.

HEAT AND UPLIFT AT KILAUEA 1919-21

In discussing the cycle of eleven years from 1913 to 1924, the story would be incomplete without a clear statement of the observed effects of increase of underground heat and the consequent uplift which was measured at the rim of the inner pit Halemaumau, and at the rim of the outer crater Kilauea. It is difficult for any one, who has not actually lived on the edge of such an active sink crater, to visualize as an actual fact the uplift of a mountain top by several feet in a few days. This is what truly happened at the edge of the pit Halemaumau when between February and May 1919, as shown in the sequence of pictures herewith, the liquid lava overflowed the rim of the pit, and a heaped tumescence from below swelled up the rim into a pressure ridge 15 to 20 feet high. And this was merely an index of what was happening on a larger scale to the whole inner floor of Kilauea Crater, and on a still larger scale to the whole top of the mountain outside of Kilauea Crater for a radius of 20 miles. (Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory, by T. A. Jaggar and R. H. Finch, Bull. Seis. Soc. Amer. Mar. 1929.)

The swelling of volcanoes was reviewed in Volcano Letter No. 264, but it may be of interest here to summarize the facts about the top of Kilauea at the time of the peak of this active cycle. Leveling measurements of the summit in 1912, 1922, and 1926 showed that the top of the mountain rose two feet before 1922 and subsided from two to nine feet after 1922, the larger figure being that of the inner crater floor. We have seen that seven thousand million cubic feet of rim rock fell into Halemaumau pit during the explosive eruption of 1924. Taking the leveling data and assuming symmetrical subsidence about Halemaumau as a center for the 1921-24 period, the volume of land withdrawn amounted to twenty thousand million cubic feet. This is nearly three times the amount engulfed in Halemaumau. The weight of such decrease of volume of the island above sea level would amount to one and one-quarter thousand million tons. Adding the volume of rock engulfed at the pit we would get a void space created inside the mountain when the lava withdrew of twenty-seven thousand million cubic feet. The down-warping was at a maximum about the crater and the form of the area lowered, with gradual decrease of lowering twenty miles out from the crater center, suggests a horizontal lens of lava evacuated under the shell of the mountain. The suggestion for



Same view as Page One five days later, February 8, 1919, showing the overflow which destroyed the trail, and the sagging crusts of new lava inside the pit on the right.

the whole period of rising and falling is that the dome of Kilauea behaved like a boil or pustule, filling and swelling during the first half of the cycle, and evacuating through an underground crack below sea level at the end.

Early in February 1919 the lava lakes of Halemaumau exhibited brimming and overflowing conditions, and a southern heap inside the pit overflowed the rim February 7 (see cut Page Two) so as to pour across country 400 feet damaging a trail at the road terminus. The liquid lava was rising and the bench magma was sinking. An earlier January overflow had abstracted weight from the top of the lava column and deep effervescence followed as in the overflow of a geyser pool. A northeastern slag heap next took its turn of building up 27 feet just inside the rim of Halemaumau and flows from it threatened the eastern stone tourist shelter. The last week of February produced mass swelling of the lava column, eruptions of standing fountains of melt, extended overflows on three sides, the lakes as well as the slag heaps contributed to the flows, and all the lakes stood as ring-shaped basins, six in number, above the rim level of the pit.

Mashing of the previous rim upward and outward next occurred at the southwest, south, and east, so as to make a pressure ridge from eight to fifteen feet high of what had been the rim before, illustrated by comparing the photograph of February 3 on Page One with that of May 6 on Page Three. The formation of this ridge, however, occurred within a few days at the end of February and the beginning of March. The ground begins to smoke and becomes stained around such a trig station as is shown as a white, circular concrete platform on Page Four. This same southeastern station and all the ground about it then rose and tilted back gradually but very rapidly in the course of a few days, so that it was sloping away from the center of the pit. The ridge formed was 20 feet wide in places, with an elephant's back curve on the side away from the pit. The three most used surveying stations were destroyed, and the net rise of the eastern side of the lava column inside of the pit at the same time was from 10 to 15 feet.

Moderate flowing during the first half of April 1919 gave place to mass swelling the third week of the month, ending in strong overflow that broke up the wall crack through the south pressure ridge, itself the edge of the pit, and this produced the longest and most liquid flow of 1919 to date. It covered the trail and reached the road terminus, and was the third flow of the year that had extended about a half mile from the Halemaumau center.

Within the year prior to February of 1919, Halemaumau had exhibited overflowing of its rim on eleven separate occasions and at nine different places Six of these extended more than 100 feet away from the pit, and of these the southeast flows of February-March 1918 had been the most extensive, reaching a half mile or more in length. Those of November 1918 came next in volume, and the flows of January-February 1919 tended to fill the gaps between the two earlier localities. August of 1918 had produced some driblet overflows at the north and southwest.

The appearance of Halemaumau in April 1919 was that of a smooth curved dome 1,200 feet across, rising from the base of what was left of the northwestern rim cliff of the pit. The swollen top of the lava column rose 50 feet above the general level of the former rim, and fell off abruptly as an escarpment 40 feet high on the southeast at the pressure ridge (see Page Three). Known landmarks on the pressure ridge measured in profile on a telescope scale from the Observatory two miles away, were seen to move horizontally easward within a few weeks. The old edge of the pit after being raised bodily was then mashed until it fell backward in a talus, and the upper part of the escarpment was now the cross-section of the inner live lava layers of the stiff lava column, where the pit floor had been lifted clear above what was left of the pit rim.

April 20, 1919, inaugurated a series of big flows from cracks in the Kilauea floor outside of Halemaumau at the north. These flows were destined to continue pouring across the northern part of the Kilauea floor throughout most of the year. They were called the Postal Rift flows because they originated at a hot crack where travelers formerly scorched postal cards. The swelling up of the rim of the pit was now extended around to the west and north, tilting the west station 4.5 degrees to the southwest, and the north bench mark 8.5 degrees to the north, so that it was lifted approximately eight feet in the course of a few days. This lifting up of old rim rock was accompanied by more or less heating and smoking of the cracks, and the outflow of liquid lava 800 feet back of the pit occurred without seismic disturbance, and was unquestionably connected through cracks with the same lava column that occupied Halemaumau. The Halemaumau lakes did not lower, but rose and increased their gas pressure while the tumescence of the inner bench magma lessened. The Postal Rift flow had advanced 1.4 miles across the Kilauea floor by April 25. T.A.J.

KILAUEA REPORT No. 1007

WEEK ENDING MAY 10, 1931

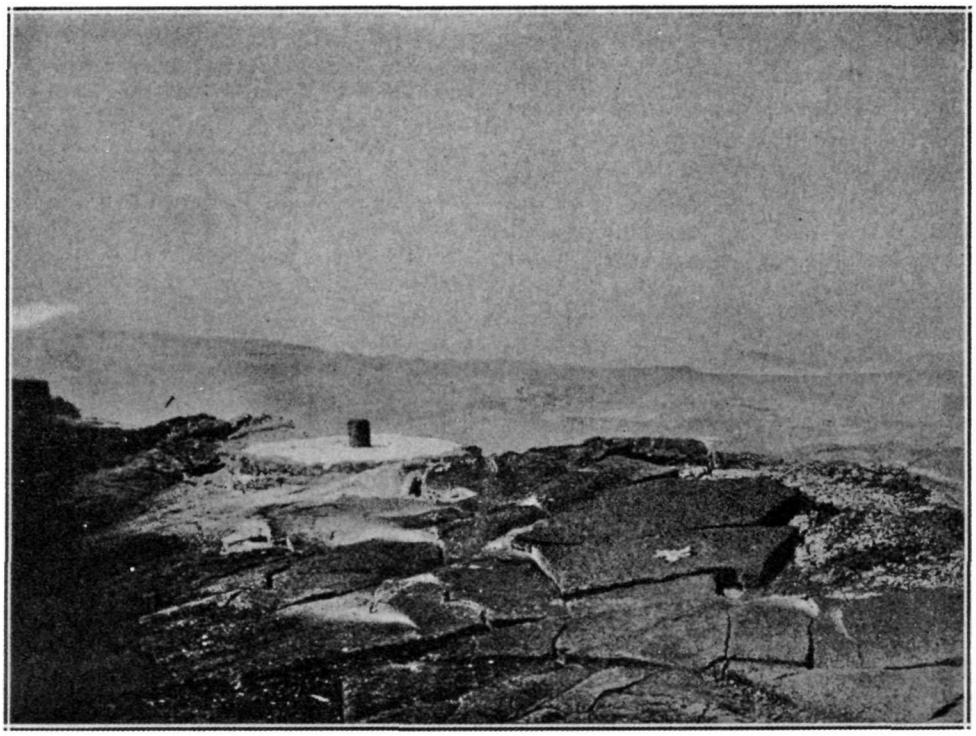
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On May 6 in the forenoon at Halemaumau pit of Kilauea Volcano there was little fume that could be detected at the sulphur spots on the floor of the pit, and very little steam appeared at the south talus. The pit seismograph indicated a gradual tilt away from the pit until May 2 and thereafter motion in the opposite direction. On May 9 some newly fallen rocks were observed at the base of the north talus.

The Observatory seismographs registered 38 tremors



May 6, 1919, showing the same southern edge of Halemaumau as in the photographs on Pages One and Two, but now quite unrecognizable. Halemaumau had become a dome, the rim had become a pressure ridge, the former eastern stone shelter lay under the flows in the foreground, and the main lake was in a hollow at the top of the dome on the right. The trig station shown on Page Four was lifted up until it fell to pieces on the "elephant's back" shown here on the left.



Southeast trig station at rim of Halemaumau when the ground was beginning to be heated, fumed, and stained by tumescence, February 21, 1919. This within two weeks was lifted up and overturned backwards away from the pit on the pressure ridge shown at the left of cut on Page Three. Photo Jaggar.

during the week and a very feeble distant earthquake was recorded at 9:24 a. m. May 10. Tilting of the ground for the week was slight ENE, and microseismic motion was slight but increased somewhat May 4-5.

TILTING OF THE GROUND FOR APRIL

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

April 6-12	0.3 seconds	W.
April 13-19	1.3 seconds	W.
April 20-26	2.5 seconds	SW.
April 27-May 3	1.4 seconds	SW.

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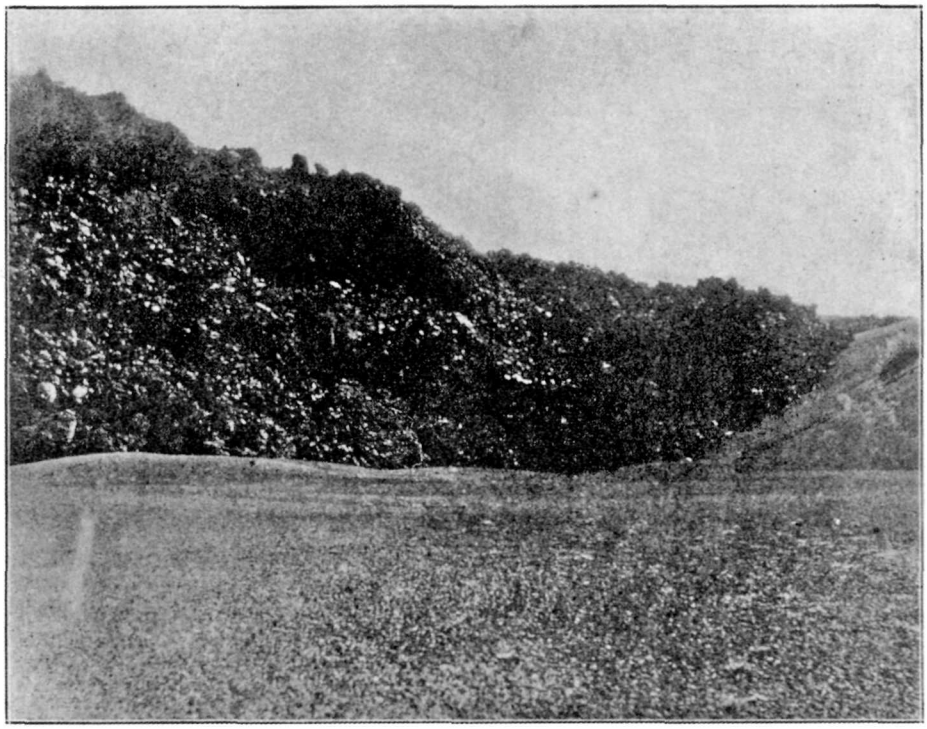
No. 334—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 21, 1931



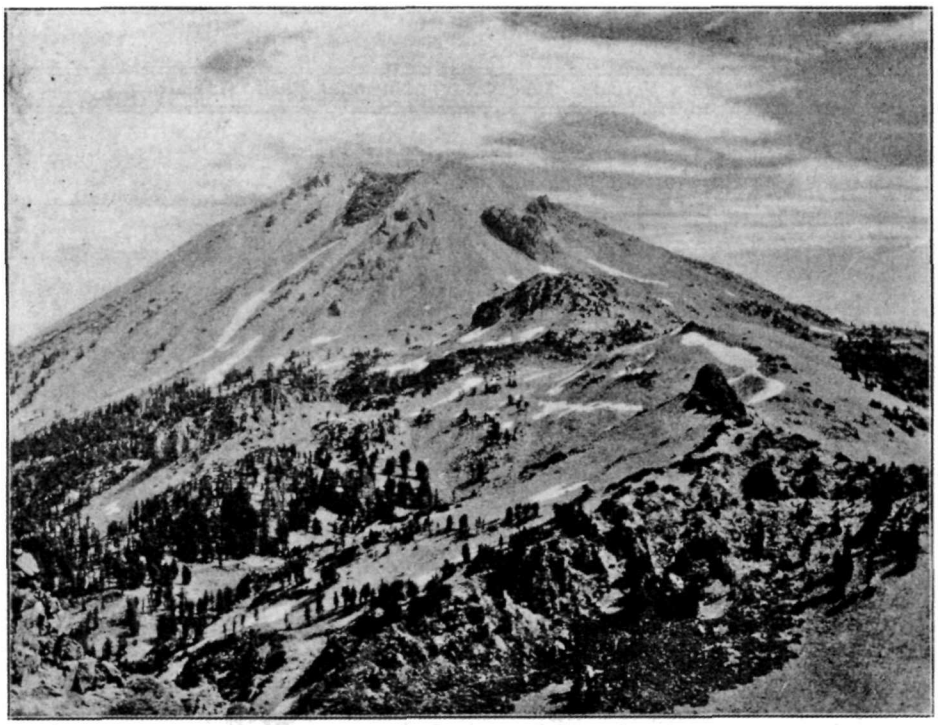
Edge of lava flow that poured out during the winter of 1850-51 at Cinder Cone, Lassen Volcanic National Park. Photo Finch.

THE YOUNGEST LAVA FLOW ON THE MAINLAND OF THE UNITED STATES

In the northwestern part of the United States there is a volcanic area covering about 25,000 square miles that extends from Lassen National Park, on the south, northeastward to Yellowstone National Park and northward to British Columbia. The eastern part of this volcanic area is the Columbia Plateau lava field, and the western part is the Cascade Range. In this range are Lassen Peak and other volcanoes that have been active in recent times. Mount Baker and Mount St. Helens were reported to have been smoking in 1843. Mount Rainier is said to have been feebly active in the nineteenth century, and steam still escapes from its summit crater. A volcanic eruption, possibly from Mount Shasta, was reported from a ship at sea in 1786. At the present time there are steam vents near the summit of Mount Shasta, 14,000 feet above sea level, so active that in a small area around them no snow can accumulate although a short distance away several glaciers have their sources.

In Arizona, New Mexico, and southern California there are very fresh-looking volcanic formations. The lava flow in the valley of the San Jose River in New Mexico is so fresh in appearance that it lends support to Indian traditions of a "river of fire" in this locality. Near Glass Mountain, in northern California, and at places in Oregon and Idaho, there are lava flows that appear to be less than 500 years old (Volcano Letter No. 292). At Cinder Cone, in Lassen National Park there are several recent lava flows, the latest of which (Page One) is believed to have poured out during the winter of 1850-51 (Volcano Letter No. 306).

It really was no surprise to those informed about the volcanic region of the northwestern United States when Lassen Peak became active in 1914. For a year the activity was largely confined to small explosions. Then during the night of May 19-20, 1915, Lassen produced the youngest lava flow on the mainland of the United States. The main crater was filled with new lava, and there were small overflows through low notches in the rim both to the east and to the west. The western branch of the flow is still in place, as shown on Page Two. Only remnants of the eastern branch of the flow remain, though there is good evidence pointing to the conclusion that it was the larger branch. Part of the eastern branch of the flow slid down the mountain shortly after it had been poured out, at the time of a mud flow during the same night. The photograph reproduced on Page Three, taken May 22, shows a remnant of the eastern flow, but most of this also slid down the steep mountain slope a few hours later. The most forcible explosion of the series took place during the after-



Lassen Peak from Mount Diller at the southwest August 27, 1927. The western branch of the youngest lava flow in the United States, produced in 1915, is the dark mass extending a short way down from the notch in the summit. Photo from Finch.

noon of May 22, 1915, after this photograph was made. Activity continued in varying degree until August 1917, but since then there have been no true volcanic eruptions of Lassen Peak.

Earthquakes that have their origin in the Lassen edifice are rather common as shown by the seismographs of the Lassen Volcano Observatory of the U. S. Geological Survey at Mineral, California. The fact that from 36 to 266 earthquakes are recorded each year at Mineral indicates that Lassen Peak is still somewhat uneasy.

Some references on Lassen Peak are as follows:

U. S. Geological Survey, Geologic Atlas, Lassen Peak folio (No. 15), by J. S. Diller, 1895.

The Volcanic activity and hot springs of Lassen Peak, by Arthur L. Day and E. T. Allen, Carnegie Institution of Washington, Publication 360, 1925.

Pictorial history of the Lassen Volcano, by B. F. Loomis, Anderson, California, Anderson Valley News Press, 1926.

The kingship of Mount Lassen, by Mrs. F. H. Colburn, San Francisco, Nemo Publishing Co.

The quartz basalt eruptions of Cinder Cone, by R. H. Finch and C. A. Anderson, Univ. Calif. Publ. Geol. Vol. 19, No. 10, 1930. R.H.FINCH

HOT VOLCANISM OF NORTHWEST UNITED STATES AND CANADA

The article which precedes this is of great interest in presenting a newly discovered photograph (Page 3) by Mr. Loomis taken on May 22, 1915, at the same time as the one reproduced in Volcano Letters Nos. 266 and 304. The new one is different in showing the east side of the crater region of Lassen Volcano so clearly as to make it plain that the summit dark area is an unmistakable aa flow.

Lassen Volcano, therefore, produced in the end phases of its eruption May 19-20, 1915, stiff lava flows from its crater lips both east and west, and though the explosion of May 22 destroyed part of the eastern flow, fortunately Mr. Loomis was there in time to record its presence, and the remaining lava in the crater and on the west side was left in place to cool off where it may be seen today.

The history of the Cinder Cone and of Glass Mountain in that same volcanic district shows the area capable in recent times of pouring out extensive flows into the forest. It is still possible that within a few years activity may be renewed somewhere in northern California from the volcanic system represented by Lassen and Shasta, so as to pour out fresh lava flows. Mr. Finch shows how many places in the northwestern United States are active volcanoes with evidence of volcanic heat.

In addition to these places there may be mentioned the numerous hot springs of California thoroughly investigated by Waring (U. S. Geol. Surv., Water-Supply Paper No. 338, 1915), and some of these are boiling and accompanied by steam jets, as at Devil's Kitchen in Lassen Park shown on Page 4. Especially noteworthy is The Geysers canyon where steam is used for power north of San Francisco in the St. Helena range. Near Clear Lake there are old volcanoes, and there are boiling waters at Calistoga, and at the Little Geysers, and fumaroles at the sulphur bank, which is near to The Geysers. At The Geysers there is super-heated

steam and volcanic gases, pointing to a magmatic origin (Steam Wells at The Geysers, California, by E. T. Allen and Athur L. Day, Publication 378 Carnegie Institution, 1927). This can only mean excessively hot gas-charged magma under the Coast Range close to San Francisco and not far from the center of the earthquake of 1906.

In addition to the abundant volcanoes of the Sierra Nevada and the Cascade Range from Lassen Peak to Mount Baker in Washington, Professor R. W. Brock (Proc. Third Pan-Pac. Sci. Cong. Tokyo 1926, Volcanoes of the Canadian Cordillers, p. 688) reports the discovery in 1909 of volcanic cones and lava flows 40 miles north of Vancouver, and also hot springs, marking an extension northward into Canada of the active volcanoes of the United States. The volcano Garibaldi is a cone rising 3,500 feet above the plateau to a total elevation of 8,700 feet, made up of cinders with some interbedded lava streams. In the Lillooet District there is andesitic pumice covering 1,500 square miles. On Naas River in British Columbia there is a lava flow consisting of olivine basalt, 20 miles long, and said by the Indians to be less than 200 years old. It dammed a river forming what is called Lava Lake, and there are explosion cones five in number, the description of which closely resembles that of Cinder Cone at Lassen. On the Unuk River there are other recent lava flows and vents so fresh that the volcanic ash can still be seen as black patches on the glaciers. Craters and flows on Ruby Creek in the extreme north of British Columbia, vast deposits of volcanic ash on the Yukon plateau, a volcanic cone north of the Pelly River, and some other places, lead Brock to the statement, "Complete exploration may show as much recent volcanic activity in western Canada as in most sections of the Pacific volcanic girdle." T.A.J.

DEATH OF PRESIDENT THURSTON

The editor records with the utmost grief the death on May 11, 1931, of the Honorable Lorrin Andrews Thurston, President of the Association, in Honolulu.

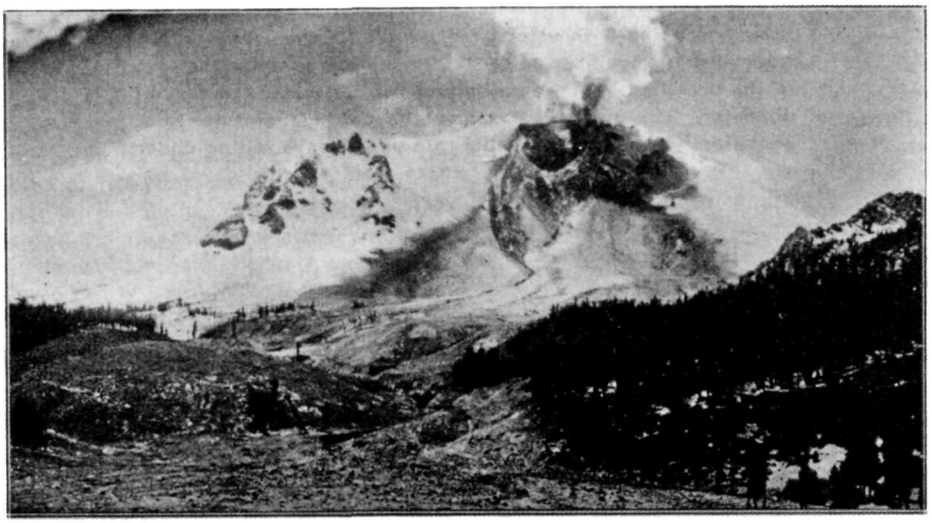
KILAUEA REPORT No. 1008

WEEK ENDING MAY 17, 1931

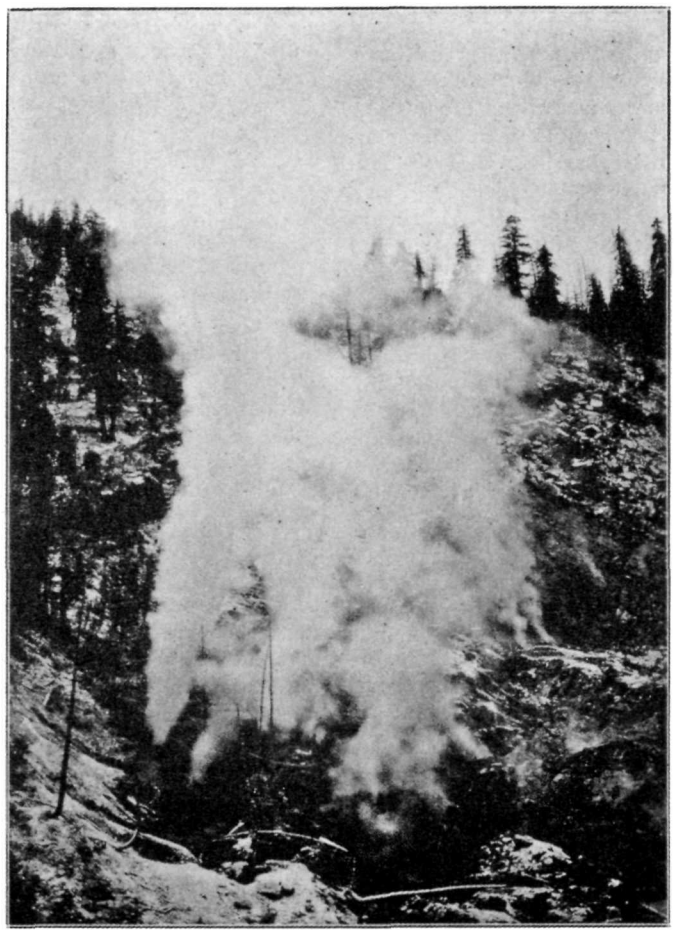
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanic conditions are very quiet at the Hawaiian volcanoes and at Kilauea the only seismic movements of any consequence are very slight tremors. At Halemaumau pit on the inner floor of Kilauea Crater a visit at 10 a. m. May 14 showed everything quiet about the bottom lava of 1930, no steam was visible at any vents, and a little fume was infrequently detected at a yellow sulphur spot near the middle. One or two rocks were heard falling at the northeastern and northern walls of the pit. The same conditions were noted at 9:15 a. m. May 16, and a small slide occurred at the north wall at 9:25 a. m.

Twenty-eight tremors were registered on the Observatory seismograph during the week ending midnight May 17, and one very feeble local seism at 4:41 p. m. May 13. Tilting of the ground accumulated slightly SW, and microseismic motion was slight.



Lassen Peak from the northeast May 22, 1915. The dark area under the steam cloud is a part of the eastern branch of the lava flow that came out during the night of May 19-20, 1915. Photo B. F. Loomis.



Steam escaping with velocity in Devil's Kitchen, Lassen National Park, November 14, 1930. During the summer the seat of the principal vent was a boiling pool of water ten feet in diameter. The steam was above the boiling point for that elevation. A cold, disagreeable rain was always falling under the vapor cloud. Photo from Finch.

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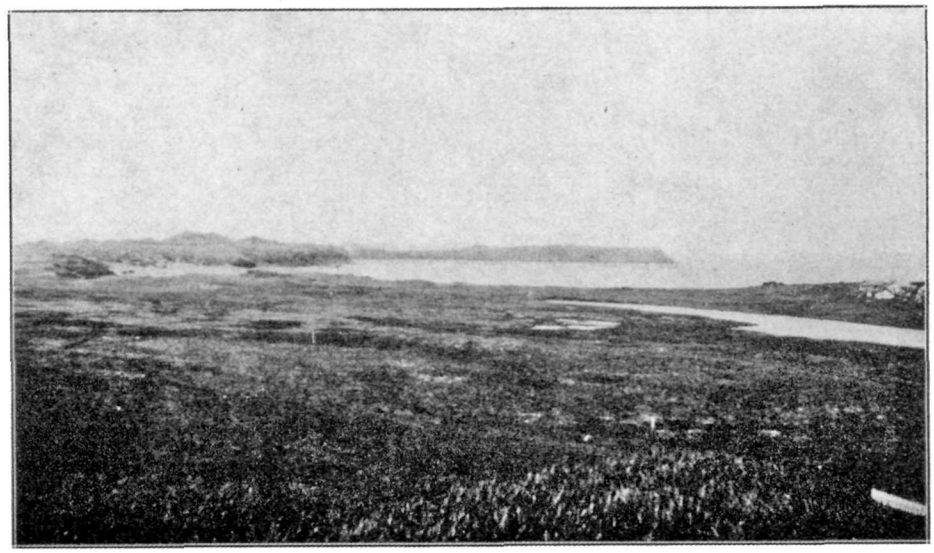
The Volcano Letter

335

Two dollars per year | Ten cents per copy

No. 335—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 28, 1931



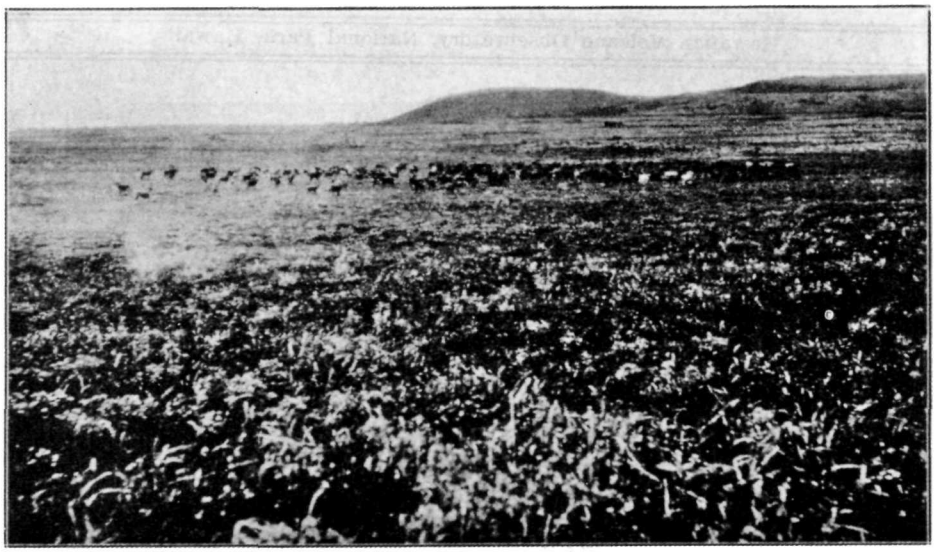
South end of St. Paul Island in the Pribilofs showing Gorbat rookery and Reef Point rookery with Otter Island in the extreme distance and St. Paul village beside the salt lagoon on the right. Photo Rauch.

ST. PAUL ISLAND IN THE PRIBILOF GROUP

During the writer's visit to the Aleutian Islands in 1917 he had the privilege of meeting Mr. William P. Rauch who kindly gave him specimens he had collected on St. Paul Island, the larger northwestern member of the seal islands, or the Pribilofs, where the fur seals are protected by the United States. St. Paul lies 200 miles north-northwest from Unalaska Island in the Bering Sea, and off the line of the Aleutian Islands. Mr. Rauch took photographs, some of which are reproduced herewith. The rocks of the Pribilof Islands have recently been described by Washington and Keyes (American Journal of Science, November, 1930). One of the pebbles collected by Mr. Rauch is described by these authors as hyalobasanite, a basaltic lava which would have contained much nephelite if the lava had been completely crystallized. This rock also contains olivine. Other specimens are ordinary fine-grained basalt.

Mr. Rauch writes: "I obtained a small piece of sedimentary rock containing shells, and have turned it over to Dr. P. S. Smith, Alaskan Branch, U. S. Geological Survey. This sedimentary rock was some ten to twelve feet above high tide, embedded in the perpendicular cliff just to the right of what is known as East Landing on St. Paul Island. I should judge that weathering and heavy seas had exposed it. The whole island gives one the impression of a sort of volcanic fairyland so many diminutive volcanic cones and craters, so small, and so different."

Black Bluff, a sea-dissected cone on the eastern coast, contains tuff with rounded, calcareous, or marly clay fragments with fossil shells of post-Pliocene age and of species now living including walrus bones. There is no glaciation. The island is volcanic and according to Stanley-Brown (Bul. Geol. Soc. Amer., Vol. 3, 1892, p. 496) was built up after the Tertiary with outpouring of lava from a central vent in a submarine eruption. "Its surface is diversified by at least a dozen cones and vents of unusual symmetry, surrounding in irregular fashion a true crater dome some 600 feet in height called 'Bogoslof'" (not to be confused with Bogoslof, the active volcano near Unalaska). Washington and Keyes say, "The island of St. Paul, the largest of the Pribilofs, has a greatest length of about 13 miles between its northeast and southwest points, and widths of from 6 to 8 miles. Its area is about 33 square miles. In its early stages it may have consisted of a group of 10 or 12 small islands, now joined together. The lava flows gradually built up the basement floor of the island, and these were vesicular basalt rich in olivine. There followed from the central vent great flows of basalt, with others from smaller cones, all together constituting an overlying sheet. It is more crystalline than the basement lava. The marked contact of the two sheets is near sea level. There are thin, unbroken lava domes" and small spatter heaps. No andesitic nor trachytic lavas are present and tuffs are rare. An analysis of the nephelite basanite by Washington and



Reindeer herd on St. Paul Island, looking southwest on the south side of the island in the region north of the salt lagoon. Photo Rauch.

Keyes shows a composition rich in iron, titanium, magnesia, lime, and the alkalies, with 44 per cent of silica.

St. George Island, about 40 miles southeast of St. Paul, reaches a height of a thousand feet, is bordered by bluffs, has a basement of dark basalt, and contains many breccias and tuffs as well as some non-basaltic lava. There is andesitic ash and possibly trachyte occurs.

As to activity in recent times, flames are said to have been seen to rise from the sea northeast of the Pribilof Islands, and a submarine eruption is recorded for 1815 northeast of St. George, where there are small circular shoals at depths of from three to eight fathoms. Out in the middle of Bering Sea Pinnacle Islet five miles south of St. Matthew Island, was cited by Elliott as having been in an almost constant state of activity since its discovery, and as being active at the time he was there in 1874. This author also thought Otter Island, a small rock southwest of St. Paul (faintly visible in the distance in the photograph reproduced on Page One), had been recently active. All of these facts are culled from Washington and Keyes.

Mr. Rauch made the accompanying sketch map on Page Four to express roughly the position of his photographs. The map should be turned so as to make the long right-hand point turned northeast, and not east. St. Paul village is thus at the south end of the island, Rush Hill 665 feet high is the highest point on the island at the west end, and the principal anchorage is in English Bay west of the village. The photograph on Page One shows Reef Point which projects south of the village, on the right are seen the village houses, and in front of them is the salt lagoon bordered by tundra flats. The entire island is grassy, without shrubs or trees, and the same is true of the Aleutian Islands. A considerable herd of reindeer is maintained on the island as shown on Page Two. There are two fur seal rookeries on the two points near the village, and on the lowland bars of the northeast point there is the largest seal rookery ground. Formerly a drum tractor was used for hauling the pelts across the island, now there is a wire cableway.

Looking into the interior of St. Paul Island from the village northward, one sees flat, grassy, rolling country with the salt lagoon in the foreground and four or five cones beyond, of which Bogoslof is the most dome-like. Standing on the top of Bogoslof and looking westward we see six or seven cones with marked tendency to horseshoe shape, the opening of the horseshoe generally facing toward the north as though the prevailing wind tended to build the higher heapings of the lava fountains toward the south. This is the scene photographed on Page Three. From this elevated point the expanse of flat tundra to the northeast covers about one-seventh of the island, all very slightly elevated above the sea. A large triangular lake of brackish water is inclosed by two bars which have shut off the lake by connecting an outlying islet with the main island at the northeast point. Such ponds are common partly as fresh water crater lakes and also as longshore lagoons as shown on the map by L. The letter V on the map indicates volcanic hills and craters. Looking southward from the summit of Bogoslof one sees a broad slope leading down to the southwestern embayments, all grassland over lava, with small lava pits in the foreground, the topography suggesting the pahoehoe of Hawaii. The lava conelets of the Pribilofs are much more Hawaiian in quality than the eastern islands of the Aleutians, but in some of the western Aleutian islands there are wide lava flats greatly resembling the photographs of St. Paul.

With reference to the opening northward of the horseshoe cones and the sweep from northeast to southwest of the barrier beaches that trail to the main island from the northeast point, it seems probable that the constructional action of the sea has been from northeast to southwest with the prevailing winds, thus smoothing the northern and

southeastern shores, and leaving bays at the southwest. As there are three distinct embayments and two of them fairly deep on that side, it may well be that the volcanic tumescence which accompanied the outpouring of lavas had a tendency to uplift at the northeast and some drowning of topographic depressions at the southwest. The salt lagoon next north of the village, and the topography of the three bays adjacent to it, suggest drowned valleys among lava-flow ridges. T.A.J.

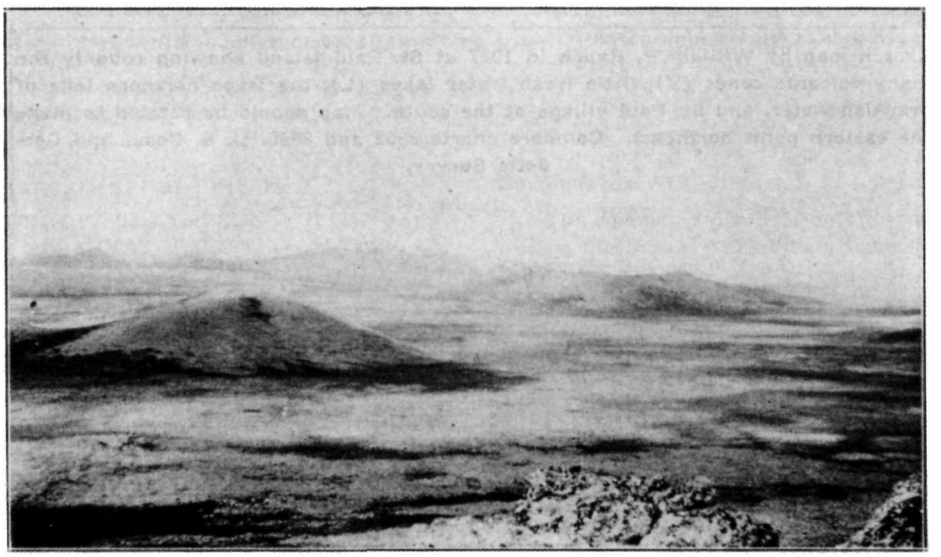
KILAUEA REPORT No. 1C09

WEEK ENDING MAY 24, 1931

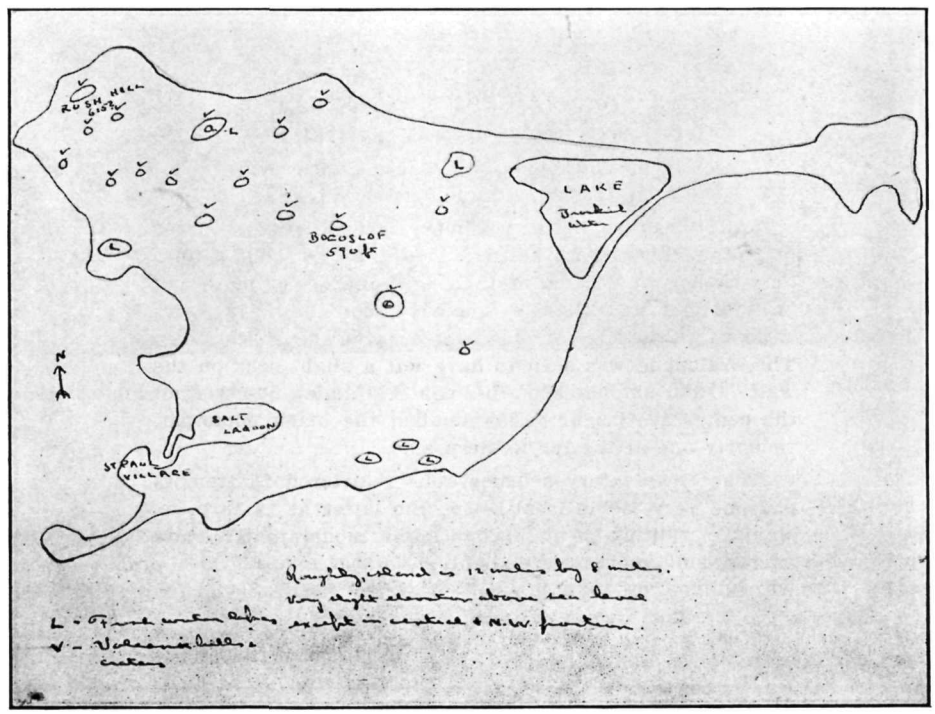
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit of Kilauea Crater a slide occurred on the northwest wall about 9 a. m. May 18 sending up a dust cloud. At 10:30 a. m. fume at the larger sulphur spot on the floor had slightly increased, but there was very little vapor rising from the wet area of the south talus. The avalanche was seen to have left a slight scar on the wall. Other sulphur spots besides the fuming one west of the center are bright yellow against the black floor, particularly one at the far western side.

The Observatory seismographs registered 25 tremors and one very feeble local seism, the latter at 12:18 p. m. May 23. Tilting of the ground was moderate SW, and microseismic motion very slight.



Photograph taken in July 1927 from the summit of Bogoslof hill in the middle of St. Paul Island looking westward toward Rush Hill in the extreme distance, that being the highest point of the island. At the right is shown a horseshoe cone resembling Diamond Head at Honolulu. Photo Rauch.



Sketch map by William P. Rauch in 1927 at St. Paul Island showing roughly the many volcanic cones (V), little fresh water lakes (L), the large northern lake of brackish water, and St. Paul village at the south. Map should be rotated to make the eastern point northeast. Compare charts 8802 and 8995, U. S. Coast and Geodetic Survey.

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No. 336—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 4, 1931



Pumice Stone Mountain, west of Medicine Lake, California, seen from the south. The white pumice closely resembles snow. Photographed July 13, 1930.

LASSEN REPORT No. 29

SOME WORK OF THE LASSEN VOLCANO OBSERVATORY 1930

R. H. Finch, Associate Volcanologist.

Mount Harkness Seismographs

A two-component Hawaiian-type seismograph has been installed in the basement of the fire lookout observatory of the National Park Service on the summit of Mount Harkness, 12 miles east-southeast from Lassen Peak, California, elevation 8,039 feet. The instrument was started in operation on August 21, 1930, but owing to early snows Mr. H. C. Lind, the fire lookout and seismograph operator, was called away a little before the last of September and only a little over a month's record was obtained. The observatory building is located near the summit of a cinder cone that rests upon a lava base. Some earthquakes were recorded better on the Mount Harkness instruments than on the ones at Mineral.

Tilt

All instruments needed occasional attention to correct for tilting. The accumulation of tilt from the Mineral seismographs appears to be less during 1930 than in former years. Coincidental with a southwest tilt at Mineral there was a southeast tilt at Harkness. Of course, it is not yet know whether the Harkness tilt is local or not.

Earthquakes

The seismographs at Mineral recorded 74 earthquakes during the year. These disturbances by month were as follows:

January	5 shocks	July	7 shocks
February	7 "	August	5 "
March	5 "	September	4 "
April	4 "	October	4 "
May	5 "	November	14 "
June	0 "	December	14 "

The numbers recorded during the last four years are as follows:

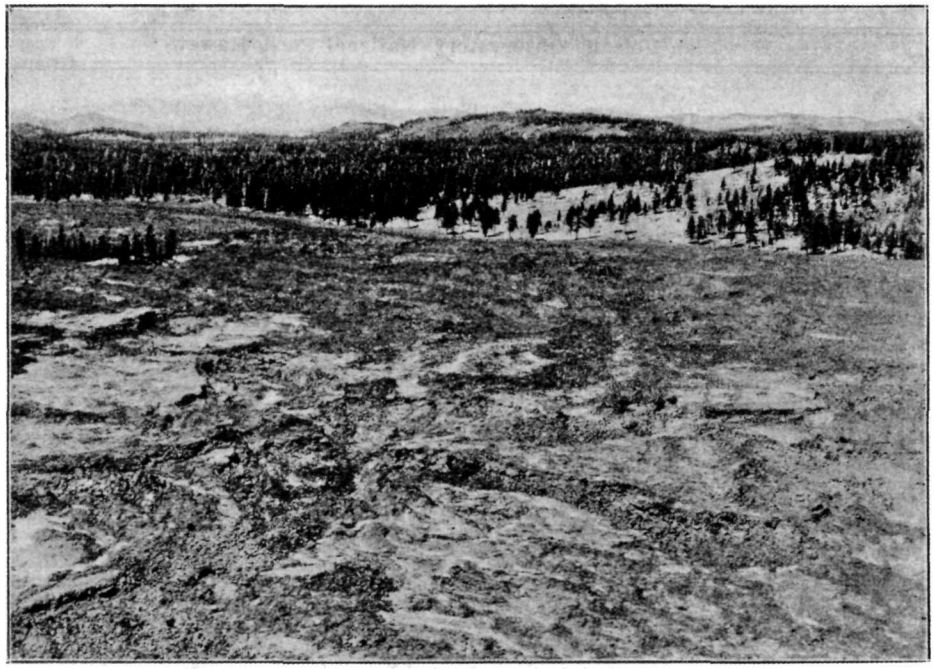
1927	266 shocks
1928	37 "
1929	96 "
1930	74 "

As in the preceding years, nearly all of the shakes had their origin in the Lassen massif.

Rainfall

The total precipitation for each of the last four years was as follows:

1927	43.32 inches
1928	42.10 "
1929	38.65 "
1930	38.94 "



View taken July 12, 1930, looking westerly across Burnt Lava Flow from edge of High Hole Crater.

Burnt Lava Flow

In July a topographic map of Burnt Lava flow, to the southwest of Glass Mountain and south of Medicine Lake, and 80 miles north-northwest from Lassen Peak, was made and specimens collected. Dr. C. A. Anderson, of the University of California, is to make a study of the specimens and a report of the flow will be prepared for publication.

Hot Springs Temperatures

Temperatures of springs at Morgan Springs on August 6, 1930, air temperature 88° F. follow:

Spring	Temperature	Remarks
No. 1	156°F	Algae and encrusted salts.
No. 2	125°	Very sluggish. Algae present.
No. 3 upper	196°	Less than normal flow. Some larvae present.
No. 3 lower	178°	
No. 4 east	195°	Flow very slight.
No. 4 west	164°	No. 4 area has been drained by ditching.
No. 4 clear pool	162°	
No. 9		No flow.
No. 17 steam at top	200.5°	
No. 17 hot water	201°	Volume as usual.
No. 20	200.5°	
No. 23 south	200°	
No. 23 north	196°	
Geyser	202°	Volume normal.

At Boiling Lake August 12, 1930, air temparature 82°:

Large mud pot northwest	196°
Boiler southwest edge of lake	195°
Boiling pool south edge of lake	194°
Dry steamer above south end of lake	201°
South end of lake	133°
North end of lake near outlet	121°

The water of boiling lake was about 12 inches below outlet. The lake level is the lowest it has been for several years according to Mr. Roy Sifford.

Temperatures at Devil's Kitchen August 12, 1930, were:

Mud pot northeast side	198°F
Mud pot north side	188°
Boiling pool north side, clear water 5 feet deep, small inflowing stream, no visible outlet	190°
Boiling pool north side, no visible inlet or outlet	196°
Large boiling pool north side with pyrite scum	194°
Steamer northwest end (poor exposure)	198°
Big boiler southwest side	196°
Steamer southeast side	198°
Big boiler east end. Pool 10 feet in diameter. Main part of boiling jets goes to a height of 46 feet, small jets reach 10 feet	196°
Steamer below Big Boiler	198.5°

At Bumpass Hell, air temperature 71°, the following were obtained August 14, 1930:

High western pool	193°
Mud pot west of No. 1	194°
No. 14, East pool	188°
No. 14, Middle pool	191°
No. 14, Big steamer	201°
No. 16	193°
Steam vent Bumpass Creek below Bumpass Hell	196°

Little Hot Springs Valley, August 14, 1930:

Clear pool east terrace	194°
Mud pot, east terrace	194°
Yellow pool	187°
Steam vent creek edge. Only fair exposure, steam emerging with considerable noise and pressure so that it was difficult to hold thermometer in vent even when tied rigidly to a stick	211°
Boiler surrounded by cold water in edge of stream	188°

At Supan's, August 15, 1930, air temperature 82°:

Big steamer (sometime in July this vent became more active and scattered mud for a distance of 40 feet from its edges)	194°F
Big steamer on October 31, Spring overflowing	192°

At Lassen Crater, August 20, 1930, air temperature 58°:

East vent near center of crater	132°
Middle vent under large rock	120°
Vent between two rocks north side of central area	162°
Steam vents above west edge of lake	146°

For earlier measurements of these temperatures at the various Lassen localities, see Volcano Letters Nos. 110, 162, 236, 238, and 279.

Land Slipping at Supan's

So many of the stakes were broken off that it was not possible to retape this area. Transit observations, however, failed to show any down-slipping. A new set of iron stakes was installed.

KILAUEA REPORT No. 1010

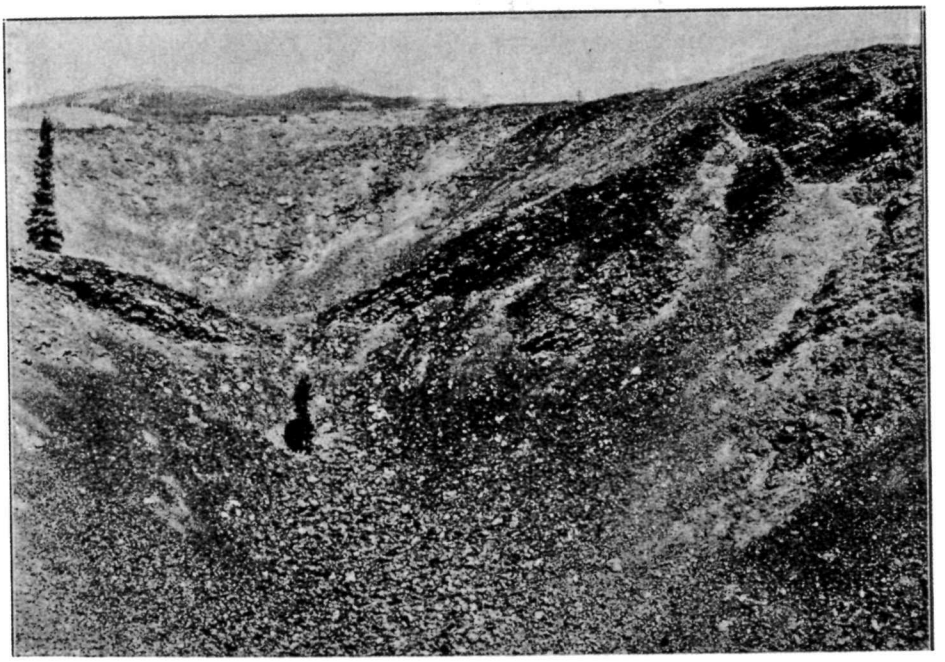
WEEK ENDING MAY 31, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

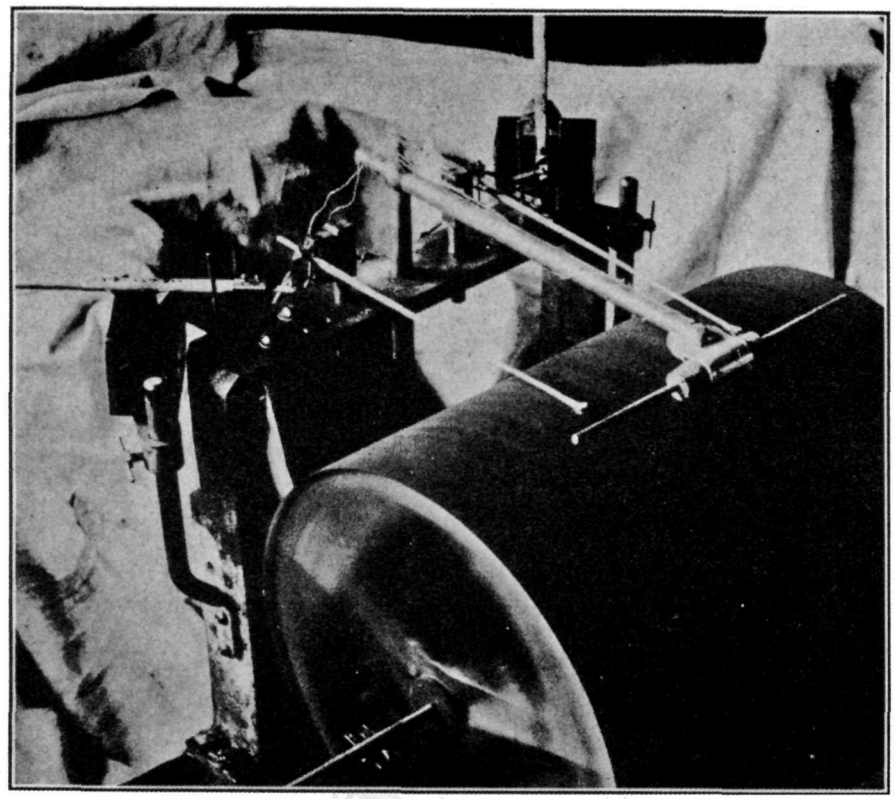
At the Kilauea fire pit on May 27, 11 to 11:15 a. m., steaming was slight at all the active vents, no steam showing on the south talus, a little on the west talus, and vigorous on the southeast rock bank. Fume was slight but steady at the west central sulphur area. A large scar from a slide showed on the north wall at the rim. At 1 p. m. a large dust cloud was seen rising north. On May 30 a very little steam showed on the south talus. Other conditions remained without changes.

The Observatory instruments registered 1 very feeble local seism and 33 volcanic tremors, including two and a half minutes of continuous tremor on May 25 and harmonic tremor from 4:06 to 4:24 p. m. May 29.

Tilting of the ground was moderate ESE. Microseismic motion was slight.



View showing the two parts of High Hole Crater in Burnt Lava Flow. Photographed July 12, 1930, by R. H. Finch.



Recording drum of Hawaiian Type Seismograph as installed at Mount Harkness. Drum covered with smoked "glassine" paper. Two pens write under the electromagnet, which lifts them every minute. They are connected with N-S and E-W arms. These are horizontal pendulums damped at the two small oil tanks. Drum moves along on its spindle.

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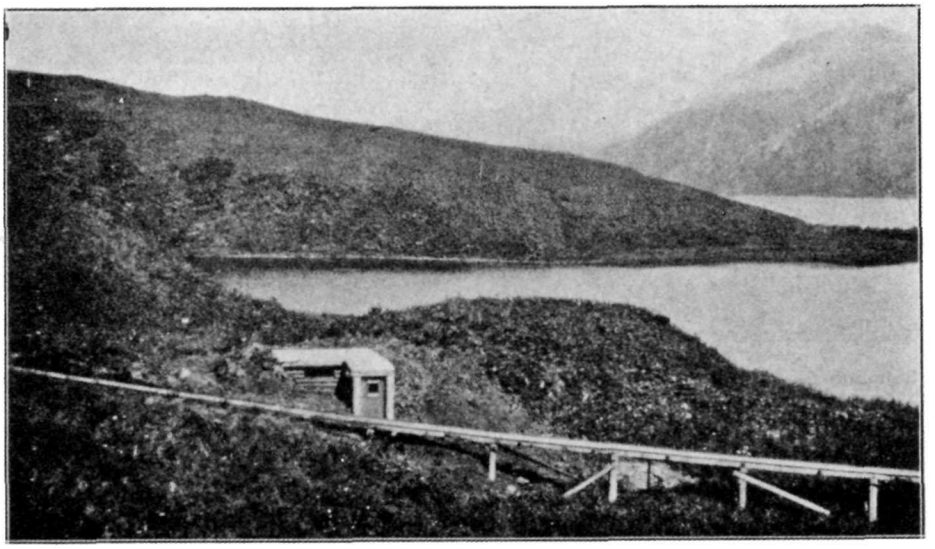
The Volcano Letter

Two dollars per year | Ten cents per copy

No. 337—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 11, 1931



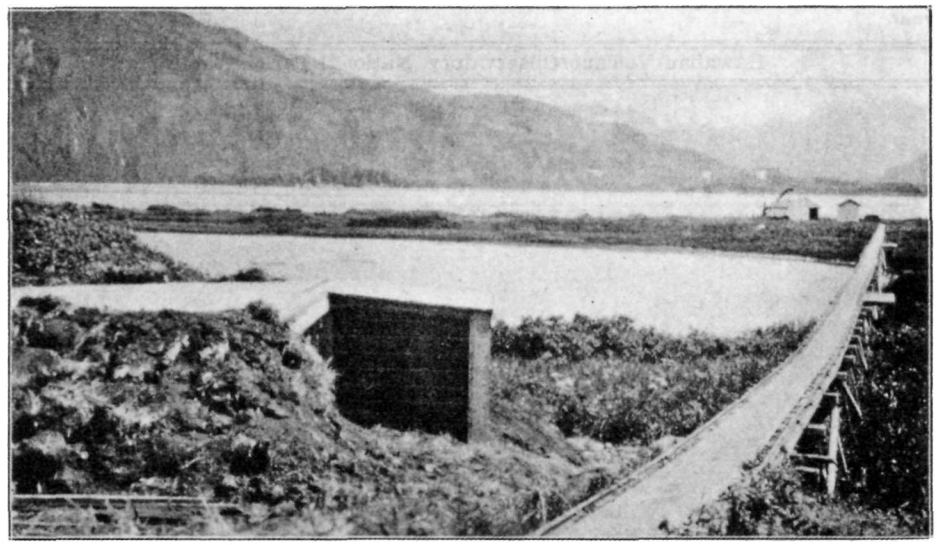
Dutch Harbor seismograph hut beside wharf tramway of Naval Radio Station as installed July 1929 by Austin E. Jones, so as to place instruments at some distance from the machinery. Looking east on Amaknak Island toward the entrance to Unalaska Harbor.

DIFFICULTIES OF ALASKAN EARTHQUAKE STUDY

The United States possesses one of the most important Volcano belts in the world in the Alaskan Peninsula and the Aleutian Islands. For a length of eighteen hundred miles from Attu at the west the ridge which separates Bering Sea from the Pacific Ocean extends in a pure curve northeast to Mount McKinley, rising higher and higher from islands at the west to the mightiest mountain in North America at the east. At the north is a shallow ocean, which is just as much a part of the combined Asia-America continent as is the Yukon Valley. It merely happens to be flooded with salt water in the present episode of geological time. At the south is the great Aleutian Deep reaching four thousand fathoms, a cleft or valley or sunken trough trending parallel with the Aleutian ridge, and in some way compensating the mysterious curved elevation. In like manner Japan is a curved ridge with the Tuscarora Deep east of it, with the outside of the curve toward the Pacific. Both places are famous earthquake belts with lines of volcanoes along the ridge. There are forty volcanoes reputed active in the Aleutian belt, many of them snowy peaks of greater and greater elevation as the line is followed northeastward to the upper part of the Alaskan Peninsula. The geology of the Peninsula and the islands shows folded sedimentary rocks of Mesozoic and Tertiary age, broken through by many igneous rocks, and overlaid by volcanic lavas and other accumulations along with glacial deposits.

The problem confronting the student of volcanology in such a place is to lay out a campaign for making use of the resident population to discover how many eruptions and how many earthquakes occur, where they occur in great number, what other movements like tilting of the ground are present, and in addition to explore individual volcanoes, promote mapping on land and sea, and gradually to acquire knowledge of places that may be used as strategic centers for continuous study of earth movements, hot springs, hot gases, and the action of lava underground.

The Section of Volcanology of the United States Geological Survey made a beginning in 1927 by establishing an Hawaiian-type seismograph in the Agricultural Experiment Station on Kodiak Island, shown on map of Alaska as the large island lying southeast of the upper part of the Alaskan Peninsula. In 1928 the volcanic area around Pavlof Volcano was mapped by the writer through an expedition conducted under the National Geographic Society. In 1929 another seismograph of the same type was established at the Naval Radio Station in Dutch Harbor on the island Unalaska (see Volcano Letter April 2, page one). Meanwhile an exploration had been made by way of reconnaissance all around the Peninsula and away out to Attu, in sequence upon a journey in a schooner through some of the eastern islands which had been made in 1907. All of this has shown us what the Aleutian lands are like, vast tundra flats with meandering streams on the north side of the Peninsula, rugged mountains and fjords crowned with



Seismograph hut at Dutch Harbor looking south, showing the harbor and mountains of Unalaska Island. Unalaska village just outside of picture on the right. Photo Jones.

volcanoes at the south, and these extending west through the grassy islands amid a climate of storms and fogs all the year around. There are a few villages of Aleut Indians and Eskimo, some canneries, huts occupied by winter trappers, and two or three sheep stations. Kodiak and Unalaska are the largest villages. In a few places there are resident white traders and officials throughout the year.

Until the present time, with between two and three years of record for the two seismographs at Kodiak and Dutch Harbor, there have been registered on the seismograms a few score local earthquakes and a very few distant ones. As a whole both places are disappointing in seismicity. Interruptions in operation due to storm and mechanical difficulties have been frequent. Storm microseisms are often so bad as to make seismic movements unrecognizable. Winter cold and wind and deep snow have produced rust and leakage and heaving at the unheated concrete huts, making endless trouble with the delicate clockworks, time pieces, electric contacts, wire connections and pivots which are essential parts of a complete two-component high-magnification seismograph. Neither Kodiak nor Dutch Harbor is actually at an active volcano, Kodiak being about 110 miles from Katmai and Dutch Harbor some twenty-five miles from Makushin.

The observers employed to tend the seismographs have all been devoted, conscientious women who were wives of officials or business men, and who do their utmost to keep the machines going even though the seismograph huts are buried under snow. The duties of these observers are fourfold: (1) to tend the seismographs, (2) to keep seismographs in repair, (3) to file and mail the seismograms, (4) to keep notes on volcanic happenings reported. It seems simple to anyone trained in physics to test the period, the damping ratio, the magnet adjustment, the tilt changes, the battery decline, and the time error of a pair of pendulums and an electrically connected eight-day regulator pendulum clock marking minutes and hours. It does not seem simple to untrained people buffeted by one of the most rigorous climates in the world, and with inspection by seismologists only at intervals of a year or more. All of this in a place without electric lights or watchmakers, where procuring supplies is difficult, where the building is unheated and the cold is intense, makes seismological registration a very different matter from Hawaii or California where supplies and assistance are abundant.

The following is from Mrs. M. V. Watkinson, the operator at the Kodiak station, who has to walk from her dwelling a mile or so up a hill to the seismograph chamber in an abandoned milk house of the Agricultural Experiment Station:

"February 21, 1930. We have had a great deal of trouble with the seismograph. The weather has been very severe, the natives say the worst for the last 40 years, so that all the water mains have been frozen. The storm has been almost continuous for twenty-eight days and has not broken yet. The time lift of the pens is not working right. The annunciator wire became saturated with moisture, in fact moisture was dropping down from walls and ceiling of room, and there were beads of water making a short between the wires. I changed the wires to waterproof covered ones, but this did not remedy the trouble. We found that the contact points of the clock were sticking, and fixed that. On February 4 and 5 the weather was so bad it was impossible to make my way up the hill. I started but had to turn back. Finally the seismograph went out of commission altogether owing to the heaving of the posts by frost. I have the machines running again, but not properly as the posts heaved diagonally. Yesterday I made the bumping test for period" (this is made by a light hanging weight giving a measured acceleration to the heavy mass).

"March 22, 1920. The continual severe weather has driven a number of halibut boats into port for repairs. The

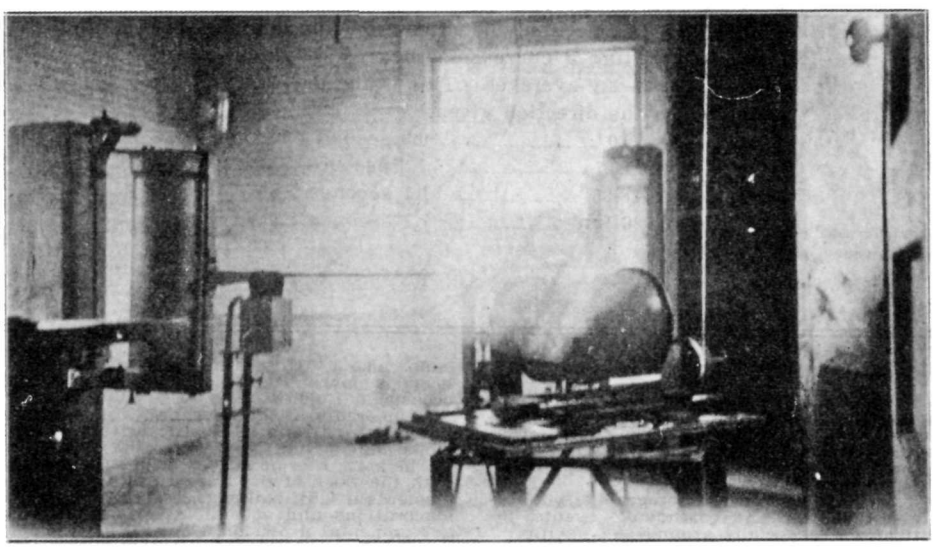
weather has been so extremely cold, with regular blizzards of snow, that it has been impossible to stay in the chamber more than a couple of hours at a time in spite of the oil heater. The records I am now sending do not mean much beyond recording the process of trying to get the machine to run properly.' On another day came the news of an epidemic of influenza with the operator and her two sons ill. In January another violent storm was reported "raging so that it was impossible to face it up the hill." A note of December says "there is no record for the 15th as the new driving clock would not fit. We were so disappointed as there were earthquake shocks next day, and we had numerous inquiries from up and down the coast as to whether they were recorded here, and it kind of hurt to have to tell that our instrument was out of commission."

The following are human documents from the journal of Mrs. Esther Wendhab, wife of Naval radio operator at Dutch Harbor, who tends the seismographs:

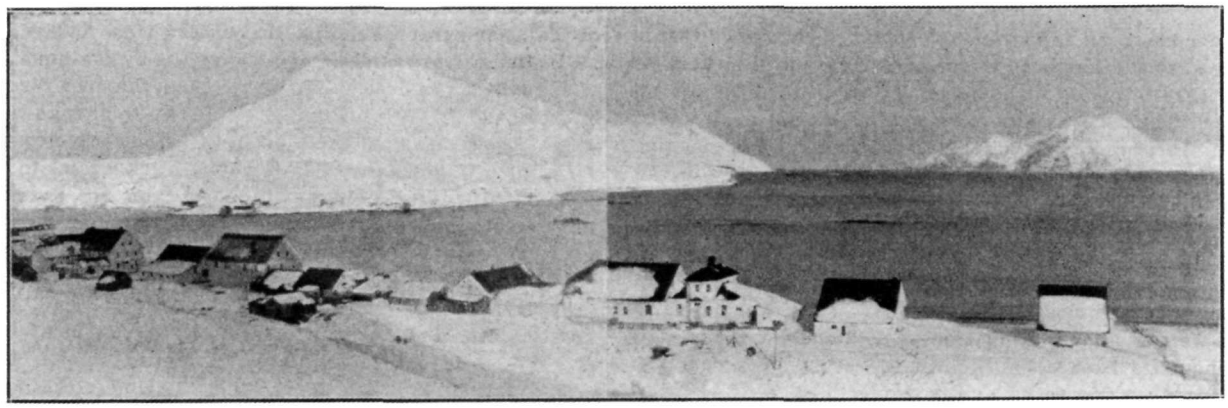
'March 18, 1931. Got 'stormed in' away from home and was unable to change the records. March 23: Was afraid to go out in the northwest wind on the icy trail. Captain Nelson of the Eunice reported a volcano smoking terribly with thick black fumes, where before he has only observed white steam, at Tulik on Umnak Island. He passed it March 21 and so unusual was its action he believes it is about to erupt. There was no record on the seismograph. March 29: Two earthquake shocks this morning, and the needle that has been causing trouble made the best record. April 2: The clock is going wrong again. The minute contact points are worn and get dirty very fast. I believe it will keep causing trouble, but I will do my best."

"February 18, 1931. Took mail to town and it stormed so badly I could not get home at all, so did not change record until following monrning. February 20: No trace of the seismograph building, had a hard time finding it, as all landmarks are under snow. Found it by the huge bank of snow that I've been piling up to get to the door recently. February 23: No chance of getting down to change record today. Terrible storm and blowing SE at seventy-five miles per hour. Will have to use the long stick again, to prod around to find the building, because even the snowbank will be gone now. February 26: The pen point came out again and stopped writing. Weather so bad nearly impossible to get down trail. Natives born and raised here (a year later than Mrs. Watkinson's report) call it the worst winter they ever witnessed, with the most snow, twenty feet deep in many places and getting worse. Have to find the building and dig it out every time now. March 2: Worked all day yesterday and fixed the arm. Put it on this morning after I finally got in. March 14: Had to fix the clock again as the points were dirty, but have it going. Weather still bad and sorry I have the work to do in such bad weather. They tell me this is the last month of that and then I believe it will be a pleasure again. It will be so much easier that it will make up for some times I've nearly frozen getting there, I'm sure. There is no news locally about any disturbances."

This sort of heroism in the cause of science deserves going on record, and was not contemplated when these stations were established in summertime. These documents show why the writer is so anxious to perfect a simple seismograph to register numbers and intensities of local shocks. Geographical distribution of shock-recorders is more important than attempts at precision where precision is impossible. Twenty shock-recorders placed with school teachers or trappers in different places in Alaska, some of these living very close to an active volcano, will tell more than precision instruments, until such time as a large observatory may be established there. T.A.J.



Early model Hawaiian-type, two-component, horizontal pendulum seismograph installed in dairy house Agricultural Experiment Station, Kodiak. In this model the damping vanes, in adjustable oil tank, are near the heavy masses, which are filled *with sand and weigh approximately 160 pounds each. Magnifying levers write on* smoked paper on the drum. Paper changed and shellacked daily. Time clock in same room, corrected by telephone from radio station. Photo Jones.



Unalaska in winter time. Seismograph station of U. S. Geological Survey is among the snowy hills on the left. Photo Yatchmeneff.

KILAUEA REPORT No. 1010

WEEK ENDING JUNE 7, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On June 1 at Halemaumau pit of Kilauea Crater very faint fume could be seen at the sulphur spot on the floor, and vapor was thicker at the southeast rock wall at edge of floor than at the south talus. On June 3 the pit seismograph indicated quiet conditions and the rock wall steamed less. At 9:30 a. m. June 6 a slide occurred at the north wall.

Thirty tremors and one very feeble local seism were registered at the Observatory, the latter at 8:41 a. m. June 6, indicating distance of origin 25 miles. Tilting of the ground was slight WSW., and microseismic motion was slight.

TILTING OF THE GROUND FOR MAY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

May 4-10	0.9 second	E.
May 11-17	1.8 seconds	SW.
May 18-25	1.1 seconds	SSW.
May 26-June 1	7.7 seconds	SSW.

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No. 338—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — June 18, 1931



This map should be corrected by showing a broad strip of Hawaii National Park between Kilauea and Mokuaweoweo craters. The 1855 flow is between the flows of 1880-81 and 1899. About the Mauna Loa center there were flows at the beginning of the nineteenth century to NW, in the first half of the century to E, then a big series to N, and an increasing series from 1868 to 1926 to SW. The 1868 earthquake centered about Pahala, the 1929 about Hualalai. ("Flow 1901" at West Point is misprint for 1801.)

PREPAREDNESS AGAINST DISASTER

Address before Hilo Chamber of Commerce June 9, 1931, by T. A. Jaggar.

Recent Disasters

Recently there have been earthquake disasters in Japan, Mexico and New Zealand. The Napier earthquake in New Zealand has awakened the world again to the problems of fire following terrific earthquake at a place of population congestion, just as at San Fancisco in 1906, and at Tokyo in 1923.

Hilo, Hawaii

To the Associated Engineers of Hawaii January 16, 1918, I talked on the "index of danger from volcanoes," showing that the four classes of disaster to a volcanic land had happened in Hawaii. These are:

Class I, Explosion and volcanic blast
Example, Kilauea in 1924
Class II, Lava flow
Example, Hilo in 1881, Hoopuloa 1926
Class III, Earthquake
Example, Kau 1868, Puuwaawaa 1929
Class IV, Tidal wave, Example Puna shore 1868, Hilo 1877, 1923

As each of these is represented by damage in this century, the topic is a live one. We have recently seen in addition terrific wind storms in Honolulu and rain floods damaging shops in Hilo. The wind combination along with lava flow or earthquake might be very serious for Hilo.

The 1918 lecture was published in Bulletin of Hawaiian Volcano Observatory January 1918, tidal wave damage in Hawaii was reviewed in Volcano Letter No. 321, and the cycles of Hawaiian volcanic happenings in Volcano Letter No. 325.

Napier Earthquake

The best way to envisage preparedness at Hilo is not to speak in hushed whispers because we are timid about frightening tourists away from our real estate. This is the attitude of some mainland cities. The insurance attitude is the correct one, expect fires, but put them out. If a terrific earthquake wrecks Hilo, let us in Hilo make a perfect demonstration of calm, unruffled preparedness, with the ready service of supplies that General Pershing had when he jumped in and helped at Chateau Thierry. There is no use in having hysterics about these things nor in publishing anything. The thing to do is to keep quiet and get action.

Now let us see what happened at Napier. Wherever you were, in your car, on the road, standing indoors, standing outdoors, suddenly there comes a tremendous crash like and explosion and down you go. Everything goes down, houses, bridges, gulches, cliffs, fires start, road fills crack open, automobiles fall into the cracks, wharfs are all down, some of the shipping is grounded, the breakwater has settled out of sight in places. In other words, the enemy has hit Hilo with a Big Bertha. The railway is out of commission, emergency telephones are called for as the wires are all down, the water mains have burst, the sewage is interrupted, the fire engines are pinned in their houses, the roads are interrupted by landslides. More than all, the people are struck dumb with shock, and until a warship arrives, to which this sort of thing is all in the days work, the population is dependent on whatever leaders happen to be soldiers.

Rescue parties are organized to dig out the wounded, portable cranes are in demand. Explosives must be used to demolish tottering masonry, which is likely to kill more people with the thousands of aftershocks that are coming along. Temporary wireless is one of the first requirements as the radio masts are down. Airplanes are summoned to rush anesthetics and medical supplies, for these things have given out. They have to be carried by air. A large number of tents are needed for temporary hospitals, and the roads interrupted by slides and cracks are not immediately available for carrying people to towns which suffered less. Sea transportation is organized as fast as possible by wireless, but that takes some time. The water supply being cut off, it is necessary to get in a chlorinating plant, organize a road survey immediately, and start work on pipes for an auxiliary water supply from a place where fresh water is available. The contents of the banks are laid wide open as well as many other valuable safes and cash drawers, and martial law is immediately organized by soldiers and constables who understand such things, a ring of pickets is run around the city, looters are shot on sight by marine guards. The jail prisoners are called out for digging, and do heroic work of rescue. Many motorists are caught in gorges and gulches and search parties have to be organized to seek them. The post office department is entirely disrupted and a quick reorganization is called for, as inquiries begin to pour in by mail as soon as any partial organization has been made; people inquire for the safety of their relatives. All lights go out at the very beginning and the organization of a temporary lighting plant and the cleaning up of wires is of first importance when the darkness of night settles over ruins, where work has to continue with the aid of flares, and where valuables have to be guarded.

Necessarily the Navy and shipping are of great use, and there were three ships which reached Napier. A small, compact, efficient, relief committee was found to be the first requirement at Napier and the organization of an information bureau to answer inquiries. Within a week when outsiders arrive to bring relief, there is need of quarters to correspond with the destroyed hotel, and there is need of increased wharf facility. Free meals have to be organized with the relief funds. Now there is need for a card record of hospital cases, of which there were 2,200 at Napier. The stoppage of the sewers and the bad water supply made it necessary to get together as many trucks as possible as soon as the road gangs had opened a way to get out of the district, and 5,000 people were evacuated from Napier and Hastings to a neighboring town which had not suffered, Palmerston. Palmerston organized itself to receive the transport of refugees. There was an acute clothing shortage, and notices had to be placed in newspapers of other towns instructing the public what to send, for they sent too many groceries and too little clothing. The loss at the central towns was of the order of $15,000,000. Fire insurance was simply not paid, for the situation was just the same as at San Francisco and Tokyo, and companies when they do write risks involving conflagration always reinsure with other companies. Only when earthquake is specified, and fire resulting from earthquake, and when these risks are paid for, can there be any expectation of restoration by insurance. **After the event** in all these cases, San Francisco, Tokyo, and Napier, insurance companies wrote earthquake risks. This is always done without any logic, on the part of the owners seeking insurance, who try to save the horses after the barn is burned down. Then after 45 or 50 years when there is real danger, everybody has forgotten it, insurance has been withdrawn, the

building code has been relaxed, and it all happens over again. Such is human nature.

Organization for Preparedness

Every city should have a small committee of far-seeing men accustomed to administer discipline, representing commerce, public health, police and national guard, transport, and statistics. These people should have a clean-cut war problem with map of the city, just as war problems are worked out by General Staffs. The needs in time of disaster may be small or big, local or general, but the big possibilities should be looked at so that nobody will be surprised. The needs are:

(1) Organization of discipline and communication.
(2) Organization of rescue.
(3) Organization of relief.
(4) Organization of relief funds.
(5) Organization of camp for refugees.
(6) Organization of rebuilding.

(1) **Discipline and Communication**

This in Hilo would naturally fall to the Police service and the National Guard, and the communication side of it would call for the assistance and representation of the Naval and commercial wireless. Public Health agencies would be needed right away, and a representative of everybody possessing motor trucks.

(2) **Rescue**

This calls for large forces of laborers and truckmen, the National Guard to protect property, Boy and Girl Scouts to act as messengers, all the auxiliary police available, and all the resources of the Red Cross, including everybody who has had any nurse training.

(3) **Relief**

The prompt selection of camp grounds, creation of sanitation, and finding of auxiliary water, light if the main sources are destroyed, and assembling of food supplies have to be governed by circumstances. This sort of thing is best directed by some one familiar with organizing a camp on military lines and capable of enforcing martial law. There are needed food supplies, tents, surgical supplies, washing appliances, utensils. fuel, stoves, and competent cooks. Don't say 'get them at the hospital.'

The natural reaction of a committee is to say, "We have camp supplies in the armory, surgical things at the hospital, and trucks in the county stables.' Remember that for the extreme crisis contemplated, all three may be toppled over and burning, or under a lava flow, with 500 people dead, 1500 needing hospital treatment, and 5,000 homeless. The thing to face is the extreme possibility, the resources in water and supplies of Olaa and Hamakua, evacuation by sea to Maui or Kona, the place for a sanitary refugee concentration camp.

(4) **Relief Funds**

There have been cases of disaster where relief funds have been misapplied. One of the first things to happen when a catastrophe is announced is for subscriptions from elsewhere to pour in. The Red Cross is the proper center, with reputable financiers to act as custodians of money.

(5) **Refugee Camp**

Supposing Hilo partially destroyed under some great calamity, it is a matter of debate where to put a relief camp. The requirements are access to transportation, good water, supplies of food and clothing, policing, and communication by telephone and radio. If the wharves at Hilo were not destroyed or buried under lava, the place might be Waiakea or the airport. If a lava flow came through that side, the place would have to be in Hamakua.

(6) **Reconstruction**

The rebulding after disaster has been a remarkable feature at San Francisco and Tokyo. The same is promised for Napier. As in the case of war, there are improvements in civilization, as well as evils, that result from a general clean-up.

One can imagine a new Hilo with a beautiful park all along the beach from the Wailuku River to the Wailoa, and with the railway moved back. One can imagine taking pride in a new city with no advertising signs visible from the harbor.

Actualities on the Island of Hawaii

Hilo is peculiar among cities in the world in that it is squarely in a volcanic belt, but happens to have been largely spared until now. So far as strong earthquake is concerned, this is equally true of Honolulu. Both of these places are liable to a terrific earthquake, when everybody will be surprised, and say, "This is the first we have ever had." Just that was said by the living generation at Charleston, Santa Barbara and San Francisco. The reason is that the earthquake interval overlaps several generations, and in Hawaii earthquakes in the 18th century before the coming of the whites made no impression on grass houses.

Hilo is definitely committed to future lava flows. The years 1801, 1843, and 1859 sent flows northwest, two of them building new land in the sea, from Hualalai and Mauna Loa. The years 1852, 1855, 1881 and 1899 sent flows towards Hilo, one reached Waiakea, and the one before it reached Kaumana (1855). The years 1868, 1887, 1907, 1919, 1919 and 1926 have sent flows at short intervals to the southwest from Mauna Loa, always different places, three of them reaching the shoreline, all destructive of ranches or roads or villages or all three. Earthquakes destructive and dangerous came in a swarm in October, 1929, shifting the area of underground activity of the enemy from Kahuku to Hualalai, and suggesting that the north side of Muna Loa as the center of it all will probably be the sector where he will concentrate his artillery for the next attack.

Apart from these dates history indicates that Mauna Loa will average activity about every four and a half years, so that we now are on the verge of a new outbreak. There are pros and cons that argue for a long interval in some parts of the century, but we know too little to apply them here. The fact is inevitable that Hilo will look up some evening and see what resembles a bright star on the northeast rift line of Mauna Loa, and a flow will start following the hollows among the flows of 1852, 1855, and 1881 in the direction of the valley of the Wailuku River. After it has been going a month we shall know whether it is likely to keep going for a year. It begins with rapid aa flows, the source cones make pahoehoe, the aa ceases, then the pahoehoe slowly tongues out from above past the earlier aa extremities, and pushing through tunnels to spreading leaflike fronts, the pahoehoe may creep through the forest downward for many months. This would invade and dry up the Hilo water supply. The lava would be fed through a source tunnel up around the nine thousand foot level, forking out into many tubes down below. If a flow once got started between the 1855 and the 1881 flows, or on the north side of the 1855 flow, it would pour down the line of the waterfalls of the main valley of the Wailuku, as it has done in prehistoric times in the past, and as it did in 1881.

The waterfalls were made by many lava dams. The visible tributaries are mostly from the north, those from the south being buried under lava, and flowing underground. On this course the lava flow would pour straight through Piihonua, and the fate of Hilo would depend on how long the tunnel supply of pahoehoe kept on flooding at the source.

Just at this point could be applied the project to stop a lava flow advocated by the late honored L. A. Thurston. And only at this point. No aa flow in its early and rapid stages could be arrested. A pahoehoe flow in the later stages of an eruption, by reason of the tunnel mechanism, could be blown up at the source tunnel about the nine thousand foot level, or just below the source cone, so as to dam the lava stream with rock and force it to start fresh. The eruption would continue just as before, with the lava starting to flow anew out of the blocked channel over the surface of the country by a slightly changed course. If the previous pahoehoe flow took five months to get down near the Hilo level, the renewed flow 30 miles up the mountain would require as much or more, and the city would be given five months respite. The main source would go out of action in that time, and Hilo would be saved. There would be no necessity of employing the army or "T.N.T." Any contractor with a couple of men and some blasting powder, carried by pack mules from the ranch, and guided by the volcanologists, can do the job. If the 1881 or 1855 situation were exactly repeated, this diversion of the flow at the source could be done. It could not possibly have been done for Hoopuloa or Alika. The 1855 flow lasted 15 months, the 1859 ten months, and the 1881 nine months. Such durations are quite possible now, for the tunnel flows on the Kilauea floor in 1919 lasted seven months, and so did the Kau desert flow in 1920.

The Observatory asks from the Chamber of Commerce its complete cooperation, with as many members of the Chamber becoming members of the Hawaiian Volcano Research Association as possible, and taking a real interest. Meantime we are devoting all our energies to learning how to predict volcanic eruption.

Contemplation of these possibilities is thoroughly sound economics for this community, and should make each firm ask, "Is our office earthquake-proof in its construction? Are our investments, our insurance, and our influence all they should be to prevent congestion, flood, or conflagration? Are we assisting those who are working on this problem? Or are we saying, "This is all nonsense. Life is too short. Such a thing couldn't happen to Hilo."

KILAUEA REPORT No. 1012

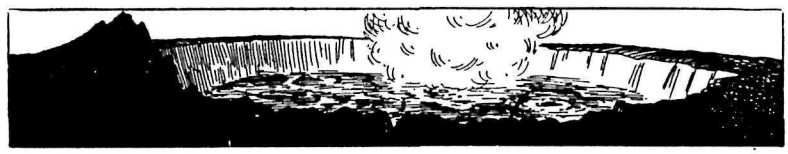
WEEK ENDING JUNE 14, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On June 8 at 9:40 a. m. seismic conditions were quiet at Halemaumau pit and the sulphur spots on the floor and small steam vents at edge of floor were as usual. The sulphur spots have gradually increased since December 1930.

A notable slight local earthquake was felt generally on the Island of Hawaii at 6:51 p. m. June 11, with motion stronger and quicker in North Kona near Honokahau than elsewhere. This was the only place where one or two small objects were overturned. The shock was felt as a slow motion at Waimea, Hilo, Kilauea, and in Kau, and the evidence of distance on the seismograms made the origin probably under Mauna Loa. There were other very feeble shocks felt at Keauhou Ranch at 4:29 p. m. the same day and at 9:03 p. m. felt in Hilo.

The seismographs of the Observatory registered four other very feeble local seisms at 9:08 p. m. June 12 with distance of origin 14 miles, at 9:22 a. m. June 8, at 3:06 p. m. June 13 and 6:11 June 14. In addition 28 tremors were registered during the week. The total of seismic disturbances for the week numbered 35. Tilting of the ground was slight WNW, and microseismic motion very small.



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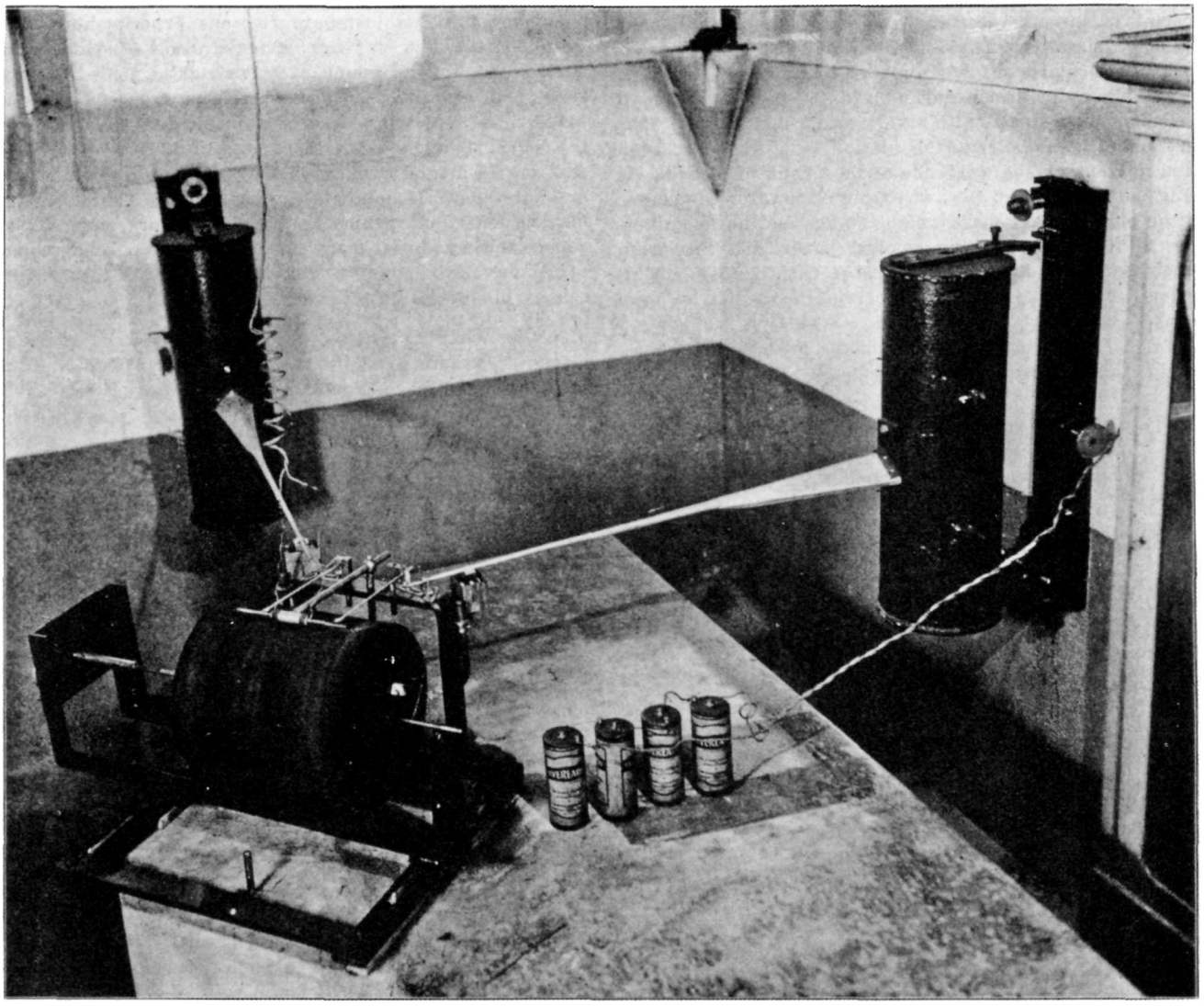
The Volcano Letter

339

Two dollars per year | Ten cents per copy

No. 339—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 25, 1931



Pair of Hawaiian Type horizontal pendulum seismographs, designed and built at the Hawaiian Volcano Observatory. Two heavy masses are hinged against plates on the wall east-west and north-south. Aluminum pens connected with booms from these masses write on a drum driven by clockwork and moving along on a screw. Paper is smoked and changed on the drum every day. The cross-bar electro magnet lifts the pens every minute and hour. The paper is shellacked and stored as the seismogram of the day. Photo Maehara.

EARTHQUAKE INSTRUMENTS HAWAIIAN VOLCANO OBSERVATORY

When the original building of the Hawaiian Volcano Observatory was constructed in February 1912, a preliminary equipment of instruments had been secured through the Massachusetts Institute of Technology, and by a special order placed in Japan. There were a pair of 100-kg. Bosch horizontal-pendulum seismographs made in Strasburg, an Omori portable two-component small seismograph for ordinary earthquakes, an Omori strong motion seismograph recording three components with an automatic starter, and a large one-component Omori horizontal pendulum of high magnification for distant earthquakes. A cellar 18 feet square and 9 feet deep was finished in concrete under the Observatory on the northeast edge of the greater Kilauea Crater. This was equipped with several concrete tables adapted to the instruments. During the first year of occupancy the instruments were set up and tested for the peculiarities of the Hawaiian ground, and the portable seismograph was used for a time in the

hut built near the north rim of Halemaumau. Mr. H. O. Wood had charge of seismology from the summer of 1912 to 1917.

The tests at the fire pit showed that the insensitive Omori portable pendulum would yield nothing distinctive of that place. A high magnification instrument was needed. Mr. Perret in the summer of 1911 with a delicately poised seismoscope had shown the presence of tremors at the pit edge when lava was fountaining inside the cauldron, and special pulsations recording the heavier gushes of the periodic fountain then called "Old Faithful." In September 1928 a one-component horizontal pendulum was installed in a shallow depression dug in lava 450 feet southeast of Halemaumau, covered with a very small shelter hut. This instrument was built at the station, and had first been used in Kona on the west side of the Island of Hawaii. It hangs so as to record tilt away from or towards the center of the pit, its heavy mass weighs 30 kg., and its magnification is 70. It records on smoked paper, and the drum covered with paper is smoked at the Observatory, is protected by a special box, and is carried to the pit by automobile and changed every two days. This pit registration has made valuable records at times of outbreak, and shows tremors and tiltings different from those at the Observatory two miles away.

This sort of evolution, with gradual change of instruments suited to special needs, has gone on with all the instruments. Seismometry on an active volcano is quite different from that of a station which devotes most of its energies to distant earthquakes. Most of the seismometric stations of the world are of the latter type. In Japan for many years the meteorological stations and other establishments have maintained instruments for the study of local earthquakes, but the main purpose of these stations in Omori's time was to record "ordinary" earthquakes, meaning registration of frequency, time, and intensity of the shocks that would ordinarily be felt, so that some scientific data could be gathered on the subject. This led to the making of more sensitive instruments of higher magnification and to the attempt to make a "universal" seismograph, which would satisfactorily record both local and distant shocks. Most of the German instruments make this attempt, and most of the earthquake lists do not distinguish satisfactorily between distant and local shocks. The "local' shock is a phenomenon still dubious and obscure, for if it is intense enough and deep enough to register on distant instruments, it may be "felt" over a wide area, and on the other hand very intense disastrous earthquakes like the one at Managua recently may be very local in perceptibility, and fail of registration at the remote stations. An earthquake may be accompanied by a massive movement of the ground with actual faulting of the sod at the place of sensation. What is felt in this case is not an "elastic wave." Many felt earthquakes are entirely elastic waves, with no discovered faulting of the ground. The natural history of this subject needs much research.

From this the reader should understand that it is an actual fact that no one knows what an earthquake is. Waves of compression, transverse waves due to the rigidity modulus of the rock, surface waves involving an up-and-down movement, waves reflected at different surfaces of change of density within the crust of the earth, waves traveling at different speeds, the ground or hill or cliff or plain under foot oscillating with its own period as an independent pendulum, spells of tilting, places of local tilting, mass movements of sideways shifting, mass movements of sudden uplift or depression, mass movements of sudden tilting—all of these things are supposed to exist in the crust of the earth, and a one-component pendulum, meaning a pendulum capable of swinging in only one direction, does not tell much about them. What little is known indicates that a house totally distorts the motion of the ground. The one-component pendulum totally eliminates all but one set of motions of the ground, tends to swing on its own account, and tells nothing by itself as to whether the motion is massive or elastic, irregular or harmonic, until subjected to rigorous experimental criticism. The result of years of registration of many local earthquakes on the Island of Hawaii quite denies the notion of an epicenter. The epicenter is supposed to be a place right over the source of a shock. At the epicenter the shock should be felt most strongly. It is quite true that on the Island of Hawaii many shocks are felt which are not felt in Honolulu 200 miles away. There is thus localization. But within the island there are hundreds of shocks felt equally at many places, with the seismographic evidence pointing to epicenters where there is no more intensity of perception than anywhere else.

Now what is this seismographic evidence? This is clearly important, for if we may harness an island with instruments, and that island has many earthquakes of a small and harmless type, we may really study the nature history of the earthquake. From the beginning this was the aim of the Hawaiian Volcano Observatory. People think they can tell the direction of an earth shock which they feel. All they can tell is the way the maximum of a hundred motions affected the particular room or chair or bed where they were placed. The seismograph is a rocking chair specially placed in a chosen room in the rock of the earth itself where the vibration of the building will not create a separate pendulum. The writing of the seismograph on smoked paper, when a little earthquake occurs, begins with a preliminary tremor as the paper moves along under the pen, then a movement of greater amplitude follows, or the "long waves,' and this is the part which is felt. This tails off to nothing in the course of minutes. A sensitive person standing outdoors might feel very faintly the preliminary as a mere tremble because it is quick. The long wave he would feel as a thud. The tail portion is slow and not usually felt. The writing levers of a seismograph, after magnifying the motion 100 times, have hardly any energy, hence the tiny pen tip pivotted and touching lightly a smoked surface to avoid friction. Even the restraint of a spider's web on the pen may spoil the record. The preliminary quick tremor has been proved to be a combination of the compressional and rigidity waves which reaches the instrument more quickly, by faster travel, than the long waves. The long waves are a combination of mass movement and wave motion. The sharp change from the preliminary to the long waves makes it possible to measure in seconds the duration of the preliminary. The longer its duration the farther away the place of origin of the disturbance. Hence with several seismographs in different places we may triangulate on the origin location underground. If we can find the origin location underground we do not need to trouble about "epicenters."

As shown in the accompanying pictures, the seismograph chamber at the Observatory contains now horizontal pendulums built right here registering all components, the electrically connected clock registers time on the drums, and there are other stations with similar instruments in Hilo and Kona for triangulation. The horizontal pendulums also record tilting of the ground. T.A.J.

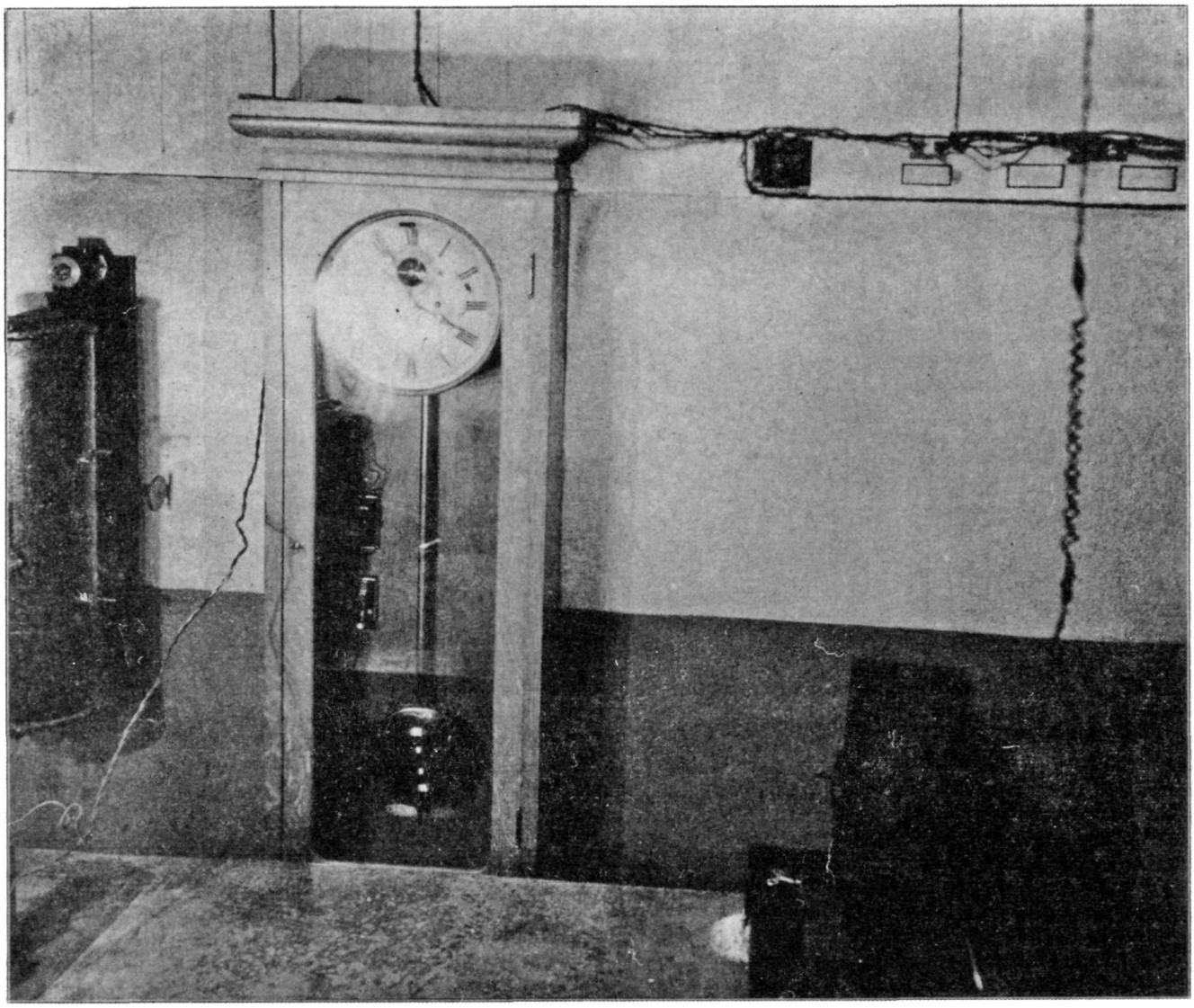
KILAUEA REPORT No. 1013

WEEK ENDING JUNE 21, 1931

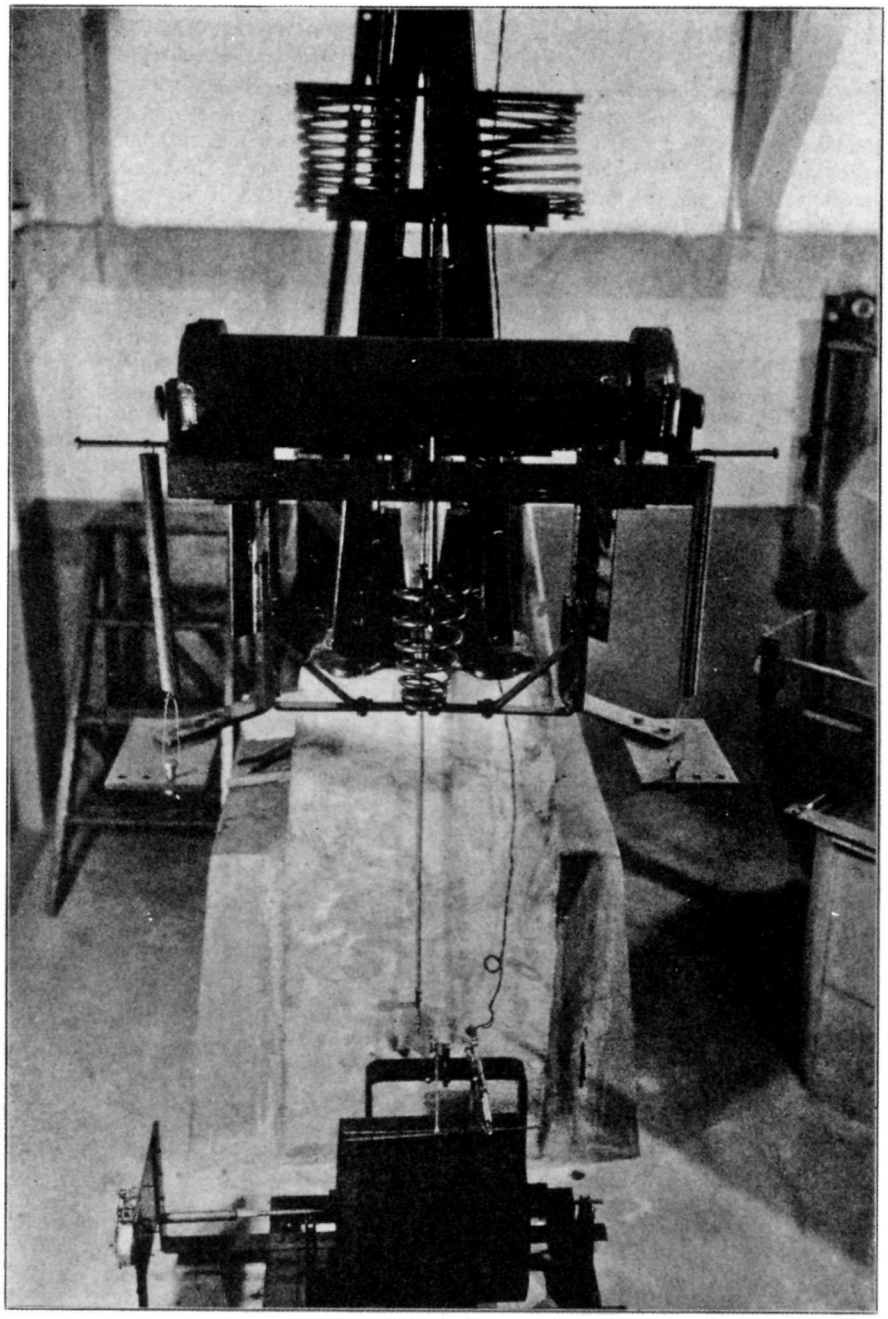
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On June 15 at 9:15 a m. a small slide occurred at the north wall of Halemaumau. Steam is emerging at the southeast rock bank. Fume is notably absent at present.

The Observatory seismographs registered 26 tremors, one very feeble local seism, and one feeble shock felt locally. The last was at 10:45 a. m. June 16, with indicated distance of origin 11 miles. Tilting of the ground was slight ENE, and microseismic motion was slight.



Howard electrically fitted regulator clock connected with all the self-recording instruments of the Observatory. The error of the clock is compared with wireless time every day. The wireless signal is impressed with telegraph key on all the seismograph drums. The clock is compared daily with a chronometer, and the temperature of the chamber is recorded.



Vertical component seismograph built at the Hawaiian Volcano Observatory. The heavy mass is here hung on spiral springs, with temperature compensation from small springs. The heavy mass is free swinging and registers the up-and-down motion of the rock under the concrete cellar. The up-and-down motion is smaller than the horizontal motion in earthquakes. Photo Maehara.

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The Volcano Letter

340

Two dollars per year **Ten cents per copy**

No. 340—Weekly Hawaiian Volcano Observatory, National Park, Hawaii July 2, 1931



Myrtledale Geyser near Calitoga, Napa County, California. Made artificially by casing a well 180 feet deep, where a stratum containing boiling water is reached. The spouting occurs once every 45 minutes, when the release of steam pressure is satisfied, and it takes another interval to bring the replacement underground water to the boiling point.

VOLCANIC WATERS OF NAPA COUNTY, CALIFORNIA

In the Coast Range north of San Francisco, on the border between Lake and Sonoma counties, stands the St. Helena range marking some recent volcanic activity where there are hot gases and steam and sulphur which have been pouring forth from Teritary time until the present. "The northern and western ranges in these counties are composed largely of altered sedimentary rocks that probably belong to the Franciscan (Jurassic or Lower Cretaceous) formation. Glaucophane schists and serpentine are associated with them. The age of other altered sedimentaries here" is unknown, some geologists thinking them Lower Cretaceous.

"In Napa County and the southern part of Lake County several peaks and ridges are formed of lava that is probably of Teritary age. This lava overlies the altered sediments, and tuffaceous phases of it form prominent cliffs at a number of localities. Numerous carbonated springs of slight flow issue in this region north of San Francisco Bay, both from the sedimentary rocks and from the lavas, and hot springs exist in several places. A few springs of noticeably sulphureted water have also been examined but are less numerous and less important than those of the carbonated type."

So wrote Waring (Springs of California, Water-supply Paper 338, U. S. Geological Survey) in 1908, pointing out that upright fault or fracture lines have close relation to the hot springs of California. "At Calistoga, near the head

of Napa Valley" (three to four hours' journey north of San Francisco) "are several hot springs at which during the seventies there was a large resort. The hotel burned in the early eighties, however, and since that time the springs have not been of more than local importance. The name 'Calistoga' is said to be formed from the words California and Saratoga, but the springs are not at all like those of Saratoga Springs in New York. In 1910 the caretaker of the property had provided two bath-houses of two tubs each, half a dozen small cottages on the place were rented, and a few campers had pitched their tents nearby. Hand pumps supplied hot water directly to the tubs, and cool water was piped from a tank.

"Four main springs rise at the base of a knoll of buff-colored tuffaceous material at the northern border of the meadow land, and a few pools and seepages appear in the meadow itself. The observed temperatures of the principal springs ranged from 126° to 173° and their flows from about one-fourth gallon to five gallons a minute. The hottest spring, which yields about one gallon a minute, appears to be the most strongly mineralized, though its mineralization is only slightly perceptible to the taste. Algae probably give it the slight flavor that has caused it to be called a "chicken-soup" spring.

"At Calistoga Hotel, about 400 yards west from the springs, a dug well supplies warm water for tub baths and a swimming plunge. Warm water is also obtained in several other wells nearby, and there is one strongly flowing artesian well."

The following analysis of the swimming pool water, having a temperature of 122° Fahr., is characteristic, made by W. Anderson in 1888; constitutents are by weight in parts per million:

Sodium	212.0
Potassium	8.2
Calcium	12.0
Magnesium	5.7
Iron	6.0
Aluminum	2.4
Manganese	Trace
Sulphate	110.0
Chloride	255.0
Iodide	13.0
Carbonate	27.0
Silica	62.0
	713.3
Hydrogen sulphide	42.0

Concerning the geology of the hot springs Waring writes: "The position of the springs near the base of the knoll of volcanic tuff that rises in the valley land and the fact that a fault has been traced along this part of the valley furnish suggestive evidence that faulting has here provided escape for deep-seated water. The lava may also produce a high temperature gradient that aids in giving the abnormal temperatures to the water. The amount of heated water that rises is probably better indicated by the area of meadow-land that is formed than by the visible flow of hot water, for there is doubtless much seepage that is not observable."

This last conclusion has been borne out by discoveries since 1910 which prove the valley to be underlaid by boiling water instead of hot water (Waring maximum 173° F.). The writer visited Calistoga July 31, 1926, and learned that in 1915 borings 180 feet deep in the flat valley floor produced artificial geysers which spout up through the casings of wells 100 feet or more at intervals of 45 minutes to two hours. One of these, the Myrtledale Geyser, is shown on Page One. For a mile of length the east side of the valley is over an artesian basin of boiling water, whereas the springs are cold on the west. Mr. Finch determined the temperature of Plummer's Geyser March 22, 1927, to be 218° F., and Pacheteau's capped geyser 213.5° F. (Volcano Letter No. 236).

On the mountainside, five miles to the west of Calistoga, in Sonoma County, is the Petrified Forest where immense sequoias have been silicified in volcanic ash, mostly fallen in pairs, and with their butts toward Mount St. Helena. The suggestion is strong that St. Helena was the source of a volcanic blast that overturned them in prehistoric eruptions. The fossil tree shown on Page Three is 110 feet long with a diameter of 12 feet. There is a crater higher up the hillside.

Finch reports (Volcano Letter No. 236) that Mount Konocti, near Clear Lake north of this Napa country, is the most recently active volcano in this part of California. It is believed to have erupted somewhat over 1,000 years ago, or well within the historic period of Europe. The hills east of Sulphur Bank, itself east of Mount Konocti, contain a fairly well preserved crater, there is one on the south peak of the mountain, and between this country and Calistoga the lava flows capping the hills appear progressively older. Across the hills to the west at "The Geysers" in Sonoma County is superheated steam used for power (Volcano Letter No. 62, Allen and Day Publication 378 Carnegie Institution) believed to rise from hot underground magma.

It is worthy of note that the San Francisco earthquake of 1906, apart from the massive shift of terrain from Santa Cruz to Point Arena on the great fault, the greatest intensity was at Santa Rosa, with extensions of the belt northward toward Geyserville and southward to Petaluma. In the Napa valley and about Clear Lake there were other belts of apparent intensity VIII-IX R. F. This region of present-day volcanic heat of highest temperature for California, and of volcanoes active in the historic period, made localized centers of disturbance of enormous intensity. Therefore we should not treat too lightly the possible connection between underground magma and great earthquakes. (Map 23, Carnegie Institution, California Earthquake.) T.A.J.

KILAUEA REPORT No. 1014

WEEK ENDING JUNE 28, 1931

Section of Volcanology, U. S. Geological Survey

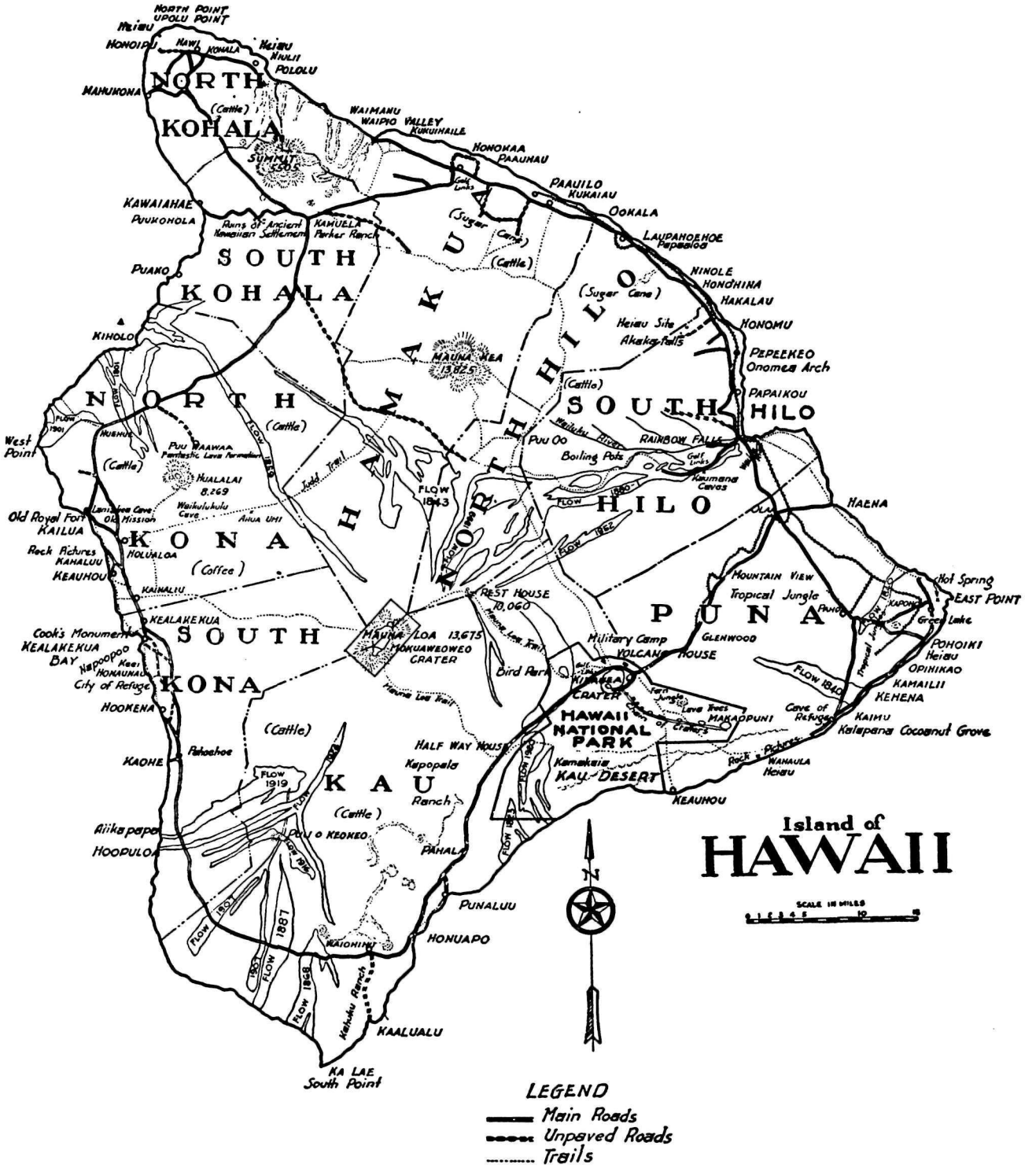
T. A. Jaggar, Volcanologist in Charge

The week at Kilauea has been quiet and uneventful. On June 22 there was a little steam on the south talus of Halemaumau, but none elsewhere. On June 23 no steam was seen. Dust was dense near the north talus, probably due to air currents, there having been moderately strong trade winds, without rain, blowing and creating much dryness. On June 27 the pit remained unchanged. Sulphur areas appeared less conspicuous except a bright spot on the west side of the floor.

Twenty-two very feeble tremors were the only seismic disturbances recorded by the instruments at the Observatory. Tilt was slight NW. Microseismic motion was slight.



Silicified big tree at the petrified forest in ash beds five miles west of Calistoga, California. This tree, "The Queen," is 110 feet long and 12 feet thick... The replacement of the wood fibre by silica was accomplished by hot waters. These sequoia trees were overturned in pairs, their tops pointing away from St. Helena volcano. Probably an ancient steam blast eruption did the work.



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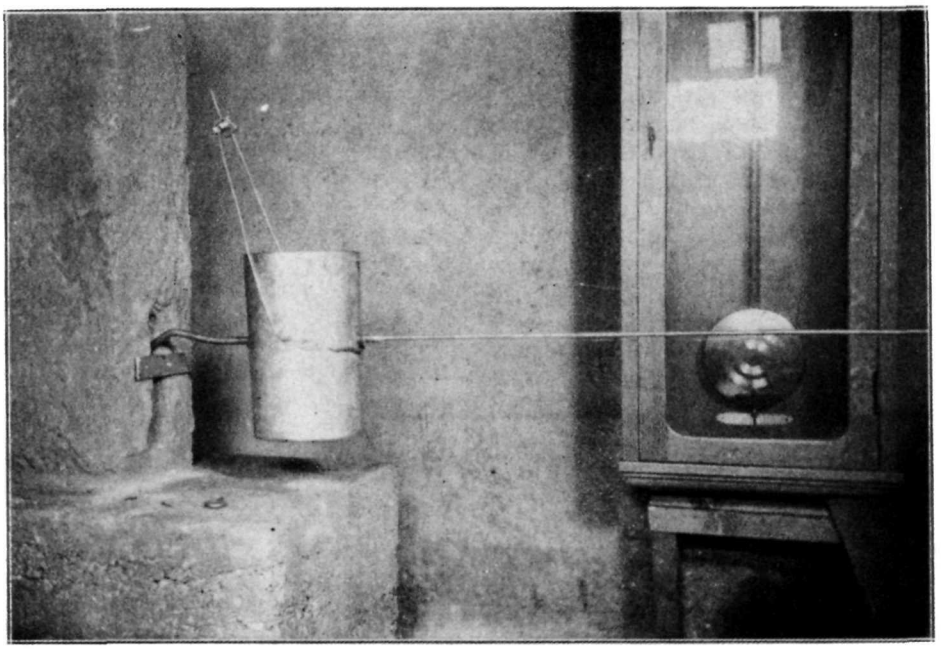


Experimental seismograph built of homemade materials at the Lassen Volcano Observatory by R. H. Finch, showing heavy mass, suspension and boom, the concrete pier and post, and the Howard clock.

MAKING A SIMPLE SEISMOGRAPH

The seismograph in most common use is a horizontal pendulum. The photograph shown on Page One is the hanging part of such a pendulum which anyone with a little ingenuity might make for himself. The machine shown in our illustrations is in fact one constructed by Mr. R. H. Finch in two months in the autumn of 1926 for preliminary tests of earth motion at the Lassen Volcano Observatory in California. This instrument was made entirely out of materials and labor available in any country town. There is here shown a clock on the wall which is a good timepiece made by the Howard Company in Boston, Mass. This is fitted with electrical contacts closing the circuit of a four-cell dry battery for about two seconds every minute and about six seconds every hour. It is a weight-driven pendulum regulator with eight-day movement. The electrical contacts on the minute and hour are for marking the time continuously on the smoked paper which covers the drum of the seismograph, so that any hour or minute may be identified on the paper for discovering the time when an earthquake has marked the paper.

On the left is shown a concrete post in a basement room with an upright hollow or groove cast at the bottom where the post rises from a concrete table or pier. It is better to have the cylinder as shown hanging from an isolated post than to hang it from the wall. We have tried both plans for different instruments at the Hawaiian Volcano Observatory. As the hanging cylinder is very sensitive to the slightest tilt given to its supports, walls are not desirable. The upper part of the concrete wall of a cellar on the outside of the building is heated by the sun for some parts of each day. The heating expands the wall and it cools at night, thereby contracting. The seismograph is so sensitive, magnifying earth motion some two hundred times in case of a horizontal displacement, that the distortion of the wall under expansion and contraction will cause the writing pen to swing sidewise an inch or more in the course of a day. This causes the lines to interfere and interlace with each other. A certain amount of normal tilting of the ground is to be expected in the course of each day anywhere, and it is likely to be exceptionally big at an active volcano. Therefore we do not want any tilting due to solar heating of the house. What tilting we get, measured by the swinging apart or the close approach of the lines, should be indicative of what the actual ground is doing under the whole country, and therefore is measurable for the particular two directions in which a single horizontal pendulum swings.

The dimensions of the cellar shown in the picture are ten by ten feet, and the general plan of the instruments followed the lines of the Omori seismograph. The concrete post, ten by ten inches square, stands 27 inches high above the pier which is 18 inches high above the floor and two feet square. The cylinder consists of a cast-iron container holding nine circular lead discs, which

make the whole weigh 225 pounds. The lead discs are each bored and threaded in the center to take a large screw-eye, so that the container can be handled by one man by lifting the discs out or putting them in separately.

An iron rod, bigger near the post, and smaller at its outer end, passes horizontally through the middle of the heavy mass or cylinder. This protrudes 52 inches from the center of the cylinder. The big end of the rod is bent and lies in the niche at the base of the post, supported by a short hinge of spring-steel wire. This wire hinge is terminated by metal balls in two slots cut with a hack-saw. One of these slots is in the flat iron strap shown pinned across the niche, the other in the bent end of the rod. The heavy cylinder is supported by a stirrup hanging from a piano wire which is made fast to a simple adjustable bolt in two angle irons pinned to the top of the concrete post. For these attachments to the post it is convenient to use expansion bolts, which are readily put in holes drilled in the concrete. The adjustments of the upper attachment of the piano wire permit of winding it up to lift the mass, and of moving it right and left to bring the outer end of the rod or boom to a medial position.

From all this there results a mass hung like a door with a boom protruding out from it, designed to record those oscillations or tilts of the earth at right angles to the plane of the suspension. The boom is braced by fine steel wires extending from its outer end to the cylinder. If the boom points to the east, the inertia of the mass registers the north-south earthquakes. Another similar pendulum is hung north-south to record the east-west earthquakes. Or better, for the same earthquake, two such pendulums register the north-south and the east-west components of the motion. Under each pendulum the system is damped, or prevented from free swaying on its own account, by sheet-aluminum vanes attached to the boom, protruding downward into a metal tank of automobile oil, so that with swinging of the pendulum, the vanes move edgeways in the oil. The little oil tanks, four or five inches square, not shown in the illustration, are supported by a removable stand in front of the pier.

The registering mechanism is shown in the figure on Page Three. The recording drum is built on a steel spindle threaded with ¼-inch worm at the end away from the drive-clock. This moves the drum lengthways in a sleeve at the driving end. The drive-clock is a Seth Thomas two-barrel power movement with rotation of spindle once in 30 minutes. The inner sleeve of the drum is set by a screw on the clockwork spindle. The worm end of the drum spindle rests on knife-edge wheels. Glassine paper is wrapped around the drum, pasted at the ends, smoked over a kerosene lamp, and the drum is set in place with the set-screw locking it to the clock. The writing lever-pen from the pendulum has a hinged stainless steel tip which rests on the smoke surface. The lever pens are made of aluminum. They are pivotted about a vertical axis near the end of the booms. The pen tips and the levers have pivots made of standard clock and watch balance staffs. Motion is transmitted from the boom to the lever by light metal T-bars, with the ends of the cross-bar in the boom and the lever respectively. The drum ends are made of ply-wood and the surface of pasteboard. The pen tips are magnetized, lifted to make a gap in the written line on the smoked paper every minute by an electro-magnet connected with the time-piece on the wall. The drum surface moves 30 mm. to the minute. The static magnification of the boom is five and of the writing lever forty, making the total 200. A marker pen attached to the plate supporting the drum and lever system, is made to write a line for a few minutes once a day on the side of the smoked paper, to be used as a datum line for measurement of wandering of the pendulums under tilting of the ground.

The free period of the pendulums is adjusted to seven seconds by moving the upper support of the piano wire in and out from the posts. The pen tips are laid back with a horseshoe magnet when the drum is changed. The change of paper is made once a day and the seismogram removed is passed through a bath of very dilute shellac and denatured alcohol, which fixes the smoke image of the line written by the pens. In the second photograph there is shown the second boom vanishing into the foreground, connected with the second pen by its T-bar impinging on an angle piece in the lever at right angles to the lever. In this way both pens, north-south and east-west, write during the day bands of lines side by side on the same paper. The paper is 12½ by 38 inches. Each line is interrupted by its minute and hour marks, the operator indicates the time of the starting mark by scratching it in the smoke, and simple counting of the succeeding hour marks on the smoke is all that is needed for timing an earthquake autograph that may appear. The light pasting of the ends of the paper on the drum is easily separated by a slender paper-cutter. The seismogram is dated and marked with its location before shellacking.

It will readily be seen from this account that any amateur with mechanical aptitude can build for himself a senstitive seismograph, and he can learn all about the technique of the science if he will consult the back files of the Bulletin of the Seismological Society of America, the headquarters of which are at Stanford University, California. T.A.J.

KILAUEA REPORT No. 1015

WEEK ENDING JULY 5, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Conditions remain unchanged at Halemaumau pit. The cauldron is quiet and dry. Strong northeast trade winds continue.

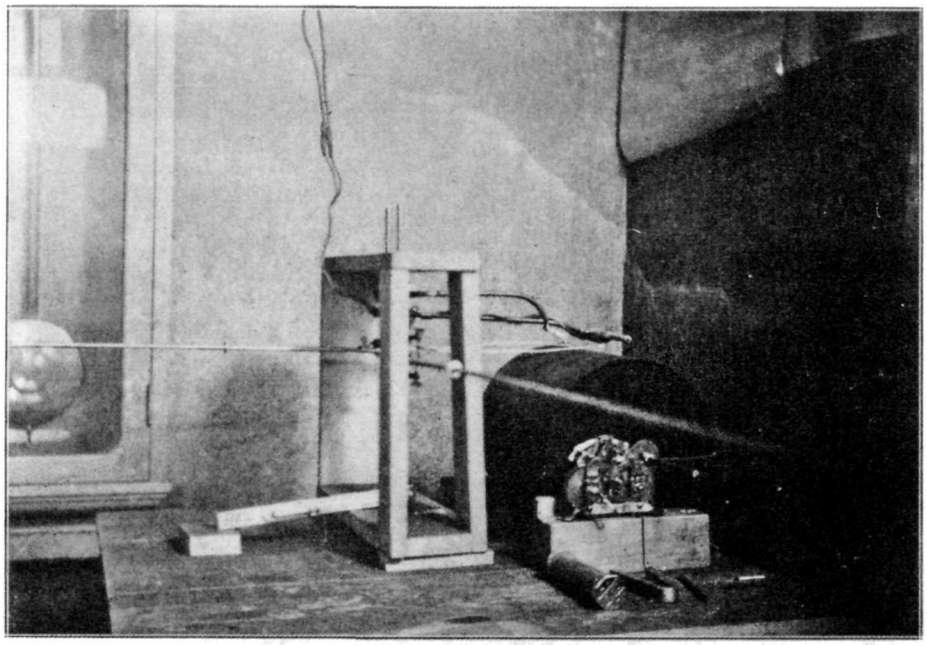
Seismic disturbances recorded during the week included 34 tremors and two very feeble local seisms. One of the latter at 12:08 a. m. July 4 indicated origin distance 23 miles from the Observatory.

Tilt for the week was slight NNW. Microseismic motion was slight.

TILTING OF THE GROUND FOR JUNE

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

June 1-7	0.1 second	W.
June 8-14	1.4 seconds	NE.
June 15-21	0.3 second	ENE.
June 22-28	1.4 seconds	NNW.



Recording end of homemade seismograph, showing booms of both north-south and east-west pendulums, pivot connections with writing levers, straight wound electric magnet for marking time, and the driving clock and drum, the latter with smoked paper.



Interior of seismograph cellar at St. Mary's School, Hilo, Hawaii, showing two-component seismograph hung on wall of chamber, with recording drum in middle of room.

THE VOLCANO LETTER

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

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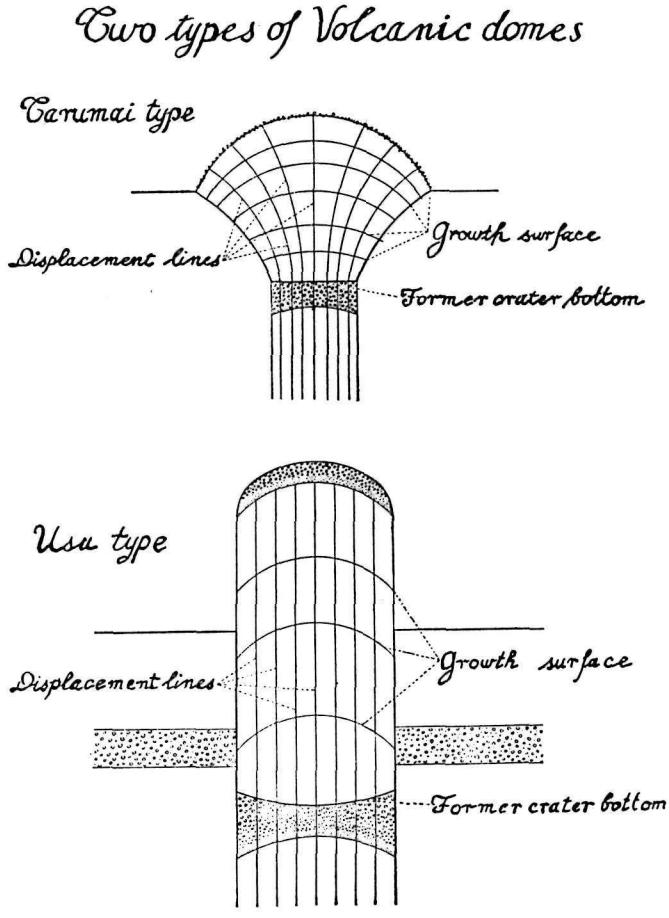
The Volcano Letter

342

Two dollars per year — Ten cents per copy

No. 342—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 16, 1931



Sections by Tanakadate showing the two types of lava domes and their structual characters.

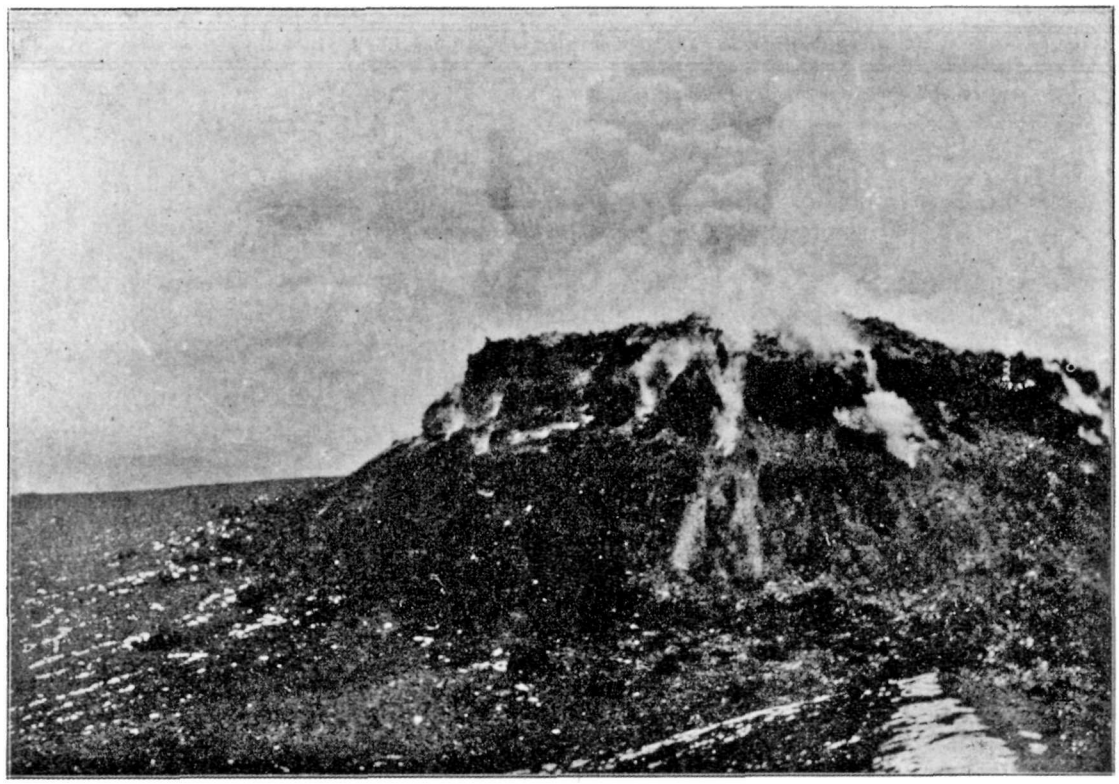
TWO KINDS OF LAVA DOMES

A clear analysis of the materials and the rising of stiff lava into two kinds of lava domes in Japan has been made by Tanakadate. (H. Tanakadate, Imperial University, Sandai, Japan. Proc. Fourth Pacific Science Congress Java 1929, pp. 695-703.)

The first is the Tarumai type, based on the Volcano Tarumaisan in the north island of Japan, which pushed up its crater floor into a dome in 1909. Before the eruption the crater was a funnel 600 meters across, gently sloping inward above and precipitous within. The funnel was 65 meters deep with a bottom 60 meters across, exhibiting active solfataras there and in the wall.

March 30 to April 12, 1909, there were big steam-blast eruptions, lava then filled the funnel, then the pudding rose into a dome reaching its maximum at the end of April, finishing its growth in mid-May, and remaining there ever since. Tanakadate expresses the mechanism by the upper diagram on Page One. By expressing the original crater bottom as a horizontal line in section, lava covered with gravel, the successive stages are shown by the **growth surface** lines, when the gravel must have been scattered on the increased area of the top of the dome. Such loose materials were found sparsely scattered on the slaggy surface of the dome when it was explored after it had cooled off between 1909 and 1917. Explosive eruptions in the latter year through fissures in the dome flung out fragmental materials on to the dome. At present detritus and lava blocks caught in the lava are found on the dome.

The **displacement lines**, radiating from the former



Lava dome of Tarumaisan in Hokkaido, two hours after an eruption of October 30, 1926, which fissured the dome of 1909. Photo K. Shibahara.

bottom of the crater upward, correspond to the successive positions in lateral displacement of equally spaced points on the crater floor at the beginning. Each imaginary vertical filament of lava in section rises and widens, the more in the center, the less where restrained by wall friction. The displacement lines are perpendicular to the growth surfaces.

The lava developed prismatic structure, mostly at right angles to the growth surface, with columns parallel to the displacement lines. In crater pits and fissures of the dome can be seen the chasms bounded by columnar joints, caused by contraction when the surface cooled, making upright parting planes.

In the large caldera of Usudake Volcano, near Tarumaisan but farther south (see map Page Four), is found the second type of lifted plug or dome, illustrated by the lower diagram on Page One. There are two domes on Usu (see map Page Three), and three crater lakes. Taking the bigger one called O-usu, it is 725 meters above sea, 350 meters high about its base, and is smoothly round like a cathedral. The top of it is not a round shell of rock, but is composed of gravel, sand, and clay 3 to 6 meters thick. The gravel contains fragments of quartzose rocks, crystalline schist, and several old volcanics; there are andesites with pyrite and hematite. The pebbles are reddened with oxidation, as though through the heating effect of the dome lava, and are sometimes bowlders a foot in diameter. They are smooth and scratched with parallel streaks like glacial erratics. The sands and clays are baked to natural brick.

The dome itself of rock is exposed on one side with the surface scratched, and a structure of parallel shells. Elsewhere fragments mask the rock. The sectors of the dome are cracked and faulted so that one sector may have been thrust up, another has lowered.

If the dome was regular on its rising, the volcano may have formed its caldera of subsidence in the course of a river, which deposited ordinary gravel, sand, and clay in the crater lake. The highly viscous lava rose and congealed under these deposits. The lava continued rising, lifting the plug, and heaving up the overlay of sediments. This made a structure with vertical side walls and dome-shaped top. The friction on the confining wall produced the streaks and striations. Just the same thing was shown by the Pelee spine. The lava and sediments agglutinated and formed a hard crust. The lava core pushing into the gravel layers produced the striations in the pebbles.

The parallel-shelled structure gives evidence that at first the growth surface was horizontal, later the viscous sides lagged and the center rose most, arching the top. Sinking of parts of the magma below, and renewed pressure, bring about the splitting into separate sectors or columns with differential lift at the top.

In the case of the Tarumai dome of the first type, the recession of magma caused a flattening of the top of the dome. (See Page Two).

The O-usu dome is much more siliceous than the Tarumai dome. The O-usu rock is a dacite with 68 percent of silica, that of Tarumai on augite andesite with 61 percent. The O-usu rock is fine grained, light gray, with few and small porphyritic crystals and a trachytic groundmass. The Tarumai rock is coarsely porphyritic with large anorthite feldspar prisms, and smaller augites. The lava shows fluidal streaks of red and gray.

The old outside lava wall of the caldera of Uusu is basic, and so was the new lava of the lower slopes of Usu, thrown up as bombs in the uplifting eruption of the outer flank in 1910. Both of these have only 51 percent of silica (see Volcano Letter No. 302).

Other volcanoes which have produced the low-dome type of eruption are Bogoslof, Katmai, and Galunggung. The spine or plug has been upraised in Pelee, Lamongan, and in the inner fin of McCulloch dome at Bogosloff in 1907. T.A.J.

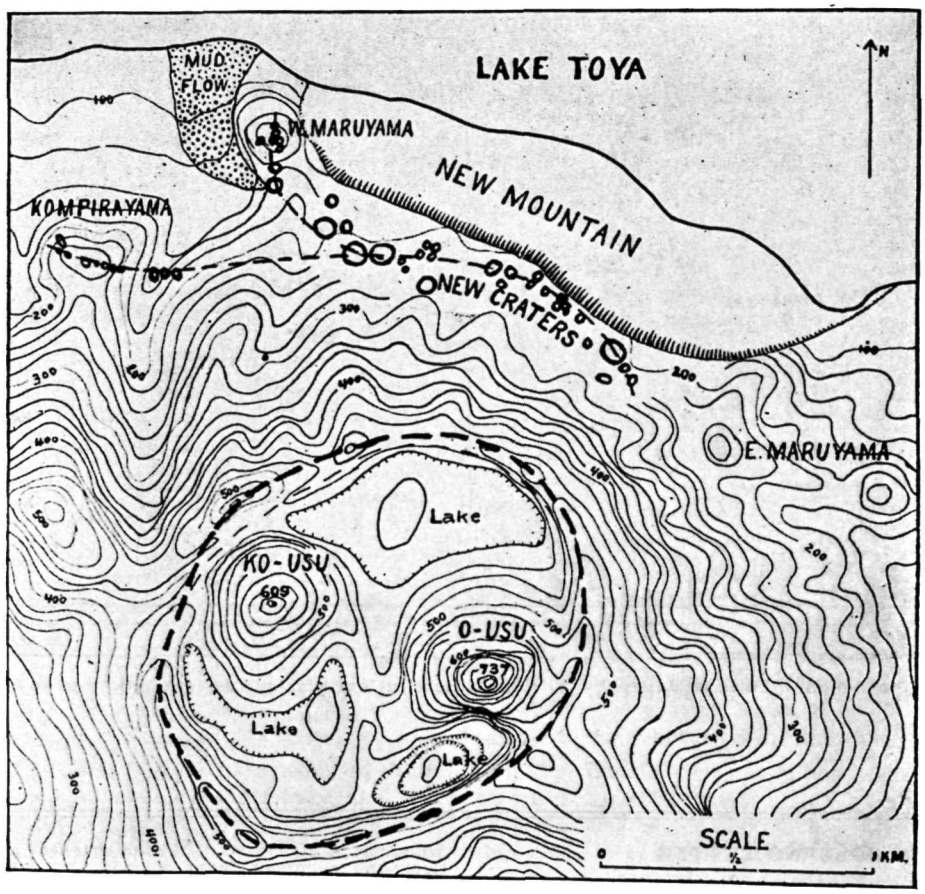
KILAUEA REPORT No. 1016

WEEK ENDING JULY 12, 1931

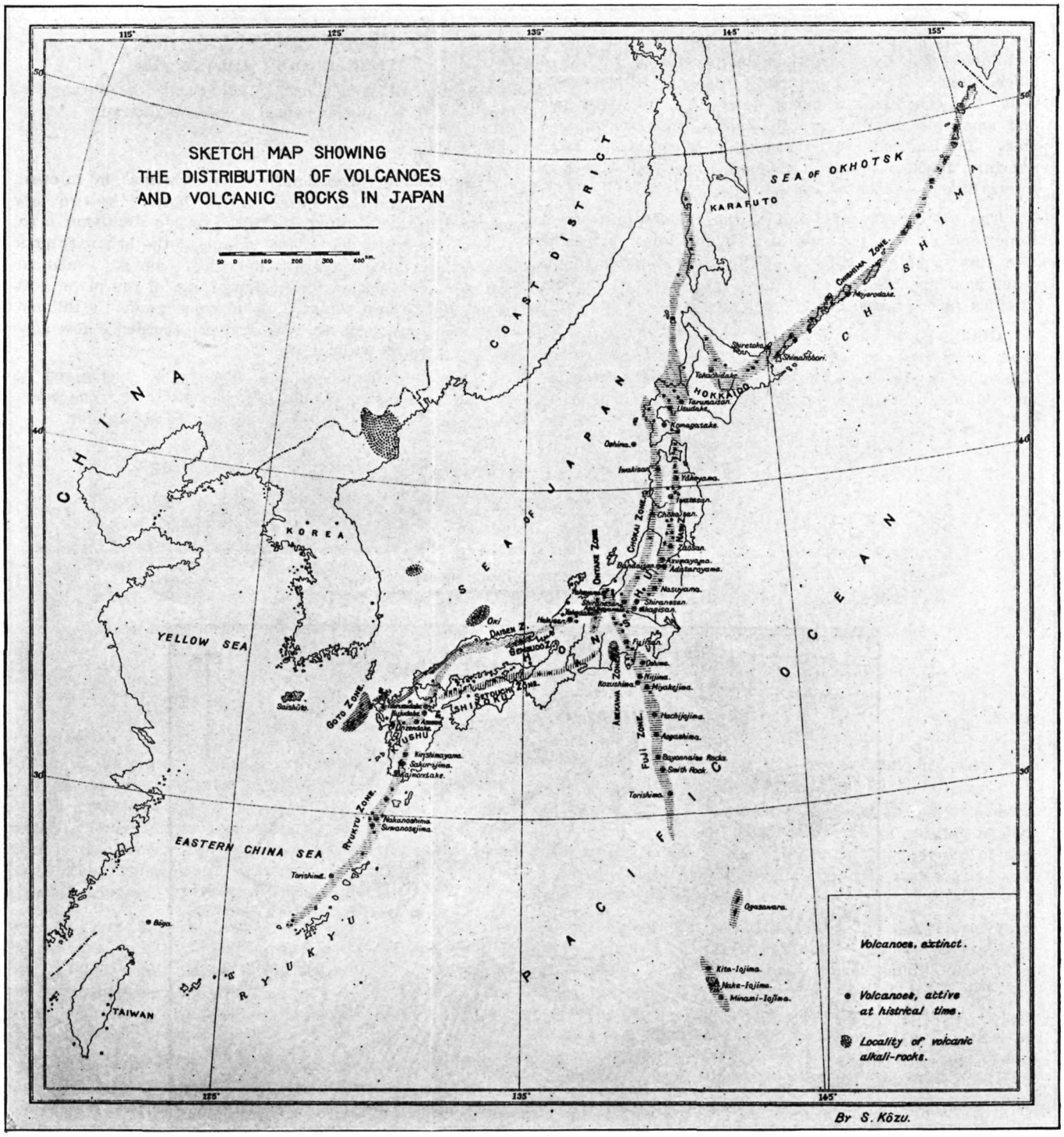
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau has shown a few changes of interest. Blue fume has reappeared on the bottom in two new places, directly north of the 1930 cone in a sulphur area, the edge of which has caved in, and at the bright sulphur spot on the far northwest side. Dust from an avalanche was seen rising from the northeast rim of the pit at 4:30 p. m. July 10 in a compact cloud which gradually thinned. The seismograph on the crater floor recorded a few slow motion tremors without tilt.

The instruments at the Observatory registered 18 tremors and 5 very feeble local seisms during the week. Tilt was slight W. Microseismic motion was slight.



Map showing old caldera ring and domes of Usu, the active craters of 1910, and the uplifted "New Mountain" of 1910. After Daly.



Map of volcano belts in Japan by S. Kozu, showing extinct, active, and alkaline lavas.

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The Volcano Letter

343

Two dollars per year **Ten cents per copy**

No. 343—Weekly Hawaiian Volcano Observatory, National Park, Hawaii July 23, 1931



Haleakala seen across Hawaii Channel from the summit of Hualalai. Photo Emerson.

HAWAIIAN VOLCANO LANDSCAPES

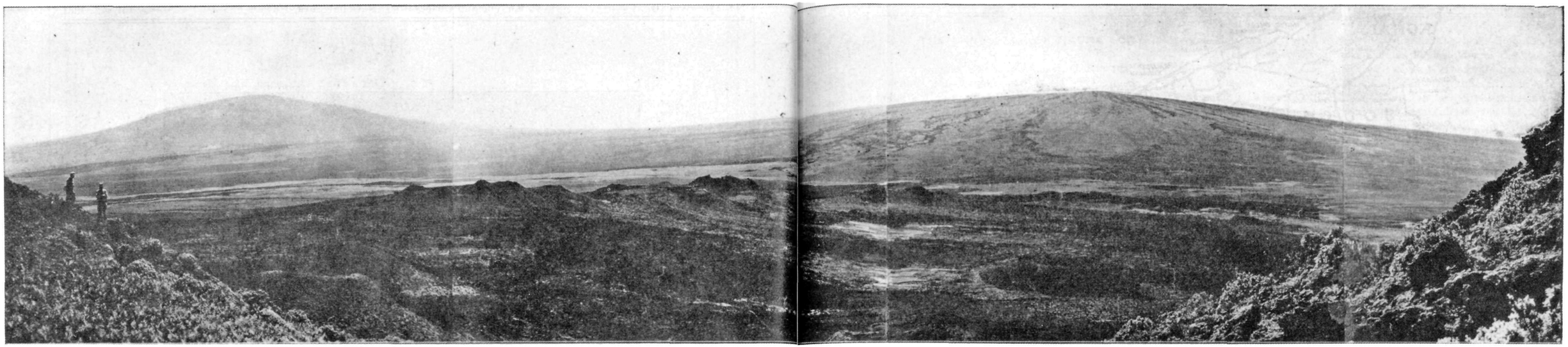
Professor Norman E. A. Hinds has produced an interesting paper on "The Relative Ages of the Hawaiian Landscapes" (Univ. of Cal. Publ. Bull. Dept. Geol. Vol. 20, No. 6, pp. 143-260, pls. 15-42, 13 text-figures; Berkeley 1931). He reviews the evidence for the supposition that Kauai is the oldest of the windward group of Hawaiian Islands, and points out that the extra heavy rainfall there, to speed up erosion, has not been sufficiently allowed for. Kauai may be younger than Oahu. He also accents downfaulting of island blocks along shore-lines which has robbed some islands of their mass. The text by Wentworth on quantitative estimates of marine and fluvial erosion in Hawaii (Jour. Geol. Vol. 35, 117-133, 1927) and Wentworth's Bishop Museum papers come in for criticism, and it is refreshing to note that both Hinds and Wentworth attempt to evaluate erosion on the basis of rainfall and drainage, and even to make some estimates of rate of removal of soil in carving landscapes. This is the beginning of a science of erosion.

Hinds writes: "According to Wentworth, the depths of material removed from the various mountains by streams stand in the following order: (1) East Oahu; (2) Kauai; (3) East Molokai; (4) West Maui; (5) Mauna Kea; (6) West Oahu; (7) East Maui; (8) Lanai; (9) Niihau; (10) Kahoolawe; (11) Kohala; (12) the rest of Hawaii. The estimates for East and West Oahu and Kauai apparently neglect extensive loss of bulk by downfaulting, hence the amounts of removal by rivers in these three cases are excessive. On East Molokai, Kohala, and Niihau, streams have eroded a residual of once larger domes since about half of these mountains has been carried below sea level by downfaulting. It is not improbable that faulting may have been partly responsible for the development of some of the great canyons on Kohala, East Molokai, Kauai, and Oahu."

Hinds uses the term "engulfment" for downfaulting, but this word "engulfment" is a volcanologic term for downbreak in volcanic craters or underground conduits, *and is hardly identical with graben downfaulting.*

"For Lanai, Wentworth has calculated the average rate of removal as one foot in 5,000 years, and from this he has estimated the approximate age of the landscape of that dome to be 125,000 years. Using the same rate of removal, he obtains figures of 225,000 years for Kohala and 2,090,000 years for Kauai." Hinds objects to applying a dry island rate to a wet island.

"According to wentworth, the relative amounts of



Panorama of Mauna Kea and Mauna Loa from a summit cone on Hualalai. The near foreground of Hualalai shows a slope of 35°. Mauna Kea has slopes of 12° to 40°, and Mauna Loa on the right 3° to 8°. The long 1859 flow sweeps to the left from Mauna Loa. The foreground cones extend the Hualalai rift toward Mauna Loa. The left of this picture (Kuna Kea) is incorrectly named "Hualalai" in pl. 16 of Hinds. Photo Emerson.

material removed by wave action from the various islands stand in the following order: (1) Hawaii; (2) Kauai; (3) Molokai; (4) Niihau; (5) Maui and Kahoolawe; (6) Oahu; (7) Lanai." Hinds objects that the several domes on Hawaii are of different ages, and have been cliffed by the sea in different amounts. And that the formation of cliffs by faults has not been recognized. "The determination of relative amounts lost by downfaulting and by later marine erosion probably is impossible, though approximate values may later be obtained."

The point of this discussion is that the Hawaiian Islands form an excellent field for measures of erosion in time, if some one will only go at it experimentally by the observatory method.

Hinds arrives at the following conclusions:

The order of extinction of the younger Hawaiian mountains apparently has been: (a) Haleakala, (b) Mauna Kea, (c) Hualalai. Mauna Loa and Kilauea are still in process of construction, hence their landscapes will undergo certain changes before their major activity ends." (With Haleakala known to have made lava flow about the middle of the eighteenth century, and Hualalai in 1800-1801, one wonders why these two should be considered extinct.)

"The constructional surfaces of the old, high domes have been largely destroyed either by erosion alone or by erosion and downfaulting. On all the mountains either major or minor features of the relief have been formed by faulting, and in the ultimate destruction of the domes, faulting is one of the chief agents.

"West Oahu, West Molokai, and West Maui each became extinct before the eastern member of these doublet islands. The landscape of Kohala is the oldest on Hawaii."

Probably both of the Oahu domes are older than Kauai since the close of the last principal volcanism. The more rapid rate of fluvial erosion on Kauai, owing to the climate, does not establish the greater age of the landscape. The relatives ages of the landscapes of the high old domes appears to be: (1) West Oahu, (2) East Oahu, (3) Kauai, (4) East Molokai. West Maui and Kohala are younger, but their sequences is yet to be determined."

"Neglecting buried landscapes, the oldest landscape in the windward Hawaiian Islands is that of the Penguin Bank The final products of the destruction of lava domes are the volcanic stacks like Nihoa, roof islands, calcareous sand islands, and submarine banks without islands which make up the leeward group."

Hinds disagrees with Wentworth in the latter's belief that the Hawaiian Islands emerged in the late Tertiary. "The destruction of the leeward islands suggests that volcanism ceased there well back in the Tertiary, hence the mountains must have risen above the ocean long before, perhaps even in Mesozoic time. Buried erosion surfaces in the windward volcanoes prove that interruptions in the volcanic cycle took place and that there was deep erosion before the renewal of eruptions. The erosion of the present landscapes of the older domes probably began in late Tertiary or early Pleistocene times. The time required for the cutting of the great cliffs of Kauai very likely took at least two million years." T.A.J.

KILAUEA REPORT No. 1017

WEEK ENDING JULY 19, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Kilauea Volcano remains dormant. A few rocks were heard falling north at 11 a. m. July 16. On July 17 dust clouds from avalanches were seen at 5:30 and 9:40 a. m., and a scar showed on the northwest wall of Halemaumau. No fume or steam was reported visible during the week.

The instruments recorded 18 tremors and 3 very feeble local seisms. The average tilt movement for the week was slight northwest. Microseismic motion was slight.


NORTH KOHALA
SOUTH KOHALA
KAWAIHAE
PUAKO
KIHOLO
WAIMANU
WAIPIO VALLEY
KUKUIHAILE
HONOKAA
PAAUHAU
PAAUILO
HUKAIAU
OOKALA
LAUPAHOEHOE
Papaaloa
NINOLE
HONOHINA
HAKALAU
HONOMU
PEPEEKEO
Onomea Arch
PAPAIKOU
SOUTH HILO
HILO
HAENA
MAUNA KEA
13,825
NORTH HILO
SOUTH KONA
NORTH KONA
KAILUA
KEAUHOU
KEALAKEKUA
Cook's Monument
KEALAKEKUA BAY
City of Refuge
HOOKENA
KAOHE
Honaunau
Napoopoo
Keei
Pahoehoe
MAUNA LOA 13,675
HONUAWEOWEO CRATER
KAU
Ranch
HALF WAY HOUSE
Kapopala
PUNA
Military Camp
VOLCANO HOUSE
GLENWOOD
Mountain View
Tropical Jungle
Hot Spring
EAST POINT
POHOIKI
Heiau
OPIHIKAO
KAMAILII
KEHENA
KAIMU
Kalapana Cocoanut Grove
Cave of Refuge
MAKAPUNI
HAWAII NATIONAL PARK
KAU DESERT
Kamakaia
WAHAULA
Heiau
KEAUHOU
Bird Park
Halemaumau CRATER
REST HOUSE
10,060
Volcano Golf Course
Volcano Tree Trails
Haunu Loa Trail
Kaumana Caves
Boiling Pots
RAINBOW FALLS
Puu Oo
Waiakea Tree Trails
Tropical Jungle Trail
Crater Rim Trail
Kilauea Iki Trail
Kona Coffee Trail
Puu Waawaa
Pantastic Lava Formation
Hualalai 8,269
Lanihaiea Cave
Old Mission
Waiululahulu Cave
Ahua Uhi
Old Royal Fort
Rock Pictures
KAHALUU
HOLUALOA
(Coffee)
KAINALIU
Puu o Keokeo
PAHALA
Aiikapapa
HOOPULOA
Kaohe
Kaiohinu
Punaluu
HONUAPO
Kaalualu
Kahuku Ranch
KA LAE
South Point
West Point
Puu Kihe
Puu Ahumoa
Puu Kii
Puu Ou
Puu Kaeo
Puu Kalepeamoa
Puu Huluhulu
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The Volcano Letter

344

Two dollars per year — Ten cents per copy

No. 344—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 30, 1931

THE LANDSCAPE OF MAUNA LOA

Hinds speaks of Mauna Loa and Kilauea (Hawaiian Landscapes, Bull. Geol. Univ. of Cal. Vol. 20, No. 6, 1931) as being still under construction, with shallow weathering, and stream gulches only where eruptions have not recently taken place. "On certain parts of the rainy, windward side of the mountains, where flows have not been erupted for long periods of time, the lavas are decomposed enough to allow the growth of a heavy jungle forest in the soil cover. The more recent lavas are virtually untouched by ground water or atmospheirc solutions, and even in the rainest sections, have little or no vegetation on them."

This last statement is not correct for the 1881 flow at Hilo, where the rainfall is 200 inches, and good sized trees and bushes cover the flow.

"Where the climate is dry, weathering is much slower and there is little soil on any of the flows." This is particularly true of the Kau Desert on the southwest side of Kilauea, of Kahuku on the southwest side of Mauna Loa, and of the northwest flows of Hualalai. These places have rainfalls of 30 to 70 inches.

"Only a few permanent streams are present, and these have not cut deep valleys. Most of the constructional surface is unbroken. The eruption of new lava apparently is sufficiently frequent to cover most of the exposed surface before any considerable amount of weathering or erosion can take place.

"Short stretches of the coast are cliffed to heights of 50 or 60 feet, since flows apparently do not reach sea level often enough to prevent some inroads by wave abrasion. The occasional flows which pour into the ocean repair in part destruction thus caused. Low fault scarps are present, especially on the southeastern flanks of the domes, and part of the cliffed southeastern coast (of Hawaii Island) has been developed by faulting.

"Parasitic cinder cones in considerable numbers dot the flanks of the dome; part of these show rude linear arrangement as though erupted at various points along radial fissures.

"At the summits of both Mauna Loa and Kilauea are volcanic sinks, in which the principal eruptive center is located," Mokuaweoweo the Mauna Loa crater being 3½ by 1¾ miles in dimensions and 800 feet deep; Kilauea Crater 2 by 1¾ miles and 500 feet deep.

"The sinks are depressions resulting from the collapse of the crust in the vicinity of the principal eruptive center as liquid material has been emitted from below the surface. Small step-faulted blocks are present locally about the walls of the sinks." Near the middle is the conduit pit through which the lava rises and falls, in the case of Kilauea. Mokuaweoweo has cones and pits in the middle.

"As long as activity prevails at the central vents or eruptions take place from lateral fissures, the surface may be periodically renewed and the pre-existing topography blotted out. The final constructional outlines therefore are not complete.

"Kilauea is a small mountain far down on the southeast side of Mauna Loa at an elevation of about 4,000 feet. The relative ages of the two domes has been disputed. Jaggar formerly held that Kilauea is the older of the two, and that Mauna Loa has grown up in a great vale between Kilauea and Mauna Kea. Daly believes that Kilauea is fed by a laccolithic offshoot from the larger volcano, and now is independent of the main reservoir because of the sealing of the connecting channel. **It is now generally accepted that Kilauea is the younger mountain."**

"Field evidence supporting this view has been presented by Stone, who has recently described the general features and the geology of the volcano. Stone notes that Kilauea is an independent dome on the flank of Mauna Loa, but because of the very gentle slope of both Mauna Loa and Kilauea its domelike character is not apparent in some parts of the area. Important data are given by Stone proving the superposition of the Kilauea volcanics on older lavas from Mauna Loa and the association of the Kilauean series with faults which developed in the side of the greater mountain."

With reference to the general acceptance of the youth of Kilauea, the reviewer does not know what this statement is based on. Mr. Stearns in his "Geology of Kau" (Water-supply Paper U. S. Geological Survey) leaves the question open. In Kapapala and along the valley between Kilauea and Mauna Loa it is Mauna Loa flows which are overlapping the Kilauea slopes. The great sink of Kilauea is an old-age feature of a major dome. It was not the vale between Kilauea and Mauna Loa, but rather between Kilauea and Hualalai, that appears to have lain under the modern slagheap of Mauna Loa. Mauna Kea was the ancestral dome at the northeast which blocked any growth of Mauna Loa in that direction. Hence the pronounced development of a long lobe of Mauna Loa into the sea at the southwest. Both Kilauea and Mauna Loa have parallel lava rifts, starting at their craters, and trending respectively southwest and northeast.

The history, however, was not so simple. Both Kilauea and Mauna Loa appear to be over an older topography. Kilauea sink is in line with two other sunken amphitheatres southwest of it, Wood Valley and Mohokea. back of Kapapala and Hilea. These three sinks appear to lie along a common rift in the ancient land which the new dome volcanoes are burying. The live Mauna Loa of the present day has three centers of lava heaping, northeast, on top, and southwest. The accompanying panoramas show something of this vast bulky mass. T.A.J.

KILAUEA REPORT No. 1018

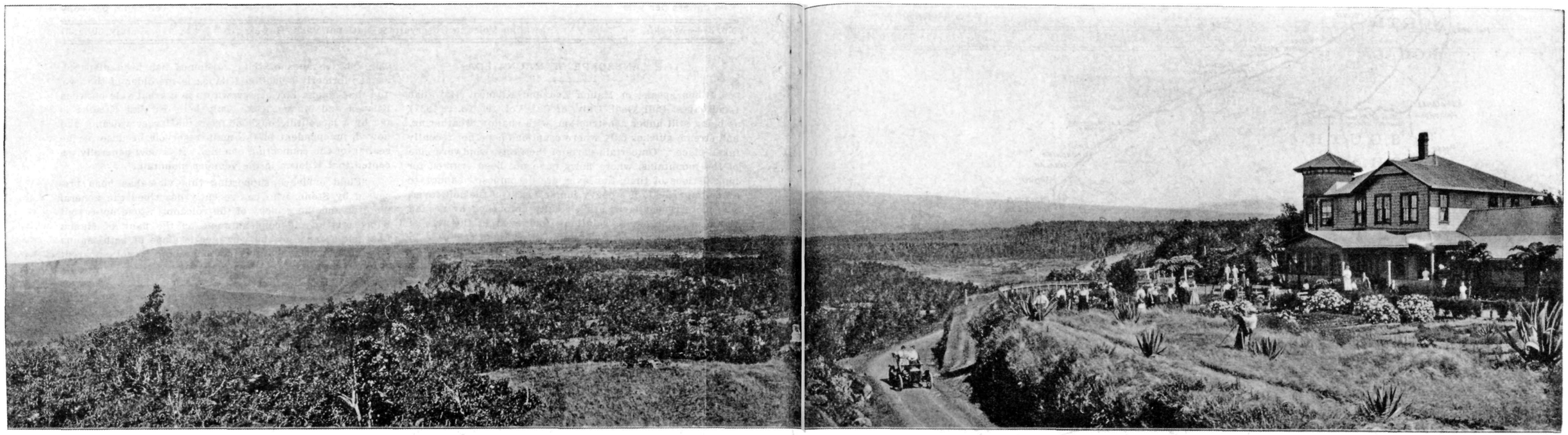
WEEK ENDING JULY 26, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

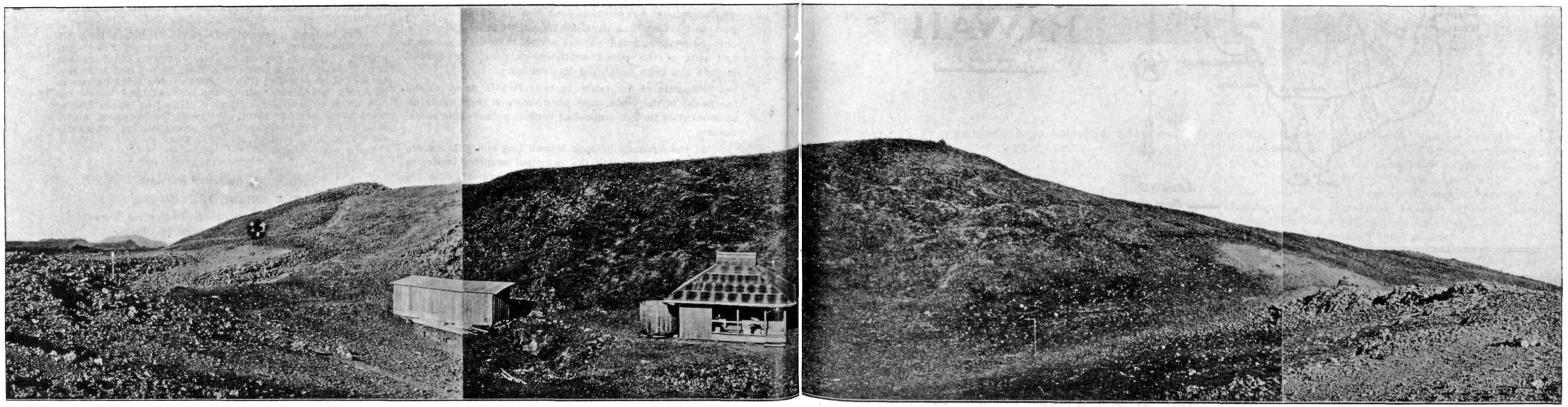
On Monday, July 20, the interior of Halemaumau was partly obscured from view by fog and light rain. Some steam was seen at the southeast rock slope. Heavy rains Tuesday caused great steam clouds to rise from the pit. All vents within the pit were steaming actively on July 22. Fuming was also strong at two places north of the 1930 cone. The pit seismograph showed heavy tilt due to the weight of rain water in the vicinity.

The seismographs at the Observatory registered three spells of strong continuous tremor on July 23: 6:43 to 7:05 a. m., 7:49 to 8:02 a. m., and 5:31 to 5:45 p. m. In addition there were 16 tremors and 2 seisms.

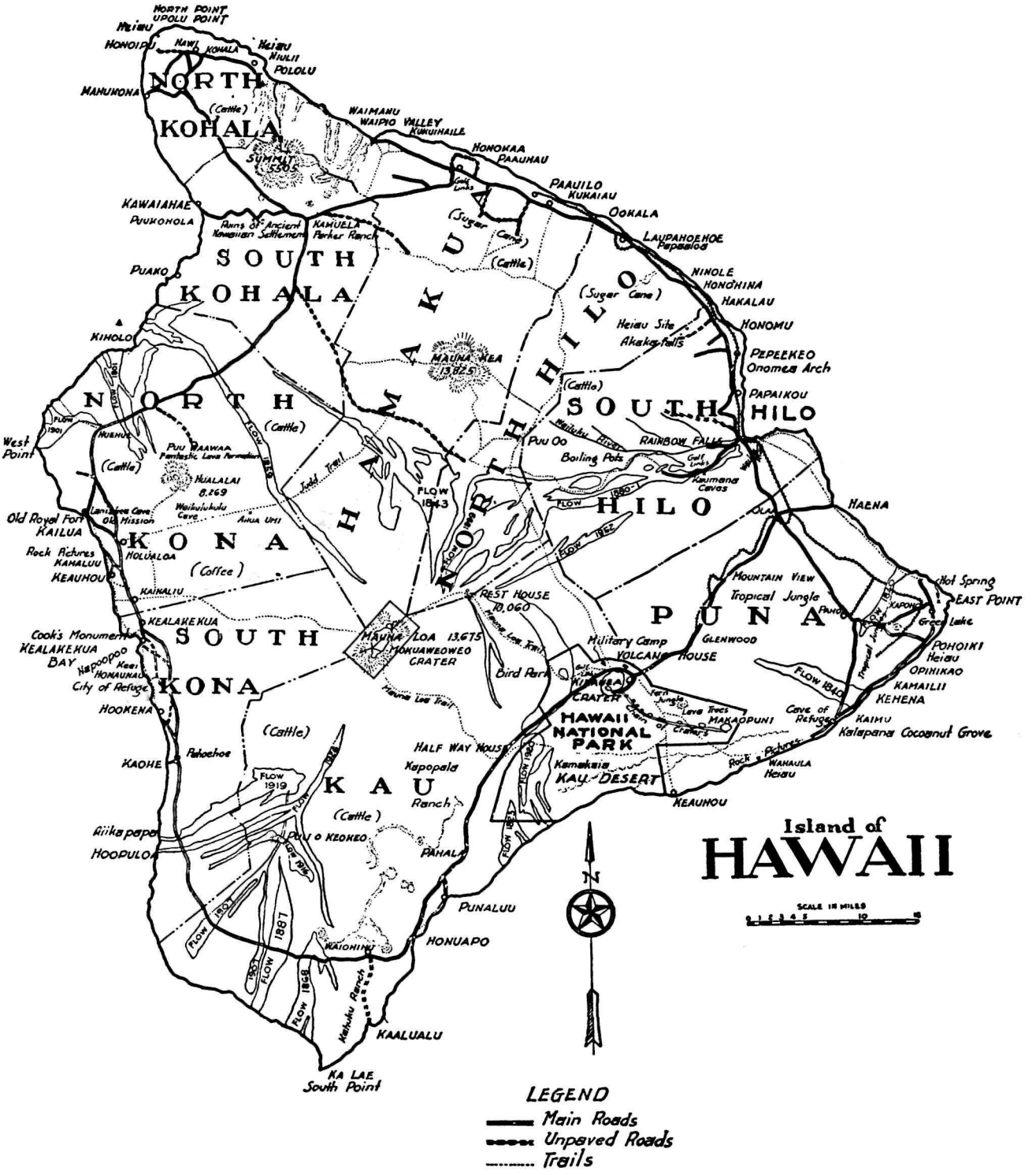
Average tilt for the week was slight NE. Microseismic motion was strongish on July 21 due to windstorm, and thereafter slight.



Panorama of Kilauea Crater, Mauna Loa, Mauna Kea, and Volcano House, looking west. Shows the three lobes of Mauna Loa and the valley between Mauna Loa and the foreground ridge of Kilauea. Mauna Loa slope 6° on left, 4° on right. Photo Gartley about 1912.



Puu Ulaula, or Red Hill, looking north, showing the rest house on the northeast rift of Mauna Loa. A characteristic old clinker-lava cone at elevation 10,060 feet. Center of the northern lobe of Mauna Loa. Photo Wood in 1916. Slope 20° on left, 10° to 19° on right.



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The Volcano Letter

Two dollars per year | Ten cents per copy

No. 345—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 6, 1931



Toes of pahoehoe lava on north floor of Kilauea in 1919 lava. Photo Maehara.

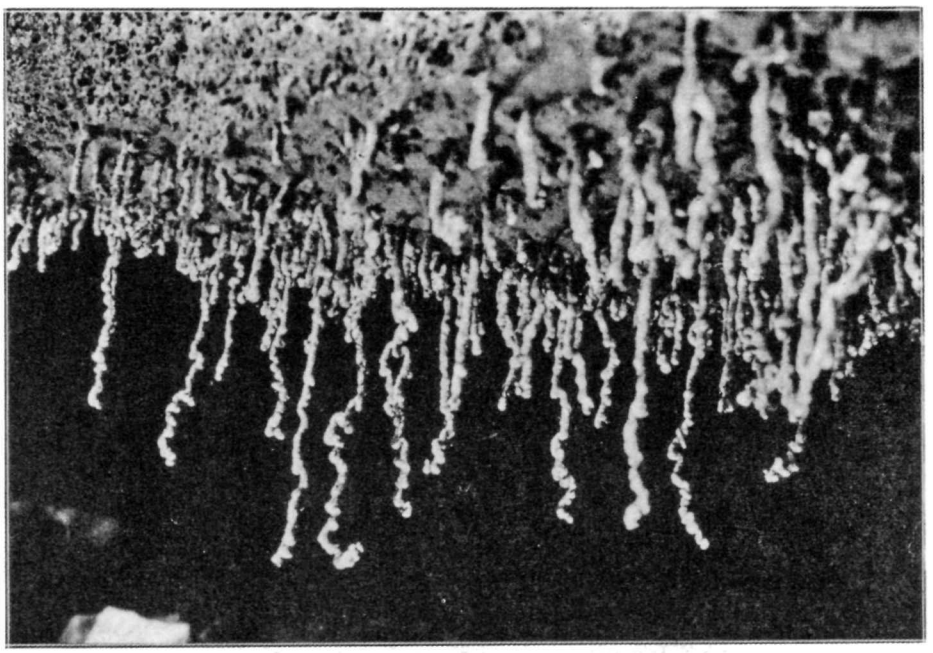
LAVA STALACTITES, STALAGMITES, TOES, and "SQUEEZE-UPS"

In Volcano Letter No. 300 Professor Colton described "squeeze-ups" in lava fissures whereby basaltic magma plastic like stiff clay has been forced up a crack several feet into the air, with sides of the solidified paste grooved like slickensides as it scraped past the roughnesses of the walls of the fractured rock. As something of this kind occurs in Hawaii on both big and small scales, and in addition we have stalactites and stalagmites of entirely different origin which have been erroneously attributed to water, it would seem of interest to review the subject.

The supreme "squeeze-up" of history is the Pelee spine in Martinique. All lava dome eruptions are similar in origin and one may quite justifiably inquire whether "squeeze-ins" as well as "squeeze-ups" do not constitute many of the intrusions of geology. The hydrostatic pressure of granitic intrusions at Schneeberg in Germany is such that it split folia in slate, penetrated between the thin paper-like layers of the slate, and recrystallized the clay to hornstone. The Pelee spine was a central pencil of paste in a cumulo-dome, scored vertically on the outside as it scraped the walls of its container and rose 1,000 feet into the air. Then its top curled over and spalled off. It was never sucked back, but flaked away to a stump. Its composition was a hypersthene andesite, and so it was more viscous and refrectory than basalt.

In the history of "bench magma" inside Halemaumau pit there have been many occasions when the crags of semi-solidified basaltic paste at 900° C., forming the walls of the container of the lava lakes—not the walls of the pit—have risen as separate pencils of paste within other material of greater hardness. When they did this they showed scraped surfaces. When the entire lava column of this bench material has lowered rapidly, it has fractured into terraces on the insloping funnel wall of old rock, and the terrace faces show scraping made by the sinking block of the next terrace below.

In the filling of basins with pahoehoe lava by overflow



Worm stalactites from glaze of roof of cavern, Kilauea floor. Photo Maehara.

in the larger craters, there are built "schollen-domes" or hillocks of swelling crust. What was a puddled flat. with ropy lava shell, begins in the course of hours to swell up. A laccolith of basalt paste is rising inside, because of some equation between resistance to further spreading and resistance to upward lift. If upward lift is the easier for the onflow of the feeding stream which is pouring through a tunnel to feed the flat, there will be no further escape of "toes" pushing out from under the skirt of crust. When the swollen dome, 50 to 100 feet across, lifts a shell 3 feet thick, there finally arises a star-shaped opening between sectors in the top of the dome. The dome gets to be 10 or 15 feet high. Then the paste "squeezes up" through the opening on top. It either trickles down and skins over, or it sputters up and builds a spatter cone. If it has partially crystallized inside the heap it may rise as an "aa" or clinker lava pudding and so produce a stiff plug or spine or "squeeze-up," to use Colton's expression.

The picture on Page One shows four toes with festooned skins of pahoehoe lava which has welled up from a crack in the floor of Kilauea Crater in 1919. Each toe is derived by squeezing out from under the skirt of the toe next preceding. The festoons are convex downstream. The farther toe welled up a crack, the next two were progressively formed by swelling and rupturing fronts, and the long one in the foreground is double and exhausted the lava available. While incandescent and in action these toes or "pushes" as Brigham called them resemble a bag of red jelly. They are a foot or two in diameter.

Stalactites and stalagmites in grottoes and caverns tell quite a different story. Here again there are some which are products of splash phenomena, and are nothing more than lava drip where a stream has vacated its banks and left pointed glassy shreds hanging from shelves. Not so with such vermiform or rod-like stalactites and driblet spires as are shown on Pages Two and Three. These photographs were taken by flashlight in a cavern on the Kilauea Crater floor. Such caverns were in 1919 red hot and full of flowing lava. They were formed by streams which crusted over and then kept on flowing under a bridge of crust. These same streams in tunnels of their own congealment are what lead at the front of a flow to the escape of toes such as are depicted on Page One.

But there comes a time in every flow where the supply of lava diminshes. In such case the amount flowing from the source does not equal the capacity of the tunnel. Accordingly the river of melt bubbling along inside the tube lowers so that the upper half of the pipe is full of gas or air, the walls are of bright yellow incandescence, and the gases escaping from the lava are continually burning to maintain a very high temperature on the ceiling of the cavern. With this temperature above 1,200° C., air being sucked in below as the hotter gas escapes through cracks and windows in the roof, there is set up a blast furnace condition often maintained for weeks or months on the inner rock lining of the cupolas in the ceiling and of the side walls of the tunnel. This flow of gas quietly burning with great volumes of excess oxygen dragged up the tunnel from inumerable holes, cracks, and pores, melts the tunnel walls to a glaze of quite different crystallinity from normal lava.

In 1919 it was repeatedly possible to go to the "windows" of collapse in the roof of the "Postal Rift Tube," where from Halemaumau a torrent of lava was flowing through a tunnel, and to look inside and see an orange-hot cavity with a golden river sweeping by underneath, little bubbles continually breaking the surface of the glowing stream, and adding gas to the evenly brilliant walls. On these walls hung motionless stalactites, some like currants, some like grapes, some like walking sticks, and some like worms. These are what are shown in the photographs. They are the material of the gas-melted glaze. They form very slowly. When incandescent they may be rocked back and forth like macaroni before it has dried.

If the heat has fallen below their formation temperature, a touch will break them off. They do not trickle. They form by accretion.

If we take one of the worm stalactites and examine it with a lens, its outer skin has very delicate tracery of ripples in a silvery coating of magnetic oxide of iron. If we break a worm stalactite it has vesicles inside lined with crystals of feldspar and augite. If we make a thin section of a solid part it is crystalline, but different in texture from crystalline basalt. If we break a rod stalactite it may be hollow like a pipe-stem. The stalagmites underneath must be made by drip in some early high-temperature stage of the stalactite formation above them. I have never seen worm stalactites so hot that they were visibly dripping. In any case the drip is melted rock, and has nothing to do with water. These stalactites are sometimes two feet long.

There are two kinds of extrusion within caverns which are direct squeezings of molten slag. One is a "miniature volcano" of the cavern floor. Types of these are seen in the innermost recesses of Thurston's tube at Hawaii Natoinal Park. It is cone or pie-shaped with slopes like a miniature Vesuvius. Another is the "barnacle stalactite" squeezed through pores or cracks in the cavern walls while all are incandescent. These things are all products of pressure adjustment between cracking shell of cavern and molten matter in the flow beyond the shell. The barnacle stalactite has striations on the sides and may even be a thin papery layer which has oozed through a small crack and stands out from the wall. Lastly, there are glaze stalactites which take massive forms like udders and teats. T.A.J.

KILAUEA REPORT No. 1019

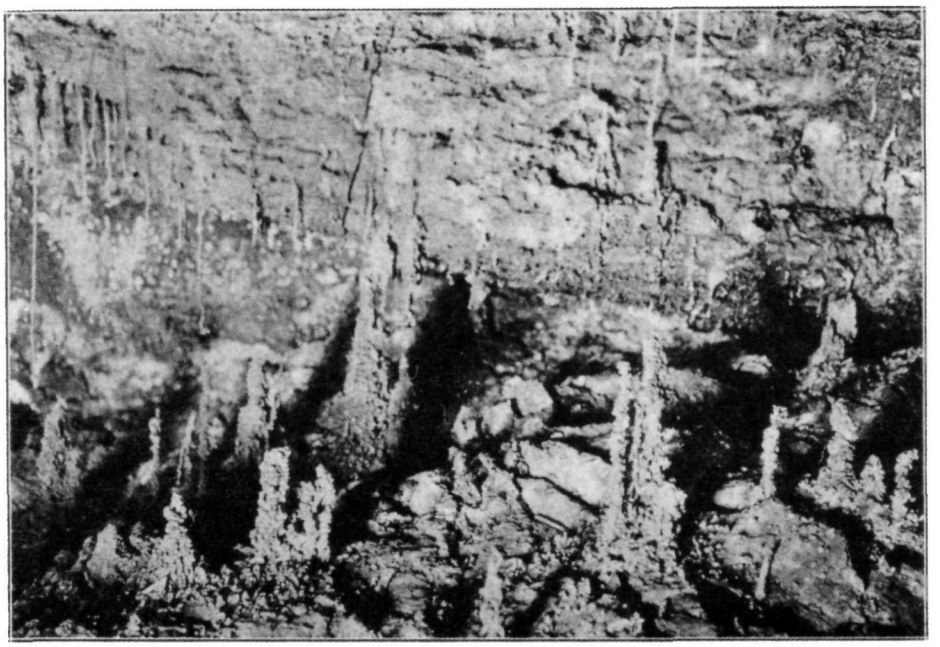
WEEK ENDING AUGUST 2, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The volcano remains inactive. On July 27 some sulphur spots on the Halemaumau bottom seemed a little brighter yellow. No steam or fume was detected. Crack measurements near the southeast rim showed no noteworthy changes. A local earthquake at 2:43 p. m. July 30 was felt at the Observatory and by a few people in the near vicinity. It has not been reported felt elsewhere on the island.

The instruments at the Observatory registered 15 tremors, one very feeble seism, and one feeble seism. In addition there was one spell of continuous tremor 4:43 a. m. to 5:09 a. m. July 30.

The avarage tilt movement for the week was slight NNW. Microseismic motion was slight.



Worm and rod stalactites, and stalagmite spires below, inner recesses of cavern, Kilauea floor. Photo Maehara.



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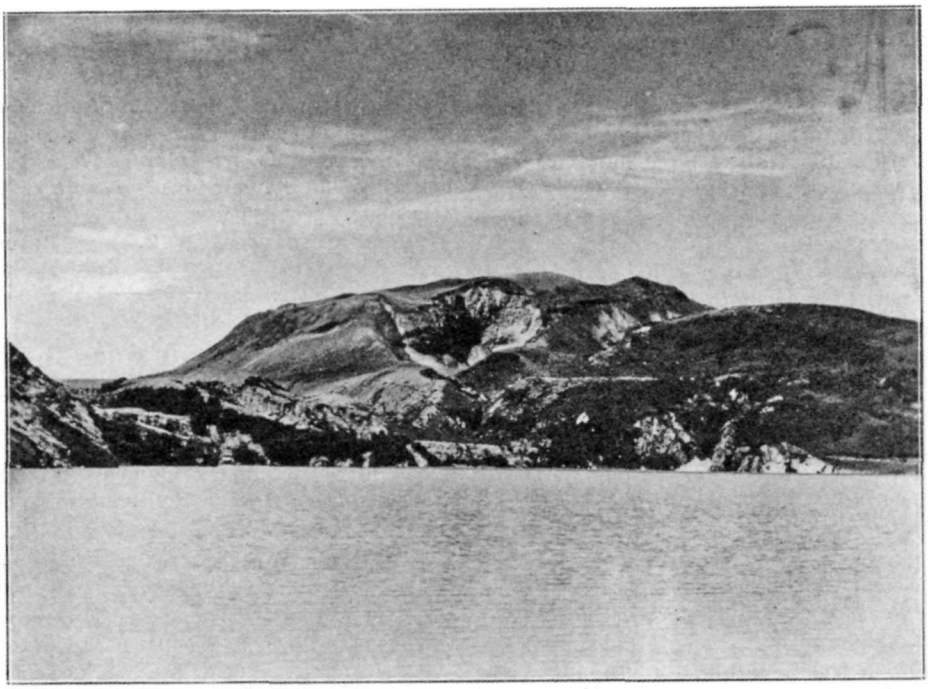
No. 346—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 13, 1931



Tarawera Volcano and the Tarawera chasm of 1886, showing the refilled Rotomahana Crater in the foreground. Country covered with ash. Photographed in 1925 by Baker.

ERUPTION OF TARAWERA

In June of 1886 a steam-blast eruption took place from the old volcanic mountain Tarawera and the geyser basin Rotomahana. This event in the thermal springs district of the North Island of New Zealand is worthy of review. The volcano region lies 60 miles to the west of Napier, which was stricken by earthquake February 3, 1931 (Volcano Letter No. 327).

Tarawera lies in the Taupo volcanic zone trending N. 38° E. from Ruapehu to White Island. This zone is famous for many hot springs, geysers, mud volcanoes, and solfataras. Masses of heated magma must exist at no great distance below the surface. Ruapehu, Ngauruhoe. and Tongariro, in the southern part of the zone, are definitely active volcanoes 5,500 to 8,900 feet high. Lake Taupo is in a subsided area north of these volcanoes and covers 242 square miles. About midway between Lake Taupo and the Bay of Plenty is Tarawera Lake, northeast from Lake Taupo. Tarawera Mountain is next to the lake, a flat-topped mass of porous rhyolite lava of light gray color, standing 3,606 feet above sea level, and 1,040 feet above the lake. It was not known to be an active volcano, but studies of its structure show that it is a true cone, with beds dipping outwards, lava streams on its lower slopes, and a plug of what was viscid lava from a former eruption in a NE-SW fissure on its top. There is something of concentric structure in this lava cap.

The warm lake Rotomahana lay two miles southwest of Tarawera, bordered by hot springs and jets of steam. The siliceous sinter of the White and Pink Terraces was on ground which sloped down to the shores of this lake. Water which overflowed the terraces boiled as geyser in the basins above. Rotomahana with its terraced sculpturing, azure warm waters, flocks of dainty terns, and greenery amid steam jets was one of the fairylands of the globe.

At the top of the White Terrace was a snow-white geyser bowl 90 feet broad full of clear blue water boiling up violently in gushes 15 feet high. The basin became dry when south wind blew, but filled again when the wind changed. When the basin was almost full on these occasions, columns of boiling water 20 feet in diameter were hurled 60 feet into the air. In November 1885 there were unusual eruptions of this geyser sending a column of water up 150 feet and of steam 1,020 feet, unheard of in the experience of the resident Maoris. This was the prelude to

the great eruption eight months later. The acid waters of the crater basin on White Island Volcano in the Bay of Plenty disappeared in the middle of 1885, leaving the bed dry. In April of 1886 Ruapehu sent up unusual steam jets, At the beginning of June, 1886, a creek went dry on Lake Tarawera, then with a rushing sound the lake water came running up, overflowing the creek bed, and thereafter retiring twice after the fashion of unusual flood waves. No earthquake was noticed, but some fault block movement in Tarawera Mountain may have caused the retirement of the waters.

The district is thinly populated. Natives on Lake Tarawera did not survive to relate what happened. The nearest observers were at the Wairoa, eight miles west of Tarawera. The previous year had been very dry. After a fine evening June 9, 1886, earthquakes occurred at 12:30 a. m. June 10 and increased in violence for an hour. The northern part of Tarawera Mountain split open and a column of black ash-laden steam arose. This spread to other parts of the plateau summit of the mountain. At 2:10 a. m. there was a violent earthquake, followed by a loud and prolonged roar. A black cloud ascended and spread outwards. Red-hot fragments were seen darting from the cloud. Lightning began to appear, there was rumbling, a red glow lit the scene and as fresh outbursts occurred the clouds were lit up with stronger glow. Fireballs fell about the summit.

The fissure probably split its way southwest through Lake Rotomahana soon after 3 a. m., for about that time earthquakes were especially severe, the heaviest one happening at 3:20 a. m. Engulfment on a big scale probably occurred at this time. This continued southwest from Rotomahana to other craters. By 3:30 a. m. the whole line was in violent eruption for a distance of nine miles from beyond Tarawera on the northeast to Lake Okaro on the southwest. Glow was seen only at the Tarawera end. The clouds spread out, stones and sand began to fall at Wairoa about 3 a. m, then at Rotorua about 4 a. m., and a fierce southwest gale at this time drove the ash-laden cloud away from Rotorua in the direction of the Bay of Plenty. It dropped its ash over all the country between Rotorua and the sea. The chief violence of the eruption was over before 6 a. m. At Rotorua darkness lasted until after 9 a. m. At Wairoa ash fell until 9 a. m., and about Lake Tarawera many people were killed. In the direction to which the ash cloud was blown, at Opotiki, 47 miles away, it was pitch dark until 10:20 a m., when the fall of dust became lighter, and daylight gradually appeared. Detonations were heard even as far away as Hokianga (253 miles) and Auckland (133 miles).

Along the line of the great fissure a series of steam-blast craters was formed. The greatest was the Rotomahana Lake crater, with a hot lake left at the south and another at the north. A great chasm was left in the southern face of Tarawera Mountain, shown in the photograph on Page One, with the Rotomahana lake refilled. There were lines of pits at the north and at the south. The Pink and White Terraces were blown out, with fragments left in the debris. Bold Pinnacle Rocks of rhyolite stand near where the White Terrace geyser was. The southern portion of Rotomahana Crater is bounded by high cliffs of horizontal strata. Tarawera chasm in the hillside is a gash a mile and a quarter long. The bottom is marked by crater-like hollows. The largest hollow has a thousand-foot wall at its back Large trees were blown off the mountain and their stubs were found near Rotomahana. Molten augite andesite was believed to rise in the fissure during the glowing stages of the eruption, and was ejected explosively as scoriae, sand, and dust. There were also bombs one to eight inches in diameter, with cracked surfaces. The rock is black and approaches basalt, with sp. gr. 2.93. Olivine occurs sparingly. The only ryholite ejected was fragmental from old country rock.

At the south end of the Rotomahana Crater there developed in later years the famous destructive mud geyser Waimangu, irregular in its outbursts and at times behaving like a steam-blast volcanic eruption. On several occasions it caused loss of life. (From A. P. W Thomas, Eruption of Tarawera. N. Z. Gov't Report, 1888.) T.A.J.

TILTING OF THE GROUND FOR JULY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily sesimograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in the direction given.

June 29-July 5	0.9 second W.
July 6-12	0.4 second NW.
July 13-19	0.7 second NNE.
July 20-26	0.4 second NNE.
July 27-August 2	0.8 second WNW.

KILAUEA REPORT No. 1020

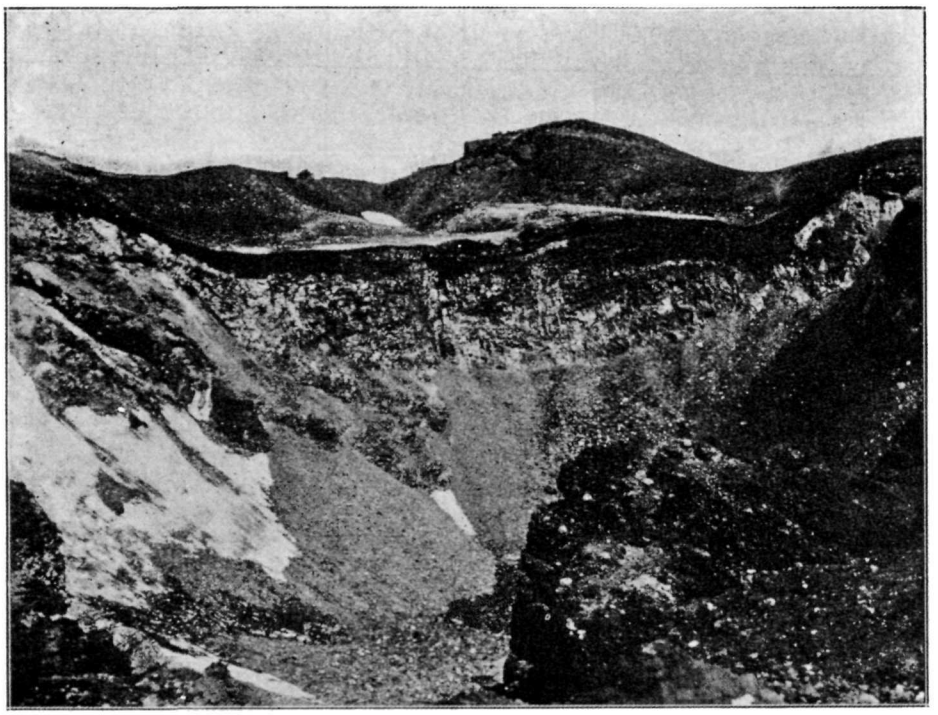
WEEK ENDING AUGUST 9, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

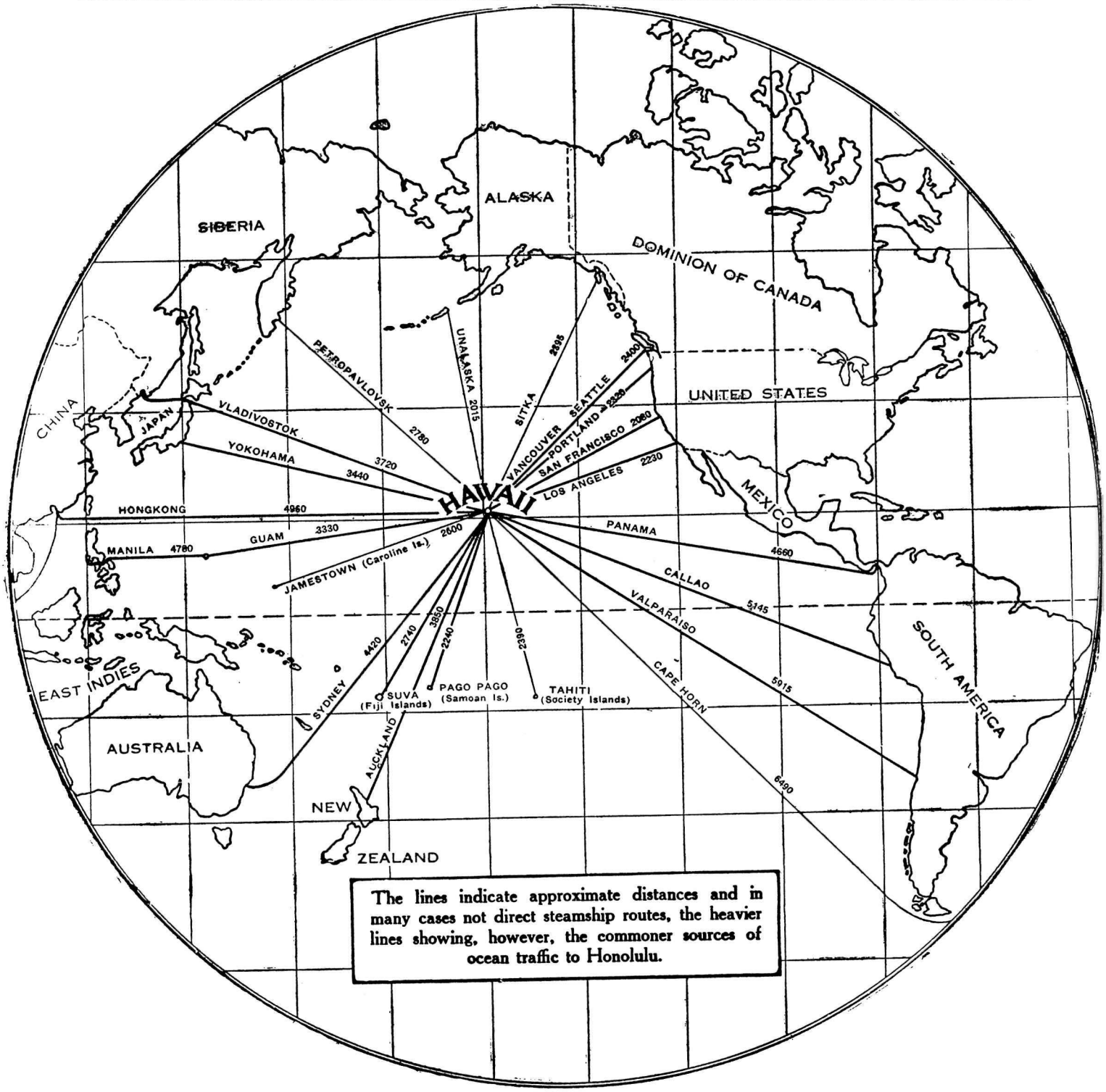
The week at Kilauea passed without changes in volcanic conditions. On August 3 no fume was visible on the Halemaumau bottom. Steam showed at the southeast rock slope but not at the south talus. A strip of sulphur at the lower edge of the south talus appears to be spreading in the direction of the 1931 cone. Rim cracks were measured and showed no changes. On August 4 fume reappeared at the sulphur spot north of the 1931 cone. The pit seismograph had registered two small tremors with slight tilt toward the pit. On August 8 steam and fume were absent from the interior of the pit. A few rocks were heard falling on the north talus at 9:30 a. m. The pit seismograph recorded a few slow-period tremors.

There was a very considerable increase in the number of seismic disturbances recorded by the instruments at the Observatory, including 39 tremors and 6 seisms. One of the latter at 1:43 a. m. August 3 showed distance to origin 23 miles; another at 4:22 p. m. on the 8th showed distance 14 miles and was felt locally. In addition there was a teleseism at 3:54 p. m. August 6 feebly recorded.

The average of accumulated tilt was slight NE. Microseismic motion was slight.



Crater of Fujiyama, August 1917, showing a typical engulfment crater with dikes in its walls, with a section of a lava fill, and inner debris slopes of last engulfment. This is not especially different from Tarawera Chasm, though nothing is reported about engulfment during the Tarawera eruption. Fujiyama Crater is central, whereas the New Zealand craters of 1886 are numerous and in a line. It is probable enormous engulfment occurred at Rotomahana, when the lake and the geyser terraces fell into a void. Photo Baker.



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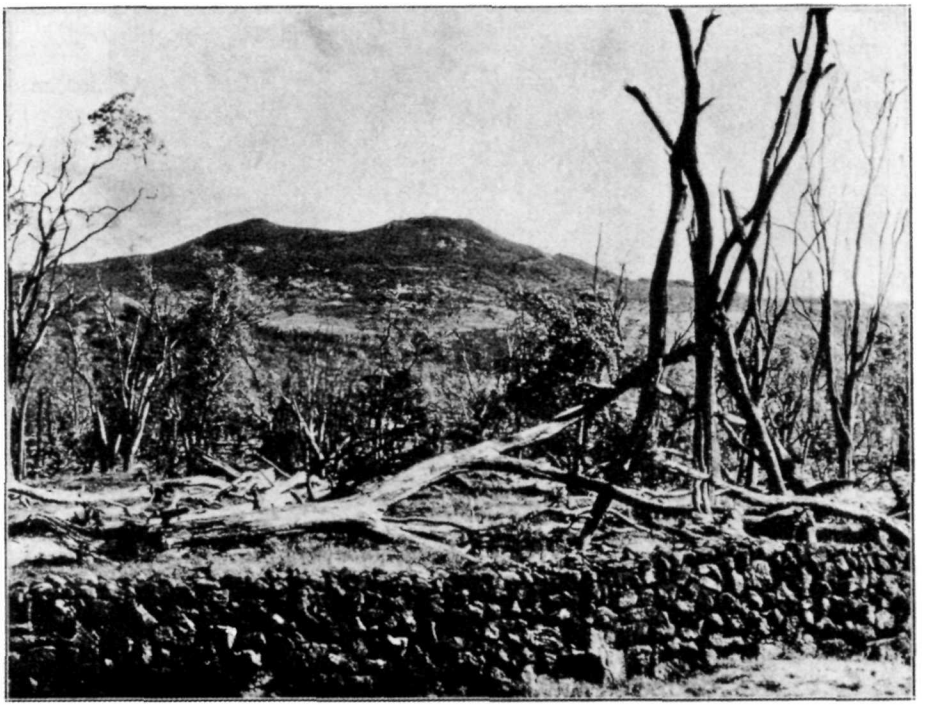
No. 347—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 20, 1931



Hualalai as seen from the southeast. The two prominent points are large cones of cinder and slag. The largest summit pit crater is not visible but is located just over the skyline formed by the saddle between the two cones. Photo O. H. Emerson.

HUALALAI

Hualalai Volcano lies entirely within the bounds of the North Kona District of the Island of Hawaii. It has the shape of an elongated dome with the longer dimension of the dome lying almost on a line drawn due northwest from the summit crater of Mauna Loa. The belt road around Hawaii follows the slopes of Hualalai for a distance of more than 30 miles between Kealakekua and Waimea, half encircling the volcano. The broad fan-shaped plain which culminates in Keahole Point, the westermost point of the Island of Hawaii, is formed of pahoehoe flows from this volcano.

The summit peak of Hualalai has an elevation of 8,251 feet above sea level, more than twice the elevation of Kilauea Crater, but lacking more than 5,000 feet of attaining the extreme altitudes of Mauna Kea and Mauna Loa. Because of its moderate height, the mountain is covered with vegetation almost to its very summit. There is a remarkable contrast in type of vegetation on the two opposite slopes of the mountain due to different conditions of rainfall. The northeast slopes, the trade wind side, are reached by trade winds only after they have crossed the broad plains of Waimea and have lost most of their moisture. As a consequence, the entire northern slope of Hualalai has a relatively small rainfall, probably nowhere exceeding 40 or 50 inches of rain a year. The vegetation of this slope accordingly is made up of the kinds of plants which exist on a small amount of moisture, but it is sufficiently luxuriant to provide pasture for cattle so that most of the northern slopes are utilized as range land by the Huehue and Puuwaawaa ranches.

Conditions on the southwest or leeward slopes are very different. The area is sheltered from the trade winds by the mass of the mountain, so that a true land and sea breeze is characteristic. During the night, the slopes of the mountain cool off more rapidly than does the ocean which causes a breeze to blow from the colder mountain slope toward the warmer ocean. Then as the sun warms the mountain slope more rapidly during the morning hours than it does the surface of the ocean, the wind reverses and blows



A small pit crater near the summit of the mountain. In the wall is exposed an old lava flow (at bottom of picture) covered with several feet of bedded cinders from a nearby cone, and over all two or three flows of recent lava which have been poured out since the cinder cone activity. Photo O. H. Emerson.

from the sea onto the land. This day breeze is laden with moisture from the ocean, and as it cools on its way up the mountain side, it drops its excess moisture in almost the same general area every day. As a consequence of this combination of conditions, the rainfall gradually increases from sea level up the slope of the mountain till it reaches a maximum (over 100 inches a year) at an elevation between 2,500 and 3,000 feet, then decreases gradually from this rain belt to the top of the mountain. Thus the vegetation of the southern slope of Hualalai changes with this distribution of rainfall from the semiarid plants at sea level, through fern jungles in the rain belt, then back to the forests and grasses of the dry lands on the higher slopes. The belt road passes through a region of moderately heavy rain and the lands accessible from the road are used for coffee and other planted crops. The lower and upper dryer slopes are used almost entirely as grazing lands by the ranches of the area, but the narrow belt of highest rainfall is too wet and swampy for human use, so in the main is left as native fern jungle.

Hualalai is by far the most "climbable" of all the volcanoes of Hawaii. The ascent to its summit and side trips over its slopes are pleasure jaunts compared to the gruelling climbs to the summits of Mauna Loa or Mauna Kea or to the arduous wanderings through the jungles on Kilauea. It also is an extremely interesting volcano from the standpoint of the geologist or volcanologist.

The first mystery of Hualalai is the question of its relation to Puu Anahula and Puuwaawaa. These two areas are located on the northeast slopes of the mountain and are kipukas, or islands, left in the younger floods of lava from the top of the volcano. From their position so near to Hualalai, they would seem to be a part of that volcano, yet the lava of which they are formed is very different from all the other lavas of Hualalai, but very similar to some of the lavas of the Kohala volcanoes. So far the question has not been answered whether Puu Anahula and Puuwaawaa belong to a very old stage of the activity of Hualalai or whether they really are parts of the Kohala mountains.

Leaving this question open, it is known that the volcano as we see it began its activity by pouring floods of aa and pahoehoe lava out of a number of vents arranged along a fissure line or zone of cracks which is almost straight in a northwest-southeast direction. As more and more of these flows were poured out they built an elongated dome. Activity was more pronounced at one particular part of the fissure line so that the dome of flows was built up to a greater elevation at this spot. There may possibly have been a summit crater similar to Mokuaweoweo on the top of this Hualalai dome. Certainly the structure of the Hualalai dome, elongated along a line of cracks, is very similar to the structure of Mauna Loa as it exists today.

Gradually the eruptions from the Hualalai dome began to change from quiet outpourings of lava flows to eruptions which were more violently explosive and which broke up the molten lava into small particles of cinder and ash. These cinder eruptions broke out in many places along the main rift line and built up huge conical piles of cinders and ash, as well as poured out smaller flows of aa lava. Many of these cinder piles can be seen on the lower slopes of the mountain below the Huehue Ranch, and the two most prominent ones form the two highest points of the mountain.

After these explosive eruptions, for some reason the activity changed back again to the more quite type, and the later flows have been poured out with less explosive activity at the source vent. Accompanying this change in type of activity, the main activity seems to have shifted from the center of the volcano out along the rift line in both directions from the center. There has been a moderate amount of the later activity at the top of the dome, enough to pour out a few small flows and to build several large pit craters at the top, but by far most of the later flows have been poured out from points on the rift line down both slopes from the center. Most of the pit craters and slag cones which show up so well along the rift line on the relief map which was made by Dr. Pope have been formed during these later eruptions.

This type of activity has continued into historic time. There have been apparently several flows from Hualalai since the occupation of the island by the Hawaiians according to accounts given by natives to Ellis in 1823. He says: ". . . . the traditional accounts given by the natives of the eruptions, which, from craters on its (Hualalai) summit, had in different ages deluged the low land along the coast; . . . ." (Ellis, p. 53). The only activity which has occurred since the arrival on the island of English settlers took place in 1800-01. On Dr. Pope's relief map two recent flows are shown on the north slope of the mountain. The western and shorter one of these is marked as the flow of 1801, and the other as the flows of Kaupulehu. There has been a considerable discussion as to whether or not both of these flows are of the same date, i.e. 1801. In a personal communication Dr. Pope states that he is convinced that the Kaupulehu flow belongs to the 1801 eruption.

Ellis' description of a visit to the source crater of the 1801 activity certainly seems to indicate that the Kaupulehu flow is the one in question. Parts of his description follow:

"Having traveled about 12 miles in a northeasterly direction, they arrived at the last house on the western side of the mountain." (Probably Huehue Ranch) ". . . . Leaving the path, the party began to ascend in a southeast direction and traveled about six miles."

At this spot the party spent the night. The location of their camp probably was on the northwest ridge of Hualalai, a few miles above the present belt road.

"Having united in their morning sacrifice of thanksgiving to God, and taken a light breakfast, they resumed their laborious journey. The road, lying through thick underwood and fern, was wet and fatiguing for about two miles, when they arrived at an ancient stream of lava, about twenty rods wide, running in a direction nearly west. Ascending the hardened surface of this stream of lava, over deep chasms, or large volcanic stones imbedded in it, for a distance of three or four miles, they reached the top of one of the ridges on the western side of the mountain.

"Between nine and ten in the forenoon they arrived at a large extinguished crater, about a mile in circumference, and apparently 400 feet deep, probably the same that was visited by some of Vancouver's people in 1792. The sides sloped regularly, and at the bottom was a small mound, with an aperture in its centre. By the side of this large crater, divided from it by a narrow ridge of volcanic rocks, was another fifty-six feet in circumference, from which volumes of sulphureous smoke and vapour continually ascended. No bottom could be seen; and on throwing stones into it, they were heard to strike against its sides for eight seconds, but not to reach the bottom. There were two other apertures near this, nine feet in diameter, and apparently about 200 feet deep.

"As the party walked along the giddy verge of the large crater, they could distinguish the course of two principal streams, that had issued from it in the great eruption, about the year 1800. One had taken a direction nearly northeast; the other had flowed to the northwest, in broad irresistible torrents, for a distance of twelve or fifteen miles to the sea, where driving back the waters, it had extended the boundaries of the island. They attempted to descend this crater, but the steepness of its sides prevented their examining it so fully as they desired." H.A.P.

KILAUEA REPORT No. 1021

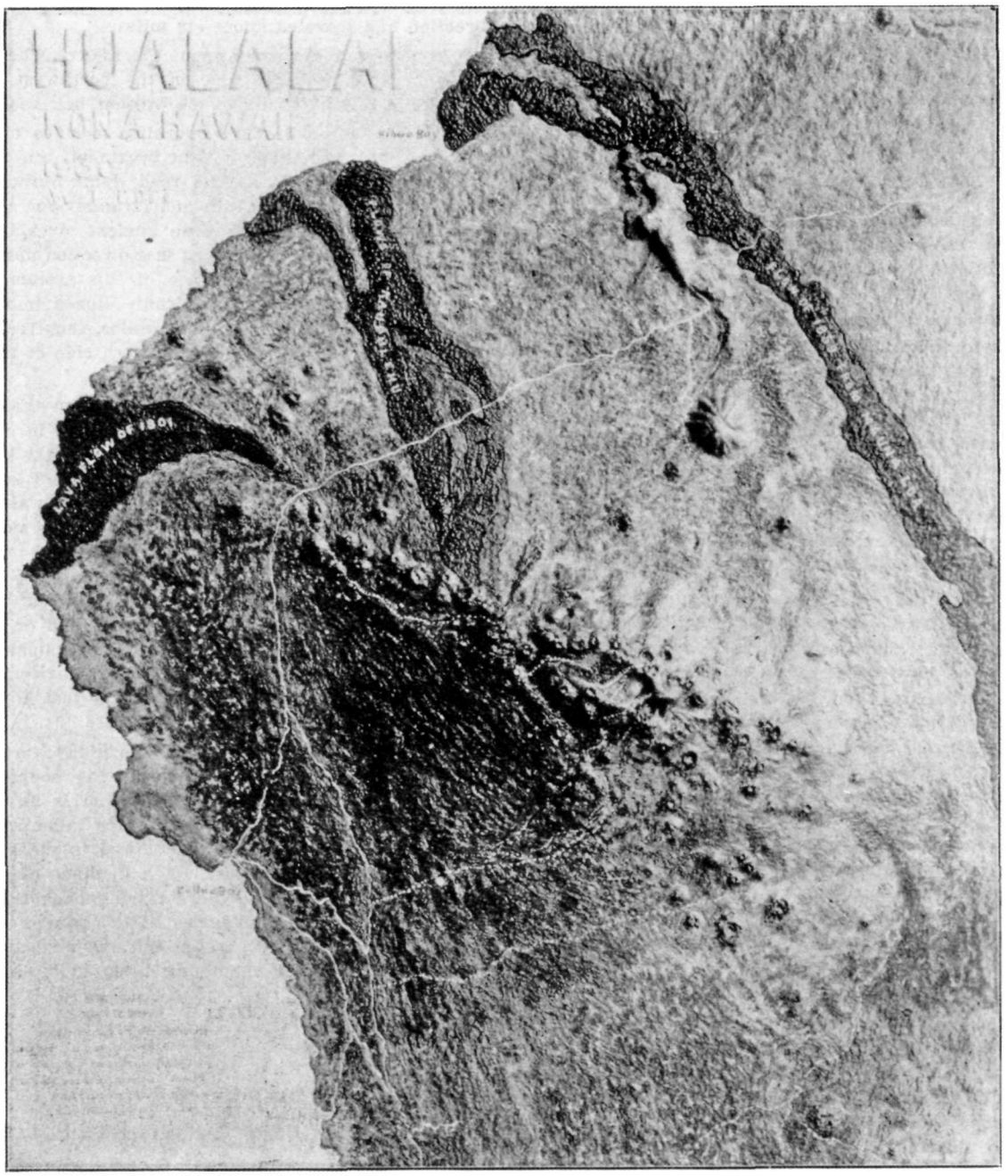
WEEK ENDING AUGUST 16, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There is nothing new to report. Steam and fume were detected occasionally at vents within Halemaumau, usually very thin as dry weather has prevailed. On August 13 about 9 a. m. there was a large avalanche from the middle of the northwest wall, causing much dust. Another avalanche dust cloud was observed from Uwekahuna about 9:20 a. m. August 15.

The seismographs at the Observatory recorded 23 volcanic tremors, six very feeble local seisms and one teleseism. Three seisms gave indicated distances as follows: August 12 6:11 a. m., 4 miles; August 13 6:20 a. m., 11 miles, and 7:03 a. m., 5 miles. None was reported felt. The teleseism registered at 11:04 a. m. August 10 without distance phases.

Tilt for the week was slight NNE. Microseismic motion was slight.



Model of Hualalai, 1930, by Willis T. Pope. Shows recent flows and the northwest-southeast summit rift well marked by cinder cones and pit craters. Distance from Kailua Bay to Keauhou Bay (southwest corner) is about six miles

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No. 348—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 27. 1031



A typical pahoehoe surface on a lava flow. The skin of vesicular glass which forms rapidly is often wrinkled and contorted into curious shapes. Flow from southwest flank of Kilauea December 1919. Photo Finch.

VOLCANIC PRODUCTS

The statement is often made that the islands of the Hawaiian group have been formed by volcanic action. In other words, the islands are built of materials which have been thrown out from a number of separate volcanoes. It may be of interest to consider in some detail what these volcanic products are of which the Hawaiian Islands are made.

Geologists who have studied the question are rather well agreed that the basin of the Pacific Ocean is made up largely of a kind of rock known as basalt. One of the facts on which this statement is based is that most of the material thrown out of the numerous volcanoes in the Pacific Ocean basin is basalt of nearly uniform composition. This is certainly true in the Hawaiian Islands. All of the volcanoes in the Hawaiian group have drawn the materials for their eruptions from a common, deep-lying supply of basalt. Geologists do not agree as to the exact physical condition in which the basalt exists under the ocean. However, for the study of volcanic products it is unnecessary to determine this original condition. We are interested in the basalt only after it begins to be erupted from one of the volcanoes.

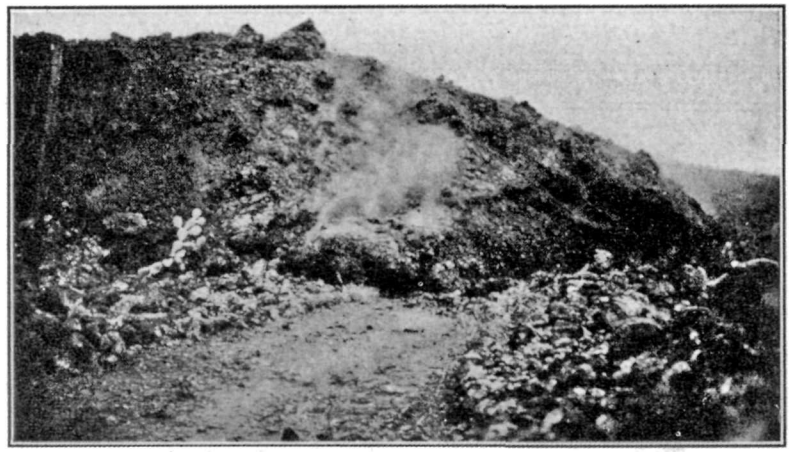
Under appropriate conditions of heat and pressure, part of the deep supply of basalt under a volcano becomes liquid, and then is capable of being erupted from the volcanic vent at the surface of the earth. When it is in this liquid condition it is called "magma." Magma may be defined simply as liquid rock. In more detail it may be defined as a solution of a number of chemical elements in different chemical combinations just as sea water is a solution of many chemical elements, the most important of which are sodium chloride (common salt) and pure water. Chemists express the amounts of the different elements in a rock in terms of their weight when combined with oxygen. A typical basaltic magma would be made up of the following principle elements in the given proportions:

Oxide of silicon	50%
Oxide of aluminum	14%
Oxide of iron	10%
Oxide of magnesium	8%
Oxide of calcium	10%
Oxide of sodium	3%
Oxide of potassium	1%
Other substances	4%

In addition to the main elements, the magma contains very small amounts of many substances such as water, manganese, titanium, phosphorus, sulphur, nickel, chromium, copper, chlorine, carbon, and molybdenum. Thus we see that a magma is a very complex liquid made up of a large number of elements in solution.

The magma can exist as a liquid only at very high temperatures. Dr. Jaggar made a number of measurements of the temperatures in different parts of the magma lake ranging from about 750 degrees Centigrade to 1,500 degrees Centigrade. Iron in a blast furnace would be white hot at the higher of these temperatures.

When the magma begins to rise in the throat of the volcano, some of its elements begin to combine to form gas such as water vapor, sulphur dioxide, and carbon



The lava flow from Mauna Loa in 1926 as it crossed the road like a moving cinder pile. The clinkery, broken surface of the aa flow is radically different from the smooth, glassy surface of the pahoehoe flow, yet the lava forming the two different flows may be of exactly the same composition. Photo Boles.

dioxide. The gas comes out of the magma solution, begins to expand and form bubbles, and cause the whole mass of the magma to swell and froth like soda water in a bottle after the cap is removed. The expanding gas makes pressure within the liquid magma which helps force it to the opening in the crater of the volcano and makes the magma erupt. If the gas pressure is relatively low and the opening to the volcanic vent is fairly open, the escaping gas makes fountains of liquid lava at the vent such as are seen in Halemaumau or at the heads of the Mauna Loa flows. However, if the gas pressure is great and the escape of gas is partly obstructed, the lava may be thrown out of the vent with great violence. These stronger gas explosions break the lava up into drops and fragments of different sizes so that, instead of a lava flow, an eruption of volcanic ash and cinders will result. Such activity has formed the large cinder cones on Mauna Kea and such craters as Diamond Head on Oahu.

Going back to the magma, as the gas begins to bubble out and the lava rises in the volcano, its temperature is lowered by radiation of heat to the rocks forming the throat of the volcano and to the open air. As the temperature drops, some of the constituents of the magma combine and crystallize from the solutions as minerals which can become solids at high temperatures. Olivine (Hawaiian diamond) is one of these minerals which begins to form crystals while most of the magma is still liquid. Some of the liquid lava dipped from Halemaumau had large crystals of olivine floating in it. Since the olivine crystals begin to grow before the lava is erupted, many of them attain a large size and are conspicuous in some flows as large greenish crystals known as phenocrysts Olivine is made up of magnesium, iron, and silica and is called a magnesium-iron silicate.

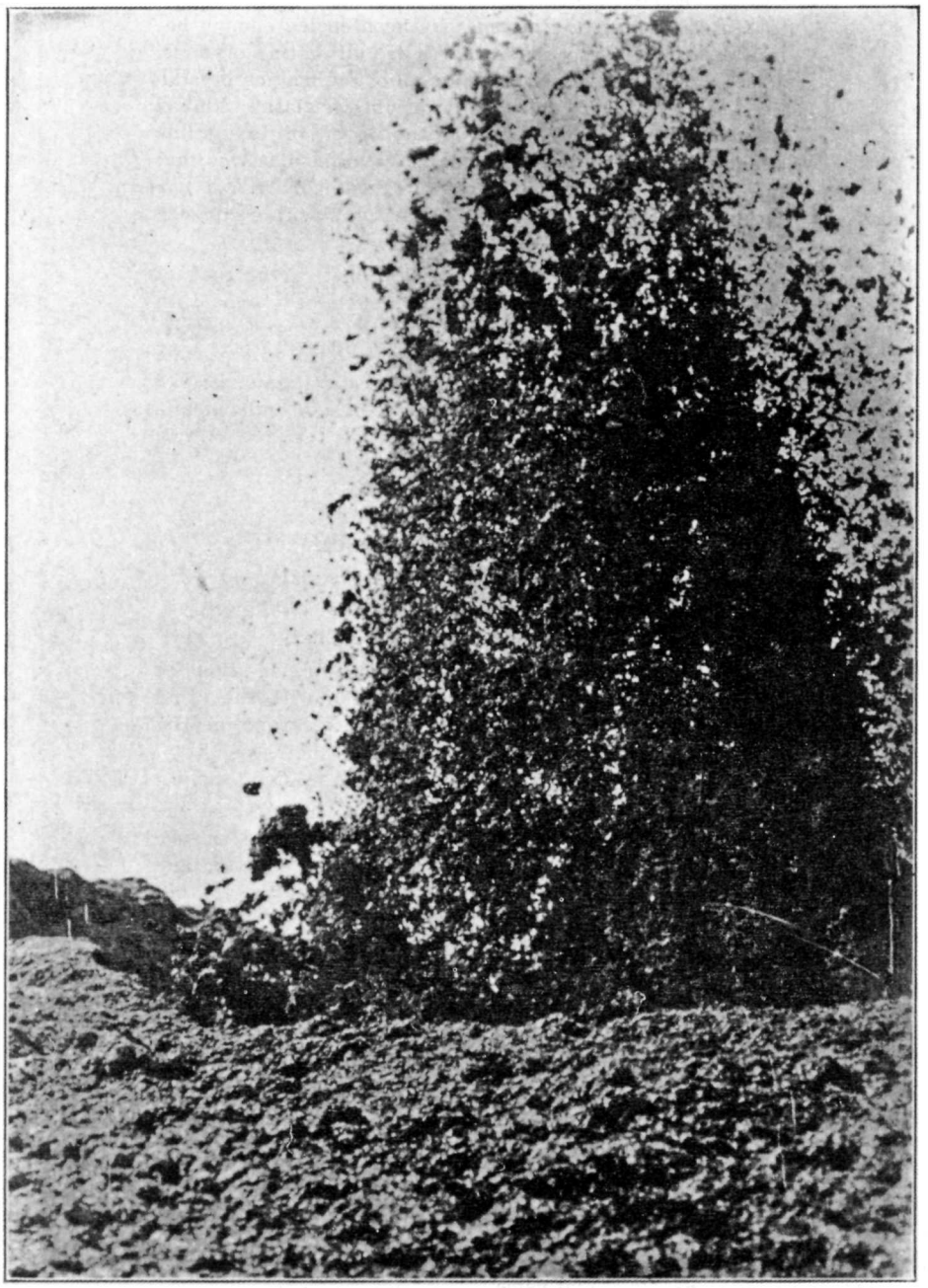
Other minerals begin to precipitate from the magma when the temperature drops still lower. The two other important minerals which form from basaltic magma are pyroxene and calcium feldspar. Proxene is made up of calcium, magnesium, iron, and silica. Calcium feldspar is made of calcium, aluminum, silica, some sodium, and a little potassium. Proxene and calcium feldspar are the most abundant minerals in basalt, olivine is third in abundance, and the only other common mineral of much importance is magnetic iron ore which is present up to 5 or 6 per cent in some basalts. Though olivine is the most common phenocryst in the Hawaiian basalts, occasionally pyroxene and calcium feldspar are found as black and white phenocrysts, respectively.

If magma cools fairly slowly, there will be time enough for all of its constitutents to combine in crystals of the above mentioned minerals. However, if the liquid magma is cooled very rapidly it may freeze to a solid form without giving the elements time to form crystals. This rapidly frozen magma is a volcanic glass which is called basaltic obsidian.

If the magma is thrown out in explosive eruptions, such as have occurred on Mauna Kea, the small drops of magma which are suddenly blown out into the air cool very rapidly and form small particles of basaltic obsidian. Many of these particles are full of gas bubbles and so form a sort of glass sponge which is called pumice. The larger fragments or blebs of magma may be big enough to cool more slowly and so have time to crystallize to some extent. Many of them are full of bubble holes also and so form slag-like pieces which are called cinders. An explosive eruption thus produces fine grains of glassy ash or pumice and coarser fragments of partly crystalline cinders.

A small part of the magma which comes out in a quiet eruption is blown into the air by the fountains at the source vent. This part freezes rapidly and forms a little pumice and Pele's hair which is basaltic glass drawn out into fine threads. However, most of the magma from quiet eruptions pours out as lava flows. These are of two types, aa and pahoehoe, which are distinguished by the character of the surface of the lava flow and not by any difference of composition of the lava.

If the magma which flows out is so hot that it contains very few crystals, the surface of the flow rapidly freezes and forms a thin skin of basaltic glass on top of the flow. This skin acts as an insulator and permits the rest of the lava in the flow to retain its heat and so to cool slowly enough for complete crystallization. A flow



Fountaining lava at the source of the 1919 flow from Mauna Loa. The force of the rising gas throws the lava into the air and blows it full of bubble holes. Pumice and Pele's hair are formed by this sort of fountain. If the explosive force becomes much greater, all of the rising lava may be blown into the air to form cinder and ash cones. Photo Jaggar.

which has formed such a glassy skin on its surface is called a pahoehoe flow.

In contrast, if the magma has been cooled enough before exposure to the air so that it is full of tiny crystals, as soon as it is exposed to the air all of the magma crystallizes rapidly. Thus, instead of forming a glassy skin on its surface, the flow forms a top layer of crystalline clinkers. This clinkery surface also is an insulator so that the inner part of the flow loses its heat slowly and has time to crystallize completely. A lava flow with a clinkery surface is called an aa flow.

Aa and pahoehoe flows make up most of the rock of the Hawaiian Islands. Cinders and ash are present in appreciable quantity on the islands of Maui and Hawaii, and are fairly conspicuous as building material in the make up of Oahu. For example, Punch Bowl and Diamond Head on Oahu are craters made up largely of ash and cinders.

H.A.P.

KILAUEA REPORT No. 1022

WEEK ENDING AUGUST 23, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There are no visible changes in volcanic conditions at Kilauea. Halemaumau remains quiet and with the usual vapor activity. The records of the seismograph nearby indicate quiet conditions.

There were 21 short tremors registered by the instruments at the Observatory, one two-minute tremor, and one eight-minute tremor; and three very feeble local seisms. One of the seisms, occurring August 21 at 12:09 a. m., and having close epicentral distance, was felt locally; another at 11:05 p. m. August 22 showed distance to origin 32 miles.

The average tilt for the week was very slight NE, with a decided trend to N toward the end of this period. Microseismic motion was slight.

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The Volcano Letter

349

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Marked crack where it emerges at southeast rim of Halemaumau, showing method of measurement with wooden calipers at painted spots.

VERTICAL AND HORIZONTAL GROUND MOVEMENT

"Tilting of the ground as recorded by the slow and persistent wandering of the recording pens of the seismograph has been found through past years at the Observatory to be well worth observation. Such tilting away from the pit of Halemaumau has in general been correlated with rising of the lava column, while tilting towards the pit has usually come with retirement of the lava or at times of general collapse. The tilt at the Observatory appears to have a normal annual range of about 10 seconds of arc towards the pit (southwest) during the first half of the year, and a recovery during the second half. This normal movement and some other shorter period variations may not be strictly due to volcanic causes. General temperature changes either of the instrument room, of the ground upon which the Observatory stands, or of the face of the cliff near the Observatory may produce tilting effect and so account in part for this annual change, though experi-

ments show that it certainly is not a purely local movement. Volcanic conditions are known to produce tilt also, and these volcanic tilt effects are superimposed upon the tilts produced by other causes." (R. M. Wilson in "Review of Local Seismic Features for the Year," Monthly Bulletin of the Hawaiian Volcano Observatory, Vol. XV. No. 12, December 1927.)

Quantitative measurements of the uplift and depression of the Kilauea dome have been made on several occasions in the past by means of precise spirit levels and horizontal movement detected by a careful retriangulation of a network of stations about the pit also connected by precise levels. The first spirit levels were run in 1912 by the U. S. Geological Survey and subsequent runnings of this line by the same organization in 1920 and the U. S. Coast and Geodetic Survey in 1927 have shown the value of spirit levels as a means of detecting even small amounts of vertical displacement. The methods used are fully described in Monthly Bulletin of the Observatory Vol. XV, No. 6, 1927.

The net of triangulation stations about Kilauea was first established in 1920 and the connecting levels run during the same period. Final adjustments of both surveys by the method of least squares was made by the computing section of the Geological Survey in Washington, D. C.

In 1927 and 1928 Mr. R. M. Wilson, engineer and mathematician of the Observatory at that time, who was also the author of the 1920 surveys, made an identical resurvey of this net. The results correlated satisfactorily with the general breakdown and depression of the Kilauea dome during the seven-year period which they covered. Horizontal movement was shown to be a general pull-in of all points towards Halemaumau as a center.

Similar repetitions of surveys have also been extensively made by the Japanese government in their quake-stricken provinces and the U. S. Coast and Geodetic Survey has retriangulated the area along the San Andreas rift in California. ("Earth Movements in California," by William Bowie, U. S. Coast and Geodetic Survey Special Publication No. 106.) The results of these measurements as of those in Hawaii show clearly and accurately the amount of displacement of the earth's crust which took place during the period of the cataclysm. Now as has been said some of these displacements were very small and required the most accurate of modern engineering methods to detect, also the surveys were made after the greatest movement had occurred. The question arises since such small movements have been measured after a quake has occurred, would it not be possible to apply these same methods to the prediction of quakes, or as more closely concerns us in Hawaii, the rise of the Kilauea or Mauna Loa lava columns?

The measurements in California and Japan have been concerned partly with quakes of tectonic origin, and as such quakes are caused by continued long strain and warping of the earth's crust over a number of years until it has reached the breaking point. it would seem that here a periodic survey of known active fault areas would be of value. This in Japan is called "chronic tilting" by Imamura. (Topographical changes accompanying earthquakes or volcanic eruptions, by A. Imamura, Publ. E. I. C. No. 25, Tokyo, 1930.)

Here in Hawaii any such measurements would have to be correlated with data from the seismograph or tilt-meter and continued through two or more active phases, since the actual tilt of the ground from day to day is small and not perceptible except by magnification. However, cumulative tilt is undoubtedly a measurable quantity and since accumulated tilt away from the pit has been shown generally to precede an active period, it is possible that measurements of the relative change in elevation of established bench marks together with the measurement of the horizontal angular change between such points would give a more firm basis for prediction.

With this end in view, and for general engineering use, four new stations marked with standard U. S. B. M. tablets have been established about the rim of Halemaumau. One is a few feet from the seismograph cellar at the pit and the other three form a rough square spanning the crater. Triangulation of these points has been made for any immediate emergency. Later they will be connected by precise levels to the 1927 circuit and a more accurate triangulation made with perhaps an especially measured base.

Horizontal angles are observed by a repetition with a Berger transit graduated to 20 seconds. Each angle is observed 12 times, six times in a clockwise direction, three settings made with telescope direct, and three reversed, both verniers being read. The angle is then measured in a similar manner but in a counter-clockwise direction, the mean of the 12 readings giving the correct angular value free from instrumental errors. Horizon closures are made in the same way. Particular care must be given to the centering of the instrument over the station and of the signals over their respective marks.

The larger net of Kilauea stations will also be reoccupied and identical angles measured as the loss of any lines from the previously adjusted figure would necessitate an almost complete new adjustment and much of the value of the work lost from its intended purpose, a comparative study with the two older surveys, together with the accumulated data for the same period from the seismographs.

A similar resurvey with the spirit level would give a means for study of any relative changes of elevation among the several stations in the net.

The measurement of rim cracks about Halemaumau has in the past proved of interest, as well as of value to the public in marking off weak or dangerous sections about the pit. The measurements, however, have not been very refined, instrumental errors amounting to as much as two or three millimeters due partially to uncertainty of exact points of measurement as well as the inaccessibility of some of the points. These measurements are to be resumed with new points added from time to time and the methods of measuring revised. Tumescence of the Kilauea dome as the result of rising lava has its effect on the more deep-seated fractures; a lift of this lava column before eruptions in 1927 and 1929 caused a widening of the superficial rim cracks with sections breaking off and avalanching into the pit.

Kilauea, due to its accessibility, is ideally situated for observation and measurement of tilt. Mauna Loa, on the contrary, presents a problem. Previously established triangulation points of suitable accuracy are scarce, and the precise spirit levels to the summit run by the U. S. Coast and Geodetic Survey in 1926 provide the only accurate datum bench marks on the entire mountain.

Mauna Loa above timber line alone comprises an area of over 500 square miles and is really accessible only by means of three trails; one on the Kona or west side and two on the southeast side. Water is obtainable only at

the summit from melted ice or snow in the cracks and from scattered water holes along the forest edge.

Most of the historic activity, however, with a few exceptions has occurred along the two rift zones or ridges and at the summit crater, and all of the flows since 1881 have commenced within a relatively small area along the southwest rift a few miles above Puu o Keokeo, though generally preceded by an eruptive period of several hours at the summit.

The establishment of a net of triangulation about the whole mountain similar to the Kilauea net would be of immense value for future study, but the expense of surveying such a net would be more or less prohibitive. Astronomic azimuth observations would have to be made, a base line measured, the present transit replaced by a repeating or direction theodolite, and the net carefully connected to the recent inter-island triangulation by the Coast Survey. However, small independent nets spanning the most active parts of the rift zones as well as the summit crater would not be prohibitive in cost, and like the small Kilauea net would be readily subject to periodic remeasurement and hence comparative study. Extension to these nets of the existing levels could be made and vertical displacement measured from time to time.

Mauna Loa as a whole presents a problem of absorbing interest as yet practically untouched. Some sort of auto road to the summit and one from the Kona side to the southwest rift would go a great way towards overcoming the obstacles encountered by any one attempting observations on the mountain. The roads would also open an entire new field to the tourist. Seismograph and tiltmeter stations would be established at critical points and proper attention given them.

With its present inaccessibility Mauna Loa can be perhaps best studied through the means of small triangulation nets connected by levels and the construction of tiltmeter stations with a tiltmeter devised which would record its readings at the distant Observatory and require but infrequent field inspection. Dr. Jaggar is at present working on plans for such an instrument.

The Puna District and Hualalai have been scenes of recent severe shocks and also present fields for the study of tilt problems.

The above notes represent an outline of some of the work the Observatory has done in the past and what the writer hopes to take up in the future in the investigation of the horizontal and vertical movements or tilt of the ground about the several active volcanic regions in Hawaii.

E.G.W.

KILAUEA REPORT No. 1023 '

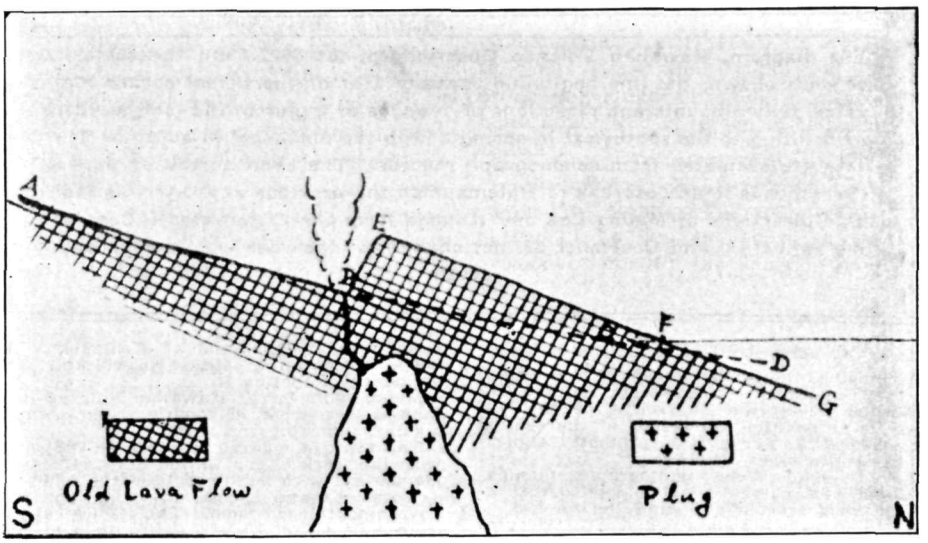
WEED ENDING AUGUST 30, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

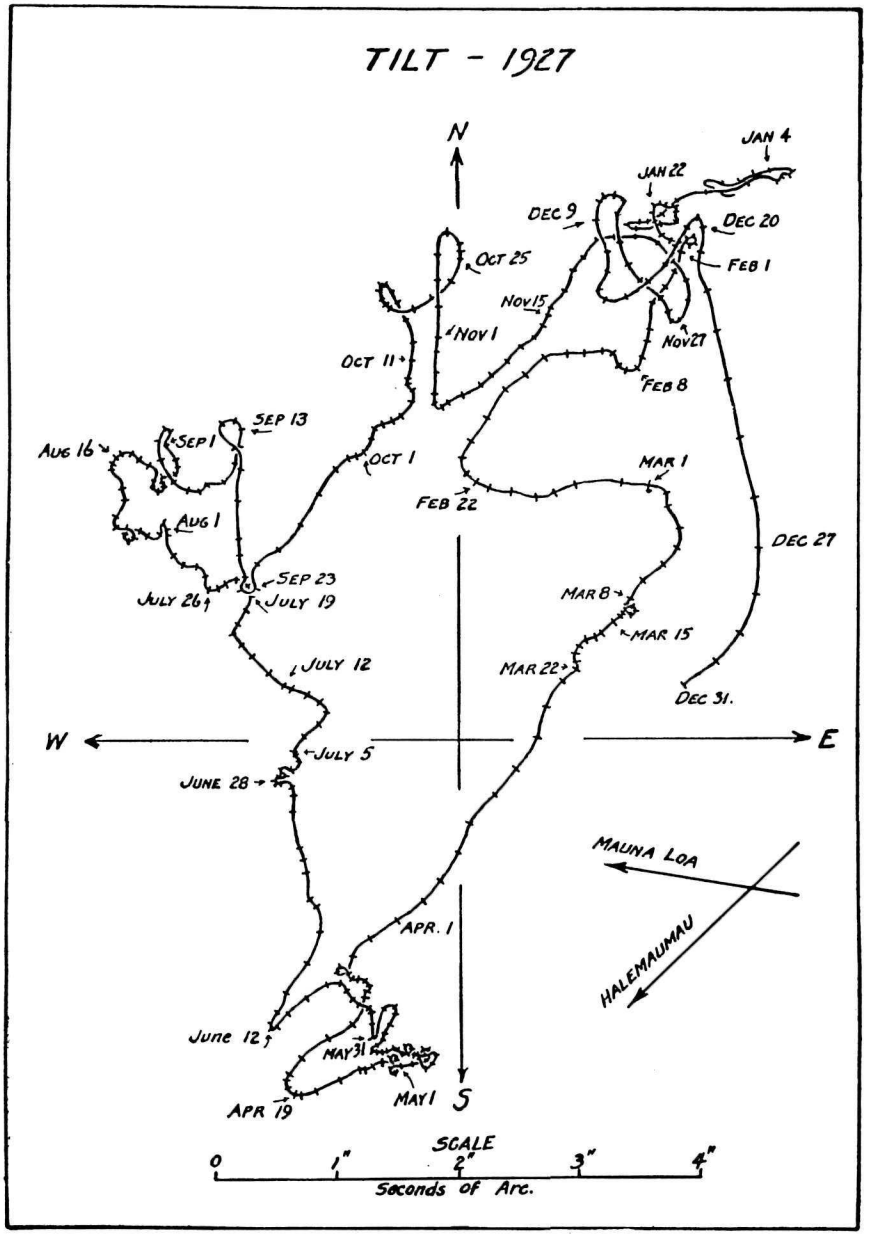
At Halemaumau pit slight fume was observed rising from a sulphur spot on the north side of the 1930 cone on the afternoon of August 23. Steam was notably absent August 24. A slide from the wall occurred about 9:40 a. m. August 26, and fume was observed on the floor. About 7 a. m. August 30, soon after the moderate earthquake recorded below, an avalanche at the pit on the northeast side sent up a thick cloud of dust.

The seismographs at the Observatory registered 19 tremors and 4 local seisms. Of these one at 2 a. m. August 25 was very slightly perceptible and indicated distance of origin 14 miles. A stronger earthquake was felt generally on the island at 7:53 a. m. August 30, dismantling instruments in Kona, Hilo, and at Kilauea, indicating distance of origin 15 miles from Kilauea and 35 miles from Hilo. It was felt as a slight and prolonged tremor near Kilauea, and more strongly in Hilo, Olaa, and Kona. The facts suggest an origin under the northern part of Mauna Loa, and this is confirmed by the vertical component seismograph which indicates an origin northwest of the Kilauea Observatory.

The average tilt for the week was moderate to the N, and microseismic motion was slight.



Profile of north slope of Usu Volcano in Japan where during a single eruption the block shown was lifted 500 feet and the whole mountain was affected by elevation and tilting. After Ouinoue.



Tilt diagram, Hawaiian Volcano Observatory, for 1927. On the scale in seconds shown, the line beginning January 1 in the northeast corner indicates daily amounts and directions of changes of a plumb line for the year, with tilting to the southwest in spring and to the northeast in autumn. The data are caculated from seismograph records. The bend northwest July 8 corresponds to an outbreak of Halemaumau the previous day. Arrows indicate directions of Mauna Loa and Kilauea from the Observatory. Comparing January 1 and December 31, net change for the year was four seconds south.

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The Volcano Letter

350

Two dollars per year — Ten cents per copy

No. 350—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — September 10, 1931

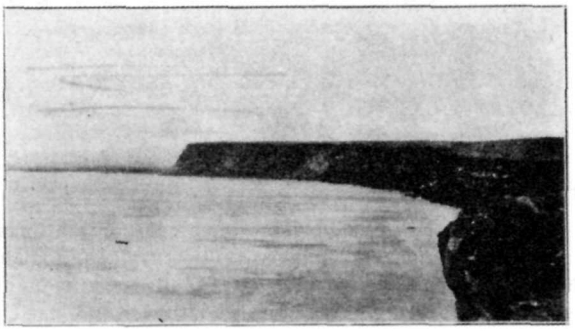

Figure 1. Looking north along the west-facing fault cliff, north of Ka Lae, Hawaii. In the main cliff may be seen the edges of many lava flows. The top of the lava cliff is backed by a gently-sloping terrace, back of which is a low cliff cut in loess. Back of the loess cliff is gently rolling loess grassland. In the distance, at the left, is down-faulted western block. Photo H. S. Palmer.

LOESS AT KA LAE, HAWAII

Ka Lae, the southermost point of the Island of Hawaii, may be reached by leaving the main highway about four miles west of Waiohinu, and driving southward about twelve miles over secondary roads. One first goes through the Kamaoa homesteads and then across open, strongly wind-swept grasslands to the Lighthouse Reservation at the extreme tip of the island. Ka Lae is bounded on the west by a west-facing fault cliff which, though low at the south end, increases in height inland to 500 feet or more (figure 1). The fault cliff extends inland at least ten miles from Ka Lae and is said by fishermen to extend also some distance southward under the sea. The block west of the fault has sunk and has thus formed a depression into and along which lava flows have poured on several occasions within historic times. The block east of the cliff, in contrast, has been freer of lava flows in recent times because of its greater elevation. Its coastline runs northeastward from Ka Lae and has been built out into the sea by prehistoric lava flows.

The block east of the fault cliff is entirely covered by variable thicknesses of a fine grained, yellow-brown material. In some places this has been drifted into sand dune ridges which parallel the direction of the prevailing trade wind (see figure 2). Along the top of the big fault cliff this upper fine grained deposit has been cut back slightly from the edge. This forms a small secondary cliff in which different layers of the upper material are exposed.

At many places there are small lenses of coaly or carbonaceous material at horizons in the little cliff which are below the present surface. Each coaly lens represents an accumulation of vegetable matter in a chance depression in what formerly was the land surface, but which has since been buried by new layers of silt. For the most part, nothing can be made out as to the nature of the plants that supplied the vegetable matter, but one block was found bearing the clear impression of a dicotyledonous leaf. The presence of the leaf print, as well as the presence of the coaly lenses, proves that the fine-grained material has been carried in in some way, and that it is not a residual soil formed by the weathering of the lava in place. Moreover, the fine-grained material rests on rather fresh lava rock and does not show the transition from surface soil to fresh rock, through various degrees of weathering, that residual soils show. Since wind is the only transporting agent that can be conceived of as having operated here, the material is properly classified as loess, a term that was originally applied in Germany to fine-grained wind deposited sediments.

For some miles east of the Lighthouse Reservation at Ka Lae, the actual shore line is of lava rock, largely pahoehoe lava. It is exposed as a rather uneven rock terrace, in places submerged and in places making a clifflet two or three feet high along the water's edge. The terrace rises inland to heights of four to six feet above sea level, and is from ten to a hundred feet wide. Back of the lava terrace is a single or compound loess cliff. In the few places where it is a single cliff it is in general about six feet high. Where it is a double cliff, the lower cliff is about four feet high and exposes a red-brown loess. The upper cliff is four to eight feet back of the top of the lower cliff and is about two feet high. It is composed of yellow-brown loess. In places there are low dune ridges of sand a short way back of the top of the upper cliff and resting on the finer-grained, yellow-brown loess (see figure 3).

The upper cliff is protected at its upper part by a good turf, the roots of which effectively bind the top few inches of loess and greatly retard its erosion. The lower part of the loess is not thus bound and therefore is readily cut away by windblown sand. Thus the turf layer is slowly undermined and is forced to collapse by the removal of its support.

In many places the red-brown loess cliff is double instead of single. The top of the lower red-brown cliff seems to be due to the slightly greater resistance to erosion offered by the remains of an old turf layer (see figure 3).

The ability of the lower or red-brown loess to resist erosion presented a different problem, for it lacks the protective network of roots, except at the one horizon mentioned in the preceding paragraph. Samples were taken near the top and near the base of the yellow-brown layer, and near the top, near the middle, and near the base of the red-brown layer. The samples were numbered from 1 to 5, in the order just named. Fair-sized portions of each were weighed and then dried to constant weight at 108° C., to determine the amount of moisture they contained. Smaller portions of each were then weighed out and leached with a fairly large volume of distilled water to extract the soluble salts. The extract was then analyzed

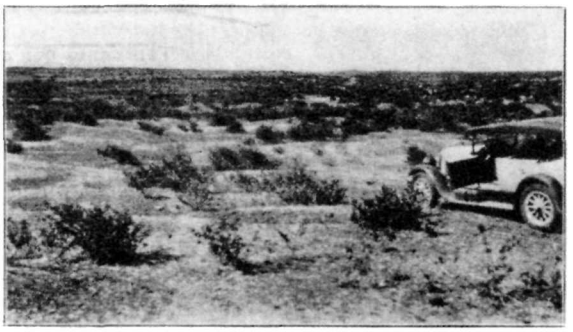

Figure 2. Low, grass-bound sand dunes, between and around which the road wanders, about five miles north of Ka Lae. Photo H. S. Palmer.

for chlorine, and the equivalent salt content of the original sample calculated. The results of these determinations are given in the following table.

Moisture and Salt Contents of Loess Samples from Ka Lae

Sample number	Position of sample	Per cent water lost at 108° C.	Per cent salt (NaCl) in sample
1	Top of yellow-brown loess	4.64	0.79
2	Base of yellow-brown loess	13.72	1.26
3	Top of red-brown loess	24.40	5.31
4	Middle of red-brown loess	22.36	5.46
5	Base of red-brown loess	21.62	2.16

It is clear that the red-brown loess is much moister than the yellow-brown loess. Except for its basal portion, it is also saltier than the yellow brown. The conclusion seems inevitable that salt water is carried up by capillary action into the red-brown zone. The upper limit of capillary rise appears to be the top of the red-brown loess. There appears to have been some reaction of the salt which has oxidized the iron of the loess so that the red-brown color has developed. The nature of the reaction is not known, but is presumably like the proverbially bad rusting of iron by salt spray. The new iron compounds thus formed seem to cement the red-brown loess a little and thus to give it some resistance to erosion.

Reference to the table will show one inconsistency in the preceding discussion, for the base of the red-brown loess is less than half as salty, though almost as moist, as the middle and top parts. One might expect the base to be the saltiest and moistest as it is nearest to the source of supply of salt water. A reasonable explanation of the greater saltiness above is that, as capillary action raises water and its dissolved salt, subsoil evaporation removes the water and leaves the salt behind. Thus there is a progressive accumulation of salt to such depth as evaporation can reach. In the lowest layer exaporation is virtually inoperative and no such concentration of salt has taken place.

The slightly greater moisture content of the middle and top as compared with the base of the red-brown loess is perhaps due to some retention of water by the hygroscopic action of the salts.

The accumulation of the loess has taken place in part since the occupation of the Hawaiian Islands by human beings. At one place, a hundred feet or so east of the Lighthouse Reservation, there is exposed in the loess cliff a pavement of wave-rounded bowlders. That they got here through the activity of human beings is shown (1) by their rather regular arrangement, (2) by the fact that the pavement consists of only one layer of bowlders, and (3) by the fitting of coral fragments into the chinks between the lava bowlders. All of these features are characteristic of the platforms made by the Hawaiians so often along the shores for use in ceremonies in connection with fishing operations. Waves would not select bowlders of such uniformity of size; they would not select coral for chinking; and they would not make a uniform layer only one bowlder deep. Clearly the platform is man-made, yet it is overlain by loess, so part at least of the loess has been made since the platform was made and therefore since human occupation of Hawaii.

The horizon of the bowlder pavement or platform is traceable as a somewhat pebbly and shelly layer for about a hundred feet. The pebbles and shells may well have been scattered by the persons who made and used the platform. If so, it is a sort of fossil kitchen midden.

It happens that the bowlder pavement lies between the yellow-brown and the red-brown horizons of loess. This may be purely accidental, but it may be that the coarse layer breaks up the capillary channels so that the reddening and cementing actions are stopped at their level.

The fact that the loess cliff is within ten to a hundred feet of the water's edge suggests that it is a wave-cut cliff. However, on July 12, 1930, there was a place at which some initials had been cut in the red-brown loess cliff. The date was illegible as it had been cut away by a little vertical groove due to run-off from above. At other places the cliff was similarly grooved. It appears, then, that waves are doing less at such places than is run-off. One might expect the energy of storm waves to be dissipated largely in crossing the lava rock terrace. In ordinary weather waves do not come near the cliff, even at high tide. Where the lava bench is narrowest (see figure 3) the loess is being cut back by storm waves, it would seem, and makes a single cliff in both the red-brown and yellow-brown loess layers.

Outcrops of the loess on top of lava rock are continuous along almost all of the shoreline from Ka Lae northeastward to Kaalualu. Puu o Mahana, three miles northeast of Ka Lae, is a tuff cone, the seaward part of which has been cut away by waves. Loess makes a rather deep mantle on its lower windward slopes, but seems not to have lodged readily on its upper windward slopes nor on its leeward slopes. Whether any loess underlies the tuff is not known.

About a mile and a half northeast of Ka Lae there is a young flow of aa lava, which divided a mile or so inland and reached the shore as two flows, leaving a kipuka in between. Underneath the southwestern of the two arms there is some loess, the precise relationships of which were not ascertained. This loess is believed also to underlie the northeastern arm of the aa flow. Much fuller observations were made on a similar occurrence of loess beneath another young lava flow about half a mile southeast of Kaalualu.

On the west side of Paiahaa Bay, the small bay just west of Kaalualu Bay, the shore line is cut for some distance in a pahoehoe flow which has the usual somewhat irregular upper surface. On this pahoehoe flow lies a bed of loess with a smooth wind-made upper surface. Since the lower surface of the loess follows the irregularities of the upper surface of the pahoehoe flow, the thick-

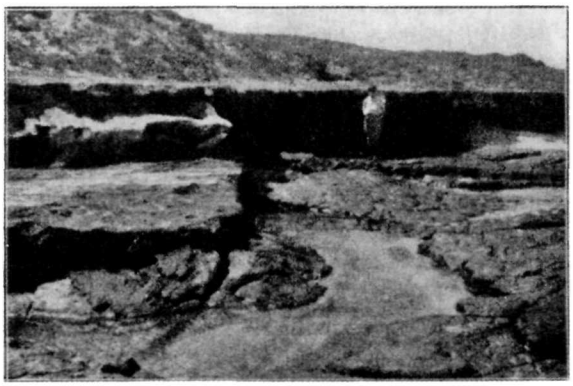

Figure 3

The ridge forming the sky-line is a sand dune ridge, resting on the yellow-brown loess, which extends down to the level of the man's belt. The separation of the loess horizons is lost in the shadow behind the man. At the left of the picture the uppermost clifflet is in yellow-brown loess, below which are two clifflets in red-brown loess. The lowest clifflet is in front of a broad bench and leads down to the terrace cut on pahoehoe lava. Quiet pools of sea water occupy depressions in the pahoehoe terrace. At the right, coral fragments and shells have been piled against the loess cliff. Photo H. A. Powers.

ness of the loess varies from eight to ten feet. The loess bed and the underlying pahoehoe curve downward in both directions till they are hidden beneath a heap of boulders at the foot of the cliff. This loess is older than most of the loess along the Ka Lae-Kaalualu shoreline. At a typical point its red-brown, lowest zone is about two feet thick and reaches an elevation of about seven feet above sea level. It is overlain by about six feet of loess which shades upward from darker to lighter yellow-brown. The topmost six-inch layer of the loess is very dark gray, in fact nearly black, in color because the vegetable matter that it once contained has been charred or carbonized by the heat of the pahoehoe lava that flooded over it.

Immediately overlying the loess is a pahoehoe flow about three feet thick; on this there is an aa flow, also abou three feet thick; and at the surface there is about two feet of loess which is continuous with the layer of loess that is so extensive. Perhaps the two lava flows are of approximately the same age as the artificial bowlder pavement at Ka Lae for the thicknesses of both the overlying and the underlying loess deposits are about the same at both places.

The lower loess deposit is much weaker than the overlying pahoehoe flow and has therefore been cut back farther so that for a distance of about a hundred feet the pahoehoe overhangs as a ledge with an average width of two and half or three feet. Thus between 250 and 300 square feet are exposed, which give some clues as to the nature of the older loess at the time that the pahoehoe lava flooded over it. A rather cursory examination revealed over 30 molds of trunks and limbs of trees. Half a dozen of the molds are vertical and represent growths which the pahoehoe surrounded but did not destroy. The largest of these erect molds has an elliptical cross-section which is 10 by 12 inches at a level 12 inches above the former ground level. The tree that made the mold had a gently fluted trunk. The other erect molds are from one to four inches in diameter. The erect molds extend through the three feet of pahoehoe but are capped by the overlying aa. They imply, without doubt, the existence of half a dozen trees or saplings in the 250 or 300 square feet.

Prostrate molds greatly outnumber the erect molds, and represent either dead wood that was lying on the ground or stems and trunks that were knocked over by the advancing lava. They range in diameter from one to three inches. One prostrate mold is two inches in diameter and five and a half feet long. Since some of the prostrate molds may well be the relics of trees that were alive until they were pushed over by the advancing lava it seems probable that the 250 or 300 square feet bore more than the half dozen that are definitely implied by the erect molds. There must, therefore, have been a fairly thick cover of trees at this place. This conclusion is supported by the presence of much charred vegetable matter in the black loess immediately underlying, far more than could be produced by the charring of the turf that now grows in this region.

We can reconstruct the following events in the history of this small area southwest of Kaalualu. Soon after the eruption of the lower pahoehoe flow volcanic activity ceased temporarily and was succeeded by wind work which brought in 8 to 10 feet of loess. The loess formed a fertile soil in which a fair growth of trees took root. The climate must have been somewhat moister than it now is to permit the growth of good-sized trees. Short-lived volcanic activity followed, and made two thin lava flows, the first of pahoehoe and the second of aa. Since then there has been no volcanic activity at this particular place, and winds have brought in two feet more of loess which supports a fair growth of turf-making grass. At present, wind is adding slowly to the upper surface of the loess, and is also, with the help of waves, exposing the edges of the various rock layers as a low cliff.

I am indebted to Dr. Howard A Powers, of the Hawaiian Volcano Observatory, for much help in the field study on which this paper is based. It is in fact a question where he or I should have written it.

Harold S Palmer.

KILAUEA REPORT No. 1024

WEEK ENDING SEPTEMBER 6, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit continues to remain quiet with about a dozen stained spots on the floor of 1930, one of these yellow with sulphur showing very slight bluish fume. Older spots are whitish and dead ones are brown. After rain vapor mixes with the fume and very light vapor appears at the south talus. Measurement of rim cracks August 31 showed no widening.

Three tremors at the pit seismograph about September 5 indicated slight tilt away from the pit. The Observatory seismographs on the northeast rim of Kilauea Crater registered 37 tremors, of which one was accompanied with east tilt and another lasted two minutes. Five very feeble local seisms were registered, of which three indicated origin only four miles away. Average tilting of the ground was slight SW, and microseismic motion was slight.



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No. 351—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 17, 1931



Newly acquired Engineering Building of the Hawaiian Volcano Observatory, standing back in the forest east of the Volcano House garage. Photo Maehara.

VOLCANOLOGIC OPERATIONS OF THE U. S. GEOLOGICAL SURVEY AND THE HAWAIIAN VOLCANO RESEARCH ASSOCIATION, 1930-1931

The Geological Survey covers stations at Hawaii, Lassen, Kodiak, and Dutch Harbor; the Research Association supplements the work at Kilauea with stations at Kona and Hilo. The eruption at Kilauea November 19 to December 7, 1930 added 70 feet of lava to the bottom of Halemaumau. Such eruptions have averaged one a year at Kilauea for six years. The flow from Mauna Loa in 1926 and the earthquake spasm of Hualalai in 1929 add to the evidence that the Hawaiian volcanic system is fully alive. Mauna Loa in the twentieth century has had an outbreak once in four years, so that there is reason to be prepared for live lava in Hawaii within the next year.

Lassen station reports declining tilt and earthquakes. In the Aleutian belt Pavlof, Aniakchak, and Tulik have been reported active. The circum-Pacific region has produced disastrous earthquake at Napier, Oaxaca, Managua, and in the Izu Peninsula near Yokohama, and volcanic disturbances in northwestern Argentina, not far from the south Chile volcanoes investigated by the Research Association through Dr. John B. Stone. All the disasters mentioned are close to active volcanoes.

Growth of the Section of Volcanology leads to division in subsections as follows, with T. A. Jaggar directing the work, the Kilauea laboratories of the Hawaiian Volcano Research Association serving as headquarters, and a somewhat increased staff appearing in 1931-32:

Volcanology of Hawaii

T. A. Jaggar, Volcanologist in Charge
- Observation of volcanoes
- Designing and building instruments
- Preparation of publications
- Administration

Seismology of Hawaii

E. G. Wingate. Associate Topographic Engineer, in Charge
- Correlation of leveling and tilt
- Drafting and research in maps of crater
- Recording Hilo tide data
- Special investigations of Mauna Loa
- Special topographic mapping wherever required

Seismologic routine

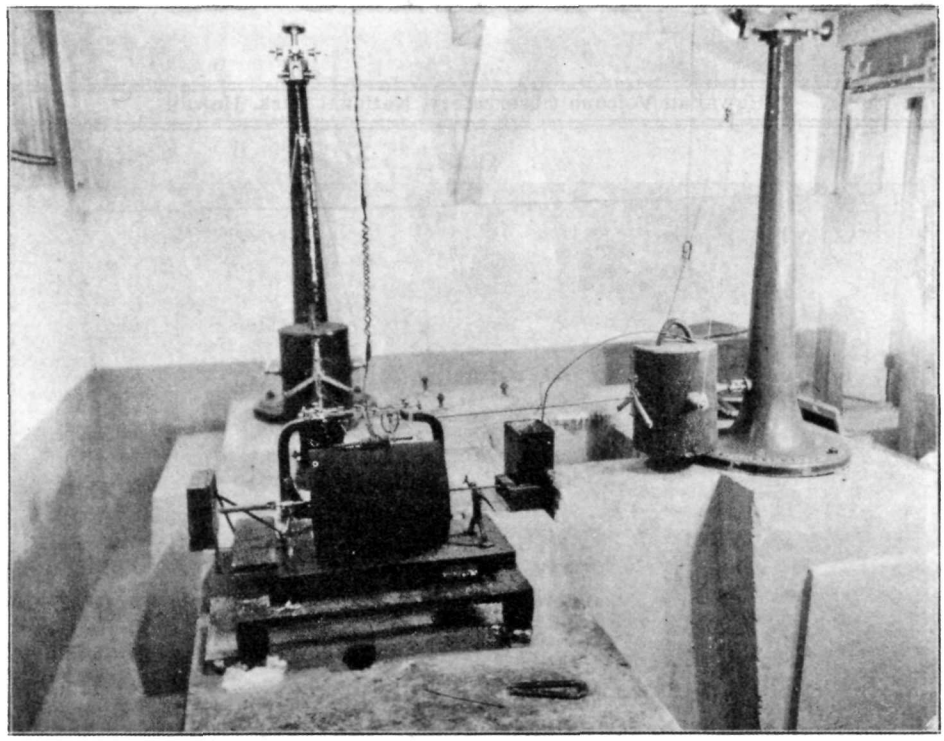
A. E. Jones, Assistant Seismologist, in Charge
- Operation of seismographs
- Measurement of seismograms
- Preparation of earthquake bulletins

Volcanologic Surveys of Hawaii

H. A. Powers, Assistant Geologist in Charge
- Field mapping of lava and ash formations
- Petrologic study of specimens and analyses

Volcanology of Northwestern United States and Alaska

R. H. Finch, Associate Volcanologist in Charge
- Operation of Lassen Volcano Observatory
- Operation of Alaska stations
- Investigation of northwestern volcanoes
- Installation of new seismometric stations



Bosch-Omori seismograph rebuilt at the Hawaiian Volcano Observatory with high-speed drum, damping tanks, both arms writing on a single smoked paper, and pen tips lifted by an electromagnet for marking minutes. This instrument has been most satisfactory for many years for registering tilt and local earthquakes in the cellar at Kilauea, and the records of this machine are the basis for new studies, of tilt, and depth and distances of earthquake origins. Photo Maehara

The Volcanologist has given a course in Volcanology at the summer sessions of the University of Hawaii for three years past, many of the students being teachers in schools in Hawaii. These persons will be useful volunteer seismologic observers. The Volcanologist represented the Geological Survey on the Naval Eclipse Expedition and studied the volcano Niuafoou in the autumn of 1930, leaving a shock-recorder there and supplying another to the Dominion Astronomer of New Zealand, Dr. C. E. Adams.

Messrs. Wingate and Jones joined the staff in July and September 1931. Dr. Powers has studied the shore line changes with Dr. Palmer, has mapped soils and loose deposits all over the island Hawaii, but especially in Kona in collaboration with Mr. J. C. Ripperton of the U. S. Agricultural Experiment Station, and has mapped in detail the lava flows and volcanic ash of the west slopes of Hualalai and Mauna Loa. As a petrologist he is studying these materials microscopically. This work of a geologist has in view extending our knowledge of the structure of Hawaii. (See Geology and Water Resources of Kau District, by Stearns, Clark and Meinzer, Water-supply Paper 616, 1930, U. S. G. S., and also Products and Structure of Kilauea, by J. B. Stone, Bishop Museum Bull. 33, 1926, Honolulu.)

The remaining members of the staff of the Hawaiian station are: R. B. Hodges, clerk and disbursing agent; Tai On Au, mechanic; H. Yasunaka. janitor; and M. F. Lacerdo, tide gauge operator at Hilo. R. V. Woods and J. B. Albert operate the seismographs at Kealakekua and Hilo.

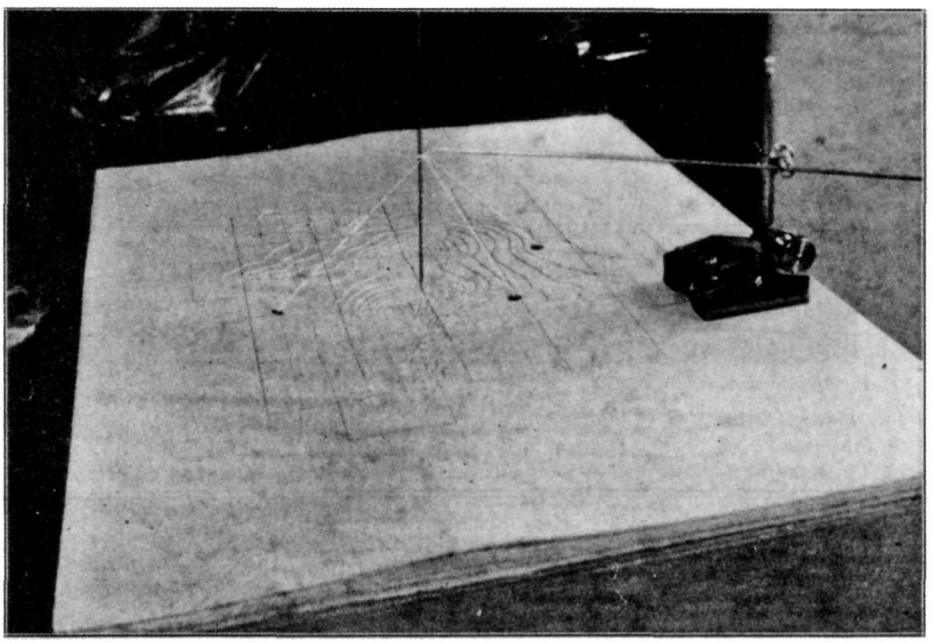
Associate Volcanologist Finch operates three seismograph stations near Lassen and with assistants studies the hot vents and the geology of old lava flows in northern California. The instrument at Mineral is operated throughout the year; those at Viola and Mount Harkness are discontinued in winter. Mr. Finch has spent the summer of 1931 inspecting the Aleutian seismograph stations, and making an exploration of Akutan Volcano and its hot crater. He left Kodiak for Seattle on September 6.

The study of local tilting of the ground in Hawaii, as correlated with faults, with earthquakes, and with volcanic centers of tumescence, has justified more men and instruments. One of the interesting developments has been the registration of "tilt earthquakes." These are seismograms of local earthquakes showing at several different instruments, not all at the same place, that the ground has tilted and offset the pens in the same direction, at the moment when the local shock occurred. In other words the creaking action of the motion of the fault block has been accompanied by a slight tipping. The direction of this tipping is a discovery of prime importance, and the coordination of many such tippings at the same place, occurring simultaneously with earthquakes, indicates the manner of action of the net tilt for a given period. It is obvious that to discover the geographic boundary of such tilting, distributed instruments are necessary, and these instruments should be simplified as much as possible so as to show graphically without computation the direction of the tilt, as well as its angular amount.

With this in view, an observation made several years ago with a small plumb line to which a vertical lever was attached was utilized in the spring of 1931 as basis for construction of a new tiltometer. The instrument was at first placed in a shallow well in concrete in the seismograph cellar of the Observatory, the device consisting of a heavy mass hung vertically on piano wires, with a magnifying boom rising vertically from the center of the mass so suspended and counterpoised that the faintest deviation of the mass as a plumb bob would be highly magnified at a pointer moving in a horizontal plane at the upper end of the sytem. This pointer is free to move in all directions in accordance with the absolute direction of tilt which disturbs the heavy mass as a plumb bob, and the linear amount of its motion radially from its adjusted center is a measure of the angle of tilt.

Another line of experimental investigation which was set in motion in January 1931 promises much for the location of earthquake centers. The determination of depth of origin for local earthquakes on the Island of Hawaii has puzzled us for many years. Mathematical methods of determining depth of origin for more distant or stronger earthquakes are in vogue in California and Japan, dependent on exact time-keeping. Omori used a simple method of determining distance by the preliminary tremor at several stations, and figuring the depth of centrum by the overlap of these distances beyond their point of intersection on a map. In other words, if the distances indicated are greater than their meeting point in plan, the origin is not in the horizontal plane, but is below the horizontal plane by the amount in which the distances are excessive. The determination of the meeting point of these lines underground, and the depth of that point below the local topography, is somewhat troublesome where a large number of earthquakes have to be investigated. The method, however. is good when the formulae for determining distance by the preliminary tremor have been checked for a given terrain.

In order to determine the depth of origin graphically by this method in Hawaii, a model was built showing the island as a hollow shell, as though the topography were seen from below. (See cut Page Three.) On this shell the several seismograph stations are accurately located and threads are carried through holes at these stations to weights hanging below. These several threads are drawn together at one point on an adjustable carrier which may be moved around until the lengths of the threads correspond to the centrum distances for a given earthquake indicated by the several seismographs. The threads are marked in miles to the scale of the model. A rod similarly marked may thus be placed against the meeting points of the threads, and this indicates vertically the depth of a given earthquake center. and the position of the epicenter, after the straight threads have been adjusted for any given earthquake. Thus the shell model (upside down) graphically exhibits the hollow space inside the island on a table, and the threads may be quickly adjusted to exhibit the point in space corresponding to the earthquake center, and their angles of emergence at the model should correspond to the angle of emergence of the earthquake wave. Tests with this model will show at once whether the several computed distances meet at a point or not, and so serve to check the theory of distance as applied to the preliminary tremor. Also the azimuth of the graphically determined center from each station may be checked against the theoretical azimuth determined



The inverse contour model of Hawaii, perforated to receive weighted threads at the spots marking seismograph stations The scriber shown has the three threads drawn together. By moving this junction point around until the three distances on the threads, on the scale of the model. correspond with the three distances to origin indicated by three seimograms for the same earthquake, the location of the centrum is determined graphically as though the observer were under the island. A brass scale rod as shown then determines the epicenter and the depth. The horizontal and vertical scales are identical in the model. Photo Maehara.

seismometrically. The preliminary trials of this graphic method for the same earthquake as registered in Kona, at Kilauea, and at Hilo have yielded promising results.

The third activity in our shops by way of seismometric experimentation has been the renewal of construction of shock-recorders as reported in 1929 in connection with the campaign of the Scientific American for enlisting amateurs in seismology, and in connection with assisting New Zealand in her earthquake difficulties. This last cooperation was given added zest by the terrible disaster at Napier in February 1931. after which the minister for scientific research, Dr. Marsden, of the New Zealand government, telegraphed to me asking for shock-recorders of my design. Through the Hawaiian Volcano Research Association, which furnished the materials, I at once set about new tests of an improved shock-recorder which registered several local earthquakes in our basement. The Research Association will supply the New Zealand government with eight of these instruments, and incidentally the Hawaiian Volcano Observatory will profit by this investigation, which is along the lines of what I did with similar instruments at Niuafoou in the South Seas on the Eclipse Expedition of 1930. Both in Alaska and in Hawaii it is becoming inceasingly evident that we need distribution of simple instruments, and in Hawaii there is a new demand through the school teachers who are distributed here, who have taken my course in Volcanology during three summers at the University of Hawaii.

The Research Association has added to the buildings of the Volcano Observatory the house shown on Page One, to be used for offices of the engineer and geologist. With this there is water supply and a garage. In addition a garage and carpenter shop have been rebuilt near the main observatory building.

A publication of interest to students of volcanology is Bulletin No. 77 of the National Research Council, "Physics of the Earth: I, Volcanology," Washington, 1931, by Day, Sapper, Friedlaender, and Jaggar. Dr. Day writes the Introduction; Dr. Sapper, "Volcanoes, their activity and their causes," covering the geographical aspects of the science particularly; Dr. Friedlaender, "The Present Condition and the future of Volcanology," reviews methods and theories; and Dr. Jaggar, "The mechanism of volcanoes," discusses experimental work, gas mechanism, and the relation of earthquakes to volcanic magma. There are long lists of references. T.A.J.

KILAUEA REPORT No. 1025

WEEK ENDING SEPTEMBER 13, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The bottom of Halemaumau pit shows nothing remarkable. Fume continues to emerge at a spot west of the 1930 lava pool. Vapor rises at the north end of the south talus and at the south wall above the floor. Dust rose from the pit at 9:20 a. m. September 7. The bottom fume smelled of sulphur at the southeast rim September 8. On this day new points were located at the rim cracks and an improved caliper was applied to these cracks. This work is in charge of E. G. Wingate, who has recently located datum stations near the pit for triangulation and leveling.

At the Observatory instruments 54 tremors were registered, but some of these may be occasioned by blasting by the road workers. One distant earthquake weakly recorded began at 10:18 a. m. September 9. One feeble local seism occurred at 5:19 p. m. September 12, was felt locally, and came from an origin close at hand. A very feeble shock was felt at 10:29 a. m. September 12. Four other very feeble seisms were registered, several showing easterly tilt, and two indicating origins very near. On September 7 nine tremors at the Halemaumau seismograph occurred in close succession, all indicating inward tilt toward the pit.

Tilt for the week at the Observatory was slight E, and microseismic motion was slight.



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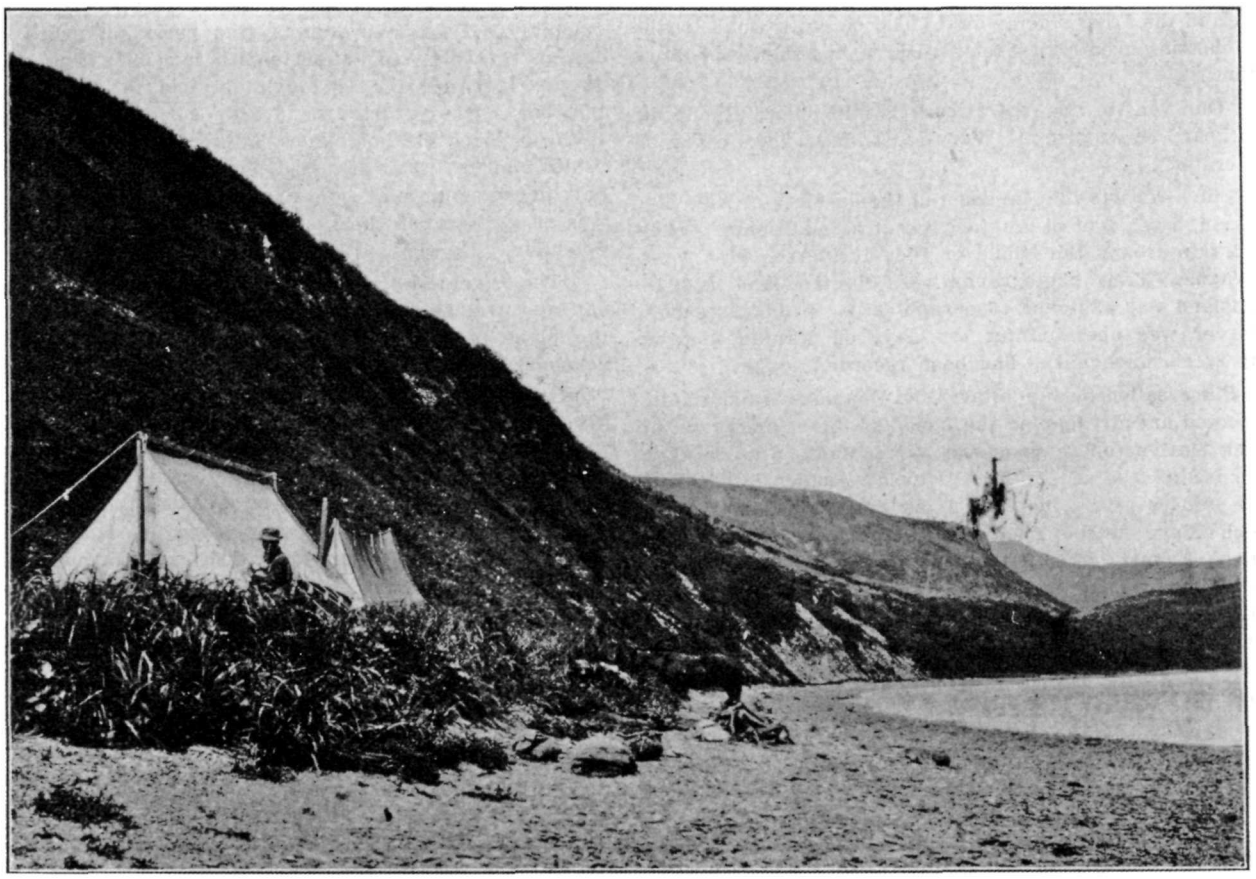


A camp in the Aleutian lands showing country quite simi'ar to Akutan. (Captain Harbor, Natl. Geog. Exped. 1928)

ALEUTIAN EXPLORATION 1931

The increase in work permitted to the Section of Volcanology of the U. S. Geological Survey by Act of Congress in 1931, as shown in the organization outlined in Volcano Letter No. 351, is based in part on recognition of the importance of the Alaskan Peninsula and the Aleutian Islands. These are essentially a long interrupted line of volcanoes, many of them active, adjacent to the great Aleutian Deep where many major earthquakes occur. This is an extension of the series of Japanese and Kamchatkan volcanic arcs, and offers a most fruitful field of study, in which at present it is possible to do only the barest preliminary work, but this work should be done as a foundation for more systematic and detailed investigations in the future.

The Lassen Observatory will expand its work in the volcano areas of California and Oregon, and during each summer, field work is provided for, on one of the volcanoes of Alaska, combined with inspection of seismograph stations at Kodiak and Dutch Harbor. The volcano on Akutan Island was selected for exploration this year and Mr. R. H. Finch did the work, taking with him as guide and packer John Gardner of False Pass.

Akutan is the volcano, like Stromboli, which is often seen smoking by mariners, on the left of Unimak Pass as the ships for Nome pass through to Bering Sea. It is not far from the middle of the Aleutian arc, counting Iliamna as the easternmost volcano far up the Peninsula. The peaks of Akutan are 3170 and 4100 feet high. The island is 17 nautical miles long, and it lies next NE of Unalaska Island. As a volcano it is relatively accessible as compared with great snowy peaks like Shishaldin, it is close by Dutch Harbor, it possesses a village, a harbor and a whaling station, and close at hand is the hot sulphurous deposit of Akun Island. It is just north of the 54th parallel and in longitude 166° west.

Mr. Finch took the steamer "Catherine D.," thanks to the courtesy of the Pacific American Fisheries of Bellingham, leaving that port July 1, 1931. Arrived at King Cove, the seat of one of their salmon canneries, near the west end of Alaskan Peninsula, he embarked on the mail steamer "Starr" July 16, Gardner joined him at False Pass, and the two disembarked at Akutan July 17. Two ascents were made to the summit crater, and on the second the party was caught in a fog cloud, which is a serious matter in these mountains.

The ascent of July 24 proved very interesting and Mr.

Finch secured some good photographs. The crater is some two miles in diameter with a cone about 600 feet high near the center. "The cone is quite uniformly hot, though but little steam is escaping. The heat appears as a dry heat. The outer crater contains a lake in the southwest side. On one side of the lake there is ice, with small icebergs breaking off occasionally, while the temperature of the water on the other side averages 119° F., with small localities showing even higher temperatures, and there is boiling action."

"One vent in the central cone is still open. Rumbling was heard on August 11. Very recent lava flows occur in the crater."

Finch reports that he secured the services of Alec McGlassan, a resident of Auktan, to act as additional packer for a trip around the island on foot during the first week in August. Many photographs were obtained and most of the island was sketched topographically. A Jaggar shock-recorder was operated for ten days on Akutan, but on July 26 no earthquakes had been recorded so far.

Finch sailed on the "Starr" for Unalaska August 10th, inspected and overhauled the needs of the seismograph at Dutch Harbor, operated at the Naval Radio Station, then returned to Akutan on the "Victoria" August 16th. This gave him two days more to finish operations on Akutan, which island he left for the trip back to Kodiak on the "Starr" August 18th. He remained at Kodiak overhauling the seismograph there, in charge of Mrs. M. V. Watkinson, until September 5, when he sailed for Seattle on the Admiral Line steamer. His full report on the mapping of Akutan and the seismological work, with photographic illustrations, will be awaited with interest. T.A.J.

IMPROVED JAGGAR SHOCK-RECORDER

The photograph on Page Four shows a new form of the shock-recorder described first in the Scientific American, November, 1929. The original machine was set up horizontally, as though left side of picture were the bottom, a 10-pound lead cylinder being cast about two flat blades clamped in a vertical plane. This made a sensitive small horizontal pendulum hung like a door, with the blades as hinge, and a boom extending out from the weight has a brass pen pivotted at its outer end resting on a smoked cardboard disc. A common clock movement rotates the disc and moves itself along slowly so that a day's registration is like a gramophone record. The disc is changed every day, and fixed with shellac. The disc itself is a timepiece for subdivision into minutes.

This machine was of great service counting the hundreds of earthquakes that occurred near Hualalai in 1929. It was tested in the South Seas in 1930 and some models like it have been made in New Zealand. In Niuafoou I set up two complete weighted arms and clockworks at right angles to each other on the concrete floor of a warehouse. As each box was three feet long, this took much space. The object was to record separately east-west and north-south earthquake motion. There was also recorded the motion of rats, kittens, chickens, cockroaches and spiders, and these were not planned for. The apparatus must therefore be housed in a tight case, and tending such an extensive machine each day on the floor is laborious. Horizontal surfaces of the smoked cards are hard to examine and are tempting to insects.

An improvement in the machine, with the principle of action but slightly changed, is shown in the cuts. The cylindrical mass has its two flat hinge blades clamped horizontally below, the boom protrudes upward, and the recording disc is in a vertical plane like an ordinary clock. The pivotted pen on the top of the boom is arcuate and long, and may be tipped over against the smoked card at about 45 degrees to the disc surface. The blades are stiff enough to give the system a free period of nearly one second with only about one eighth inch of spring blades exposed between the lead cylinder and the clamps. At this period the inverted pendulum is stable and upright. If the exposed part of blades is shortened the period becomes shorter. This inverted pendulum system oscillates only in the azimuth at right angles to the hinge line, which was also true when the system was swung as a horizontal pendulum.

The advantages of the new system are that the clock can now roll along on pulleys on a rubber-shod track in the plane of the clock-work wheels. These pulleys are attached to the spring barrels and given a diameter appropriate to the travel-speed desired. The center sleeve of the disc plate slides on the minute-hand spindle, so that the card makes one revolution per hour. The whole apparatus is enclosed in an upright clock-case with glass front (not shown) and screwed against the wall. The boom is of balsa wood. The clock may be slid sideways on its tracks so as to move the disc under or away from the pen. When disc is removed the clock is wound, a new disc is smoked and screwed by a central button to the plate, and is slid back to the starting position under the pen. With a steel point the date and the time of starting and stopping are marked on the smoke. The card is smoked by twirling it over a smoking kerosene lamp until it is an even brown. The rear suspension of the clock is a free pulley on a second track. The pen and the top of the boom may be seen at the right in the cut on Page Three. A final advantage of this machine is that in the corner of a room two complete shock-recorders may be set up at right angles on the two walls, with their two dials side by side. Obviously the handling of the discs is easy, and almost no floor-space is required.

Several earthquakes have been registered and the seismograms are good. It is necessary to choose a very quiet cellar wall, as the instrument is extremely sensitive to the opening and closing of doors. T.A.J.

KILAUEA REPORT No. 1026

WEEK ENDING SEPTEMBER 20, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There are no essential changes in the bottom of Halemaumau pit. There is a little fume on the floor and vapor at the edges of the floor, and these increase in visibility after rain. Measurement of the rim cracks shows little change.

The seismographs at the Observatory registered 43 counted tremors, of which three were continuous, and one of these spells lasted from 6:33 to 7:50 p. m. September 20. There were many smaller tremors September 18.

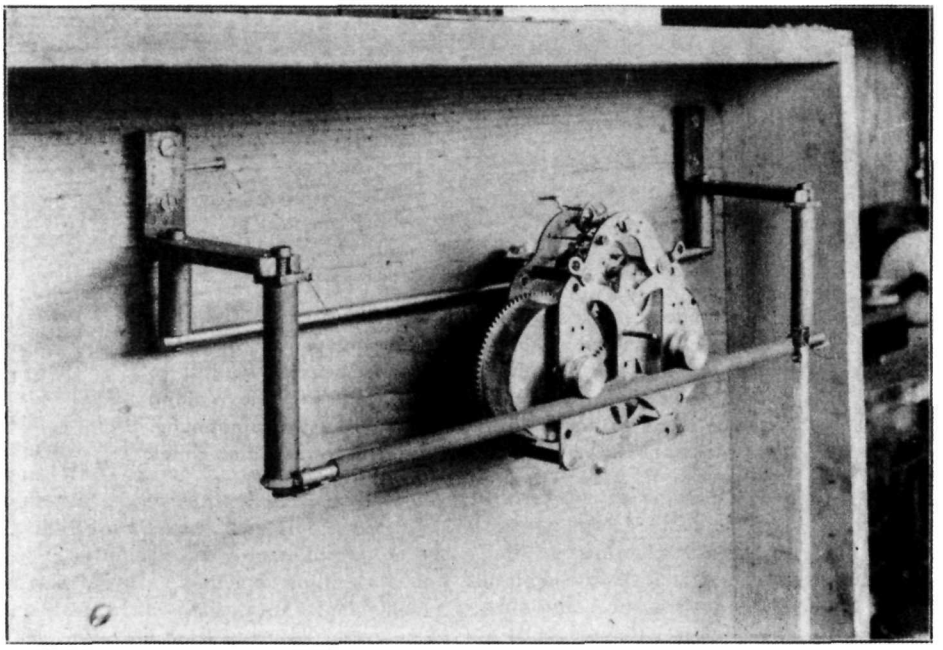
Two feeble earthquakes were felt at Kilauea at 4:23 a m. September 18 and 6:14 a. m. September 19. These indicated origin distances of six and four miles from the Observatory. The first was accompanied by tilt away from the pit at Halemaumau. Neither was observed in Kona,

and the indications suggested Kilauea origins. There was one very feeble quake September 14. Tilt for the week was slight NE, and microseismic motion was slight.

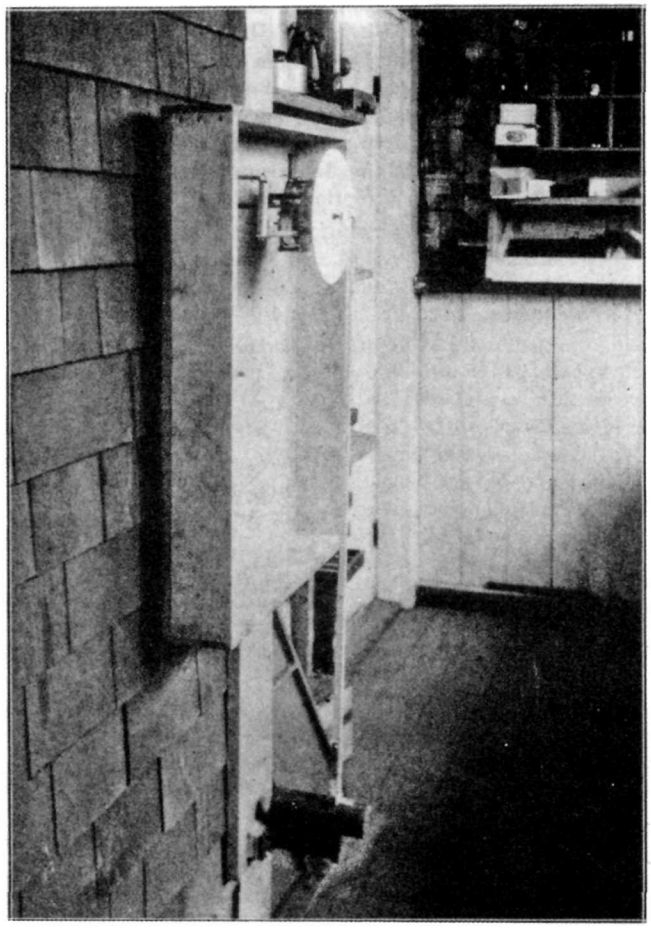
TILTING OF THE GROUND FOR AUGUST

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

August 3 - 9 .....1.3 seconds NE
August 10-16 .....0.4 second W
August 17-23 .....1.4 seconds NNE
August 24-30 .....1.0 second WSW



Seth Thomas clock on tracks with Jaggar shock-recorder boom and pen on right. A card disc is affixed to the central spindle, and the pen falls over on its smoked surface recording time and size of earthquakes. Photo Maehara.



New model Jaggar shock-recorder without case. Cylindrical weight below attached by flat springs to angle-iron clamps on wall. Boom and pen rise from weight, to write on revolving disc above. Clock and disc move along slowly so as to write circle in circle like a gramophone. An earth shock writes a zig-zag, and the clock disc times the occurrence.

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353

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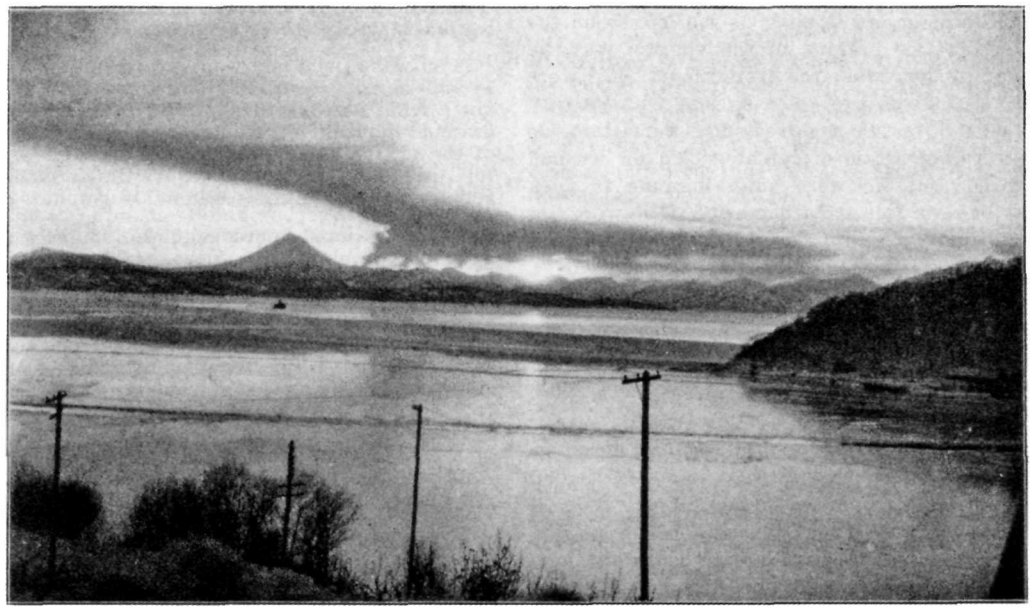


Gorely Volcano seen smoking during its eruption January 1, 1931. View from Petropavlovsk, 67 km. from the volcano. The summit of Gorely is behind the range, and the conspicuous cone is Vilutchinsky, which is nearer. Photo I. Larin.

KAMCHATKA VOLCANOES IN 1931

Professor P. T. Novograblenof, Director of the Kamchatka Museum at Petropavlovsk, under date June 24, 1931, has kindly sent us the accompanying photographs and a description of volcanic activities in Kamchatka during the winter and spring. This material is of great value as hitherto the world of science has heard but rarely from this great volcanic region. In Volcano Letter No. 314 it was noted that the Academy of Sciences of U. S. S. R. is doing volcanological work in Kamchatka. Also the eruption of Gorely Volcano was mentioned, lasting from September 1929 to March 1930 and covering much of southern Kamchatka with ash. Also there was activity of Kluchevskaya and Shiveluch in 1929 and 1930. An excellent account of travels in Kamchatka, 1920-22, with two valuable maps and numerous photographic illustrations has been published in German by Sten Bergman entitled, "Volcanoes, Bears, and Nomads" (Strecker and Schroeder, Stuttgart, 1926).

The active volcanoes of Kamchatka extend NNE-SSW along the eastern side of the peninsula, and near the middle of the belt is Kluchevskaya in the midst of a mighty group of volcanoes rising to a height of 4,861 meters. About 60 km. to the south lies Tolbachinsky Volcano. Petropavlovsk, the capital, with a population of something over a thousand people, is on the north side of a bay in the southeastern part of the country, and across the bay from it to the southwest the southern end of Kamchatka is occupied by a belt of great volcanoes, and this is prolonged farther south in the arc of the Kurile Islands. Several of these big cones are in full view from Petropavlovsk, the most conspicuous being the pure cone of Vilutchinsky Volcano shown in the photographs. The white steam from Mutnovsky shown in the photograph on Page Three is about 66 km. from Petropavlovsk, where the picture was taken.

The following is an account by Bergman of his visit to Mutnovsky Volcano:

"On this day we reached an elevation of a thousand meters on the volcano which is here surrounded by a lava plateau which extends as a shoulder around the greater part of the volcanic mass. Here we were at the upper limit of vegetation, where the last scrubby alder thickets gave out. The crater of Mutnovsky lay on the other side of the cone, and we had now to follow this shoulder around the mountain until we were immediately under the crater.

"Toward evening a mischance that we had most feared occurred: the weather which during the day had been misty, closed in dense and it began to rain. Impenetrable clouds veiled the entire mountain. We were in a waste of lava, where there was not a stick of wood, and where it would not do to be overtaken by night. So we climbed down through rain and fog to the upper limit of the bushes and found after a long search a small thicket where we succeeded in pitching our tent, and after much labor ignited a fire. Since, however, our silk portable tent was not adapted for plateau rains, particularly where there was no opportunity to draw the surfaces tight, we were soon as wet as though we had been immersed in a lake with our

clothes on. In order to give the drops of rain as little chance to accumulate as possible, we sat huddled together surrounded by our sleeping bags and rain coats throughout the entire night, and had abundant time to repent us of our sins. I thought of my warm bed at home in Sweden, and during the long hours of this sleepless night had opportunity to appreciate how little we realize our blessings.

"Not until morning did the rain cease, but the fog still hung over the mountain, though not so low as on the preceding day. We saw nothing of the volcano, but the plateau shoulder of lava was free from cloud. We were about an hour getting a fire to going so that with its help and numerous cups of tea we acquired some warmth inside and out. We were not afraid of catching cold for we had long since proved that we were quite immune to such disease in that fine air free from bacteria. If it were not so it seems probable we would never have gone home to Sweden.

"After ridding ourselves of our wet clothes and donning from the packsacks some relatively dry ones, we were ready for the march. The weather cleared and a fresh breeze sprang up so that after some hours our outer clothing became perfectly dry.

"We had not proceeded far before the first bear appeared and I attempted to photograph him. He headed straight for us. Taking advantage of the unevennesses of the ground and crouching down, I succeeded in getting within 20 meters of him and made an exposure with my camera in one hand and the rifle in the other. As soon as I snapped the shutter the bear saw me and made off. Above the bushes the snow-buntings appeared, fluttering about and showing up sharply and beautifully in contrast to the black lava. We gave the day to studies of birds and enlarged our acquaintance wth them as compared with another volcano previously visited. The birds of the two volcanoes were strikingly alike.

"Just as on the previous evening we pitched our tent in the uppermost alder bushes, but we had made good headway toward the crater after this day of trudging across the treacherous lava waste. On the following mornng it was still cloudy, but the volcano was clear. We could have no question about the position of the crater, whence rose a frightful column of smoke. We headed for the crater at once, which was about 500 meters above our camp ground and 3 to 4 km. away. The sun came out during our climb and showed us a completely new and magnificent landscape, which had been hidden from us during the days of fog and rain.

"The nearer we came to the crater the more noticeable was the smell of sulphur, so that finally breathing was difficult, and made us all cough, including our little dog Kuma. In places fume came out of cracks in the ground which was so porous that it seemed as though we might break through and burrough underground like a sand crab. The extraordinary colors of the ground varied from sulphur yellow to deep red. At last we stood on the rim of the gigantic crater, the smoke of which we had so often seen from the window of our house in Petropavlovsk. The crater is not quite at the summit of the volcano, so that we could climb still farther and from above look down obliquely at the colossal spectacle; a frightful cauldron of boiling vapor. From this lava pinnacle we were able to see still more: adjacent to the smoking crater there was a still larger abyss where far below we saw a glacier and a small waterfall. These were several hundred meters down, and the cliff above them was almost vertical. Then the fog closed in on us and it was with great difficulty that we made our way back to the vegetation line."

Mr. Eric Hulten, botanist of the expedition, on another trip after waiting for many days for clouds and rain to cease, succeeding in reaching the crater with his party and in getting a better view of Mutnovsky and its outlook. The smoking crater lies on the west rim of a large cauldron, and the party followed a small ridge on which stands a number of knobs. From the highest of these the clouds were seen rolling in from the sea, and the volcanoes were beginning to don their cloud caps.

"It was a wild and wonderful panorama. Not less then 14 big volcanoes were in sight, from Schupanowa, ten miles north from Petropavlovsk, down to Kambolnaja, the southernmost volcano of Kamchatka. For a time the smoke of the crater blew directly over us, and a fine dust rain fell consisting of milky drops, which made small white spots on our clothing, presumably sulphur.

"As the wind veered and the smoke went in another direction we obtained a view that I shall never forget. It was as though we were permitted a glimpse of the workshop of the gods, where gigantic forces are at work such as began millions and millions of years ago when the first strokes of creation fashioned the earth. White jets of steam shot whistling and blustering out from holes in the cliff, hot water ran down from the walls and melted its way through a glacier whose sharp-edged broken green and crevassed blocks of ice were heaped together in a jumble at the mouth of a huge canyon that led away from this Hell cauldron. In the midst of the ice two mighty steam jets arose, and through the crooked tunnels that had been melted out of the ice one could see the bedrock of the mountain. Higher up the cauldron wall where its edge stood several hundred meters above the glacier the younger crater belched its smoke upward, as though a thousand locomotives were clustered together opening their safety valves—and yet we knew that this was but a weak imitation of what Mutnovsky once was.

"And how describe the cliffs themselves? They had not the common gray color of a mountain, but were painted over in fantastic shades. We sat on a minor cliff of bright colors which gave place below to a terra cotta precipice, and showed on the right a row of sharp pointed gray-blue pyramids which stood on an underpinning of white spotted with baked dark carmine and indigo blue points. Beyond the wall of the kettle was bright blue with big yellow areas of pure sulphur, which were bordered with green and orange rings. All of this, along with the gray-white rifted snow covering of the glacier, on which diamond shaped small black pyramids were strewn, and also the sharp green-blue ice pinnacles, left us with a memory never to be forgotten. Bornachoff, one of our companions, who had never known fear, became suddenly very anxious and careful, and it was with difficulty that I persuaded him to follow us down the yellow-white cliffs of the gorge. Possibly there awakened in him a trace of the terror his ancesters felt for the 'smoking mountains' that one dared not approach too near, lest the 'Gamuli,' the mountain spirits, might be cooking their whales, which nighttimes they go down and fetch up out of the sea, one on each finger, and flying bear them home.

"The stream pouring out below was buried under snow and ice blocks, and we reached the tunnels and got under the upright walls which lead down into the crater, out of the rifts of which small and furious jets of steam escape. There rose a thin knife-edged slice of rock out of the ice, from the walls and base of which hundreds of steam jets shot up. Warm water ran down carrying red-brown mud, and a grayish-yellow brook broke its way through the ice, the melted green walls of which could be seen transparent behind the vapor. The jets of steam so hissed and roared that it was necessary to shout in order to be heard. In such an environment one may believe anything, and none of us would have been astonished to look up and see an ancient mountain spirit of the Kamchadals sitting astride one of these cliffs holding out a whale on a spit wherewith to cook it in a steam jet.

"This devil's canyon under the glacier was near the summit. The veil of smoke hid whatever the crater might conceal in its depths, but there was no lava lake nor in-

candescence, but rather numerous holes some hundreds of decimeters across as sources of jets of steam."

1931 ACTIVITES

During the winter three big volcanoes, Tolbachinsky, Kluchevskaya, and Gorely, were in activity, all situated on the eastern shore of the peninsula.

Tolbachinsky, elevation 3730 m., had a magmatic explosion March 4, 1931. Its cone and the vicinity were covered with ash. In the village Tolbachik, 41 km. from the volcano, the ash was a few milimeters thick.

Kluchevskaya, elevation 4861 m., had a severe eruption on March 25, 26, and 27, 1931. All day March 25 this beautiful volcano was quiet, but after sunset in the village Kluchi, 32 km. from the crater, was heard a crash, and then a column of fire appeared upon the summit. The rumbling increased in successive periods of noise, and during the night the volcano thundered and several loud explosions were heard. In Kluchi next morning ash fell and the air darkened. The volcanic ash and sand were falling during three days. All traveling by dog sledge became impossible. The strip of country covered with ash on top of the snow was 240 km. long and 50 km. wide; the average depth of the ash was 1 cm.; therefore during this short eruption Kluchevskaya threw out approximately 120 million cubic meters of ash on the northern side only.

Professor Novograblenof describes the ash as consisting of freshly broken pieces of different sizes, a small portion of them appearing rounded as though melted. There are pieces of lava glass and pumice and fragments of the minerals pyroxene, magnetite, plagioclase, and colored undetermined substances.

Gorely Volcano, elevation 1831 m., has continued in activity since 1929. In the summer of 1930 it was more or less quiet, but in the autumn its eruptions were renewed. For example, on September 30, 1930, it threw out clouds of vapor and ash in large quantity. The dark blue masses of ash fell in South Kamchatka over a vast area. January 1, 1931, the column of gases and ash over the summit of Gorely was more than 5,000 meters high. The eruption lasted until January 17, when the column was 6,000 meters high. The volcano smoked like a battleship (cut Page One). The smoke extended toward the northeast for a distance of more than 90 km. (cut Page Three). There was some reflection of fire seen on the summit. When the atmospheric pressure was very low the activity increased.

Mr. V. S. Kulakof, geologist of the Kamchtka volcanological expedition under Professor A. N. Zavaritsky, visited Gorely in May. He states that on the summit there are five and possibly six craters. Only one of these, 250 m. in diameter, is in activity, and no lava flows poured from this last eruption. Bombs, lapilli, sand and ash fell. Ash was falling mixed with snow. One hundred meters from the edge of an eruptive crater a thermometer thrust into ash showed -2° C. Under the ash there were layers of snow. The bottom of the crater could not be seen owing to the clouds of fume rising from the chasm. We are greatly indebted to Professor Novograblenof for this information. T.A.J.

KILAUEA REPORT No. 1027

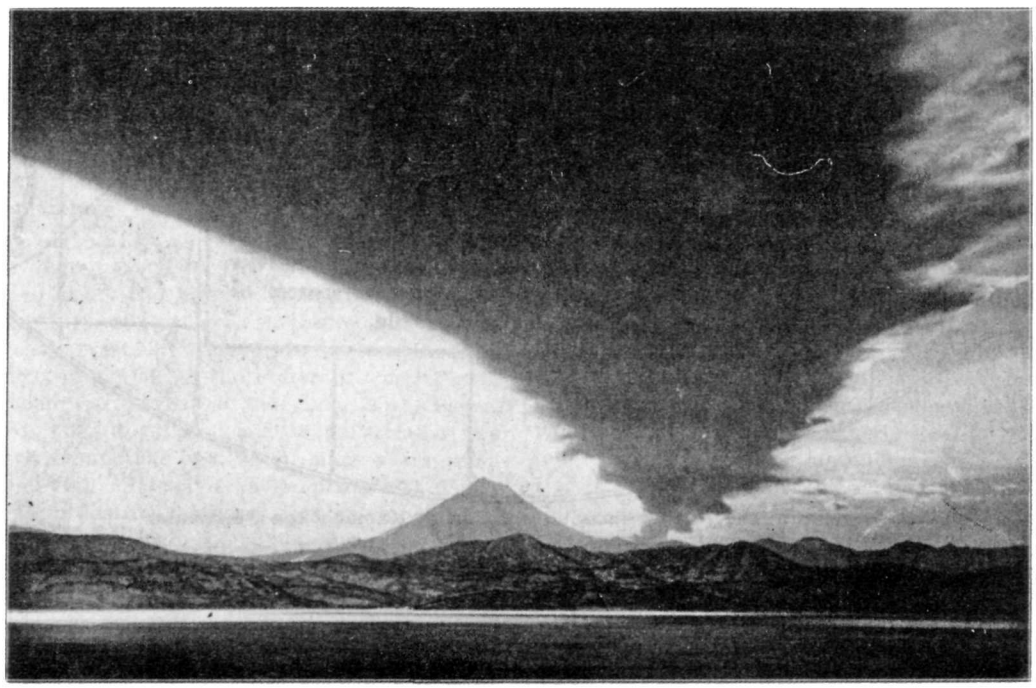
WEEK ENDING SEPTEMBER 27, 1931

Section of Volcanology, U. S. Geological Survey

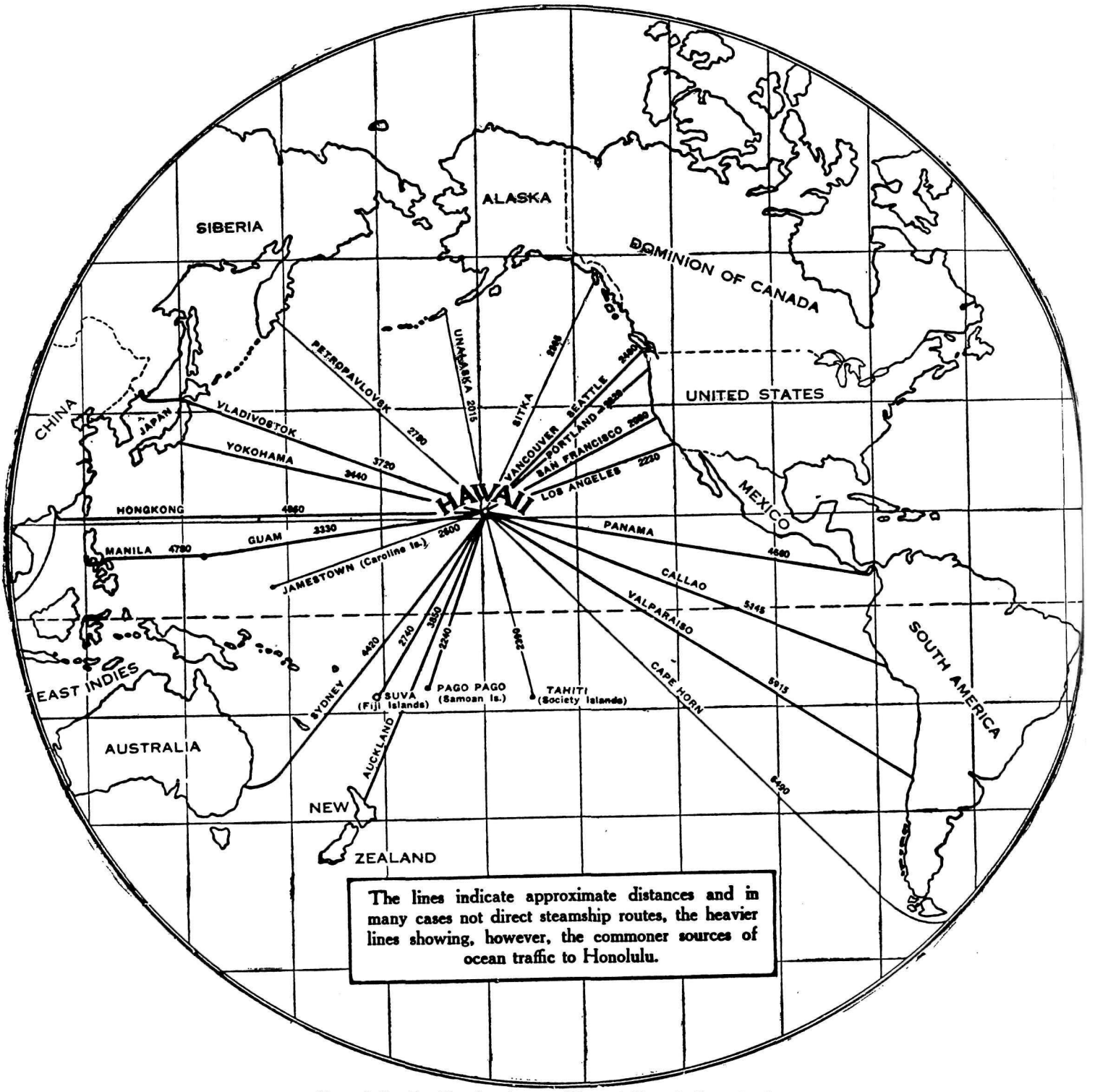
T. A. Jaggar, Volcanologist in Charge

At 10 a. m. September 21 there was very little fume at the sulphur spot on the floor of Halemaumau and what there was appeared to emerge in puffs. A very little vapor came out of the rock of the wall of the pit southeast just above the bottom. Measurement of rim cracks showed no widening. There have been no other changes during the week. Surveys are in progress to determine a profile of the pit which may be used when lava returns.

The seismographs at the Observatory registered 26 tremors, of which one was prolonged, and two were accompanied by easterly tilt. One doubtful distant earthquake was weakly recorded at 3:15 a. m. September 21. Four very feeble local seisms were registered, showing tendency to easterly tilt and origins very near. Tilting of the ground for the week was slight E and microseismic motion was slight.



Heavy column of smoke from Gorely Volcano as seen from Petropavlovsk 67 km. away, January 17, 1931. The white steam on the left is from Mutnovsky Volcano in the background, the sharp cone in the middle is Vilutchinsky, and Gorely is on the right. Photo I. Larin.



Map of the Pacific showing position of Kamchatkan Peninsula.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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354

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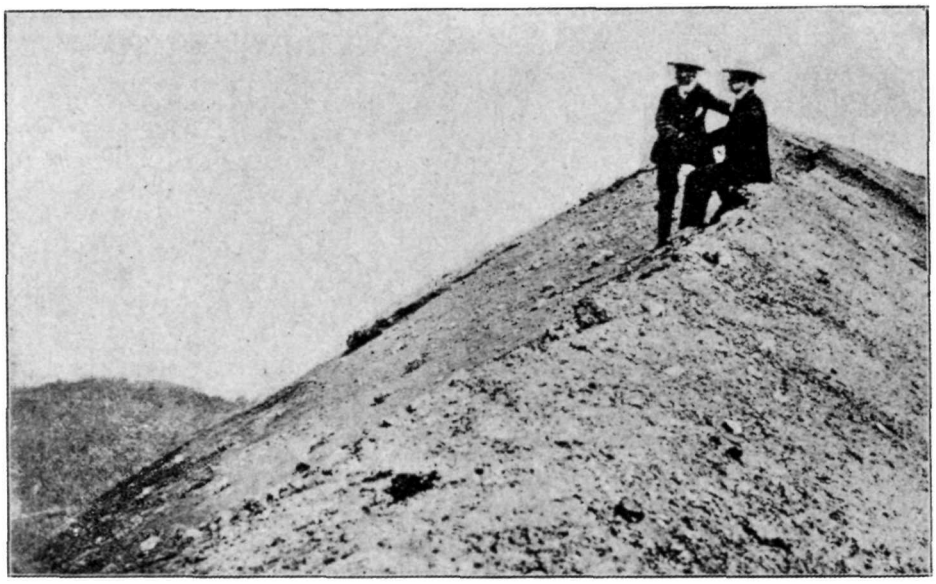


Steep summit between the craters of Turrialba Volcano, Costa Rica.

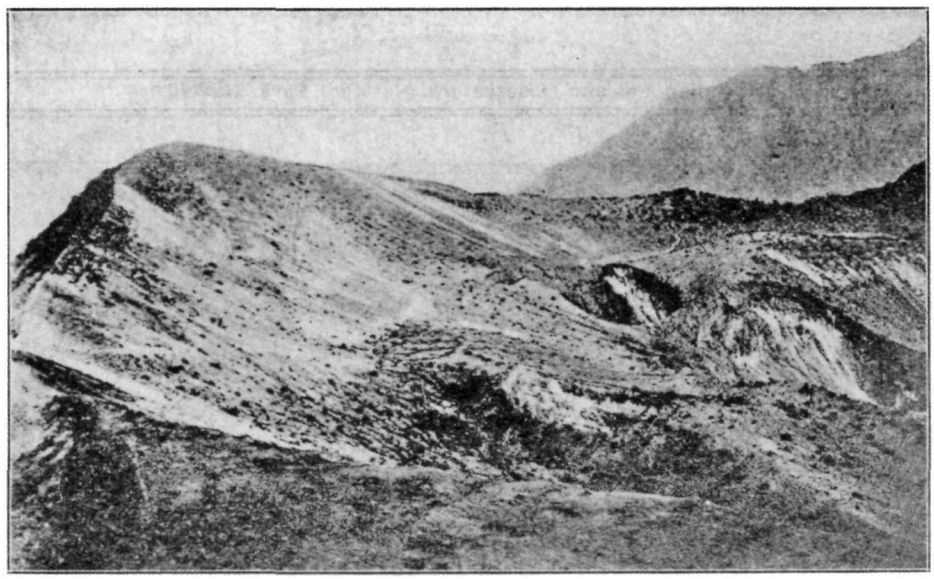
ACTIVE VOLCANOES OF COSTA RICA

Pittier describes the mountains of Costa Rica as divided into a southeastern system of old eruptive rocks without volcanoes, and one peak reaching an elevation of 12,467 feet; and a northwestern system with active craters. This chain of volcanoes begins with the conical peak of Turrialba, rising in an uninterrupted slope from the Santa Clara plains to a height of 10,965 feet. Going west from Turrialba we pass Irazu, Barba and Poas volcanoes, and from there northwestward the range diminishes in height past the less conspicuous volcanoes Tenorio, Miravalles, La Vieja, and Orosi, when we reach the Nicaraguan boundary (Costa Rica, Vulcan's smithy, by H. Pittier, Nat. Geog. Mag. June 1910).

Dr. Jaggar visited Costa Rica in the early summer of 1910 in order to study the effects of the terrible earthquake of May 4, 1910, at Cartago. He visited the craters of Irazu and Poas. President Jimenez kindly furnished the following account of a visit to the crater of Turrialba in 1864. The account states that at that time Poas, Barba, and Irazu were "not altogether dead," but Turrialba was in complete activity, and had been so for many years, sending out thick and high columns of smoke mixed with plenty of sulphur so as to destroy the vegetation on the slope of the mountain. Large deposits of sulphur of great purity were said to exist on the northeast side.

The biggest craters, more than 300 feet deep, showed black and yellow walls leading into the depths where more than a hundred mouths five to six feet in diameter, fringed with yellow layers of sulphur were hissing and sending up vapor with a noise like steam boilers. The roar of the steam was terrifying especially on the east and west corners of the crater where two larger vents sent up excessive vapor with a rush. All of the vents together made a large column of fume at the lip of the crater over 90 yards in circumference, and this made a high column above the mountain in calm weather as seen from the town of Heredia. The vapor was said to increase in winter time after heavy rain. There is an eastern extinct crater adjacent to the active one, and yet a third to the northeast where water collects in winter time. Between the three craters are three sharp ridges meeting in peaks of which th northern and eastern are the steeper. (See cut Page One). The circumference of the crater region is about 1,800 yards. Its shape is somewhat elliptical and irregular. Its inside walls are nearly vertical, covered in places with yellow layers of sulphur, and on account of the noxious fumes and the loose ground the descent is dangerous, and to return might perhaps be impossible. The outer wall of the crater to the west is peculiarly dangerous to walk upon; wherever one digs with a stick a small smoking chimney is created with deposits of sulphur and other salts, and in a short time the heat rising from the hole so made is excessive. The ground on the plateau about the summit is covered with lava fragments, sand, clinker, sulphur, and various salts, and there is little vegetation except to the south where the ground is not reached by fume. Here there are dwarf scrub and creeping plants. The walls show layers of rock of many different colors exhibiting the structure of the mountain, and there is sign of lava flows toward the north, where also the greatest devastation has been brought by fallen materials.

Pittier (1910) describes Turrialba as having a beautiful crater, forming a narrow elongated basin, in constant activity through the ejection of sulphurous vapors mixed with sand seen escaping noisily during recent years from the broad vent at its westernmost extremity. The only known violent eruption of Turrialba occurred in 1869 when



Crater of Irazu Volcano, showing part of cup and inner pits.

it threw out much explosive material and fine sand carried by the trade winds far to the west.

Irazu is about 360 feet higher than Turrialba, and a portion of its open crater, containing several interior pits, is shown on Page Two. The following is from my journal of 1910, when we started for the summit from a beautiful dairy ranch in the forest high on the mountain flank:

On June 3 we were up before the dawn, our hostess served coffee, and accompanied by a guide we mounted our beasts and entered a steep winding woodland path. Mr. Alfaro pointed out a rather large quick-flying bird which gave a plaintive whistling call: it was that rara avis the Quetzal which in Guatemala is regraded as the national bird. We passed from the tree line to a zone of shrubs and here the glorious summit view burst upon us, the Caribbean Sea far to the east and a dark Pacific loom under the clouds to the west. We were standing on one of the dividing peaks of the Central American watershed and viewing both oceans at once! Below us stretched the fair and fertile plains of Paraiso, Cartago, and San José, too far away to show any sign of the recent tragedy. Beyond to the south were the calm, dark mountains, as still, silent, and emblematic of **terra firma** as though earthquakes had never been. More tumultuous were the moving clouds, especially over the Pacific where they caught the high roseate lights and dark shadows of the dawn. Looking eastward towards Limon the rising sun made a trail of tropical glory along dim misty waters and pale pearl-gray clouds below, the foothills piercing the clouds like islets in a billowy sea.

As geologist I noted the much greater fall of the eastern streams, such as the Raventazon, as contrasted with the extended gently falling drainage of the broad valley to the west occupied by San Jose, San Domingo, Heredia, and Alajuela and other towns. The Raventazon shows a gorge just east of Paraiso and it is clear that if any massive uplift of this country is going on which causes the drainage to cut deeper, the maximum uplift is on the eastern side of the country. If the movement is a tilt, then it is a tilt **up** on the east, down to the west. This agrees with the appearance of elevated coral shelves and forelands in British Honduras and at Limon in Costa Rica, in that such raised oceanic formations give evidence of elevation on the east cost. And the west coast shows drowned valleys.

As one looks down from the summit of Irazu on Cartago and Paraiso, these towns appear to lie on an intramontane plain, and all about them are the evenly rectangular tilled fields of a fertile agricultural land. They are really on the pediment of the volcano, where the outwash from the gulches has built fan-cones of soil and bowlders onto the floor of a broad valley which originally drained **westward**; ie., towards San Jose and the Pacific. The evidence of this change of drainage is shown by a barbed stream beyond (S. E. of) Paraiso, in a deep gorge which now joins the Raventazon at an acute angle headwards, whereas its original junction with a normal west-flowing drainage was at an acute angle mouthwards. In other words, the Raventazon and its tributaries has robbed the waters of formerly west-flowing rivers and thereby has forced the continental divide to shift from a former position east of Paraiso to a present position west of Cartago. Cartago is thus practically on the continental divide, in territory where the divide is, so to speak, disputed by a conquering eastern drainage, which is cutting deep canyons, and a conquered western drainage which has lost volume and is losing rapidly its basin lands. This physiographic change may have significance as one of the many causes which serve as trigger to the earth stresses which make the earthquakes.

Continuing our climb, now in the bushy zone of the high summit, we came to bare patches of soft black cinder with new fractures in the earth. These fractures were marked by rows of caving holes—in one place two feet wide and another six feet wide and the rows trending WNW. Such cracks are not unusual in the crater region of a volcano and these in Irazu are not necessarily the product of the recent earthquake disturbance. The WNW trend is about parallel to the main fissure system which must underlie the chain of volcanoes of which Irazu is a part.

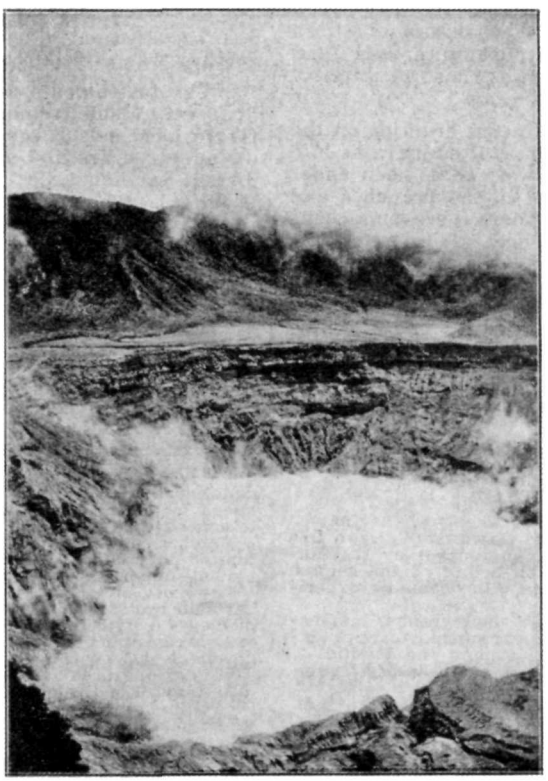
The summit of Irazu was soon reached. This is on the

south side of the crater and is merely the highest point of its rim. The crater north of us, as we stood on the peak in an uncomfortably stiff breeze, appeared to be an irregular drainless depression over a mile wide with two broad shelves of lava within it, one over the other like steps, on the side toward us, and a quantity of irregular deep pits in the opposite or northern side of the hollow. The effect is as though the whole cauldron had once been filled with lava to the level of the highest step; the lava seems thereafter to have hardened and tumbled in on the north and amid the tumbled blocks new explosion craters were formed at different times, making the several roundish or elliptical pits. The lower step would by this explanation be a piece of the frozen lava lake which had slipped down toward the convulsed northern half of the bowl. On the east there is the largest of the pits, which reaches almost the dignity of a subordinate crater. The northern rim is very low, and the northern side of the mountain is profoundly eroded in deep, steep furrows by the headwater branches of a muddy river, known as the Rio Sucio, by reason of its turbid waters This river is undoubtedly the main drain of the crater by underground channels. The crater had some shrubby and herbaceous vegetation. There is nothing immediately suggestive of recent activity or earthquake slides. The ground on the crater rim is covered with angular fragments of andesite and blackish gravel. The walls of the steps and of some of the pits show bedded sections of lava, hard rock, while the "treads" of the step-like terraces have "playas," dried mud ponds, on their surfaces. There are seven or eight pits, mostly choked at the bottom visibly by slide-rock, but one or two extend below into black holes which continue indefinitely. There is a shallow pond of milky water in one of the pits.

To the east rises Turrialba, a beautiful flat-topped cone, said by those who live on its flanks to be the theater of hollow murmurings from the bowels of the earth. These "retombos," or terrestrial grumblings, we heard described by all our friends resident in the vicinity of San Jose, and the residents had become so sensitive to these noises that they heard them constantly even during the time of our stay. We never succeeded in hearing them, or if we heard them, in distinguishing them from thunder, which we heard nearly every afternoon. We were also unfortunate in being unable to perceive any of the aftershocks of the earthquake, though they were felt by others and instrumentally recorded at the observatory.

At the headwaters of the Rio Sucio on the north side of Irazu there are bare brown landslide surfaces occasioned by the tropical rains and the steep slopes. The river has cut a canyon with vertical walls a short distance below the summit cone. A tributary waterfall cascades over the eastern cliff of this gorge. Just below the north rim of the outside surface of the mountain, and on the flanks of one of the gulleys that lead into the Sucio, there is a patch of bare sulphur-covered rock extending 200 yards down the mointainside. Mr. Alfaro informed us that the solfataric activity which generated this patch began about 1888 and that the sulphur, which may be removed in fairly thick cakes, is deposited from gases which emerge from pores of the rock. We saw no hot water or visible vapor, but recent photographs and records by other observers indicate that solfataric steam is ejected from time to time.

Some days later we took horses from the village of San Pedro for the ascent of Poas Volcano. Through country lanes we climbed, with the volcano ahead appearing as a mass of densely wooded hillocks. We entered the jungle by way of a narrow path over muddy hillslopes and muddier tangles of enormous roots. We frequently had to dismount and whip up the animals ahead of us. This jungle was remarkably different from the open groves of Irazu. There are here great trees with hanging vines, aerial parasitic flowers, some orchids, immense horn flowers and ferns, and all kinds of dense, shrubby undergrowth. We came upon a jaguar trap, and the guide told us that two of these cats had been caught in it. It consisted of a rectangular pen made by driving heavy sticks into the ground and roofing them with logs. A freshly killed fowl was placed as bait inside the pen, and provision was made for a heavy shutter to fall and close the opening when the bait was touched. Twice during the ascent we came to open meadows surrounded by elevated land which are possibly old craters. We passed wild cattle. Finally we dismounted and entered



Lake of steaming water, usually in effervescence, in crater of Poas Volcano. Photo Jaggar 1910.

upon the last stage of the journey on foot. The jungle thinned somewhat to a scrubby growth probably determined by occasional ashfall from the volcano. Poas is much lower than Irazu, its elevation approximately 8,000 feet. Bushes became open with a gravely soil between them, and then we came out on the edge of the greater crater at first obscured by clouds. We could smell sulphurous acid.

After a visit to a higher cold lagoon which fills a subsidiary crater, we returned to the edge of the greater crater and found it free from cloud. It proved to be a big cauldron filled with whitish water in constant ebullition, and bordered by bare, low banks of clay and bowlders radially trenched by hundreds of rain rills. The upper lip appeared to be half a mile in diameter; the depth from the rim to the water surface was perhaps 800 feet, and the distance across the pool 1,500 feet. On the north side of the crater a hill appeared. somewhat higher than the one we were on (see cut Page Three). Toward the west from the water-filled basin there is an irregular tract of "bad lands" drained westward by a gulch which shows a bedded section of agglomerates and tuffs towards its head. This gulch does not drain the boiling pool at the present level of the water, though it would do so if that level were raised a very few feet. There was evidently much relatively new sand and dust and gravel from the eruption of January 25, 1910.

The water in the muddy pool was bubbling up chiefly at one spot near the eastern side of the pool. It rose in a small dome of ebullition from time to time. There were sheets and tails of vapor rising from all over the surface of the water and the color was a pearly gray. The water appeared to be hot but not boiling hot, and the ebullition appeared to be the escape of vapors from a vent below. The eruptions of Poas are described by Pittier as geyser eruptions, and the column of steam and water, when a big jet occurs, is said to reach heights of thousands of feet, and to constitute the greatest geyser in the world. It is doubtful whether such eruptions may be described as a true geyser, for this volcano throws out bombs, ash, and mud, and the gases which rush upward through the water are highly sulphurous, and probably are not steam in the sense of being occasioned by the boiling of this same water column. It appears to be merely a case of a volcanic eruption making its way through a crater lake. In the bigger eruptions the lake is probably discharged completely. Such was the eruption of January 25, 1910, when stones fell on the edge of the crater, and the finer dust fell at San Jose, 20 miles to the southeast. Pittier states that the water of the crater lake "tastes like strong vinegar."

There was good evidence of the recent eruption on the rim of the crater. Lumps of gray ash, clotted by rains into the appearance of portland cement, were to be seen under the bushes where they had gathered in the branches and fallen off to the ground beneath. There were pumiceous bombs, large blocks of rock, which had fallen from great heights into the soft earth of the hillside. They had punched holes in the ground and buried themselves. We dug up several of these, in size from a few inches to two feet in diameter; one was found buried 38 inches below the surface of the ground. There were many stones coated with sulphur.

Pittier describes the eruption in question as follows: "At 5 p. m. January 25 a smoke-like column rose from Poas to prodigious height, estimated at no less than 13,000 feet. After reaching its higher point, the column spread into a mushroom-shaped grayish cloud, which, carried by the trade winds, soon covered like an immense screen the whole valley of San José."

"An hour after the first indication of eruption a rain of ash began to fall, increasing in coarseness as well as in quantity as the eruption proceeded.

"Near the crater volcanic mud was mixed with stones and the latter broke thick limbs and roots of trees and penetrated deep into the ground. When visited after the eruption, the boiling of the crater lake had ceased.

"This eruption was followed on April 13 by a serious earthquake over all the central plateau of Costa Rica, just after midnight. Everyone ran into the streets. There were numerous shocks the next day, and several public buldings were badly wrecked. Ground was rent and fissured in the neighborhood of Cartago. On May 4, at 6:50 p. m., came the terriffic jolt from the east which wrecked the city of Cartago, just at the foot of Irazu Volcano. This was one of the most intense earthquakes of modern times." (See Jaggar and Spofford, Costa Rica earthquakes, Jour. Assoc. Eng. Socs. 46, No. 2, (Feb. 1911). T.A.J.

KILAUEA REPORT No. 1028

WEEK ENDING OCTOBER 4, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Fume was fairly strong at the floor vents of Halemaumau early in the week, appearing irregularly in puffs, probably due to the strong NE wind. Heavy rain increased steam activity in the pit. Accumulation of water in a pool near the Halemaumau seismograph caused deceptive tilt of that instrument away from the pit.

On October 1 fume was plentiful at the SE sulphur spot. Two small slides from the north wall were observed at 7:35 and 7:40 a. m. There was the usual increase of steam after rain on this day and the next. A small slide also occurred on October 2 at 7:30 a. m. A faint smell of sulphur was noticed on the west side of the pit.

The instruments at the Observatory recorded a total of 19 very feeble tremors, one showing easterly tilt; 3 very feeble local seisms, one at 8:40 a. m. October 3 showing distance 4 miles and another showng easterly tilt; and a distant earthquake at 8:45 a. m. October 3 (uncorrected H. S. T.). The record of this shock is much larger than the Napier disaster of February 2, though the distance, 3750 miles, is not so great. Phases were as follows:

eP 8:53:42 a. m.
eS 9:01:17 a. m.

The average of accumulated tilting of the ground at the Observatory was slight ENE. Microseismic motion was slight

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The Volcano Letter

355

Two dollars per year **Ten cents per copy**

No. 355—Weekly Hawaiian Volcano Observatory, National Park, Hawaii October 15, 1931



Lake Amatitlan and Agua Volcano in Guatemala.

VOLCANO ACTIVITY OF CENTRAL AMERICA

In some early numbers of the Volcano Letter the question was reviewed as to what constitutes comparative volcanic activity for different districts. Different methods suggested have been Von Wolff's "Index of decadence," where an index number is applied to the percentage of extinct volcanoes for the total number of new districts; the total number of historical "outbreaks;" the number of volcanoes active for the aggregate length of the volcanic zone; volume of output of lava; and lastly volume of output of explosive materials. It was found that the volume of output makes the most consistent table for a list of regions, but that the output of lava is at the opposite end of the list from the output of explosive material. Thus Iceland leads all other districts in output of lava and the Dutch East Indies lead the world very greatly in output of fragmental deposits for the period of human history. The oceans and subarctic regions are the great lava producers, the continental borders and the equatorial belt produce much explosion.

Reading by explosive output alone, we get the following series by Sapper's revised tables (Zeitschr. Vulk. XI, Heft 3, 1928):

		Cu. Km. Fragmental
1.	Java belt	185.0
2.	Central America	58.0
3.	Alaska-Aleutian	30.0
4.	Iceland	10.0
5.	South America	9.5
6.	Japan	8.2
7.	Philippines-Molucca	6.5
8.	Kamchatka-Kurile	6.0
9.	New Zealand-Tonga	4.1
10.	North America-Antilles	3.5
11.	Mediterranean	3.5
12.	Melanesia	3.1
13.	Atlantic Ocean	2.2
14.	Indian Ocean-Africa	2.0
15.	Central Pacific	1..5

Contrast with this the following list in the order of lava output:

		Cu. Km. Lava
1.	Iceland	15.5
2.	Central Pacific	11.0
3.	Indian Ocean-Africa	8.0
4.	Atlantic Ocean	5.5
5.	Mediterranean	5.1
6.	Kamchatka-Kurile	5.0
7.	Japan	3.5
8.	Alaska-Aleutian	2.0
9.	New Zealand-Tonga	2.0
10.	North Amerca-Antilles	1.5
11.	South America	1.2
12.	Philippines-Molucca	1.2
13.	Central America	0.6
14	Java Belt	0.5
15.	Melanesia	0.1

If we compare these two columns it is evident that for the geologist to whom explosive violence is characteristic of terrestrial activity, the Dutch East Indies stands at the top. And to him for whom magmatic outflow is all important, Iceland and Hawaii are the leaders, though Hawaii comes at the bottom of the list based on explosiveness. Japan occupies nearly the same position (Nos. 6 and 7) in the two lists, and the districts occupying the same position in both lists are New Zealand-Tonga and North America. It is clear that explosive violence and lava outflow are opposed, and that if either of these qualities is to be used as a measure of volcanic activity, the other should be in the nature of a measure of decadence.

If we grant that engulfment and the admission of ground water is what leads to explosion, and that on the other hand the rise of primitive magma and exclusion of ground water is what leads to lava flow, then it would appear that only the latter magmatic happening can be construed as a measure of pure volcanicity. Any magmatic vent in the earth-crust may enter into an explosive phase through the recession of the magma, this has happened in Iceland and Hawaii, and the fragmental output thus produced is merely a rearrangement of broken rocks.

On the other hand, it is quite possible that some volcanic regions are charaterized by intrusive magma in just as great volume as anything poured out in Iceland or Hawaii. These places would make steaming solfataras and boiling waters, would deposit much sulphur and other salts along cracks, and if the intrusive magma receded, would generate explosive eruptions, followed by an exhibit of little or no lava at the surface. The little lava exhibited might be a stiff plug or dome of highly siliceous magma at the crater. It happens that just such andesite or dacite domes are well known at many explosive volcanoes. This proves that these volcanoes are truly magmatic, but that they do not make lava flows.

Decadence of volcanism. then, as interpreted by explosion, may mean merely a transition from basaltic flow lava to andesitic intrusion lava. In this connection Central America is very interesting. Sapper lists 26 active volcanoes between Costa Rica and the Mexican border, averaging one every 50 kilometers when this line of activity is treated as a single belt. Central America ranks thirteenth in lava output among volcanic regions, but is second only to the Dutch East Indies in explosive output.

In a recent article on the most active "volcanic regions," Dr. Sapper has compared the strongly active districts of the world by density of clustering of volcanoes, by frequency, and by output, and makes the following remarks on the resulting tables:

"Iceland in the period since 1500 A. D. has exceeded all other places in output of lava, in that it has poured out a third of the world's lava output, or about 16 cubic kilometers out of a total of 50 cubic kilometers. Hawaii comes next to Iceland in lava output.

"In the production of broken material the Dutch East Indies have produced more than half of the 325 cubic kilometers ejected on earth since 1500 A. D., with Central America coming next and the Aleutian-Alaska system third." (These figures differ from the tables in Volcano Letter No. 12, owing to the inclusion of a large volume for Katmai in 1912. This illustrates how quickly proportions may change through a single volcanic event.) If one considers the great length of the Java-Sumatra and the Aleutian belts, respectively, as compared with the shorter Central American belt, and thus includes density of clustering as a measure of activity, it is found that the output of Central America per hundred kilometers of length is 4.6 cubic kilometers of explosive material, whereas that of the Dutch East Indies is only 3.7. This would make the Central American region the most productive of explosive material per unit of area, with the Dutch East Indies second and the Alaska-Aleutian belt third. It further appears that when these belts are examined in detail, the two ends are less productive than the middle. It is remarkable that the three most important regions on earth for throwing up explosive material, and so giving evidence of cycles of intrusive activity at the present time, all lie in inter-continental districts—Java between Asia and Australia, the Aleutian Islands between North America and Asia, and Central America between North and South America. The Central American belt is strikingly different in its volcanic activity from the much weaker volcanism of the mainland of North and South America. By this demontration, Sapper makes the Central American region one of the most important on earth.

In the map on Page Four there are shown many volcanoes between Turrialba in Costa Rica and Tacana near the Mexican border of Guatemala The last Volcano Letter discussed the moderate activities of the Costa Rican group. In Salvador and Guatemala there are volcanoes producing lava flows, and others producing extrusive lava domes. In Nicaragua there are volcanoes of first magnitude and very frequent activity represented by Masaya, whereas Momotombo and Coseguina are both distinguished for some of the greatest eruptions of history. It is worthy of note that two of these are on opposite sides of Managua, where the recent earthquake occurred, and that the proposed route of the Nicaragua Canal is in the midst of an earthquake and volcano belt.

In Volcano Letters Nos. 87 and 262 some description has been given of Santa Maria Volcano in Guatemala near the city of Quetzaltenango. This is the most interesting active vent of the Central American group at the present time, and will be treated in the next number. The illustration on Page One shows Agua Volcano, one of the beautiful cones near the capital, Guatemala City. There are three in this group, Agua, Fuego, and Acatenango. Here again it should be noted that some of the terrific earthquakes of history occurred right at the foot of all these volcanoes, and both of the cities named were recently wrecked, Quetzaltenango in 1902, and Guatemala City in 1917. Here and at Managua it is legitimate to inquire whether intrusive magma does not strain the earth-crust to make great earthquakes. There is no reason whatever for expecting

simultaneous "activity" at the nearby volcanoes if an intrusive mass, by spreading laterally far underground, suddenly breaks or splits the earth shell subterraneously.

Acatenango, elevation 3960 meters, is a double cone close to Fuego, and at the end of the nineteenth century it exhibited slight fumarole activity in its southern summit crater. At 8 p. m. December 18, 1924, an explosive eruption broke out and lasted 20 minutes. A crack opened about 300 meters north of this summit, in the saddle between it and the northern peak called Tres Marias. (See cut Page Three.) The crack was right on the line connecting the two cones. Fiery glow was seen and products of the eruption were water, sulphur vapor, and fine gray ash. There were 15 cups along a rift 75 meters in length; bright yellow sulphur deposits were formed along the crack. There were light falls of ash in three towns. An ascent of the volcano by residents January 5, 1925, discovered the straight line of vents steaming like an engine ending at the south with a new large crater 60 meters in diameter and 80 meters deep. The steam rushed out violently so as to eject small stones. The west slope was covered with ash, and one's feet sank in it 20 centimeters at each step. The individual fumaroles were 2 to 4 meters across and up to a meter and a half deep. The ash was dark and muddy and there were sulphur stains. The big new crater sent up dark, yellow, sulphur vapor, whereas at the north end of the row of small cups pure steam was rising. At the southern summit crater there was no participation in the eruption, but a little white vapor rose at the west edge.

The second outbreak occurred February 10, 1925, at a large crater in the middle of the north slope of the southern peak. This also lasted 20 minutes, with wind in different direction from the first one. There was hissing from the new fumaroles, but the explosion was not so strong as before. On February 22 there was decrease of activity, and a new ash field made a conspicuous white object for 200 meters on the east slope of the summit. A new pit had been formed 50 by 40 meters in size, on the rim of which lay many stones in the midst of the ash, of 50 centimeters diameter. There was further activity at 4 a. m. March 4 and again at 2 p. m., so that a new ashfall occurred, and when the peak was visited March 13 some of the fumaroles had increased their activity. There was wet ash around all the openings, some blocks of rock a meter in diameter were found during the ascent, and trees were broken down. A compass needle showed no disturbance on Acatenango, whereas Fuego at its summit produced great irregularities in magnetic declination. At this time Fuego also was showing increased fumarole activity.

On May 7 a strong outbreak of ash again occurred at Acatenango, and it was found that trees 30 centimeters in diameter were broken off one meter above the ground, only the eastern of the saddle fumaroles were active weakly, while the western ones had caved in to form a large hole where gas was escaping. A small channel had formed connecting different openings. From the mid-slope crater on the north side of the southern peak steam arose feebly, but from the summit rose big steam jets mixed with ash, and a part of the crest had fallen in. All these facts suggested a gradual increase of activity from the beginning of the year 1925.

A later note (Zeitschr. Vulk., Vol. XI, Heft 3, p. 188) states that Acatenango in 1926 after September was in continuous light activity from the same vents, and March 30, 1927 a great rumbling occurred heard in the neighboring towns. Some fine gray ash fell March 31 and April 1 while thick steam clouds rose from the peak. Then the activity died away and nothing more was heard from this peak. Steam was occasionally seen. On the other hand Fuego in August 1927 had increased its activity, 25 irregular fumaroles were in action on the southern peak and about 10 on the east side. There was much sulphur at the peak of Fuego. Out of the crater steam puffs shot up every 10 minutes, and during two hours there were six slides heard in the crater, which is from 300 to 400 meters deep. The east-west diameter is 150 meters and the south-north 75 meters. The northeast rim consists of ash and is higher than the southwest margin, which shows bedrock. T.A.J.

TILTING OF THE GROUND FOR SEPTEMBER

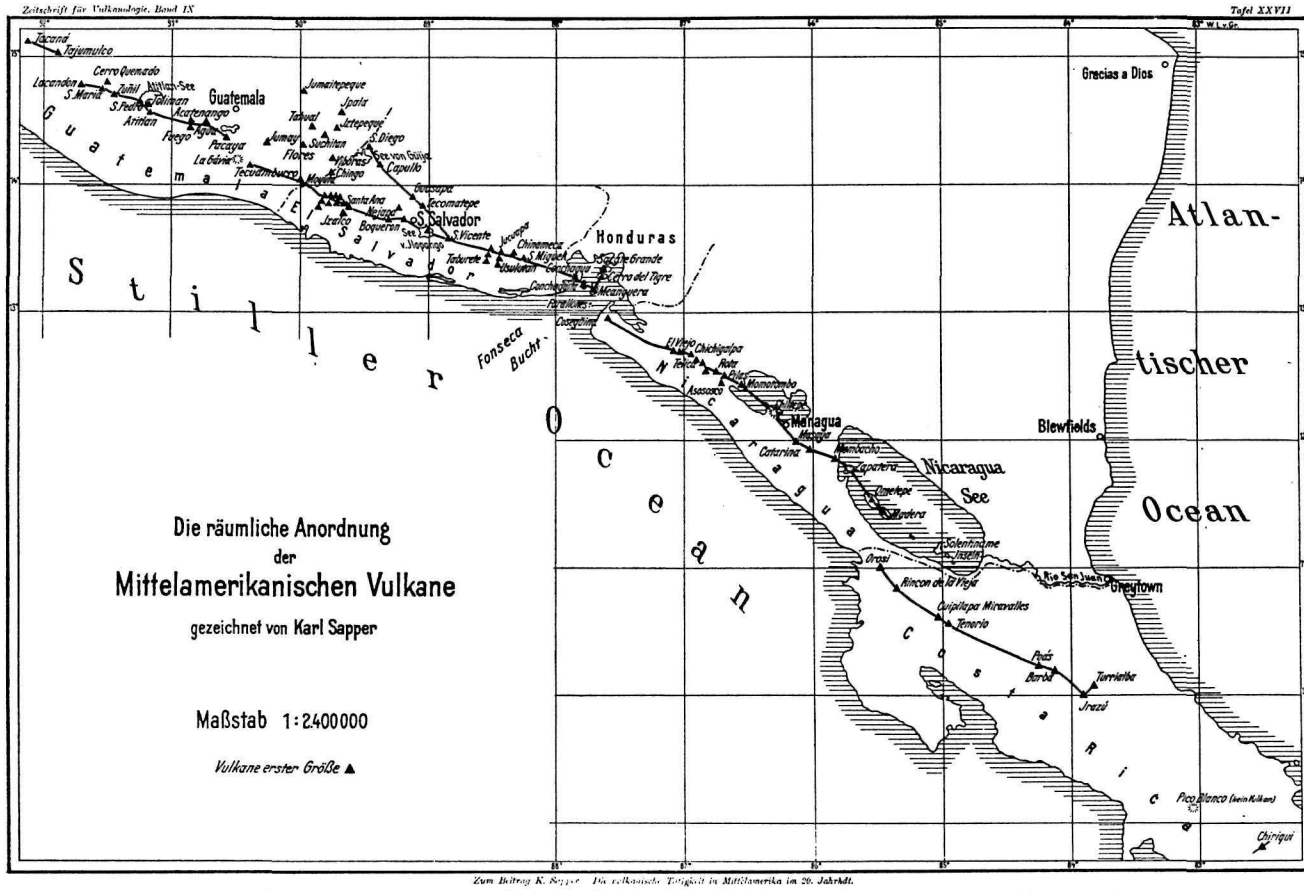
The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

August 31-September 6	1.1 seconds	SW
September 7-13	1.7 seconds	NE
September 14-20	0.5 second	E
September 21-27	1.4 seconds	ENE

E.G.W.



Looking south from Tres Marias at the main peak of Acatenango in 1925. After Sapper.



Map of Central America, showing the belts of active volcanoes, from Costa Rica on the east through Nicaragua, Hondura, Salvador, and Guatemala. After Sapper.

KILAUEA REPORT No. 1029

WEEK ENDING OCTOBER 11, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

At Halemaumau blue fume in the bottom was thin throughout the week. Steam activity also decreased very noticeably. The east rim cracks were measured on October 5 but no changes were found. On the 6th the seismograph at the pit indicated very quiet conditions. On the 8th a few quick-period tremors were recorded. On the 9th a distant earthquake was recorded at 2 p. m.

The seismograps at the Observatory recorded during the week 28 tremors, of which only one gave indication of distance—10 miles. Of a total of eight very feeble local seisms, one showed distance 4 miles, one 6 miles, three 9 miles, one 28 miles, and two 42 miles from the Observatory. One in the third group was felt at Uwekahuna at 3:41 p. m. October 6. There were no stronger shocks.

One teleseism, distance 3500 miles and lasting 1 hour 45 minutes on the record, was registered at about 2 p. m. October 9, the origin not even approximately known as yet. The teleseism of October 3 reported last week was tentatively located by the Honolulu station of the U. S. Coast and Geodetic Survey at 14° S lat., 160° E long., in the Coral Sea near Rennel Island at SE end of the Solomons.

Average tilting of the ground for the week was slight NNW. Microseismic motion was moderately strong.

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356

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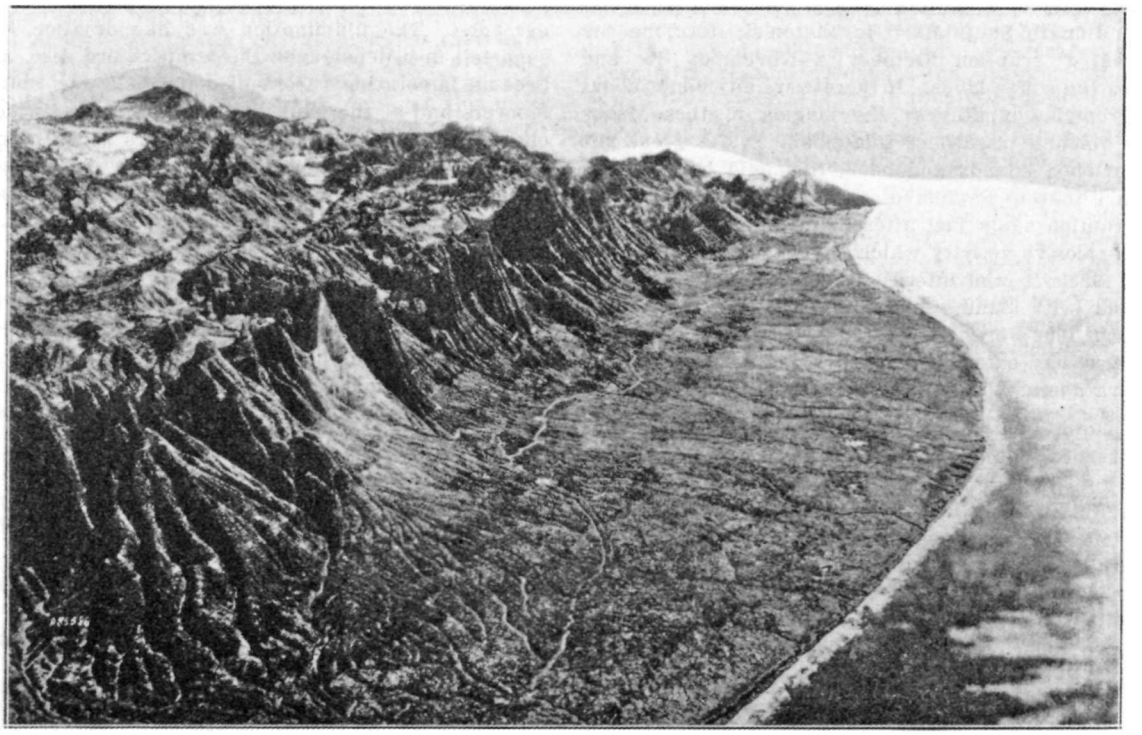
No. 356—Weekly Hawaiian Volcano Observatory, National Park, Hawaii October 22, 1931



Photograph of a large model of Guatemala, looking southeast along the Pacific coastal plain, which has been uplifted at the base of the line of active volcanoes. Great vertical exaggeration. Santa Maria Volcano with hole in its side from the eruption of 1902. At the left the mountainous plateau of Guatemala. a region of fertility, and one of the coffee belts of the world. Adjacent to this volcanic rift have occurred some of the biggest earthquakes of history.

ERUPTION OF SANTA MARIA NOVEMBER 1929

Santa Maria Volcano in western Guatemala has become a key vent of great importance in connection with the seismic and volcanic activity surrounding the Caribbean Sea. (See Volcano Letters 87 and 262). Heilprin states (The Eruption of Pelée, Lippincott, Philadelphia, 1908) that there was no recorded eruption prior to 1902, and in this apparently Sapper concurs. The 1902 outburst in October split open a great hole in the southwest flank of the mountain (see cut Page One) at about 6,500 feet elevation. the chasm being about the same size as the present Halemaumau, 3,300 feet across. and 800 feet below the rim stood a geyser-like lake of boiling water spouting and making sulphurous fumes until after 1906. Then the volcano became quiet until 1922 when at the end of June new explosive eruptions began and a dome of hornblende-hypersthene andesite lava rose through a fissure in the bottom of the crater and in August of that year had grown until it stood 300 feet above the downhill rim of the cauldron. Thereafter the dome kept growing until in 1925 there was a big castellated heap 1,600 feet high and 4,000 feet across. The growth was replaced by solfataric activity which continued until May 14, 1928, along with the slow development of a second swollen dome on the north and northwest sides of the former dome (Termer, Zeitschr. Vulk. XII Heft 2/3, p.231). About the site of this new plug eruption a short-lived explosive eruption occurred May 14, 1928, throwing ash over the country to the depth of a few millimeters.

Heilprin (l.c. page 71) believed the events of 1902 indicated that in a region like the Caribbean, volcanic and seismic phenomena over distances as great as 2,000 miles are related, that the deep-seated strain of magma might make great earthquakes such as geologists call "tectonic," that the slipping, upheaval and torsion of surface formations in the rock of the earth's crust might be resultants of the jarrings already given to the deeper earth-crust by magma, that the seismo-volcanic condition of the crust is proved to be connected with electro-magnetic phenomena as shown by the magnetic storms all over the earth accompanying the Pelée eruption, and that there is marked synchronism or close following of major disturbances. as has been proved at different periods for eruptions and great earthquakes far removed from each other. The striking illustration of these facts was a destructive earthquake at Quetzaltenango in Guatemala April 17, 1902, synchronous with the first outbreak of Pelée in Martinique at the other end of the Caribbean Sea 2,100 miles away. Two hundred

miles south of Quetzaltenango, Izalco Volcano broke out in Salvador and was in full eruption May 10, two days after Pelée had destroyed St. Pierre. Sourière in St. Vincent had broken out more than 100 miles south of Pelée the day before the St. Pierre catastrophe. Both Soufrière and Pelée continued their eruptions in concert into the autumn of 1902, and during this time Masaya Volcano in Nicaragua started eruptions which continued for two years. And finally Santa Maria in Guatemala developed its unprecedented eruption October 24-November 15 and devastated the coffee lands. If there were any doubt about the sub-crustal sympathy of the magma in these leaps from the volcanic fissure of Guatemala to the great rift of the Caribbee Islands and back, it should be dispelled by the fact that in September 1929 Pelée broke into explosive eruption again just after Santa Maria in 1928 had renewed explosive activity which came to a crisis in November of 1929. It is of interest in comparing Soufrière of St. Vincent with Santa Maria, to note that both these volcanoes in 1902 were left with boiling crater lakes. Now Santa Maria has exterminated this lake and replaced it with a lava dome: will Soufrière eventually do the same?

The photograph on Page Three has much in common with the scenes pictured on the northeast slope of Lassen Peak after its eruption of 1915, and this photograph represents part of a stream bed in the forest below the crater of Santa Maria as it appeared after the new catastrophe of 1929 which destroyed human life and wrecked plantations with an incandescent down-rushing cloud of ash, and torrential floods which transported gigantic bowlders. In both Lassen and Santa Maria volcanoes, as well as at Pelée in 1902, the source of the down-blast was a crater partially filled with a stiff plug of lava.

In the evening of November 2, 1929, in the vicinity of Santa Maria, there had been no forewarning of the coming danger. It was sultry and there was a dry lightning storm, but there had been such electrical phenomena in that vicinity of the lava dome frequently. At Las Animas, close to the volcano on the downhill side, about 9:30 p. m. November 2, persons sleeping on the plantation were suddenly awakened and saw a glowing rain and a flood rushing from the heights of the volcano. Alarming underground noises followed each other in quick succession, then glowing sand and ash fell on the roofs. Those who were so fortunate started to flee finding it difficult to breath the hot air. The bell was rung to awaken the laborers and all hastened toward the Rio Concepcion, where the river bed was found full of boiling mud erroneously called "lava" by the peasants. This was beginning to overflow the adjacent land. They made for another branch of the stream and found it equally in flood so that they were penned on a peninsula between the two torrents and the volcano. They spent the night in the plantation house; when there was a pause in the rumblings shrieks of the sufferers and calls for help could be heard. When they attempted to go to the rescue they found that the cries came from natives who were already engulfed in boiling mud. Nothing could be done. Early the following morning when daylight enabled them to see the devastated land, they improvised a bridge of logs across the stream and about 25 persons were rescued. The wounded were taken to a house on the main road where a relief commission soon began the work of rescue. Bodies were seen protruding from the hardened mud and some persons were trapped in the wreckage of houses. The residence house of one plantation was found totally destroyed and in many places it was necessary to lay down boards in order to cross the excessively hot mud and ash. The manager of this second plantation reported hearing a terrible thundering, and on looking up toward the crater he saw red-hot masses weighing tons being hurled into the air and breaking to pieces when they struck the earth so that glowing fragments and sparks bounced away. Then came subterranean rumblings and fiery streams seemed to pour down from the crater in winding avalanches of incandescence. The illumination was like daytime. Ash and sand fell in a dense rain, the temperature rose, and flight became imperative. Here also the bell was rung for the laborers and at the bank of the Rio Tambor, which had a channel 100 meters deep and 80 meters wide, the river was found in flood and so incandescent with the dry accumulations on its upper surface that they lighted the bank. This is a very remarkable statement, but quite believable, and accounts for phenomena observed in many of the explosive eruptions of Java and elsewhere, when stream floods have been confused with lava flows. It is easy to believe that light pumiceous ash will make a dry bed on top of a mud stream, capable of holding incandescent fragments so as to remain luminous while it flows. Throughout this eruption of Santa Maria the natives thought the contents of the river beds were lavas.

The River Tambor had almost reached the top of the bridge, the under irons were bent, but as yet they had not given way. A smaller stream, the San Jeronimo, was visited and was found to be flowing backwards owing to the fact that this stream pours into the larger river Concepcion, which by reason of its greater height and viscosity due to ash sent a backwater flood up the smaller stream. This was an added danger to the plantation as soon as the backflood poured into the lands and about the buildings.

There was no time to be lost. The laborers were panic stricken and demoralized. Twenty-six of them escaped over the bridge. The man describing the event said his chauffeur wished to go back to the garage to get the automobile and he had to use force to prevent his doing so and snatch the key out of his hand. While he was trying to persuade him to come across the bridge there was a sudden rush of the fiery mud across the slope at the bridge head; this liquid, by its great weight and stickiness, grasped the man's legs and dragged him downstream into the hot torrent. There was only a single heartrending cry and he was gone. Half of the laborers had delayed and were still in the plantation, and now streams of overflow could be seen making their way through the hamlet. The man remaining on the bridge called to them as loudly as possible, but his voice was drowned in the thunder of the cataclysm. He saw his residence collapse, and his automobile torn out and tossed like a toy on the surface of the stiff flood. More thon 25 of those who had remained in the grounds perished. The narrator saw there was nothing for him to do but to save himself, and he ran across the bridge just in time to see it carried away, leaving the plantation cut off. Then the ruins of his house disappeared.

Dr. Sapper concludes that this was a true fiery downblast of the Pelée type such as destroyed St. Pierre. If this eruption is compared with the first outbreak of Santa Maria October 24, 1902, there are marked differences. The 1902 explosion was enormously bigger in output of material, and while the loss of life was not greatly different, the destruction of property was much less in 1929. The area covered in 1929 was comparatively small, whereas hundreds of square kilometers were buried in 1902. The thickness of ash in 1929 was from 2 to 10 centimeters as against 10 to 20 meters in many places in 1902. Whereas in the earlier eruption earthquakes were numerous and big, in 1929 they were few and unimportant. The noise in 1902 was heard several hundred kilometers away, whereas in

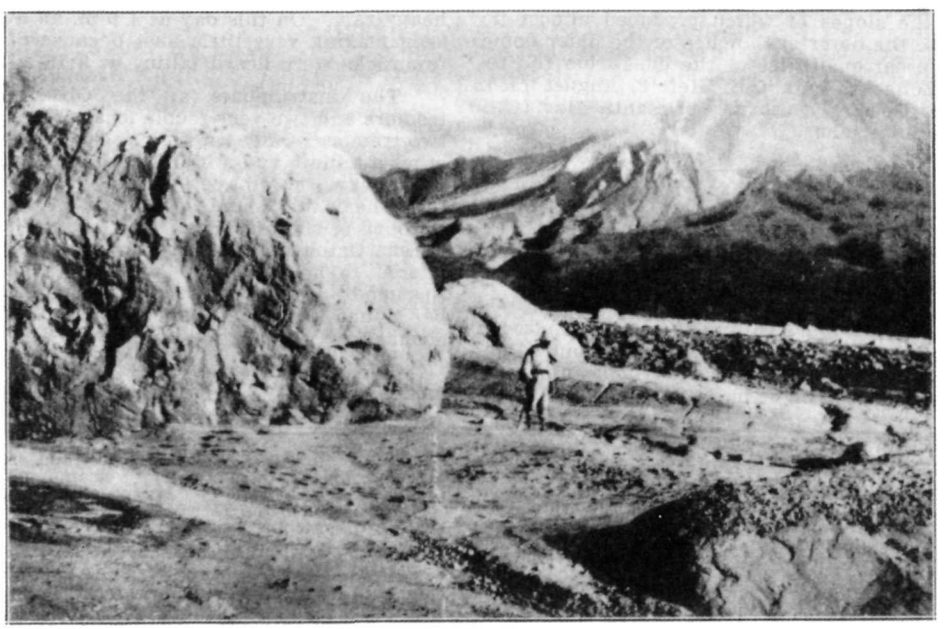
this recent eruption it was confined to the immediate neighborhood.

On the other hand. the devastation in the immediate path of the fiery blast was terrific in 1929, though probably not so great as that which destroyed St. Pierre in Martinique. There was the same deep booming noise, the electrical phenomena in the sky, the hurling out of glowing masses, the carrying of big bowlders on the flood paste of the streams. A notable difference lay in the fact that the Martinique eruption was by daylight at 8 a m., whereas the 1929 eruption at Santa Maria was at night so that light phenomena were conspicuous. The lava dome of Santa Maria glowed with reddish incandescence and glowing masses rolled into the gulches. The force of the blast was much greater at Mount Pelée accompanied with hurricane violence so as to carry big stones like cannon balls. In the Guatemala outbreak the glowing sand and ash masses flowed downwards simply by gravity. There were heat phenomena in both blasts, but the Pelée blast did damage to much greater heights, for there were hills in the path of the hot blast of Santa Maria where vegetation and houses stood uninjured above the level of the destructive cloud. There were at least two distinct blasts in the 1929 eruption. The contents of the ash cloud consisted of hot stones, sand, and dust which retained their heat a long while, and the same was true in 1902 at Soufrière and Pelée. The killing of people in Martinique was due to hot steam mixed with ash, and no case was identified of true asphyxiation. In Guatemala there were more cases apparently due to unbreathable gas, a fact confirmed by many accounts indicating that the people died without any outcry. The breathing of intensely hot air might produce this effect, particularly if it were charged with dust, and the reviewer would point out that incandescent substances driven through vegetation would very quickly generate enough carbon monoxide for instantaneous poisoning. There were cases in both eruptions where the bodies were burned beneath relatively uninjured clothing, owing to death by scalding rather than incineration.

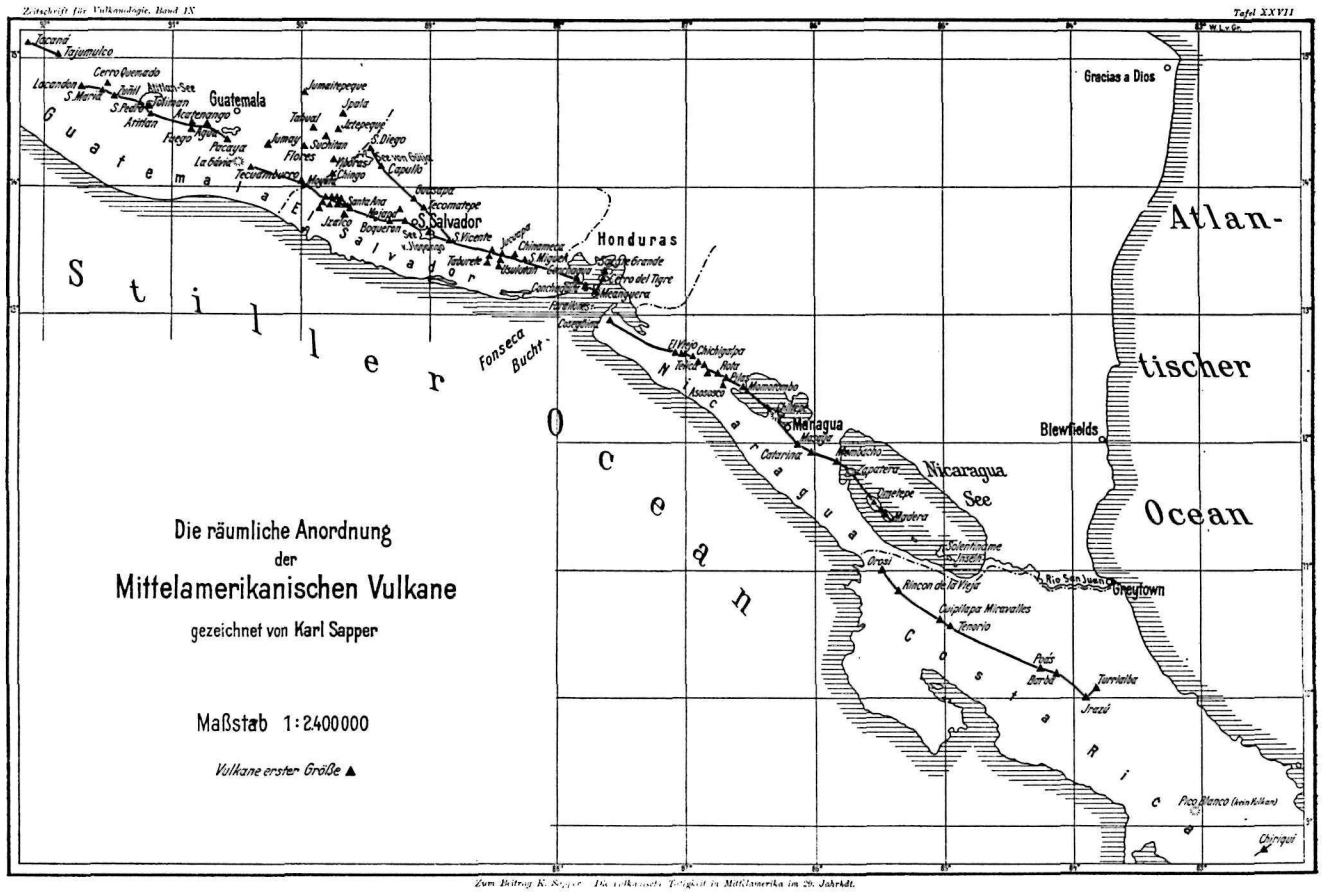
At the place nearest to the Santa Maria crater roaring and whistling of the blast were heard, but in distinction from the Martinique happening an inrushing reverse wind was conspicuous, blowing toward the crater, trees showed scour on the side way from the crater, and in some cases were scorched on the side remote from the volcano. This recalls the indraft at Vesuvius in 1906, when stones broke windows on the sides remote from the volcano. A peculiarity of the Guatemala happening was the wetness of the climate and the occurrence of the eruption at the end of the rainy season. Thus it came about that glowing stones and sand clogged the streams and caused their waters to boil, greatly increasing the volume of the liquid, and in places the valleys were filled with solids so that the flood swept through the intervening lands. It happened that the downblast coincided with the drainage system. There is no reason to suppose that the gigantic bowlders (photograph Page Three) were thrown to the position where they now lie any more than in the case of the flooding of Hat Creek in the Lassen cataclysm of 1915. These big stones were carried with the mud jumble.

Very little pumice fell at the beginning of the eruption. There was much reddish ash. An analysis showed the presence of sodium chloride with three per cent of lime sulphate and traces of silica. Petrographic investigation of a rock sample from the lava dome gulch at elevation 1,800 meters above sea level determined the magma to be a hypersthene-hornblende andesite containing 55 per cent of plagioclase, hypersthene in well bounded crystals, hornblende deeply corroded and showing dense borders of magnetite granules. Three ash somples of various coarseness were examined, with splinter outlines of irregular shape generally showing colorless glass, but sometimes none, and otherwise containing fragments of feldspar, red brown hornblende, and rare rhombric pyroxene. Otherwise there was some augite and a moderate amount of magnetite.

The place of origin of the 1929 blast was the lava dome of 1922. This dome had begun to glow some days before the outbreak. A rift was formed in the south side of the dome where eariier small glowing discharges had taken place. The place was thus prepared for a glowing avalanche along a gash into the valley below. Somewhere along the middle of the dome an elongate crateriform depression was seen after the eruption, its alignment almost due south. (See cut Page Three.) Here after the main eruption a steep-sided bulbous lava mass welled up, the



Looking north after the eruption of November 2, 1929, showing the lava dome in the midst of the crater in the side of Santa Maria Volcano, and in the foreground the flood waste occasioned by the eruption. The ash torrents mingled with flood waters carried the huge bowlders shown. The downblast originated in a rift in the lava dome. There is new lava in the rift. Photo from Sapper and Termer.



Volcanic map of Central America showing the position of Santa Maria Volcano at the west end of Guatemala. From Sapper, Zeitschr. Vulk. IX.

avalanches from the slopes of which produced almost no dust, in contrast to the outer avalanches of the older dome which stirred up great quantities of the dust from the recent eruption. (Zeitschr. Vulk. XIII Heft 2, August 1930. K. Sapper and F. Termer, Outbreak of Santa Maria 2-4 November, 1929. In German.) T.A.J.

KILAUEA REPORT No. 1030

WEEK ENDING OCTOBER 18, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There is nothing new to report at Halemaumau. During observations throughout the week very little fume and steam were noted, except a slight increase October 12 after heavy rain. On this day at 4 p m. an avalanche north was seen making very little dust because of the wet walls. A few rocks were heard falling at 9:15 a. m. October 16.

The instruments at the Observatory recorded 40 tremors and two very feeble local seisms. There were only two tremors of any length, one lasting five minutes and the other a minute and a half. The latter, judging by the period of its wave, may have been part of an earthquake with a focus near the Island of Hawaii. A seism at 12:32 p. m. October 14 showed distance to origin 6 miles; one at about 5 p. m. October 13 was obscured by the hour mark, but appeared to be less than 30 miles from the Observatory. Spasmodic tremor occurred for more than nine hours October 16 and about six hours October 17. There were no felt shocks.

Tilt was moderate NNE. Microseismic motion was moderate.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano. also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 357—Weekly Hawaiian Volcano Observatory. National Park. Hawaii October 29, 1031



Ropy festoons of pahoehoe basaltic lava, on the Mauna Iki trail southwest of Kilauea Crater. Shows the wrinkling mechanism by which lava flows in the direction of the arching, with twisting of the wrinkles where the middle belt flows the faster. Photo 1931 by Lewis M. Werth.

THE VISCOSITY OF LAVA

By Jean Kinsley

Little experimenting has been done dealing with the viscosity of lava. Viscosity has been defined as the resistance to flow. Where lava is the chief product of a volcano, the shape of the dome may depend on the viscosity of the lava, as well as on its copiousness in different stages of the upbuilding of the dome. The rate of flowing will depend on viscosity, and on change of viscosity as the lava cools. Highly basic lava is more liquid and less viscous that the less fusible acid lava, rich in silica, such as rhyolite or trachyte. Some basic lavas like basalt are fluid enough to run down a one per cent slope, and form flat domes with slopes of from four to ten degrees. Mauna Loa is an example of such a dome, immense in size, yet flat in profile. The andesitic lavas of Japan and Central America are much more viscous, forming cones with slopes of from 25 to 35 degrees, though this production of slope is often complicated with fragmental materials. What effect viscosity actually has, has been little experimented with.

Dr. George F. Becker (Some inquiries into rock differentiation, American Journal of Science, January 1897. page 29) discusses viscosity in connection with theories of diffusivity. Becker estimates the rate of flow of the Kilauea lava stream of 1840 at 22 feet a minute down a two per cent slope. The flow was fed from fissures for a considerable part of its length, thus maintaining a fairly constant temperature. Water according to Becker would flow 24 times as fast. Since lava is 2.5 times as dense as water, it would then be 24 times 2.5, or 60 times as viscous as water.

Becker refutes the possible assertion that lava underground is more fluid before it erupts. Viscosity increases with pressure, and underground magma is under great pressure and close to the melting point. It can not be superheated, according to Becker, or it would melt the surrounding rock and be reduced in temperature. Therefore he concludes that, owing to the pressure, viscosity must be greater before eruption than afterwards. To this statement may be added the heating effects occasioned by gases released from solution, which would diminish viscosity when eruption begins.

Dr. H. S. Palmer (The viscosity of lava, Bulletin Hawaiian Volcano Observatory, January 1927, Vol. XV, No. 1) assumes that Becker based his measurements upon progress of the first front of the flow of 1840, which would be slower than the streaming after a channel has been established. Hence Becker's estimate of the viscosity is too high. That is, he makes the lava too stiff.

No general law connecting temperature with viscosity has been found, though there are several interpolation formulae permitting computation of the variation of vis-

cosity with temperature for any given liquid. In case of water, the decrease of viscosity per degree of rising temperature is greater at the lower temperatures. Becker says that fluid lava need not necessarily be superheated above its melting point, and this agrees with observed facts of measurement in the Kilauea lava lakes which indicates that they are undercooled. Viscosity varies with the molecular weight, and the heavier basic lavas, other things being equal with reference to relation of temperature to fusing point, should be more viscous by reason of their density. But chemical composition and crystallinity play important parts, and the quantity of gas bubbles may act as ball bearings in increasing mobility.

Dr. T. A. Jaggar estimated the Alika flow of 1919 on Mauna Loa in its established channel near the source to be moving 15 miles an hour. Four miles west of the source it was moving three miles an hour. The source lava was pahoehoe, the other aa. The lava feeding the fields moved through the stream forks in the channel about 200 feet an hour, but the field itself moved about two feet an hour. Dr. Palmer thinks that Dr. Jaggar observed a surface thread of lava in the middle of the channel, which would have a velocity 5 to 15 per cent greater than the mean velocity of the inner lava river for its full width. (See photograph of lava festoons Page One.)

The rate of flow of the Alika stream Palmer assumes to have been steady with a force 1.4 times greater driving the lava stream to overcome its viscosity, than would drive a comparable water stream, since the specific gravity of the gas-charged live lava is 1.4. He writes: "If streams of two fluids were alike in all respects except specific gravity, the driving forces would be in the same ratio as the specific gravity. And if the velocities were the same, the viscosities would be proportional to the specific gravities; that is, to the driving forces. Since the velocity of a stream is inversely proportional to the viscosity, we may write the equation

$$\text{Viscosity} = \text{a constant} \times \frac{\text{specific gravity}}{\text{velocity}}$$ "

From this formula he concludes that the viscosity of the Alika flow was about 15 times greater than that of water. He conceded the possibility of error in comparing the Alika flow with a similar stream of water, from uncontrolled conditions of the channel and grade.

Jaggar in 1921 (for Alika flow details see Bulletin Hawaiian Volcano Observatory, October 1919, pp. 127, 133-4, 156; also February 1921. pp. 28-9) made an experiment at Halemaumau comparing the viscosity of live lava in a rift cone, and in the lava lake. He attempted to avoid stream errors by measuring the rate of entry of live lava through an aperture in a vessel immersed in it. The apparatus was a metal cylinder 27 inches long of 3 inches inside diameter, on which was a cap with an opening 1.5 inches in diameter. This on the end of a long pipe was immersed about a meter in the molten liquid in the cone and left there for 4 minutes. On withdrawal, the cylinder was found to be about one-third full of pahoehoe lava.

The same experiment was tried in the bubbling lake, with the result that the cylinder was incompletely filled, but in larger volume than before. The current in the molten slag carried the cylinder irrestibly sidewise so as to prevent it from remaining vertical. Large gas vesicles were found in the glassy lava inside the vessel, showing that gas vesiculation had played a part in permitting the lava to enter. A defect in these experiments was the cooling effect of the iron on thrusting it into the lava without preheating to the lava temperature.

In the first experiment, 1180 cubic centimeters of lava weighing 1656 grams had entered the cylinder, filling it 33 per cent. In the second lake experiment, 2500 cubic centimeters entered with a weight of 3500 grams, filling it 83 per cent. The viscosity was thus greater in the spatter cone lava. The density of ordinary Hawaiian lava is from 2.7 to 3.0, but the vesicular lava of the experiment had specific gravity of only 1.4, owing to the large proportion of gas. The radius of the orifice was 2.9 centimeters, and the time of flow 240 seconds. The temperature of the lava in the first experiment was 1100 degrees C., in the second experiment 1200 degrees C., as might be expected from the lower viscosity of the highly effervescent lake lava.

TWO SURFACE FORMATIONS NEAR MAUNA IKI

The photograph on Page One is relevant to what was said above about viscosity of basaltic lava. The ordinary small pahoehoe lava flow has the form of a leaf, with the feeding stream considered as the stem. This stem or feeding thread of molten slag skins over on its upper surface and quickly divides itself into at least three belts of motion, consisting of two drawn-out curtains at the sides, and a belt of festoons in the middle arching downstream. These festoons are at first merely wrinkles, then they cluster together and pile up into folds, then the different speed of flowing of the faster central belt and the two lateral belts tends to twist the contact wrinkles into ropes. Finally the whole structure forms a crust and the incandescent stream inside flows under the bridge of festoons. This stream later escapes at the lower skirts of the flow and leaves the arch of festoons a hollow shell which is apt to cave in and reveal a cavern. The presence of arched festoons is a sure sign of the original direction of flow with the crest of the arches pointing downstream. It often happens that the hardened shells exhibiting such festoons become swollen up in the later history of a flow puddle so that the surface slopes backward in the opposite direction from the slope that made the festoons.

The photograph on Page Three exhibits the detail of a footprint made by a barefooted Hawaiian in the ash mud of 1790 east of Mauna Iki. This is one of the hundreds of footprints which mark the old trail of that time, the material being a pisolitic ash with some small angular pebbles. The pisolites or mud raindrops of the period are the small, round, whitish objects seen at the left of the picture. The footprint shows the five toes and the spread-out effect as the foot squashed down in the mud of that period, which has since hardened like cement so as to preserve the footprints from erosion throughout nearly a century and a half.

T.A.J.

NOTES FROM THE ALEUTIAN ISLANDS

The seismograph observer, Mrs. Wendhab, reports from Dutch Harbor that the trader Mr. Schroder, who owns the store at Chichagof Harbor in Attu, came back from one of his voyages at the end of August and reported that on May 30, 1931, about 12 midnight (following), a very severe earthquake was felt at Attu. He had himself experienced the California earthquake of 1906 and he thought that this one was very nearly as severe. Everything on the shelves was dislodged, dishes were broken, and there was general

havoc. Aftershocks continued every few days accompanied by a distinct roaring noise which preceded the shock and grew in volume as though something was coming closer with great rapidity. Then would come the shake, the roaring accompanying it, followed by a passing on of the movement and a dwindling of both tremor and sound.

Our seismograph records at Kilauea did not show any registration of a large distant earthquake at that time.

Mr. R. H. Finch reports that Aniakchak Volcano on the Alaskan Peninsula was exploding in May 1931 and scattered ashes over a hundred miles from the center. The material that fell at a great distance was very fine and looked like flour under a pocket lens. Some account of this Aniakchak eruption has recently been reported by the explorer Father Hubbard. Katmai Volcano was observed to be smoking early in July. Pavlof was smoking nearly all summer and according to the Reverend D. Hotovitsky of Belkofsky this volcano was in active eruption about May 20, 1931, making a noticeable ashfall, and at times glow was discernible at the crater. Two other volcanoes on the Peninsula were reported fuming.

Gareloi Volcano, a peak 5,334 feet high far to the west in the Aleutian Islands, was very active during the spring and summer of 1930. The appearance of half of the island was said to be changed by lava flows from fissures, and a hut was destroyed belonging to fox farmers. R.H.F.

KILAUEA REPORT No. 1031

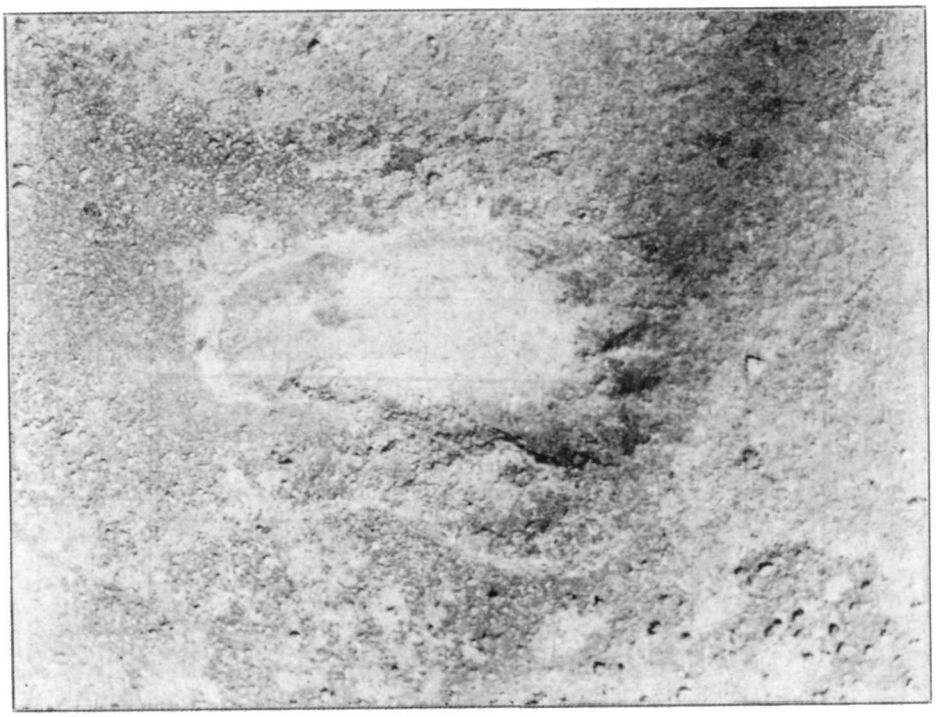
WEEK ENDING OCTOBER 25, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The fume area on the Halemaumau bottom appeared inactive on October 19, and only thin fume and steam were noticeable on the 20th. After light rain on the 21st there was some increase of fume. On the 22d both fume and steam were entirely absent. The seismograph at Halemaumau showed quiet conditions and practically no tilting. There are two new large bowlders on the pit floor between the south and southeast taluses. On October 24 at 8:30 a. m. there was a large avalanche north causing much dust. Crack measurements on October 20 showed no changes.

The seismographs at the Observatory registered 11 tremors, three of which were doubtful, and one very feeble shock, with good phases, from a distance of about 37 miles. In addition during the first two days of the week there were 46 spasmodic tremors, possibly artificial due to road machinery. There has been so much vibration from this cause as to obscure the records during daylight hours. The heavy machinery working in the neighborhood of 100 yards causes periods of one-tenth second and a half millimeter amplitude.

The average of tilt was slight N, and of microseismic motion moderate.



Footprint in ash east of Mauna Iki remnant from the native trails of the eighteenth century. Shows pisolites on the left and small stones on the right.' The natives walked in volcanic mud of the time, which has since hardened. Photo 1931 by Lewis M. Werth.



Map of the Pacific Ocean. Attu Island is the westernmost of the Islands extending towards Kamchatka from Unalaska, and Aniakchak in on the outer part of the Alaskan Peninsula east of Unalaska. Pavlof is still farther west on the Peninsula, and Gareloi is an island midway between Unalaska and Attu.

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No. 358—Weekly Hawaiian Volcano Observatory, National Park, Hawaii November 5, 1931



Lava floor of 1929 showing the large half-dome against the west talus left by the fountaining grotto of about July 25, 1929. This half-dome still protrudes at the edge of the floor left by the activity of November-December 1930. Photo Baker.

REVIEW OF HAWAIIAN EARTHQUAKES 1929-1930

The Volcano Letter has recently reviewed the cycles of volcanic activity at Kilauea, showing a tendency to eleven-year periods, and indicating that the present cycle began with the return of lava to Halemaumau pit in July 1924. From time to time we have reviewed the earthquake frequency, showing that recently the Kilauea station registers about 1,000 disturbances per year due to local cause. The following was the record of 1929:

By weeks ending on the dates listed, the following were the frequencies of local earthquakes for 1929:

Date	Number for Week	Notes
Jan. 2, 1929	2 very feeble	
Jan. 9	8 very feeble	Some continuous tremor.
Jan. 16	8 very feeble	
Jan. 23	1 feeble	Several continuous tremors.
	21 very feeble	
Jan. 30	10 very feeble	Less continuous tremor.
Feb. 6	1 moderate	Felt Feb. 5 Hilo and Kohala.
	9 very feeble	
Feb. 13	7 very feeble	Some spasmodic tremor.
Feb. 20	17 very feeble	Continuous harmonic tremor Feb. 20 with outbreak of lava.
Feb. 27	3 slight	
	5 very feeble	Tremor ended when lava stopped Feb. 21.
Mar. 6	1 slight	
	1 feeble	
	4 very feeble	
Mar. 13	4 very feeble	
Mar. 20	17 very feeble	Five prolonged tremor spasms.
Mar. 27	20 very feeble	Seven tremor spasms.
Apr. 3	16 very feeble	Irregular very feeble tremor.
Apr. 10	5 very feeble	Tremor ceased after April 6.
Apr. 17	9 very feeble	
Apr. 24	8 very feeble	
May 1	8 very feeble	Some very faint tremor.
May 8	4 very feeble	

Date	Number for Week	Notes
May 15	1 feeble 6 very feeble	
May 22	3 very feeble	
May 29	7 very feeble	
June 5	8 very feeble	
June 12	16 very feeble	
June 19	2 moderate Several very feeble	One prolonged tremor.
June 26	1 moderate 7 very feeble	One tremor spasm.
July 3	8 very feeble	
July 10	1 feeble 28 very feeble	
July 17	2 feeble 16 very feeble	One tremor spasm.
July 24	19 very feeble	Numerous tremor spasms July 21 and harmonic tremor accompaning lava flow began to be steady the morning of July 25.
July 31	17 very feeble	Harmonic tremor ended July 28 when fountain went out of action.
Aug. 7	2 feeble 27 very feeble	One period of spasmodic tremor.
Aug. 14	28 very feeble	Some continuous tremor.
Aug. 21	1 feeble 19 very feeble	
Aug. 28	1 slight 16 very feeble	
Sept. 4	15 very feeble	
Sept. 11	4 very feeble	
Sept. 18	1 feeble 8 very feeble	
Sept. 25	221 earthquakes and tremors	Violent earthquake disturbances near Hualalai. Some long tremors at seismograph.
Oct. 2	244 earthquakes and tremors	Many more felt in North Kona.
Oct 9	129 earthquakes and tremors	The two strongest shocks were September 25 and October 5.
Oct. 16	97 earthquakes and tremors	North Kona crisis declining.
Oct. 23	3 feeble 9 very feeble	41 prolonged tremors. Total 53 seismic disturbances as compared with 97 for the previous week. The orgin continued to be near Hualalai.
Oct. 30	1 feeble 39 very feeble 56 tremors	Hualalai origins continue active.
Nov. 6	1 feeble 21 very feeble 35 tremors	Hualalai origins continue active.
Nov. 13	2 feeble 28 very feeble 32 tremors	Hualalai origins continue active.
Nov. 20	16 very feeble 12 tremors	Hualalai crisis dwindling.
Nov. 27	2 feeble 12 very feble 18 tremors	Hualalai crisis dwindling.
Dec. 4	2 feeble 13 very feeble 10 tremors	North Kona still feeling shocks.
Dec. 11	8 very feeble 9 tremors	Five indicated North Kona origin.
Dec. 18	9 very feeble 4 tremors	Five indicated North Kona origin.
Dec. 25	3 very feeble 10 tremors	Felt in North Kona.
Jan. 1, 1930	1 feeble 8 very feeble	Five indicated North Kona origin.

The year 1929 as recorded seismically above for Kilauea, was notable volcanically for actual inflow of lava at Halemaumau pit February 20-21 and July 25-28, and for such subterranean disturbance at Hualalai Volcano that intense shaking affected the North Kona District and much of the Island of Hawaii from September 19 to the end of the year. These three events are clearly reflected in the harmonic tremor produced by the Halemaumau eruptions at the Kilauea Observatory, and in the great excess of earthquakes and tremors of all classes which accompanied the Hualalai disturbance beginning with the week which ended September 25. Seismically the frequency and intensity of the Hualalai spasm were both at a maximum during the first fortnight and declined rather evenly thereafter. No lava outflow was determined as occurring under the sea or anywhere during the Hualalai crisis. If we compare the seismic record shown above with the earthquake freqency and intensity that accompanied the explosive eruption of Kilauea in May 1924 (diagram Page Four Volcano Letter No. 328), it is apparent that the seismic maximum at Kilauea was toward the end of the eruptive period, and both frequency and intensity increased as this maximum was approached. There is good reason to think that the Kilauea steam blasts of 1924 were occasioned by an outflow under the sea. Therefore it seems improbable that any submarine outflow occurred at Hualalai in 1929, for the seismic behavior was exactly the opposite of that of Kilauea. It seems more likely that lava flowed in under Hualalai with an upward pressure, splitting open deep rifts, and preparing for eventual outflow somewhere to the north of the Mauna Loa center.

After this gradual dwindling of the Hualalai earthquakes at the end of 1929, it will be of interest to examine the frequencies of local earthquakes at the Kilauea Observatory for 1930, by weeks ending on the dates listed:

Date	Number for Week	Notes
Jan. 5, 1930	8 very feeble	Five indicated North Kona origins.
Jan. 12	7 very feeble 12 tremors	One indicated North Kona origin.
Jan. 19	5 very feeble 5 tremors	One indicated North Kona origin.
Jan. 26	3 very feeble 6 tremors	One indicated North Kona origin.
Feb. 2	1 slight 6 very feeble 7 tremors	North Kona origin. Three indicated North Kona origins.
Feb. 9	4 feeble 2 very feeble 8 tremors	Three probably North Kona origin.
Feb. 16	7 very feeble 16 tremors	One indicating North Kona origin.
Feb. 23	1 slight 9 very feeble 13 tremors	
Mar. 2	3 very feeble 8 tremors	Two indicating North Kona origin.
Mar. 9	1 feeble 7 very feeble 5 tremors	Three indicating North Kona distances.
Mar. 16	1 feeble 5 very feeble 9 tremors	
Mar. 23	5 very feeble 2 tremors	
Mar. 30	4 very feeble 9 tremors	
Apri. 6	5 very feeble 12 tremors	
Apr. 13	1 very feeble 12 tremors	
Apr. 20	3 very feeble 6 tremors	
Apr. 27	3 very feeble 4 tremors	
May 4	5 very feeble 6 tremors	
May 11	3 very feeble 11 tremors	
May 18	8 very feeble 11 tremors	
May 25	1 moderate 2 feeble 3 very feeble 5 tremors	Probably in Puna. Probable origin North Kona.
June 1	1 very feeble 9 tremors	

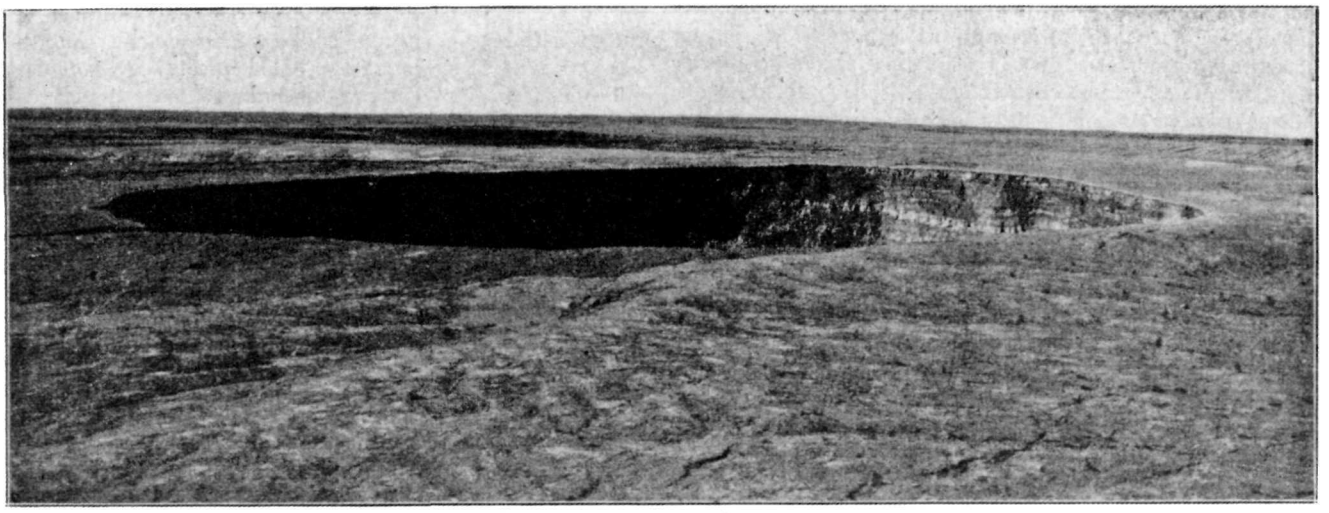
Date	Number for Week	Notes
June 8	3 feeble	One probably Hualalai.
	1 very feeble	
	6 tremors	
June 15	1 slight	
	3 very feeble	
	4 tremors	
June 22	6 very feeble	
	7 tremors	
June 29	1 very feeble	
	5 tremors	
July 6	3 tremors	
July 13	4 very feeble	
	4 tremors	
July 20	6 very feeble	
	6 tremors	
July 27	1 moderate	Strong in North Kona.
	5 very feeble	
	4 tremors	
Aug. 3	3 very feeble	
	10 tremors	
Aug. 10	2 feeble	Several tremors notably at Halemaumau.
	3 very feeble	
	5 tremors	
Aug. 17	3 very feeble	Several tremors.
Aug. 24	1 feeble	
	3 very feeble	
	25 tremors	
Aug. 31	5 very feeble	
	31 tremors	
Sept. 7	6 very feeble	
	26 tremors	
Sept. 14	1 very feeble	
	46 tremors	
Sept. 21	5 very feeble	
	49 tremors	
Sept. 28	1 moderate	
	2 feeble	
	7 very feeble	
	23 tremors	
Oct. 5	1 feeble	
	3 very feeble	
	25 tremors	
Oct. 12	3 very feeble	
	17 tremors	
Oct. 19	1 moderate	
	2 very feeble	
	17 tremors	
Oct. 26	1 moderate	
	1 very feeble	
	57 tremors	
Nov. 2	1 slight	
	3 very feeble	
	42 tremors	
Nov. 9	1 feeble	
	44 tremors	
Nov. 16	10 very feeble	
	48 tremors	
Nov. 23	1 feeble	Harmonic continuous tremor accompanied lava outbreak at Halemaumau November 19.
	8 very feeble	
	24 tremors	
Nov. 30	None	Harmonic volcanic tremor continuous along with lava inflow at Halemaumau.
Dec. 7	2 very feeble	Harmonic tremor and lava action ceased December 7.
	4 tremor spasms	
Dec. 14	3 very feeble	
	33 tremors	
Dec. 21	1 feeble	
	3 very feeble	
	36 tremors	
Dec. 28	1 feeble	
	42 tremors	

The year 1930 as here recorded seismically for Kilauea was notable as retaining traces of the Hualalai seismic spasm in North Kona until March, and thereafter the seismicity may be considered normal as compared with past years. Volcanically there was registered continuous tremor accompanying lava outbreak in Halemaumau from November 19 to December 7 with one week in the middle of this activity showing no local earthquakes at all. It may be said that, except for phenomena of volcanic tremor and tilt, the three lava inflow eruptions of Halemaumau in 1929-30 were notably quiet seismically. and this characteristic was observed in 1927 and at other times. Rising below a sealed vent may make strong preliminary shocks some time before the eruption, but through an open vent like Halemaumau the movement of lava does not make earthquakes.

The totals for the two years were 1,516 local disturbances at the Hawaiian Volcano Observatory for Kilauea seismographs in 1929, and 1070 disturbances for 1930 To show the difference in a distance of 50 miles for a localized seismic spasm, compare the 1929 figure for Kilauea with the 6,211 shocks that were registered in the vicinity of Hualalai between September 21 and October 16, 1929. The Kilauea total for the same period was about 691 shocks, many of them felt.

The totals of seismic disturbances at Kilauea per year since the explosive eruption of 1924 have been:

1925	922
1926	1778
1927	1149
1928	1034
1929	1516
1930	1070



The vast lava pit of Halemaumau taken from the high western bluff of Kilauea Crater. This is the pit the bottom of which has been gradually filling since the tremendous engulfment of 1924. Photo Baker.

The high total of 1926 was due to the Mauna Loa eruption in April, just as that of 1929 was due to the seismic spasm on Hualalai. It is of interest to note that for the 20 days of this Mouna Loa eruption the maximum of both frequency and intensity of earthquakes was reached during the first week in the registration at Kilauea, and in this it was similar to the happenings on Hualalai, and in like manner was contrasted with the seismic record of the Kilauea subsidence and steamblast eruption of 1924. This is further evidence favoring the supposition that the Hualalai disturbance marked an upward lava pressure which suddenly disrupted the mountain by intrusion of lava which has not yet been evacuated.

It will be seen that the average of the last six years at Kilauea is 1278 local disturbances per year, including tremor spasms, whereas the record from 1914 to 1925. inclusive, (Volcano Letter No. 54) showed an average per year of 1022 local earthquakes, wherein all the tremor spasms were not counted, and wherein also the very exceptional total for the year 1924 of 5877 shocks was included In general the figures for the eight years of continuous lava activity in Halemaumau pit between 1914 and 1923. inclusive, omitting 1916 and 1919 when Mauna Loa introduced complications, averaged 410 local shocks per year, which is less than the average at the present time. The figures are not strictly comparable as the listing of tremor spasms greatly increases the totals at present. Nevertheless it appears certain that free lava flow in the pit causes a decrease in numbers of earthquakes. T.A.J.

KILAUEA REPORT No. 1032

WEEK ENDING NOVEMBER 1, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Crack measurements on October 26 found no changes. Two new measuring points were marked on the northeast side of Halemaumau, where freshly broken ground was discovered on October 24. By October 31 one of these points had moved open nearly one-half inch. Fume and steam were absent. On the 27th both fume and steam were fairly thick after rain. Conditions at Halemaumau were quiet seismically. The pit was visited on the 29th after a felt earthquake at 5:45 a. m., and fume appeared strong and steady. There was no apparent avalanching from the shock. The seismograph at the pit showed tilt away from Halemaumau, which would appear to indicate tumescence. A second felt earthquake occurred at 11:34 p. m. October 31.

The records from the instruments at the Observatory were obscured during the daylight hours by artificial tremors caused by road machinery. There were also numbers of disturbances from blasts. Forty known tremors were counted, and 16 that were either artificial or natural. Of three very feeble seisms, one was very local and another was probably from Mauna Loa. Two feeble shocks were felt as noted above. The first showed distance about five miles from the Observatory and the second about 10 miles. Parts of two distant earthquakes were recorded feebly November 1 at 2:12 p. m. and 11:45 p. m.

Tilt for the week was slight WNW. Microseismic motion was moderate to heavy.



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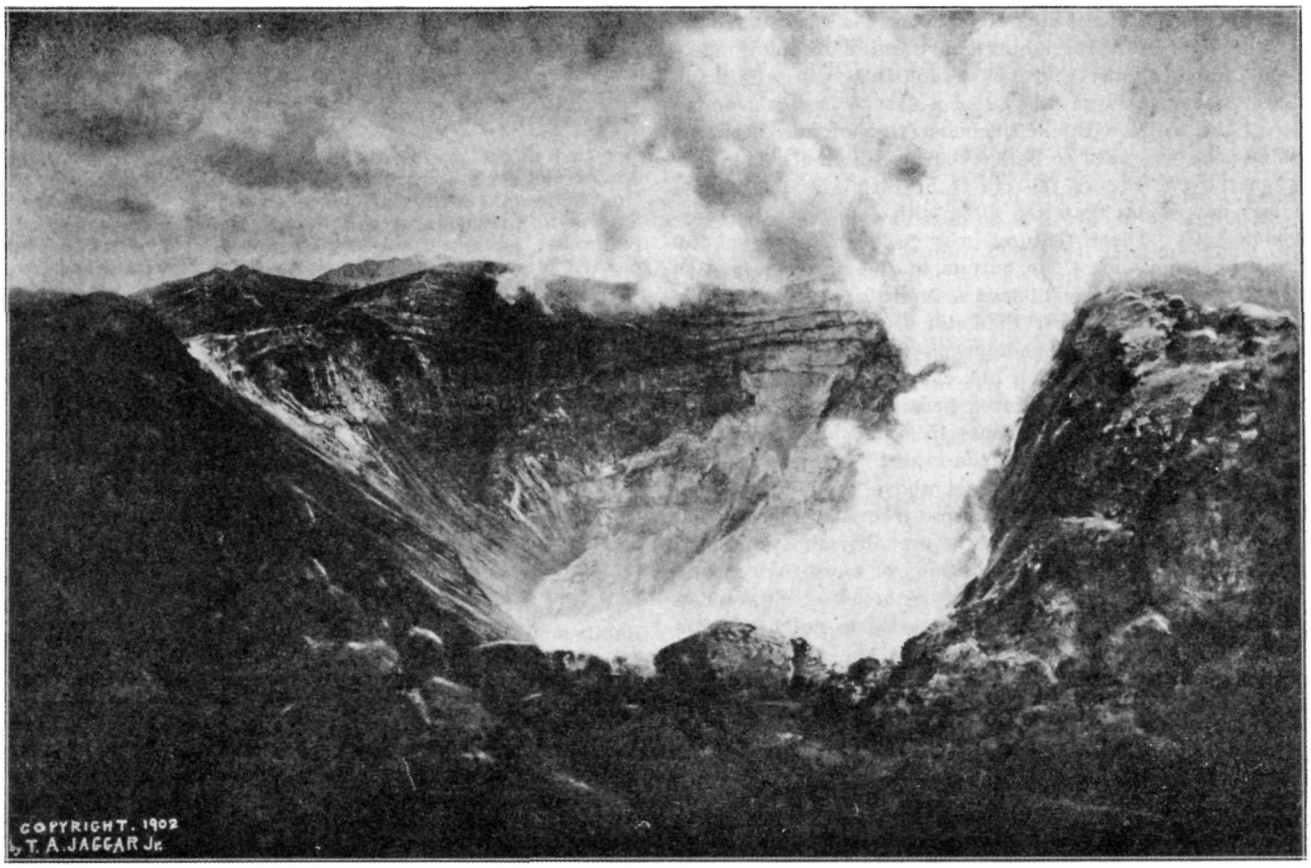


Interior of Soufrière crater, St. Vincent, from southwest rim May 31, 1902, showing boiling pools in the bottom after the great eruption of May 7, 1902, and before the later eruptions, which tended partially to fill the inner bowl with ash surrounding a circular lake at higher level. This filling followed a series of geyser-like gushes in March 1903. Photo Jaggar.

THE CRATER OF SOUFRIERE VOLCANO

A remarkable feature of the volcanic eruptions in the Caribbee Islands made famous by the destruction of St. Pierre by the volcano Pelée in Martinique in 1902, was the fact that a great steam-blast eruption at St. Vincent, 100 miles south of Martinique, occurred at 1:30 p. m. May 7, 1902, and the next morning, about 8 o'clock, occurred the cataclysm at Mont Pelée. There was clearly sympathy along the subterranean rift above which the line of islands has been built. The writer visited both volcanoes in May 1902, and was with the first party that made the ascent of Soufrière Volcano on May 31. He made a sketch map of the crater and a photographic panorama reproduced herewith. We shall here examine the evolution of this crater, which contained a lake before the eruption of May 7, showed boiling water in the bottom immediately afterwards, and refilled to about the former lake level during the following year.

It may be well at the outset to describe the crater as it appeared during our visit of May 31. We ascended the mountain following the spurs which had been swept bare on the southwest side. The mountain is a rugged cone deeply trenched by radial gorges and charted as being 4048 feet high. The old slopes had been steepened by rapid wash and landslides, the luxuriant vegetation was swept away, the slopes were furrowed with feathery patterns of rill drainage cut in the muddy ash covering, and each spur was like a very steep roof with a smooth pathway along the divide and erosion corrugations at the sides. Here and there huge stumps remnant from the former jungle lay prone or jutted upward with limbs charred and sharpened to dagger points by the volcanic sand-blast. At 1610 feet elevation the smooth spurs changed to a steep tumble of mud clots. sometimes knee deep and sticky, with blocks of rock two feet or more in diameter scattered about by the eruption.

After nearly three hours of climbing we came to the crest and looked down into an enormous cauldron, almost circular, showing on the opposite side a wall striped with horizontal bands of columnar intrusive lava, and the peak of the mountain beyond rising high into steam clouds. On the right was a black precipice falling away 2,000 feet almost sheer, and on its face there purled upward from the bottom a long, noise-

less column of steam which broke away in billows. Down at the bottom was a pale green muddy pool sending up a hundred tails of steam and boiling vigorously. On the opposite shore of the pool springs from the wall trickled across a flat making red and sulphurous stains, and uniting into a brook which had built a small delta. The middle bands in the wall were of gray lava, one of these showing a funnel-shaped section as though the slag had filled an upright fissure that spread out above into a drooping mushroom. Farther down there were reddish brown tuffs made of fragments A large dike filled a fissure from bottom to top of the wall on the left, and at the top the northern crater edge was seen to be backed by a higher ridge. Between the two occurs the crater of 1812 which is a subsidiary cup or flat that was filled with debris by the eruption of 1902. These features may be seen in the photograph on Page One. The bottom of the crater was 2550 feet below the highest distant summit, and 1660 feet below the rim. The upper diameter is 4870 feet, and the western rim where the photograph was taken stood 2735 feet above sea level. The old chart indicated 2013 feet for this elevation. The figures here given were obtained by rough angular measurements from the ends of a base line paced off on the edge of the crater. The eastern rim of the bowl stood over 2000 feet above the boiling pool. This pool was about 1200 feet across from east to west and was incessantly changing. It is probable that the oval of the crater had a greater dimension of more than a mile diameter north and south. The north-northwest corner had been blown away or had collapsed so as to notch the rim outward. The column of steam rose from a point south 18 degrees east from the center of the cauldron and was about 50 feet wide. The base of the steam column marked that part of the lake which was in most violent ebullition, sputtering fiercely and occasionally sending up spurts of black mud and rock fragments a few feet above the bottom of the crater. Jets of steam were seen to come directly from rock fissures on the southern side. The level of the lake was about 1100 feet above the ocean and some 800 feet lower than the lake surface that existed in this crater before the eruption. The pool of boiling water appeared shallow, for the slopes of slide rock shelved off into it at low angles and mud islets rose in the middle.

The crater lake of the Soufrière, before the eruption. was described as a pearly green sheet of water, set in sloping verdant crater walls, smelling of sulphuretted hydrogen, and the water was cold. A native trail crossed the mountain and people had bathed in the lake. The level of the lake surface was 1,930 feet, so that the southern wall over the water had been 1100 feet high, and the northern about 1700 feet. There was no known outlet. Soudings of 43 fathoms near the shore and about 88 fathoms near the center indicated that the bottom of the depression had its deepest part to the north of the center and the bottom must have been over 1600 feet below the southern lip of the crater. In other words, the rock bottom left by earlier eruptions was not very different from what the 1902 eruption produced. The former crater was described as nearly circular, with its northern lip 3623 feet above sea level and about 600 feet higher than the southern lip. The edge of the crater had been an irregular knife edge with inward and outward slopes both of from 30 to 40 degrees, and the crater depression was due to engulfment and erosion. It had not been difficult, with the aid of bushes and small trees, for passers-by to descend to the edge of the lake.

The eruptions of May 1902 disrupted the bottom of this cauldron and somewhat enlarged it, but the small crater under the crescent ridge on the north took no part in them. The phenomena were quite like those of Mont Pelée, gigantic cauliflower clouds, a downblast at the southwest, heavy accumulations of broken rock, sand, and dust 50 to 80 feet deep in the gulches, and this material so hot that the subsequent revival of spring waters made explosions in the valleys where the streams made contact with the banks of hot gravel. These banks were crusted over by a shell of rain mud which tended to retain the heat. Down some of the gulches there were doubtless combinations of flood and blast, similar to those described at Santa Maria in 1929 (Volcano Letter No. 356). Glow appears to have been seen above the crater in certain eruptions, and we may conclude that glowing magma lay under the crater lake, but it never reached the stage of lifting a crater plug as on Mont Pelée.

Just after a notably disastrous explosion of Pelée August 30, 1902, Soufreière followed with a damaging eruption that took no lives. This occurred on September 3 in a series of pulsations with detonations. They reached their climax in 20 hours, sending up a black cloud alive with electric displays and accompanied by some earthquakes. Mud flowed down one of the valleys and there was a heavy fall of ash to leeward. An inspection of the crater September 22 showed newly ejected blocks down to 400 feet below the summit, the great pit was 150 feet deeper than it had been, the lip had been lowered on the west, and banks of ash were piled against the northern and eastern walls. Steam rose from a fissure at the south. At the bottom was a small lake of stone-colored liquid in ebullition and sending up steam clouds.

An intense eruption occurred October 14, 1902, with preliminary clouds of dust-laden steam and the rumbling of avalanches at 8 p. m. followed by violent detonations at midnight. By 12:30 a. m. "a ball of fire" was followed by an incandescent hurricane, or cloud, or blast, down the Larikai valley west-northwest from the crater. At Chateau Belair southwest of the volcano stones began to fall about 2 a. m. October 15 and continued for two hours along with strong electrical displays and the rumbling of thunder. Mud fell at 2 a. m., the detonations died away at 5 a. m., there were several earthquake shocks, and volumes of dust-laden vapor rose from the crater for two days. Dust was carried to Barbados, and coarse debris fell to windward.

An ascent of Soufrière October 28, 1902, was made, and volumes of steam were found rising from the crater. Numerous cones of ashes were being thrown up to a height of 40 feet over a fissure close to the southern wall, and the lake was boiling near the center.

A phenomenon of interest November 26, 1902, was a mud flow down the Rabaka River which leads from under the crescent summit of the mountain to the southeast, as an extension of the Larikai valley on the opposite side of the volcano. This river had been completely blocked by ash avalanches during five months of heavy rainfall. Probably a lake formed in the higher reaches of the river. When the dam broke, two raging steaming torrents descended the valley, destroying the remains of a sugar mill, and blocking up the old stream bed near the sea, so that the river now runs in a new channel to the north of the old one.

An examination of the crater by Sapper February 6, 1903, showed that landslides had deepened the gap at the north, that the diameter of the crater was 1320 meters, that the longer diameter was WNW-ESE, and that the lake had dimensions 540 by 340 meters and its height above sea level was 585 meters or 1919 feet, agreeing with the old chart. In other words, the water had come back to the old level. The lake water was boiling in the center and at the southeast corner.

There was not much saddle left between the northern craterlet and the big pit, this region was deeply covered with ejecta, the smaller crater contained a shallow lake 230 feet in diameter, and fumaroles were found in the main crater rim in two places. It is an interesting and unexplained condition that in both Pelée and Soufrière there are main craters forming profound pits well below the summit on one flank of the mountain, just as at Santa Maria in Guatemala, and minor flat cups containing ephemeral shallow ponds close to the summit. Apparently the great active craters are on a radial fracture line and

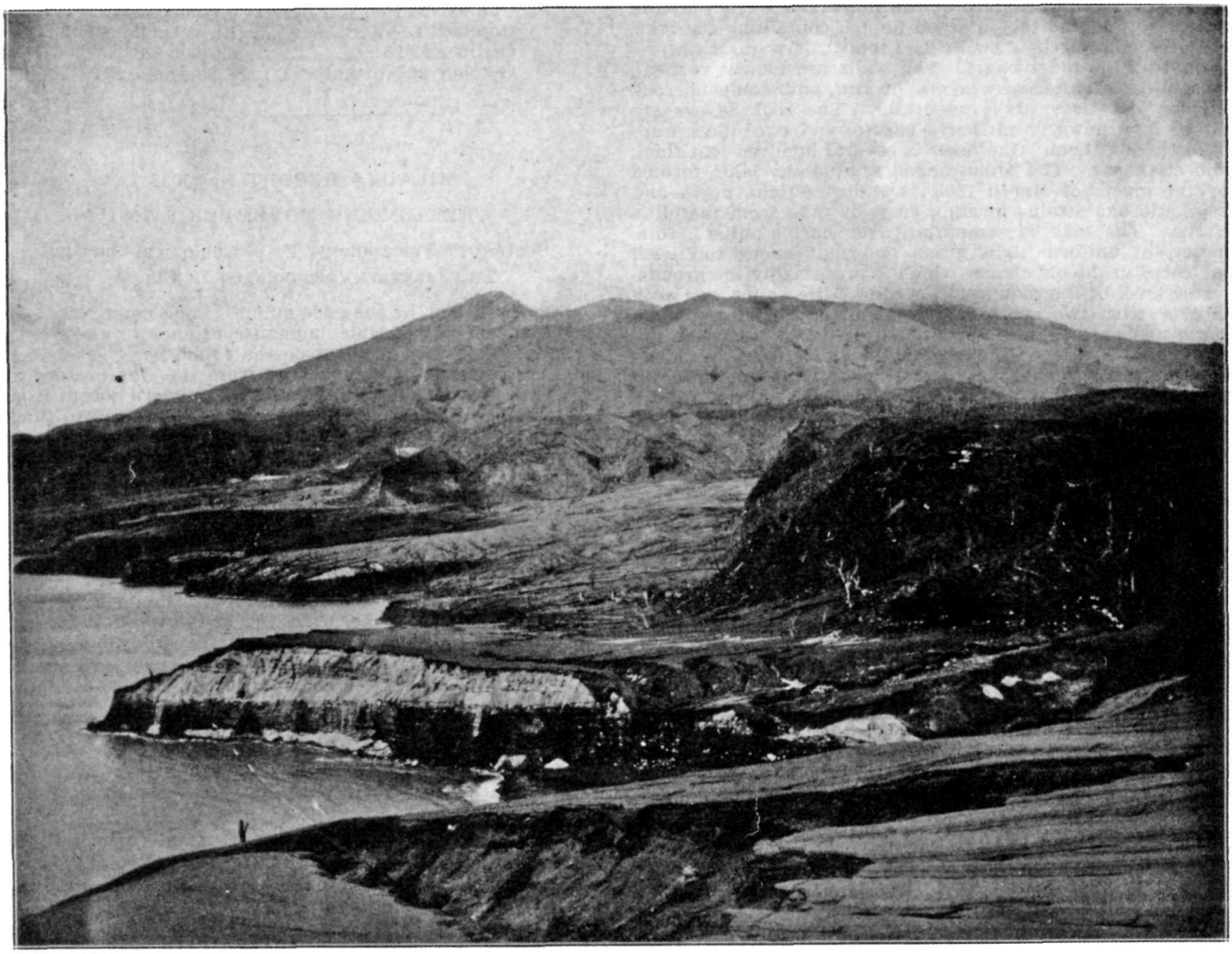
the little summit cups are adjacent to an old outlying lip of some former engulfment, as at Monte Somma on Vesuvius.

Lacroix and Hovey visited Soufrière crater March 3, 1903, hot mud ejections upward through the crater lake were happening from time to time, and these as photographed by Lacroix strongly recall the mud geyser explosions of the Waimangu crater in New Zealand. A sudden descent of a torrent of mud was seen in one of the western valleys. The condition of the slopes was unstable and a cloudburst could easily produce phenomena of this kind. Avalanches were falling at the crater, there was an increase in quantities of small stones and large ejected blocks of old rock on the slopes outside the crater, and the water of the lake was quiet and yellow with mud between spells of ebullition. When agitated it became more gray in color. The geyser-like gush which was photographed arose from the center of the lake as a mass of inky mud entangling blocks of rock. One photograph shows it as seen from the south-southeast rim in process of rising, like sheaves of rockets, with upward jetting shreds in the profile and rounded undersurfaces to each sheaf. At this stage it was a thousand meters high above the lake. A photograph made 20 seconds later shows the nodes expanded into steam clouds and the beginning of showers of backfall. The mass of mud, which rose noisily, fell heavily back with a roar, followed from below by a fresh column of vapor. A heavy shower of mud fell at the rim of the crater. These explosions were seen 50 miles away, and were precursors of the last considerable eruption. Hovey, who had seen the crater in 1902, comments on the rapidity of erosion since the first eruption, estimates that 25 million tons had been carried out to sea by the one valley Wallibu at the southwest, and notes many andesite bombs up to three feet in diameter among the ejecta.

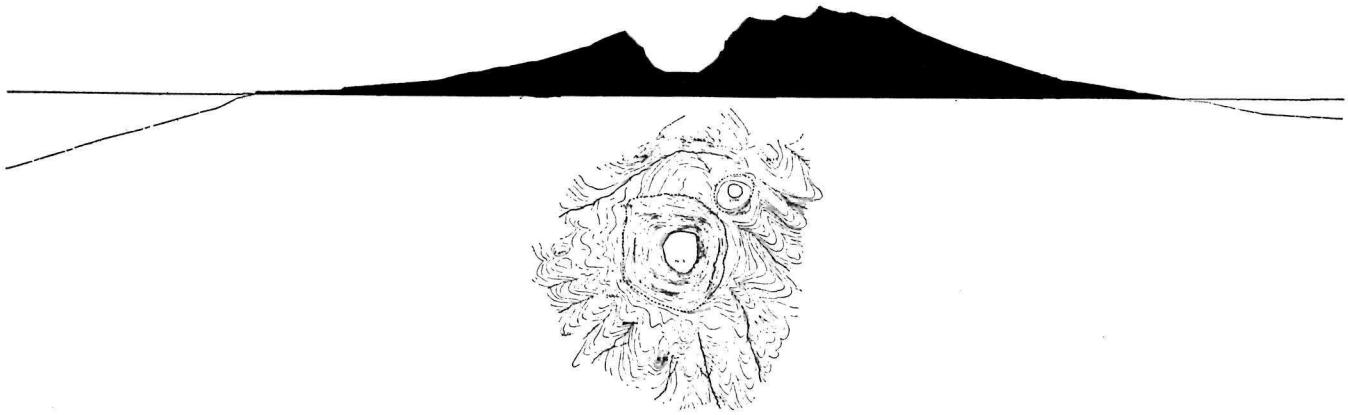
On March 21, 1903, Soufrière crater emitted much steam, on March 22 at 7:25 a. m. an explosive black cloud appeared, of cauliflower shape, rising to a tremendous height and then passing away in all directions. Detonations ceased about 10 a m., but there were later noises from the crater and there were several earthquakes during the morning. Dust-laden vapor continued to rise for nine days. A few inches of dust had fallen at the west coast, and 20 feet of new gravel in one of the ravines, with a hot bomb, weighing 75 pounds, on top of an ash layer. Some illumination at the crater was seen on the evening of March 30.

A visitor at the beginning of April 1903 described the inside of Soufrière crater as changed in appearance with the bottom filled up with chocolate-colored ash to about the old water level. In the center of this new deposit was a narrow funnel, which gradually widened in later months. The southern lip of the crater had been built up with new ash, much of the northeastern wall had caved in, and fissures in the new bottom deposit were steaming.

In the spring of 1907 Tempest Anderson revisited



Soufrière Volcano looking northeast, showing the mouth of Wallibu River in foreground and the ruins of the sugar mill, after the eruption of May 7, 1902. The steep sea cliffs were produced by submarine landslip, and Richmond village was buried under 45 feet of hot gravel. This hot gravel shows white under a coating of wet sand, and up the river the stream water produced incessant explosions in contact with it. Photo Taylor May 31, 1902.



Profile section and map of Soufrière crater made by a sketch survey May 31, 1902, by T. A. Jaggar. Vertical and horizontal scales the same, 0.64 mile to the inch. Bottom of crater 2550 feet below summit, 1660 feet below rim. Diameter crater lip 4870 feet. Coast benches east 60 and 200 feet above sea level. Depth of ocean in profile 125 fathoms east, 530 fathoms west. Profile on line north 66 degrees east.

Soufrière (Report on Soufrière, Part I, 1903, Part II, 1908, Phil. Trans. Roy. Soc. Lon., Vols. 200 and 204), and from his review much of the above is taken. He obtained a new and excellent picture of the inner ash terrace of the crater bottom and the enlarged funnel, containing the lake, restored as a circular pool. The topography was as represented on the older chart. The walls are nearly vertical, consisting of alternate layers of tuff and compact rock dipping outwards from the crater. The rock layers are either lava flows or intrusive sheets, and two dikes were seen cutting them. One layer is several hundred feet thick and columnar. The broad bench around the lake, formed by the ejecta of March 1903, is widest on the north and east, and has a talus forming on it by falls from the cliffs above. The lake is something over half a mile in diameter, of uniform light green color, at about the level indicated in the old charts, which is presumably the groundwater level of the mountain. A very little vapor was seen in 1907 from two spots near the foot of the crater walls south and east. There appeared to be more stones on the ground northeast of the crater than elsewhere, and the deposit of new ash a few feet thick on the southern lip was deeply trenched by rain rills and sloped inward evenly at 30 degrees. The upper section of the northern walls shows continuous tuff beds, while the lenses of andesite below interlock, like a pile of flat fish. (See cut Page One.)

T.A.J.

TILTING OF THE GROUND FOR OCTOBER

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

September 28-October 4	0.4	second N
October 5-11	0.1	second W
October 12-18	1.9	seconds NNE
October 19-25	0.5	second N
October 26-November 1	0.3	second SSW

E.G.W.

KILAUEA REPORT No. 1033

WEEK ENDING NOVEMBER 8, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Conditions at Kilauea are quiet. Crack point No. 25 on the northeast rim of Halemaumau continues to move open steadily at the rate of about one-half inch per week. Dust from an avalanche was observed from the Observatory at 1:50 p. m. November 3. Fume and steam were absent from Halemaumau except on November 4. On this day in thick fog and mist fume showed steadily at the central sulphur spot, and steam occurred on both the south talus and southeast rock slope.

Road work near the Obseravtory has lessened so that there are fewer artificial disturbances on the records. There were 59 tremors, a few probably of artificial origin. There were no other earthquakes of any class.

Tilt for the week was moderate NE. Microseismic motion was moderate at the beginning of the week, increased to strong on the 3rd, and decreased the following day to moderate for the remainder of the week.

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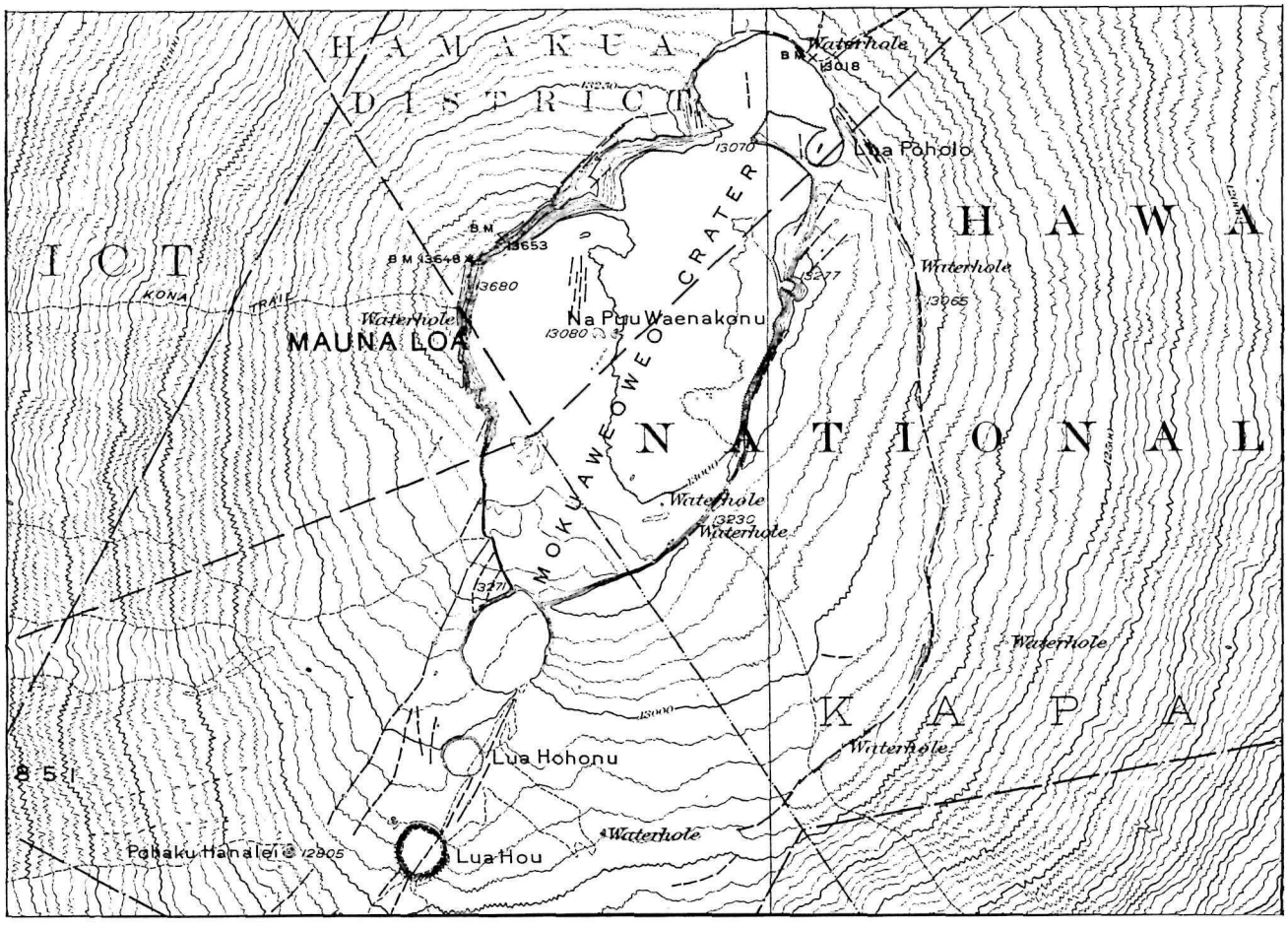


Map of Mokuaweoweo in 1926, topography by E. G. Wingate, scale 1 inch to the mile, contour interval 50 feet outside of the crater, contours largely omitted on the inside. Shows the arrangement by which the crater is a group of coalescing pits in a straight line.

THE CRATER OF MAUNA LOA

The summit crater of Mauna Loa is a sink-like depression or caldera at the meeting point of two fissure belts, the one trending approximately S. 30° W. from the south end of the crater, the other N. 65° E. from the north end of the crater. The crater itself extends these fractures into its western walls, but if the walls were considered extensions of the rifts they would each have to be bent westward, for the west wall of the crater in plan makes an angle of 120° 1.5 kilometers to the northwest of the center of the caldera. The meeting point of the two larger rift systems on the mountain is really at the north embayment of the crater, making an angle as indicated by the above trends of about 145°. The southern rift therefore really extends the whole length of the crater in the direction following the line of pits N. 28° E., thus departing from the northern rift belt 37°. As shown by the modern map on Page One (U. S. G. S. Mokuaweoweo quadrangle) the crater Mokuaweoweo, as the summit crater of Mauna Loa is called by the Hawaiians, really consists of five depressions, of which the second from the north is the large caldera: and this in turn is made up of three parts described as the north and south lunate platforms, and the central more or less circular sink with a group of cones in the middle. It is debatable whether the two lunate platforms were ever themselves separate circular pits in the history of the collapse and merging of the row of pits which has created the crater. It seems likely that they were, for stages of growth of such merging are represented by the order, south pit, north embayment, north lunate, and south lunate, progressively more and more obliterated as distinct circles.

It will be remembered that the Kilauea Crater is at a rather sharp angle between the eastern row of pits and the southwest rift. In like manner on the map of Hawaii the Mauna Loa crater is at a very open angle off to the west of Kilauea, between its northeast and southwest rifts. Both are sinks or subsidence cauldron at the apex of southeastern sectors of the respective domes. The resemblance of both in detail to the craters on the moon, when due allowance is made for scale and gravity differences, will be discussed in another place. In both Mauna Loa and Kilauea the cauldrons lie immediately under the summit points, which in each case stand at an angle of the western wall. The generation of the largest summit pit, therefore, by pulsations of rising and sinking lava, and the overflow of that lava, is directly related to the highest heaping of the lava pile.

In Volcano Letter 325 and 326 the cycle of 132 years in Hawaii after 1792 suggested a building up of increasing lava outflows to 1858, a decline thereafter to 1924, and

throughout the cycle a tendency to big collapses occasionally which may have been produced by submarine outflow. It is of interest to examine the old maps of Mokuaweoweo, the greater center of all this activity, to discover when its floor built up, and when it subsided.

Such imperfect maps as exist have been collated by the writer in four drawings on Pages Three and Four, reduced to a common scale, and drawn with contours of 20 meters interval. The four mappings were by Wilkes in 1841, Lydgate in 1874, J. M. Alexander in 1885, and B. Friedlaender in 1896. To these some details have been added from sketches by other observers. On Page One is reproduced the map abridged from Wingate on the engraved sheet of the U. S. Geological Survey to show without the original details the outline of 1926. In the Wilkes map of 1841 the original summit elevation has been retained on the ground that total subsidence was probable in the half century following, and in any case Wilkes reported a summit point farther north than Alexander, at the main bend of the west wall where there was subsequent caving in. The other maps on Pages Three and Four are drawn to conform to the Alexander summit level. Lydgate's map of 1874 appears disproportionately large, and the size and depth of the south pit is dubious for both Lydgate and Alexander, but it may have been deeper than it is now.

The north embayment in 1841 contained a pit at its western end; in 1874 it was as a whole an elongate pit; after 1885 it contained a pit at its eastern end. The main cauldron contained changing small pits and cones and lava lakes. The conspicuous changes in the crater which the maps show are a breaking back of the western walls to the main fractures originally indicated by Wilkes, and a pronounced deepening by subsidence between 1841 and 1874, followed by filling of the bottom thereafter, and overflowing of the two lunate platforms by this central filling. That the walls cave in was reported by Stearns in August 1924. This was just after the great collapse at Kilauea (U. S. G. S. Water-Supply Paper 616): "During the week at the summit avalanching of rocks from the walls was common, especially on the east side, and made climbing in and out of the great caldera dangerous. At 12:10 a. m. August 23 two smart earthquake shocks were felt in quick succession. The first shock had intensity 4 R. F. and the second intensity 8 R. F. The camp was 40 feet from the rim S. E., and when the earthquakes occurred tons of rock avalanched from the wall in front of the camp, sending up a cloud of dust that was clearly visible in the starlight. Other avalanches were heard thundering to the bottom of the caldera, especially a short distance northeast of the camp. In the morning the pass to the floor, a quarter mile northeast of the camp, was no longer recognizable. A thin section of the rim had fallen down and left a vertical cliff, and a new crack several hundred feet long and over a foot wide had opened a few yards from the brink. Avalanching was frequent all that day, especially at east pit."

Wilkes made the crater a line of four pits and two big platforms. and the circularity of the main cauldron was never afterwards so marked, and it was then the deepest part of the crater. The floor of the cauldron was made of flat sheets of pahoehoe, with ridges 3 to 15 meters high, many fissures trending NNE., and some deep chasms. Wilkes shows a crescent escarpment concentric with the main cauldron in the surface rock of the country separating the south lunate platform from the south pit. This does not appear today, and is of interest in connection with the southeastern plateau shown on the modern map (Page One), bounded by curved fractures on the east and south, which suggests an old greater crater that has been filled up on that side. If these fractures extended around to the southwest, they have been obliterated by later floods of lava, and the crack shown by Wilkes was one of them. In the south pit Wilkes counted 70 horizontal layers, a cascade of frozen lava extended from the lunate platform of the big crater into the south pit, and a great steam crack extended down the mountain southward, and others trended northeast. The only activity was vaporing, especially on the west side of the floor of the main cauldron, and Wilkes mapped 14 cinder cones. one of the inner ones being 61 meters high. Wilkes indicated the cracking, the lava sputter that built cones, the concentric subsidence that built pits, and the sinking fault blocks that connected the pits. He showed that the in-breaking area was a wide isosceles triangle with hinge line at the southeast and apex at the northwest.

Lydgate's survey 33 years after Wilkes, followed five outflows and also the great crisis of 1868 when Mauna Loa had started anew, after an unknown interval, to discharge lava from its low southern slopes. The western wall of the cauldron is a third higher, and the eastern wall twice as high as in 1841. Severance in 1870 had reported the eastern wall still higher (366 meters). Lydgate reported a maximum depth of 320 meters. The southern pit was larger and deeper than that reported by Wilkes. The northern embayment had become a long elliptical pit with two cones on its floor. and Lydgate's report indicated two cones in the main cauldron also. The lunate platforms had sunk deepér and changed proportions. A new southwest extension of the main crater floor contained the active lava pool of June 1874, 153 meters in diameter, and the scene of lava fountains for years after 1872. The floor was rising owing to repeated overflows, and the crisis of 1868 appears to have been a turning point from crateral subsidence to upbuilding of the floor. A subsidence of 27 meters for the summit of the mountain (based on Alexander 1885) is quite conceivable, if there was a sinking of approximately nine square kilometers of crater flooring to a depth of 100 meters between the times of Wilkes and Lydgate. There was 25 years of outflow from 1843 to 1868, implying withdrawal of matter from within the mountain. At least 165 kilometers of lava flow, measured longitudinally as radial ribbons of varying width, was discharged down the mountain slope. Subsiding crest of the dome may follow subsidence of crater floor due to relief by outflow in excess of that balance of pressure of rising lava, which by sill intrusion might keep the crater stationary.

The question of actual height of Mauna Loa is important, for this summit over live lava certainly fluctuates over pressing intrusive magmas which recurrently exude through fissures. Menzies in 1794 made the elevation 13,564 feet (4134 meters); Wilkes 1841 made it 13,750 feet (4194) meters); Alexander 1885 made it 13,675 feet (4168 meters), "obtained with a spherical signal on the summit accurately determined by triangulation from more than 20 stations on Mauna Kea, Hualalai, and in South Kona." The U. S. Geological Survey (U. S. Coast Survey data) made it 13,680 feet (4170 meters) by precise levels from Hilo tide guage in 1926, showing stationary conditions after 1885. Apparently the summit rose between 1794 and 1841, and sank between 1841 and 1885. There may have been some vast outflows of Mauna Loa in the last half of the eighteenth century preceding the great Kilauea eruption of 1790, which accounted for the low level of the summit measured by Menzies.

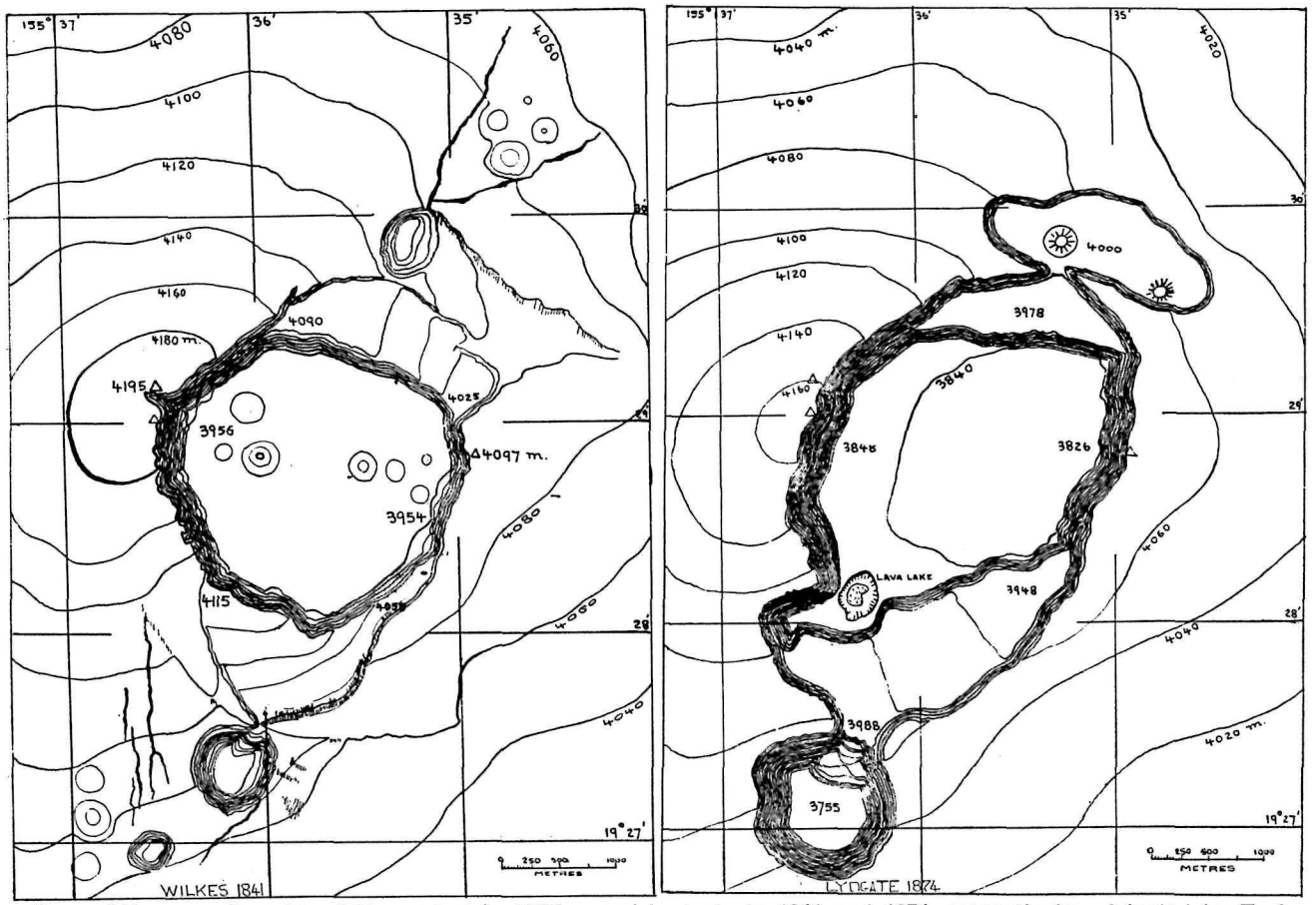
In July 1880 Brigham reported at Mokuaweoweo fresh lava spread over the central floor, obliteration of the inner walls of the lunate platform, talus suggesting recent earthquake, and a lava flow away from the crater on the southwest rim which came from fissures near the brow of the cliff. The flooding of the summit crater with lava from 1872 to 1876 was accompanied by repeated lakings, crater flows, and fountains, and no recorded outflows, except that in 1877 there was a submarine lava flow at Kealakekua Bay. The lava flow of 1881 produced 68 linear kilometers of streaming, starting in November of 1880 after summit effusions in the spring of that year, and taking its origin on the northeast rift 10 km. ENE. from the north embayment of Mokuaweoweo and 3350 meters above sea level. There is a large pit crater where this flow emerged, and the lava divided into two streams, one flowing towards Kilauea. the other towards Mauna Kea, and this latter again divided and its longer arm reached Hilo after nine months of activity.

Alexander in 1885, eleven years after Lydgate, mapped great changes of building up. The south pit was smaller, filled by lateral inflow from wall fissures and from the gateway. The south lunate platform had less relief and was smaller. A fresh lava flow had poured across the platform into the south pit and lava cataracts from cliff-edge fissures had flowed onto the platform. The main floor

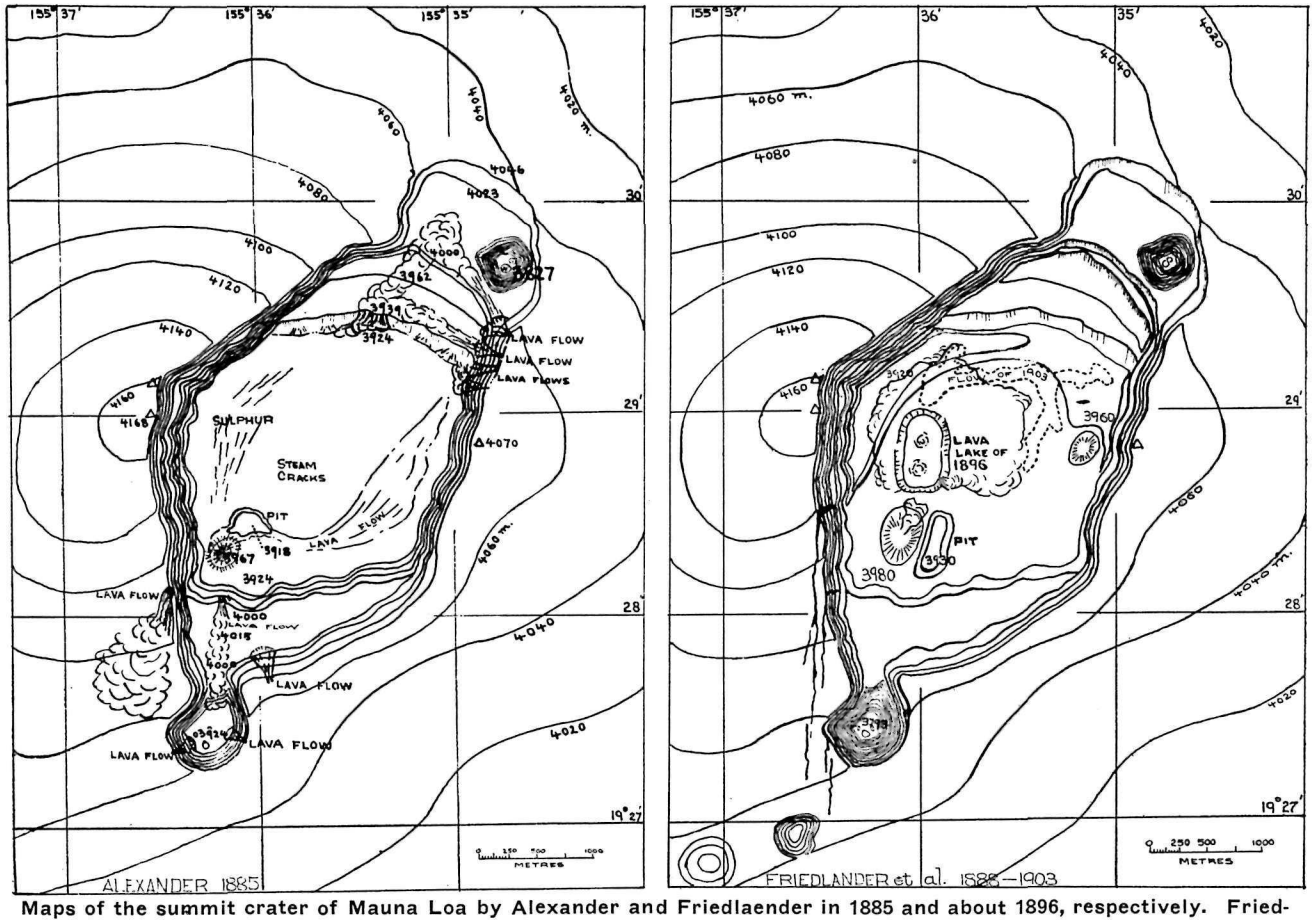
had been built up to new high levels from a vent in the southwest corner. This vent migrated northward 600 meters after 1874; the lava filled 100 meters of depth on the north and east, 80 meters on the west, and 40 meters on the south. The floor apparently sloped away to the northeast from a lava lake at the south just as at Kilauea. The walls had changed, but the northwest angle at the high summit remained the controlling feature of the crater. Alexander saw vaporing from hundreds of cracks in the floor, from the cone at the southwest corner, and from the wall fractures at the heads of the lava cataracts. The floor cracks were streaked with sulphur, the cone was of hot friable lava and pumice 43 meters high, north of it was a solidified lava pool surrounded by a rim six meters high, and the lava of the greater crater floor was pahoehoe. The north lunate platform was overflowed, the promotories had crumbled back. the northern embayment had changed to become a second and higher platform, the western cone was replaced by a lava flow, and the eastern one by a circular pit 183 meters deep and 305 meters across, with a central cone on its floor emitting vapor.

Wood in 1915 (Am. Jour. Sci. May 1916) describes the changes since 1885 as a building up of the floor, submergence under lava of the lunate platforms, and as products of the floor eruption of 1903 a central cone and lava flow, with a NNE rift east of it representing the fresh cones of 1914. The lava flows of 1914 on the floor had covered large portions of the two platforms and the central cauldron. Wood mentions blade lava of extraordinary quality unlike anything in Kilauea, the blades characterizing the texture of the surface of both pahoehoe and aa. Stearns in 1924 indicates the geology of the crater as distributing fresh recent lava, mostly since 1832, all along the line of the crater pits, this widening out into fans of flows at the NNE and SSW slopes of the mountain. He mapped fissures, spatter cones, cinder cones, pit craters, faults. water and ice holes, trails, and fumaroles. The principal scene of eruptions in Mokuaweoweo is a fissure zone about one and one-half miles long extending northeastward from the southwest side of the main crater, and along this zone lie chains of cones. The 1914 cone stands in the southwest part of the floor 100 feet high, is still steaming, and southwest of it is a small crater which contained the lava lake of 1903. Hot yellow pumice lies northwest of it in a field from which dense, blue, sulphur fumes ascend. North of this is a depression 15 or 20 feet deep covered with pahoehoe having islands of aa. Heat radiates from cracks in the floor and rim of this craterlet. Northeast of it is a line of driblet and pumice cones 10 to 75 feet high. The large cone of 1903 near the center of the greater crater, has the remains of another lava lake near it with a hot solfatara west of this lake which is depositing crystalline sulphur. This large 1903 cone lies west of the fissure of 1914.

The fissure zone passes across the south platform up to the rim of the caldera and may be seen in the crater wall. On the rim 200 feet above the platform is a small driblet cone and the lava actually shows as a dike in the cliff below. Southwest from the crater rim is a line of driblet cones which poured out lava that cascaded over the vertical wall of the caldera and spread out on the floor, showing that lava was being extruded on the floor and on the cliff above at two levels different by 300 feet. According to the map by Stearns, which is based on Wingate's topographic map, the country rock east and west of the crater is older basalt showing explosion debris in two marked accumulations northwest and southeast of the central cauldron. T.A.J.



Maps of the summit crater of Mauna Loa by Wilkes and Lydgate in 1841 and 1874, respectively. Adapted by T. A. Jaggar to a common scale and contour intervals of 20 meters. Lydgate's map supplemented by notes of Hall in 1873 and Brigham's discussion of 1880. Lydgate's summit elevation adopted from Alexander in 1875.



Maps of the summit crater of Mauna Loa by Alexander and Friedlaender in 1885 and about 1896, respectively. Friedlaender's outline is based on the Alexander map and is here supplemented with notes by Merritt and Baker in 1888, Guppy in 1879, and Ridgeway in 1903. Adapted by T. A. Jaggar to a common scale and contour intervals of 20 meters.

KILAUEA REPORT No. 1034

WEEK ENDING NOVEMBER 15, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The only noteworthy changes, at Halemaumau are a steady tilt away from the pit, as indicated by the Halemaumau seismograph, and continuous widening at crack point No. 21. Measurements indicate that this point has moved one and one-half inches from October 26 to November 12.

Fume and steam were thin on November 9. Fume increased on November 10 and was thick November 12 after rain.

Because of wet weather road work slackened, and consequently there were fewer artificial disturbances on the records of the Observatory. Of 81 tremors registered, one gave distance 4 miles, 4 gave 15 miles, one gave 18 miles, and one gave 42 miles. Eight tremors were probably of artificial origin. Of six very feeble local seisms, one with indefinite phases showed distance 18 to 28 miles from the Observatory; the others had obscure phases.

Tilt for the week averaged light ESE. Microseismic motion was moderately strong at the beginning of the week, decreased to light on the 14th, and was light to moderate on the 15th.

THE VOLCANO LETTER

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano. also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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The Volcano Letter

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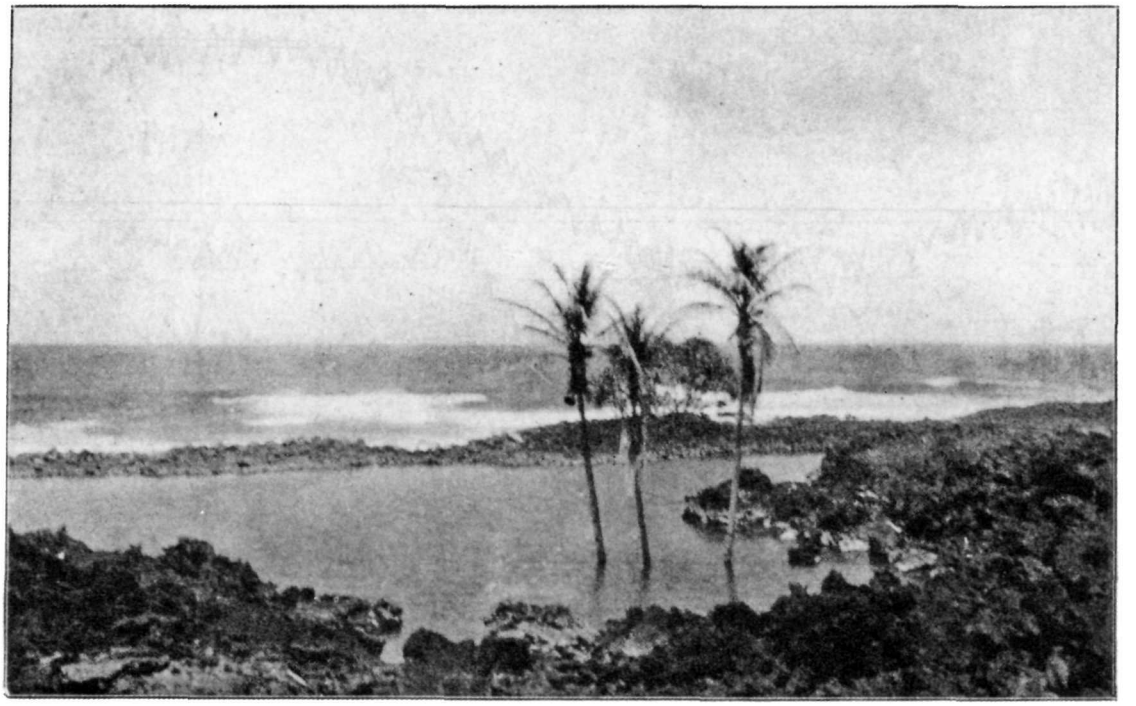
No. 361—Weekly Hawaiian Volcano Observatory, National Park, Hawaii November 26, 1931



Kapele lagoon at east end of Kula fault where a block of land subsided April 21-23, 1924, at the east point of the island of Hawaii. Along with earthquakes and cracking open of the country, this shore line subsided 10 to 12 feet so that these coconut palms, on the date of this photograph, June 9, 1924, and ever since, were submerged with their butts under 8 feet of water. Photo Finch.

PUNA SHORELINE SUBSIDENCE

The Puna District of Hawaii in the vicinity of Kapoho, the east point of the island, was the scene of destructive seismic activity in the spring of 1924. This activity was recorded in Bull. Hawaiian Volcano Observatory April 1924 and in Bull. Seis. Soc. Amer. Dec. 1924. Photographs of the region affected are reproduced in these articles and in the Bulletin of the Observatory for January 1926.

On April 21, 1924, there began a prolonged mild quaking in the Kapoho district, approximately 88 felt earthquakes were counted, and on April 22 and 23 extensive cracks began to open near Kapoho. About 20 pronounced chasms were mapped by an Observatory party. Leveling surveys were run along the railroad by Superintendent Boles of Hawaii National Park, and these indicated a new profile 9 feet lower than before, south of the quarry at Kula, and one foot lower than before at Kapoho station. The block of country between the Kapoho hills and the Kula fault where the greatest downthrow occurred sank in varying amounts from one foot to over 11 feet. At the ocean end of the Kula fault a new lagoon running 200 feet inland was formed, and coconut trees were found standing in 8 feet of water (see cut Page One).

The earthquakes were quite localized and were not felt in Kalapana, about 12 miles to the southwest, nor were any changes in elevation or cracking of the ground noticed in the country south of Kapoho.

Reports, however, have come from time to time during the last few years to members of the Observatory staff of a gradual subsidence of the Puna coast as far south of Kapoho as Kaimu and Kalapana. After a recent conversation with Mr. Henry Lyman of Kapoho, a trip was made through the Puna District for the purpose of verifying, if possible, these reports and gathering further evidence, as well as for locating likely points for future observation and measurement.

The trip was made November 12, 1931, and residents were interviewed at Kapaahu, Kalapana, Kaimu, Opihikao, Pohoiki, and Pahoa; Mr. Richard Lyman of the last place gave information concerning Kapoho and the general conditions of the district. The following was the evidence from different places:

Kapaahu, Kalapana, Kaimu;

Four families were interviewed. None had noticed any change in shore elevation. The washing of waves over the black sand beach and piling back of the sand was thought to be the result of changing currents and unusually high waves. A mark was placed at Punaluu Pond in Kapaahu, and this will be observed from time to time.

Opihikao;

Only one family found at home and these proved to be newcomers.

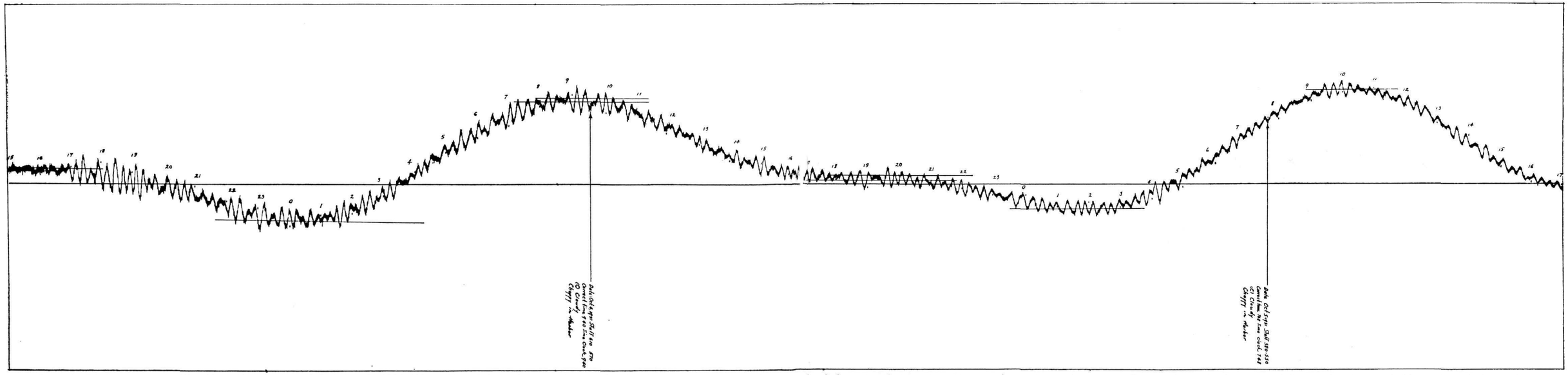
Pohoiki;

One family named Mioi was interviewed. They state as common knowledge in that district that the land has lowered, but are certain that the drop took place during the Kapoho earthquakes of April 1924. They do not connect this tradition with the shore line.

Kapoho;

Mr. Richard Lyman thinks that the sinking occurred entirely at the time of the destructive earthquakes of 1924.

Kapoho crater was visited and it was found that the



Record of tide gauge at Hilo, Hawaii, evening of October 3, 1931 (Hawaiian date), showing trace of seismic sea wave originating near the Solomon Islands in a large submarine earthquake. The earth wave took about 9 minutes to reach Hawaii, and the water wave something over 8 hours. The range of the wave movement shown at the beginning of the disturbance is about 6 inches on the tide staff at Pier One, Kuhio Wharf.

middle one of the three pit craters which formerly had a moderate sized pond with water lilies, had gone practically dry. This is due probably to an unusually dry year. Puu Kukii, which in 1922 was covered with growing cane, is now overgrown with guava except where the 1924 disturbance left a bright red scarp. The Kula fault and Koae were also visited, but showed nothing new.

The investigation indicates that probably shore subsidence has extended from Kula as far south as Pohoiki and perhaps Kaimu, and that this subsidence occurred all at once in 1924 and is not a continued slow movement. The down-faulting corresponds on a smaller scale with that of 1868 in this same district (see Memoirs Bernice Pauahi Bishop Museum Volume 2 No. 4 1909). E.G.W.

Erratum

In Volcano Letter No. 359, Page Four, map of Soufrière Crater, the scale is 0.64 inch to the mile, and contour interval 100 feet. In Volcano Letter No. 360, Page Four, line 8, read "crack point No. 25."

EARTHQUAKE AND SEA WAVE OF OCTOBER 3, 1931

On the morning of October 3 the seismographs of the Hawaiian Volcano Observatory showed the record of a big earthquake somewhere, and indicated that possibly a seismic sea wave might arrive at the shores of Hawaii. On October 22 the London Times reported that a severe earthquake occurred on October 4 (the equivalent of October 3 in Hawaii on the western side of the date line) in the central and eastern areas of the British Solomon Islands. The damage was not serious in the central part of the group, but in the island of San Christoval the earthquake was followed by a seismic sea wave which destroyed 18 native villages with a loss of life estimated at 50. The center of the disturbance was believed to have been in the vicinity of Rennell Island, one of the southernmost of the group.

"The British Solomon Islands protectorate consists of the southern islands of the Solomon group, lying to the southeast of New Guinea. The native population is estimated at 150,000, and Europeans and Asiatics between 400 and 500. The principal articles of trade are copra, green snail, and trochus shell, ivory nuts, pearl shell, and tortoise shell.

"The earthquake was recorded by instruments in England, Italy, Australia, and New Zealand," and all around the Pacific. It was a world-shaking earthquake of great energy.

The primary or P wave of the earthquake arrived at the Hawaiian Volcano Observatory at 8:52:06 a. m. Hawaiian standard time. The secondary or S wave arrived at 8:59:35 a. m. The interval was 7 minutes 29 seconds which by the tables indicated 3680 miles as the distance to the origin. The indicated time of occurrence was 9 minutes 27 seconds prior to the arrival of the first preliminary wave, which would make the big earthquake at the source region 8:42:39 a. m. by Hawaiian time.

For some little time we expected a sea wave, but nothing arrived sufficient to excite notice without the aid of the tide gauge. As the velocity of such an ocean wave has been found to be about 450 statute miles an hour, it should arrive about 5 p. m. of the same day. It should take a little over 8 hours to travel to the Hilo tide gauge.

By an inspection of the records the direction of the earthquake origin was found by the direction of the first disturbance of the pendulums to be approximately northeast or southwest 3680 miles from the island of Hawaii. To the northeast the origin would be in the center of North America and accordingly there would not be a water wave. To the southwest the origin would be off New Zealand or New Caledonia and there should be a sea wave. As there were a number of shielding island chains in that direction, and from what we know by previous experience here, it was decided that a wave would likely be damped out by their shielding action, and in any case not be dangerous. Accordingly no warning was sent out.

Later findings verified these rough estimates. The Coast and Geodetic Survey announced the first tentative location of the earthquake center as latitude 14°south and longitude 160°east, and the time of occurrence as 8:42:48 a. m. H. S. T. The Jesuit Seismological Association gave a second tentative epicenter as latitude 10° south, longitude 161.4° east, and the time of occurrence as 8:43.10 a. m. H. S T.

These placed the epicenter in or near Solomon Islands. The report above quoted verifies this and announces a big tidal wave.

The tide gauge in Hilo bay on the east side of the island of Hawaii shows that the waves began to arrive within 3 minutes after 5 p. m. October 3 H. S. T. The water in the bay rose and fell every 15 minutes for the next 48 hours. The rise and fall averaged about half a foot total range and the motion was so slow as not to be noticed by the casual observer. The record, however, is plainly shown on the marigram (see cut Pages Two-Three), and the very long duration of it is unusual. There was first a lowering of one-quarter of a foot followed by a rise of three-eighths of a foot, with somewhat irregular seiches thereafter for two days.

These waves are so flat that they can not be seen on the open ocean. Since they travel at the rate of 450 statute miles an hour, and 15 minutes apart, they will measure 112 miles from crest to crest, and being less than half a foot high on the open ocean they are not perceptible.

Such seaquake waves in the water, or tsunamis as they are technically called, have been known to continue even for two or three days with slowly diminishing amplitude (Dutton, Earthquakes, page 280). In R. M. Wilson's account (Bull. H. V. O. XVI June 1928) of a tidal wave arriving at Hawaii from the coast of Mexico, the maximum risings exceeded a foot, and there were several recurrences of the smaller waves at intervals, the whole lasting for 24 hours.

In this sea wave of October 4, 1931, the oscillations lasted for 48 hours. There are several ways to account for this long endurance of water disturbance, for some sea waves last only a few hours. There may be reflections or echoes from the coasts near the origin of the earthquake, which would have the effect of adding to the number of wave trains. In this case the waves, large at the source, may have broken up into numerous small ones by the groups of islands and shallows that they pass through. Again, a large body of water, such as is inclosed in any bay or small sea, if once set in motion is very slow to stop and would vibrate in its natural period for a long time after being disturbed. It is difficult to say in what proportions these possible causes affect the lengthening of the record. (See Bull. H. V. O. March 1928, Monthly Weather Review March 1924, and Volcano Letter No. 274 March 27, 1930.)

A.E.J.

KILAUEA REPORT No. 1035

WEEK ENDING NOVEMBER 22, 1931

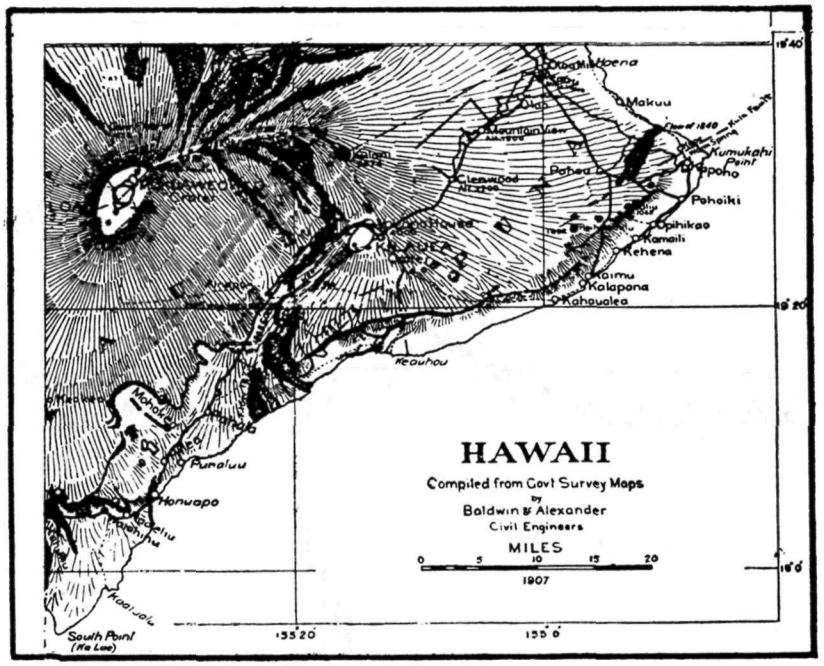
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Kilauea continues inactive. Halemaumau pit shows no significant changes, the fume and steam on the floor varying in visibility according to the temperature and the amount of recent rainfall. A few rocks were observed falling from the northeast wall on the forenoon of November 18. Crack point No. 25 shows a widening of the rim fissure here 5/8 inch between November 12 and November 20, 1931. On November 20 new fallen fine debris was seen on one of the northern taluses. The crack above mentioned is where the rim is breaking down at the northeast by adjustment of the pit circle where a year ago there was heavy avalanching and excessive cracking back of a very precipitous part of the wall.

Artificial disturbances were fewer on the records of the Observatory. Fifty-one tremors were recorded, four of which indicated approximate distances of from 40 to 60 miles. On the 19th occurred part of a teleseism without definite phases. A feeble seism at 6:46 p. m. November 22 was felt locally. Its epicenter was 5 miles from the Observatory. At 5:10 p. m. a very feeble seism was registered with a distance of about 12 miles.

Tilt for the week was slight NE. Microseismic motion was moderate, becoming strong at the end of the week. The tilt or ground movement indicates a quiet condition. What slight tilt has occurred can be attributed to seasonal effects. The number of recorded shocks is less than occurred during the preceeding week. The shocks appear to have originated at greater distances than those of last week.



Map of southeastern Hawaii showing Kilauea, Mauna Loa, and the Puna fault cliffs extending northeast to the Kula fault, where the land on the south side subsided in April 1924. The photograph on Page One is looking seaward on the south side of the Kula fault cliff where it enters the ocean.



Black sands of Kaimu beach in November, 1931, showing invasion of the coconut grove and roadway by the sea. The road is being moved back. Photo Powers.

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The Volcano Letter

362

Two dollars per year **Ten cents per copy**

No. 362—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 3, 1931



New steam vent discovered on south slope of Diamond Peak in southwestern part of Lassen Volcanic National Park. The locality is solfataric but was not known to be steaming prior to the autumn of 1931. Photo taken October 14, 1931, by R. H. Finch, Lassen Volcano Observatory.

CHEMICAL ANALYSES OF KILAUEA LAVAS

One phase of the study of volcanoes which attracts no public attention, but nevertheless is of utmost scientific importance, is the study of the changes which take place in the composition of the lava during the life cycle of a volcano. Geologists may express the composition of a rock either in terms of the kind and amounts of the different minerals which make up the rock, or in terms of the kind and amounts of the different chemical elements contained in the rock. Of course the mineral composition and the chemical composition depend on each other so that a statement of either kind of analysis gives a picture of the composition of the rock. Since an analysis of the chemical composition can be made more accurately and can be expressed in more definite quantitive terms, more attention is paid to determining the chemical composition of different lavas of the important volcanoes which are studied.

Scientists have been studying the chemistry of the lavas of Hawaiian volcanoes for many years. Geologic literature contains first rate analyses of over a hundred different specimens of lava from the several volcanoes of the islands. Part of the work of the Geological Survey is to carry on with this collection of quantitative data. During the past two years, chemical analyses have been made of six different lavas from Kilauea and two from Mauna Loa. These new analyses are given in Table I at the end of this article.

It is obvious that these eight different lavas show very little difference in their chemical composition. Furthermore, the same lavas are decidedly similar in their mineral composition. They all belong to a class of rocks known as basalt. The Hawaiian lavas contain porphyritic crystals of olivine in a groundmass of about equal parts of plagioclase and pyroxene, with glass only in the quickly cooled surface phases (see Volcano Letter No. 348). Not only do the different basalts from Hawaii show a similarity in composition, but they also are remarkably like basalts from other volcanoes in the Pacific islands and basalts from the huge volcanic fields of India, Iceland, and other islands of the north Atlantic, Patagonia. and the Columbia River plateau of North America. This similarity in composition of basalts the world over, together with some other technical reasons, has led many geologists to believe that the whole surface of the earth is underlain by a layer of eruptible basalt of fairly uniform composition. This parent basalt is considered to be the original material of all volcanoes, and the many other kinds of lava with different compositions have all been derived from this basalt by some process of differentiation. The average of 16 analyses of Kilauea basalts, and the average of several other types of this parent basalt, are given in Table II.

The different lavas from Kilauea do not show any great variation from this average basaltic composition. That would mean that no great amount of differentiation has taken place in the lavas during the life of the volcano. This should logically be the case when we consider that Kilauea is a relatively young volcano and probably has lived only part of its normal life cycle. The same is true of Mauna Loa, and the lavas from the present active Mauna Loa do not show very much variation in their composition. It is in the older volcanoes of Hawaii which have completed their life cycle that we would expect to find the greatest change in composition of the lavas, and such is the case. The lava of Puuwaawaa is almost true pumice and obsidian with a chemical composition of trachyte (62 per cent silica, 12 per cent alkalies soda and potash). Also many flows on Kohala and Mauna Kea approach trachyte in their chemical composition.

One of the many problems confronting us is to determine, if possible, how and why this change in composition takes place. The most alluring reason for desiring a solution to this problem is that gold and many other precious metals are associated not with basaltic rocks but with rocks, like the above, which approach a granite in chemical composition. It thus is essential to understand the origin of these ore-bearing rocks in order to learn more of the origin of the valuable ores themselves.

TABLE I

Lavas, Hawaii

1. Olaa. Mauna Loa aa flow, road cut on government road at south boundary of Waiakea Forest Reserve. Analyst J. J. Tahey.
2. Reservoir. Mauna Loa pahoehoe flow, from reservoir at Piihonua. Analyst J. J. Tahey.
3. Quarry. Kilauea pahoehoe flow, National Park quarry, on Hilo road one mile from Observatory. Analyst J. J. Tahey.
4. 1917 Halemaumau. Splash from lava lake. Analyst J. J. Tahey.
5. 1919 Halemaumau. Splash from lava lake during eruption of Alika flow from Mauna Loa. Analyst J. J. Tahey.
6. 1919 Halemaumau. Pahoehoe flow NE edge of floor of Kilauea Crater. Analyist, J. J. Tahey.
7. 1921 Halemaumau. Pahoehoe flow S edge of floor of Kilauea Crater. Analyst L. T. Richardson.
8. 1929 Halemaumau. Scoria from lava fountain. July 1929. Analyst R. E. Stevens.

	1	2	3	4	5	6	7	8
SiO_2	50.41	52.14	51.35	50.14	50.37	50.52	50.85	51.00
Al_2O_3	12.37	13.60	13.36	13.93	14.20	13.85	15.30	13.03
Fe_2O_3	1.94	2.31	1.32	0.57	1.28	0.98	0.28	1.83
FeO	9.56	8.80	9.85	10.07	10.10	9.77	10.42	10.02
MgO	7.68	7.26	7.62	8.25	7.75	7.07	7.80	6.76
CaO	12.56	10.14	10.74	11.17	11.24	11.33	11.45	12.40
Na_2O	1.68	2.02	1.93	1.29	2.20	1.51	.70	2.02
K_2O	0.40	0.48	0.50	0.41	0.56	0.47	.58	0.73
H_2O+110° C.	0.22	0.16	0.29	0.03	0.06	0.04	.18	0.35
H_2O—110° C.	None	0.06	none	none	none	none	trace	none
TiO_2	2.26	2.20	2.50	3.20	2.33	3.63	1.55	2.33
P_2O_5	0.57	0.29	0.28	0.23	0.02	0.22	.22	0.14
Cr_2O_3	0.05	0.02	0.03	0.07	0.05	0.06	.05	0.008*
						less than		
NiO	0.004	0.005	0.025	0.002	0.008	0.001	.002	trace
MnO	0.06	0.07	0.07	0.06	0.14	0.14	.10	0.18
	99.76	99.55	99.86	99.42	100.31	99.59	99.48	100.80

*Quantity of sample insufficient.

TABLE II

	K	D	O	T
SiO_2	49.9	50.6	50.0	47.5
Al_2O_3	12.7	13.6	13.7	13.9
Fe_2O_3	1.45	3.2	2.4	3.6
FeO	10.0	9.9	11.6	9.4
MgO	9.9	5.5	4.7	6.8
CaO	10.5	9.5	8.2	9.8
Na_2O	2.0	2.6	2.9	2.9
K_2O	.45	.7	1.3	1.0
TiO_2	2.7	1.9	2.8	2.7
P_2O_5	.25	.4	.8	.4
MnO	.12	.16	.24	.22

K. Average of 19 analyses Kilauea lavas. 13 from H. S. Washington, Petrology of Hawaiian Lavas. (Amer. Jour. Sci.)

D. Average of 11 analyses Deccan (Western India) lava. H. S. Washington, Deccan Traps and other Plateau Basalts. (Geol. Soc. Amer.)

O. Average of 6 analyses Oregon basalts, H. S. Washington, Deccan Traps, etc. (Geol. Soc. Amer.)

T. Average of 33 Thulean (Iceland-Britain-Greenland) basalts. H. S. Washington, Deccan Traps, etc. (Geol. Soc. Amer.) H.A.P.

LASSEN REPORT No. 30

NEW DIAMOND PEAK STEAM VENT

R. H. Finch, Asociate Volcanologist

A new steam vent was discovered in the Lassen Volcanic National Park during the early autumn of 1931. It is located just below Diamond Peak on the ridge between East and West Sulphur Creeks. This is in the southwestern part of the park near the new road which crosses the mountain mass. The vent was discovered by National Park workmen, and is shown in the photograph on Page One, taken October 14, 1931. As the steam appeared in a clump of trees, the workmen thought at first that they had discovered a forest fire. Adjacent to the new vent, especially on the slope just below, are old solfataric areas. It appears, however, that there has been no activity in this locality for a great many years. Steam escapes from a small vent in the center of an area over which sulphates, chiefly alum, are being deposited. The temperature of the steam is 198 degrees Fahr. The photograph was taken with a view to making later pictures that will show changes in chemical erosion, etc.

The map shown on Page Four is a reduced copy of the topographic map of Lassen Volcanic National Park surveyed by E. P. Davis and R. G. Stevenson of the U. S. Geological Survey in 1925-26. The new road between Upper Meadow and Helen Lake has been completed since the map was made. Mineral, headquarters of the Lassen National Forest, where the volcano observatory is located, is three miles outside of this map to the southwest. Lassen Volcano is in the middle of the west part of the park, the Loomis Museum (where seismograph No. 2 is located) is at Reflection Lake inside the park northwest, and Mount Harkness (where seismograph No. 3 is in the forest ranger station) is just inside the park at the southeast. Cinder Cone and its lava flows lie between Snag Lake and Butte Lake in the northeast corner of the park. The principal hot and boiling spring areas, and the solfataric deposits, and steam jets which accompany them, are in the south-

western part of the park amid the mountains of the northwestern end of the Sierra Nevada above which Lassen Peak stands as an imposing volcanic cone 10,453 feet high.

R.H.F.

KILAUEA REPORT No. 1036

WEEK ENDING NOVEMBER 29, 1931

Section of Volcanology, U. S. Geological Survey

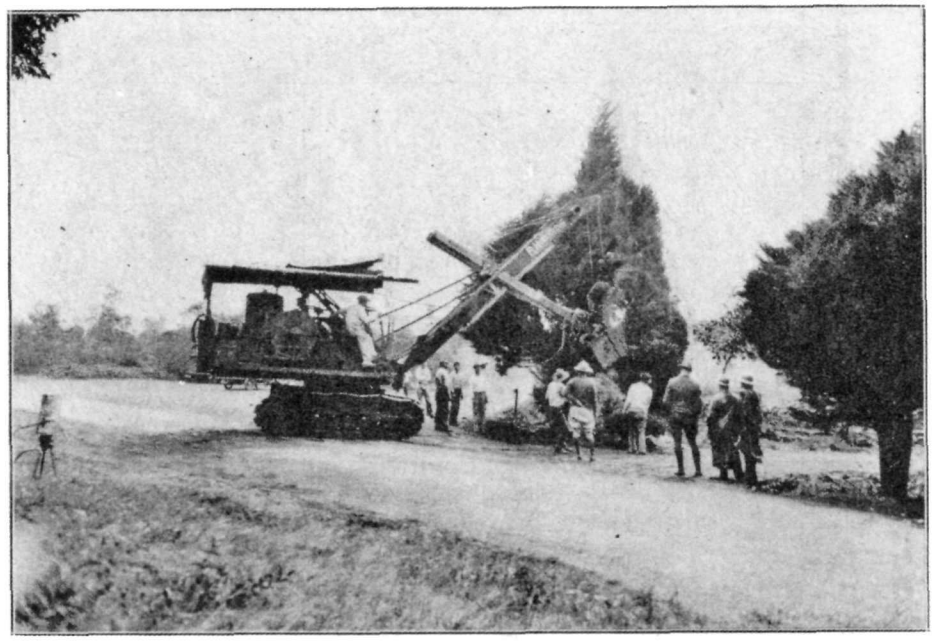
T. A. Jaggar, Volcanologist in Charge

No significant changes in the bottom of Halemaumau pit have occurred. The crack at the northeast edge, No. 25, opened three-quarters of an inch November 20-30. Measurements show a lowering of the rim block adjacent to the crack about one foot between October 26 and November 23. At 10:35 a. m. November 24 an avalanche producing much dust occurred at the northeast wall of the pit under this crack.

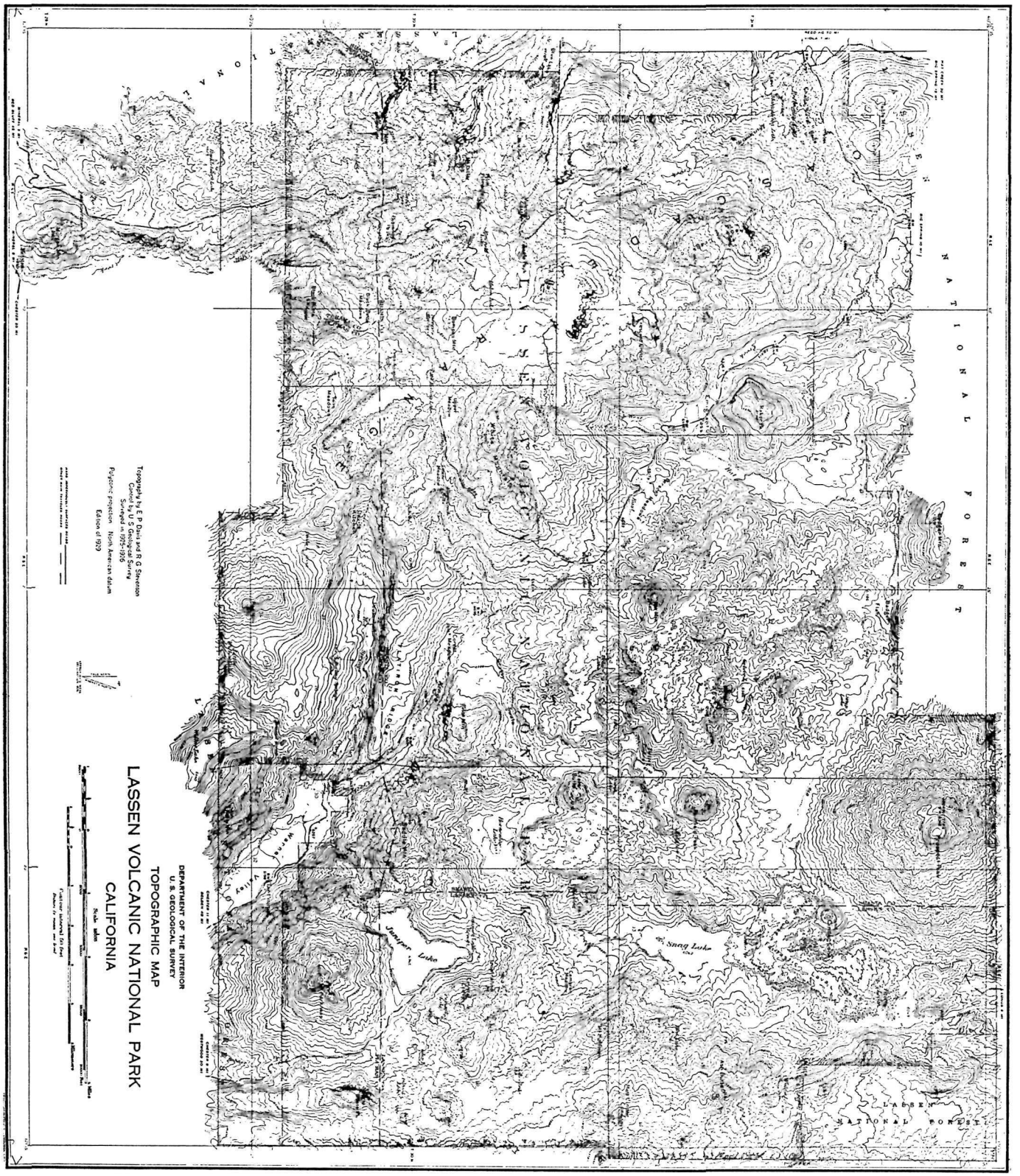
Designs have been drawn and preparations made for rebuilding the seismograph hut at Halemaumau with the cooperation of the National Park Service.

During the week 22 volcanic tremors were registered at the Observatory on the northeast rim of Kilauea Crater as compared to more than 50 of the next preceding weeks. Four gave evidence of distance of origin, one 20 miles, and the others 40 miles. There were two other disturbances possibly of artificial origin, but doubtful.

Two very feeble local seisms were registered, one indicating origin distance about 1 mile, the other about 20 miles. Microseismic motion has been very heavy during the week, probably owing to ocean waves pounding the steep shores of the island, as there has been some strong wind. Tilting of the ground has been very slight NNW. General conditions indicate volcanic quiet, the tremors show about the same distance of origin as the week before, and one of the very feeble shocks indicates origin close at hand, the other far enough away to have occurred under Mauna Loa.



Contractor moving cypress and Japanese cedar trees back from the road front, for purposes of new road construction, Hawaiian Volcano Observatory. Large pits were dug to receive the trees, black fertilizer and loam mixtures were prepared in the pits, and the power shovel with caterpillar treads lifted each trunk with its ball of soil and deposited it at its destination. Photo Jaggar.



Map of Lassen Volcanic National Park, U. S. Geological Survey 1925-26. Seismographs of the Section of Volcanology are maintained northwest. southwest, and southeast of Lassen Peak, as described in the text.

The Volcano Letter

363

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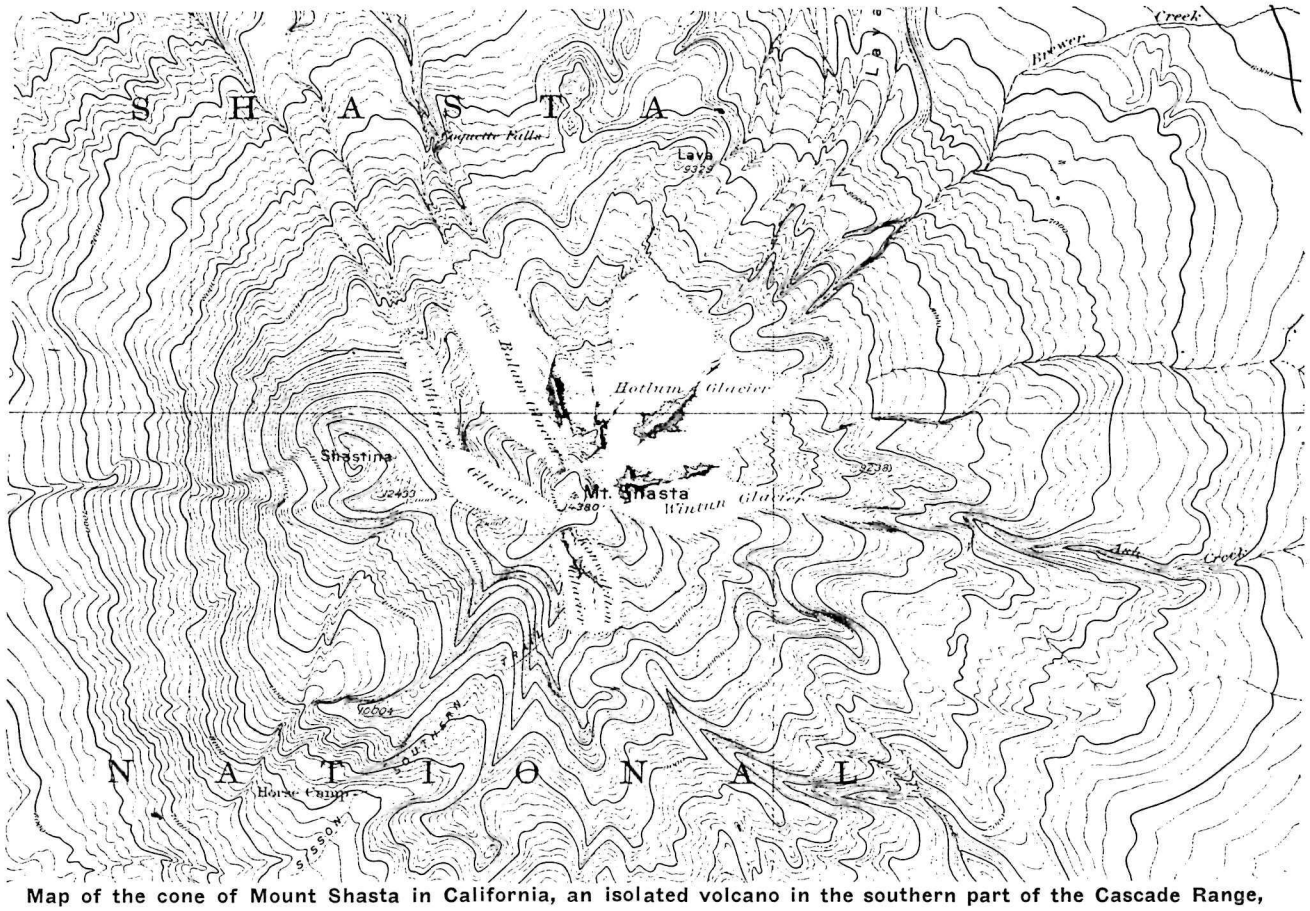


Map of the cone of Mount Shasta in California, an isolated volcano in the southern part of the Cascade Range, with hot springs and steaming vents, and well marked old lava flows about the flanks. Like most of these cones, remnant glaciers surround the summit, which stands 14,380 feet above sea level.

THE ACTIVE AND RECENTLY EXTINCT VOLCANOES OF NORTH AMERICA

Review by G. L. Chang

The most prominent fact brought out by a study of the geographical distribution of volcanoes is that, with but few exceptions, they are mostly situated on the borders of continents or on the ocean's floor.

The volcanoes of North America form a part of a great system of volcanic vents which may be said to surround the Pacific Ocean. This chain of fire beginning in Terra del Fuego extends along the west border of South America, where its course is marked in the Andes by some of the loftiest igneous mountains in the world; it is narrow and well defined on the west border of Central America and far into Mexico, where still steaming craters, some of which are among the highest summits on the continent of North America, define its position. The volcanic belt broadens in the northern part of Mexico and the United States, but is marked by few active craters. Again contracting and approaching close to the ocean's shore, and in several instances marked by island volcanoes, the igneous belt follows the coast of British Columbia and Alaska, and extends westward throughout the length of the Aleutian Islands. Still active craters in Alaska show the positions of earth fractures which unite the volcanic belt of the new world with the still more energetic volcanoes of Kamchatka, Korea, Japan, Formosa, the Philippine Islands, New Guinea, New Caledonia, New Hebrides, and New Zealand. The length of this vast system of active volcanoes, from the southern end of South America about the Northern Pacific to New Zealand, is about 30,000 miles. Within the embrace of the great curve, and rising from the deeply submerged floor of the Pacific, are many volcanic islands and still active craters.

A branch of the western arm of the volcanic system just referred to embraces Java and Sumatra. A corresponding offshoot of the eastern arm is marked by the volcanoes of the West Indies.

It is a matter of observation that the loftiest moun-

tains of a continent face the largest ocean washing its shores. In a similar way it may be remembered from a study of the distribution of volcanoes that the largest volcanic belt in the world embraces the largest ocean. Whether this association indicates an essential or genetic connection between the height of mountains, the prevalence of volcanoes, and the extent of water bodies, remains to be shown.

The volcanic areas of North America form a part of the great Pacific belt, but include an exceptional portion of it, since from central Mexico to southeastern Alaska there are chiefly dormant vents. In this interval of some 4,000 miles, however, there are many recently extinct craters, as well as hot springs and geysers. It is in this break in the chain of steaming craters that the breadth of the volcanic belt is greatest. This coincidence is significant of some subterranean change.

An examination of the map of North America, in which the positions of most of the active and recently extinct volcanoes are indicated, will show that active volcanoes are confined to the western portion of the continent, and for the most part to the immediate border of the Pacific. No volcanoes sufficiently recent to be recognized by their topographic forms occur east of the sharply defined eastern border of the Cordilleran mountain series. The central and eastern portions of the United States, the central, eastern, and northern portions of Canada, and much of Alaska excepting its immediate southern border, are without evidence of recent volcanic activity. No active or recently extinct volcanoes have been discovered in the Greenland region. Iceland, as is well known, is an active volcanic center.

The most recent volcanic rocks in all of the vast region just referred to—east and north of the Cordilleran series and embracing five-sixths of North America—are, so far as known, confined to the Atlantic border and occur in the Newark system. They were poured out in part as molten lavas during the mesozoic era, or the middle age of the earth's geological history. Erosion has been so great since the volcanoes from which they came were in activity that scarcely a vestige of the cinder cones or of the mountains they formed now remains. The preservation of such records as still exist is due to the facts that volcanic rocks were buried beneath sedimentary deposits and, for a very long period, so depressed that they were below the ocean's level, and thus escaped removal by erosive agencies.

Still more remote in the earth's history, volcanic eruptions on a grand scale occurred in what is now the Appalachian region and in the Lake Superior basin These ancient volcanoes illustrate the fact that even in the remote past volcanoes were situated on continental borders. When the vents from which the rocks were derived were in activity, the continent had increased but little from its original Archaean nucleus. and the sea occupied the whole of what is now the Mississippi Valley and the northward extension of the same interior basin to the Arctic regions.

The volcanic mountains of the west are nearly all of post-Tertiary age. Some of the lava flows of Idaho, Washington, and California were poured out during the Tertiary and were buried beneath the sediments of great lakes, the date of which is recorded by the fossils they contain.

A portion of the Pacific volcanic belt is only a score of miles wide in Central America, but broadens in the central part of Mexico somewhat abruptly to about 800 miles, and touches both the Gulf and Pacific coasts. A gradual increase in breadth occurs north of Mexico, and in the latitude of San Francisco and Denver it attains its maximum width about 1,000 miles. When followed northward, it again contracts, and in Alaska is as narrow and sharply definied as in Central America. The narrow tapering southern extremity of this volcanic belt curves eastward; its similar northern extremity, which also contracts in breadth towards its extremity, curves westward.

It is in the narrow, curved extremities of this volcanic belt that volcanic eruptions have occurred most recently, and here most of the still active volcanoes of North America are situated. In the broader and less curved central portion chiefly dormant volcanoes occur. (Russell, Volcanoes of North America.)

THE VOLCANOES OF THE CASCADE MOUNTAINS

Review by C. B. Crawford

The Cascade Mountains extend from northern California across Oregon and Washington. Lassen Peak is situated at the extreme southern end of the range; the northern extremity extends past Mount Baker into British Columbia. This range, 500 miles long and 50 miles wide, runs parallel with the Pacific Coast about 120 to 200 miles inland, and its peaks rise 5,000 to 14,000 feet above sea level. The eastern border shows monoclinal structure due to the tilting of fault blocks. Russell suggests that the lava composing the Cascade Mountains, more especially in Washington, is an extension of Columbia lava, which was poured out in successive sheets and afterwards broken, and the blocks thus formed tilted at various angles. However, they are not wholly composed of lava; there are Tertiary rocks of unknown age beneath the lava which have been raised and tilted by the same disturbances. Much of the northern portion of the range is free from lava, the rocks being largely granite and schist, showing that the range as a whole is not of volcanic origin.

The great volcanic peaks hereinafter discussed are of a later date than the uplifting of the main Cascade Range, and owe their origin to the escape of molten material through fractures which were formed at the time of the disturbances. The conclusion that these peaks are of volcanic origin rests in some instances on their general appearance and their occurrence in a volcanic region. None of them is an example of very fresh volcanic activity with the exception of Lassen Peak. Most of these peaks have craters at their summits or on their flanks. They are for the most part the result of Tertiary eruptions and have been modified by erosion, have developed glaciers, and dominate the neighboring mountains.

Mount Shasta is probably typical of the peaks of the Cascade Range. It is a volcanic mountain which has suffered from erosion caused by streams and glaciers. It is 14,380 feet above sea level and its summit is 4,000 feet above the timber line. Small glaciers are still present on its sides. On the west end, 2,000 feet from the summit, is a cone with a crater in its top known as Shastina. On the lower slopes are similar craters, some built of cinders. some of lava. The mountain itself is composed of lava flows with a minor quantity of scoria. On the flanks of Shasta are well defined lava streams which still retain their original rough surface. The longest and most copious of the more recent streams that flowed from Mount Shasta started at an elevation of 5,500 feet. This stream divided into two branches, one of which was 12 miles long. The other entered the canyon of the Sacramento River and reached a distance 50 miles from its source before it cooled. This stream is of ancient date as is shown by the erosion the river has been able to perform in making a new gorge 100 feet deep through the flow. These lava streams, however, show no evidence of having been glaciated, and are considered as being of more recent date than the time when the glaciers starting from the summit reached the plain below; they are subsequent to the glacial epoch. Besides the two principal vents, there are numerous subsidiary ones. There is no history of eruption within memory of man.

Lassen Peak, the most recently active volcano in continental United States, is 10,453 feet above sea level at its summit and marks the terminus of the Cascades. The Lassen Peak district is crossed from northwest to southeast by a belt of volcanic cones about 50 miles long and 25 miles wide. The Cinder Cone is closely connected with Mount Lassen and shows at least two periods of eruption separated by a time sufficiently long to allow 10 feet of infusorial earth to accumulate on the ancient bottom of Lake Bidwell. The first period was one of explosive eruptions which formed the Cinder Cone and ash field; the second of quiet effusion of a large mass of lava. The whole aspect of the Cinder Cone is new, but the evidence demonstrates that the earliest eruption occurred before the beginning of the 19th century. Its age is shown by the relation of the old and new forest trees to the volcanic sand of the first eruption. The living trees grew on the top of the sand but the dead ones were standing at the time of the eruption and grew from the soil beneath the sand. This evidence was thought by Russell to show that the first erup-

tion occurred some 200 years ago and the second more than 75 years ago. The most recent activity occurred 1914-1917 at Lassen Peak in the form of an explosive eruption. Ash was thrown out and large steam clouds were observed. The crater floor was upheaved, rough lava overtopped the rim, and an explosion hole 1,000 feet in diameter was formed. These eruptions were accompanied by blasts from the crater which leveled trees in their path.

The history of Mount Pitt in southern Oregon is similar to that of Shasta. It forms a beautifully regular volcanic cone which shows the remnant of a crater at the summit.

Mount Hood, 11,225 feet above sea level at its summit, is in northwest Oregon. Its summit retains only a portion of the crater walls. In 1888 it was reported that there were still fumaroles on the northeast slope and steaming rifts on the side near what is known as Crater Rock. Sulphurous fumes were very strong. A peculiar phenomenon was noticed in the occurrence of a fumarole in the deeply snow-filled crater. Mount Hood was reported in eruption in 1859 and 1865 (Jillson, Geog. Review, June 1917). A resident reports there was fume from Mount Hood the whole summer about 1886.

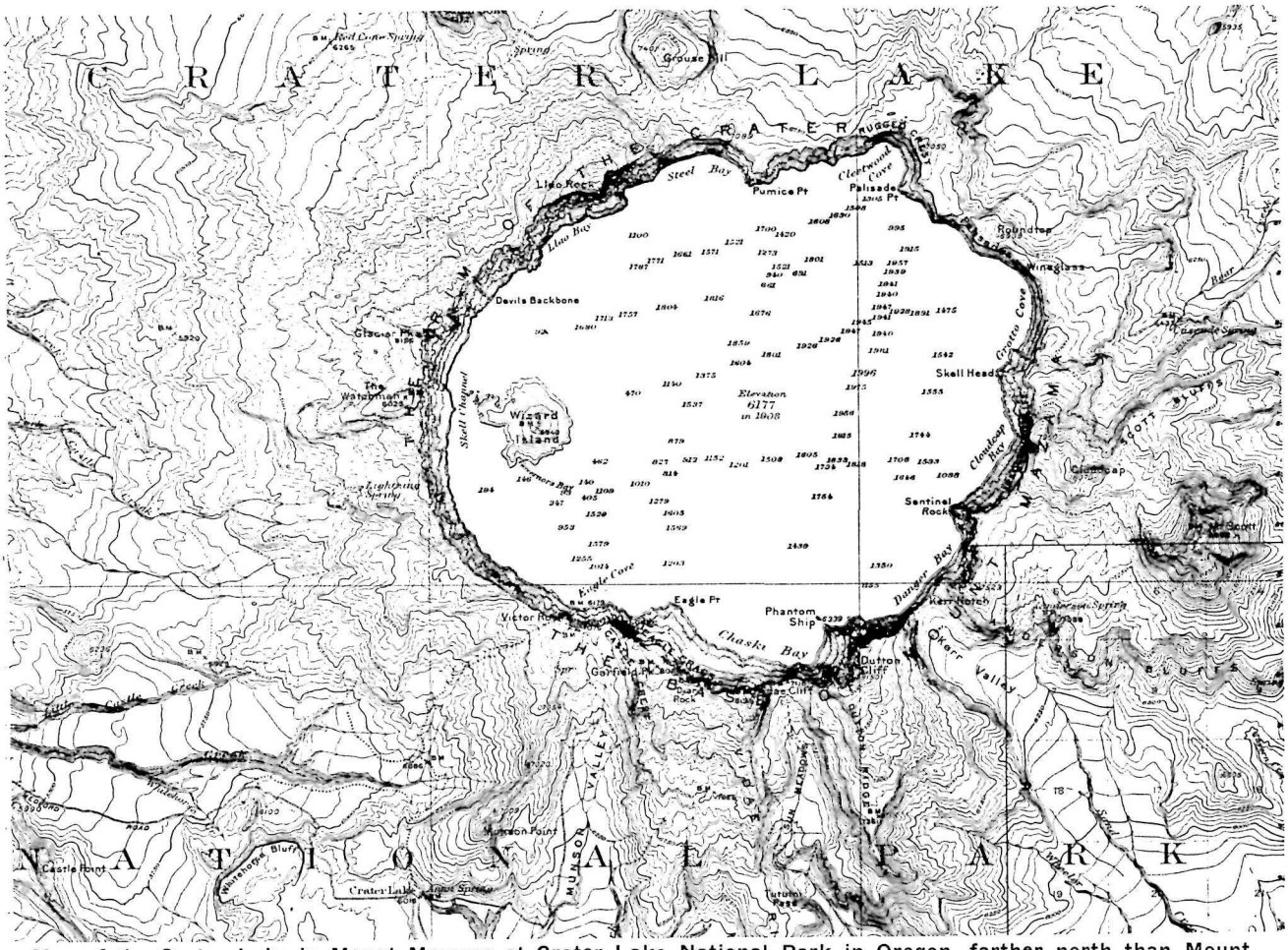
Mount Adams, 30 miles north of the Columbia, is deeply truncated at the summit and its slopes are scarred. It is very broad—possibly due to the great size of the original crater, or possibly to the blowing away of the top. Authentic history is unavailable, as it has not been much studied. It has radiating glaciers.

Mount St. Helens (9,671 ft. high) is of regular conical form, which suggests that it may be younger than Mount Adams. Reports of frontiersmen say that it was in activity in 1841-42. There is apparent from a distance the track of a lava flow which cut its way through the forest for miles. There is also discernible a lava flow northward for about 20 miles through the timber. This flow left many interesting tree molds in its path. When the last flow took place the lava appears to have passed over wet places or areas where the steam generated escaped at the surface leaving what are termed "blow-holes."

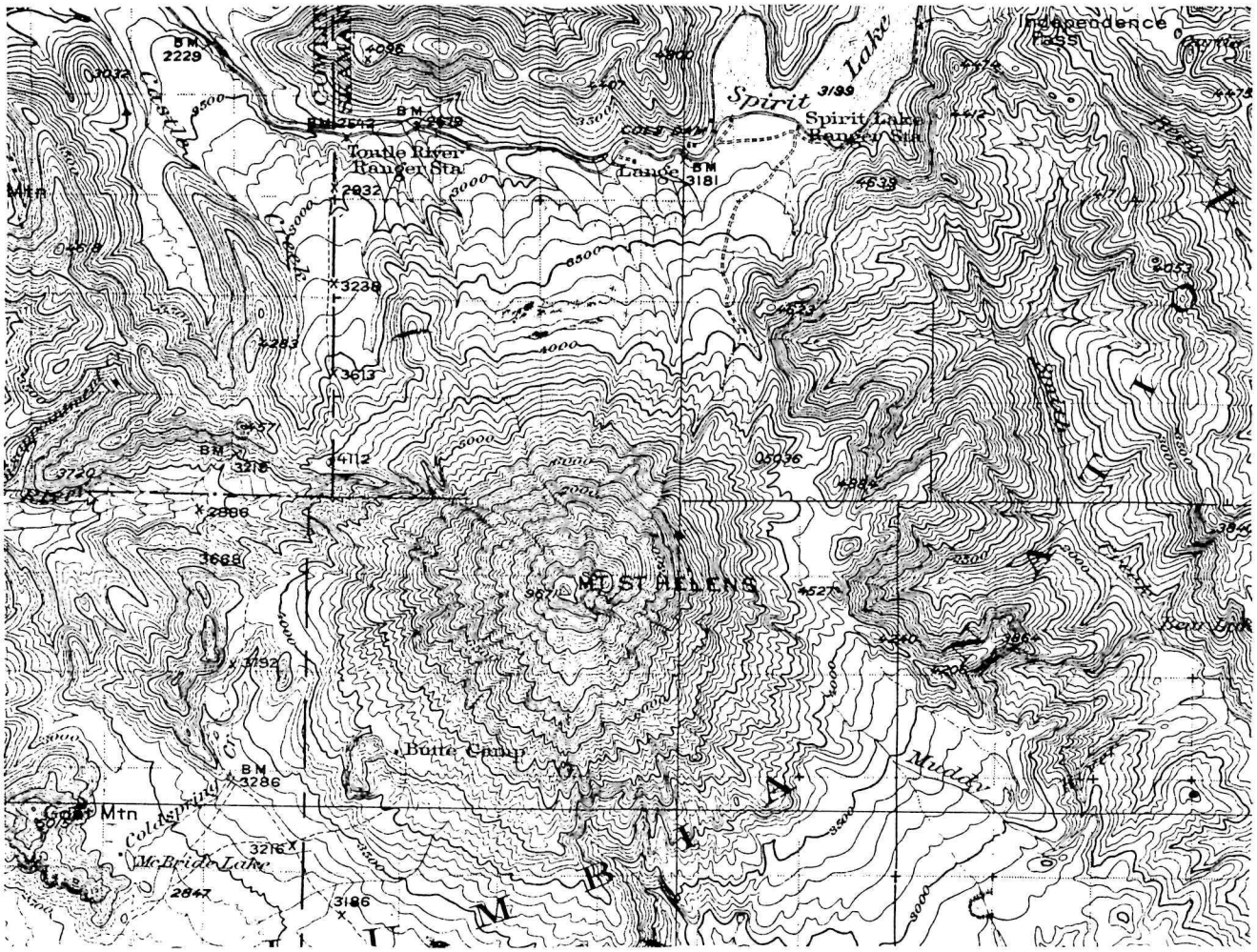
Mount Rainier has a bowl-shaped crater almost circular in form and now filled with snow. Adjoining it are the remains of an earlier crater in the interior of which the more recent one has built itself. There are exposed areas of black lava free from snow which show evidence of internal heat at no great depth below the surface. Countless small jets of steam and gas are present around the interior rim of the crater. No recent eruptions are recorded.

Mount Baker is the most northerly of the volcanic mountains of the Cascade Range south of the Canada line. (See Volcano Letter No. 334 for British Columbia volcanoes.) Little can be said of the history of Mount Baker. The summit is broken, whether due to erosion or volcanic explosions can not be said. Indians state that an eruption occurred about 1843 sympathetic with that of Mount St. Helens, and covered the whole country with ashes, and that the waters of the Skagit River became hot enough to cause the death of all the fish.

Thus the history of the great peaks of the Cascade Range proves to be that of active volcanoes, but now of very slight heat. The history is fragmentary and incomplete. (Largely after Russell.)



Map of the Crater Lake in Mount Mazama at Crater Lake National Park in Oregon, farther north than Mount Shasta. The west rim of this engulfment crater stands 8,156 feet above sea level, and the lake 6,177 feet. The greatest depth of water is 1,995 feet.



Map of Mount St. Helens in Washington State at the Columbia National Forest north of Lewis River. This is a volcano with a record of activity in historic time, elevation 9,671 feet, with radial glaciers, and radial lava flows which have dammed the drainage. Maps U. S. Geological Survey.

KILAUEA REPORT No. 1037

WEEK ENDING DECEMBER 6, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The bottom of Halemaumau remains unchanged, with one fuming sulphur spot and steam on the talus almost absent. Widening continues at a single northeast rim crack where the edge is evidently breaking down. Dust from an avalanche rose at the north rim at 9:08 a. m. December 6.

At the Observatory 24 volcanic tremors occurred, 4 of which indicated origin distances respectively of 2, 4, 46, and 53 miles. Three very feeble local seisms indicated distances of 9 miles for two of them, and 23 miles for the other. Microseismic motion in the middle of the week increased from strong to very strong, and tilting of the ground was moderate ESE.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

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The Volcano Letter

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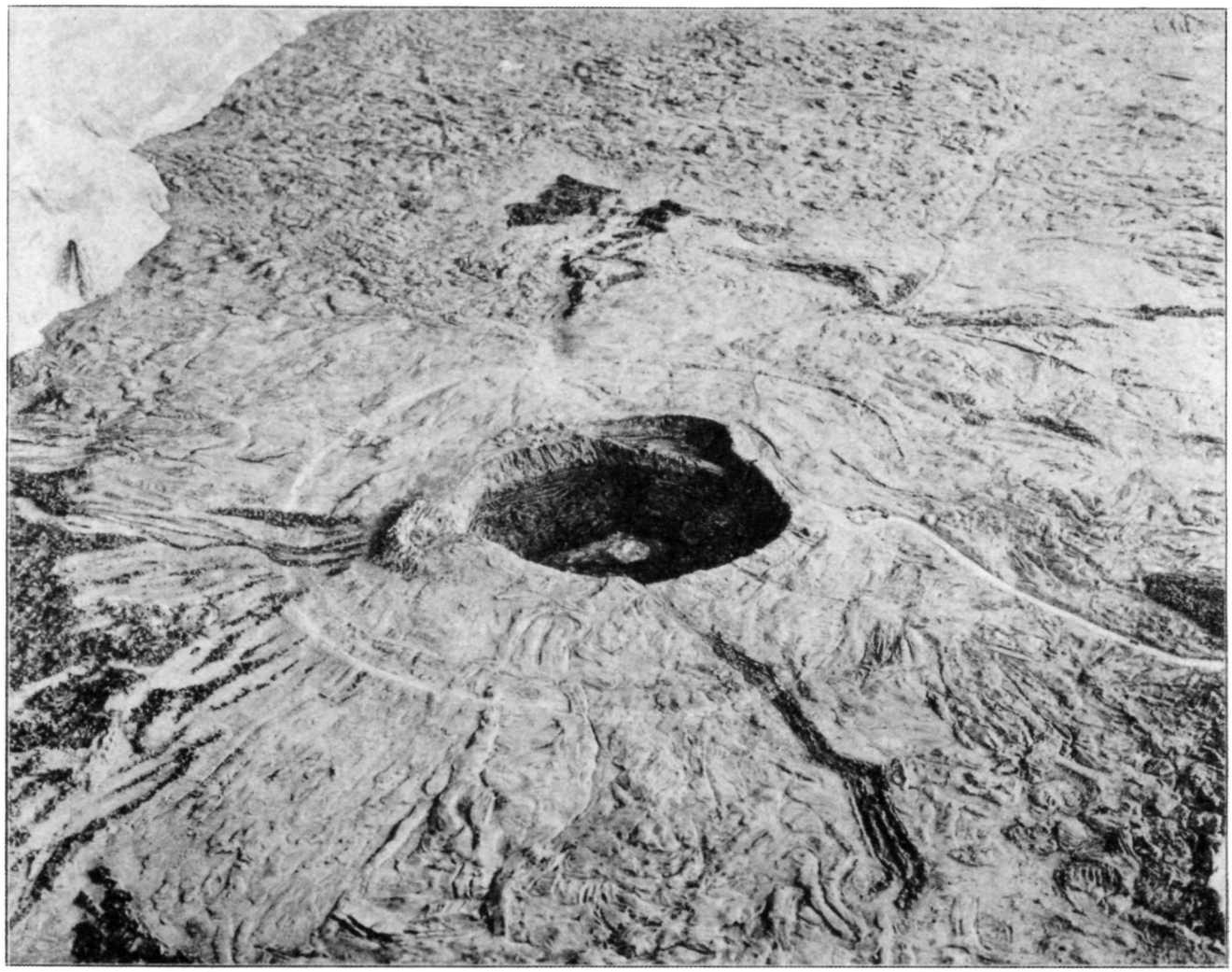
No. 364—Weekly Hawaiian Volcano Observatory, National Park, Hawaii December 17, 1931



Kilauea Crater 1913 looking north. Showing detail of Halemaumau pit when 1,300 feet in diameter. The outer crack of the Postal Card Rift was the trace of the rim of 1894. There was a subsided shelf at the northeast, and huts were maintained at the north rim by the Hawaiian Volcano Research Association. Photo of Curtis model at Harvard University.

THE CRATER OF KILAUEA

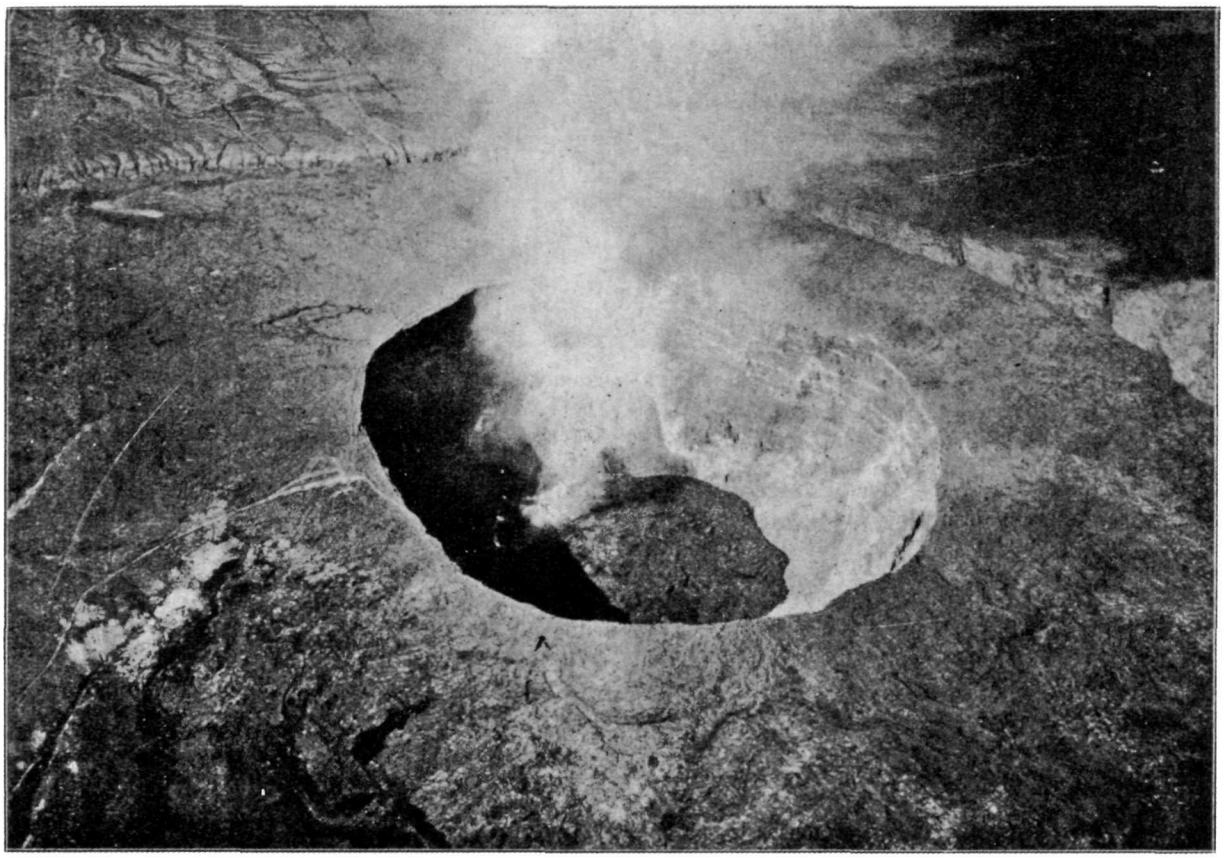
The illustrations of this number are arranged to show the evolution of Kilauea Crater from 1913 to the present time. The cycle 1913-1924 (see Volcano Letters 319, 320, 325, and 326) filled the inner pit, overflowed its rim to build up the floor of the outer crater, and then withdrew the lava, and the inner pit was enlarged by collapse. This 11-year cycle marked for the island of Hawaii the end of a volcanic supercycle of about 132 years, which reached its peak of lava flowing in 1858, and thereafter declined in pulsations of less outflow for both Mauna Loa and Kilauea

Referring to the recently published pictorial review of the evolution of the summit crater of Mauna Loa (Volcano Letter No. 360). it was shown that Mokuaweoweo is the product of merging pits at the angle where two rift lines meet. In like manner the accompanying map indicates that Kilauea Crater has been enlarging by the merging of pits at the angle where two rift lines meet. The rift lines are the southwest Kau Desert cracks that produced the Mauna Iki flows of 1920 far down the mountain flank, and the Chain of Craters fissure that produced flank activities in 1922, 1923, and 1924. The Kilauea angle is almost a right angle shown at the north corner of Kilauea Crater and at the fault cliffs farther north back from the crater's rim. In both Kilauea and Mauna Loa we have to deal with a sector of the mountain flank that has collapsed about its tip at the mountain summit.

The inner pit Halemaumau is the vent that happens to be open near the tip of the sector for the present epoch of activity. Within the last century both Keanakakoi and Kilauea Iki have taken part in this emission and withdrawal of lavas that we call "activity." There were great collapses of Halemaumau in 1840, 1868, and 1886, and in the early part of the 19th century the greater crater of Kilauea was all a large pit with its bottom more than a thousand feet below where it is now. As shown in the contour map, Halemaumau at the peak of the recent cycle was



Airp'ane photograph of Halemaumau pit November 9, 1923, taken vertically with the sun at the east. The earlier pit had been overflowed in 1919, its rim built up, and then had collapsed to a longer diameter of about 2,000 feet. This diameter is approximately coincident with the Kau Desert rift line trending southwest. Photo 11th Photo Section from elevation 4,000 feet. U. S. Army.



Present pit of Halemaumau 3,500 feet in longer diameter, photographed from the air, looking west, November 25, 1930, during the new activity of that period tending to fill the bottom of the pit. The road terminus *is entirely new and 700 feet back of the former one.* Compare oval cracked area outside of pit to the south with the same in cut above. Southwestern rim of Kilauea Crater and Kau Desert cracks are shown. Photo Air Corps, U. S. Army, 11th Photo Section.

at the top of a new heap built up since 1886, which had overflowed extensively in 1894, 1919, and 1921. The cut on Page One shows the large outer circle of cracks which had been the pit rim in the early nineties, but was built up by the action of a smaller inner pit in 1894, until the inner heap had overflowed the outer rim, and all that remained of this earlier wall was a scar. The tendency of a building period to make the pit smaller is what may be expected through the congealing of lava on the older walls of collapse. The same thing happened between 1913 and 1919, the rim shown in the first cut became more perfectly circular and smaller, as shown on the map on Page Four, and the lip of the cauldron was built up about 30 feet, so that the pit was replaced by a heap, with lava lakes on top.

It will be observed in Cut 1 that two crescent niches in the rim of Halemaumau northeast and west were filled up and disappeared during the overflows of 1918-21 (compare map Page Four). In the same way there had been extensive niches and outlying small pits extending the Halemaumau of the decades next preceding 1894. These niches are the sites of subordinate pits that are formed by the rise and fall of lava up and down cracks extending from, and close to, a larger pit. The development of an outlying vent which is at first a crack leads to a concentric structure about a vertical shaft, owing to the tendency of lava to freeze in the narrower portions of the crack, and to enlarge the vent circularly in the wider portions. The remarkably perfect circularity of the structure reaches its best development in an active lava slag-pool within a surrounding bench of its own semi-cooled substance. where by pulsations up and down, the central shaft is finally shaped like a paste-tube, and the convectional circulation builds the marginal rampart equally at all points about a center.

We now come to the phenomena of subsidence illustrated by the two airplane photographs on Page Two. It will be remembered that the culmination of constructional overflow was in 1919, and that from 1920 on, the bottom of Halemaumau subsided strongly, while the lava which it had contained flowed out repeatedly from the flank of Kilauea Mountain. Again and again the lava in the pit frothed up to the rim or nearly so, one such rise making the spasmodic and tumultuous overflow of 1921. The overflow or outflow was each time followed by bigger and bigger collapse at the pit. This collapse was dominantly guided by the deep rift in the mountain to the southwest, so that the resultant enlargement of Halemaumau was to an oval in plan extending the pit in that direction. This is illustrated by the first of the two photographs, taken November 9, 1923, and showing the results of the tremendous subsidence accompanied by avalanches which in May 13-27, 1922, enlarged the pit from a maximum diameter of 1,400 feet to 2,000 feet. The floor of Kilauea just outside of Halemaumau to the southwest had been heating, fuming, building cones, and flowing from cracks for four years. It was undermined by tunnels along the line of the Kau Desert rift, and the largest portion of these tunnels, close to the pit, caved in and engulfed a crescent of rim rock, as shown in the picture.

An object of great interest in this picture is the three-armed lake of lava, which was building up the inner floor in the autumn of 1923. An island stands at the meeting point of the three arms. This clover-leaf arrangement of the inner lakes had happened repeatedly during many years prior to this time. It appears to mark a tendency of the inner heap to fracture by tumescence into three sectors, and there is some reason to suspect that the larger domes of Kilauea and Mauna Loa have tendency to a similar breakage. Thus about the Mauna Loa center there are cracks to the northeast, the southwest, and towards Hualalai; about the Kilauea center there are cracks to the southwest, to the east, and towards Kulani north, (a cone in the forest between Kilauea and the northeast rift of Mauna Loa).

The second airplane photograph of Halemaumau, taken November 25, 1930, again during a period of activity of the bottom, exhibits the enormous pit left by the explosive engulfment of 1924. This is also an oval, its greatest length determined underground by the Kau Desert cracks, which appear in the background. It has now become 3,500 feet long, and a very striking feature of this picture is the tendency to concentric rim cracking, shown especially at the left by faint lines of black close to the rim of the pit, these cracks showing clearly the effort of nature to make a perfect circular funnel. This is the more remarkable as the rock which is so breaking is more than 700 feet back from the edge shown in the upper photograph. This enlargement will be realized if the reader will compare the irregular elliptical broken area of the outside lava surface at the south, which in the picture of 1923 lies away from the rim, and in that of 1930 is on the rim. The road terminus of 1930 is entirely different and far to the left of the road loop shown in the 1923 picture. This older loop would now lie far inside the pit, if it were redrawn on the photograph of 1930. The tendency to circularity by collapse, like the tendency to circularity by upbuilding, must be occasioned by a highly centralized shaft.

This picture of 1930 shows the inner dome of the Kilauea floor surrounding Halemaumau pit, and this dome expresses not only the overflows of the peak of the cycle, but also the tendency to swelling which had been characteristic of that time. This tendency to swelling is also a characteristic of the larger volcanic edifice, and its measurement with tilt instruments is one of the most fundamental scientific procedures for interpreting what is going on inside a volcanic mountain.

The history of pulsations of rising and falling lava, as creating a constructional smaller pit of effusion, and then a destructional larger funnel of subsidence, and this within a short cycle of 11 years, is indicative of the larger process that has made the greater craters through larger ages of activity. The crescent niches at the border of Halemaumau, in the pit of 1913 and the pit of 1923, are closely imitated in the lunate platforms of the Mauna Loa crater, and the two similar ones at the northeast (Sulphur Banks flat) and southwest ends of Kilauea Crater. To such extent as the Mauna Loa niches represent outlying lava pits, they are like Keanakakoi and Kilauea Iki outside of Kilauea at the east. There is a tendency for the walls of the Halemaumau funnel to assume at times a rounded pentagonal outline in plan; the same thing is true of the general plan of Kilauea Crater, and of the inner cauldron of Mokuaweoweo. All of these features are also characteristic of many of the craters on the moon, so that to a volcanologist there is no appeal in the impact theory of lunar craters. T.A.J.

TILTING OF THE GROUND FOR NOVEMBER

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

November 2-8	2.3 seconds	NE
November 9-15	0.7 second	ESE
November 16-22	1.2 seconds	ENE
November 23-29	1.0 second	SE

E.G.W.

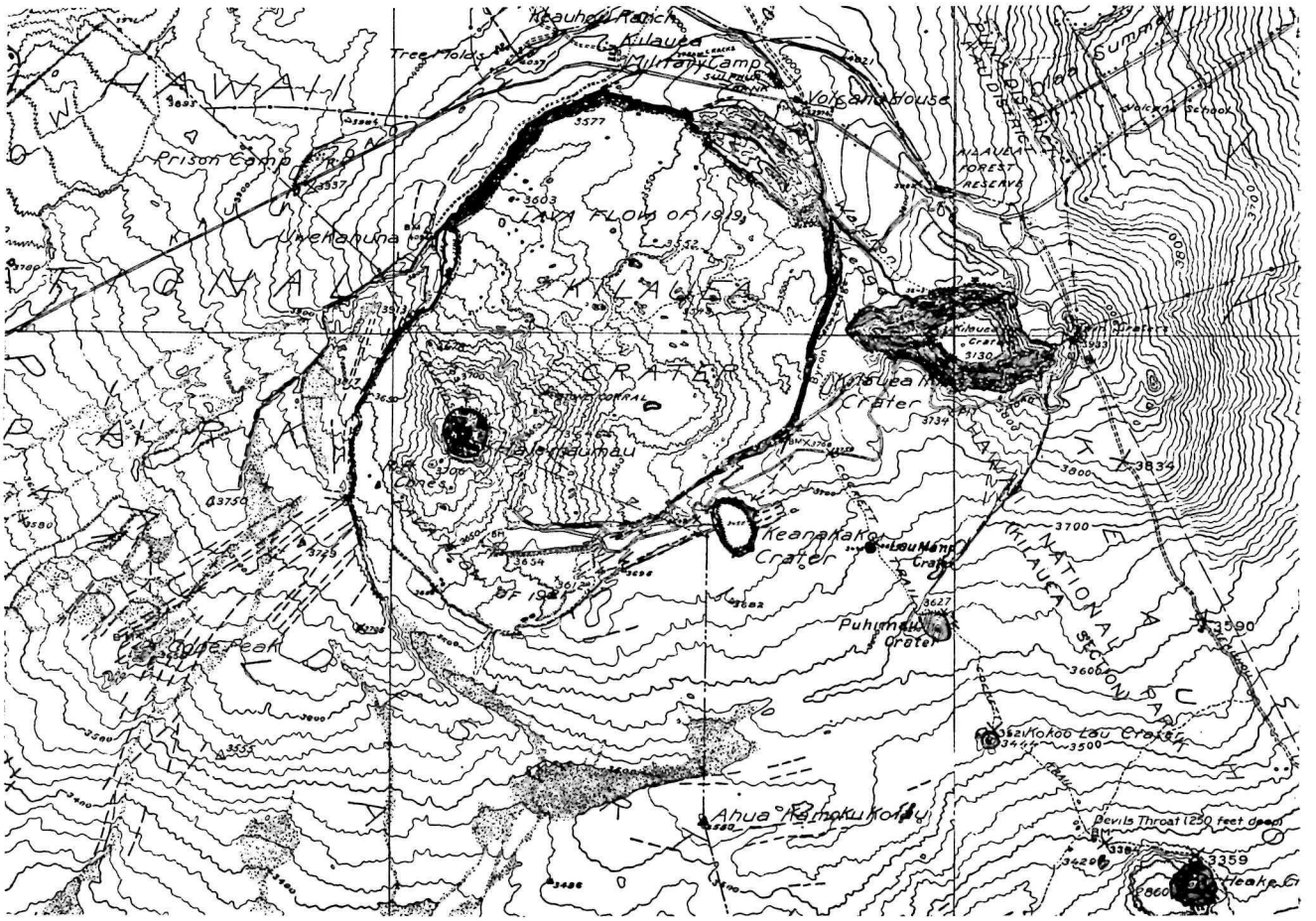
KILAUEA REPORT No. 1038

WEEK ENDING DECEMBER 13, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

On December 7 at 9:50 a. m. there were the usual steaming cracks about Halemaumau pit and on the Kilauea floor which are always seen during damp and cool weather. The fume at the principal sulphur patch on the bottom of the pit appeared denser and rising in puffs. The crack No. 25 at the northeast rim of the pit, which has recently widened. with subsidence of the block on the inner side of it, showed further widening as did other cracks. A small slide fell here at 10:06 a. m. At 3:30 p. m. this rim block fell completely and made an avalanche. A block of the rim fell in from 100 to 150 feet long and from 1 to 20 feet wide. New cracks appeared in the ash for 250 feet



Map of Kilauea Crater, U. S. Geological Survey, showing Halemaumau August 13, 1921, prior to the first collapse and enlargement shown in Cut 2, but after the overflows which had obliterated the conditions of Cut 1. The lava flow of 1919 had filled north corner of Kilauea Crater about 60 feet, and the lava flow of 1921 had filled the south corner and slightly overflowed through a gap as shown by dotted line. From the Postal Card Rift (Cut 1) had arisen flows to the north which created the Postal Caverns. The hot cracks had originally been used by tourists for browning postal cards.

to the north but not to the south. Several small slides were observed after 4 p. m. at the northeast wall, and fresh bowlders lay on the northeast talus. The perceptible earthquake of 10:20 a. m. December 8 dislodged three slides, respectively SW, SE, and NE of the pit, the last the largest. The quake was perceptible at the SE pit rim as a NW-SE swaying. On December 10 in calm weather the fume from the sulphur spot on the bottom of the pit rose in sufficient volume to be seen from a distance rising above rim of pit. This had diminished December 12. After the slides of December -8 the crack widening ceased and some cracks showed a slight closing.

The seismographs at the Observatory recorded 57 disturbances, including twice as many tremors and three times as many small earthquakes as occurred in previous weeks. There were 46 volcanic tremors, 9 very feeble shocks one of which was felt, 1 feeble shock at 12:30 p. m. December 13, and 1 moderate earthquake 10:22 a. m. December 8 that dismantled instruments. This indicated origin 14 miles from the Observatory and persons near Mauna Iki in the Kau Desert reported noise seemingly from Mauna Loa progressing underfoot, and rocks were heard falling down cracks. The tremors indicated origin distances of 6, 9, and 14 miles. the other earthquakes distances of from 9 to 23 miles. Microseismic motion for the week was moderate, and tilting of the ground was light NE.

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The Volcano Letter

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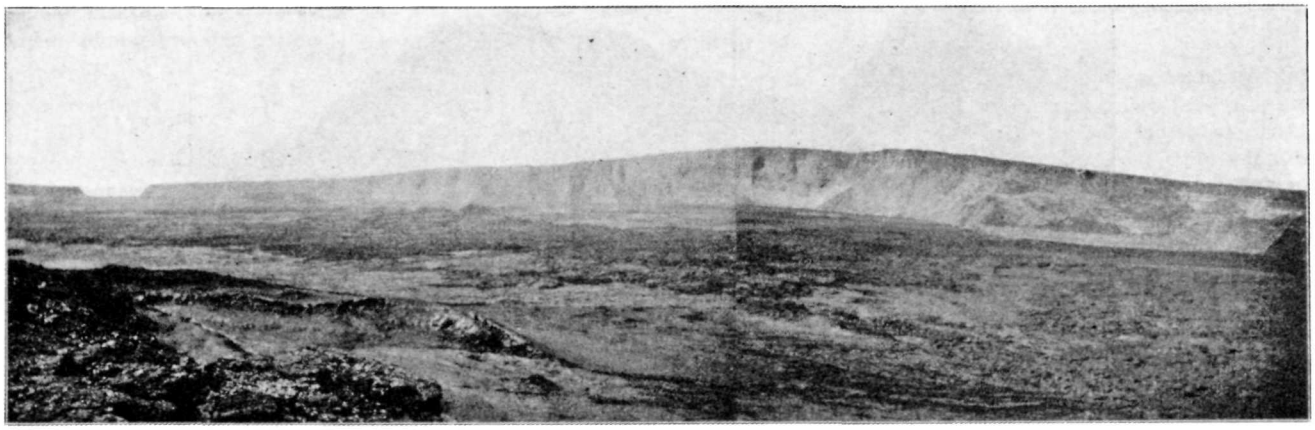
No. 365—Weekly Hawaiian Volcano Observatory, National Park, Hawaii December 24, 1931



Mokuaweoweo Crater December 1, 1931, looking southwest from the rim salient between it and the northesat embayment. The smooth lava in the left foreground is the floor of the crater, described in the text, which broke out years ago simultaneously with one on the rim behind the camera. Photo Doerr.

SUMMIT OF MAUNA LOA 1931

Through the courtesy and cooperation of Superintendent Leavitt and Chief Ranger Christ of the Hawaii National Park, two members of the Volcano Observatory staff were enabled to make the ascent and spend two nights at the summit of Mauna Loa observing volcanic conditions and making preliminary geologic investigations. As no Observatory party has been to the summit crater since R. M. Wilson's trip in 1927, and as the close of one of Mauna Loa's four and one-half year cycles has passed (the last activity being in the spring of 1926), and renewed activity may be expected at any time, it was deemed advisable to make an inspection at the present time before the winter snows set in.

The party which left the Park headquarters at 6:10 a. m., November 30, 1931, was composed of Naturalist Doerr of the National Park. in charge, Powers and Wingate of the Observatory staff, and Rangers Brumaghim and Lee of the National Park. The party went by automobile as far as the Ohaikea tanks, where Levi, packer and guide, had the riding horses and pack animals ready for the trip. Chief Ranger Christ was on hand to superintend the start.

The path from Ohaikea leads across country for about a half mile where it joins the new Park trail, from Brown's ranch and the Bird Park, to the summit. The new trail as far as the Rest House at Puu Ulaula is an excellent one. crossing two tongues of the Keaumoku flow and continuing upward through lovely, grassy glades and groves of koa, mamane, and ohia. Ohelo, aalii, and pukeawe are shrubs which are found in abundance. The stone wall marking the upper boundary of the Kapapala grazing lands was passed at 9 a. m., and from that point the vegetation quickly thins out. At the Rest House, elevation 10,000 feet, which was reached at noon, only a little scattered grass and some stunted ohelo and pukeawe are to be found.

Rangers Brumaghim and Lee left the party at this point to make camp at the Rest House for several days while marking the upper part of the trail. The rest of the party, after a short rest for lunch, continued on to the summit which was reached at 5 p. m. Camp was made in the "Hotel de Jaggar," a partly collapsed lava tube on the northeast rim of Mokuaweoweo. The guide returned to the Rest House with the animals which he reached about 8:30 p. m., after a trying trip in the dark.

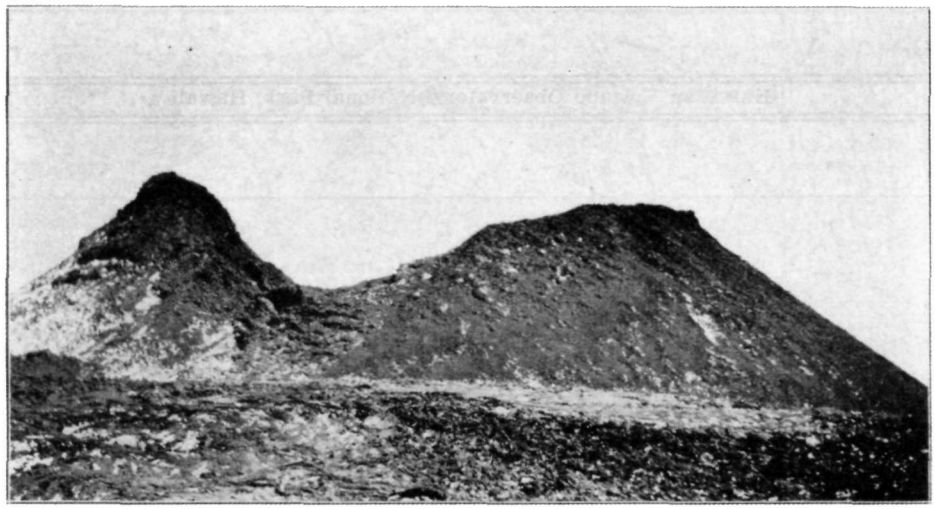
The "Hotel de Jaggar," which has been used for a camp by parties staying overnight at the crater, and by Wingate's topographic party in 1925, was found in rather shabby condition. No attempt at policing the camp apparently had been made for some time.

Due to lack of precipitation on the mountain in the last few years, cracks which held a quantity of ice in 1925 were nearly dried up and such moisture as remained was frozen solid to the bottom. An ample supply, however, was chipped out with a small pick and melted over the fire, for water for the party.

The topographic party in 1926 and 1925 used two small, one piece, kerosene stoves for cooking at the summit camp. On the present trip, charcoal was carried up for fuel and readily proved its superiority, being much easier to pack, and making a more even fire for cooking, as well as being cleaner and less offensive.

December 1 was given to an exploration of the east side of the north embayment. and along the east rim of Mokuaweoweo as far as Wilkes camp ruins, from which point the return to camp was made by following the outlying fault cracks which parallel the east rim of the crater. The party had intended to continue to the south end of the crater, and the head of the upper 1926 flow, but the sky, though clear until noon, had become overcast and threatening, and by 2:30 p. m. snow was falling. During the rest of the afternoon and the evening of December 1 about three-fourths of an inch of snow fell.

The observations made. from a volcanic standpoint, show some changes since 1926, but nothing significant was



Hanalei Peak December 1, 1931, one of the huge cones of frothy lava and slag built up along the northeast rift by the fountains at the source of one of the recent "rift flows." Photo Doerr.

noted. The principal change appeared to be the shifting of the main fuming area from the central part of the crater, in the vicinity of and to the west of the cones of 1903, to the area of the main cone of 1914 in the southwest part of the crater. This cone was steaming strongly and considerable fume was visible at the sunken area west and south of it, and along a few cracks to the east. On the northwest part of the sunken area west of the cone, new patches of sulphur have appeared which are brilliant yellow in color. Steam appeared over this entire area.

Some steam and a little fume were visible in the central part of the crater, which Mr. Doerr said was less than on his visit of November 10 of this year.

Steam along the northeast rift appeared in about the same places and amount as in 1926. Three spots on the floor of the northeast embayment were seen steaming in cloudy weather, and steam appears at one point on the south lunate platform.

As a base for reports by future visitors, a map was prepared showing the locations of the above points with the approximate strength of steam and fume recorded, based on the assumption that very voluminous fume might become visible from the Volcano House, 22 miles away, on a clear day. It is hoped that by this means some check may be kept on visitors' data at the summit crater.

A number of striking geological formations were hurriedly examined. The trail approaches the northeast end of the crater for the last quarter mile over a very shelly pahoehoe flow, which is mantled with khaki-colored pumice and lava froth. The pumice was formed by lava fountains in the northeast rift from which the lava was extruded. This surface flow was formed before the northeast embayment of the crater had reached its present size and shape. It is plainly seen that the walls of the crater are being extended by cracking and slumping of the lava at the edge, and the blocks of wall, which have dropped down most recently, are made up of the same pumice-covered pahoehoe which forms the rim. The floor of the northeast embayment is covered with younger lava which laps up on, and partly buries, some of the huge blocks which have fallen in from the wall. The southwest wall of the northeast embayment slopes rather gradually in its upper part, then is cut off sharply by a cliff down to the lava floor. A small gush of lava has broken out through the loose blocks of the sloping part of the wall and flowed down into the crater. However, this flow is cut off sharply at the cliff. Apparently this small side flow poured out at a time when the crater was filled with lava to the level of the top of the present cliff. Since then, the whole floor of the embayment has sunk many feet, leaving the small feeding flow suspended far above the present floor.

In the southeast side of the northeast embayment is a pit almost circular in shape, much like Halemaumau only a great deal smaller and a little over a hundred feet deep. This pit does not appear on a map of the crater made in 1872, but is shown on one drawn in 1885 (see discussion by T. A. Jaggar in Volcano Letter No. 360). On the east wall of this pit are several patches of cascade lava, remnants of a large lava fall which spilled over the east rim into the pit. This pahoehoe flow came from several large cracks in the outer rim of the main crater about a half mile to the south, and at 200 feet higher elevation. The lava poured out from the cracks, flowed north down the steep slope till it reached the northeast wall of the northeast embayment. Here it piled up high on the wall, then spilled over westward into the small pit. As the lava flowed into the pit, the level of the pond receded about 20 feet, leaving a "high lava mark" of crust and splash along the northeast bank. Part of this same flow tumbled westward over a 200-foot cliff into the main crater. At the same time that the flow was pouring out of cracks on the top of the rim, another flow with its fountains was pouring out from cracks in the sloping floor of the main crater 200 feet below and almost beneath the fountains of the rim flow. The lavas from the two vents, one 200 feet above the other, flowed together on the floor of the main crater. This same strange phenomenon took place in the 1851 eruption from the southwest side of the main crater, only here the difference in elevation, between the floor fountains and the rim fountains was over 300 feet.

While at the summit all of the party suffered from severe headaches and to a slight extent nausea, possibly in part due to charcoal fume.

The lowest temperature recorded on the trip was 22° F at 6 a. m. on December 2.

Very few goats were seen either on the ascent or descent. The descent was made without event, though rain fell over most of the region below the Kapapala stone wall. Park headquarters was reached at 6:30 p. m. December 2.

E.G.W. and H.A.P.

KILAUEA REPORT No. 1039

WEEK ENDING DECEMBER 20, 1931

Section of Volcanology, U. S. Geological Survey

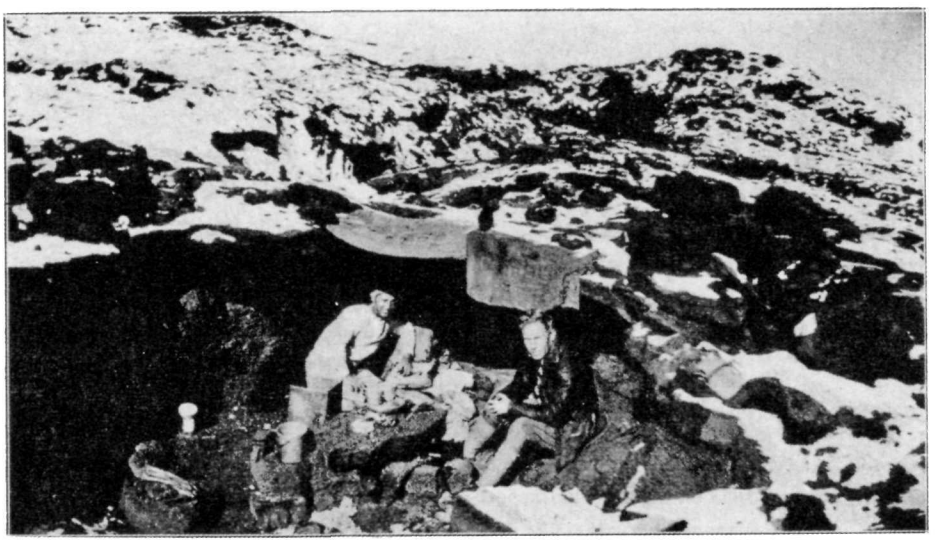
T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains stationary and inactive and the increased seismic activity of the previous week proved temporary. At the pit a few rocks were heard falling at the northwest wall at 9:55 a. m. December 14. Crack measurements showed a decrease of width SE, and slight widening E and NE. Crack mark No. 25, which recently showed excessive widening, is now stationary. A noisy avalanche was heard at 4:10 a. m. December 16, and subsequent inspection of Halemaumau showed fresh debris on NE talus. There were other fresh scars on the walls NW, S, and SE. Crack measurements showed no change in the rim.

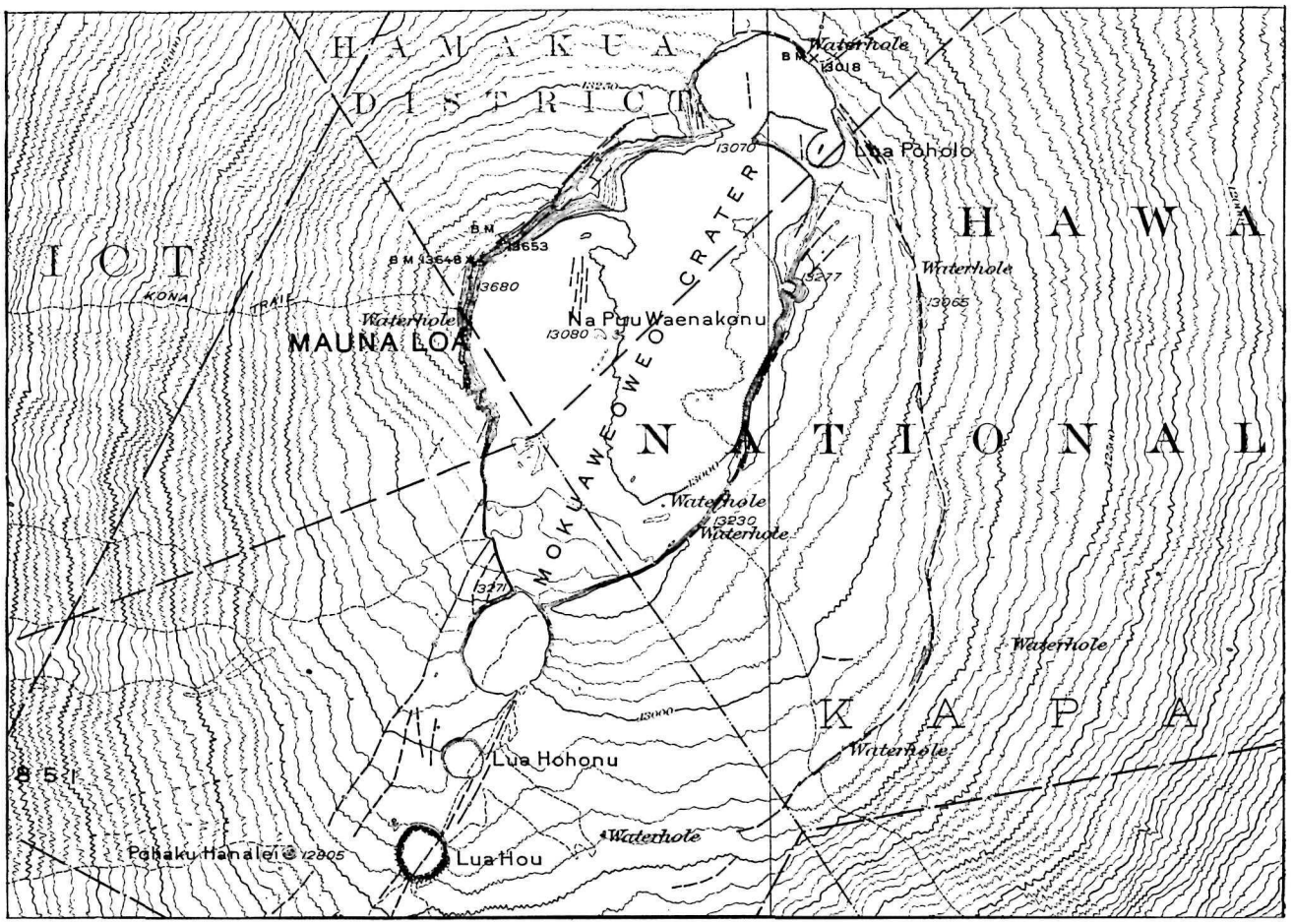
During this week the Park force has excavated a new seismograph cellar near Halemaumau and construction is in progress.

Thirty-four seismic disturbances were registered at the Observatory, of which 28 were tremors, and 6 were very feeble earthquakes, of which four indicated origin distances of 4. 9, 14, and 18 miles. The last at 10 minutes past midnight the morning of December 16 was felt at Kapapala Ranch. Its duration was approximately 15 seconds and its estimated origin distance agrees with the ranch distance within a mile.

Microseismic motion was heavy December 14-16, moderate to heavy December 17-19, and very heavy December 20. This was probably due to heavy seas on the Hamakua cliffs. Tilting of the ground was moderate ENE, with increase and change to the east beginning December 16.



Hotel de Jaggar, the collapsed lava tube which is used as a camp by parties staying at the summit. The "bedroom" extends back about 20 feet behind the men in the ""kitchen." Photo Doerr, Dec. 1, 1931.



Map of Mokuaweoweo, the summit crater of Mauna Loa, by E. G. Wingate, surveyed in 1925-26, U. S. Geological Survey.

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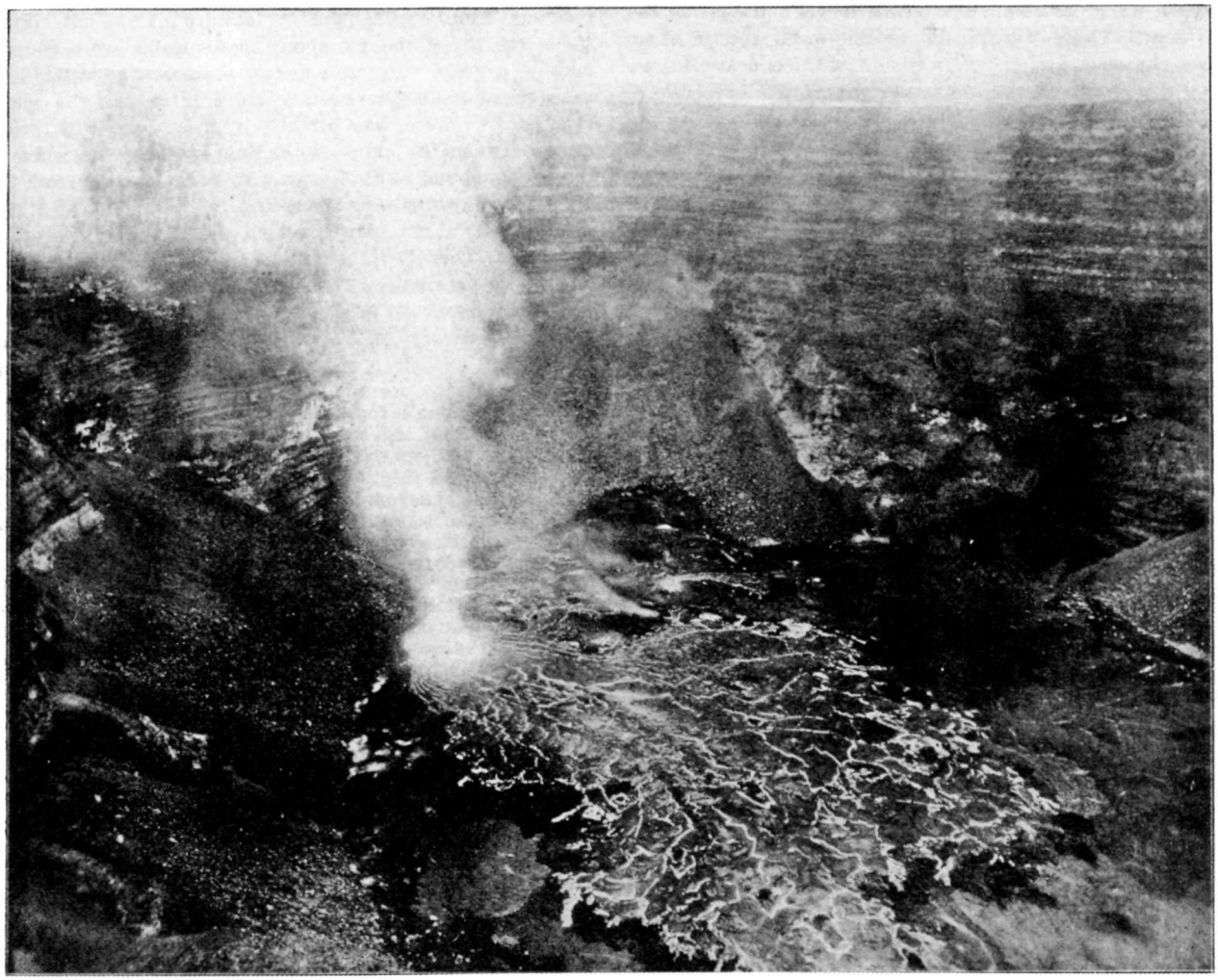
No. 366—Weekly Hawaiian Volcano Observatory, National Park, Hawaii December 31, 1931



The outporing of lava November 19, 1930, which prepared the floor for the eruption of December 23, 1931. The bright fountain at the left built a big cone, and the high half-dome against the talus at the back was the grotto of 1929. The new crack of 1931 extends straight across the middle of the floor between these two, and the new fill covers all of what is here shown by about 100 feet.

JOURNAL OF HALEMAUMAU ERUPTION DECEMBER 23 27, 1931

There is much about this eruption identical in character with those of 1927. 1929, and 1930, each of which tended to add 50 to 60 feet to the bottom of the pit after the lava had shrunk and solidified. and each tended to break out along a crack either diagonally across the former floor or tangentially along the former edge of the floor. The duration of these eruptions varied from a day to three weeks; it is quite in order for such an eruption to develop increased violence of fountaining even when it is dwindling, as the spurting fountains are indicative of clogging vents.

There has been a series of events pointing to the coming of this eruption. The interval average for seismic and volcanic crises in Hawaii during the last 20 years has been one year, and the average of outbreaks of Halemaumau since 1924 has been one a year. The last outbreak ended December 7, 1930. so that now an eruption was expectable. The tilt instrument near the southeast edge of Halemaumau has shown 50 seconds of tipping of the ground away from the center of the pit since the last eruption, suggesting upward pressure. The tilt instrument at the Observatory on the northeast rim of Kilauea Crater has shown tilt away from the crater center of 5.4 seconds to the northeast between November 30 and December 20, 1931, suggesting upward pressure in the mountain. Finally came the rim block avalanche on the northeast edge of Halemaumau December 7 and the excessive number of seismic disturbances for the week ending December 13, 1931, followed on December 23 by the smart local earthquake in the forenoon that left 15 scars of avalanches on the big west bluff of Kilauea Crater, and left the walls of Halemaumau pit con-

tinually sliding for hours. This was undoubtedly the actual rending asunder of the inner heap which constitutes the floor of Kilauea Crater.

December 23.

When the dust cleared after the earthquake of 10:38 a. m., Wingate saw that avalanches had fallen around the northern walls of the pit, scattering debris and dust on the 1930 floor. There were scars on the walls and in some places rim rock had fallen, while 15 whitish scars on the great west wall of the big crater marked places where avalanches had fallen. Before the earthquake the rim cracks measured had shown no opening and the sulphur patches on the 1930 floor shown no fume, this being attributed to dispersal by strong northeast wind. After the earthquake there was no visible increase in fume. Sixteen crack points on the edge of Halemaumau were measured and showed increases in width up to more than an inch in places. A large block on the east rim had moved as a whole, and fresh cracks in the dirt appeared along the north, east, and south rims. Small slides were continuous for hours. After 2:15 p. m. six large slides were counted in 20 minutes. About 2:40, when he was working at surveying stations back of the rim, Wingate heard a low, rumbling noise not like an avalanche. He ran to the edge, where heavy fume clouds had already reached the rim level and were spreading about the interior of the pit. The whole floor was rapidly cracking open along a straight line athwart the middle of the bottom beginning at the southwest under the rift tunnels. Lava fountains there started up and spread to the northeast along the crack. Voluminous fume followed immediately after the first cracking, and the molten lava appeared following the fume. The whole time consumed for the break was probably less than half a minute. It was just at this time, 2:36 to 2:39 p. m., that the seismographs at the Observatory showed sudden development of continuous harmonic tremor from slight to strong.

Wingate reported visibility bad, but the botttom crust appeared rather to be pulled apart than to be heaved up and broken. There was undoubtedly tumescence. He was in imminent danger of asphyxiation, but went to the Park phone and could get no answer. He returned to the rim for a few seconds and saw spatter from the fountains blown high over the rim wall. Some of this from later fountains has been collected, light brown basaltic pumice like the "thread-lace scoria" of the Kilauea Iki region, and like the first ejecta of the Mauna Loa cones. Hasty count showed him 17 large fountains with the two strongest at the northeast end of the crack across the bottom of the pit. Then he ran for his car, badly gassed, and succeeded in escaping to the Keanakakoi sandspit where the air was clear. The sun was obscured for a time, appearing as though viewed through smoked glasses, bluish over the pit against a dark background, and reddish brown in transmitted light where it blew away and was seen against the sky. This was the first time that a scientific observer here watched details of first outbreak inside the pit, and it will be remembered that it was Mr. Wingate's party, engaged in topographic surveys, that was camped nearest to the place of summit outbreak on Mauna Loa in 1926.

The outbreak at the Observatory was observed by the change from rising dust to rising fume, and by the sudden development of harmonic tremor at the instruments. Also there was sudden change at the time of the earthquake in tilting of the ground from northeast to south.

At 4 p. m. the volume of fume rising was greater than in any recent eruption since 1924, and the eddying tornado effects due to convection from the large number of fountains, including the four enormous dome fountains at the north end of the bottom crack, coupled with the high wind from northeast, submerged the road terminals under clouds of sulphur dioxide. The fume and grit were bad on the roadway from Uwekahuna to leeward of the pit. From the north lip of the pit about 30 fountains were counted making a great roar, in a nearly straight line, after darkness began to fall between 5 and 6 p. m., but the seeing was poor. There was already a great lake with bright lines between the skins, spreading out over the whole of the inner mound of 1930 lava. At 4 the glowing froth had been seen flowing away from the fountain line, at 5:30 it was already a flat lake covering the irregularities of the 1930 floor. Therefore the volume of inflow in the first three hours was enormous. The poisonous blue fume tended occasionally to spread in a low layer to the eastward, so that it was necessary to make a wide detour. A fortunate photograph at 7:30 p. m. by Higashida showed four large fountains at the corners of a square under the northeast sill, with a small fountain in the middle, and a grotto fountain against the bank, while the line of smaller fountains extended southwestward across the middle of the lake in the line of the two eastward big gushers of the square. The crack proved to be very slightly offset to the west from the rift tunnels in the southwest Halemaumau wall. The inward convectional draft was from the north and west, and the brown clouds boiled up and rolled off over the desert to the southwest and southeast. Spurts from the big fountains were probably several hundred feet high, but they could not be measured. Pellets of pumice and Pele's hair fell to leeward. The line of smaller fountains were partly merged, and partly isolated, and there were some outlying fountains, with concentric patterns of bright lines clear to the edges of the big lake. where there were outward-pushing toes and some minor grotto fountaining. The illumination at night was so brilliant that every detail of the ground could be seen by pedestrians.

December 24

At 2 a. m. the amplitude of the continuous tremor diminished to about half, and at 5 a. m. increased slightly, and thereafter continued. This was the index of the cessation of the big northeastern fountains. At 3 a. m. Powers reported the fountaining almost stopped except for a few bubbling spots along the rift line. The bright-line pattern of the lake surface extended to the edge of the new fill. The liquid lava had reached the rock cliff, covering the low talus NNW. Both 1929 and 1930 spatter cones appeared to be covered.

At 10 a. m. the botttom appeared to be a continuous leaf-shaped lake with nearly flat floor, the line of fountains making a short belt of big domes southwest of the center. This was extended by small bubble fountains in both directions, ending at the southwest in a small grottto fountain at the bank which was increasing in size. There were traces of crust islands at the southeast about where the 1930 cone had been. The shore line of the lake had made a nearly continuous rampart of congelation and piled crusts, interrupted at one place between the northwest and west taluses where the liquid lava appeared to be nearly against the rock wall. There was a cross line of small fountains, nearly straight and at right angles to the main fountaining line between the central group and the southwest grotto. There was another straight line of fountains parallel with the central line across the northwest part of the lake. The crust nortwestward from the central fountains showed a pattern like a flow or belt of streaming. Small islets were forming in front of the southwest grotto, and the central fountains showed signs of migrating southwestward during the day. There were concentric skins of pahoehoe pattern. The northwest edge showed some cliffs in the rampart facing inward. The southeast edge showed toes of flowing through the rampart. The brightness at night was moderate.

December 25

At noon the nature of the activity was in general as before, but the gas pressure at the fountains was increasing and there was apparent a change in the cross line of small fountains to become the arc of a circle concentric with the lake instead of a straight rectilinear belt. The southwest border fountain was building a higher grotto against the talus, bright lines were radial from this grotto, and there was a clifflet or infacing scarp along the northeast rampart. Rapid moving puffs of blue fume rose up the west wall from the fountains. The liquid lava about the central fountain belt made slow waves outward. The fountaining waxed and waned, some individual spurts going up 200 feet during a time of high pressure, and the noise was like surf on rocks. There was a fine-meshed pattern about the central fountains bounded by a U-shaped curve of contact to the southwest with a broad horseshoe of coarse-meshed bright lines extending from the southwest grotto as a center away to the east and west so as to envelop the central more liquid pool. It was evident that the northeastern region was cracking and solidifying so that the rampart belt was widening inward, and measurements later proved that the southwest was becoming a center of elevation with individual pools about the several fountains. and these tended to stream and make overflows northeastward, over something that was solidifying below. The lake was definitely against the WNW wall of the pit, without any rampart.

December 26

At 9 a. m. a new fountain had developed to the northeast of the elongated central belt, and the southwest grotto was now dominant with a large crescent niche behind it built against the talus. The lake edge was here irregular. At noon it was apparent that the northeastern fountain was sending streams radially outward to the northeast and that the central fountains occupied the most liquid portion of the floor with a fine greenish pattern to the skins. This area was a thick crescent with two horns northward. The big strong fountains of the southwest grotto had built up a high canopy of spatter on the bank, a crescent wall with overhang which broke down from time to time and immediately built up again. A coarse bright-line pattern extended out to the north and east from this grotto with a surface in daylight like black satin. The central fountains were smaller and more separated. There were fresh overflows between the rampart and the talus at the east.

December 27

Measurements by the Observatory engineer on this day showed that lava covered the top of the 1930 cone to a depth of 50 feet, and the depths of the new covering on the irregular relief of the 1930 mound were as follows:

West Bay, 85 feet
North Bay, 96 feet
Northeast Bay, 98 feet
Southwest Bay, 115 feet

As there are shallower places over the big 1930 cone, the average depth of the new fill was about 90 feet, its size 2600 feet long northeast-southwest and 1950 feet wide, covering an area of about 80 acres. Its volume is estimated at 260 million cubic feet, which would amount to some 20 million tons. If this had been distributed over the interval from the beginning it would mean about 45,000 cubic feet per minute from all the vents. The height of lava lake above sea level at southwest grotto was 2773 feet, making the depth of the pit from the southeast rim 971 feet.

At 10 a. m. December 27 fountaining was more violent and the lava from the central group of fountains had encroached on the southwestern crusted belt and on the northeast fountain pool. The later was fountaining steadily but with decreased strength.

At 3 p. m. the northeast margin of the floor for perhaps one eighth of the area had become bench lava. Marginal overflowing was active SE and N. The southwest horseshoe lake was feeding flows at the edges, and the middle lake was spilling over a bench magma slope at the northeast. At 5:30 p. m. the northeast fountain was making only a sluggish gushing, but the southwest grotto had become a very powerful continuous fountain with a high grotto behind it, and this was beginning to develop the true Mauna Loa type of spraying jet. Detonations now accompanied some of the viscous bursts of the central area.

At 11 p. m. the southwest fountain was sometimes 400 feet high, overflow continued southeast, the lake was shrinking, and gas bubbles burst with loud reports. T.A.J.

KILAUEA REPORT No. 1040

WEEK ENDING DECEMBER 27, 1931

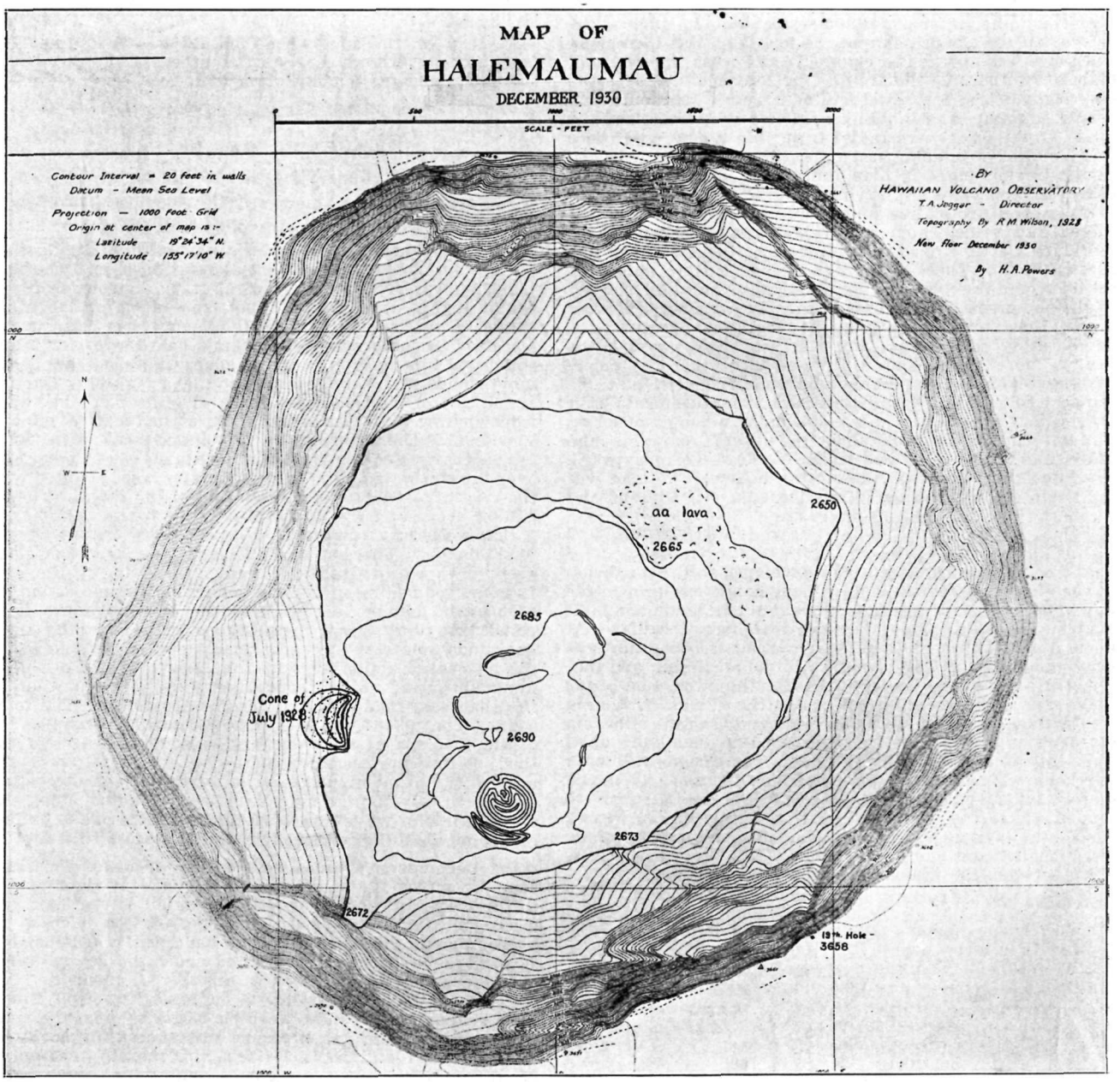
Section of Volcanology, U S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The past week has produced a new outbreak of lava in the bottom of Halemaumau pit about 2:36 p. m. December 23. This was preceded at 10:38 a. m. by a strongish earthquake highly localized and not generally felt at other points on the island. Mr. E. G. Wingate was close to the pit when the outbreak occurred, and heard a low rumbling which led him to look over the edge, where he saw heavy fume clouds filling the interior, and lava fountains starting at the foot of the southwest talus. The floor cracked open from southwest to northeast in less than half a minute. The floor broken appeared to be pulled apart with some tumescence. Spatter from the fountains was blown high over the rim wall, and 17 large fountains were counted with the two largest at the northeast end of the crack. Then a gale of dust, sand, and fume overran the tourist station and it was necessary to retreat to avoid asphyxiation by sulphur dioxide. The sun was obscured by a brownish cloud seen to be blue in reflected light. Lava during the next 11 hours foamed into the pit in enormous volume estimated 6500 cubic feet per second, and the density of the fume cloud was very great for Kilauea. The two or three enormous fountains at the northeast end of the line inside the pit ceased action about 2 a. m. December 24, the fume diminished, and normal conditions were restored whereby the southeast road terminal became accessible. The fountaining continued in a belt of big central gushers and a grotto fountain at the talus at the southwest end of the line. Before the cessation of the big fountains, the brilliancy of the pit at night exceeded anything seen thereafter, and about 30 fountaining points were counted along the straight line of vents that crossed the middle of the bottom of the pit in the direction of the Kau Desert rift.

On December 24 there was a line of small fountains straight across the south end of the lake at right angles to the main rift, and another line parallel to the main rift across the northwest part of the lake. Islets of crust appeared about where the 1930 cone had been. On December 25 a more liquid pool was defined about the central fountain, there had now developed a rampart all about the lake, and the southwest fountain was building a grotto. There were brilliant radial and concentric patterns about the main fountains, and the gas pressure was increasing so as to fling up individual spurts 200 feet into the air. December 27 there were three principal fountaining areas with streaming northeastward in concentric horseshoes. The gas pressure was still stronger and tending to concentrate southwest in spraying jets sometimes 300 feet high, building a huge spatter niche, while the central fountains made detonating puffs of blue fume. Measurements showed the average fill to be 90 feet deep above the 1930 floor and about 260 million cubic feet of new lava had poured in.

Prior to the eruption there were 11 tremors and 7 very feeble earthquakes recorded. Four indicated origin distance four miles. The earthquake of 10:38 a. m. December 23 was strong enough to overturn some objects, especially on Uwekahuna Bluff, and would rank as grade IV R. F. Two very feeble shocks occurred after the eruption. Traces of continuous volcanic tremor appeared after the 10:38 a. m. earthquake, became quite continuous at 2:36 p. m. December 23, reached a maximum at 2:39 p. m., and continued so until 2 a. m. December 24, when the big fountains stopped, and the continuous tremor diminished in amplitude. December 24 at 5 a. m. this tremor increased slightly and has continued ever since. Microseismic motion has been moderate to heavy, and tilt changed suddenly at the time of the strongish earthquake from moderate ENE to strong S. The pit seismograph has for months been indicating tilt away from the center.



Map of the lava floor of December 1930 with 10-foot contours for the bottom area, showing the big 1930 cone and solidified lake at the south, from which the rest of the bottom sloped away as a mound. The cone of July 1929 is shown at the left. All of this is now buried by the new eruption, and the grotto center of 1931 is just south of the 1929 cone.

THE VOLCANO LETTER

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Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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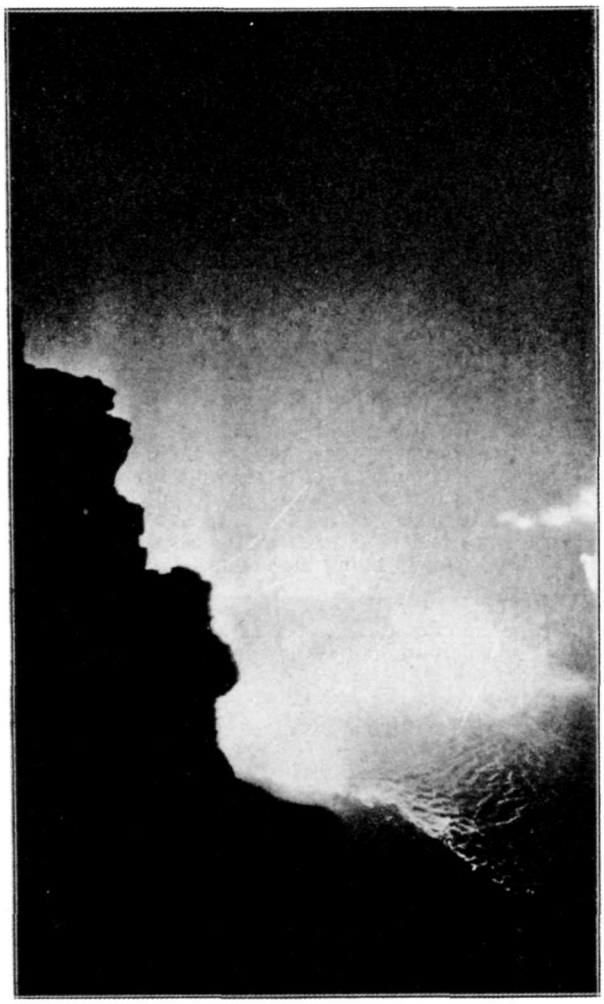
No. 377—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 7. 1932



The large northeastern fountains of lava in the bottom of Halemaumau pit, Kilauea Volcano, on the evening of the first day of the eruption, December 23, 1931. from the north-northwest rim, 7:30 p. m. Photo Higashida.

JOURNAL OF HALEMAUMAU ACTIVITY DECEMBER 28-JANUARY 3, 1931-32

It is now evident that the activity of the bottom of Halemaumau in the current eruption is stronger, and the lava fill more voluminous than in any outbreak since 1924. The current week brings to a close the eleventh day of the eruption with the fill at the highest southwestern side of the bottom of the pit at an elevation 110 feet above the corresponding floor of 1930. The progress of the week has determined a concentration of all visible inflow at the big southwestern grotto, where the lava piles up a horseshoe cone with an open cup overflowing to the floor of the pit. The topmost spatter of this cone stands 280 feet above the highest summit of the cone of 1930, and only 650 feet below the tourist station at the southeast rim of the pit. The line of central fountains disappeared after December 29, when it became evident that the southwest border of the floor was to become the top of a new mound from which flows would radiate across a swollen heap of fresh lava in the pit, and these flows have themselves developed a lake at the top of the mound bordered by a rampart of crusts which divides the lake at the southwest from the slope down to the edge of the floor at the northeast. This lake is continually fed by the torrents of lava from the fountaining craterlet, and from time to time the lake breaks through its rampart with overflows that flood the northern slopes of the mound. Seismic activity as usual has dwindled since the magma was released, harmonic tremor from the fountains is continuous, and the change in tilt from northeast to southwest at the Observatory is what would be expected with the lava ejection relieving upward pressure and replacing it by heavy weight of new fill.

December 28

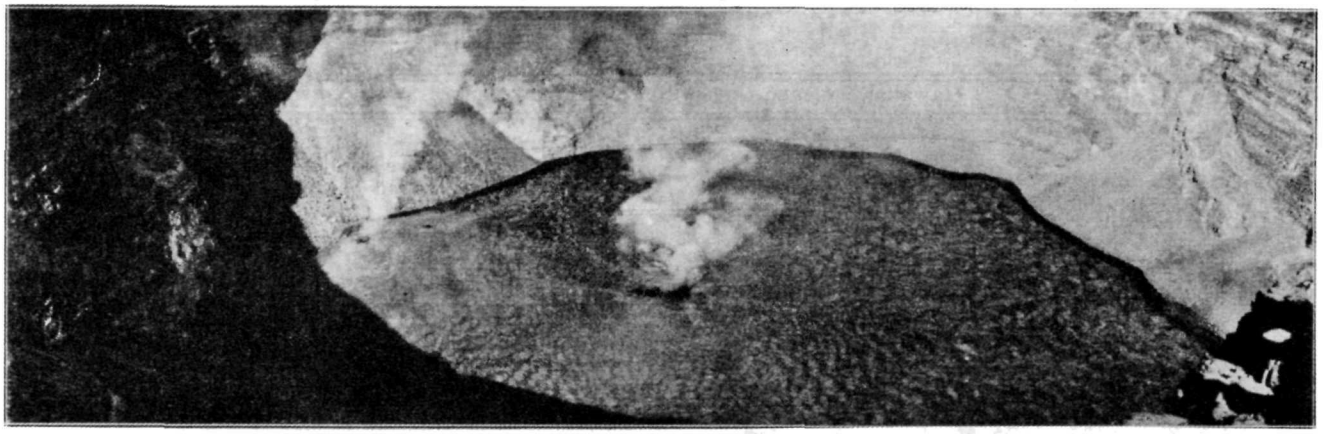
At 11:20 a. m. the concentration of activity at the big southwest fountain was sending frothy jets 350 to 400 feet high and spattering halfway up the west talus. The material appeared to be basaltic froth, and in dimensions and structure the whole cone and fountain were like the Alika source cone of 1919 on Mauna Loa (Volcano Letter 348, Page Three). Heat was strong on the edge of the pit, and this grotto fountain played like a jet from a hose. swinging slowly around a central vertical position, and dropping its light spatter first on one side, then on another. The resemblance to the Mauna Loa source cone was increased by the action of the minor fountains in the central lake and the two explosive vents, at the north, of the fountain line, which are making extraordinary flings of ropy lava to a great height, and detonations accompanied by puffs of blue gas. Just these things happened in the northern cones of the Alika rift, in contrast to the big fountain, with its frothing pool, farther south.

The central fountain was a bubbling pool which occasionally sent up a string of slag even higher than the steady spray of the southwest cone, and this string would loop and bend at the top, and then fall with a slap on the pool below. Both the central fountain and the one farther north made explosive bursts with loud thudding detonations, some of which sounded like a chemical explosion. At the area of the northern fountain there were three definite streams pouring northward on a downhill slope from an edge of crust. indicating that a lake had formed within a slag heap. About 18 fountains of small size extended from the center to the southwest.

The whole area of the northern edges of the floor was cracked and mashed into pressure ridges like the slopes of the mound of 1930. There were four or five jets of blue fume in this slope area. A wide patch of crust made an island about where the big cone of 1930 had been. The lake was leaf-shaped with the southwest fountain at the stem, and the latter was building a high, cracked half circle of its hardened flings on the uphill side against the talus behind it. The inside of its cup would continually cave in revealing red-hot walls. Measurements had shown a gain in height of the built-up bottom of 100 or more feet at the southwest, and only 40 feet to the northwest of the center of the pit, showing that there was development by both overflow and tumescence around the region of maximum fountaining. A cloud of blue fume was always rising from the big fountain, and smaller amounts of it came from the other fountains.

A nationwide broadcast was sent out from the edge of the pit describing the activity for the half hour following 10:45 a. m., by KGU of the Honolulu Advertiser. A microphone attached to the end of a long timber was thrust inside the pit so that listeners might hear the roar of the big fountain and the explosive bursts of the central and north central vents. The arrangement of this apparatus, with wires for relays by radiophone, had been accomplished in less than a day, and was of interest as showing what could be done for securing assistance in case such a volcanic happening were disastrous.

New cracks were discovered in the bottom lava of Ki-



Panorama of the bottom of Halemaumau at 10 a. m. December 24, 1931, looking northwest. This shows the condition when the line of central fountains was in action, the liquid was a continuous lake except for a narrow border rampart, and the southwest grotto at the left was small. Photo Jaggar.

lauea Crater outside of Halemaumau, occasioned by the stresses which produced this eruption at the time of the earthquake of December 23, as follows: Three cracks concentric with the rim to the northeast and seven cracks concentric with the rim to the northwest within 500 feet of distance. Close under Uwekahuna bluff in the same direction appeared nine similar cracks as though the inner heap of Kilauea Crater were broken by motion on the fault of which the Uwekahuna bluff is the trace. The west, southwest. and south outer country of the Kilauea floor showed widening of old cracks and development of some new ones. Large blocks of spatter from the fountains were found to leeward of the pit, and a wounded tropic bird was picked up which had been dashed against the pit wall by the wind and was bleeding. The earthquake of December 23 had dislodged a bowlder three feet in diameter from the Uwekahuna wall and rolled it 200 feet out on the Kilauea floor. Several new steam vents were noted about the inner talus heaps of Halemaumau.

At 4 p. m the southwest grotto fountain had a quiet spell jetting only about 50 feet high, and along the inner belt there were only two sluggish small fountains southwest of the center. Sluggish lava flowed from the grotto. At 9 p. m. for about a half hour the southwest grotto was merely bubbling, but later it renewed activity. The rift fountains in the lake had almost disappeared.

December 29

At 8:30 a. m. the southwest fountain had completely revived, the pit had been bright at night, and the central fountains had gone out of action. Flows were pouring over the floor in two streams from the southwest half-cone, and at this time the northern edges of the floor appeared slumping inward, and the southern edges were being built up and the southern half of the floor was evidently becoming a mound. The flows spreading out on the floor were meandering in leaf-like forms and there was nothing that could be called a lava lake except the pool surrounding the fountain inside the cone, which was hemmed in by an island of half-hardened lava that divided the two streams in front of it. At 8 p. m. the situation remained the same except that only the western of the two torrents from the cone was open.

Elevations above sea level of various points inside Halemaumau were as follows on December 29:

Summit Southwest Grotto	2860 feet
Edge lava in front of grotto	2764 feet
Southwest floor level of pit	2763 feet
Small cone center of pit	2761 feet
West bay of floor	2744 feet
Northwest bay of floor	2743 feet
Northeast bay of floor	2740 feet
Interior floor northwest	2738 feet

It will be seen by these figures that the southwest grotto was 96 feet high, the small central cone was seven feet high by a measurement taken on a point beside it (2754 feet), and the maximum relief of the bottom area between a sagged portion of the northwest floor and the top of the southwest grotto was 122 feet. There had been a slump of from 5 to 10 feet over most of the northern floor and overflows were slowly filling the collapsed area.

December 30

At 8:30 a. m. the fountaining at the southwest grotto continued to fluctuate and as on the previous evening the torrent from the craterlet was pouring to the west of the island in front of it and spreading over the crusts of previous flows. There were some trickling flows at the northwest edge of the new fill, but otherwise the northern floor was now inactive. The last gas puffs from the central vents had been noticed on the afternoon of December 29.

At 3 p. m. the two torrents from the southwest craterlet, cascading on each side of the island in front of the open eruptive amphitheater, had reasserted themselves as glowing streams, the eastern one pouring from under a crust. The puddled flows in front showed the usual bright-line pattern radiating from the two inflows, with numerous islets of accumulation. and enough building around the edges of the big puddle (covering the greater part of the southern half of the floor) to produce the effect of 20 overflow streams out from the edges of the lake of lava. This was to develop into a definite leaf-shaped lake with ramparts about its border, and with the southwest grotto for its source well.

At 8 p. m. the fling of the big fountain was continually falling on the outside of the cone, while the bombardment and overweighting of the inside caused red-hot avalanches into a pool beneath. Two torrents poured east and west of the island in front, but the western one was now arched over with crust at its narrowest part, with a cascade pouring from the froth pool in under the crust.

During these days a single, thin column of blue smoke from the fountain rose high above the west rim of the pit making a cumulus of rain moisture above, thin on a sunny morning, thick and spectacular in the moist evenings. The sun in late afternoon here and in Kona appears like a red ball through the fume. The nights show spectacular glowing cloud effects over the pit, with the glow waxing and waning. No fume obscures the view.

December 31

At 9:30 a. m. it was evident that the area of flows was widening in front of the southwest fountain, and that the cone was growing. Only the west cascade appeared as an open channel. Some jets from the fountain appeared to go up 400 feet. There were frontal streams at the north and northeast edges of the heap. The activity appeared somewhat greater than on the previous evening.

January 1

At 11 a. m. the lake over the southwestern part of the floor continued to enlarge. The floor was now getting to be a mound with concentric ridges and ramparts within the northern half of the area and many cracked areas. The outer edge is like a spoon with some inward slope. The top of the mound is at the southwest and the big fountain is building it up with a lake at the crest. Much pumice has been found in the country outside of Halemaumau to the southwest, some of the pieces two to three inches across. In the night following this day the glow over the pit was very bright, and was added to by the development of electrical storms on the mountains which produced snow on Mauna Loa and Mauna Kea.

January 2

At 9 a. m. the activity appeared to be as strong as ever. At 10:30 a. m. it was evident that the lake in front of the fountain had definite border ramparts where some lava spilled over, the pool covering about one-third of the floor. The spatter rims of the grotto had built out about 150 feet from the large western talus, forming a typical Mauna Loa horseshoe cone with the main channel about 100 feet wide above where it divides about islands into cascades. Apparently the weight of the lake accumulations was causing the sunken northern area to rise. and measurements detected slight rising against the walls of the pit. This is the isostatic effect, frequently noticed a decade ago, when the bench magma is weighted down on one side and the other side rises. At 3 p. m. the fountain was smaller and more like normal Kilauea lava. The lake was scalloped with two big flows through its rampart. At 8 p. m. there was much cracking and foundering of crusts in large fields of half-hardened lava to the north of the lake. The lake overflows were in wide streams on top of these fields.

January 3

At 11 a. m. a single wide cascade was flowing toward the east, the ramparts around the lake were continually pushing out and being overflowed, and the fountain was more sluggish. T.A.J.

KILAUEA REPORT No. 1041

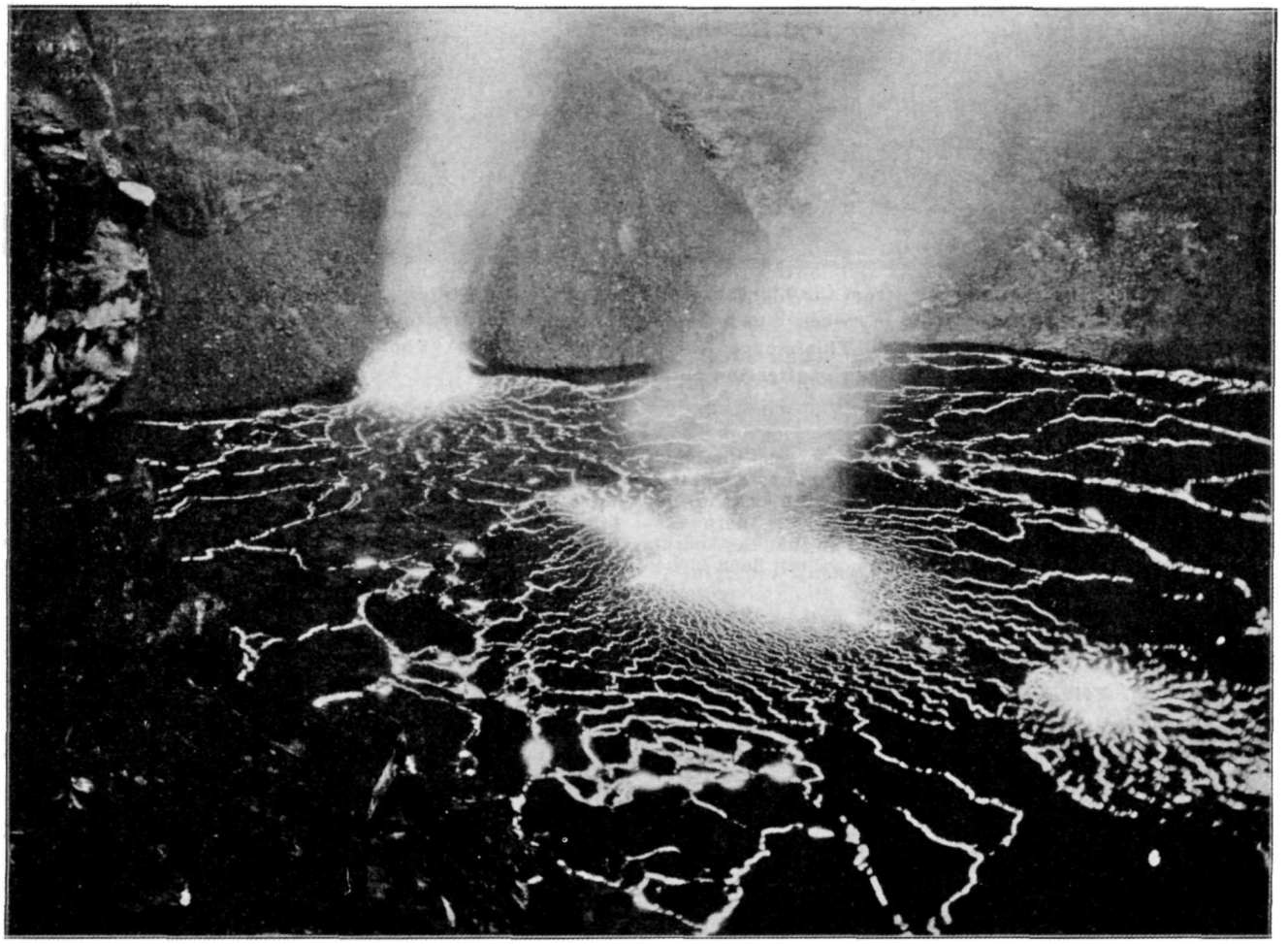
WEEK ENDING JANUARY 3, 1932

Section of Volcanology, U. S. Geological Survey

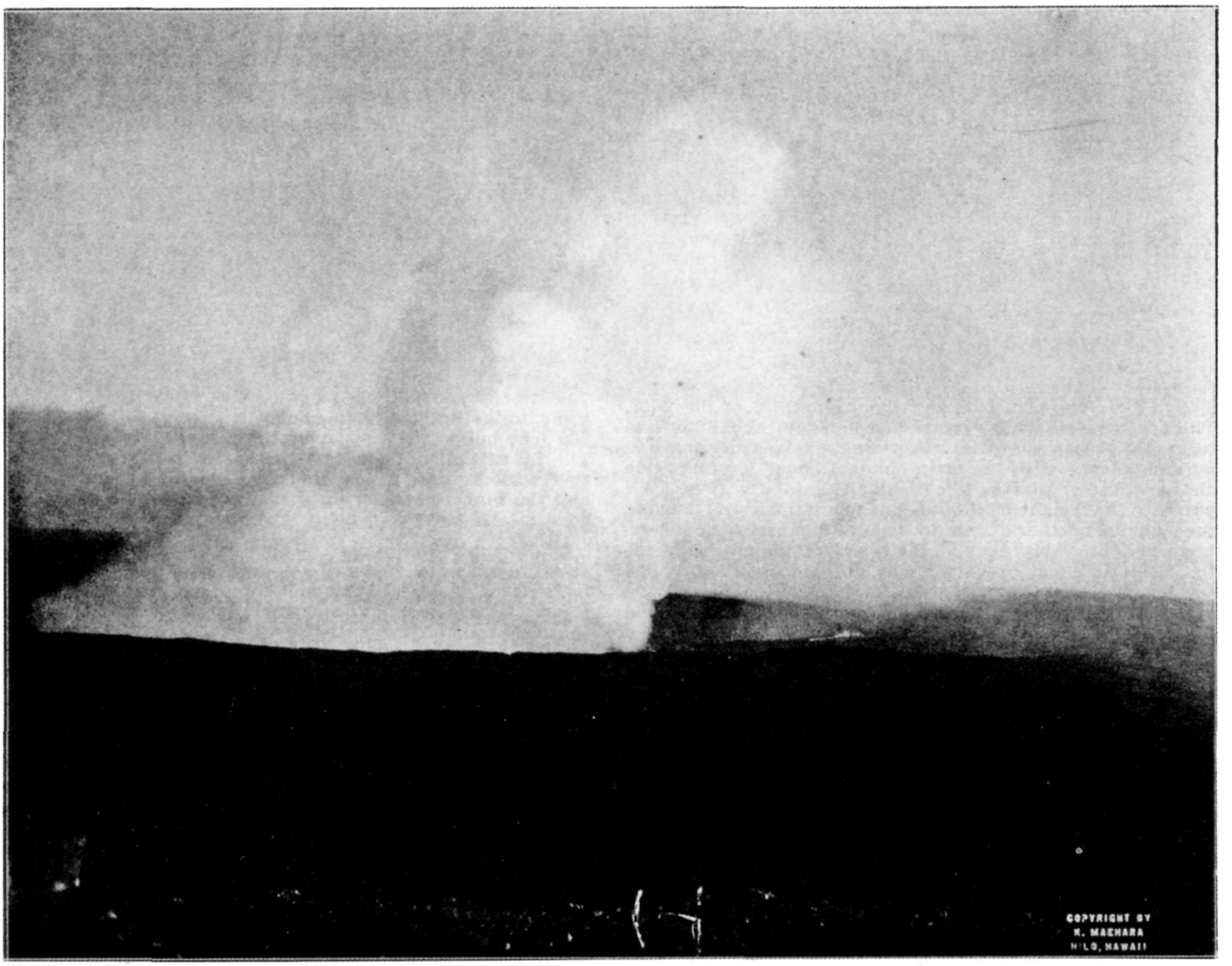
T. A. Jaggar, Volcanologist in Charge

The outbreak of Halemaumau pit in Kilauea Crater which began December 23, 1931, has produced a more voluminous fill than in any outbreak since 1924, and has brought the middle of the floor to an elevation less than 900 feet below the tourist station on the rim of the pit. The fill at the southwest on the eleventh day of the eruption was 110 feet above the corresponding floor of 1930, and the highest spatter on the talus beside the big source cone is about 650 feet below the southeast rim of the pit.

The central fountains disappeared December 29, the southwest grotto became a source cone for flows which built up the floor into a mound, and this activity still continues, with a lake built in front of the cone across the southern half of the bottom of the pit. The cone became an armchair niche 100 feet high with cascades pouring out



Halemaumau by evening light at 5:30 p. m. December 26, 1931, looking west, showing the growth of the southwest grotto at the expense of the central fountains and the co ncentration of the lake in a crescent in front of this grotto. Photo Powers



Halemaumau pit as a whole seen from the highest west bluff of Kilauea Crater on the first evening of the eruption of December 23, 1931, about 5 p. m., when blue-brown fume was puffing up from the big northeastern fountains in intolerable clouds of sulphurous gas. This stopped early the next morning. Photo about two and a quarter hours after the outbreak by Maehara.

of it to make a golden pattern of streaming across the lake. The latter made overflows about its edges, and so weighted down the heap as to cause some swelling up on the opposite side of the bottom area. On December 29 there was difference of elevation across the bottom so that the southwest cone was 122 feet higher than the northern floor. The inflow fountain diminished in size.

Harmonic tremor at the seismographs has been incessant. One feeble local seism December 30 at 11:18 p. m. was felt and indicated origin distance 14 miles. It was felt strongly at Puu Ulaula on northeast slope of Mauna Loa at elevation 10,000 feet. Three very feeble shocks occurred, of which one was felt. time 2:20 a. m. January 3. Microseisms have been heavy, and tilt was moderate SW.

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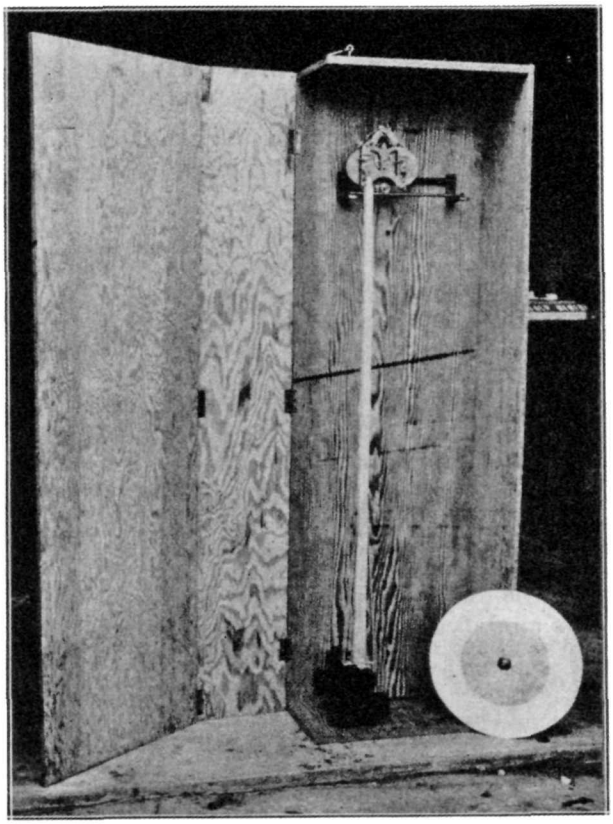
The Volcano Letter

368

Two dollars per year — Ten cents per copy

No. 368 — Hawaiian Volcano Observatory, National Park, Hawaii — January 14, 1932



Case and shock-recorder, with cardboard seismogram and aluminum disc removed, showing the general assembly.

EDITOR'S NOTE

In November 1929 the Scientific American published an article entitled, "Amateur Seismology," describing a simple instrument in the form of a horizontal pendulum consisting of a lead weight hung on a pinched hacksaw blade with an aluminum boom and pen writing on a smoked paper disc, revolved and moved along by a simple clock after the fashion of a gramophone record. A number of experimenters in the United States have made modifications of this instrument, and at the Hawaiian Volcano Observatory we have continued to experiment.

The text herewith is a set of instructions with appropriate illustrations to accompany eight new model shock-recorders which have been sent for service in New Zealand, under the Department of Scientific and Industrial Research. These differ from the original horizontal pendulums in that the mass and boom stand upright from the wall bracket which supports them, so that the entire case may be screwed against a cellar wall in the position of an upright clock. The necessity of having a large tabular surface is avoided and the clock rollers fall into the plane of the spring barrel, which simplifies the mechanism. T.A.J.

JAGGAR SHOCK-RECORDER VERTICAL OR WALL MODEL 1931

Instructions for Assembling

Each shock-recorder should have made for it a case, like a wall clock, a box 48 inches high, 15½ inches wide, 6½ inches deep, inside measure, with sides and cover made of 3-ply wood, the ends and back-board of more substantial planed lumber; and the metal parts are as follows:

2 narrow pieces of channel iron bolted together to form a basal support for the pendulum, and to be screwed against the back-board of the box at the bottom.

A heavy mass with two flat springs, anchored in lead inside a short iron pipe, and protruding from its side. These springs are pinched between the two channel irons about one eighth inch from where they enter the heavy mass. The heavy mass thus stands above the channel iron bracket as an inverted pendulum.

A long balsa-wood boom with a light pen at the upper end and attached at the bottom by aluminum plates and braces screwed into appropriate holes on the face of the heavy mass so that the boom stands upright.

A pair of tracks screwed against the back-board of the box at the top to hold the clockwork which rolls itself along on these tracks.

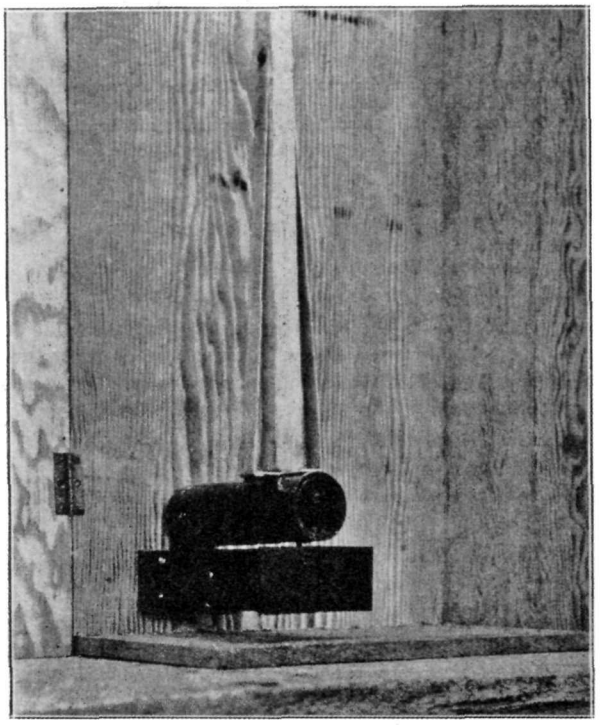
The clockwork equipped with rollers to fit the tracks, the double rollers on the back track and the single roller on the front track. The clock moves from left to right as you face it and is regulated so that its central spindle rotates once an hour when it is working.

Aluminum disc with central sleeve to fit spindle of clock, and central thumbscrew for handling the disc and for clamping to the face of the disc a circular card of white Bristol board 11 inches in diameter, punctured in the center to fit the pin of the thumbscrew cap. A smaller disc 3½ inches in diameter is clamped over the card only for smoking, in order to keep the card clean in the center.

Assemble tracks as shown on drawing, screwing the track rods on the angle bracket and placing at the back the track covered with rubber tubing. As the box is not supplied with the instrument, the placing of the parts on the back-board should be scaled from the drawing.

Clamp the flat springs of the heavy mass in the channel iron support, leaving ⅛ inch of spring between support and mass. Screw the channel irons against the back-board (1 inch round-headed brass wood screws) with the heavy mass uppermost. The lower edge of the channel irons stands ½ inch from the lower extremity of the back-board inside the box, and 4 inches from the left side of the back-board.

Lay out 36¼ inches vertically from the upper side of the channel irons to the angle of the bracket supports on the back-board, and draw a horizontal line as guide for placing these bracket supports. It is understood that the box stands upright against the wall like an old-fashioned clock. The left track bracket stands 2⅝ inches from the left side of the back-board.



Foot of case showing bolted channel iron pinching the two clock springs which are cast into the heavy mass. The boom of balsa wood is screwed to the top of the heavy mass by appropriate braces of aluminum.

Screw the balsa wood boom with its braces onto the mass, so that it stands vertical. The clock is set on the tracks with the small roller in front.

For removing and placing the disc on the spindle, the pen at the top of the boom is laid back, and the clock is simply slid well to the right, where the disc will be clear of the pen. Here the disc may be pressed by friction on the spindle or gently pulled off it by a slight rotation.

The period of the pendulum, set swinging by hand and timed with a watch, should be about ½ second to the right, and ½ second to the left, or a total of 1 second complete period. The longer the spring exposed between the clamp and the heavy mass, the longer the period. Count the number of swings for a full minute.

Needless to say, the adjustment should be such that the boom stands exactly plumb, and the arc of the needle when the point drops over against the carboard disc should bring the point, at about 45 degrees, on a horizontal line passing through the center of the disc, and about 2 inches to the left of the center.

It is possible to bend the supporting springs slightly in order to make the boom vertical, but it is undesirable to do so If these springs break, ordinary clock spring is obtained to replace them, the lead in the pipe which makes the heavy mass is melted and poured off, the springs are straightened and clamped in position, and the melted lead poured back into the pipe.

The weights and channel irons are lettered alike, in pairs. The left side of the shock-recorder box should be hinged against back-board and hooked forward top and bottom, when closed. The cover should be hinged to this side broad. Thus the left side of the instrument may be laid wide open for adjustments.

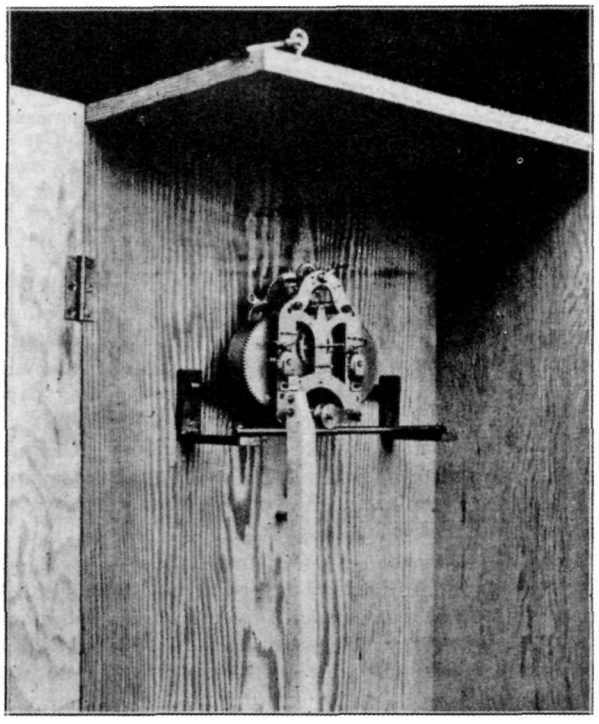
Operation of Shock-Recorder

Wind clock by removing it from tracks and place it back on the tracks. Screw a card disc on front of aluminum disc, by placing over the card the smaller disc, with its handle outward, and clamping with black rubber thumbscrew. Hold this by the back and twirl it slowly over a smoking kerosene flame (a lamp turned up to vigorous smoking of the chimney, kept for this purpose), with the card face downward until the whole card is an even light brown. Do not be afraid of putting card directly in flame provided it is kept twirling. The resulting brown if touched should streak with the finger showing pure white card. It is this brown film on which the shock-recorder pen writes a white line round and round the card during 24 hours. An earthquake interrupts these lines with a zig-zag pattern. The disc is its own clock-hand, as explained below. The smoked card should be handled entirely by the central rod so as not to smudge and disfigure the edges. Let the card, if warped by the flame, straighten itself out by cooling thoroughly.

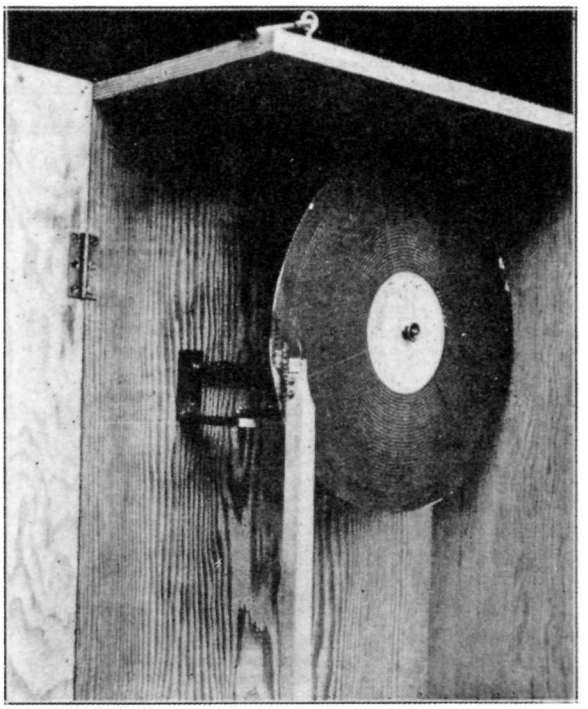
The disc is now pushed on to the clock spindle, with clock at right side of tracks, so that the edge of card is inserted behind the boom. The clock is now slid bodily to the left on the tracks until top of boom is 2 inches to the left of center of card, that is, opposite the inner part of the smoked band. Now tip the pen over, its point resting on the smoked surface. Use a stick like a painter's maul to rest the wrist on, and write with a dry point on the smoke the date, hour, and minute of starting, beside the white line which the pen makes. An ordinary pen without ink is good for this, scraping white figures on the smoke.

The machine is now at work for 24 hours and is left in complete quietness. It is vital that the wall be in a quiet cellar. Any upstairs wall will be affected by opening and shutting doors. The case should be screwed to a cellar wall where nobody goes except the operator once a day. Air currents, carpenters at work, an automobile on the ground close to the building, or a nearby engine, may make an artificial earthquake record. For good seismological work, complete quiet to the location is essential. Also look out for spiders and cockroaches.

Have a regular hour, say 8 a. m., for tending the shock-recorder. When the 24 hours is ended, mark the date and time beside the pen point, tip back the pen, slide the clock to the extreme right, gently remove the disc from the



Top of case showing driving clock on its tracks, impelled by rollers and turning the central spindle once per hour. Lateral movement 3 millimeters per hour.



Top of case with seismogram in place, showing brass pen and lines written on smoked card after 24 hours' work.

spindle by a slight right-hand rotation, and pull on the knob while the left hand holds the clock on the track.

The day's record must now be fixed for permanent keeping. Lay disc on table and carefully remove card from disc, touching card only by the edges. Prepare a flat pan, at least one foot in diameter, containing a solution of one part commercial liquid white shellac and fourteen parts denatured alcohol. This must be kept in a bottle between operations, as it evaporates rapidly. Holding the card by the edges between the two hands, pass it face downwards under the liquid once only, and hang it up to dry with a thumb tack. Data about the record, felt earthquakes, wind or weather, and the names of place and operator, may be written in ink on the white center of the seismogram card. This is now a permanent record of that day's seismical happenings at that place.

To get the time of an earthquake registered on one of the hour lines of the seismogram, it is essential that the disc rotate exactly once an hour. The clockwork may be regulated by the lever at the top in the usual manner, marked S for slower and F for faster. Prepare a tracing-cloth circle to put over the disc for reading time. Divide this circle in ink into 60 parts by tracing an ordinary clock face at the watchmaker's shop. Draw radial lines for each minute and heavier ones for each 5-minute point. Number these 0, 5, 10, etc., **backwards** as compared with an ordinary clock.

Suppose you started at 8:10 a. m. and the card disc is so marked at the inner first line of the spirals written round the disc by the day's work of the instrument. Set your radius 10 over that point with the tracing cloth centered over the seismogram. Suppose you have an earthquake recorded that was felt at 10:20 that forenoon. The first 0 reading around the line on the inner circle is 9 a. m., the second 0 is 10 a. m., and following on right to left counterclockwise 5, 10, 15, 20 minutes, the earthquake trace will lie under the 20 (10:20 a. m.) at its maximum amplitude; and the unfelt preliminaries will appear a fraction of a minute before the 20. The tail of the earthquake, or the dying away, will appear as a continuing vibration for several minutes.

By regulating the driving clock with some care for a few weeks, the amateur seismologist may get time within a minute by keeping track of the error of the clock as recorded at the end of each day's run. If the error is a constant, it may be best to leave the clock unregulated, and divide the error for 24 hours by the number of minutes in 24 hours. This gives you the error per minute. This applied to the number of minutes from the time of starting to the time of the earthquake corrects the card time for the earthquake.

A good operator should keep a good timepiece by which to mark the seismogram at the beginning and end of each day. Accuracy to the minute is probably near enough for such a rough machine, but persons with physical or astronomical training, receiving time by radio, can use this instrument as a timepiece if they are ingenious. It is customary to set up the shock recorders so that the face of the case is toward the north or south, and the pendulum thus swings east and west.

Erratum. The number of last Volcano Letter (377) should be changed to **367.**

KILAUEA REPORT No. 1042

WEEK ENDING JANUARY 10, 1932

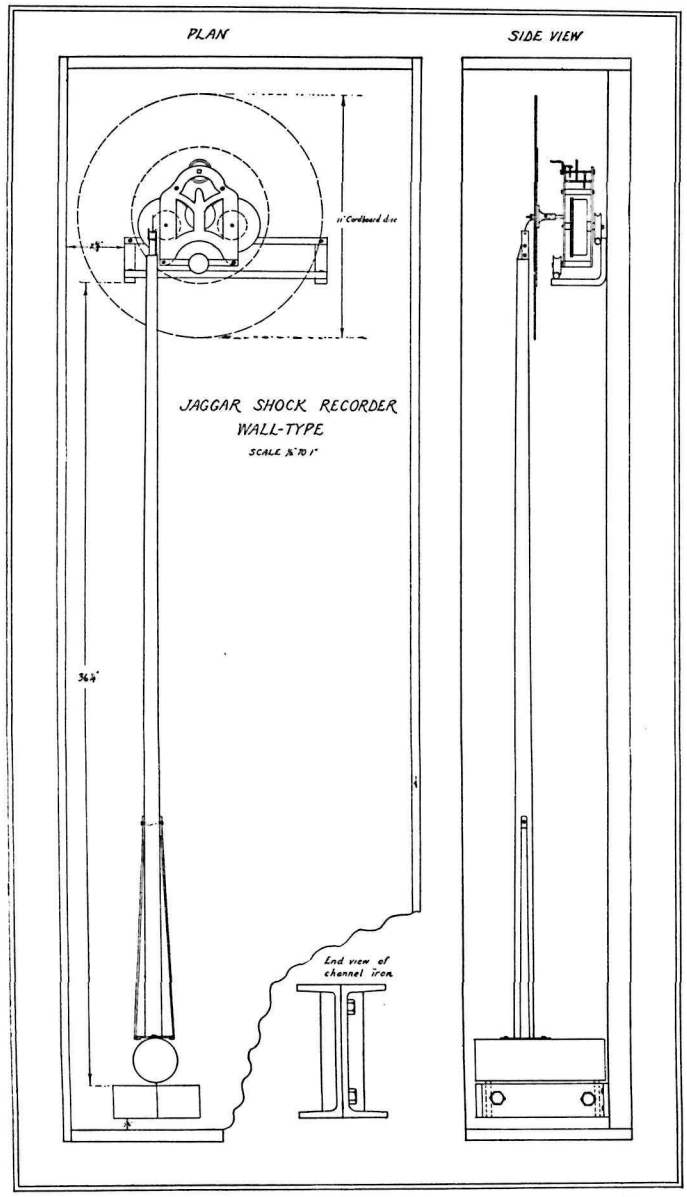
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Activity in Halemaumau continued until January 5, then stopped, leaving a floor with a big cone at one side, as in 1930. January 4 there were three streams from the cone, and an overflowing lake below occupying one third of the floor. January 5 the fountain had spells of stopping in the early morning, though the fume column was brightly lighted, At 10 a. m. there was the usual puffing and splashing, lake ramparts were overflowing east, and 3 rapid cascades poured eastward from the channel. At 2 p. m. the big fountain stopped and a little one formed in front of it: two streams gave place to one. Some booming was heard at 2:20 p m. Tremor on the seismographs at the Observatory was showing spells of increase and decrease. There was some backstreaming from the new fountain over the black lava of the interior of the cone. During the afternoon the cascades narrowed and the fountaining fluctuated, with booming. About 6 p. m. tremor at the Observatory ceased and the fountaining stopped gradually. At 8 p. m. there was very dull red glow, the pattern of lake and cone was outlined in glow cracks, the overflows were dull, and a few glow spots appeared at north edge of floor. The channel fountain made a few spurts of sparks, and a small glow chamber broke open at the central conelet. There were noises of cracking slabs, of small southern slides from the wall, and of hissing with the spurts.

January 6 the lake had slumped leaving hummocks. There were crackling sounds. The inner wall of cone flaked away leaving glow exposed. A little fume came from the east base of cone and other points. Steam rose at southern taluses. January 7 there were two small slides northwest and northeast about 11 a. m. January 9 rain made a hissing on the new floor. There were fume spots around the lake edge and at the cone. Some rocks fell and a small slide occurred at 11:10 a. m. New debris of reddish color had added 40 feet of width to the northwest talus. January 10 a crust ridge at southeast margin of bottom emitted blue fume which showed above the whole pit in afternon light, cumulus cloud still formed above the pit at higher levels due to heat, and a few points of glow still showed at night.

The seismographs registered 24 tremors, one indicated a probable origin distance 18 miles, 4 very feeble local seisms suggested origin distances of 6, 32 and 42 miles, and teleseisms were registered at 3:53 p. m. January 4 and at 46 seconds after midnight the morning of January 9; this last indicated a doubtful origin distance of 880 miles. Microseismic motion was mostly moderate, and tilting of the ground was moderate to the south. The harmonic tremor from the fountaining lava in Halemaumau increased between 1 and 2 p. m. January 5, and then decreased until it disappeared at about 6 p. m. in remarkable coincidence with the cessation of lava inflow.



Front and side elevations of shock-recorder and end view of channel-iron bracket supporting the mass. Cardboard disc 11 inches diameter.

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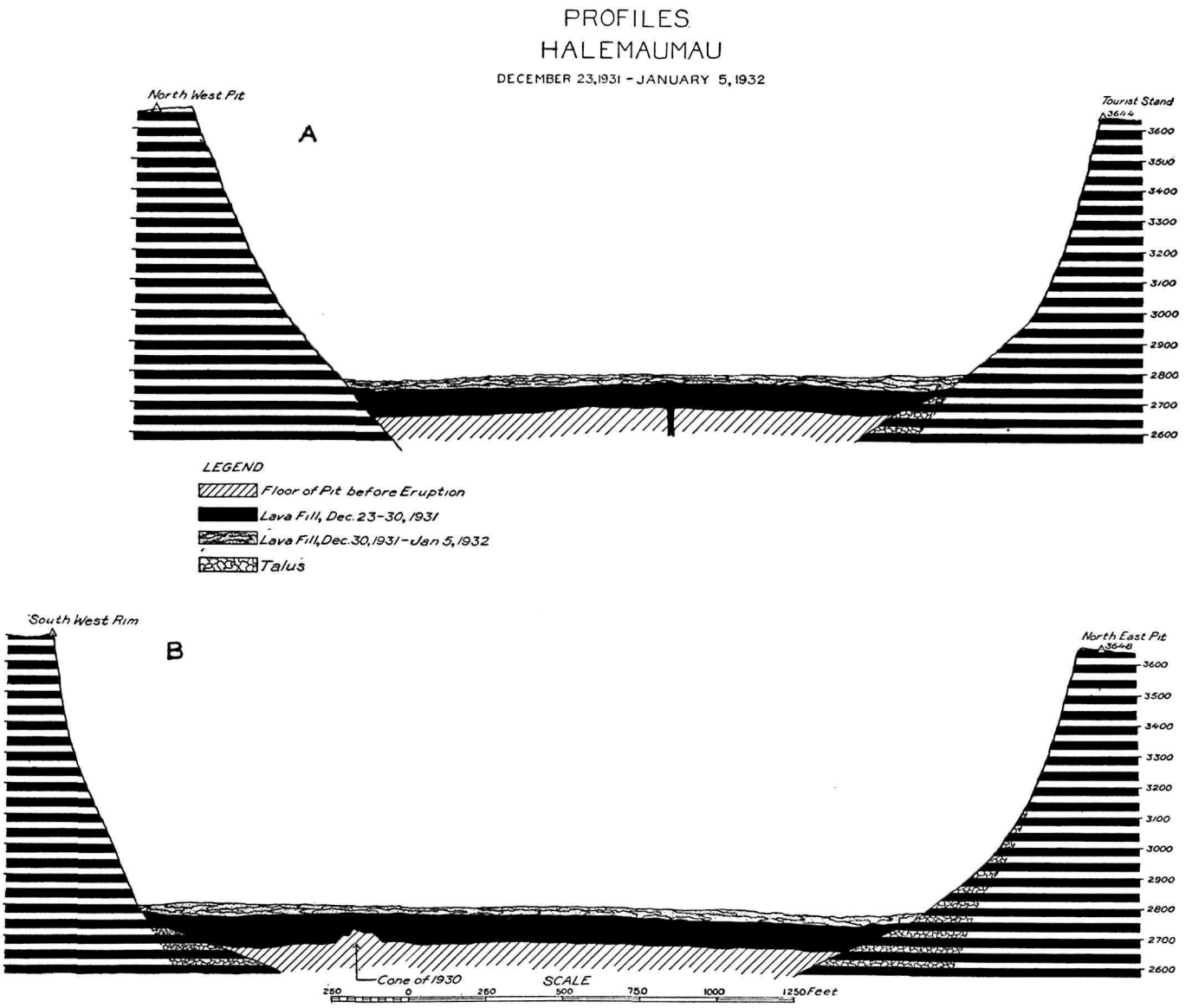


Profile sections of Halemaumau pit at the end of the eruptive period December 23, 1931, to January 5, 1932, showing topography of bottom left by the eruption. See discussion in text, and map on Page Four. Drawn by E. G. Wingate.

JOURNAL CONCLUDING HALEMAUMAU ERUPTION JANUARY 4-10, 1932

The eruption which began in Halemaumau pit of Kilauea Volcano December 23, 1931, finished its apparent surface activity the evening of January 5, 1932, after somewhat more than thirteen days of inflowing lava.

Elevations of the parts of the surface of the new bottom when the lava lake was highest, 9:30 to 11:30 a. m. January 5, 1932, reported by E. G. Wingate, were as follows:

Area over 1930 conelet filled 73 feet.....elevation 2793 feet
Southwest bay filled 134 feet.....elevation 2792 feet
Lake under southwest cone filled 125 feet..elevation 2798 feet
Lake southwest of center filled 107 feet..elevation 2777 feet
West bay filled 113 feet.....elevation 2773 feet

The amount of filling over the whole floor was about 115 feet, or some 25 feet more than was shown by the measurements of December 29-30, 1931. The accompanying section profiles show the later fill light colored and the earlier

solid black. December 29 was the day when central fountains stopped. At the end the principal mound was the southwest cone itself, at the edge of the lava floor, not shown in the profile. The average bottom elevation 2789 feet, is 855 feet below the tourist station at the southeast rim of the pit.

The final heaping up of the border cone, with the fountain in its midst sending multiple cascades of lava to spread out on the floor, was quite like the closing stages of the eruption in November-December 1930. The cessation was rapid and quiet, without any marked down-sinking, within a few hours. The flowing simply stopped, the surface solidified, and the tremor at the seismographs stopped simultaneously with the end of fountaining.

January 4

The flow of lava from the southwest cone out over the floor of the pit continued as before, but there was no longer a single lake of lava filling the bottom of the pit as there had been during the first days of the eruption. The line of fountaining vents across the middle of the pit no longer appeared. Everything had been concentrated in an upflow at the big cone at the base of the southwest talus. There were doubtless intrusions going on within the heap covering the bottom of the pit, but their only effect at the surface lay in what was revealed by the surveys with transit showing differences of level of different parts of the bottom. Other effects of piling up, which produced differences of level, were due to the puddled flows from the cone as shown in the accompanying map, which have collectively been called a lake, because of a definite rampart bordering the pool in scallops and numerous islands of clustered crusts. The thickness of the new fill is various, both because of irregular heaping up, with a maximum near the southwest cone, and because of irregular topography of the mound of lava of 1930 which the new fill covered. This variability is shown in the profiles in their relation to the map.

On this morning at 7:30 a. m. there was the usual convection cloud of rain moisture due to the heat rising from the lava fountains and lake. At 8 a. m. three streams were forking from a wide river at the open side of the cone. Rapid cascades carried black crusts past two small islands in the central rivulet. The fountain was variable, as a whole not so high as at the beginning of the previous week, at times somewhat sluggish, and then developing a spurt of high jets with a roar. There were occasional brilliant slides as the red-hot sides of the cone caved in.

At 3 p. m. the fountains were bubbling steadily in the cone and spouting up from 50 to 75 feet. One river of lava poured out from the center of the horseshoe, its course at first northeast, and then deflected to the east by the slaggy slope which had been built up as a mound straight in front of the cone, when the river in earlier days had forked both east and west around an island. The western torrent no longer showed, whatever it may have been doing in tunnels, and the eastern one now divided into three streams surrounding three islands. The whole distributary system radiated out with bright lines and surfaces covered with satiny skins into a lake that covered about a third of the floor and was confined in a well defined rampart. On the west side there was much overflow amid crust islands and one small overflow stream poured from the lake to the east. Back of this was a large island which had been a remarkably persistent feature throughout the eruption, and perhaps marked the site of the cone of 1930. The rest of the floor showed pressure ridges and mounds and irregular hardened flow patterns, with chasms and cracks particularly conspicuous near the borders at the north.

January 5

Surveys were made from 9:30 to 11:30 a. m., and before this at 8 a. m. it was seen that the flow had lessened, but the fountain was still central in the cone, though weaker. The volume of outflow had lessened considerably as shown by the size of the streams, and the lake on the floor was smaller and the overflows through the ramparts had dwindled. Most of the filling appeared to be in the south bay. The river flowing from the cone forked into two streams with rapid cascades, and the islets were tending to become peninsulas. Fume above the pit had increased at 8:40 a. m. At 10 a. m. it was seen that the increased fuming was due to a revival of the fountain, which appeared quite normal with much puffing and splashing. Heat from the lake was strong at the south edge of the pit. The lake had vacated its ramparts on the west, and was overflowing ramparts to the east.

The scarp or heap in front of the main channel appeared brick-red and rusty on its upper surface. Three rapid cascades poured eastward from the channel, and over the pool on the floor of the pit there was streaming with radial zigzag bright lines fanning out to the east and northeast. Three island accumulations divided the cascades. The north floor of the pit showed scallop rampart patterns over its surface, and some pressure ridges. A remarkable feature was a group of four crevasses trending northeast toward the dike in the northeast wall of the pit. These were on the line of the first fountains of December 23, and where the line of fountains had been buried up by subsequent flows. The hardened surface, however, had become cracked on the line of the original rift and was apparently gaping open by tumescence.

The new floor of the pit was now against the rock wall between the taluses at the NE, NNW, WNW, S, and at two places on the E. The old rock wall at the southeast which had extended to the 1930 floor as a triangular ledge parting two taluses was now entirely buried. The cone and crater around the big fountain appeared to be in adjustment, and the noise of the cascades was a steady crackling.

The afternoon of January 5 created a new situation, with reports of avalanches, of a new position of the fountain, spells of excessive harmonic tremor at the seismographs alternating with very weak tremor, and dwindling of the cascades. The details of these changes were as follows, proving important as on this evening the eruption stopped:

At 2 p. m. the big fountain central to the cone went out of action and was replaced by a small fountain in what had been the main stream northeast from the craterlet. Inquiry from bystanders indicated that the large fountain was still erupting at 1 p. m. when the activity during 15 minutes migrated into the channel and about 1:15 the large fountain stopped. At 2 p. m. small streams were pouring down both cascades, but at 2:15 only the southern stream was visible leading from the channel fountain. It was at this time that heavy tremor at the Observatory was replaced by very weak motion.

At 2:20 p. m. booming noise was heard continuing for five minutes, and the northern cascade reasserted itself. It stopped, and the lava in the pot appeared to be rising and flowing back over part of the black lava where the central fountain had been. This action increased. At 2:42 p. m. the channel fountain appeared to be migrating northeast, somewhat smaller than before, and the streams were darker colored. Booming noise was repeated 2:58 to 3 p. m. and again at 3:15, when the cascades were small, duller in color, and flowing more slowly. At 3:24 there was a spell of vigorous fountaining. At 3:30 there was intermittent spurting with some booming. The southern

cascade was very narrow and most of the outflow poured through the northern channel. At 3:55 there was a spell of rather heavy fountaining.

During the course of these changes the crater margins in the cone had caved in, the pool on the lake floor was lowering and becoming dotted with many islands and crusted lumps, and there were some fuming patches about its borders. The dwindling of inflow appears to have been gradual from 4 to 6 p. m., though at the beginning of this time the fountain sent up some spurts 50 feet high. The cessation of the tremor at 6 p. m. probably coincided with actual cessation of inflow.

At 8 p. m. there was very dull red glow over the pit, hardly perceptible on the walls as seen from a distance, and almost none on the cloud above. When the pit was visited, it was found that the pattern of the lake was outlined in bright glow cracks, that of the overflows was less bright, and the cone was clearly outlined by incandescent fissures. There were a few glowing spots at the north edge of the floor. Gas activity still asserted itself in occasional spurts of sparks from the site of the channel fountain. There were hissing noises at these times. A small central cone in the floor which had been the last remnant of the central fountains caved in about 8:15 p. m. revealing a glowing chamber inside and making a noise of cracking slabs. There were some slides heard at the south wall of the pit. It was observable that the glow pattern of the floor showed colors in blue, purple, and red, suggesting the presence of some small flames through the cracks.

January 6

At 6 a. m. there was no visible flowing lava, and cracking sounds were nearly continuous with spells when they were louder. This suggested that cooling and slumping were going on. There were numerous glowing points like a bed of coals. Occasionally a cascade of cinders would fall from the inner walls of the cone showing glow underneath. There were some squeaking noises like rubbing slabs. Where the lake had been there were parts of the outlying rampart and numerous hummocks. A little fume rose at several places in the bottom of the pit, but was not noticed at the cone. There was steam from the talus slope above. Later in the day slight fuming was noticed at the top of the new cone and still more near its eastern base. The lake surface had evidently been slumping. Vapor was noticed on the southeast talus.

January 7

The end of this eruption, as in 1930 and the other short-lived fills within Halemaumau which have occurred since 1924, showed no sinking of the entire lava column. Such sinking was a characteristic of the end of eruptive episodes between 1915 and 1924. The explanation of the difference appears to be a difference in continuity of inflow and volume of material in the upright shaft that remains fluid. These small annual eruptions of the last few years appear to come up a crack in the bottom of the pit, cover the former floor with a layer of paste which more or less congeals with the term of the eruption, the inflow concentrates at one well, and this material also congeals and forms a plug. There may be more or less pastiness and incandescence to the bottom of the temporary fill, and loss of gas from this viscous fluid accounts for some slumping of the surface, also volume is diminished by crystallization. But there is no sign of sudden back-flow into the depths, such as caused lowerings of hundreds of feet in 1916, 1919, etc. The evidence seems rather to favor the supposition that there is a steady upward pressure of magma at present released by an occasional breaking through.

On this day, January 7, the floor of the pit was very irregular and hummocky and all sounds of settling had ceased. Two small wall slides were heard at the northwest and the northeast about 10:50 a. m. Otherwise the bottom was still and motionless just as the congealing lava had left it.

January 9

During rain in the forenoon there was a slight hissing sound from the hot floor. There were fume spots chiefly about the borders of the recent lake and at the south side of the cone. Rocks fell from the walls and a small slide occurred at 11:10 a. m. The rim cracks at the northeast continued to show slight widening such as had been noticed prior to the recent eruption.

January 10

Blue fume was observable over the pit when the sun passed behind the rising vapors, especially at the southeast, and much of this came from a smoking ridge of crust at the southeast margin of the floor. Cumulus was still forming in the high air above the pit, and a few points of glow in the floor were visible at night. T.A.J.

KILAUEA REPORT No. 1043

WEEK ENDING JANUARY 17, 1932

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Volcanic activity at Halemaumau pit remains dormant, and the most interesting development of the week for the Hawaiian Volcano Observatory has been the completion of a new seismograph hut erected for the Geological Survey by the Park force. This hut is close to the southeast rim of Halemaumau, in the same location as the former hut, but capable of housing two or more instruments, for more complete measurement of local earthquakes, tremor, and tilt.

On January 12 new fallen material was observed under the southeast wall and the floor appeared more hummocky. January 13 three slides were reported near the southwest rift crack in the wall during the forenoon, and in the afternoon fume was conspicuous, especially at the southeast hummock, rocks were heard falling, and rim cracks showed slight widening. Sulphur stain appeared in spots. Rather sudden northwest tilt had appeared at the Observatory. At 8:30 p. m. January 17 a glowing crack was seen near the southwest fuming hummock and one spot of glow in front of the new cone. Occasional rocks fell from the walls and a small slide from the north wall occurred at 8:50 p. m.

The seismographs registered 63 spasmodic tremors, two indicating origin distance 18 miles, one 42 miles, and one 46 miles. Five very feeble local seisms indicated distance chiefly 14 to 18 miles. Microseismic motion was moderate, and tilt slight NW.

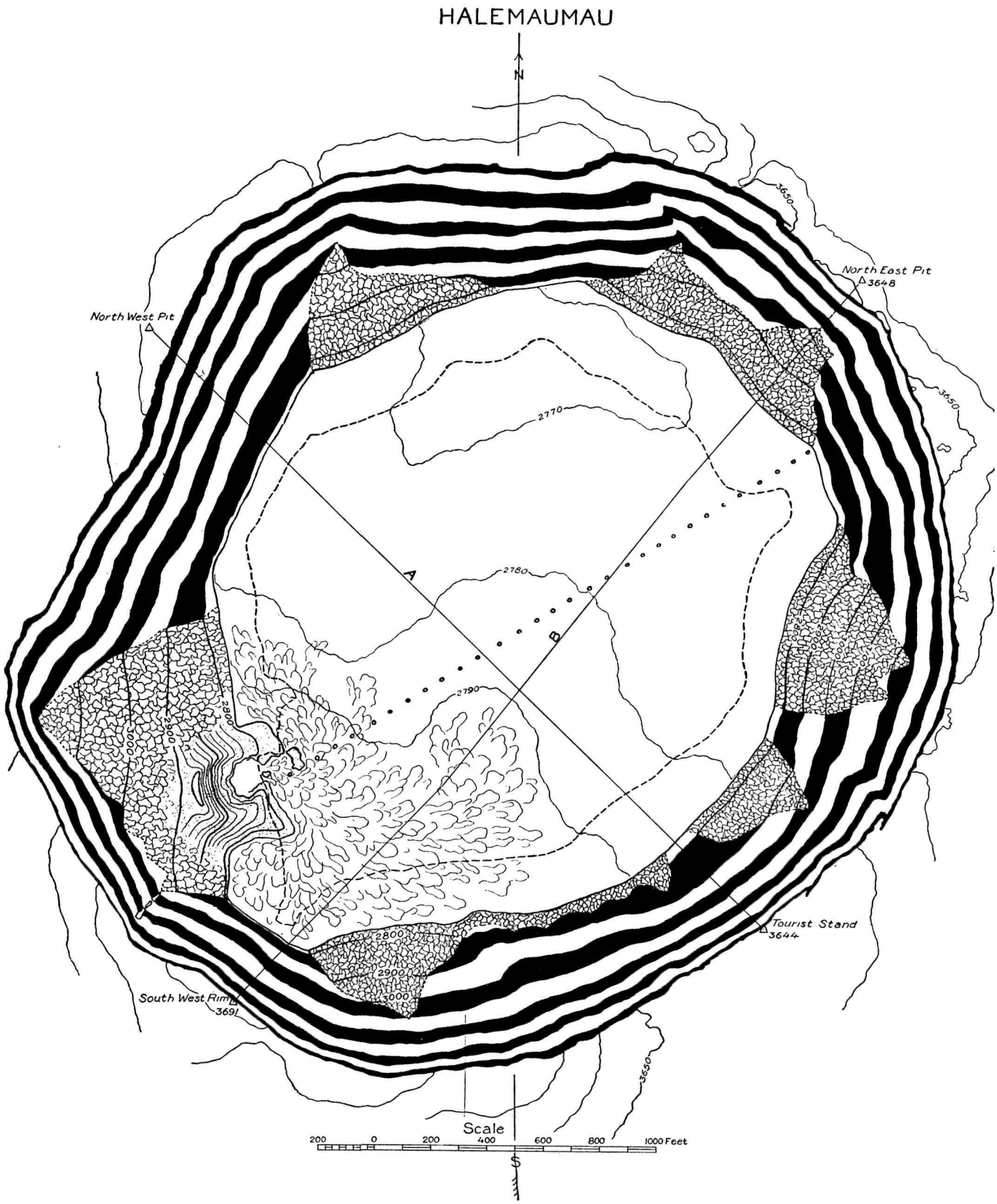
TILTING OF THE GROUND FOR DECEMBER

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

November 30-December 6, 1931	1.4 seconds	ENE
December 7-13	0.8 second	NE
December 14-20	3.2 seconds	NE
December 21-28	2.8 seconds	WNW
December 29, 1931-January 4, 1932	2.0 seconds	WSW

Tilt on both N-S and E-W components of the seismograph, as shown by the daily plat, had at the end of the eruption of Halemaumau pit, which occurred December 23 to January 5, indicated a return to a point on the seasonal curves almost identical with the points recorded immediately before the sharp NE tilts, indicated above as occurring just before the outbreak.

This would appear to indicate that these northeast tilts beginning 10 days before the outbreak were due to tumescence that was preparing to split open the lava of the bottom of the pit. These effects were so strong in their northing at the Observatory for the first half of the week December 21-28 indicated above as to make the average tilt show some north, though the actual swing of the pendulums on the day of the outbreak December 23 was strongly south and west. It will be seen that for the time of eruption the averaged tilt of the fortnight was strongly westerly, which is a direction towards Mauna Loa. E.G.W.



Map of January 5, 1932 to accompany profiles A and B, showing new southwest cone. Dotted line was floor of 1930.

THE VOLCANO LETTER

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The Volcano Letter

370

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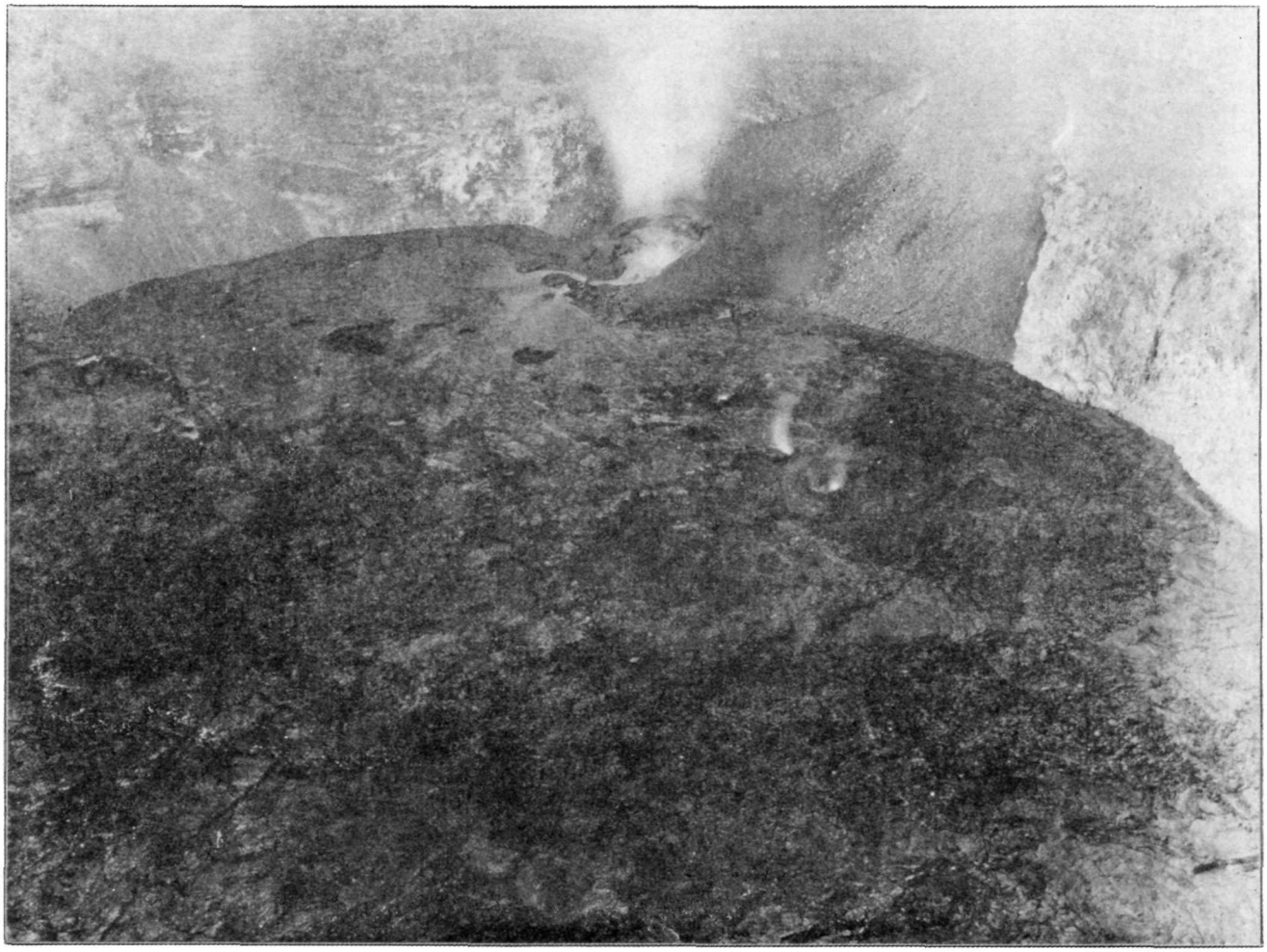
No. 370—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | January 28, 1932



New floor of Halemaumau, looking southwest 11 a. m. January 5, 1932. Lava stream pouring from conelet on southwest talus. In left foreground tension cracks on rift. Note burial of talus slopes as compared with 1927 Page Four. Photo Powers.

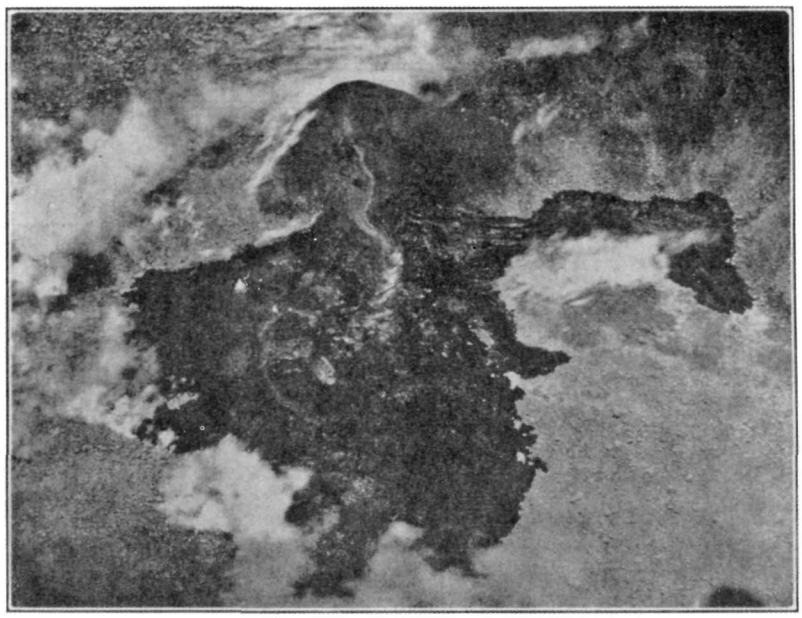
COMPARATIVE DATA ABOUT RECENT ERUPTIONS

The conclusion of the eruption in Halemaumau pit from December 23, 1931, to January 5, 1932, makes it of interest to review the data concerning recent eruptions of Halemaumau in Kilauea Volcano, which have tended to become annual. It was stated in Volcano Letter No. 366 that there had been a series of events tending to forecast the recent outbreak. Besides the expectable interval of about a year, there was accumated tilt away from the center suggesting upward pressure, there was a week of excessive tremors and earthquakes 10 days before the outburst, there was opening of measured cracks by unusual amounts leading to a rim-block avalanche at Halemaumau December 7, there was a strongish earthquake December 13 when Park rangers reported rumbling noises and slabs falling down cracks on the Kau Desert rift southwest of Kilauea, and there was an unusually strong shock on this same rift, within the crater, the forenoon of the day the eruption began. Features accompanying the eruption were the steady harmonic tremor which started and ceased in coincidence with lava inflow, occurrence of the crisis a year and 34 days after the outbreak of 1930, the sudden change of tilt accumulation at the edge of Kilauea Crater, from a tendency away from the center, to an inward tilting as soon as the gas and lava released the upward pressure; the gushing up along a straight crack on the rift line; the concentration to a conelet at one end of this crack; the accumulation of 115 feet of fill; and the duration of only 13 days.

This was all stated to resemble the incidents of former years, and it will now be profitable to compare these incidents systematically, in order to find out what was characteristic of each prelude, in how far these preludes resembled each other, and in what respects the eruptive sequences resembled each other.

Lava Inflow of 1924

The first volcanic event here following the great explo-



First lava eruption in bottom of Halemaumau after explosive crisis of May 1924. Cone and flows under west talus July 22, 1924, with lava flow spreading on bottom of pit. Photo Emerson.

sive engulfment which enlarged Halemaumau pit in May 1924, was the inpouring of lava at the bottom of that pit July 19-31, 1924. The pit was left in a condition of great instability with many avalanches and small earthquakes in June, and red-hot walls far down where intrusive rocks were exposed. A local seismic spasm led to a strong shock June 13 of grade about Rossi-Forel VI, when outside the north rim of Kilauea Crater new cracks were produced in the soil. The seismograph station is on the northeast rim of Kilauea Crater, and showed strong northeast tilts twice during the three weeks preceding the lava outbreak. Blue fume shot up from the pit at noon July 19, this at 1:45 p. m. was a jet spraying up through a vent in the southwest talus, making a small trickle of lava which collected in a puddle in the cup of talus that formed the pit floor. The jet became a fountain 125 feet above the bottom of the pit, the puddle spread about in leaf form with some internal fountaining, the cone became over a hundred feet high around the source, but the floor coating was only 25 feet thick. Harmonic tremor at the seismographs lasted from July 20 to 29.

Mauna Loa Eruption 1926

Mauna Loa broke out near the summit April 10, 1926, at 3 a. m., spread down the southwest rift its splitting action with frothy lava outflow, and sent a torrent to the sea which quickly ceased, but upland flows on the mountain ridge endured until April 30. At Kilauea there were numerous earthquakes indicating origins at Mauna Loa distances during several preceding months, there was a large increase in earthquake frequency during the Mauna Loa eruption, at Halemaumau there were rock slides due to quaking, and new cracks back from the rim broke the surface soil. Harmonic tremor at the Kilauea Observatory sympathized with the maxima of the Mauna Loa eruption April 10 to 22. At the same station there was slight accumulation of east tilt away from Mauna Loa during 1925-26, and very strong east tilt accordant with the Mauna Loa flowing April 11-24, and a reaction to moderate west tilt throughout May after Mauna Loa ceased.

Halemaumau Inflow 1927

After midnight July 7, 1927, a new outbreak of fountains in the bottom of Halemaumau split across the floor of 1924 in a line trending northeast-southwest, with the southernmost fountain some distance up the debris slope as before, and this was the only one which kept working more than a day. The line of four fountains lay but slightly to the west of the rift tunnel line shown by dikes in the wall of Halemaumau. Half the lava of the eruption came in during the first hour. The lake rose around the vents with the exception of the southern cone standing 120 feet above lake level. The area of new lava, shaped like a leaf with the cone at its stem, was 1760 feet long by 1420 feet wide. The new fill was about 110 feet deep when the last gushing ceased July 20, but the cone summit stood much higher.

On March 20 there had been a deep-seated strong earthquake felt generally throughout the Territory, and objects were thrown down and broken in Hilo shops. On June 8 a small shock was felt about the island of Hawaii, and a strange light was seen believed to be a meteor. On the day of the outbreak July 7 a moderate earthquake at 3:21 a. m. came about three hours after the lava inflow began.

Cracks on the Halemaumau rim had widened excessively at the northeast side of the pit June 22 and thereafter, so that visitors were warned away from the edge. There was no widening after the eruption began. Tilt was to the north a fortnight before the eruption, and to NW and WNW thereafter. This westing of the tilt after the beginning of Kilauea outbreak has appeared repeatedly. Harmonic tremor at the Observatory appeared in a short spell at 10:55 p. m. July 6 about an hour before the outbreak, then was continuous for 24 hours July 7-8, and showed temporary recurrences July 10-12.

Halemaumau Inflow 1928

This eruption was very small, and its occurrence as lava upflow through cracks across the 1927 floor, in coincidence with a landslip from the northwest which compressed that floor, was explained at the time as a "false eruption" merely due to the squeezing up of 1927 lava still liquid under the crust. There is reason to revise this theory.

What happened on January 11, 1928, about 12:30 a. m. (just after midnight or midday appears to be a favorite time for eruptions), was the appearance of red glow from liquid lava in Halemaumau just after a monstrous

avalanche from the northwest wall which caused a big tremor on the seismograms at 12:26 a. m. It was found that new lava had spouted up at three places on the floor corresponding approximately with the sites of the two northern fountains of 1927. How much the rosy glow seen at first was due to fountaining is not known, but it disappeared in 20 minutes and at 1 a. m. the lava areas were flows glowing through cracked crusts with some blue flame at one vent. The northwest talus cone of the bottom of the pit had been overridden by a big fall of rocks from the wall so that the entire mass of debris slid forward and out on the lava floor in a pointed heap covering a sector of the northwestern surface. Two of the outflows were near the tip of this heap, welling up cracks and flowing away from the heap, and the other was at the north some distance from the debris. If the phenomena had been wholly a squashing down of the crust and a welling up of the liquid around the crushed area, the flowing should have been toward the debris heap. The flows cooled off within a day and the avalanches thereafter ceased, a remarkable fact, for these avalanches from this uneasy wall, and also from other walls of the pit, had been tumbling for a month.

The strongest reason for considering this a true lava outbreak is found in the seismic record of the preceding month December 1927. During this month 243 local earthquakes were registered, the roars from loud avalanches were frequently heard at the Observatory two miles away December 17-28, the slides were from the northern and the southern walls notably in the vicinity of the rift belt, and the eastern cracks at the edge of the pit showed measured widening of 2 to 3 inches increasing toward the north. The July floor became overlapped with debris all around, about 8 seconds of southerly tilt accumulated at the Observatory during the month preceding the outbreak, and the December record suggested a lowering of the pit bottom. However, this may have been an error, for on January 7 the WNW rim of Halemaumau showed new cracks breaking the sod 50 feet back from the rim, and large deep cracks three feet or more wide gave up hot steam. Such widening of cracks, preceding other eruptions, appears to have indicated localized swelling under the pit, whatever may be happening to the outside rim of the greater crater, where the Observatory measures tilt. It was precisely at this WNW rim where the big avalanche occurred at the time of lava outbreak. With the release of the liquid lava the tilt at the Observatory changed from strong southwest to slight northerly. Seventy-eight local earthquakes had occurred December 24, more than a month before the outbreak, and the number of general shocks indicating origin distances 15 to 30 miles away, during December and early January, suggests that seismic conditions were affected by a deep-seated cause. The high frequency of local shakings changed to normal abruptly after January 11. All of this evidence goes to show that a change in magmatic pressure under Kilauea Volcano produced extraordinary seismic conditions for six weeks, there was unusual motion on the rift belt along the west side of Halemaumau pit, and the adjustment of a deep-seated block there, both released the eruption and brought the avalanching period to a close.

Halemaumau Inflow February 1929

At 12:46 a. m. February 20 molten lava gushed up in a big fountain at the northwest edge of the bottom along a straight fracture 1370 feet in length. A great lake filled the bottom east of the fracture line, some 60 feet in depth, the southern vents quickly became submerged in the lake, and the northern one built a half-cone of pumice with jets of the Mauna Loa type shooting 225 feet into the air. Pellets of basaltic pumice and Pele's hair fell outside of the pit. The pit seismograph registered tilting, accompanied by small earthquakes, two hours before the eruption was noticed, and straight away from the center. At the same instrument continuous strong volcanic tremor was written during the period of fountaining. This all ceased when the eruption ended about 1 p. m. February 21, and strong tilt was indicated back toward the center of the pit during four hours preceding the cessation of action. The eruption left a net gain of 5 seconds tilt away from the pit.

The prelude to this eruption, as shown by tilt instrument at the Observatory, was strong southerly seasonal tilt throughout the weeks before and after the outbreak, but with a gradual change from east to west. There had been tremor January 5-9 and 16 28, probably occasioned on January 5 by much avalanching, accompanying excessive opening of cracks at the tourist station on the southeast rim of Halemaumau. This necessitated changing the trail and making a new viewpoint. The climax was reached January 10, when slides became fewer. On February 5, 15 days before the outbreak, an earthquake occurred at 2:25 a. m. felt throughout the island of Hawaii.

Halemaumau Inflow July 1929

On July 25 about 4:35 a. m. the seismographs at the Observatory registered a series of very small earthquakes a few minutes apart, each accompanied by tilt to the east. Then strong continuous harmonic tremor developed. Lava again broke out at the west edge of the floor in the bottom of Halemaumau. The center was a fracture through the talus, tangential to the bottom plug, making big fountains at the base of the west talus. The seismograph at the pit showed inward tilt the first day, outward tilt thereafter, and tremor registered continuously while the lava fountains were in action. The eruption ceased the evening of July 28 and the liquid lake reached a depth of 94 feet, followed by settlement of 20 to 30 feet after solidification.

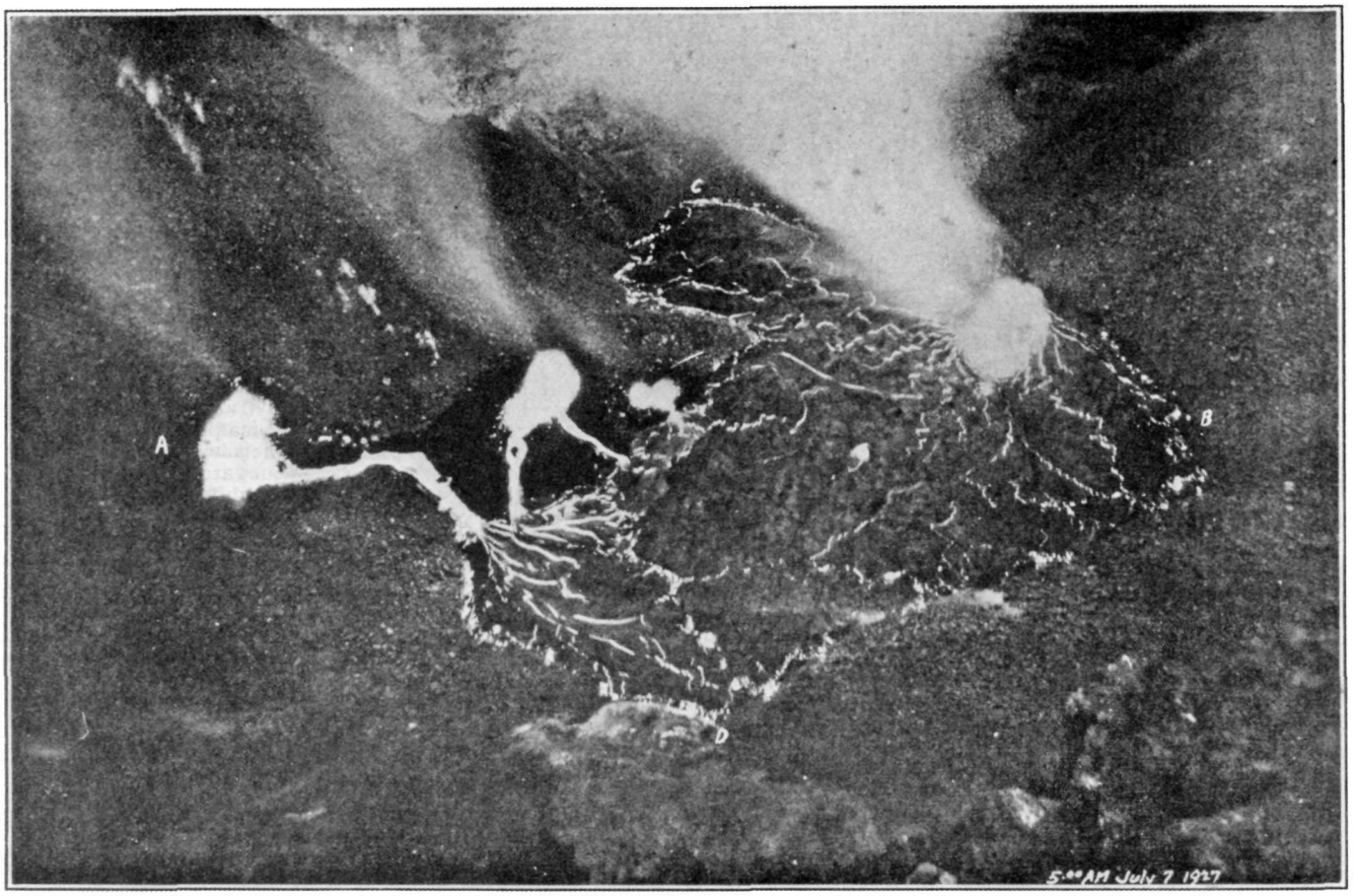
The ground tilted moderately north at the Observatory during the week preceding the eruption, and the tilt changed to southwest on the day of the eruption, becoming moderate south for the week. Cracks at the east edge of the pit had shown by measurement tendency to open since May 15 There had been two strongy felt earthquakes on the morning of June 18, occasioning avalanches on the west bluff of Kilauea Crater as well as in Halemaumau.

Halemaumau Inflow 1930

It should be here recorded that an extraordinary seismic crisis about Hualalai Volcano occurred in October 1929 which appeared to indicate a new shift of magma from under Mauna Loa in the direction of Hualalai. No lava outflow coordinate with this movement has yet appeared.

At 1:29 p. m. November 19, 1930, lava broke through the 1929 floor of Halemaumau in three fountain groups south of the central region, two of these being of small size which disappeared during the first two days, the third continuing to spout vigorously and build up a cone. The lava spread over the 1929 floor, then built a central lake of molten lava surrounded by ramparts, through which overflow on three sides removed the new lava as rapidly as it was supplied, and completely covered the former floor of the pit. After two weeks of action the lake area was 500 by 800 feet, the cone was 75 feet high and 200 feet in diameter at the base, the entire new bottom area was 2300 feet by 1700 feet, and the new mound stood above the former bottom 175 feet at the cone, 100 feet at the lake, and at the north side of the floor about 50 feet. The eruption ended December 7. Tremor accompanied the eruption as before and died away at the end. Tilt change was from moderate northeast November 10-16 to moderate southwest after the outbreak began, with a return to strong north and northeast in December. The pit seismograph had recorded tilting of the ground away from the pit and many small tremors a week before the outbreak. On the day of the outbreak this instrument recorded 18 small shocks culminating in a very feeble earthquake ot 11:06 a. m. with a slight tilt toward the pit. This was followed by a series of 30 small shocks and other earthquakes. Moderate and slight felt earthquakes and avalanches had occurred in September and October.

Reviewing the seven Halemaumau inflows in seven years, a typical eruption may be said to be heralded by one or more strongish earthquakes a few weeks before the outbreak, or by unusual seismic frequency, and 1931 produced a smart earthquake a few hours before inflow. Cracks on the rim of the pit are apt to exhibit distension of the edifice by spreading open, and so loosening the inside walls as to make avalanches. This is likely to occur along with centrifugal tilt just before the eruption. All of these eruptions appear influenced by the northeast-



Eruption in bottom of Halemaumau July 7, 1927, at 5 a. m. Shows the four main vents in line, that on the left being the high cone which persisted. Looking west-northwest. The floor of 1932 is against the wall at the top of the picture. Photo Wilson.

southwest rift belt which crosses Kilauea Crater; the final gushing splits the former floor and rapidly concentrates at one vent. There is temporary inward tilting and continuous tremor while the gas foaming of the fountains is going on. The whole series of eruptions marks an upward pressure accumulating. The eruptions have increased in volume of output and violence of effervescence, but their duration has been variable from 1 hour to 18 days, with the last two outbreaks the most enduring. T.A.J.

KILAUEA REPORT No. 1044

WEEK ENDING JANUARY 24, 1932

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The settling down of the Halemaumau floor, the bottom of the inner pit of Kilauea Crater, is all that has happened during the past week, and the cracks in the new lava of the recent eruption are no longer seen glowing at night. After excessive rainfall for several days, the hot lava fill on January 20 was seen to be steaming from hundreds of small vents all over the surface, the new cone was ringed by steam, there was steam on the taluses and walls, and vertical lines of vapor vents could be followed up the western and southern walls. These are upright cracks in the wall where the east and west fault blocks are marked above by steam cracks parallel with rim of pit. On January 18 at 8:30 a. m. after 4.10 inches of rain in 24 hours a steam cloud rose from Halemaumau and water cascades poured from Uwekahuna. At 2 to 3 p. m. some rocks were heard falling, rim cracks N and NE showed very slight widening, a central vent in the floor showed much blue fume, and eight others showed less, and new debris overlapped the lava floor at the base of the talus slopes. January 22 the pit was absolutely quiet.

One feeble local earthquake occurred 2:06 a. m. January 19, origin distance 32 miles. There were 29 spasdomic tremors, some indicating origins 2, 6, 29, and about 35 miles away. Microseismic motion was moderate, and tilting of the ground moderate ESE.

THE VOLCANO LETTER

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The Volcano Letter

371

Two dollars per year **Ten cents per copy**

No. 371—Weekly | *Hawaiian Volcano Observatory, National Park, Hawaii* | *February 4, 1932*

REVIEW OF EARTHQUAKE RECORD KILAUEA 1931

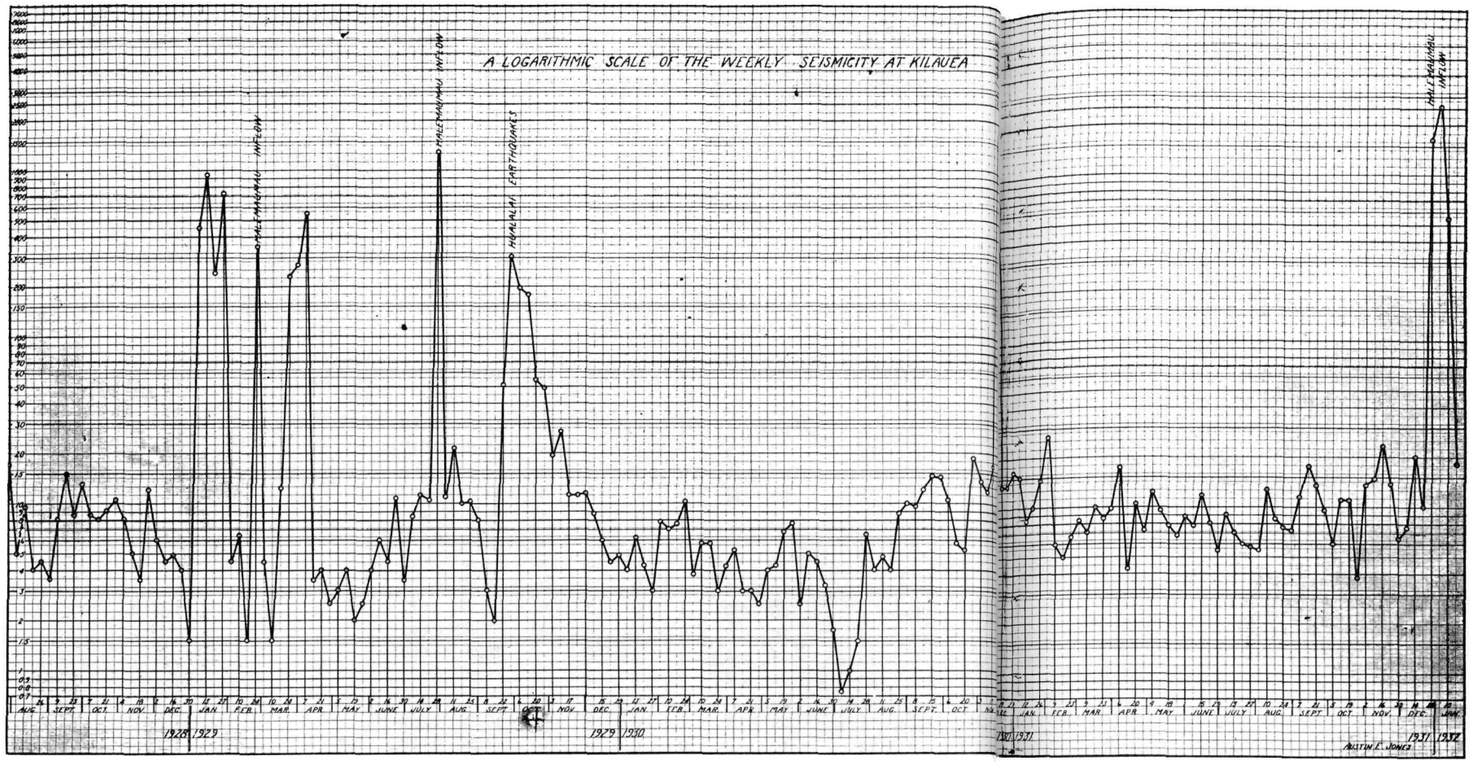
tr —tremor, value ¼ Rossi-Forel
vf —very feeble, ½ Rossi-Forel
f —feeble, 1 Rossi-Forel
SSRF—seismicity summation R.F.
sl —slight, value 2 Rossi-Forel
mod—moderate, 3 Rossi-Forel
tel —teleseism, or distant earthquake, no value for local seismicity.

Week ending 1931	tr	vf	f	sl	mod	tel	SSRF	log
Jan. 5	55	1	1	0	0	1	15.25	1.183
12	27	3	0	0	0	0	8.25	0.917
19	22	5	0	1	0	2	10.00	1.000
26	30	14	0	0	0	0	14.50	1.162
Feb. 2	40	27	1	1	0	0	26.50	1.423
9	11	2	1	0	0	1	4.75	0.677
16	12	2	0	0	0	0	4.00	0.602
23	19	1	0	0	0	0	5.25	0.721
Mar. 2	25	2	1	0	0	0	8.25	0.917
9	16	2	0	1	0	0	7.00	0.845
16	34	3	0	0	0	0	10.00	1.000
23	22	2	0	1	0	3	8.50	0.929
30	29	3	0	0	0	1	9.75	0.989
Apr. 6	55	5	1	0	0	1	17.25	1.237
13	17	0	0	0	0	0	4.25	0.628
20	18	6	1	1	0	0	10.50	1.021
27	23	3	0	0	0	1	7.25	0.861
May 4	33	4	2	0	0	0	12.25	1.088
11	38	0	0	0	0	1	9.50	0.978
18	29	1	0	0	0	0	7.75	0.889
25	25	1	0	0	0	0	6.75	0.829
June 1	33	1	0	0	0	0	8.75	0.942
8	29	1	0	0	0	0	7.75	0.889
15	27	6	0	1	0	0	11.75	1.071
22	26	1	1	0	0	0	8.00	0.903
29	22	0	0	0	0	0	5.50	0.740
July 6	34	2	0	0	0	0	9.00	0.954
13	18	5	0	0	0	0	7.00	0.845
20	18	3	0	0	0	0	6.00	0.778
27	19	2	0	0	0	0	5.75	0.760
Aug. 3	16	1	1	0	0	0	5.50	0.741
10	39	6	0	0	0	1	12.75	1.105
17	22	6	0	0	0	1	8.50	0.929
24	24	3	0	0	0	0	7.50	0.875
31	19	1	2	0	1	0	7.25	0.861
Sep. 7	36	5	0	0	0	0	11.50	1.061
14	56	5	1	0	0	1	17.50	1.243
21	43	1	2	0	0	0	13.25	1.128
28	26	4	1	0	0	1	9.50	0.978
Oct. 5	20	2	0	0	0	1	6.00	0.778
12	28	8	0	0	0	1	11.00	1.042
19	40	2	0	0	0	0	11.00	1.042
26	11	1	0	0	0	0	3.25	0.512
Nov. 2	40	3	2	0	0	0	13.50	1.131
9	59	0	0	0	0	0	14.75	1.169
16	81	6	0	0	0	0	23.25	1.367
23	51	2	0	0	0	0	13.75	1.138
30	22	2	0	0	0	0	6.50	0.810
Dec. 7	24	3	0	0	0	0	7.50	0.875
14	46	9	1	0	1	0	20.00	1.303
21	28	6	0	0	0	0	10.00	1.000
28	6,531	9	1	0	1	0	1641.00	3.215
1932								
Jan. 4	10,080	3	1	0	0	0	2522.00	3.419
11	2,544	4	0	0	0	2	638.00	2.805
18	63	5	0	0	0	0	18.25	1.260
25	29	0	1	0	0	0	8.25	0.915

A CHART OF KILAUEA SEISMICITY

The accompanying diagram exhibiting seismic motion of the ground is a compilation of earthquake activity, representing one of many attempts to show in a single graph a combination of the number and intensity of earthquakes for a given time. What is called seismicity, or the earthquake shakiness of a country, is compounded of tremors and small shakes and big shakes, with many of the smaller phenomena and very few of the big ones. If all are a release of some form of underground energy where magma is moving under a volcano, it is reasonable to think of a single big earthquake as in some way the equivalent of many small ones. (See discussion of Earthquake Intensity Scales, Volcano Lettetr No. 223, April 4, 1929.)

At the Hawaiian Volcano Observatory the weekly descriptions of local seisms or quakes describe them as very feeble, slight. moderate, etc., and these words are not colloquial, but are systematic. The word "slight" means relatively big as compared with "very feeble." By giving a weight or value in terms of the Rossi-Forel scale to each descriptive word, we can add together these values for the number of earthquakes of each grade for each week and secure a figure standing for the combined shakiness of that week. The following is the table of weights:



Curve of rising and falling earthquake and tremor activity, expressing combined weekly frequency and intensity of local earthquakes, and duration of local tremors. measured at the Observatory on northeast rim of Kilauea Crater from August 1928 to January 1932. By A. E. Jones.

Observatory Scale	Weight	Description
Tremor	¼	Can barely be seen on the seismograph records; when continuous the unit is the minute of duration.
Very Feeble	½	A slightly larger shock, not ordinarilly felt by people even when very close to the origin. Rarely reported felt by persons lying down.
Feeble	1	Felt by few or none, an earthquake on the border line between being instrumental and felt. No. I Rossi-Forel scale.
Slight	2	No. II Rossi-Forel scale. Felt slightly.
Moderate	3	No. III Rossi-Forel scale. Felt moderately.
Strong	4	No. IV Rossi-Forel scale. Felt strongly.

An earthquake felt strongly is still in the weak class, but from the point of view of instrumentalists, operating seismographs that magnify the earth's motion one hundred times, this quake is strong because it always dismantles the connecting bars of a sensitive seismograph. This does not mean that it breaks anything.

These grades are weighted roughly in terms of the Rossi-Forel scale as ¼, ½, 1, 2, 3, 4, and mathematically, in terms of accelerations, the Rossi-Forel scale is logical in that Grade II is twice as big as Grade I, etc., up to Grade IV. Beyond Grade IV the progression is not arithmetical.

If in one week we have 10 tremors or 10 minutes of tremor (value 2½), three very feeble shocks (1½), a slight earthquake (2), and a moderate earthquake (3), the resulting index of that week's seismicity is the summation of these values equal to 9. Thus in the accompanying tabulation the week ending July 6, 1931, had that value because of the very large number of tremors.

If we were to have several days of continuous tremor, each day would produce 1,440 minutes of tremor, or an index of 360. Such an example can be shown for the last eruptive period of Halemaumau beginning in December of 1931. During the week ending December 31, 1931, there were 11 tremors, 9 very feeble shocks, 1 feeble one, and a moderate earthquake preceding the eruption which began on December 23. The summation index to this point is 11.25. This was followed by four days and a half of tremor, the index of which amounted to 1630. The total index of seismicity for the week is obtained by adding together the two figures and amounts to 1641 units.

If this were platted on uniform coordinate paper, the figure 1641 would be about 180 times as great as that for the week mentioned above having the index of 9, so that if inches were used as units on the paper, the line would rise 135 feet. To avoid this difficulty the logarithms of all index numbers have been taken and platted for the number of units involved vertically above each date. In the accompanying table the logarithmic figure is shown in addition to the seismicity figure. On the curve a logarithmic scale has been drawn across the diagram with the seismicity sums R. F. on the left. These read from 0.7 to 9000 and the sheet is thus adequate to contain all the peaks and hollows for the three and a half years from July 1928 to January 1932.

To judge by the height of the peaks, during eruptions of lava flowing into Halemaumau in February and July 1929, November 1930, and December 1931, making a pronounced rise of the curve in each case, determined largely by continuous tremor, evaluated for each minute arbitrarily as one-quarter unit, it seems likely that this arbitrary value is much too great. The method, however, has the advantage of exhibiting an effect of these eruptions on the seismicity curve with much vividness. A.E.J.

DISCUSSION OF SEISMICITY CURVE 1928-32

The table which was used by Mr. Jones in compiling the curve described above, will be better understood if it is presented in full for this past year 1931 in order to show how the curve was drawn for the right-hand side of the diagram. The table is on Page One.

Curves of earthquake frequency by months and by three-day units have been experimented with at the Hawaiian Volcano Observatory as follows: By Jaggar, monthly local earthquake frequency compared with maximum intensity from 1912 to 1916, in "Seismometric Investigation of the Hawaiian Lava Column," Bull. Seis. Soc. Amer. Dec. 1920, p. 259, when it appeared the peaks were at rythmic intervals of about nine months and increasing along with a series of Mauna Loa events. Next a study by Wilson Bull. Haw'n Volc. Obs. Dec. 1927, fig. 47, wherein the three-day frequency was smoothed by overlapping means, did not include harmonic tremor (nor did the one above), and analogy with the lunar half-month was suggested. Taking frequency alone, there was no peak accompanying the July eruption of Halemaumau 1927, but a comparative symbol indicating intense earthquakes showed a swarm of them not reflected in frequency curve, but occurring at the beginning and the end of the eruption. Thus Wilson's curve, compared with the new method by Jones, would have shot up for the 1927 eruptive period, had it embodied an integration of harmonic tremor and intensity along with frequency, as has been done in the new type of curve. In a diagram compiled by Finch for comparison with tilt (Bull. Seis. Soc. Amer. Mar. 1929, p. 41), marked peaks in monthly earthquake frequency for the years 1913-1925 are shown to accord with drops in the lava of Halemaumau and with Mauna Loa outbreaks, the highest frequency according with the tremendous drop of 1924. In 1916 when there was a sudden drop of the Halemaumau lava immediately following an outhbreak of Mauna Loa, there were two peaks of earthquake frequency side by side accompanying these events (Jaggar, Amer. Jour. Sci. Apr. 1917, fig. 2 p. 259).

The outstanding features of the curve for seismicity at Kilauea from 1928 to the beginning of 1932 are the high peaks of suddenly increased seismic activity that accompanied the four outbreaks of Halemaumau. By consulting the last number of the Volcano Letter, January 28, 1932, the reader may learn the details of these eruptions February 28, 1929, July 25, 1929, November 19, 1930, and December 23, 1931. It was there stated that in general these eruptions were progressively more intense and more enduring, and it is clear from the chart that the four peaks of seismicity are progressively higher and wider. Mr. Wilson's curve mentioned above showed a composite peak of earthquake frequency in December 1927 immediately preceding the very mild outbreak of January 1928, and this was made up of much tremor accompanying avalanches in Halemaumau pit and the widening of some cracks on the edge. If that episode were added to the left-hand side of our diagram, we should find a still smaller peak for the actual eruption week of 1928 and a big complex peak preceding it. So for the seven weeks preceding the February eruption of 1929 there is a composite and enduring peak of seismicity which was accompanied by widening of cracks and numerous avalanche tremors, as well as other seismic events distinctly premonitory to the lava inflow of February 20.

Not so clear is the explanation of the third peak between March 10, the time of low tremor following the eruption, and April 14, when general decline began. The only events of note during this time were rather protracted spasms of tremor, a certain number of avalanches, and some rather strong tilting. It seems likely that this peak in seismicity represents a distinct slump in the lava column following the eruption, but its qaulity of gradual rise and sudden fall to a point below normal is unusual.

If we look at the curves on either side of the other Halemaumau eruptive periods as shown in our diagram, there is nothing analogous to these peaks of preparation and of aftermath.

The Hualalai earthquake crisis of September-October 1929 is developed as a very sudden rise in the seismicity curve, followed by a stepwise decline for 17 weeks, and this curve is quite in accord with the facts of observation, for the strong intensity and the strong frequency showed maxima soon after the beginning. It will be seen that this is a true earthquake curve of sudden intensity, followed by swarms of aftershocks, and quite unlike the steep bilaterial curves that accompanied the Halemaumau outbreaks.

When it comes to the general curve of seismicity in the diagram, disregarding the high peaks, it is evident that this curve as a whole tended to fall below the figure 10 from 1928 to July of 1930, and that then there was a pronounced rise in seismicity, and thereafter the small crests tended to rise above that figure. The minima approached low levels right while the maxima were reaching high ones about February 1929, again in September of that year, and the lowest of all was reached in July of 1930. In the whole diagram there is possibly some suggestion of a wave movement with troughs of minima 16 months apart. When it comes to the small oscillations, there is a marked tendency to troughs from two to six weeks apart, possibly corresponding to the lunar month and half-month. This tidal effect for both seismicity and lava movement has been discussed before. The fact of the diagram are 20 cases of complete periods occupying four to six weeks, 20 occupying three weeks, and 14 occupying two weeks. The mean is 3.4 weeks, which is near enough to the lunar month for such crude results over a short interval of time.

There are many questions raised by this diagram as to the comparability of local seisms, spasmodic tremor, harmonic tremor, and avalanche tremor, and the equivalence of the units used in terms of acceleration, or of whatever product of amplitude and period properly constitutes seismic intensity. It should be noted, however, that this is not an intensity curve, but is rather an intensity-duration curve, and this taking account of frequency is new, and the seismologist of this station is to be congratulated on the experiment. T.A.J.

KILAUEA REPORT No. 1045

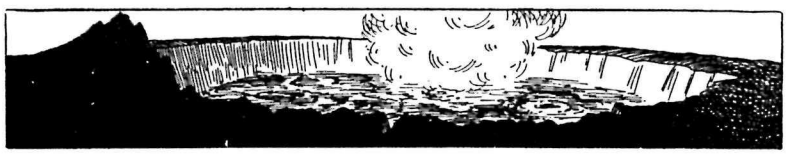
WEEK ENDING JANUARY 31, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Nothing remarkable has happened at Halemaumau pit suggestive of movement of lava. The new floor is hot and a high cumulus occasionally forms above the pit. On January 26 in the forenoon no single vents on the floor could be identified as emitting fume, there had been sliding from southerly walls as shown by numerous bowlders and fresh debris on the 1932 floor SE, and red material on floor S. The northeast rim cracks continued to widen slightly by measurement. At 11:18 a. m. a slide from the northeast wall, beginning near the top, made dust.

The seismologist reports 1 very feeble local seism January 28 at 8:18 a. m. with indicated distance 6 miles. Forty-eight local tremors were recorded, 3 suugesting origin distance 9, 18, and 23 miles. A distant earthquake registered January 29 at 3 h 21 m 12 s a.m., indicating approximate origin distance 3100 miles, began too indefinitely to show direction of origin.

Microseismic motion has been moderate, and tilting of the ground moderate to the east.



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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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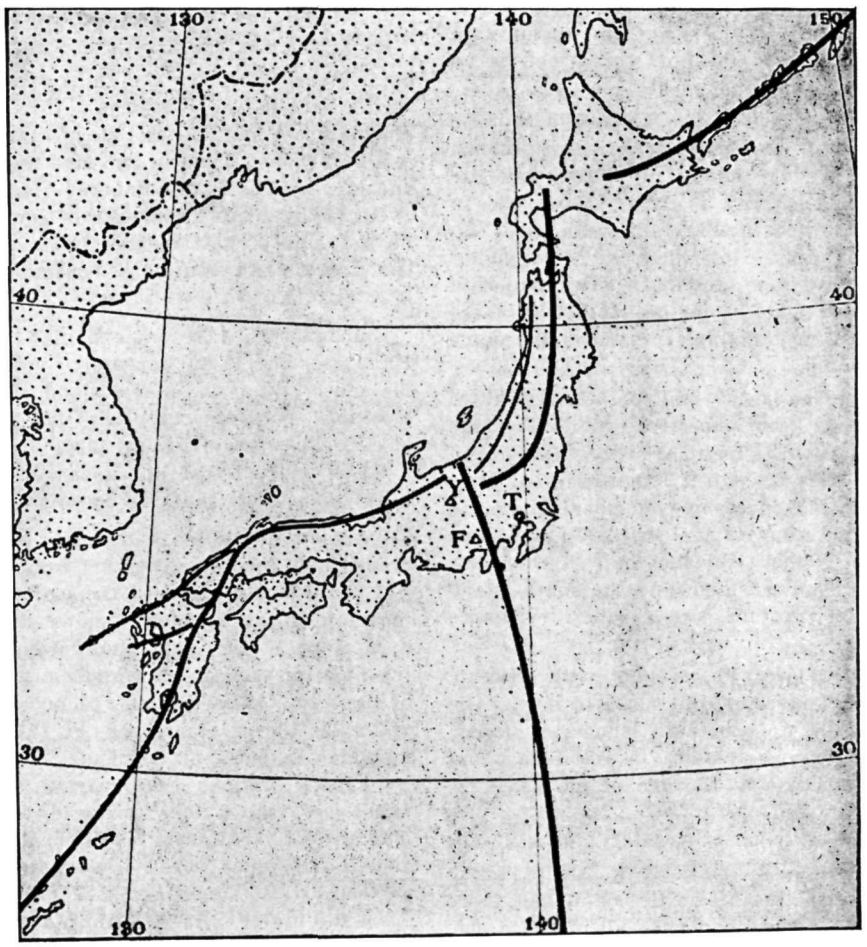
No. 372—Weekly Hawaiian Volcano Observatory, National Park, Hawaii February 11, 1932



Map of volcanic arcs in Japan, showing the main central Honshu arc, with the Kurile arc at the northeast and the Ryukyu at the southewest. T=Tokyo, F=Fujiyama, Y=Yakedake. The Fujiyama zone extending to the south leads through the Ogasawara Islands. By Omori.

RECENT ERUPTIONS IN JAPAN

An impressive series of arcuate fissures in the crust of the earth, each 1200 to 1500 kilometers long, including the Ryukyu islands, the three mainland islands of Japan, the Kurile Islands at the north, and the Ogasawara line of islands south from Fujiyama, makes up the volcano domain of Japan. In all, this involves 5,000 kilometers or 3100 miles of scattered volcanoes, amid hills and mountains built above the fractures, so that as cracks they are concealed.

The eruptions from 1924 to 1931 have been tabulated by Tanakadate (Japan Jour. Astron. and Geophys. Vol. IX, No. 1, 1931, p. 47).

The activities are divided into smoke explosions, ash explosions, explosive eruptions, pumice flows, mud flows, submarine eruptions, and "increase of normal activity." This normal activity in volcanoes like Aso, Oshima, Tarumai, and Asama involves lava in the crater pit. Lava flows are rare in Japan because the andesites are siliceous and viscous, and the gas or steam of an "eruption" effervesces explosively through the incandescent slag that plugs the crater. "Fire phenomena," or "pumice flows," or "flows of lava blocks," or "glowing lapilli" are frequently described, as seen from a distance. These descriptions means an internal intrusive magma disrupted. (See Tanakadate, "Eruptive Types," Volcano Letter No. 323, March 5, 1931.)

The activity of the seven years speaks volumes for what Japan has to offer to the student of volcanology. Professor Tanakadate has made a very striking compilation of the facts, the upshot of which is that there are only a few months of each year without reported eruptions in some of the volcanic zones.

There are large shiftings from one zone to another.

There was in Japan a striking rise in distributed frequency in 1927-28, and in intensity in 1929, with a lower Japanese volcanicity before and after these three years.

It happens that these were years of sunspot maxima (see Volcano Letter No. 326), and 1928-29 produced extreme volcanicity elsewhere including the Dutch East Indies, Tonga, Chile, Guatemala, Martinique, and Italy.

Reviewing each year for Japan and beginning with September 1924, we get smoke explosions from Asamayama in central Honshu, followed in the next three months by Yakedake a short distance farther west.

In 1925 Yakedake, Asosan in south Japan, and Shirane in central Honshu were all performing in January, blowing fume and dust, and Yakedake kept it up throughout the year. Asama increased activity in May. Suwanose in the Ryukyu Islands erupted in March, Asosan made increasing explosions in July, November, and December. And in the autumn came a submarine eruption, with floating pumice fields, at Hatoma in the south end of the Ryukyu Island line. Kamchatka had eruptions the same year.

In 1926 Yakedake was active but quieter, while Tokachi in the north island made a big explosive eruption in May and continued in the autumn. Tarumai in the same island erupted in October, Asama in central Japan renewed fume explosions preliminary to increasing demonstrations in succeeding years, and Asosan in the south did the same but more violently throughout the last half of the year. The north island, the central island, and the south island were now all in action together, and Aleutian volcanoes also broke out.

This continued and increased in 1927 with Asosan, Yakedake, Asama, and Tokachi (from south to north) the main performers, and all on the main islands of Japan. All four had ash explosions, chiefly in April-May, but Asama reached such maxima at the end of the year.

While in 1928 the number of explosive incidents was less, the diversity of location of intense episodes was greater. Matuwa, an island in the northen Kuriles, broke out in February, Tarumai in the north island had three eruptions, and nearby Tokachi had one; all of these concern the northern area. For central Honshu, Asama was fiercely active the first half of the year, Shirane again blew out crater holes, and Oshima near Tokyo revived in the summer. Yakedake slept. Asosan in Kyushu had four eruptive spasms, of which one was an ash eruption and one was accompanied with mud flow.

The year 1929 produced two major explosive eruptions, Komagadake in the north island in June, and Asama in central Japan in September. Tarumai had another outburst, Yakedake had two, and Asosan had two, of which the last was an ash explosion in October. Komagadake had a revival in September, and Asama had fume explosions four times, in addition to its major eruption. Kamchatka volcanoes were active.

A marked dwindling occurred in 1930, with Asama, however, making ash explosions four times in summer and autumn. Matuwa in the Kurile Islands again exploded in its favored month, February. Yakedake had two explosions in the spring, and Asosan one in the autumn. The Aleutian region reported two eruptions.

The late spring of 1931 produced outbreaks in Asama, Yakedake and Asosan, and the same season was notable for activities in the Aleutian Islands and a major eruption at Aniakchak on the Alaskan Peninsula.

Now let us consider the details of some of the Japanese events. The Tokachi eruption beginning May 7, 1926, was in the center of the north island at a sulphur mine operated at a solfatara on the side of a peak 2,077 meters high. Explosions with fume and sulphur flame increased in violence at a place not historically known to be strongly active. But this is in the Ainu wilderness, and merely shows, as elsewhere in all the solfataric belts of the world, that sulphur and heat may anywhere develop a volcano.

On May 24 three persons were killed in a preliminary burst, debris covering the slope and overwhelming a hot-spring bath house. Then at 4:10 p. m. a tremendous explosion upset five million tons of the mountain flank. This material rushed down in two mud flows devastating forests and farms. The dead numbered 144, the wounded 207, and twenty-five square kilometers of country were devastated. Lava lumps of new magma appeared later as bombs in the debris, and eruptions continued but diminished in 1927 and 1928.

Komagadake, 1140 meters high, is near the city of Hakodate, and is an impressive volcano like Vesuvius at the south end of the north island. It has a record of big eruptions, some as recent as 1905 and 1919. There was an ash explosion in July of 1924. Beginning June 16, 1929, a large destructive eruption began "which ranks next in importance after the 1914 eruption of Sakurajima."

At midnight June 16 a small explosion originated at cracks and fissures extending radially from a small lava hill in the central part of the main crater. Ash fell next morning at the southern foot of the mountain. At 9:30 a. m. June 17 enormous cauliflower clouds arose resembling huge masses of wool and emitting continuous flashes of lightning. The column reached an altitude more than six miles above sea level. At 10 a. m. there were tremendous detonations, roarings, and tremblings, followed by smoke columns that carried blocks of rock, lapilli, sand, and ash which were showered over the country. The ground was almost continuously in vibration, and distinct earthquakes were recorded at the seismograph of the meteorological station at Hakodate, 33 kilometers south from the crater. At 11 a. m. blocks of pumice and small stones were falling at the southeastern foot of the volcano where the forest was devastated, while the village of Sikabe, 13 kilometers to the southeast, had its fields and fishing grounds covered with three or four feet of lapilli.

In the afternoon at frequent intervals glowing masses of pumice blocks ran down the radial valleys in several directions, resembling the glowing blasts **(nuées ardentes)** as described at Mont Pelee in Martinique. These pumice flows traveled in places more than five miles from the crater. At 7 p. m. "fire columns" hung over the crater in the smoke cloud with continuous lightning flashing. The eruptive activity culminated about 10 p. m., after which it gradually declined and towards midnight ceased.

Extraordinary changes took place in the caldera crater of the volcano. The floor was elevated by tumescence, to which relief was added by accumulation of lumps of lava. Three main vents were formed on the domed floor; a round craterlet at the west, a T-shaped fissure at the north, and twin craterlets at the southeast corner, all pouring out white fume. In addition there were numerous minor fissures on the dome.

Quantities of ejectamenta consisting of acidic andesite covered 538 square kilometers of country. Pumice flows in addition, occupying several valleys, covered 27

square kilometers. One person was killed, four were wounded, 65 domestic animals were destroyed, 3500 acres of farm lands were ruined, and about 87,000 acres of pasture and forest were devastated.

There was a renewal of explosive cauliflowers accompanied by tremblings the afternon of September 6.

Asamayama is the Vesuvius of Japan, characterized by explosions with rumbling, quaking, and air shocks, the projectiles consisting of ash, lapilli, bombs, and blocks several tons in weight. Tanakadate says, "Most of the ejecta are considered as not being juvenile" or magmatic, but the reviewer would question this, for the bottom area in the crater which he saw in 1907, appeared to be a typical andesitic aa lava.

After eruptions and earthquakes in 1924, 1927, and 1928 of increasing vehemence at Asama, there came a great eruption on September 18, 1929, at 1 a. m. which began with roarings followed by detonations. The villagers saw glowing smoke clouds ascending from the crater more than a half mile high. Red-hot blocks of lava were hurled up, and atfer three paroxysmal explosions accompanied with such fire phenomena, the energy of the eruption gradually declined, but rumbling continued. Air shocks were unusually strong, ash rain fell to the east, lava blocks were scattered about the crater, the eastern part of the crater wall was destroyed, and new pits were left in the floor of the crater. About 3.4 million cubic meters of material were thrown out.

Other explosions of Asama and earthquakes followed in 1930. On August 20 of that year a sudden explosion accompanied by a heavy downpour of projectiles killed six persons who had ventured too near the crater rim. On September 5 the explosion clouds were accompanied by incandescence, and the ash rain fell in Tokyo 140 kilometers to the south. Some of the earthquakes, centering at Asama, are registered at Tokyo.

The eruptions of Yakedake and Asosan are of the same general character as those described for Asama, with occasional "fire" and much damage to rice fields by showers of ash, and of fine cindery sand called "yona" in the Aso district. In all cases there is more or less trembling and lightning and earthquakes. The flinging out of red-hot breadcrust bombs which make new landmarks on the edges of the craters, and repeated changes in the configuration of the bottoms, are characteristics of Japanese eruptions.

After our experience at the Kilauea Observatory in trying to decide what physical phenomena may be measured all the time near an active crater, and what active craters are most useful for continuous observation, it is of great interest to study these Japanese records. The seven-year table here under discussion shows 26 incidents for Asama, 25 for Yakedake, and 24 for Asosan, with Yakedake dominant 1924-25, Asosan dominant 1926-27, and Asamayama dominant 1928-31. Oshima which fumes all the time in Sagami Bay, and has a red-hot vent in the lava cone of its inner crater, is only mentioned as throwing up ash once August 7-8, 1928, and showing fire at night to the villagers. Yet Oshima with its basaltic lava is for many reasons the ideal volcano for an observatory. It is well placed near the Tokyo center of research, it was near the center of the terrible earthquake of 1923, and it is near the middle of all the volcano belts. A headquarters observatory at Oshima could maintain substations at Asama, Tarumai, Yakedake, and Asosan, and would thereby cover well all the zones. It is a very striking fact that Aso, Yakedake, Asama, and Tarumai all lie at the intersections of two volcanic belts, and it seems likely on this account that the angle between two crustal fissures is the place of most continuous emission. T.A.J.

TILTING OF THE GROUND FOR JANUARY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumb line in seconds of arc, in the direction given.

January 5-11	0.6 second	S
January 12-16	0.4 second	NNE
January 19-25	2.1 seconds	ESE
January 26-February 1	1.6 seconds	S

E.G.W.

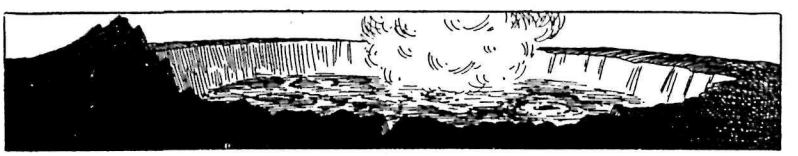
KILAUEA REPORT No. 1046

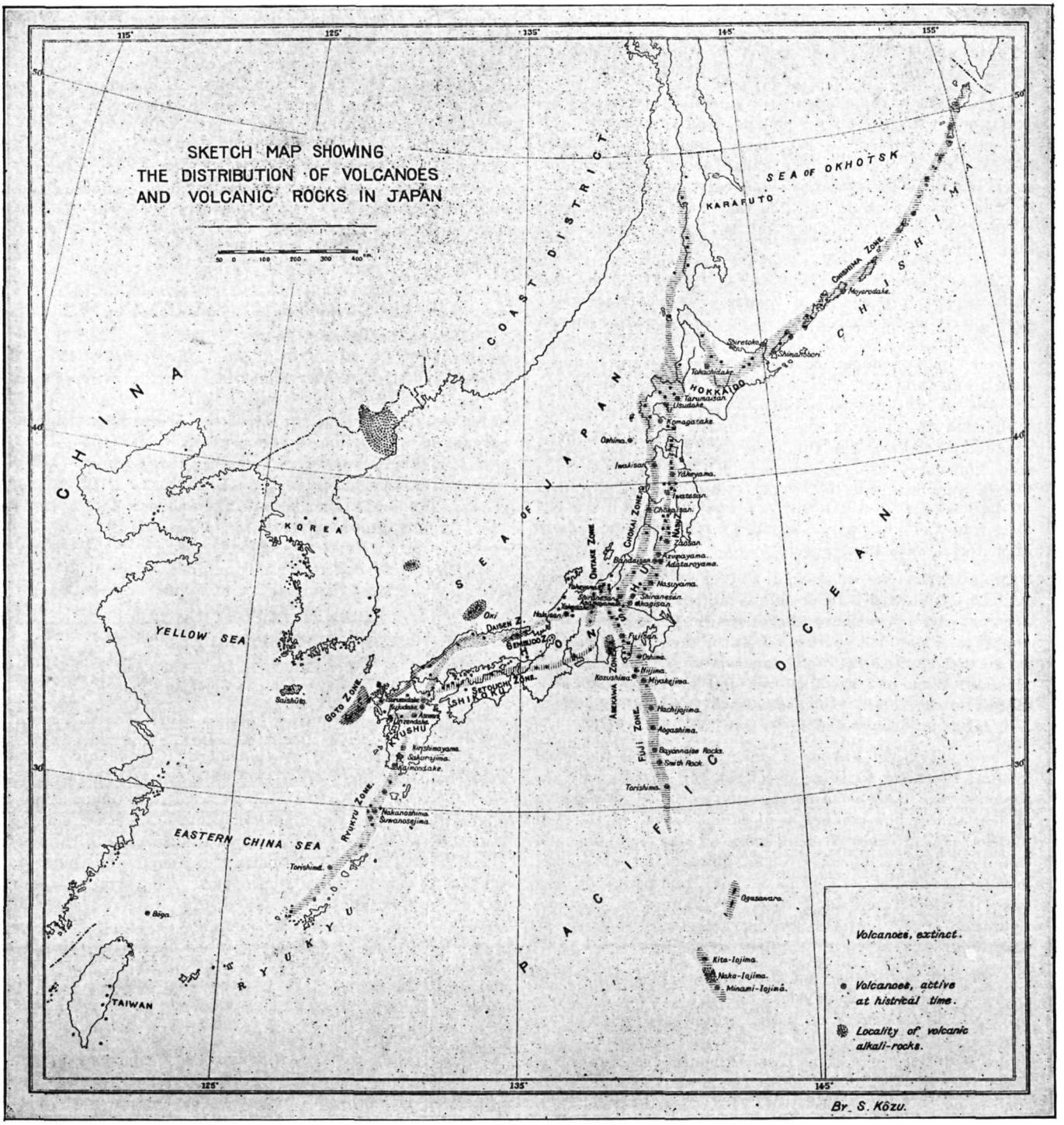
WEEK ENDING FEBRUARY 7, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

Halemaumau continues dormant. In the forenoon February 1 two or three rocks fell from the walls. Cracks on the northeast rim continued slight widening. Five vents emitting slight blue fume were counted on the floor. On February 2 rocks were falling almost continuously and slight widening of rim cracks continued. Surveys showed that the greatest amount of vertical shrinking in the new January lava floor of Halemaumau amounts to between 40 and 50 feet in the southern part. The lava here now stands 30 feet above the top of the former 1930 cone, whereas when it was liquid January 5 the depth was estimated over 70 feet. The edges of the flood have remained stationary, and the average vertical shrinkage out in the middle is between 10 and 20 feet. The average depth of fill is about 110 feet.

The seismographs recorded 1 very feeble shock with indicated origin distance 4 miles. Sixteen tremors were registered, one showing distance 23 miles. There was prolonged tremor for 4 minutes February 3 and for 18 minutes Febraury 6, this latter indicating origin distance 18 miles probably NW. Microseismic motion was moderate, and tilting of the ground moderate SSW.





Map of active and extinct volcanoes in Japan by S. Kozu. Hatoma is at the extreme southwest near Taiwan, and Matuwa is north of the middle of the Chishima zone.

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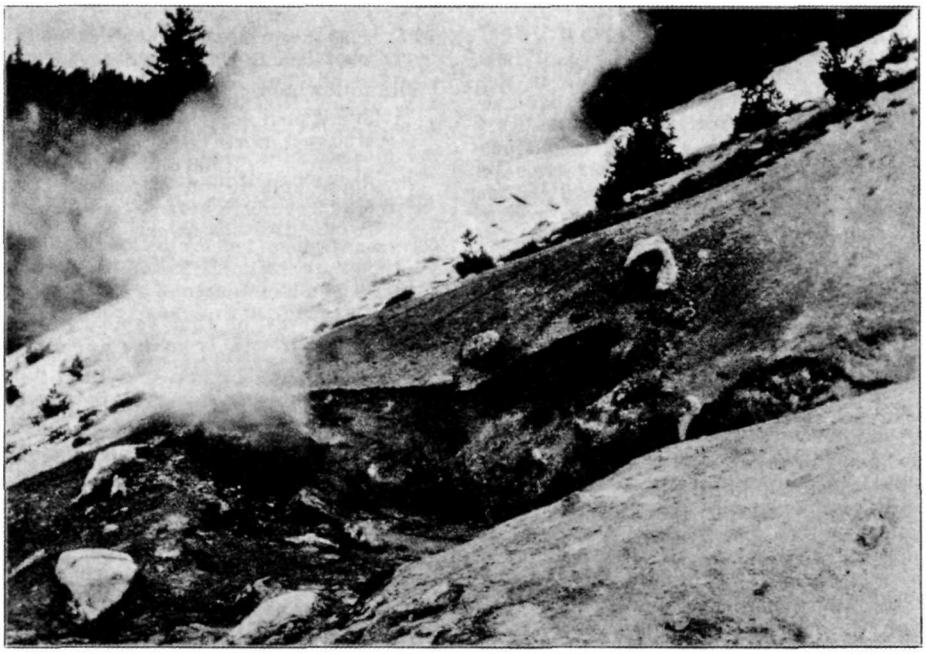


Big Steamer at Supan's Springs June 13, 1931. Photo from Finch.

LASSEN REPORT No. 31

WORK OF LASSEN VOLCANO OBSERVATORY IN 1931

Mineral, California

R. H. Finch, Associate Volcanologist

Outlying Seismographs

Besides the main station at Mineral, placed in the Forest Reserve three miles outside of Lassen Volcanic National Park to the southwest, seismographs are operated at Viola, seven miles outside the accompanying map at the northwest, and at Mount Harkness in the forest lookout station at the southeast corner of the Park. These seismographs are all of the horizontal pendulum type, those at Mineral and Mount Harkness being Hawaiian type instruments, made in the shop of the Hawaiian Volcano Observatory.

The seismograph at the Loomis Museum near Viola was started in operation for the summer on June 20. 1931, and operated by Mrs. F. J. Hermann, wife of the Park Naturalist. Except during occasional clock trouble, the seismograph registered continuously until September 25.

The seismograph on Mount Harkness was kept in operation from June 30 until October 23 by A. J. Free, Park Service fire lookout. This instrument gave some excellent records of distant earthquakes, and the seismograms were loaned for stuly to the seismographic station of the University of California.

Tilting of the Ground

It will be remembered (Volcano Letter No. 336) that in the report of the Lassen Observatory for 1930 that the accumulation of tilt to the southwest at Mineral, (that is, away from Lassen Peak), was less during 1930 than in former years, and that the Harkness station when first set up indicated southeast tilt, which also is in general away from the Lassen center of volcanism. The correction for accumulated tilt on all seismographs operated by the Lassen Observatory in 1931 was less than during 1930.

Local Earthquakes

Nearly all of the earthquakes, registered on the instruments at Lassen, appear to originate under the big volcano itself. The seismograph at Mineral registered 38 earthquakes during the year 1931. The distribution of these shocks by months was as follows:

January	7 shocks	July	0 shocks
February	2 "	August	9 "
March	1 "	September	2 "
April	3 "	October	4 "
May	2 "	November	4 "
June	3 "	December	1 "

The numbers of shakings recorded during each of the last five years are as follows:

1927	266 shocks
1928	37 "
1929	96 "
1930	74 "
1931	38 "

Rainfall

The total rainfall and the total snowfall for 1931 compared with previous years were as follows:

Rainfall		Snowfall	
Year	Precipitation	Winter	Snowfall
1927	43.32 inches	1926-27	168 inches
1928	42.10 "	1927-28	106 "
1929	38.65 "	1928 29	130 "
1930	38.94 "	1929 30	138 "
1931	46.30 "	1930-31	64 "
		1931-32	114 "
			to Jan. 1, 1932

It will be seen by these tables that the variation in the rainfall is less than that of the snowfall, and that the latter was extraordinarily different for the season 1930-31, only 64 inches, as compared with 1926-27 when 168 inches accumulated. The winter of 1931-32 is another time of very heavy snows, and Mr. Finch has recently written under date December 30, 1931, "For the past two weeks, it has been about all that I could do to keep up the ordinary routine. We have had over 78 inches of snow during that time. I climb down a flight of stairs, cut in the snow, to get into the office, and to the instrument shelter. So far I have not been able to get any help in removing the snow, but hope to find someone within a few days. It is still snowing and there is considerable possibility of our getting snowed in." The Mineral station is in the midst of big evergreen trees, high in the mountains, and has recently been something of a resort for winter sports, for people from the Sacramento valley (T.A.J).

In June 1931 some data on slump scarps were obtained. Many examples of this type of cliff can be found in northern California. A note for publication on this subject is being prepared.

Hot Springs Temperatures

Temperature measurements for comparison with the records of former years (as recorded in the 'Bulletin of the Hawaiian Volcano Observatory' and in the 'Volcano Letter' from time to time,), the measurements being made with corrected maximum Fahrenheit thermometers as part of the routine of the station, resulted as follows:

Big Steamer at Supans Springs

(Southwest part of Park west of Diamond Peak)

Date	Temperature
June 13, 1931	190° F.
July 11	195° F.
August 8	196° F.
August 30	199° F.
October 11	194° F.

Bumpass Hell

(Southwest part of Park, south of Bumpass Mountain)

On August 24, 1931, the highest temperature was 198° F. at a mud pot in the center of the area, measured at a depth of 8 feet. The highest temperature of any of the boiling springs was 196° F.

Lassen Crater

(At the summit of Lassen Peak shown in the map above the word "Lassen" in the middle of west end of Park)

On September 1, 1931, the air temperature was 78° F. and there was no snow in the crater The following were the temperatures of the several vents:

Northwest vent	130° F.
North vent	110° F.
Northeast vent	110° F.
South vent	136° F.

Morgan Springs

(Outside the Park, southwest corner of map)

On October 30, 1931, measurements of the several springs were as follows:

No. 3 Larvae Pool	156° F.
No. 14 North	152° F., flowing vigorously
No. 17	200° F.
No. 20	200° F.
Upper Geyser	202° F.

Boiling Lake

(South side of Hot Springs Creek, southern part of Park)

On September 7, with air temperature 66° F., the lake was high within four inches of the outlet. The following measurements were made:

Northwest edge	120° F.
Large mud pot, west	201° F.
Boiler, south end, water	170° F.
Boiler, south end, mud	199° F.

Devil's Kitchen

(Upper Hot Springs Creek, southern part of Park)

The following were measurements of September 7, 1931:

Small pool north side	194° F.
Mud pot north side (thick mud, surface exposure)	144° F.
Small hole at side of pool north side	200° F.
Mud pot northwest	196° F.
Pyrite pool northwest	190° F.

New Steam Vent

(South slope of Diamond Peak southwest part of Park)

The discovery of this vent was described in Volcano Letter No. 362. It is in an ancient solfataric area and had a temperature of 198° F. when it was measured October 14, 1931.

Changes at Supan's Springs

No movement was detected at the line of stakes which had been set up to measure movement, in the landslip area of Supan's Springs, near the bend in the road on Sulphur Creek west of Diamond Park, where for many years there have been fresh cracks across the valley indicating a creep of surface materials. As reported in 1930, the earlier stakes had been broken off, and a new set of iron stakes was installed in that year. New measurement in 1931 showed that no movement could be detected parallel with the valley, nor on the transit line laid out for repeated observations across the valley. There were signs of chemical erosion. The basin at the Big Steamer at Supan's Springs had moved westward a few feet. The volume of the basin had increased by about 50 cubic feet without any surface outflow to account for mechanical loss of eroded material.

On his trip to investigate Akutan Volcano and to inspect seismopragh stations in the Aleutian belt of Alaska, Mr. Finch was absent from the Lassen station from June 25 to September 13. Mr. C. A. Huff operated the station during his absence.

EARTHQUAKE IN THE SOLOMON ISLANDS OCTOBER 1931

We reported registering on seismographs (Volcano Letter No. 355) a large distant earthquake approximately 3750 miles away to the southwest, and another estimated 3500 miles away, the dates being October 3 and October 9, 1931. It has since been reported (Volcano Letter No. 361) that the first of these earthquakes wrought damage in the British Solomon Islands and was followed by a disastrous seismic sea wave, which recorded on the tide gauge at Hilo eight hours after the earthquake occurred in the Coral Sea. Northeast of this Coral Sea lies a line of active volcanoes extending through the New Hebrides, the Santa Cruz Islands, the Solomon Islands, and New Mecklenburg, the whole belt extending northwest in the region between New Guinea and Fiji, and lying between the Micronesian Islands of the western Pacific and the Coral Sea which lies outside of the Great Barrier Reef of northeastern Australia. The inhabitants of this volcanic belt are Melanesians.

The "Church of England Newspaper" January 8, 1932, publishes a report by Dr. Fox, Principal of All Hallows School, Pawa, Solomon Islands, saying the earthquakes lasted more than 15 days. On Sunday October 4 at 5:45 a. m. there was a very big earthquake lasting four and a half minutes, and then a prolonged quiver for two hours,

and then small quakes every half hour or so day and night for 15 days. But there was a second big one, worse than the first, on October 10, at 11 a. m., followed by a succession of big shocks every few minutes, till the worst of all came at 3 p. m., a violent wriggling followed by convulsive waves, when it was hardly possible for a man to keep his feet. Then smaller qaukes occurred every hour gradually getting milder.

All the mission tanks were thrown down, two of the plate timbers of the house were broken, and a wall was torn out. The boys' houses leaned over and another house had a list. The chapel survived the shock best. The tower swayed violently back and forth, and the flag-pole snapped and was thrown down. A Dover stove was smashed anl much small stuff was broken.

The mission staff slept on the shore in a leaf house, but continued to conduct services in the chapel. The boys slept on the shore, as the hill country rocked violently. During the earthquake of 3 p. m. October 10, the ocean suddenly receded from the bay to much beyond the lowest low-tide mark, and in about three minutes swirled back to about four feet above high tide mark. This happened twice, and then the water remained at high-tide level for hours when it should have been low. Dr. Fox, watching it, reported that the wave seemed to come from the east or northeast and judged the origin to be a hundred miles or so away, and wondered whether it was created by a submarine volcano.

A similar report from a station at Aitape in New Guinea (United Empire, London, January 1932) described what is presumably the October 10 quakes of 11 a. m. as occurring at 11:40 a. m. of the local time, when suddenly a rumble came from the sea. Everything heaved and swayed, chairs and other things were overturned, coconuts fell from the trees, cement piles were cracked, and water tanks telescoped and spilt. Cracks opened in the ground. A trestle bridge was thrown out of alignment. The first shock lasted 40 seconds, followed by other severe ones, while small shocks and tremors continued for a fortnight.

Another Solomon Islands earthquake was registered on seismographs November 20, 1931, and one in the New Hebrides January 9, 1932. T.A.J.

KILAUEA REPORT No. 1047

WEEK ENDING FEBRUARY 14, 1932

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge.

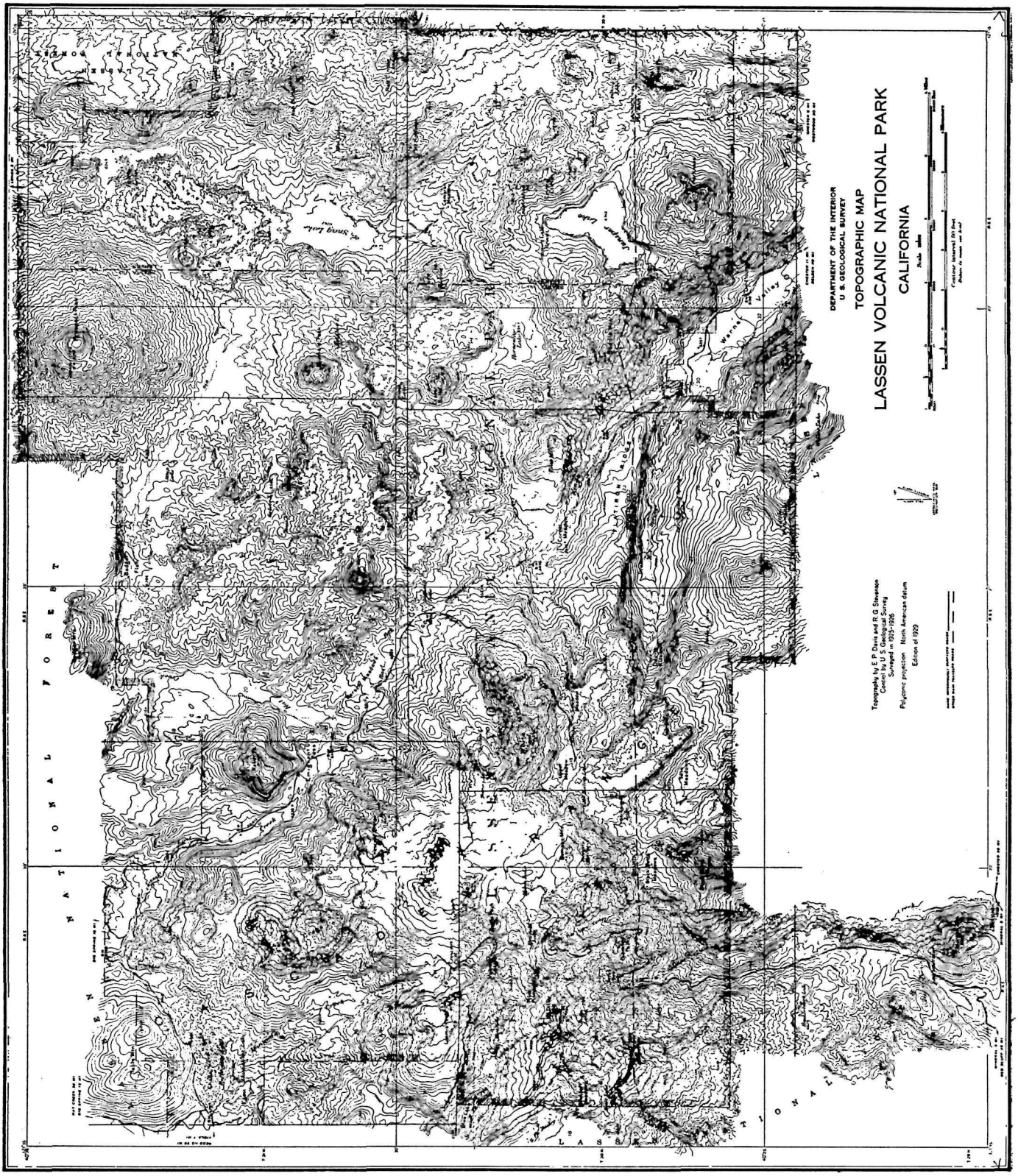
On February 8 fume was noticed at a spot under the west wall of Halemaumau and in a spot in the center of the pit. A small slide fell from the north wall at 9:46 a. m., and rocks fell intermittently. Cracks measured showed slight widening, especially on the northeast rim. On February 12 afternoon a new spot was found fuming in puffs at the west end of the southwest talus on the edge of the talus and floor. Sulphur has been forming there. Moderate fume was noted at the spot under the west wall, and slight fume was issuing from the center of the floor. At 4:10 p. m. a roar of an avalanche was heard at Uwekahuna. Its debris fell from the wall above the southwest bay and appears to be the largest since the recent lava activity. On February 14 there was no change in fuming. At 10:20 a. m. a large avalanche was heard from Uwekahuna by Park rangers. Dust obscured part of one side of the pit.

The seismographs at the Observatory recorded 23 tremors and 3 very feeble local seisms. One of the tremors originated at 14 miles distance, two of the seisms 18 miles, and one seism 14 miles. Two of the latter class were reported felt at Kapapala.

Microseismic motion was moderate throughout the week. The average tilt movement was slight SE.



Edge of glassy lava flow on the west side of Glass Mountain October 19, 1931. These obsidian flows are 80 miles north of Lassen and the rocks are being studied by Dr. C. A. Anderson. Photo from Finch.



Map of Lassen Volcanic National Park, U. S. Geological Survey. Lassen Peak is in the center of the western half with name erased.

THE VOLCANO LETTER

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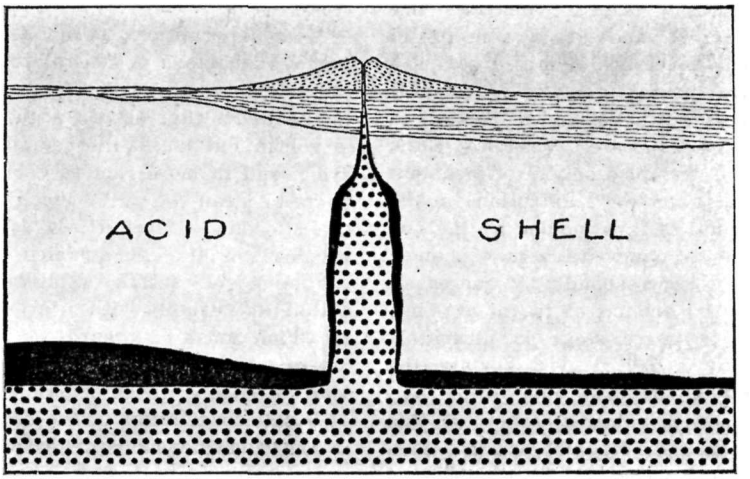
No. 374—Weekly Hawaiian Volcano Observatory, National Park, Hawaii February 25, 1932



Diagramatic section through the earth's crust showing sediments under a volcano, supposed siliceous continental shell, black solidified layer of basalt, and dotted liquid basalt of the substratum extending up into the fissure leading to the volcano. The cone is represented as 5,000 meters high. After Daly.

TYRRELL'S BOOK ON VOLCANOES

Dr. G. W. Tyrrell, lecturer in geology in the University of Glasgow, has recently produced a very readable book entitled, "Volcanoes." (No. 152 in the Home University Library, 1931, Thornton Butterworth, Ltd., London.) This is a small book of 252 pages divided into eight chapters and a bibliography. The introductory chapter describes the general facts about volcanoes. The following is an interesting paragraph:

"The most feasible method of harnessing volcanic energy in the service of man is by utilizing steam jets and hot springs. In Iceland hot springs are used by housewives for cooking and laundry purposes. A beginning has been made in that country on a project for supplying Reykjavik and other towns with a hot water supply from boiling springs. In Tuscany, natural steam power has been used for three-quarters of a century. Over an area of 100 square miles are numerous hot springs and steam jets, which yield boric acid. These natural springs and fumaroles have been largely extended and changed by industrial development. Shallow wells have been bored to tap the steam, which in one of the borings is yielded at the rate of 52,800 lb. per hour at a pressure of one atmosphere (14.7 lb. per square inch), or 28,600 lb. of steam per hour at a pressure of five atmospheres. The steam is often superheated, as its temperature varies between 100° C. and 190° C. A deep boring has now (1928) tapped steam at a pressure of 75 lb. per square inch, which can be directly used to drive turbines. Calculations based on the total production of boric acid in relation to steam, indicates that several million pounds of steam per day are now available in this field.

"Of a somewhat similar nature is the steam-well field which is now being exploited at The Geysers in California. Observations and tests prove that at this locality there is a great store of hot steam, which increases with depth. The first well was drilled in September 1922, and steam from this well furnished the power for boring the second well which was completed in July 1923. From all indications the steam both in Tuscany and California is of deep-seated origin and of practically inexhaustible quantity."

In discussing cycles, Dr. Tyrrell is impressed with the longer geological cycle, as is natural in the viewpoint of a geologist, and he makes the following statement concerning the phases of a long-term cycle:

"If volcanic manifestations are considered in relation to geological time they are found to fall into definite cycles. These cycles seem to have begun with vast floods of basalt lava, with which are usually associated swarms of dikes, and, in proportion to the bulk of lava erupted, were accompanied by an insignificant amount of explosive activity resulting in fragmental products. These enormous lava floods are therefore believed to have been emitted from fissures, and to have rushed up directly from the superheated liquid stratum which at times is formed immediately beneath the crust.

"As the cycle progresses the volcanic activity becomes localized at definite points, which develop into central volcanoes. Lava is still poured out in great bulk, and central volcanoes in this early stage build up enormous flat domes consisting mainly of basalt. At the present day these shield volcanoes occur in Hawaii and Samoa, and also in Iceland. In the earlier stages of the present volcanic cycle, the flows from adjacent shield volcanoes linked

up to form great spreads of lava only inferior in size to those from fissures.

"With the waning of the volcanic cycle, the direct uprise of magma from the depths is checked. It collects in underground chambers, and its contained gases now come into full play in determining the kind of volcanic activity at any center. Hence the volcanoes typical of this stage of the cycle are those in which explosive activity takes a prominent part. The resulting central volcanoes are naturally smaller than shield volcanoes as the supply of magma is now limited. The cones are of mixed composition, partly lava, partly fragmental products of volcanic explosion, and are known as **strato-volcanoes** because of their well-bedded or stratified structure. Vesuvius, Etna, and Fuji-san are well known examples of strato-volcanoes. With the progress of solidification (crystallization) in the magmatic chamber the amount of lava yielded by the volcano gradually lessens, and its composition may change, while the activity of gases correspondingly increases, resulting in an increase in the amount of fragmental material ejected. A purely explosive stage is ultimately reached; and if a new vent is drilled at this stage the resulting volcanic cone will be built up entirely of fragmental materials. Some small volcanic cones of this character (e.g. Monte Nuovo near Naples) are due to a single explosive outburst. The gases which are liberated in this late stage of the volcanic cycle consist chiefly of steam, and the explosions may be of such violence as partly to destroy the cone built up in earlier stages, (Katmai, Alaska; Bandaisan, Japan.)

"As the explosive activity gradually dies away, the final stage of the volcanic cycle is reached with the relatively quiet discharge of steam and other gases from jets or fumaroles (Tuscany, Icleland, California, New Zealand), associated with erupting springs or geysers, boiling or hot springs, and the emanation of carbon dioxide and sulphuretted hydrogen from fissures."

The second chapter deals with the products of volcanism, gaseous, liquid and solid. In this the author follows the usual and regrettable geological dictum that steam is more important than hydrogen as a fundamental volcanic gas. Other chapters deal with the phenomena of volcanic eruption, the shield volcanoes of Hawaii and Iceland, strato-volcanoes such as Etna and Vesuvius, decadent volcanoes such as Katmai and Lassen Peak, the roots of volcanoes and ancient volcanoes, and finally, distribution of volcanoes and origin of igneous rocks. In this last the author follows with interest the theories of Joly and Holmes to the effect that the ultimate causes of igneous activity in general are to be traced to the known facts of storage of heat through the radioactivity of the rocks.

A reading of the book shows that the author has studied carefully some up-to-date volumes on volcanic eruptions such as Perret on Vesuvius, Griggs on Katmai, and Koto on Sakurajima, that he is influenced by the time-honored but trite work of Judd on Krakatoa; and is perhaps without access to the remarkable series of modern monographs of the Dutch East Indies Volcanologic Service; that he is thoroughly acquainted with the work of the petrographers on ancient volcanoes and on the rocks collected from fossil intrusive bodies, but that he is insufficiently acquainted with the seismometric side of the subject as expounded in the big volumes by Omori on Asama, Usu, Oshima, and Sakurajima. The geodetic and engineering side of volcanology is hardly touched. The notion that intrusive volcanism is in progress today, and may be measurable in hot spring districts, does not appear in the book, but there is ample recognition that the study of volcanoes has entered upon a new phase with the establishment of volcanological observatories. The scholarship of the modern German and Italian workers, as recorded in Friedlaender's Zeitschrift and in Sapper's book, is not much quoted. The style is excellent and the author is at his best in the chapter on "The Roots of the Volcanoes." The following is a sample:

"Fissure eruptions occur at the present day only as minor phenomena of central volcanoes, especially those of the shield type. Various lines of evidence, however, lead to the belief that fissure eruptions played a leading part in volcanic action at the beginning of the present volcanic cycle, and in more remote geological periods." (This appears to mean the cycle which has become decadent since the Miocene.) "Basaltic lavas have been poured out on a colossal scale, accompanied by only the most insignificant explosive activity relatively to the effusive mode of action, and usually with swarms of associated dikes, some of which must be regarded as the feeders of the flows. There are no signs of volcanic cones at all commensurable with the size of these eruptions. These stupendous floods of basalt cover areas of the order of 200,000 square miles, and may be thousands of feet thick. Naturally, accumulations of relatively hard rocks such as basalt are extremely durable, and remain in and on the earth's crust as witnesses to volcanic events the magnitude of which has not been approached at the present time.

"The youngest basalt flood is that of the Columbia Plateau in the northwestern United States, which occupies an area of over 200,000 square miles mostly in Washington and Oregon. The Columbia region was formerly mountainous, but in Miocene times it was levelled up by enormous floods of basalt lava, and the former mountains now appear as islands and peninsulas projecting from a monotonous plain of lava. The Columbia and Snake rivers (see Page Four) have cut deep gorges through the plain which expose in places almost the entire thickness of the formation. The plateau is built of a large number of thin, confluent, interlocking flows, between which occur slaggy surfaces, thin sheets of ash, and beds of lacustrine sediments. The supposed feeding dikes are numerous and narrow, seldom reaching 150 feet, and averaging less than 30 feet in width. Igneous activity has continued almost to the present day, especially in Oregon and Idaho, with the production of youthful-looking cones and craters, and fresh, slaggy, lava flows. The average thickness of the plateau is estimated at 3300 feet, and it is known to reach a maximum thickness of at least 5200 feet. Hence the total volume of lava emitted must be of the order of 120,000 cubic miles. Great basaltic plateaux of about the same age as the Columbia plateau occur in Syria and Arabia.

"Another enormous basalt flood is that of the Deccan in Peninsular India, which occupies an area of 250,000 square miles. As this formation is nearly 10,000 feet thick on the Bombay coast, and thins out toward the east and north, it is thought to have had an equally large extension in the adjacent foundered parts of the Indian Ocean. Its total area may therefore have been 500,000 square miles . . . . in one place a boring encountered 29 distinct flows with an average thickness of 40 feet. Large dikes and other intrusive masses are found at a number of places around the margins of the basalt region The eruption appears to have taken place towards the end of the Cretaceous period, or at the beginning of the succeeding Eocene."

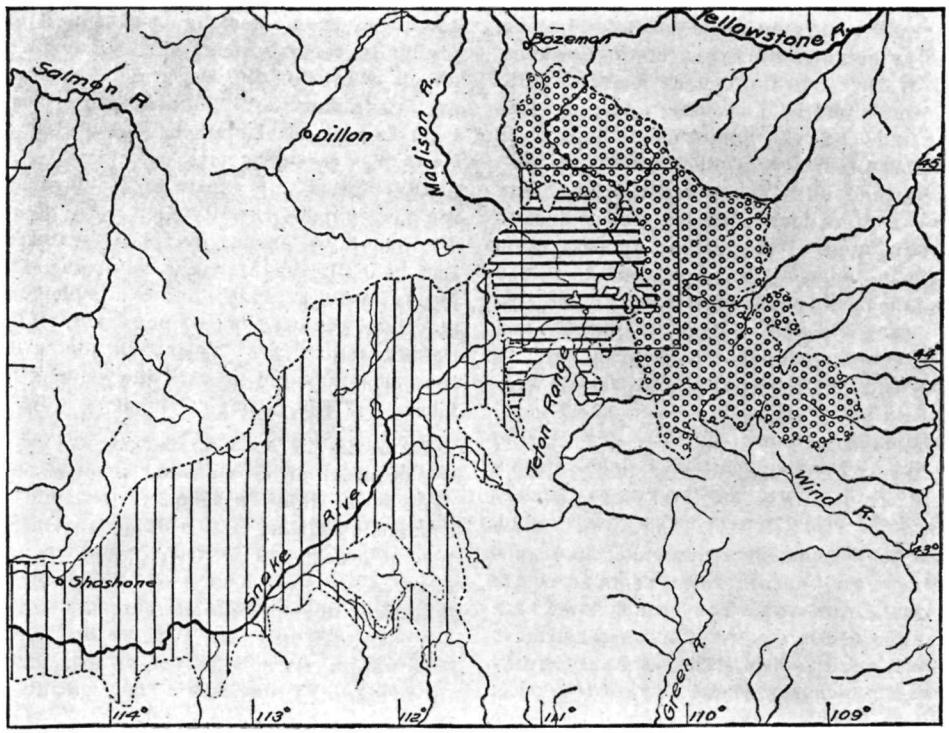
"The Stormberg basalt lavas of South Africa, which occupy an area of 20,000 square miles in Basutoland alone, and there form the great mountain scarp of the Drakensberg, are regarded by Dr. A. L. du Toit as mainly due to fissure eruptions. One hundred and fifty volcanic vents have indeed been found, and many more await discovery; but the greater number of these are filled with pulverized sedimentary material, and have never emitted lava; and the remaining active centers pierce the lowermost basalts only. The average thickness of the plateau appears to be about 3,000 feet, and individual flows are from 100 to 150 feet thick. Correlated basalt extrusions make up the 300-mile-long Lebombo range in the eastern Transvaal, and also a large area of country around the Victoria Falls in Rhodesia. The extrusion of these great masses of lava probably took place in early Jurassic times. The Stormberg lavas are intimately connected with the Karroo dolerite sills; and the relatively small lava fields of this episode, as compared with others, may be due to the fact that a greater part of the activity took place underground.

"In recent years it has become clear that exact analogues to the Stormberg lavas and Karroo dolerites exist in the Parana region of South America. The basalt flows here cover an area of over 300,000 square miles with an estimated bulk of 50,000 cubic miles. They are associated with intrusive masses which are found in a further area of 75,000 square miles. Basaltic lava plateaux of the same age as those of South Africa and South America (mid-Mesozoic) are known also in Tasmania, Antarctica, Peninsular India, and in the eastern United States."

With regard to major cycles in Europe and Asia, Dr. Tyrrell points out that crustal movement (page 228) has worked up to at least four great climaxes during known geological time, and that in the intervals minor disturbances have occurred. The geological cycle begins with the comparatively-sudden emergence of continental land masses, which rapidly become broad and high, with the simultaneous production, especially near their margins, of long ranges of fold-mountains in which the rocks are intensely compressed. The oceans at this stage are relatively small and deep. Igneous and earthquake activity is at a maximum, and on the continents there is extensive glaciation and desert formation. Climatic conditions are thus severe and extreme. At the present day the earth appears to have not long emerged from one such phase of the geological cycle. This revolutionary stage is followed by a protracted period of relative quiet, both as regards earth movement and igneous activity. The continents gradually become small and low owing to the combined effects of erosion and the gradual advance of shallow seas over their margins. The general quiescence is occasionally broken by local disturbances during which igneous activity may again become prominent. Earth movement is finally limited to a gentle up and-down heaving over wide regions, igneous activity dies away completely, and climatic equability ensues over the greater part of the earth. But beneath the apparent quiet the revolutionary earth forces gather strength, and the geological cycle is terminated by a renewed paroxysm of mountain-making and continental uplift. . . . The explanation of igneous activity is thus closely bound up with the explanation of earth movements and the geological cycle."

Errors in the book are largely copied from the original works on which it is based. If on page 55 the statement, "Torrential rains **accompany** volcanic eruption," means condensing steam, this is dubious. On page 60 the formation of Pele's hair is attributed to "strong winds," when in reality it is the bluster of the gases rushing through the fountains and convection currents which may occur in perfectly still air. On page 93 the "Death Gulch" of the Yellowstone Park is placed in Arizona. On page 67 and following, the discussion of volcanic earthquakes attributed to "explosive subterranean release of magmatic gases" is quite erroneous and inadequate. There is the usual erroneous distinction from tectonic earthquakes, without explanation or discussion of depth or mention of isostasy. The statement on page 84, **"Hawaian** explosive activity is of a mild type, caused by the rapid emission of gases from the surface of a lava lake," certainly needs modification if the steam-blast activity of 1924 is "explosive." On page 87 Pelèe and Soufriére are stated to be characterized by the "intermittent ejection of white-hot clouds composed of an emulsion of glowing gas and solid particles, which, instead of rising into the air were projected downwarls." These were exceptional and not characistic, and the downward-directed cloud in the major explosion in each case was but one component, most of the clouds being directed vertically, and in no case being "white-hot." Down-rushing blasts are common elsewhere. The belief of Penck quoted on page 109 that the 1789 eruption of Kilauea "marked the inception of the volcano" might well have been omitted. T.A.J. and R.H.F.





Region of eastern part of the great Snake River basalt fields as related to the early Tertiary rhyolites (horizontal lines) and andesites (circles) of the Yellowstone Park, itself a place of boiling springs and Tertiary volcanoes. After Daly.

KILAUEA REPORT No. 1048

WEEK ENDING FEBRUARY 21, 1932

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge.

On February 15 at 9:30 a. m. the slide of the previous day was found to have fallen from the north wall between the north and northwest taluses, causing a fresh scar on the wall and a mound of new debris on the floor. Debris added at 1:20 p. m. February 16, from the same place, built the mound to from 50 to 100 feet high. Fume was strongish at the foot of the southwest talus and under the west wall. The northeast rim cracks continued slight widening. A small scar formed during the night of the 15th from a slide at a point just west of the top of the northwest talus. Fume was quite strong from a spot at the foot of the southwest talus and came from two points about 50 feet apart. Rocks and small slides were heard falling from the north walls more or less continuously about every five minutes from 2 to 4 p. m. On February 17 the district was visited by a southwesterly rain and wind storm which caused some water to enter the seismograph cellar at Halemaumau. The pit during the forenoon was a huge cauldron of steam. Sulphurous fume was blown over the tourist stand. Keanakakoi had seven waterfalls. A lake a thousand feet long and two to three hundred feet wide formed on the southwest Kilauea floor. A little hail fell during the storm, and there was thunder and lightning near. Many trees were uprooted and a garage was blown over.

On February 21 at 10 a. m. the pit had blue fume. The north wall showed a fresh scar from an avalanche and few rocks were heard falling.

The seismographs at the Observatory recorded 11 tremors and two very feeble local seisms. One of the tremors indicated origin distance 25 miles and another about four miles. The two seisms indicated distances of 9 and 32 miles. None was reported felt. High winds during the week caused unusually strong microseismic motion, the Kona storm of the 17th being responsible for vibrations of four seconds' period. The average tilt movement for the week was moderate SW by W.

THE VOLCANO LETTER

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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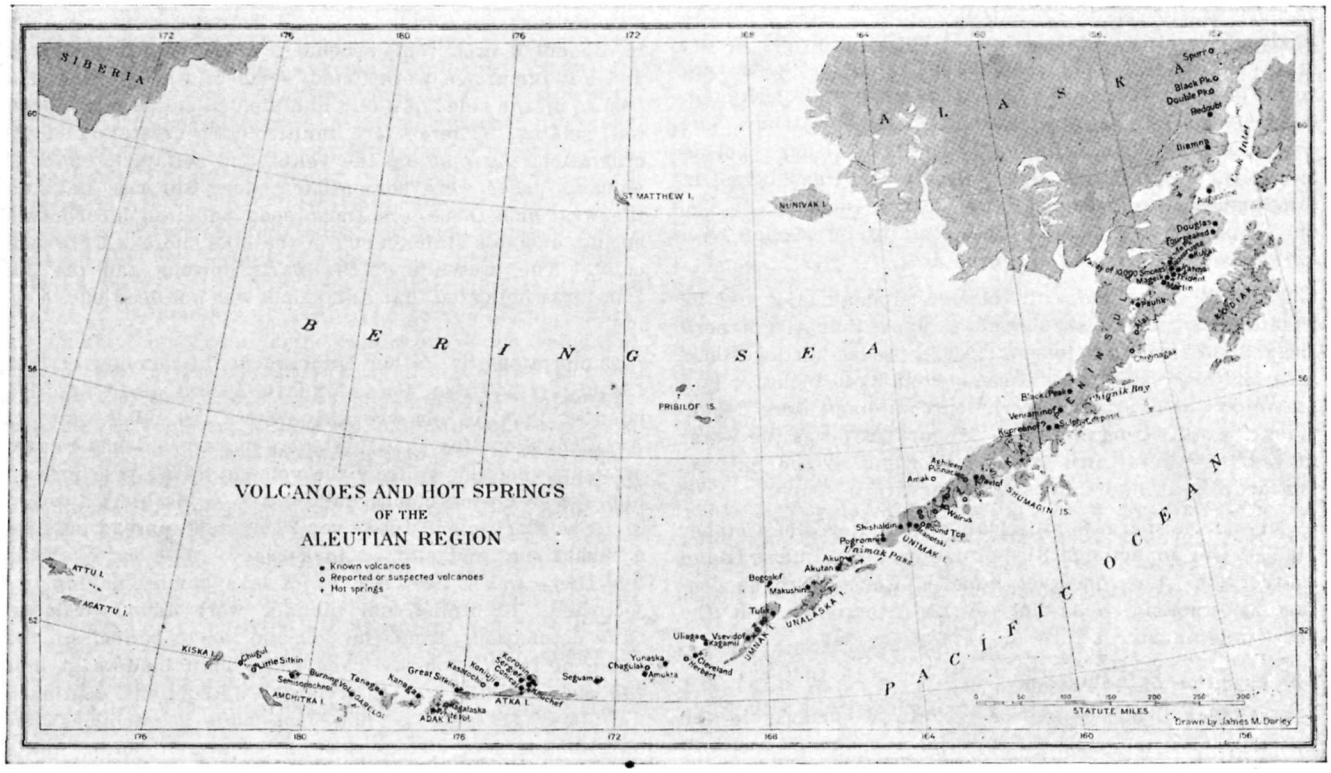


Map of volcanoes and hot springs of the Aleutian region, scale 216 miles to the inch. After Griggs, National Geographic Society, 1922. Black Peak is mislocated at Purple Crater, and Aniakchak is northeast of it.

ALEUTIAN ERUPTIONS 1930 32

Notes on activities in the Aleutian Islands and in the volcanoes on the Alaskan Peninsula were published in Volcano Letter Nos. 246 and 357. The year 1931 appears to have brought to a focus the unrest which appeared in several volcanoes in 1929 and 1930 by producing a considerable explosive eruption from Aniakchak Crater on the Peninsula 45 miles NNE from Chignik. But activity of one sort or another appears to be always present in the restless magma which underlies 1700 miles of arched and faulted Tertiary strata from Mount Spurr to Attu, and if one could picture the ridge in its entirety at any one time, some puffing gas would probably be seen.

Our reports have indicated that Akutan was smoking in 1928 and its lower slopes were covered with ash June 18, 1929. "A mountain to the west of Kanatak" was reported fuming in March 1929, and this description might apply to Chiginagak Volcano on the Peninsula east of Aniakchak. Mount Cleveland and a volcano west of it in the Islands of the Four Mountains were fuming in March 1929 and volcanoes of the Katmai group continued fuming. Shishaldin on Unimak Island was "flaming high" May 28, 1929, and glowing matter overwelled the edge of the crater and rolled down the slopes; it was reported fiery again June 23, 1929, opening three new craters low on the north side. Gareloi in the western Aleutians was said to erupt so violently in 1930 as to change its appearance by lava flows from fissures. To a volcanologist the imperfection of these accounts is their chief baffling characteristic, but the observations of mariners confirm the notion of continuous activity somewhere.

We now come to 1931, when on May 1 Aniakchak erupted, on May 20 Pavlof farther west on the Peninsula made explosions and glow and ashfall, two other volcanoes on the Peninsula were reported fuming, ash from Aniakchak fell a great distance away, and on May 30 a severe earthquake was felt in Attu at the extreme western end of the Aleutian chain.

Our observer at Dutch Harbor, Mrs. Wendhab, reports that Captain Nelson of the Alaska Commercial Company

ship "Eunice" passed Tulik Volcano on the east end of Umnak Island March 21, 1931, and its crater was sending up thick black smoke where he has observed only white steam heretofore. He thought its action very unusual and indicative of a coming greater eruption. On March 29 two earthquake shocks of unusual intensity were felt at Dutch Harbor (east end Unalaska). On May 13, 1391, the Umnak eruption was reported by Captain Nelson to be "the volcano on the east end of Umnak Island, fourth peak northwest from Tulik Mountain, pouring out black smoke and heavy clouds of steam," a place that has been dormant until recently. A singular note by Mrs. Wendhab at this time states that Mount Makushin Volcano in the northwest part of Unalaska Island, which has been very active, is now ominously quiet, causing worry." Makushin is usually a crater of quiet steam depositing sulphur. The eruptions of Shishaldin, Pavlof, and Aniakchak are reported by the radio operator at Squaw Harbor on Unga Island in the Shumagin group south of the Alaskan Peninsula to produce a particularly vicious type of static, interfering with radio communication over a wide area.

While not connected with volcanic happenings, it may be of interest to the meteorologists to know that Attu experienced September 30-October 2, 1930, a terrific northwesterly gale for three days, with barometer at 26.40 inches. Two native sod houses and Government buildings were demolished. A still stronger gale in January 1931 was the worst in the history of Attu Island, according to the natives, and drove seas into Chichagof village.

Captain Nelson saw fire issuing from Bogoslof October 31, 1931, and found qauntities of pumice near Umnak Island south of it. This observer believed Bogoslof to be continually smoking, according to his experience, but the "fire" was unusual.

The Eruption of Aniakchak

Aniakchak Crater is one of a chain of remarkable volcanoes spaced out rather evenly about 40 miles apart in the Alaskan Peninsula between Port Heiden on the north and Chignik Bay on the south. Beginning at the southwest end of the series west of Chignik and going northeast, these are Veniaminof (8400 feet), Purple Crater (3020 feet), Aniakchak (4200 feet), Chiginagak (7020 feet), and Mount Peulik (4080 feet). Veniaminof and Chiginagak are covered with glaciers. Aniakchak Crater was mapped by Sargent, described first by W. R. Smith (Professional Paper 132 U. S. Geological Survey, 1925), and mapped geologically by R. S. Knappen (Bulletin 797-F U. S. Geological Survey, 1929). Knappen's colored map is copied in half-tone herewith and shows the even spacing of Veniaminof, Purple Crater, and Aniakchak, and the vast size of the crater bowls, as well as their circularity. Aniakchak Crater has a maximum diameter of six and three-quarter miles, the lowest part of the crater floor is 1100 feet above sea level and contains Surprise Lake, two square miles in area. The walls rise almost vertically 1200 feet to 3000 feet above the bottom of the crater. A large truncated cinder cone rising 2200 feet above Surprise Lake occupies the south central part of the crater floor. Aniakchak River breaks through the east side of the rim of the great crater in a picturesque canyon named "The Gates." The area of the bottom of the crater is 30 square miles. Upper Jurassic sedimentary rocks with fossils occur in the canyon and also quartz diorite, overlaid by layers of lava and agglomerate, while all the valleys of the surrounding country are covered by thick deposits of ash, pumice, and agglomerate. Much of the lava is obsidian.

In the National Georgaphic Magazine for September 1931, Father B. R. Hubbard presents a wonderful series of pictures of the Aniakchak and Veniaminof country made from photographs taken during an exploration in the summer of 1930. Among the most remarkable of these is a picture of curving colunar structure in obsidian, and another of a subordinate crater of crescent shape in the northwestern part of the larger bowl containing an inner cinder cone from which about eight festooned dark-red basaltic lava flows radiated. The festoons were crevassed in concentric arcs. This secondary crater was investigated and hot fumaroles were found, some of which followed a fissure up the sides of a cliff and yielded steam hot enough for cooking. There were multicolored crystals and incrustations surrounding the vents, and solfataric odors of volcanic gases were perceptible. Near Surprise Lake on the west side there is a warm soda and iron bicarbonate spring, and this stains much of the lake shore with orange color. The presence of the warm springs and the hot solfataras indicated that Aniakchak was not dead but sleeping.

Explorations by Father Hubbard in the summer of 1931 (Saturday Evening Post January 2 and 16, 1932) discovered that an observer at Meshik, 20 miles west of Aniakchak, on May 1, 1931, at 10 a. m., saw a dense column of steam shooting up from the volcano. This rose for two hours in billowing clouds, followed by a big blast at noon. A dense black cloud rose over 20,000 feet, spread out like a mushroom, and started to descend. The earth shook, and there was a fiery display of lava bombs making trajectories. Lightning and thunder were added to incessant detonations from the volcano, accompanied by the crash of falling rocks. Then came light cinders at first the size of peas and then larger. Eruptions continued until May 11, when a final blast made it pitch dark for several hours at distances 60 miles away. There was a field of floating pumice with individual blocks 9 or 10 inches across in individual patches five miles in diameter on Bristol Bay, north of the volcano. Dense clouds of gas and smoke continued to rise, and another major eruption May 20 made detonations heard 200 miles away. For several days more the Ugashik cannery, 53 miles NNE from Aniakchak, reported rumbling like distant surf.

At Chignik the fall of ash was reported a pound per hour for each square foot 45 miles SSW from the source. At Ugashik the ashfall was heavier, and in the country between Kodiak and the head of Bristol Bay a mantle of ash a quarter inch deep was formed. Light ash fell in the interior of Alaska at distance of 300 miles. There was much loss of life among wild animals. There were many showers of pisolitic mud balls, and the neighboring snow-covered country and the glaciers were buried under a gray pall.

When the volcano was visited at the end of May, there were clouds of blowing dust and many dust whirlwinds. Everything was covered with ash. The vegetation was gone. Black cinders became coarser at the crater. The water of all streams was muddy. The central inner cone had a crack in its side and gas clouds rising on top. Surprise Lake was choked and muddy. The explosion vent had formed a new crater under the northwest rim, whence rose yellow and brown gas and clouds of steam. A new lava dome was being pushed up above the crater floor,

showing large, tumbled blocks. This was like Novarupta at Katmai. Beside the dome was a deep pit. Hydrogen sulphide was strong. Occasional puffs of brown smoke rose with a rumble from the new vent. The interior of this vent was found to be highly colored with yellow, red, and brown stains, and several pits more than a mile in circumference had formed in the crater floor. Quantities of vapor rose from the new lava dome. The ground was very hot near the vent, more than 200° C., and there were green deposits and signs of hydrochloric acid. There were many impact craters made by falling bowlders. The lava dome lay in the center of a depression three miles in circumference. The lava moved somewhat, there were falls of blocks, and there was much sulphur. In an airplane flight, Hubbard noted that Veniaminof Volcano, with its great circle of glaciers, which he had seen the year before snowy white, was completely mantled with dark colored ash. It may be noted in passing that Hubbard reported in his National Geographic article that an ascent to the edge of Veniaminof Crater was made from the north side, and that this crater, which is known to the natives as Black Peak, and is full of ice, was smoking in unusual fashion in the summer of 1930. The source of this smoke was found to be a cone in the center of the ice, "smoking on two sides of its upbuilt rim from slag heaps of lava, and now and then coughing out black ashes over the surrounding white snow." The ice had impressive chasms where the heat had melted the glacier. There were layers of black volcanic ash and sand a few feet thick alternating with glacial ice more than 20 feet thick. Hubbard suggested that some time-scale of Veniaminof's eruptions might be interpreted from such exposures.

On May 2, 1931, the radio operator at Kanatak, 90 miles NE of Aniakchak, reported ashfall there. On May 13 the ash from Aniakchak was more than a half inch deep and very black, falling continuously at Squaw Harbor in Unga, approximately 140 miles SW of Aniakchak. The Katmai group of volcanoes was reported to be active at this time. The Aniakchak ash that fell at a great distance was fine as flour. On May 12 a freighter at sea off the Aleutian Islands received a fall of sand during a storm (locality not given).

Later Eruptions

Captain Nelson of the "Eunice" brought word on January 18, 1932, that Mount Cleveland on Chuginadak Island, a peak 8156 feet high, approximately 150 English miles west of Dutch Harbor, had again broken into eruption, starting about January 1, 1932. It was reported to him that seven great puffs had occurred in one hour, the volcano sending up very dense smoke. Generally only a little steam had been seen at the crater during previous visits. He passes these Islands of the Four Mountains three or four times a year in his trading trips for the Alaska Commercial Company. He was suprised to see such dense volumes of black fume when he passed the island in early January, the sky being continuously darkened.

On February 10, 1932, a radio from John Gardner in False Pass informed me that Shishaldin erupted February 1, 1932, the outbreak lasting for several days with glowing material flowing down the mountain. A newspaper dispatch of February 4 called this eruption the "most violent and spectacular seen in the past century" for this volcano. The report from Squaw Harbor described "streams of lava flowing down the sides," but this glowing material is quite as likely to be trains of red-hot bowlders for these Aleutian cones. A strong wind carried the ashes many miles northward over the Bering Sea. A dispatch of February 16 said that Shishaldin had again renewed its activity with boomings coming from the creater at two-minute intervals, the volcano hurling hot rocks thousands of feet into the air.

The general map of the Aleutian belt reproduced herewith shows the distribution of volcanoes as compiled by Griggs (Valley of Ten Thousand Smokes, by Robert F. Griggs, National Geographic Society, 1922, page 60). This will give some idea of the great number of active cones along this curved line, and the geological map by Knappen shows how characteristic are the big volcanic heaps lying in a line adjacent to the coastal plain of Bering Sea on the northern side of the Aleutian ridge. This arrangement extends far to the west in the islands, where, for examples, in both Unalaska and Atka the north half of the island is volcanic and the southern half consists of older rocks. Here in the Aniakchak region the belt of mountains southeast of the volcanoes reaches heights rarely exceeding 3000 feet and consists of gently folded Jurassic and Tertiary rocks, which contain fossil plants and shells, and are overlaid by old volcanic rocks which probably date from the Miocene. The slope under the Pacific to the south reaches abysmal depths, the slope to the north, from Unalaska eastward, is very flat to a shallow sea. The line of volcanoes apparently represents a tension crack at the edge of this shallow fill of Bering Sea, through the folded strata, and following in plan a singularly perfect curve for several hundred miles. To the south of the region here considered there is a trough under the ocean parallel with the Pacific shore more than 20,000 feet deep.

T.A.J.

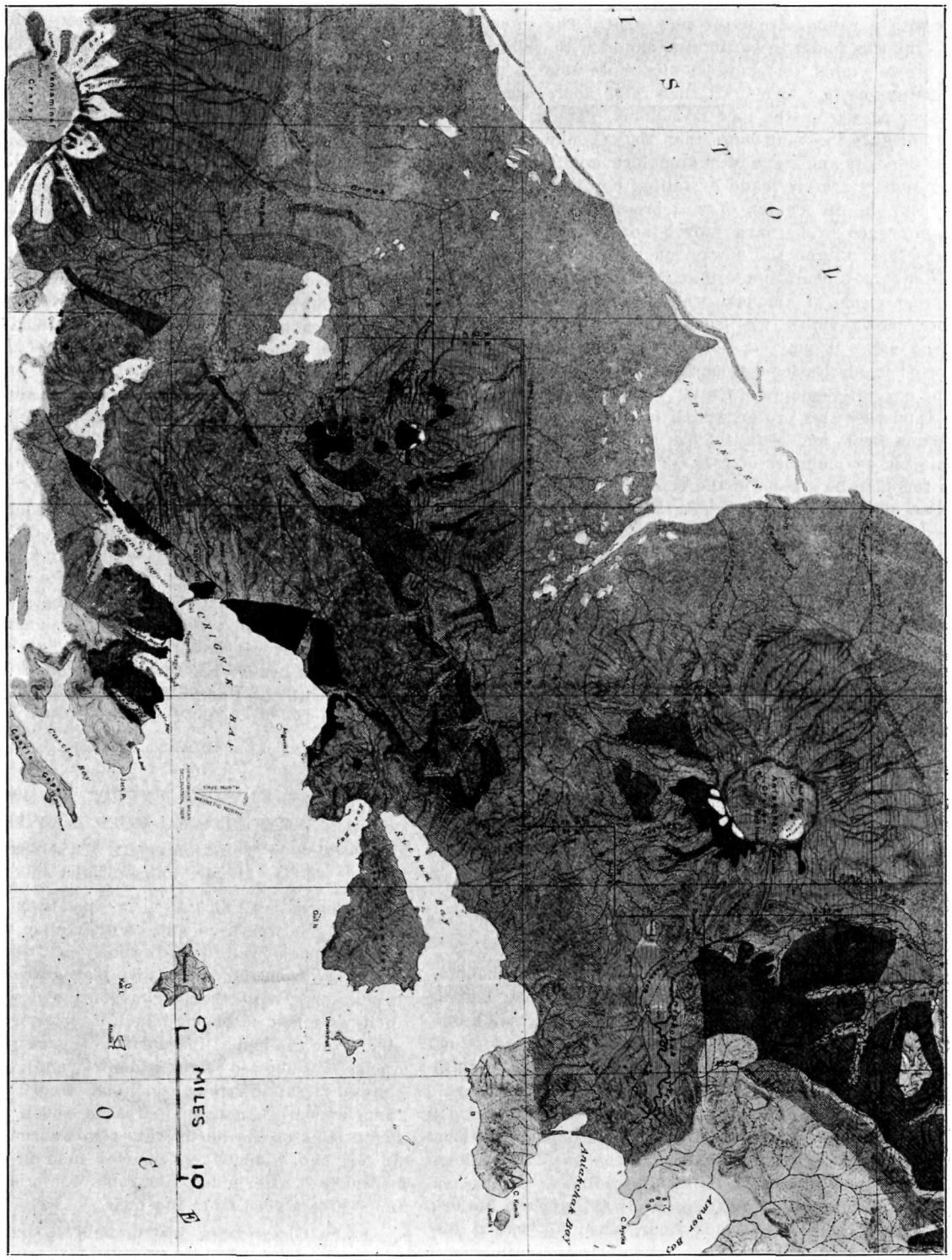
KILAUEA REPORT No. 1049

WEEK ENDING FEBRUARY 28, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

On February 22 at 9:15 a. m. dust from a slide at Halemaumau pit was seen and another slide was reported at the northeast wall the afternoon of February 21. Blue fume rose from the floor at two places west and southwest. Cracks on the northeast rim continued widening, one of them as much as one-half inch. On February 23 a small slide from the rim at the north wall occurred at 9:55 a. m., cracks SW showed slight widening, and cracks NE and N showed slight to strong widening. February 24 at 9 a. m. fume appeared to have increased and a new crack was found back of the north wall. On February 26 crack No. 31 NE had widened one-qaurter inch in four days. On February 28 after much rain, fume was pronounced SW and much steam rose from the floor.

At the Observatory instruments 45 tremors were recorded, one of them indicating distance exceeding 14 miles. Of nine very feeble shocks, three indicated origin distance 2 miles, two 3 miles, three 4 miles, and one 9 miles. Two feeble shocks of the felt class occurred. One of these February 23 at 1:30 a. m. indicated origin distance 2 miles. One during the noon hour February 26 indicated origin distance only 1 mile. Microseisms caused by windy weather were strong except on February 24 and 28, when they were moderate. Tilting of the ground was moderate SW.


ISTOK
CHIGNIK BAY
Chignik
Chignik Lake
Veniaminof Crater
Aniakchak Bay
Amber Bay
Port Heiden
Becharof Lake
Ugashik Lake
Ugashik
Mt. Peulik
Mt. Chiginagak
Mt. Aniakchak
Mt. Veniaminof
Mt. Black Peak
Mt. Kagamil
Mt. Kukak
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The Volcano Letter

376

Two dollars per year **Ten cents per copy**

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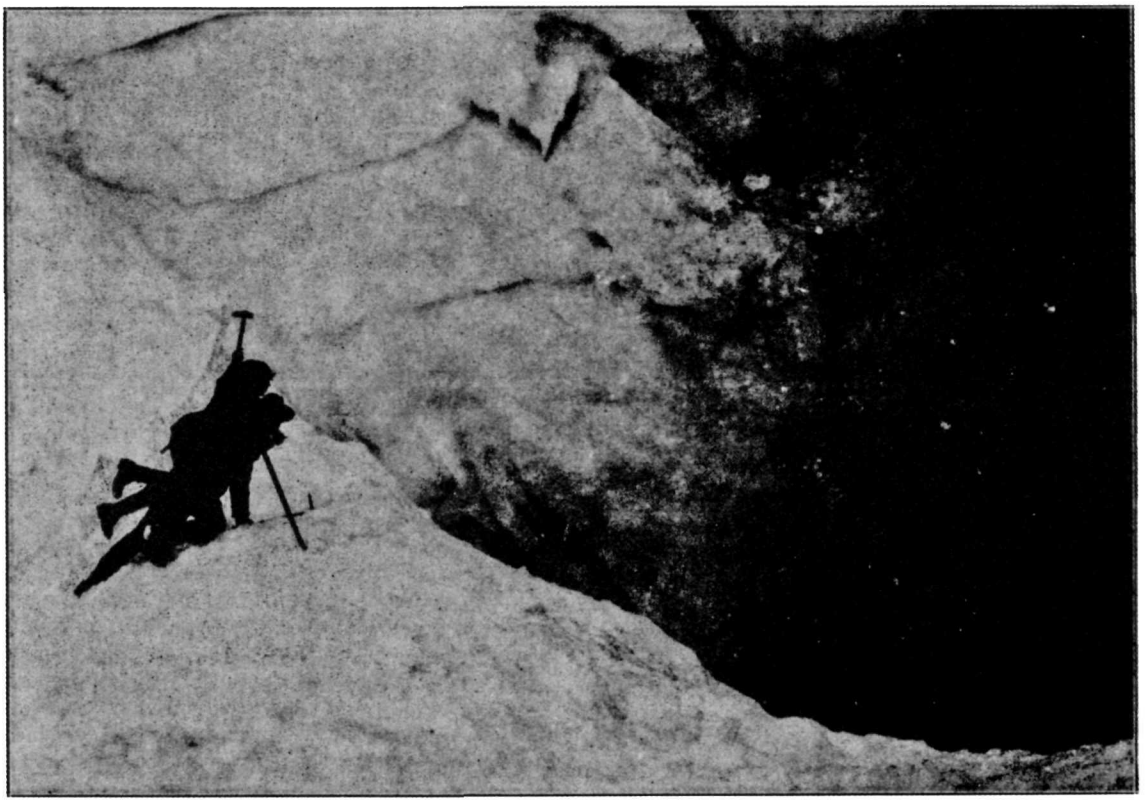


Crater in ice of Makushin Volcano, Unalaska Island, photographed in 1907, and resembling the snow crater on Mount Baker described by Rusk in 1903. Photo Jaggar.

NOTES ON VOLCANOES OF THE CASCADE RANGE

For purposes of the volcanologist, every bit of information concerning craters or heat on mountains known to be volcanoes is of value. In Volcano Letter No. 363 there was published a review with maps concerning some of our northwestern volcanoes other than Lassen Peak. In "Tales of a Western Mountaineer" (Houghton Mifflin 1924) Mr. C. E. Rusk publishes notes made during mountain climbs on some of these volcanoes which are unusual and worthy of quotation.

The crater of Mount Baker or Kulshan is illustrated by a photograph taken about 1900 by the party of John A. Lee. This shows a circular crater opened through snow and ice, with fume rising, and with crevasses extending up a smooth nevé above it. In 1903 Rusk climbed the east side of the main peak of Mount Baker accompanied by George G. Cantwell. They went to Morovits Ranch, and camped at the timber line. The whole east side of the mountain is forbidding and covered with snow and ice. There are two peaks of which the southern is the lower. When well up the slope, on glancing upward, they saw large volumes of smoke rolling from between the two peaks. When they reached the top, it appeared that for several hours the smoke from the crater had been hidden from them by the south shoulder of the main peak. As they emerged from the chimney there burst into view a most thrillingly weird spectacle.

In a bowl-like depression immediately between the two peaks of Mount Baker there was a great orifice in the snow, perhaps 50 feet across. The west side was partly blocked with snow so that the opening was somewhat half-moon shaped. Two hundred feet away a semicircular crevasse swept halfway around the pit. Up from the unknown depths of this abyss black fume boiled out. It drifted away, guided by the shifts in the wind currents, until it dissolved in the upper air. Mr. Rusk speaks of the wild, unearthly loneliness of the scene, which "impressed us profoundly, for its counterpart perhaps does not exist on earth."

This description is astonishingly like that of the ice crater containing sulphur on the summit of Makushin Volcano in Unalaska (Page One). This was photographed and described by the reviewer, and the picture published, in 1908 (Technology Review, Boston, Vol. X, No. 1, Journal of the Technology Expedition to the Aleutian Islands 1907, by T. A. Jaggar, pp. 11-12). "The rim of the greater crater of Makushin was finally reached at 12:45 July 3, 1907. Within was an expanse of snow, probably two miles in diameter, through which three or four steaming vents have maintained openings. We saw a steaming cavity ahead to

the right. Examination proved this to be a new crater opening, a vertical cavity in the snow, 75 feet in diameter, with a 300-foot wall of bedded ice and snow behind it and sulphurous steam incessantly rising through it. A great tumble of snow or ice blocks rested in front of it, and, where the steam drifted across these, their white surfaces were yellowed with sulphur. An inner cone of bowlders and sand was seen beyond this pit and south of it. This was visited and found to contain a crater some 2,000 feet in diameter, with very active solfataras working on its northern side, and sulphurous coatings about the vents."

Rusk's climb was 11 hours from the timber line to the top of Mount Baker, and was presumably early in the season of 1903. When photographed in August 1906 by F. H. Kiser, the crater gave no sign of snow orifice, nor of smoke. There was only a slight depression in the snow and the remnant of a crevasse. Professor George Davidson saw Mount Baker in very active eruption in the early fifties.

Mount Rainier or Tacoma Volcano is described by Rusk as having a great crater from a quarter to a half mile in diameter inclosed by bare cliffs 30 or 40 feet high. The bottom is filled with snow which makes of the interior a comparatively level field. Around the rim are many small vents in the rock, from which jets of steam issue. In places, and at times, this steam melts the snow, leaving cavern-like fissures between the snow and the wall of the crater. The highest point of Mount Rainier is a dome of snow just west of the crater. Mr. Rusk writes: "I crossed the crater alone. On the farther side I was surprised to find lichens clinging to the bare rock surface. I found a jet of steam issuing from a small hole in the sloping face of the rock. I stooped to see if I could detect any odor coming from the place and received a little steam-scald for my pains. The rocks were quite warm, and I have no doubt one could place a frying pan over some of these orifices and there do considerable elementary cooking. I scrambled out of the crater and a short, easy climb brought me to Columbia's Crest, the actual summit."

Glacier Peak is a volcano 10,400 feet high, easy to climb, and Mr. Rusk reached the summit at 11 a. m. The old crater is directly on top, from one-quarter to one-half mile in diameter, broken down in many places, leaving craggy pinnacles around the circumference. One of these on the southern edge is the summit. The crater is filled by a big snow field. On the east the snow feeds into a great ice-fall, the chief branch of Cool Glacier. This peak was climbed by I. C. Russell, and is not described as steaming.

In the case of Mount Hood, the only mention of heat by Mr. Rusk is described from the summit, when, looking far below, near Crater Rock, he saw big jets of steam rising into the air and drifting upward to mingle with the fleecy clouds that were idling across the face of the peak.

During the exploration of Mount Adams, Rusk mentions on the north side a dry stream course that produced a glacial torrent. This started running in the middle of the afternoon, kept flowing part of the night, and was dry the next morning as a daily occurrence which is not explained. This is a part of the Klickitat drainage.

Going up Mount Adams by the southern way, Rusk's party found thousands of dead grasshoppers on a snow-filled saddle south of the first summit. There were also other insects as well as a humming-bird and a duck, each occupying its own little depression in the snow. Rusk states on different occassions, while climbing Mount Adams, he had found numbers of such birds and insects; and once his party found a dead mouse at an elevation of nearly 12,000 feet. One often finds live spiders crawling over the snow at high altitudes, and sometimes, but not often, live butterflies and other insects are seen. Rusk believes that the dead organisms are accounted for by gales of wind, or else during high flights these creatures are blinded by snow, when they fall bewildered and chill to death. It is an interesting question whether there could be any volcanic carbon dioxide or other gas to asphyxiate the insects.

From the pictures reproduced, the Klickitat Glacier must occupy the former crater of Mount Adams, between the summit and the Ridge of Wonders. Professor H. F. Reid, who has climbed among these volcanoes, expressed the opinion that some fused fragments of rock appeared less than 100 years old (Rusk, page 98).

The following are Mr. Rusk's comments on heat in the crater region of Mount Shasta. When he was turning down from the summit, in 1923, he writes: "I had read much of the so-called boiling sulphur spring, and when we were a short distance down the talus slope, a little to the west of where we had come up, we heard a mighty gurgling roar and saw steam rising from farther down the slope. This subterranean cataract appears to start well up the talus slope and only a little below the highest summit of the mountain. It rushes down nearly to the foot of the pinnacle and apparently turns and disappears along a depression between the main summit and another nearby peak just to the south. From the noise it makes, there must be a veritable river of it, and it is certainly forced upward through some internal chimney from a cauldron in the heart of the mountain. The whole thing would doubtless be invisible, had not visitors pricked its outer covering. The underground channel is overlaid by several inches of what seems to be a blue clay. Wherever holes have been gouged in this by the points of alpenstocks or other sharp insturments, the boiling water bubbles through, making animated little springs from which the steam floats away. We saw several of these. The loose rocks on top are so hot that it is hardly possible to hold the hand on some of them, and the whole clay surface is uncomfortably warm."

"I caught some of the boiling water in my cup and the taste was agreeable and rather sour, resembling lemonade. I drank a considerable quantity and suffered no ill effects. On the little flat just below where we sat were several rock inclosures that had been piled up for shelter by men who had spent one or more nights at this place. Even in a severe storm it is possible for a man to survive, as the heat of the rocks on the slope above the boiling spring would keep one from freezing." T.A.J.

TILTING OF THE GROUND FOR FEBRUARY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

February 2-8	1.4 seconds	SE
February 9-15	1.6 seconds	SW
February 16-22	2 0 seconds	SW
February 23-29	1.8 seconds	S

E.G.W.

KILAUEA REPORT No. 1050

WEEK ENDING MARCH 6, 1932

Section of Volcanology, U. S. Geological Survey

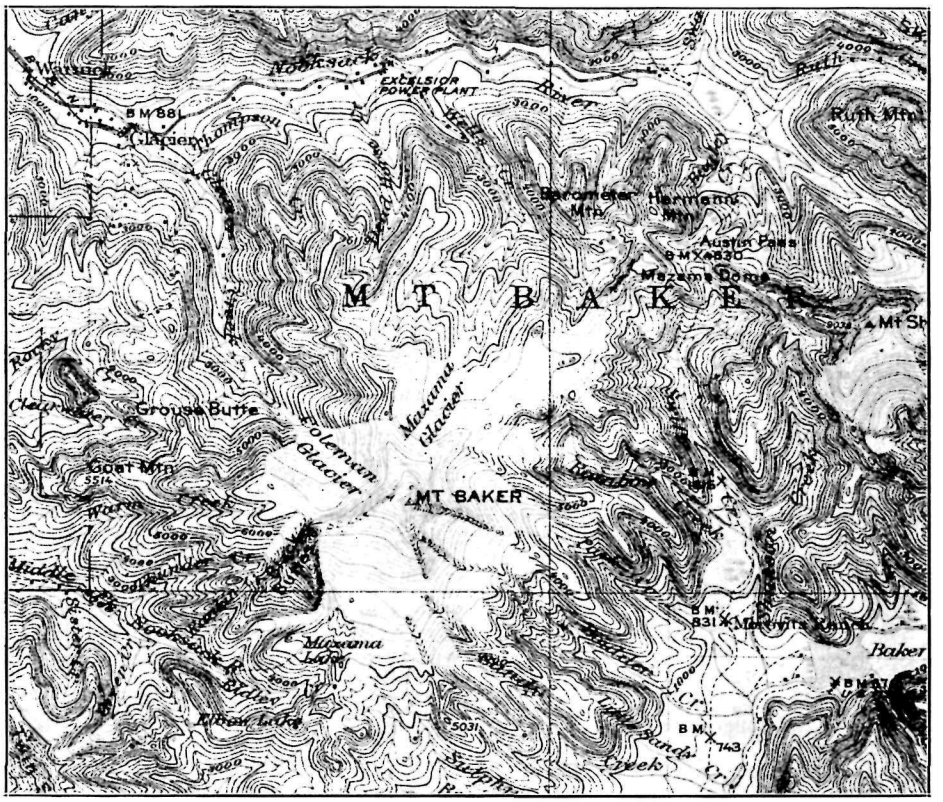
T. A. Jaggar, Volcanologist in Charge.

The widening of crack No 31 NE at the edge of Halemaumau pit has resulted in a crisis of collapse at that portion of the rim. On February 29 there was an avalanche at the northeast wall at 10:17 a. m., and the block in front of crack No. 31 appeared to be instable to judge from the continued widening of the crack. Fume was rather dense under the southwest talus. After a slight earthquake generally felt at 4:43 a. m. March 3, there was seismographic evidence at Halemaumau of strong ESE tilt. The cracks had continued widening and the northeast rim was roped off after an avalanche at 2:10 p. m. There were other avalanches during the day. Fresh debris lay under the northeast wall.

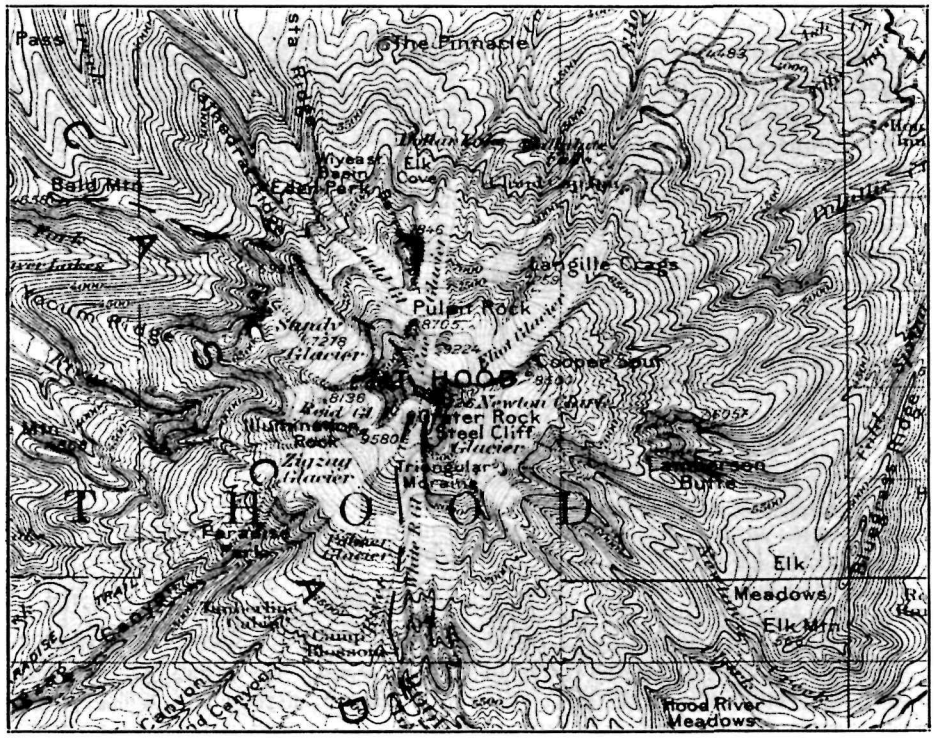
March 4 produced an unusual seismic crisis at Halemaumau and the development of glowing cracks in the January floor. The quaking spasm, which began about 12:53 p. m. and continued for six hours, was strongest for the first hour and a half, and produced eight felt shocks, and much continuous tremor. A visit to the pit showed fresh scars of slides at the west, north, and east walls and small slides were tumbling northeast. Fume was denser than usual, with sulphur odor. There was a large avalanche NE at 2:15 p. m. and others during the afternoon, as well as one NW. Crack No. 31 NE had widened one-half inch in a day. After nightfall two of the deeper cracks in the edge of the lava floor on the east side of the south bay showed distinct glow as though the seismic stress had warped open the thick shell over the still hot January lava.

March 5 produced culmination of the northeastern opening of rim cracks by collapse of the wall. At 11:10 a. m. much new debris was seen under the northeast wall and a small avalanche occurred there. There were numerous fresh cracks, back of the older ones which had been measured. The rim itself had fallen in as far back as the measuring point at crack No. 31. E. G. Wingate ran levels from the sandspit mark in the south end of Kilauea Crater to the northeast rim of Halemaumau and discovered this rim had risen 1.3 feet since the first half of September 1931. This means a swelling upward of the inner dome of the Kilauea floor to accompany the opening of rim cracks. At 3:28 p. m. a section of the northeast rim 500 feet long and 50 feet deep horizontally collapsed in a tremendous avalanche, measuring points Nos. 2, 31, and 35, the danger sign, and the protecting rope were all carried away, and the material overlapped the 1932 lava floor for a length of about 200 feet and a width of 20 feet. Most of this fell after Saturday noon March 5, but the measurements represent the total loss as seen at 9:30 a. m. March 6. The avalanche was accompanied by a small earthquake. Blue fume continued vigorous SW and slight fume rose from the glow cracks which were incandescent as before. A northern slide occurred at 10 p. m. March 6.

The Observatory registered 125 seismic disturbances for the week, including one moderate, 8 slight, 2 feeble, 37 very feeble shocks, and 77 tremors. Of these the spasm of the afternoon of March 4 from 12:53 p. m. to 6:44 p. m. included 1 moderate, 7 slight, 2 feeble, and 31 very feeble earthquakes, and 16 tremors. This spasm indicated mostly



Map of Mount Baker in Washington, scale four miles to the inch, contour interval 200 feet. Surveyed 1907-09, U. S. Geological Survey.



Map of Mount Hood in Oregon, scale two miles to the inch, contour interval 100 feet. Surveyed 1924, U. S. Geological Survey.

a seismometric distance of two miles, corresponding to the distance of Halemaumau. Other indicated distances of the week were 3, 4, 7, and 9 miles, some of which may have been variation in depth under the Halemaumau center. A very feeble shock of 11 p. m. March 1 was felt at Kapapala and the slight shock of 4:43 a. m. March 3, with indicated distance of seven miles from the Observatory, was generally felt on the east side of the island. Microseismic motion was moderate to weak, and tilting of the ground was moderate S to SSE: this tilt was strong for two days prior to March 4, and there were sudden tilts during the earthquake swarm.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Arthur L. Dean, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Richard A. Cooke and Wallace R. Farrington.

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The Volcano Letter

377

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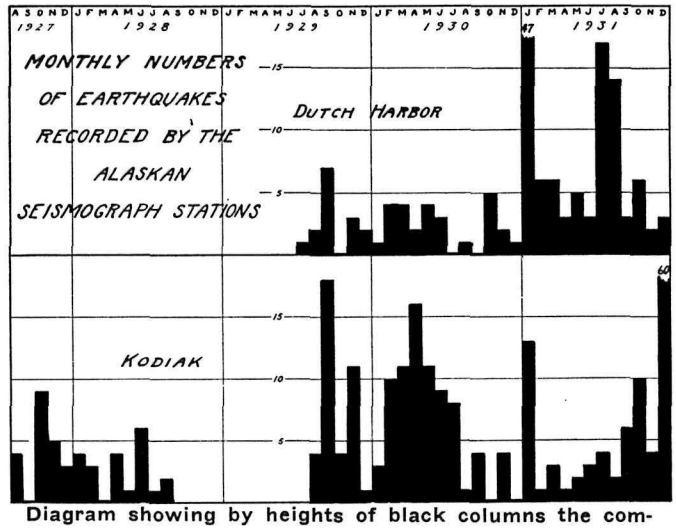


Diagram showing by heights of black columns the comparative frequency of Aleutian earthquakes, by numbers of shocks, per month, at Kodiak and Dutch Harbor (Unalaska) seismograph stations of the Section of Volcanology, U. S. Geological Survey. A. E. Jones.

EARTHQUAKES RECORDED AT THE KODIAK AND DUTCH HARBOR STATIONS

The United States Geological Survey is interested in the seismic activity of the Alaskan volcanoes. Towards that end the Section of Volcanology has placed two seismograph stations at strategic positions. As these places are more than 600 miles apart, neither records the smaller earthquakes local to the other. To facilitate a study of these records, a map of the Alaskan Peninsula and the Aleutian Islands has been prepared which is shown on Pages Two-Three. On this map circles of successive 50-mile distances have been scribed about the two stations. These 50-mile zones aid in the rough location of the earthquakes. With better earthquake reception, or more stations, closer positions could be given. These records are for the purpose of reconnaissance only.

Kodiak Earthquake Registration

The seismograph at Kodiak, Alaska, was put into operation early in August 1927 and was kept in operation until September 1928. It is at the former Agricultural Experiment Station on the hill back of Kodiak village. During this period of 13 months, 35 earthquakes were recorded. The majority of these were local to the Alaskan Peninsula. Fourteen of these quakes originated at distances of 100, 115, and 127 miles and could be attributed to either the nearer active volcanoes of the Aleutian Range or to the steeper part of the ocean bottom. There was one of 520 miles distance, reported from the Yakutat Bay region. Fifteen were teleseisms that were outside the North Pacific area. The remaining 20 shocks were at unassignable distances, but show by the quick period of the long waves that they were local to that area. Probably the 200-mile circle would include them all. Lacking an attendant the station was discontinued for a year.

The next series of records of the Kodiak station begins in the middle of August 1929. During the five months of 1929, six earthquakes were recorded from distances of 20 to 60 miles, two of which were felt by many persons. Thirty-one shocks were recorded that were not teleseisms but show distances of origin otherwise indefinite, but are probably not farther away than 200 miles. There are no teleseisms listed for that period.

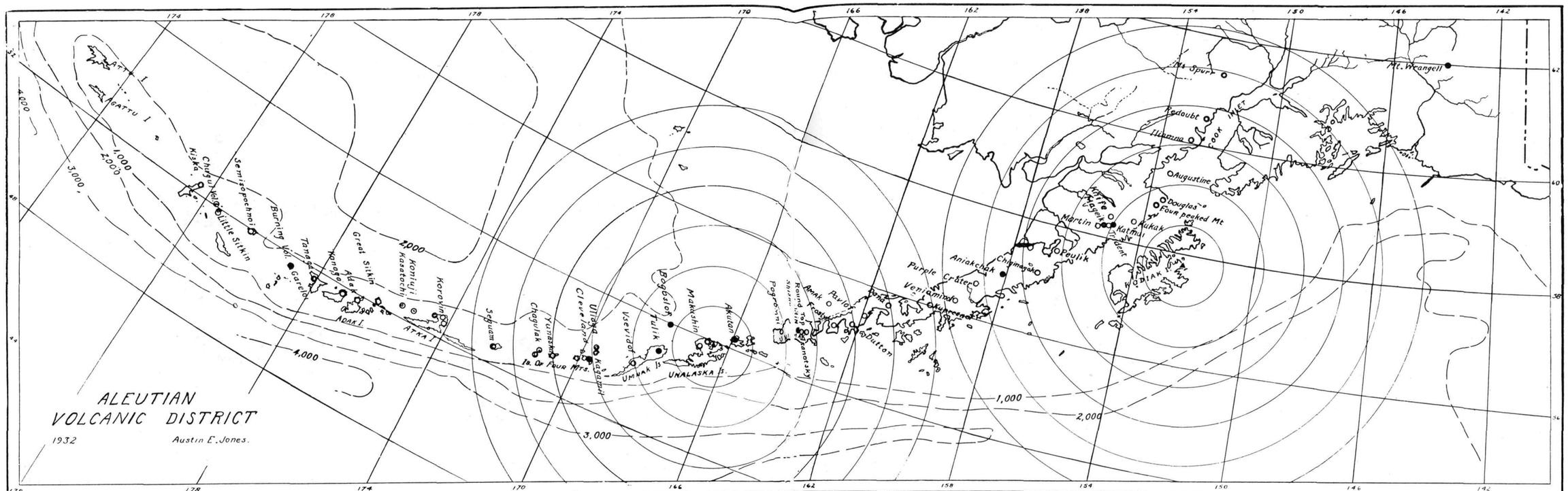
During 1930, 25 shocks came from distances of 20 to 70 miles away. One of these was strong enough to be felt generally; it dismantled the seismograph. Fifty-one local shocks of unknown distances of origin were recorded, and only one of 83 miles distance, that could have originated near Kukak Volcano. Six local earthquakes were apparently strong enough to have been felt, but were not so reported. Only one teleseism is listed for the year.

Time used is Kodiak Standard (K.S.T.), 10 hours slower than Greenwich.

Earthquakes recorded at Kodiak, Alaska

Lat. 57° 48′ 40″ N; long. 152° 24′ 20″ W; elev. 300 ft minus
Two Hawaiian-type horizontal pendulums weighing about 70 kg. set up in N-S and E-W directions. Static magnification 135 times with critical oil damping.

1931		Character	K S. T. h. m.		Distance Miles	Remarks
Jan.	1	Tremor	0	30 a.m.		
	2	Feeble	7	40 p.m.	157	
	4	15 Tremors		p.m.	75-115	Two indicate distance.
	7	Tremor	0	30 a.m.		
	7	Very feeble	3	00 a.m.	20	
	8	Very feeble	11	30 p.m.	83	
	9	Very feeble	1	40 p.m.	20	
	9	Very feeble	8	20 p.m.	143	
	11	Very feeble	3	15 p.m.	50	NE-SW.
	11	Tremor	4	30 p.m.		
	14	Teleseism	5	p.m.		Long waves.
	25	Tremor	6	37 a.m.	110	
	27	Feeble	6	35 a.m.	215	or over. Begins in hour mark. Felt in Seward and Anchorage. Epicenter 61° N 150° W.
	27	Teleseism	11	a.m.		Part of a distant earthquake. Epicenter 31° N 108° E.
Feb.	2	Tremor	6	p.m.	100	



Map of Aleutian volcano belt, showing black the most active volcanoes. The rings around Kodiak and Dutch Harbor seismograph stations are progressive 50 mile distances.

Soundings in Bering Sea at the north and Pacific Ocean at the south are in fathoms. A. E. Jones.

Mar.	18	Very feeble	5	05 p.m.	100	
	21	Tremor		p.m.	32	or over.
	22	Tremor		a.m.		
Apr.	22	Tremor		p.m.		
May	16	Feeble	10	45 p.m.	147	
	28	Feeble	6?	15 p.m.	320	Epicenter 58° N 158° W.
June	14	Very feeble	7	30 p.m.	32	NW-SE.
	16	Tremor	7	00 p.m.	74	
	27	Very feeble	7	35 p.m.	18	NW-SE.
July	5	Tremor	2	00 a.m.	30	or over.
	26	Tremor	10	17 a.m.	64?	
	26	Tremor	2	15 p.m.	110	
Aug.	1	Tremor	7	15 p.m.		
	22	Tremor	3	00 p.m.		
	27	Teleseism	6	20 a.m.		Long waves, part of earthquake. Epicenter in Baluchistan 30° N 67° E.
Sept.	1	Teleseism	3	50 p.m.	600	or greater—felt locally.
	9	Tremor				
	10	Tremor				
	10	Very feeble	12	00 p.m.	55	NE-SW.
	25	Very feeble	1	30 p.m.	60	
	26	Very feeble	5	00 a.m.	55	NE-SW.
	29	Very feeble	0	55 a.m.	160	or greater.
Oct.	3	Teleseism	10	a.m.		Part of Solomon Islands earthquake, epicenter 10° S 161.°4 E.
	12	Very feeble	3	35 a.m.	46	NE-SW.
	16	Very feeble	3	20 p.m.	64	
	17	Feeble	2	50 a.m.	172	NE-SW.
	18	Feeble	2	15 p.m.	50	NW-SE.
	25	Tremor		p.m.	108	
	25	Tremor		p.m.		
	26	Slight	1	00 a.m.	55	NE-SW.
	29	Feeble	9	45 p.m.	32	NE-SW.
	31	Tremor	2	00 a.m.		
Nov.	17	Tremor	2	40 p.m.		
	20	Very feeble	0	55 a.m.	267	NW-SE.
	20	Tremor	1	25 a.m.		
	25	Feeble	9	50 p.m.	74	NW SE.
Dec.	7	Very feeble	2	50 p.m.	78	
	9	Very feeble	2	30 a.m.	106	Over 30 similar earthquakes having no recognizable P phase between Dec 8 11 p. m. and Dec. 9 7 a. m.
	11	Very feeble	8	30 a.m.	305	20 to 25 tremors during 7:30 to 9:30 a. m.; no distances assignable.

In the above record there were 19 local quakes that originated at distances of 20 to 80 miles. Four of these came from 74 to 78 miles away and could have originated under the near side of the volcanic Aleutian Range. Seventeen occurred at places from 80 to 320 miles away, and it can be estimated that a fair percentage of these were from near volcanoes. There were 13 shocks, mostly graded as tremors, as well as three swarms of 13, 30, and 20, to which there could be assigned no epicentral distance other than that they were not farther away than about 200 miles. Parts of five teleseisms were recorded.

Dutch Harbor Earthquake Registration

The Dutch Harbor seismograph was installed July 1929 and has been run continuously. During the last half of that year one shock was recorded from a distance of 37 miles. Akutan Volcano, about 30 miles to the east, was in eruption during the late summer and autumn, and it is more likely that this earthquake occurred there than under the slope of the ocean deep to the south. Eight shocks occurred in the next zone and can be assigned either to the volcanic island Umnak or to the slope of the deep. Six other local quakes of unknown distances were recorded and one teleseism. No earthquakes were reported as felt.

During 1930 four shocks were definitely from within the first zone. One on November 6, 1930, at 3:20 a. m. local time, was felt very strongly at Dutch Harbor and originated 46 miles away. Six more shocks were from the second zone and two occurred at greater distances. There were also 15 local quakes from unknown distances. Only one teleseism was recorded during the year.

Time used is Pacific Standard Time, (P.S.T.) 8 hours slower than Greenwich.

Earthquakes Recorded at Dutch Harbor

Lat. 53° 53′ 09″ N; long. 166° 32′ 05″ W; elev. 15 ft.

Two Hawaiian-type horizontal pendulums weighing about 70 kg., set up in N-S and E-W directions. Static magnification 135 times with critical oil damping.

1931		Character	P. S. T. h. m.		Distance Miles	Remarks
Jan.	2	Tremor	8	25 a.m.	69	
	3	Tremor	11	00 a.m.		
	6	Tremor	8	35 p.m.	60	
	9	Very feeble				
	11	Tremor	6	45 p.m.	42	
	23	Tremor	4	30 p.m.		
	28	5 tremors		p.m.		
	30	35 tremors		p.m.		23-28-32-37-51 59; one at each distance.
	31	Tremor	5	02 p.m.		
Feb.	1	Tremor	5	30 a.m.	57	
	3	Tremor	2	00 p.m.	23	
	10	Tremor	5	30 p.m.	64	or 92; according to interpretation of phases.
	11	Tremor	9	25 a.m.		
	13	Tremor	4	10 p.m.		
	15	Tremor	7	30 a.m.		
Mar.	2	Very feeble	7	30 a.m.	120	
	2	Tremor	11	35 a.m.	46	
	27	Tremor	5	40 a.m.	147	
	29	Feeble ePEN	9	26 28 a.m.		Felt in Dutch Harbor.
		iSE	9	27 01	106	ESE.
	29	Slight ePN	11	13 36 a.m.		Felt in Dutch Harbor.
		iSE	11	14 08	147	
	29	Tremor	0	52 p.m.	120	or over.
Apr.	3	Tremor	7	25 a.m.	111	
	5	Tremor	4	15 a.m.	64	
	18	Tremor	8	30 p.m.	140	or over.
May	4	Tremor	10	55 a.m.	51	
	5	Tremor	2	15 a.m.	147?	
	9	Tremor	7	00 a.m.		
	20	Tremor		a.m.		
	20	Tremor	0	10 p.m.	23?	
June	19	Tremor		a.m.		
	27	Very feeble	0	50 a.m.	46	NW-SE?
	27	Tremor		p.m.		
July	12	Tremor	5	30 p.m.	46	
	13	Tremor	1	45 p.m.	50?	
	18	*Teleseism	3	20 a.m.		

* The Jesuit Seismological Association lists the following 1931 distant earthquakes from this region: May 27, Lat. 56° N Long. 168° E, Commander Islands off Kamchatka; May 29, 58° N, 158° W, Bristol Bay west of Katmai; May 30, 52° N, 177° E, near Kiska and disastrous at Attu; July 18, 58° N, 169° E, west of Kamchatka. The May 29 shock was registered at Kodiak, and that of July 18 at Dutch Harbor.

	19	Very feeble	0	05 p.m.	100-200	
	24	6 tremors		p.m.		
	24	Tremor	8	20 p.m.	83	
	29	8 tremors	11	a.m. to		
			12	m.	18	Distance of one only.
Aug.	2	Tremor	0	10 a.m.	46	
	5	Tremor	2	05 p.m.	500?	Part of a distant quake.
	8	Very feeble	4	45 a.m.	97	
	8	Tremor	5	15 p.m.		Part of a distant quake.
	9	3 tremors		p.m.		
	11	Very feeble	6	40 a.m.	88	
	11	Tremor	8	00 a.m.		
	11	14 tremors	4	00 p.m. to		
			8	30 p.m.		
	14	Feeble		a.m.	110	
	14	Tremor	6	00 p.m.	97	
	15	Tremor	4	40 a.m.	120	
	19	Tremor	6	10 a.m.	360?	
	19	Tremor	6	50 p.m.	130	
	24	Tremor	3	30 a.m.	330?	
	31	Tremor	6	00 a.m.	115	
Sept.	2	Very feeble		p.m.	110	
	8	Tremor	8	30 a.m.	42	
	18	Very feeble		a.m.	55	
Oct.	2	Very feeble	4	50 p.m.	100	NE-SW?
	10	Teleseism				
	10	Tremor				
	10	Tremor	6	40 p.m.	37	
	14	Feeble	2	00 a.m.	115	
	17	Tremor	6	35 a.m.		
	17	Very feeble	8	35 p.m.	55	NE-SW
Nov.	22	Tremor		a.m.	64?	
	23	Very feeble		a.m.	60	NE-SW.
Dec.	1	Very feeble		p.m.	125	ENE-WSW.
	6	Moderate	11	10 p.m.	46	NE-SW. Felt by all. Seismographs dismantled; dishes rattled.
	14	Feeble		a.m.	125	ENE-WSW.
	23	Teleseism	9	45 a.m.	900?	

In the above table 13 earthquakes originated in the first zone about Dutch Harbor, while 17 were in the second zone, 11 in the third zone, possibly two in the fourth zone, two outside the zones at 330 and 360 miles, and two more occurred at the probable distances of 500 and 900 miles away. Four teleseisms were recorded completely or in part. One from the Kamchatka region was remarkable for its large single S period. At least 70 local earthquakes were recorded in such small amplitudes that no distance could be determined. During the summer of 1931 there were over 200 artificial disturbances. probably caused by workmen. There were three earthquakes reported felt at Dutch Harbor. The accuracy of the location of earthquakes in these zones is largely dependent on the depth of focus of the earthquake.

During the years 1929-30 the Kodiak station recorded about 2½ times as many earthquakes as the Dutch Harbor station, while in 1931 the Dutch Harbor station recorded 37 per cent more. This would seem for seismicity to parallel Petroff's statement for volcanicity, that when the volcanoes in one part of the Aleutian chain become quiet, others in some other part of the chain become active. This relative localized shift of seismicity also shows in the graph.

Tremors

The numbers of tremors in the tables stand out. Three times as many were recorded by the Dutch Harbor seismograph as were recorded by the Kodiak seismograph, probably because Dutch Harbor is much nearer the subterranean volcanic rift line. They are seismic in character, representing sizable shocks when originating at a distance. They probably could have been felt by any one over, or near, their origin. After having traveled 50 or 100 miles, the earthquake waves have so decreased in size that they are barely registered as tremors on the receiving seismograph. The Kodiak station recorded 36 of these tremors, only 10 being pronounced enough to show distance by the S-P interval. They fall into groups of 30, 70, and 105 miles. The Dutch Harbor station recorded 105 tremors, 35 indicating distance. Most of these originated at distances from 20 to 150 miles away.

The volcanic magma underground on the Alaskan Peninsula near Kodiak may be about as active as that near Dutch Harbor if seismic distance is considered. The latter station is at about 8 and the former at 80 miles distance from part of the Aleutian volcanic rift. If we compare the tremors received at Kodiak from 100 to 115 miles, with those received at Dutch Harbor from approximately the same distance, there are five in each case received on instruments of nearly equal sensitivity. Referring to the map, there are volcanoes at those ranges from each station.

While there are only two indicated 100 miles on each side of Dutch Harbor, there are other smaller craters unlocated, near both Vsevidof and Pogromni, and both Unimak and Umnak islands have produced recent eruptions. The Katmai group is 100 miles from the Kodiak station. (See Volcano Letter No. 375.) A.E.J.

KILAUEA REPORT No. 1051

WEEK ENDING MARCH 13, 1932

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge.

On March 7 fume from near the foot of the southwest talus was as strong as on previous days. The fuming spot under the west wall was inactive. Cracks were measured and showed little change. Two new measuring points were established on the northeast rim back of the area which avalanched last week. A slide occurred from the NE wall at 10:32 a. m. The seismograph at Halemaumau registered sudden tilt in the morning, without tremor, to the east, and a gradual tilt to south. Two glowing cracks reported last week were plainly visible in the evening.

Dust from an avalanche was seen March 8 at 1:13 p. m. from the Observatory. A small quake was felt at Halemaumau at 2:07 p. m. A few rocks were heard falling.

Nothing new was observed during a circuit of the pit on March 9 in the forenoon.

Much dust from big slides was seen about 1 p. m. March 10.

On March 11 much fume was visible from the Volcano House, rising in concentrated puffs during the forenoon. At 10:08 a. m. there was a small slide from the northwest wall. Sulphur stain slowly increases about the fume spots. A slight widening of cracks was noted northeast. The glow from one of the cracks has nearly disappeared. The crack southwest of this continues to be visible at night, but not so bright as formerly.

On the evening of March 12 one glow-crack remained visible. On March 13 fume activity showed no change. A quake at 8:26 a. m. registered stronger on the Halemaumau seismograph than at the Observatory. Moderate tilt to the east was registered during a quake at 1:15 a. m.

The seismographs at the Observatory recorded 41 tremors, 12 very feeble seisms, and one feeble seism at 11:04 p. m. March 8 felt in Hilo. A very feeble seism at 1:15 p. m. March 11 was also reported felt in Hilo. Distance phases of most of the disturbances indicate origins near Kilauea. Microseismic motion was moderate for the first three days of the week, followed by two days of strong microseisms, and decreased to light at the close of the week. Average tilt for the week was strong SSE.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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The Volcano Letter

378

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Stucco building damaged by earthquake of August 31, 1926, in Horta, Azores. Photo Agostinho.

FREEMAN'S BOOK ON EARTHQUAKE INSURANCE

This monumental work of 904 pages ("Earthquake Damage and Earthquake Insurance,' by John Ripley Freeman, McGraw-Hill, 1932) includes "studies of a rational basis for earthquake insurance and of engineering data for earthquake-resisting construction."

The twenty-two chapters cover: the present situation; earthquake causes and motion; measure of earthquake violence; frequency and violence in the United States and Canada; the narrow destruction zone; structural lessons from San Francisco and Charleston; structural safety and local ground; structural lessons from other American earthquakes; earthquake-resisting buildings in Japan 1923; lessons from Italian earthquakes; lessons from Nicaragua and New Zealand; prediction of time, place and damage; figures on earthquake loss ratio; insurance rates by stock companies; affiliation of earthquake and fire insurance; municipal building codes; textbooks on earthquake-resisting design; shaking tables; the motion of the ground in an earthquake; design of earthquake-resisting buildings; data from seismograms; suggestions for a program of earthquake research.

This book by a great engineer, President of the Manufacturers Mutual Fire Insurance Company, is something entirely new in the realm of seismological literature. It is a book which should be in the office of every large corporation interested in insurance of its property, and still more in every office interested in writing property insurance. The earthquakes of California, Japan, Central America, Italy, and New Zealand, in recent years accompanied with conflagration, and affecting large cities containing modern expensive structures, have created a new problem. This problem is the economic one of enforcing adequate construction to resist either earthquake or fire or both. Mr. Freeman states in the introduction:

"The following pages are addressed to structural engineers, insurance executives, and property owners. In the beginning the author was by no means so well convinced of the prudence of writing earthquake insurance as he has become by studying the information accumulated. The facts brought together demonstrate that the actual hazard is really extremely small when considered as a mathematical ratio. Earthquake insurance might advantageously be incorporated in every fire insurance policy at remarkably small additional cost. Local building laws should be remodelled. Destructive earthquakes are infrequent, area of destruction is small, successful resistance of many buildings is remarkable, average proportion of damage is small, and earthquake-resisting buildings can be built at small additional cost."

Construction requirements are summed up as follows: "All buildings in a region liable to earthquake violence, equivalent to that of the known seismic regions of Italy, Japan, and of the United States, should be designed to resist a horizontal earthquake force, applied at each floor level, equal to one-tenth of the weight of all of the structure above that level, plus the weight of the actual contents, resting upon the floors, including the roof."

This amounts to provision for the application of a horizontal force of one-tenth of the weight of superincumbent structure and contents, applied at each portion. Requirement in building codes anywhere, of design to withstand one-twentieth of superincumbent weight horizontally applied suddenly, is recommended as a part of the structural

factor of safety against all emergencies of wind or quake. The utmost practicable structural rigidity is desirable. The oscillation period of a building should be as short as possible.

Prediction of time, place, and damage from earthquakes presents a variety of problems. Place and time are wholly generalized with reference to the future. Meteorological, electrical, and astronomical controls are unreliable. Tidal stresses probably have some effect. Earth-tilt as a forerunner of earthquakes is coming to be regarded as important in Japan. Location of concealed slipping planes in motion is the subject of an elaborate instrumental investigation near Los Angeles. An engineering survey in advance is quite capable of predicting expectable damage in any locality, in case a great earthquake should occur, by report on the stability of the ground and the quality of design in structures. With reference to maximum expectable violence, it is improbable that anything bigger than the earthquakes of the past will happen. And it must be remembered that fire did most of the damage in several of these.

The earthquake insurance hazard at Los Angeles is probably a very little smaller than that at San Francisco. A region of greatest earthquake frequency may possibly be the safest. A region of fewest earthquakes may give the greatest loss when an earth-slip does come. Certain belts are liable to recurrent great earthquakes. Such places have immunity periods after the last great shock. Soft fluvial or made land deposits are shaken much more violently than rigid ground. Rigid buildings of good design and faithful workmanship will be found practically earthquake-proof. A rigid massive foundation is important. The expected loss ratios on American experience are 3 per cent for steel-concrete and wood-frame on good foundations, 5 per cent for steel-brick and well designed factories of brick in cement mortar, 10 per cent for brick residences not exceeding 4 stories, 25 per cent on brick-veneered buildings with wood or concrete frames, and 50 per cent for concrete-block and hollow-tile buildings. Stone buildings are not mentioned.

The following is Mr. Freeman's probable loss ratio for the United States. The expected average earthquake damage in cents per year for $100 of structural value is:

California, coast	10 cents
California, great valley	5 cents
California, Sierra	7 cents
Washington and Oregon, coast	6 cents
Washington and Oregon, inland	4 cents
Rocky Mountains	3 cents
Northern mid-continent	1 cent
Mississippi bottom lands	2 cents
Great Lakes region	1 cent
Atlantic region, interior	½ cent
Atlantic coast	1 cent

One cent per $100 per year is equivalent to an average damage of $1 per year on a house worth $10,000.

The discussion of insurance is elaborate, by districts, and types of construction. Roughly the total earthquake damage (excluding fire) in the United States and Canada in a hundred years has been forty million dollars. It must be remembered that San Francisco in numerous earthquakes has lost only $20,000,000, as compared to $414,000,000 by four conflagrations. Premiums differ from probable loss in that overhead must be added.

In San Francisco, if the owner insures for not less than 70 per cent of cash value of property against earthquake, he pays a premium rate, per $100 value per year, of from 15 cents to $2.50 progressively from Class I to Class VIII of buildings, and must himself assume loss from 5 per cent to 15 per cent of the total value in such matters as cracked plastering or minor cracks in walls. This proviso enables the insurance company to avoid payment for earthquake damage on a large proportion of all buildings, where the loss does not exceed this percentage.

East of the Rockes there are four rating zones, the highest risks being places of historical earthquakes such as South Carolina, New England, and the New Madrid region of the Mississippi; the lowest are the central states and the Gulf coast. The lowest rate is 4 cents per $100 per year, or $5 per year on a wooden dwelling valued at $12,500. In Zone 1 of greatest risk, this $5 would purchase earthquake insurance of only $5,000 on a wooden house. As before there are several classes of structure of progressively greater risk and higher premium.

The book is profusely illustrated. There are splendid airplane views of the new city district construction in Los Angeles and San Francisco. There are many isoseismal maps of earthquakes, panoramic photographs of conflagrations such as San Francisco, diagrams of the possible roller joints in a design for the basement supports on an earthquake-proof building, diagrams of the displacement effects of earthquakes on buildings, distribution diagrams for severe earthquakes; a discussion with diagrams of the triangulation displacement in California published in 1924, which contained an error of 24 feet of alleged crustal creep, and the correction of this in 1928; pictures of earthquake effects on all kinds of structures in many lands, and very modern photographs of the ruins in Managua and Napier.

Mr. Freeman has been recently in Japan and has been much impressed by the admirable work of the Japanese engineers in reconstruction. He is equally impressed by the inadequacy of much seismological work, as concerned with the needs of theory rather than the needs of humanity and engineers. Mr. Freeman considers the devotion to "acceleration" in mathematical studies of earthquake damage as "worship of a false god." The assumption of harmonic motion, the formula based on amplitude, period and gravity, and the short time within which the maximum change of motion acts, all render this theoretical acceleration of small value where the relatively prolonged racking of building and ground in several directions is involved. Freeman is greatly interested in the experiments on model buildings, with mechanical shaking machinery, made in Japan and at Stanford University. He is everywhere impressed by the lack of real knowledge of the earthquake **at the place and time** where the damage is done.

He concludes with twenty-two recommendations for a practical program of earthquake research, including systematic study and translation of the Japanese works; study of dominant local oscillations; make research on artificial explosions; extend the shaking-table research; develop a strong-motion seismograph and place it; investigate all factors of public safety in every American earthquake through the U. S. Geological Survey; run levels and straight reference lines in critical places; establish tilt measuring lines; reorganize the Seismological Society of America along the lines of protection of life and property; and get contributions for research from the great power, construction, and insurance corporations. He concludes

with an apt quotation from the late President Branner: "The registration of an earthquake two thousand miles away can hardly be expected to interest a man whose family lies buried beneath the ruins of a house built of improper materials upon ground that any geologist might have told him to keep away from." T.A.J.

KILAUEA REPORT No. 1052

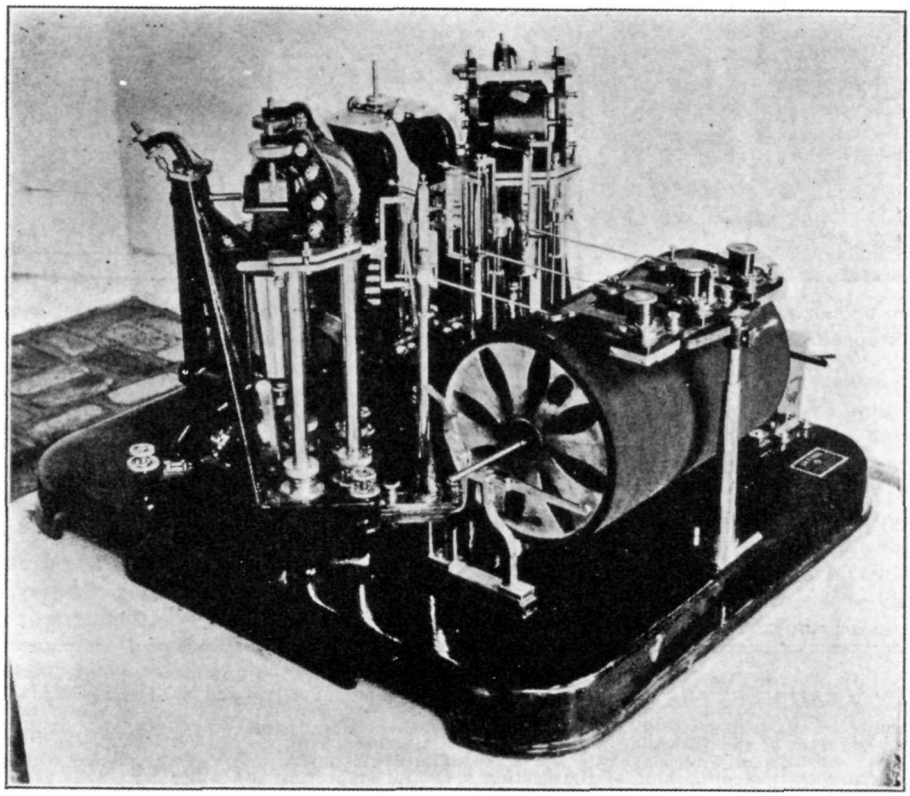
WEEK ENDING MARCH 20, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

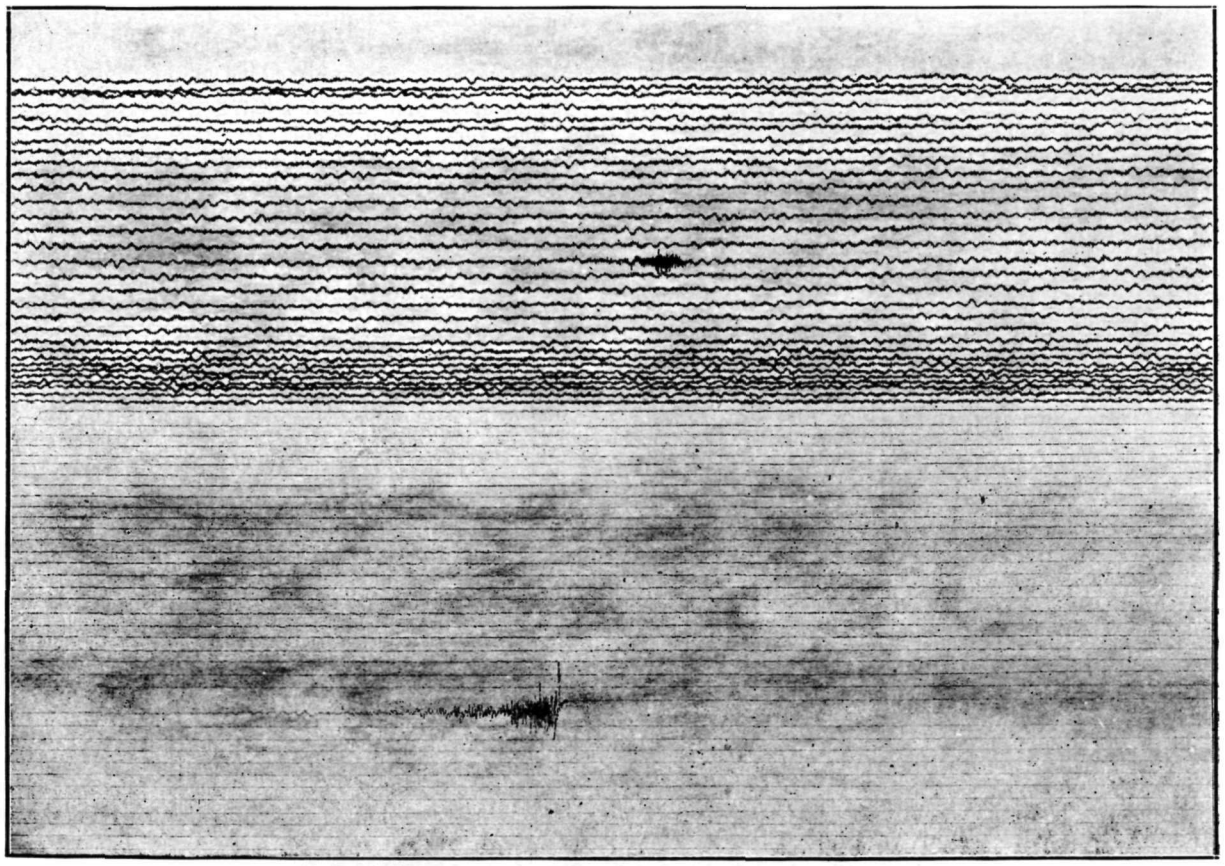
Several slides occurred in Halemaumau during the forenoon of March 14, one larger than the others at 9:37 a. m. over the north wall buttress. Fume appeared about the same. A very slight widening of the northeast rim cracks continued. At night, 8:30 to 9:30, a circuit of the pit was made to locate possible glow spots. Only the one place noted last week, at the southeast, was visible, and this was brighter and larger when viewed from the northeast rim. On March 16 fume showed little change, except that in the forenoon about 11 o'clock none could be seen at the foot of the west wall. At 3:30 p. m. blue fume was plainly visible from the Observatory. On March 17 at 10:15 p. m. fume was again easily visible, and rose from a stained spot by the west talus. At 10:30 a. m. March 18 fume was strong at the same location. On the 19th fume appeared during the forenoon to have decreased slightly. Sulphur stains were quite heavy about the fume spots. Conditions were quiet at Halemaumau. The pit was visited about 7 p. m. and two glowing spots were found at the southeast.

The seismographs at the Observatory recorded 35 tremors, four very feeble seisms, and two feeble seisms. Of the very feeble seisms, one showed origin distance about 4 miles, one about 9 miles, and two about 16 miles. Both feeble quakes showed origin distance about 23 miles. One at 6:31 p. m. March 18 was felt at Kilauea and Hilo; the other at 8:11 p. m. March 19 was felt near Kilauea.

Tilt for the week was strong SW. Microseismic motion was light the first day, moderate the next two days. strong two days, and moderate the remaining two days of the week.



Japanese seismograph designed by Imamura, with three pens writing on a single drum covered with smoked paper. Time marked by lifting pen tips with electromagnets connected with a wall clock. Pendulums record up-down, east-west, north south motion and are damped with horseshoe magnets.



A seismogram or earthquake autograph written at Kilauea Volcano. The record of crater movement when an eruption stopped. Tremulous upper lines record the eruption. Crowding of lines records tilt. The two groups of crowded oscillations are earthquakes.

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The Volcano Letter

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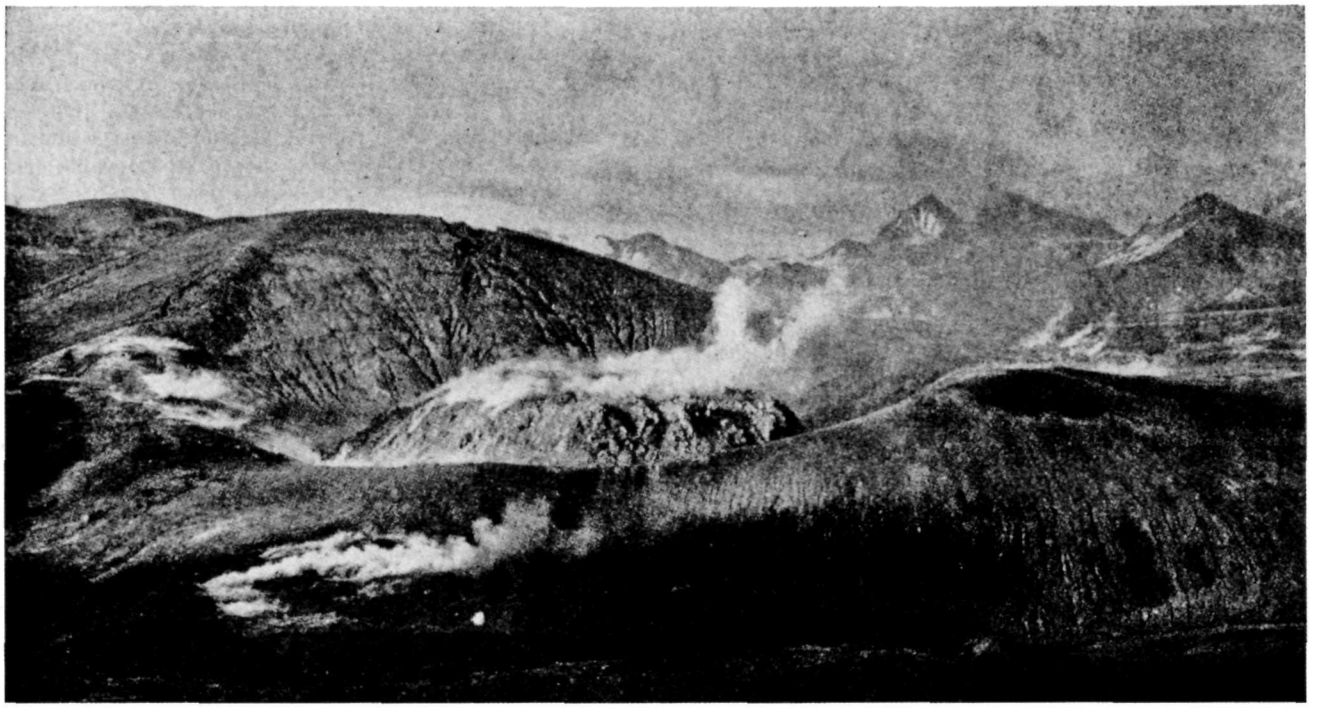
No. 379 Hawaiian Volcano Observatory, National Park, Hawaii March 31, 1932



Novarupta dome of siliceous soda rhyolite, near Katmai in Alaska, which rose in 1912 in the bottom of a new explosion crater in a valley, and developed a heap 800 feet across and 200 feet high. Photo National Geographic Society.

WILLIAMS ON LAVA DOMES

An essay of unusual importance for volcanology, with excellent illustrations and a thoughtful, philosophical summary of conclusions has just been published by Dr. Howel Williams (The History and Character of Volcanic Domes, Bull. Dept. Geol. Sci., University of California, Volume 21, No. 5, Berkeley 1932, 95 pages, 37 figures).

Dr. Williams became interested, in the subject of lava flows which arise so stiffly as to build up at once a plug or dome, by his work at Lassen Volcanic National Park where there are 13 such domes within an area of 50 square miles on an even grander scale than the puys of the Auvergne. Massive protrusions are now known to be common manifestations of volcanic activity. There are plug domes which represent upheaved conduit fillings, domes that grow essentially by expansion from within, and domes built by surface effusion. In the last class the large Hawaiian overflow heapings are better described as "shield volcanoes."

The domes described consecutively are those of the Caribbee Islands including notably the dome and spine of Mont Pelée and the dome at the volcano of Guadeloupe. Next come the Central American domes of Santa Maria in Guatemala, Popocatepetl in Mexico, and some minor ones in these countries. South America has numerous lava domes which are imperfectly known, of which the best example is the acid andesite dome, consisting of viscous hardened lava, having an extremely jagged surface, from which steam and fragmental eruptions continually issue, in the crater of Galeras Volcano. In North America, besides the Lassen domes there are those in the chain of craters south of Mono Lake, California. Here at Panum Crater the obsidian lava was so nearly solid that it rose with essentially vertical walls to about 150 feet without exhibiting a tendency to flow in any direction, so that a deep moat separates the dome from the surrounding rim of lapilli. At the Marysville Buttes in California there are banded rhyolites which form intrusive domes among Tertiary sediments along the flanks of an andesitic laccolith, steep-sided and of oval outline from a quarter mile to a mile in length. They were viscous and contained steam, and the rise of the domes was attended by violent steam explosions, some of which blasted a crater, measuring a mile in diameter, through the core of the laccolith. Next come descriptions of Bogoslof in the Aleutian Islands and its numerous domes, and of the remarkable siliceous dome of Novarupta near Katmai on the Alaskan Peninsua. "The rise of this dome, like that of almost all domes, was preceded by strong pyroclastic explosions, whereby a crater almost three quarters of a mile in diameter was opened," and coarse ejecta measuring eight feet in diameter were flung a quarter mile from their source. The explosive phase was followed by the welling up of viscous magma, which as it was slowly thrust upward broke into huge blocks. It was heaped about 800 feet in diameter and 200 feet high. The glassy lava is banded in general parallel to the margins. "Apparently the magma rose to the surface

by the active solution of the country rocks, retaining its heat largely by gas reaction. The original magma was a siliceous soda rhyolite with 75 per cent of silica containing partly fused inclusions of andesite country rock with 62 per cent of silica."

Next come descriptions of Tarumai and Usu domes in Japan, Merapi and Galunggung in Java, and Ruang in the Sangi Islands. A submarine dome during April, 1904, appeared in these islands, and after 1913 three rocks were left emergent above the water. In 1919 a short-lived dome rose above the surface, forming an island 70 meters in diameter and up to 12 meters in height. It consisted of lava blocks of amphibole andesite. There are many other stiff lava domes in the craters of the Dutch East Indies.

Ascension Island in the Atlantic has crater domes of trachyte, and the trachytic eruptions were in all cases preceded by eruptions of basalt. The protrusion of the domes followed long periods of dormancy and was heralded by explosions flinging up obsidian ejecta. The explanation appears to be that after the early outpourings of basalt, the residual magma became differentiated and capped by a siliceous slag. "This sequence of events thus affords another instance of the explosion of a gas-rich, differentiated magma, followed by the quiet upwelling of pasty lava to form" interior heaps in the craters, a sequence apparently common in dome eruptions. The trachytes are poor in vesicles in contrast with the rhyolites and basalts. The diameters of the Ascension Island domes are 400 to 500 meters, and the heights 200 meters more or less. In the Ragged Hill dome, the dome structure is indicated by a pronounced concentric rifting, with plates dipping away 35 degrees, and the platy structure apparently due to thermal contraction. There are inclusions of common basalt in the trachyte. In the case of the Riding School dome, the trachyte flowed over the rim of a basaltic crater after forming a large body in the center of the depression, and then after making a thick flow 700 meters long away from the crater, the surface of the inner dome sank back to form a basin. This withdrawal of magma in the center happened in another dome where the platy structure has an inward dip of from 2 to 5 degrees. At St. Helena there are phonolite domes more deeply eroded than those on Ascension Island, the largest of which, called Great Stone Top, was originally 300 meters high, was fed by a dike only 10 to 15 meters wide, and was accumulated, not in an old crater, but on an almost level floor of basalt. In Samoa there are rhyolite and trachyte domes closely analogous to those of Ascension Island, here also overlying older basalts.

The puys of the Auvergne in France have black basaltic cinder cones with pale-colored craterless domes of trachyte within them, and Scrope in 1825 described them correctly. He observed that basalts tend to yield low, broad cones, because of their high fluidity, whereas lavas of "low specific gravity, especially when combined with a coarse, crystalline texture, will occasion a minimum of fluidity. The trachytic lava seems to have risen upwards from the vent in so pasty or imperfectly liquid a state as to have accumulated above it in the form of a dome or bell, just as would a body of melted wax, or one of moistened clay, if forced outwards through an orifice in the cover of any containing vessel."

The domes of Auvergne are divided into three types, (1) Peléan domes, acid and basic, (2) Peléan domes with craters or with trachyte ejecta, (3) domes with elevated portions of the adjacent rocks. The augite trachyte dome of the Grand Sarcoui has the form of an overturned bowl with a maximum slope of 60 degrees, measures 750 meters across the base, and is 250 meters high. It has a smooth surface and no rock pinnacles, due apparently to the lava having poured uniformly in all directions from a summit vent. On the east flank there are quarries revealing buried talus and the rough structure of an underlying pinnacled dome. This inner heap was of the Pelée type and the overflows at the top were a late phase. In the Puy de Dôme there has been left an irregular truncated pyramid 550 meters high. It is a trachytic protrusion covered by debris from a summit vent. Lacroix explains the sequence by the opening of a fissure in the underlying rocks consisting of granite, gneiss, etc., permitting lava that was partly viscous and partly solid to rise to the surface and build a steep dome. Its crust crumbled, forming great banks of talus cemented by fine dust. Both dome and talus are biotite trachyte. Later eruptions from a new summit crater deposited fragments including pieces of the bedrock pumice, breadcrust bombs, and angular pieces of trachyte. The trachyte ejecta of these final eruptions differed mineralogically from the materials of the dome, and in texture from glassy to coarsely crystalline. The same thing was observed in the dome of Mont Pelée.

The Gulf of Santorini, in the island of Thera of the Grecian Archipelago, produced the first dome eruption well known to European geologists. In February 1866 a new islet appeared in this crater bay composed of lava blocks, pumice, and bottom debris. Steam explosions were frequent. The mass grew without earthquake or visible projection of fragments, silently, but so rapidly that it seemed like the blowing of a soap bubble. It seemed like an expansion movement with the rocks incessantly displaced from the center towards the edge. On the second day the growth was from the edge towards the center. The dome above water measured 70 to 30 meters and was 20 meters high. One could walk on top, although the lava was still glowing beneath. There was no summit crater, but rather a confused heap of big blocks grayish in daytime, fuming, and at night lighted by incandescence, while the lower slopes were covered with cooler debris. There were long crescentic fissures, almost complete circles, on top of the dome. Similar cracks have been observed at Novarupta, Alaska, and at Chaos Crags near Lassen. The first Santorini dome was named Georgios, and on February 15 a second dome, Aphroessa, rose quietly above the sea on its flank. Within two days it grew enormously, and in five days its length had reached 380 meters. Its mode of growth, like the first dome, showed nothing but a progressive displacement of lava blocks. There were, however, occasional eruptions of cinders and lapilli which decapitated and flattened the Georgios dome. On March 8 this measured 350 by 100 meters and stood 50 meters high. The blocks were either scoriaceous or compact glassy andesite. There was an incessant crackling noise and a tinkle like broken porcelain. The fumaroles had temperatures up to 300 degrees C. and the vapor contained hydrochloric and sulphuric acid. On March 10 a third dome, Reka, arose still more quietly without any crackling of blocks breaking asunder in cooling. This heap became joined to Aphroessa. Fouqué called these domes cumulovolcanoes. New hillocks of blocks were piled up and destroyed, the shapes changed, the rates of growth varied, and Georgios developed a pile of blocks on top enclosed

by a circular trench. The end of the activity was on Georgios in October 1870, four years and eight months after the beginning of activity, and the new islet finally stood 120 meters above the sea.

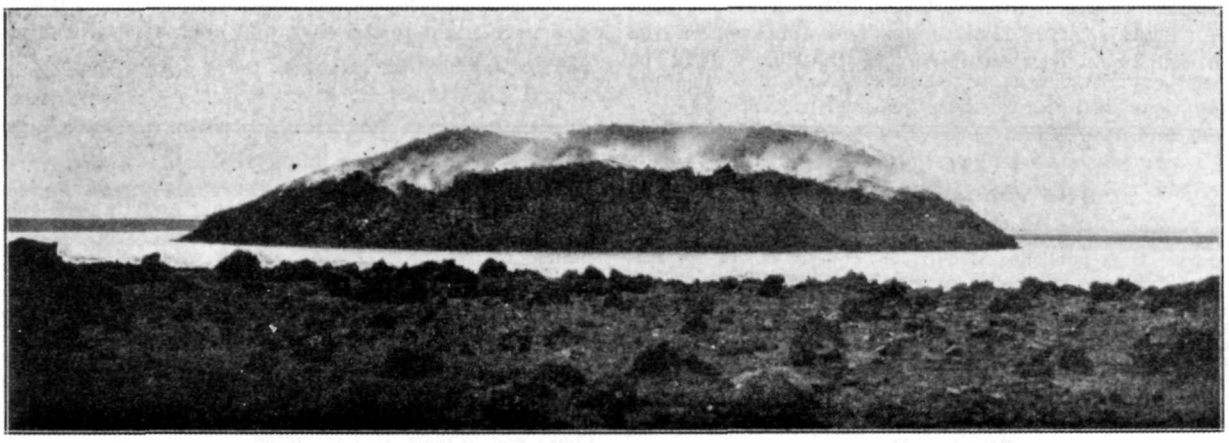
Fifty-five years later in September 1925, the same kind of activity was renewed when Fouqué dome appeared near the earlier island, circular in plan, 150 meters in diameter, and 50 meters high above a plateau of new lava on September 19. The shape of the dome continually changed. There were violent eruptions and a continuous redistribution of the loose blocks. The explosions sent up black cauliflower clouds. The temperature of the upper part of the interior of the dome was 700° to 800° C., there was no definite crater, and small jets of white vapor were emitted all over the surface. The vulcanian explosions took place from different places, mostly near the summit, blowing out loose blocks which fell back, and occasionally decapitating the dome. The blocks were solid and angular, dense, vitreous, and black, and there were no well-defined breadcrust bombs. There were concentric crevices which made a thin ring of bright red incandescence, and in daytime semicircular batteries of narrow jets of gray vapor which formed a crown around the dome. The lava flows associated with the dome had blocky crusts over compact vitreous lava free from vesicles. One small dome on the surface of the flow exhibited concentric banding. In the Georgios dome the lava contained many basic inclusions, very little gas, very little combined water, 65 per cent of silica, and may be called a glassy pyroxene dacite.

In 1831 an island formed by submarine eruption near Pantelleria in the Mediterranean appeared on July 16, had become 65 meters high and 3700 meters in circumference early in August, and was washed away by the end of October. The material was volcanic sand, lapilli, and scoriae arranged in strata around a crater. There appears to have been an upthrust of lava in viscous condition and broken at the top, similar to Bogoslof. There was trachytic pumice, but the island was basaltic. There was much carbon dioxide gas.

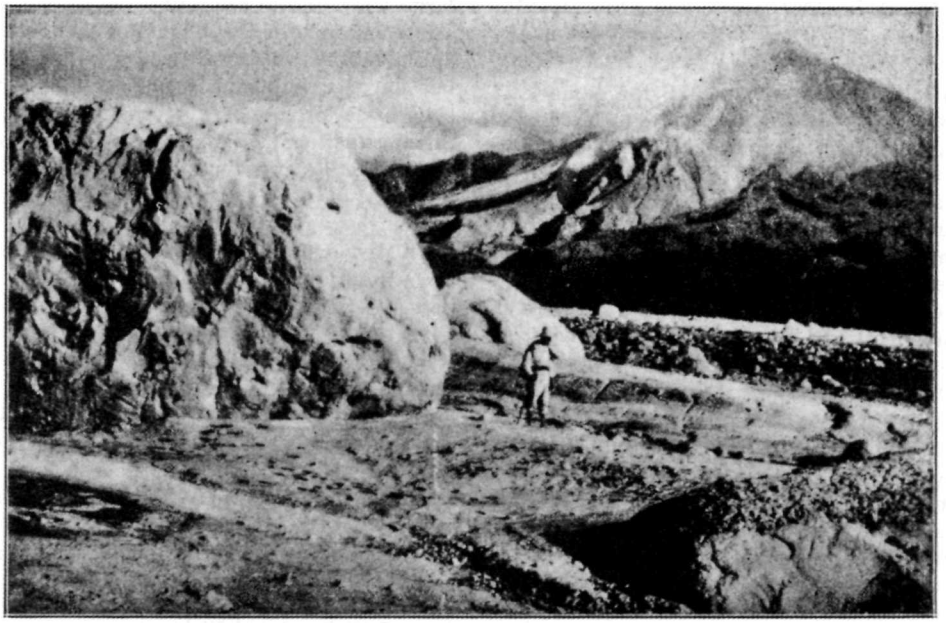
Other domes are described in the Lipari Islands and in the older lavas of Italy, in the Eifel region and elsewhere in Germany, in the Milos Archipelago of Greece, among the Virunga volcanoes of East Africa, in Kamchatka, in the Philippines, in Iceland, in the Azores, and in several places in California including the flanks of Mount Shasta.

Summarizing the characteristics of dome outflow, the largest are one to two miles across and the smallest only a few meters. In shape most of them are truncated domes and pyramids with lower slopes concealed by talus. Breaking up of crusts during upheaval, and the formation of concentric or radial ridges are characteristic features. Slickensides or scrapings are often to be seen along the walls of fissures. Glassiness is very characteristic of the lava of domes, also porphyritic structure, and and the upwelling of the lava is preceded by explosions flinging out pumice and tuff. There are usually many basic inclusions. The rocks are mostly andesties, trachytes, and rhyolites. The temperatures at times of protrusion are estimated to have been less than 850° C. Shepherd and Merwin estimated that the gas pressure inside the Pelée dome was about 100 atmospheres. Intense solfataric action is seldom conspicuous during and after upheaval. The gas content of the lavas is small, 0.15 per cent by weight at Lassen, 0.10 per cent at Santorini. The breadcrust bombs of Pelée contain six times as much gas as the material of the dome. The gases listed as extracted from rock of Pelée, Lassen, and Kilauea show excessive carbon dioxide, sulphur, chlorine, and fluorine for the former and relatively high hydrogen and carbon monoxide for an aa lava of the latter. Lassen Peak andesites have excessive combined water. One is impressed by the great excess in all these analyses of H_2O, 70 to 96 per cent, as compared with H_2, one per cent or less; CO_2, one to 20 per cent, as compared with CO, measuring from less than one to three per cent; and SO_2, on the other hand, always less than one per cent, is in less amount than the sulphur from which it is derived, which approaches one or two per cent. The unoxidized hydrogen reaching its maximum in the Kilauea lava (6.18 per cent), and the fact that one of Day and Shepherd's analyses of the gas from the liquid lava yielded seven per cent, makes it reasonable to suppose that hydrogen is the fundamental volcanic gas, but that it oxidizes during the rise of magma and consolidation, just as do the metallic ingredients in combination with silica.

The rate of growth of domes is rapid. That at Santa Maria rose 100 meters in a week, the dome of Mont Pelée rose 25 meters in a day, that of Tarumai rose 100 meters in four days. The internal structure may have concentric layering, or it may have fan structure, or it may spread



Lava heap of Bogoslof Volcano in the Aleutian Islands, surrounded by warm salt-water lagoon and ring bars of explosion debris. Activity of 1926-28, photo Wheeler.



In distance Santa Maria Volcano in Guatemala after eruption of November 2, 1929, in middle distance the lava dome which had risen in the crater in the flank of the volcano, and in foreground gigantic bowlders carried with floods of the eruption. Photo Sapper and Termer.

with irregular fissuring and sprouting like aa lava. In most cases talus forms around the border. The propelling force Williams considers to be the expansive pressure of internal gas, and generally the dome is the top of a plug forming a seal to the conduit at the close of an active period. T.A.J.

KILAUEA REPORT No. 1053

WEEK ENDING MARCH 27, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

In Halemaumau pit the afternoon of March 21 the fume at the foot of the southwest talus appeared denser than usual. Scars of two small slides had appeared on the south wall; one over the northwest talus at 2:24 p. m. raised a cloud of dust. On March 22 at 10:55 a. m. a sound like floor cracking was heard. Slide dust arose at 12:30 p. m. March 23, and a larger avalanche at 1:40 p. m. dumped fresh debris on NW talus. At 2 p. m. dust continued to rise. The avalanche tremor was registered by the pit seismograph. This avalanche fell directly from the rock of the northwest rim for a length of 150 feet, and left large bowlders below. On March 26 glow was still reported visible in evening in crack at south edge of Halemaumau floor.

Observatory seismographs registered 66 tremors for the week, and two very feeble local seisms, one of which indicated origin 16 miles away. A distant earthquake was recorded beginning at 1:36:32 p. m. Hawaiian time (10 hrs. 30 m. slower than Greenwich) March 25, of probable distance 2980 miles from Hawaii. Tilting of the ground was very slight to the east, and microseismic motion was generally moderate.

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380

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Construction of Perret's upper station on Mont Pelé proper, November 1930, at Morne Lenard. Photo Perret.

THE NEW DOME OF PELE'E

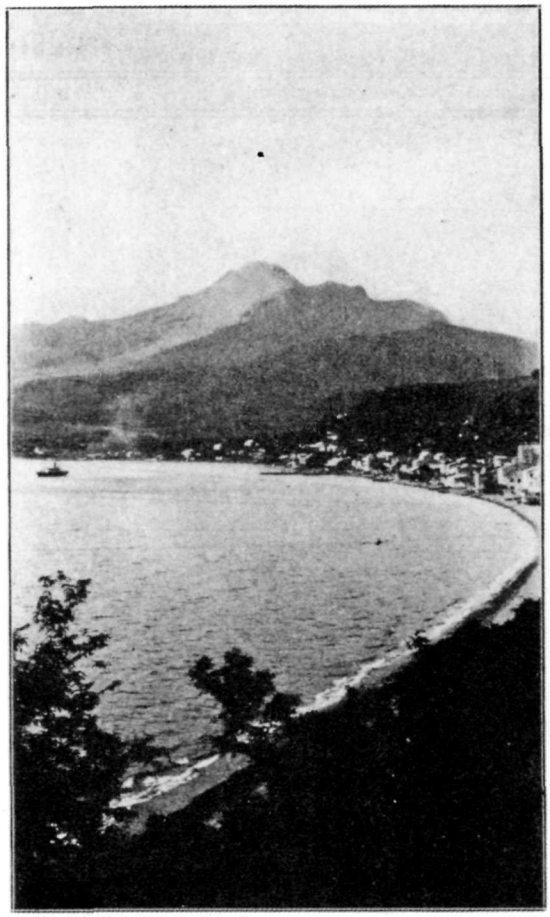
The renewed activity of Mont Pelé was mentioned in Volcano Letter No. 262. Ash eruptions were reported to have begun September 16, 1929. It appears that notes on the evolution of the dome were published in "Comptes rendus" 190-761, 190-623, and 191-1253, 1930-31, by H. Arsandaux. F. A. Perret has added two notes in the same publication, C. R. 193-1342, 193-1439, 1931. These last are reviewed here.

The formation of cone-in-cone structure by dwindling activity of mixed eruption, like Vesuvius in the ring of Monte Somma. is well known. The absence of a chimney in the center of a lava dome makes an interior edifice unexpected. Perret in January, 1930, when he first saw the Peléan dome of 1903, was interested to find it deeply caved in from the explosive process of September 1929. In the center of this cavity was an active eruptive cone.

The new excavation was a depression which widened from southwest to northeast, with a rocky ridge in the wound. The greater part of this was conical, but not the highest part. The explosive phase of eruption which continued in January and February exhibited two sources for steam-blast cauliflower clouds: a large one north, and a smaller and higher one southeast. The undermining produced a horseshoe cup with a medial extension like the latter "E.". With the kernel of the dome surrounded by talus, it was surprising to see the outer shell of weakest material hold itself up in steep walls, while the solid rock of the interior was removed. Evidently eruptive material rose high enough to form a shell whence eruptions diverged before destroying the lateral walls. From the time of the first 1929 eruption, all the explosions were from the inside of the dome of 1902-03.

The inner rocky ridge extended downhill ENE-WSW like a cock's comb, with the lower end a row of needles. Still lower at the ancient opening of the 1902 horseshoe, a series of vents in a line sent up puffs of ash. It could not be determined whether these were in new magma or a rocky remnant of the old dome.

The central ridge was not simple. It was a castellated group of towers. These were round, smooth, and spirally grooved. They appeared tubular. and often lava poured from apertures at the bottom. On the 20th of April, 1930, after an enormous downrush, round columns were left on the dome, black by daylight, but probably incandescent. The towers change rapidly. January 28 they appeared to be destroyed. But the activity appeared rather to be constructive, for on February 3 the towers appeared consolidated into an enlarged mass with the profile of a true dome. On the crest were rudimentary needles. Then came lava activity. that would have been 'Strombolian' if there had been explosive ejection, and this motion never ceased. Such crises were at first rhythmic, and alternating with the cauliflower jets, and they gradually resolved themselves into a regular constructive process, producing numerous needles On all sides of the new dome emerged slender incandescent lava flows. with emission of light transparent vapor. The process was comparable to that of lava cupolas on Vesuvius. The incandescence was dark orange under a thin crust in the darkest places, and elsewhere it was so bright that the illumination reflected on the cloud was visible at Fort-de-France. The flows were liquid a short distance apparently, then presented the well



St. Pierre as it is today, 1932. Photo Perret. Mont Pelé in background.

known "aa" streaming of fragments. The dome grew higher and on February 19 the summit was flat, crowned with small needles, and at the sides were straight talus slopes.

Two mechanisms are involved in the Pelée dome, the spread of lava and the thrusting out of needles. These last tend to rise vertically. This vertical rising is natural enough on the summit, but how about a slope of débris at 35°, where a line of vertical obelisks arises? Why does the internal magma push skyward and through chaotic material? This explanation appears to be the perforating power of rising gas. A fissure holding magma is opened to the surface by gases burrowing upward in a row of aligned chimneys. The magma follows, shells over in contact with the chimney wall, and the pencil so formed is pushed up. The lava flows are similar, but the orifices being more free, the slag remains hot and fluid.

During two months the carapace on the dome was so thin and the mass so fluid that the needles overturned on a pasty base, resembling large pears. The most conspicuous spine began March 25, promptly overturned, and rolled down the slopes. Examination of details at two spines showed one rising a meter per hour, the slope of the dome opening, like a soil clod with a mushroom pushing through. Pasty magma rose in a collar around the needle, then solidified, when the spine was three meters high. In the second case the paste was accompanied by gusts of vapor emerging between the spire and the slope. The needle remained small, but the steam jet continued several weeks. The average height of spines was 12 to 18 meters.

The dome of 1902 grew toward the northwest, overlapping the ridge there (Petit Bonhomme), so that its débris slope extended beyond the ancient crater of the E'tang Sec. The new inner dome has left a gulch on that side, but toward the east and southeast has overtopped the older dome, sent its débris slope down against the wall of the ancient valley on that side, and chilled and ceased activity there, except for fumaroles. In September 1931 the dome was migrating southwest and the long slope of ejecta was overtopping the ridges there so as to threaten the trail to the summit of the mountain. The new dome is 231 meters above Petit Bonhomme, and somewhat higher than was the peak of the old dome.

All the hot blasts (nuées ardentes) emerge from fractures in the dome of 1902 and mostly from the two openings, low north, and high southeast. After the new dome developed, the character of these gushes changed gradually. Four types of downrush are distinguished by Perret. The first is occasioned by an avalanche formed by the squeezing out of a small quantity of magma. It is an imitation of a true hot blast. The magma, not being greatly charged with gas, merely makes a heavy tumble of rocks, which slide down the slope, and excavate a trench. Dense, ashy, light-colored cauliflower clouds arise. The second type is occasioned by heavy rain falling on the dome which seems to penetrate it after a quarter hour or more, so as to start ejections of steam charged with dust which descend the slope rapidly as a gaseous emulsion. After heavy precipitation these down-blasts are certain to come, and they are important, some of them in the spring of 1930 following the gorge of the Riviére Blanche and out to sea for several kilometers. The last two types of gushing are avalanches of incandescent blocks without significant dust clouds, and finally a cooler ash phenomenon where blocks of uniform size roll rapidly and far, carrying imperfectly oxidized carbon gases, and emerging from a part of the dome which has partially congealed.

In the southeast part of the new dome there are fumaroles in a horizontal line, due to water, where the old and new domes are in contact beneath. Where the summit of chilled lava is in contact with active lava, bluish transparent vapor emerges at high temperature.

Mr. Perret has used a microphone for determining the variation in mass of the vibrating active dome. His theory is that an active edifice makes a definite note of lower pitch the greater the mass. The combined roar of slides, blowing of vapor, fall of spines, at any given moment make a musical tone, the timbre of which may be defined in terms of mi, fa, sol, la, si, etc., so the augmentation or diminution of the dome may be followed. His upper station was on the flank of Pelée at Morne Lénard.

At the beginning of November 1930 the tone was si flat. Three months later the dome was bigger and the tone was deeper, exactly la. April 13, 1931, it was sol sharp; June 4, sol; June 25, a little below sol; but on August 10 the pitch had risen to sol sharp, and it continued to become sharper, showing that the mass of the dome was decreasing, and that the arrival of new magma, inside, no longer equalled the loss by slides into the valley, and by erosion.

Establishment of a Research Center at St. Pierre

Mr. Perret has sent the following letter to the Hawaiian Volcano Research Association:

February 2, 1932.

"All the world remembers the destruction of St. Pierre, in 1902, by a terrific eruption of Mont Pelé. St. Pierre was not only the commercial center of Martinique, but the cultural metropolis of the Lesser Antilles. Excavations reveal the exquisite taste of the former inhabitants, and the relics unearthed from time to time are of great beauty, and of interest as showing the effects of the blast of hot gas and ash, which it is useful to study. Those objects—instead of being dispersed as found—should be preserved for all time in a collection, along with photographs of the beautiful ruins, fast disappearing in the rebuilding of the town.

"The recent eruption of Mont Pelé has reawakened scientific interest in this volcano, whose special type of activity is almost unique, and the products of eruption—breadcrust bombs, ash, and lava blocks in new forms—are most interesting. A complete collection of these, placed for comparison with the materials of other volcanoes, and with photographic studies of all their phenomena, is a scientific necessity.

"I may say that my own work here has resulted in a further demonstration of the pratical value of volcanology as an applied science. Eighty million francs of invested capital, depreciated to zero by panic and uncertainty, was restored to par value through diagnosis and prediction based on sound scientific deductions, with the help of apparatus devised for these purposes. For the further development of these methods, the creation of standardized instruments, the bringing together and preserving of the materials, etc., I am now founding at St. Pierre this research center, organized as museum—observing station—laboratory.

"A private institution, out of politics, and not governmental; its continuance, after me, is guaranteed by a Fiduciary Committee, consisting of men of the highest standing in the colony, including honorary memberships of the Mayor and Curé of St. Pierre. Its founding at the present time has been extraordinarily facilitated by the cession to me of a most ideal site for its emplacement, on the beautiful Morne d'Orange, 350 feet above the town, but easily accessible, and commanding a superb view over St. Pierre and of the entire massif of the imposing volcano.

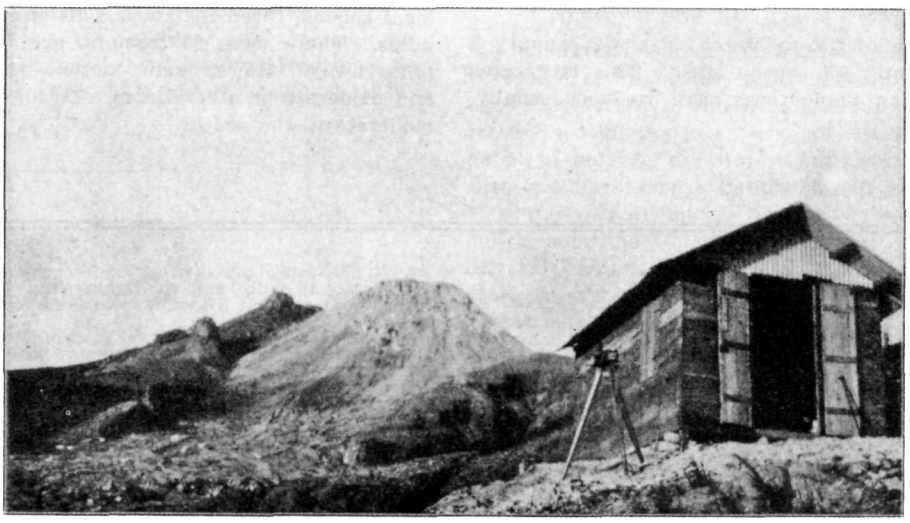
"Construction cost is largely covered by local contributions. This is not to be an American institution, but an American contribution to science in a location where this science can be best developed—a gift to St. Pierre as a continuation of American good will. St. Pierre is visited annually by some thousands of American tourists, whose interest will be quintupled by having a definite goal, where what they most desire to see will be on view.

"The contribution of one thousand dollars, as a minimum, makes the donor a founder of the institution, and the name will be on a marble tablet at the entrance, and upon the stationery of the museum. A few subscriptions are desired, above those already received, when this account will be closed. A total of ten thousand dollars is sought for the foundation.

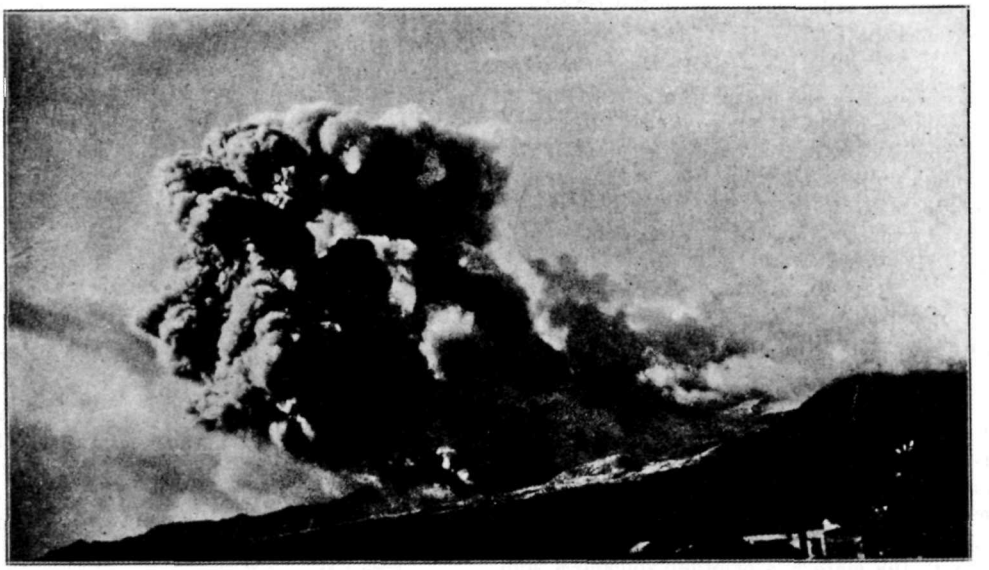
"This work—at once scientific, artistic, and humanitarian—is believed to accomplish more, with a small amount of money. than anything heretofore instituted. It will be selfsupporting through its museum, of direct service by its observation work, and world-contributing in its laboratory research. Contribution involves no obligation of future support.

"You are earnestly invited to become one of its few, distinguished founders."

Mr. Perret has been living at St. Pierre since 1929, and has already started the foundation with contributions from the Carnegie Foundation of Washington, Vincent Astor, and George F. Baker. It is to be hoped that members of the Hawaiian Volcano Research Association will be added to the list of founders, for it was Mr. Perret who camped



The upper station, Mont Pelé, after completion. Photo Perret.



Hot blast from the dome, Mont Pelé, February 9, 1930. Photo Perret.

alone on the edge of Halemaumau pit in 1911, and so started the work which established our Association. T.A.J.

TILTING OF THE GROUND FOR MARCH

The following figures show the net angular tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

March 1-7	4.6 seconds	SSE
March 8-14	3.3 seconds	SW
March 15-21	1.5 seconds	SW
March 22-28	1.1 seconds	SSW

The accumulation of tilt to March 28 since January 1 is 17.4 seconds south, 0.7 second west. This is greater southerly tilting than whole years have produced usually, with the exception of 1924. E.G.W.

KILAUEA REPORT No. 1054

WEEK ENDING APRIL 3, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

On March 28 at 11 a. m. fume was issuing from a crack at the foot of the south talus in Halemaumau, and steam on this talus was abundant 100 feet south of the fume vent. Fume at the yellow vents at the foot of the southwest talus was unusually prominent. A slide at the north wall made dust at 11:53 a. m. Crack movements at rim of pit have shifted from northeast rim, now quiet, to southeast rim, where slight opening of fissures is now measurable. The rest of the week showed no changes.

The Observatory seismographs registered 5 very feeble local seisms, three registering distances of 14, 25, and 46 miles. There were 25 tremors, one indicating origin 18 miles away. Microseismic motion was strong March 31 and moderate at other times. Tilting of the ground was moderate to the south.

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The Volcano Letter

381

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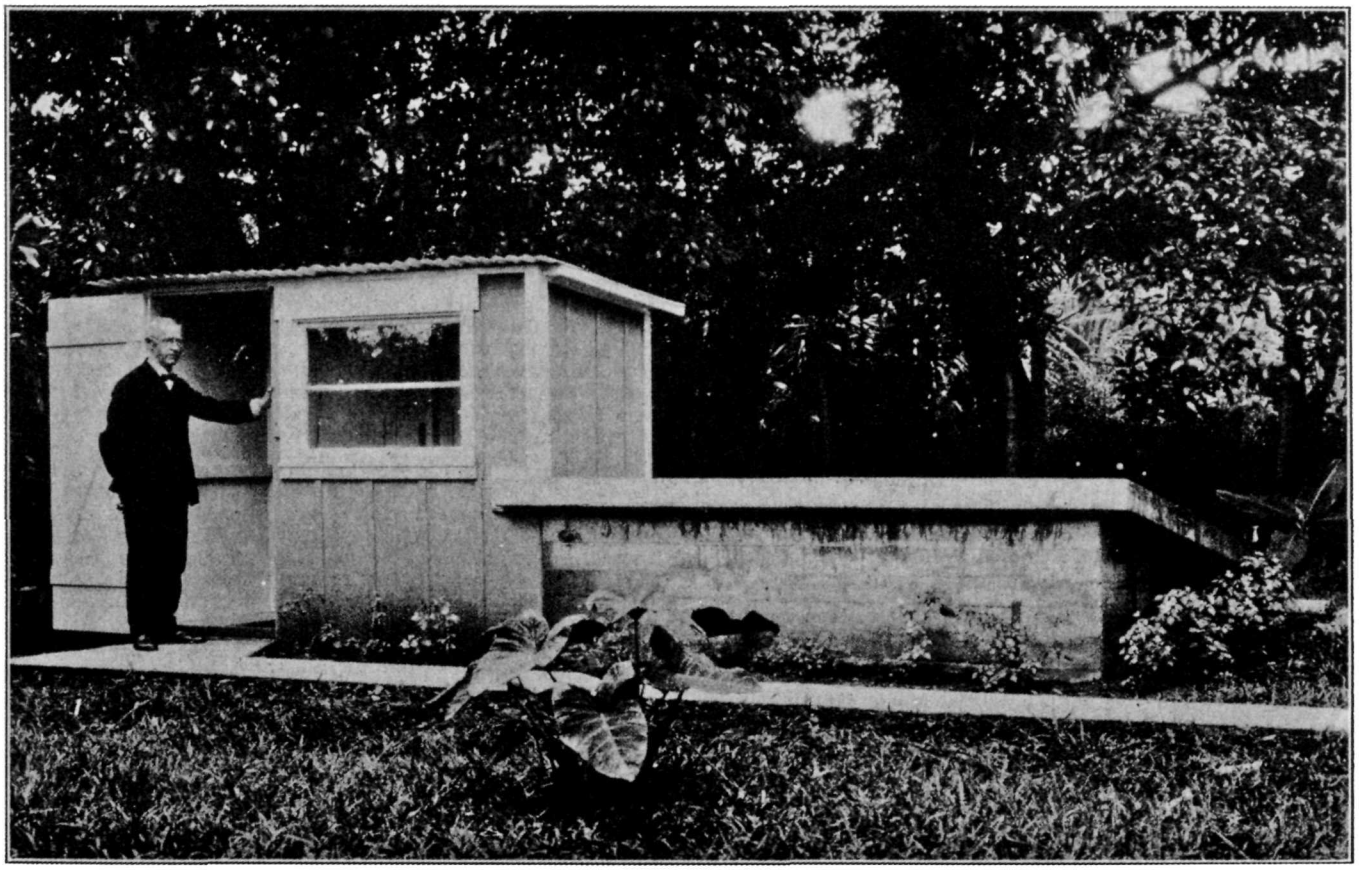


Seismograph cellar of the Hilo station of the Hawaiian Volcano Research Association, built in 1927. Brother J. B. Albert is the observer. The instrument consists of two heavy horizontal pendulums, with clock checked by wireless time signals.

TWENTY YEARS OF VOLCANO STUDY IN HAWAII

Address by T. A. Jaggar at Annual Meeting Hawaiian Volcano Research Association in Honolulu, March 31, 1932.

Administration

The Hawaiian Volcano Observatory was founded by an association formed in Honolulu in 1911 which undertook to finance a geological station on Kilauea Volcano established by the Massachusetts Institute of Technology. Ground was broken for the building on February 15, 1912, when Dr. T. A. Jaggar, who was then Professor of Geology at the Massachusetts Institute, had come to Hawaii for the purpose of establshing permanent volcano research. The Hawaiian society became a chartered corporation named the Hawaiian Volcano Research Association.

In 1919 the work was first assisted by the Government in collaboration with the Hawaiian association, and the governmental supervision was assigned to the United States Weather Bureau. The plant was leased by the Association to the Government at a nominal rental with the understanding that the Weather Bureau would furnish personnel and salaries. Since 1924 this arrangement has been transferred to the United States Geological Survey, which through the interest of the Congress has been enabled to enlarge the work to a Section of Volcanology with small stations in California and Alaska added to the Hawaiian establishment. Routine publication, now carried on through the Volcano Letter, has remained with the original Association.

The objects of the work from the beginning have been: (1) To keep and publish a record of Hawaiian volcanic activity and associated earth movements, (2) to invite specialists to Hawaii or to send them elsewhere for volcanologic studies, and (3) to do everything possible to promote the establishment of permanent volcano stations all over the world.

(1) Recording Hawaiian Volcanic Activity

The preliminary reconnaissance of the Hawaiian field was made by T. A. Jaggar and R. A. Daly in 1909. Mr. Jaggar had been engaged before this time in studies of Mont Pelée and Soufrière in the Caribbee Islands, of

Vesuvius after its eruption in 1906, of the Aleutian Islands in 1907, and through association with F. A. Perret he had been interested in the Messina earthquake. It was evident after the terrible disasters of Messina, Vesuvius, and St. Pierre, along with the earthquake-fire of San Francisco, that more studies of the earth from permanent stations should be made. This had been the subject of a crusade at Harvard and at the Massachusetts Institute of Technology, and a small endowment was obtained at the Institute for geophysical research, having in view the protection of life and property. This is called the Whitney Fund.

With the aid of this fund and through cooperation with the Geophysical Laboratory of the Carnegie Institution of Washington, Dr. E. S. Shepherd of that laboratory along with Mr. Perret, the former a chemist and the latter volcanologist, were induced to spend the summer of 1911 at Kilauea with a view to physical studies of the lava pit. Mr. Perret built a hut at the actual edge of the pit and made weekly reports to the press on measurements of change in the lava column. A cable was stretched across the pit and measurements of temperature of the liquid lava were made with electric thermometers.

The actual foundation of the Research Association was arranged at a luncheon in the University Club of Honolulu, October 5, 1911, when the late L. A. Thurston pointed out that there should be no break in the collection of records at Kilauea, and a subscription list which had been started in 1909 was revived. Mr. Jaggar arrived January 17, 1912, and weekly reports were reestablished. Through special subscriptions raised in Hilo, the present main Observatory building was constructed in February, with the Whitney Laboratory of Seismology in its basement. A topographic map of the proposed Kilauea National Park area was made by the U. S. Geological Survey as a basis for field work. The National Park became a fact in 1916 when Mr. Jaggar went to Washington to draft the final bill. The Volcano Research Association built and gave to the National Park Service the museum on Uwekahuna bluff in 1927.

The keeping of record books at the Observatory has been continuous from 1912 to the present. Mr. H. O. Wood came to the station as seismologist in the summer of 1912, a number of seismographs were set up, and the records were enriched by reports on tremors, earthquakes, and tilting of the ground, which proved to be motions of great interest, when studied in relation to the rising and falling lava.

The year 1912 was a time of vigorous activity in the lava pit, in 1913 the lava column became low and smoky, and thereafter until 1919 there was a steady rise with increasingly good opportunity for making comparative photographs. Mauna Loa broke out in 1914, 1916, and 1919, and these eruptions added to the interest of the work. In the summer of 1912 Doctors Day and Shepherd returned to Kilauea for gas collections at the live lava, and the temperatures proved to be various and somewhat proportionate to the volume of gases discharged by the many fountains. Mr. Jaggar was able to keep up the gas collections in subsequent years and to send the specimens to the Geophysical Laboratory for analysis.

The years from 1912 to 1924, however unfavorable they may have been financially, were fortunate ones from the volcanologic standpoint at Kilauea. in that they represented an eleven-year cycle of extraordinary vehemence for both Kilauea and Mauna Loa, with great variety of action, and a marvelous finale in 1924 when the crater pit of Halemaumau caved in through the recession of the lava, and a steam-blast eruption occupied the month of May 1924 in a fashion not seen here since 1790. The incessant measurements of change in gases, change in temperature, change in elevation of the lava column, and the photographic records accompanied by notes and transit measurements that produced maps of the crater fills and flows, all combined to yield a record of a decade of volcanic activity, in the most primitive volcanoes on earth, such as science had never possessed before. By primitive is meant the quality in a volcano, that exhibits the pure heat and magma, of the material under the primitive earth crust, not complicated with the impure mixtures of sea-bottom sediments and organic life such as occur on the continents. Vesuvius, Lassen Peak, and Katmai are all volcanic heaps made where the blast furnace of the earth crust has discharged through such rocks as limestone, sandstone, and slates. The glowing slag underneath has absorbed unkown amounts of carbon, lime, silica, and alumina.

After 1924 a quiet condition at Kilauea leads people to think the volcano is dead. Instead of this, we are recording some kind of outbreak nearly every year, Mauna Loa had a great eruption and destroyed a village in 1926, and an earthquake crisis on Hualalai in 1929 recalled the wonderful lava flows from that mountain in 1800, a time ten years after the last explosive eruption from Kilauea. The year 1934 will be ten years after the new explosive eruption. Are we to look for more lava flows from Hualalai? The present decade, therefore, is making a record which is a valuable asset, the like of which has not been obtainable since the end of the eighteenth century.

When it comes to earthquakes, the instruments for recording ground movements at Kilauea have been steadily improved, and the experience of 20 years with many ups and downs of the lava column, and outbreaks on Mauna Loa, and big earthquakes on Hualalai, has accumulated thousands of seismograms in the files of the Observatory. These are pieces of smoked paper fixed with shellac, on which automatic pendulums have written a graph of each earthquake or tremor or tilt, and have recorded the clock time. They are all different. Science can interpret from each graph the distance away of the source, the strength of movement, and how the elastic waves passed through the rock. Some of the instruments are in Hilo and Kona, so that when the distances indicated there are compared with the distances from the Observatory, the place underground may be found where the lava split its way upward and made a jolt. As some sets of earthquakes accompanied eruption, on the south flank of Mauna Loa, others on the different flanks of Kilauea, and yet others occurred on Hualalai, it becomes possible to classify Hawaiian earthquakes from their autographs, and the making of this classification promises years of valuable work. Those who think there is nothing to do at a volcano observatory during a quiet time should start studying some of these pieces of smoked paper.

The publishing of results is no small part of the work, and this involves, first, summarizing every week the essential observations at the Kilauea pit, at the seismographs, or on Mauna Loa or elsewhere if activity occurs. These summaries must be published in the papers, and also printed in more permanent form. It is further necessary to assemble observations of like kinds, and coordinate them for understanding the underground processes. An observatory is always a detective, trying to find out what is going on underground, from information the layman does not possess, yielded by a chemical collection, or a measurement with transit, thermometer, level bubble, or pendulum. These assembled observations have been published in scientific journals and it is one of the functions of the Volcano Letter to assemble similar communications from observatories in other lands, in order to make them known to our people here. There is much excellent work in Dutch, Japanese, Italian, French, German, and Spanish from the East Indies, Japan, Europe, and South America, for which a translation institute ought to be endowed, in order to sift out important facts which are now lost to most of the world.

Recording is nothing more than description. It is very hard to use language so as to tell the truth. The reading of any newspaper will prove this. Accurate description is all that is meant by "a theory." Modern physics is not trying to explain the "why," or to explain anything;

it is trying to describe the "how." This is what we are trying to learn about an active volcano, "how" it works. A mere quantitative measurement in figures by itself means nothing. Recording, to be accurate, meaning careful, must be checked all the time by quantitative measurements. These measurements may be put together to make a description, so that the difference between one event and another is dependent on the readings of the measurements, and not on guesswork. When enough of these differences have been collected, it becomes possible to classify events, and then the classifications fall into sequences, and the complete description of a sequence suddenly discovers (or uncovers) what has been going on, in the under-earth, at a place which was invisible. This final description of things unseen is a "theory."

Take in illustration of this the matter of prediction. How can you predict when a volcano is going to erupt? It is first necessary to measure an eruption and to tell the truth as to what an eruption is. If you classify as "eruption" the smoke from an island seen by a mariner, entirely unmeasured, and compare it with the rise of lava for six years measured in Halemaumau pit by scientists, you get nowhere. You do not know whether the mariner's "smoke" happened all the time, or every year, or every six years. You can not describe the "how." In the case of Kilauea, the scientists continue for another five years and find the lava going down and out. Then comes a lull for two or three years. They study the records for a hundred years back and find many measured risings for six years, and sinkings for five years, followed by a lull. Then they find that two volcanoes adjoining took part in this sequence. Perhaps they find in separate years that the biggest risings were in the autumn and the sinkings in the spring. This is a measurement by seasons and years, just as other measurements are by heights and depths. They average all the results. The average shows an eleven-year cycle as a probability for that pair of volcanoes. They may even find that this eleven years corresponds with sunspots, and then that the irregularities in numbers of sunspots which depart from the average, correspond with the irregularities in highest rise of the lava during the century. They know nothing about the "why," but here is a very interesting "how." Knowing all these things, they can "predict" that the next "eruption" will occupy eleven years, will begin by rising and end by sinking, will have its annual rising spasms higher in winter, and if the term is not exactly eleven years, it is likely to depart from that figure in the same way that the sunspots do. Knowing the relation of the two volcanoes, they perhaps can say, that in the course of this eruptive cycle, Mauna Loa is sure to help out Kilauea once or twice during the eleven years.

What is now an eleven-year theory, a seasonal theory, a relationship theory, and a sunspot theory, may eventually advance a step farther so as to describe how all these things are related to some bigger processes in the crust of the earth. They will then all become facts and not theories, but the larger process will remain in the realm of theory. Science is merely piled up descriptions.

(2) Studies by Specialists

In addition to work which has already been mentioned, Dr. E. T. Allen of the Geophysical Laboratory spent a season at Kilauea analyzing the vapor at the sulphur vents, and determined it to contain 96% steam and less than 1% of the sulphurous products. Boring indicated that the temperature, 204° F., is extraordinarily constant.

For two seasons Dr. Arnold Romberg worked at the Observatory on seismograph instruments, and set up optical instruments to determine in what direction the wave movements known as microseisms are propagated through the ground at this place. Also special instruments were designed to measure the tilting of the ground, which was found to have a half-daily and semi-annual change. These changes must be allowed for when measuring what tilts are made by the pressure of the lava underground. Some remarkable changes of tilt have coincided with sudden risings and fallings of lava shown by outbreaks of Kilauea and Mauna Loa. The microseismic waves were found to coincide in direction with the high cliffs of the Hamakua coast bombarded by tradewind waves.

Messrs. J. B. Stone and C. K. Wentworth at different times have studied the geology of Hawaii, and Mr. H. T. Stearns and others have produced a Bulletin of the Geological Survey on the geology of Kau. Dr. Howard Powers is at work on the geology of Kona. All of these studies are providing new knowledge of the soils of the island in relation to the lava flows and the deposits of ash from past eruptions. A basis is being laid for classification of formations and interpretation of the past history of the earlier volcanic vents which preceded the active volcanoes of today. Dr. Wentworth has made a special study of the ash, especially the cinder of the many small cones on the slopes of Mauna Kea, and has greatly enlarged our knowl edge of how those cones were formed and of the differences between the gas eruption there and the liquid lava eruptions on Mauna Loa at the present day.

Mr. Jaggar has been four times in Japan, three times in Alaska, and once each in New Zealand, Costa Rica and the Tonga Islands for studies of earthquakes and volcanoes. These comparative studies are of value not only in showing how different are the volcanoes of different lands, but also the contacts with men of science tend to encourage the last of the three objects above enumerated, namely, promotion of new volcano observatories elsewhere Mr. Finch visited volcanoes in the East Indies in 1929 and Mr. Stone explored and photographed several craters in Chile the same year, both of these men being commissioned by the Hawaiian Volcano Research Association.

Messrs. Wood and Finch have completed a bulletin now in press in Washington listing in technical form all the measured earthquakes registered on the seismographs of the Observatory from 1912 to 1923. This list comprises thousands of shocks and is illuminating in showing the large number of earthquakes which accompany sinkings of the lava, the frequency varying with the rapidity and depth of the sinking. An increase of frequency of earthquakes also accompanies sudden risings of the lava in Halemaumau. In Mauna Loa eruptions the freqnency is greater at the beginning of an outbreak, and as the frequency declines the strength of the shocks becomes greater. In general the comparison of times of fewer earthquakes in Hawaii, with times of high frequency, shows that the greatest intensities of quaking (or the strongest shocks) come when the number of shocks is at a minimum.

(To be continued)

KILAUEA REPORT No. 1055

WEED ENDING APRIL 10. 1932

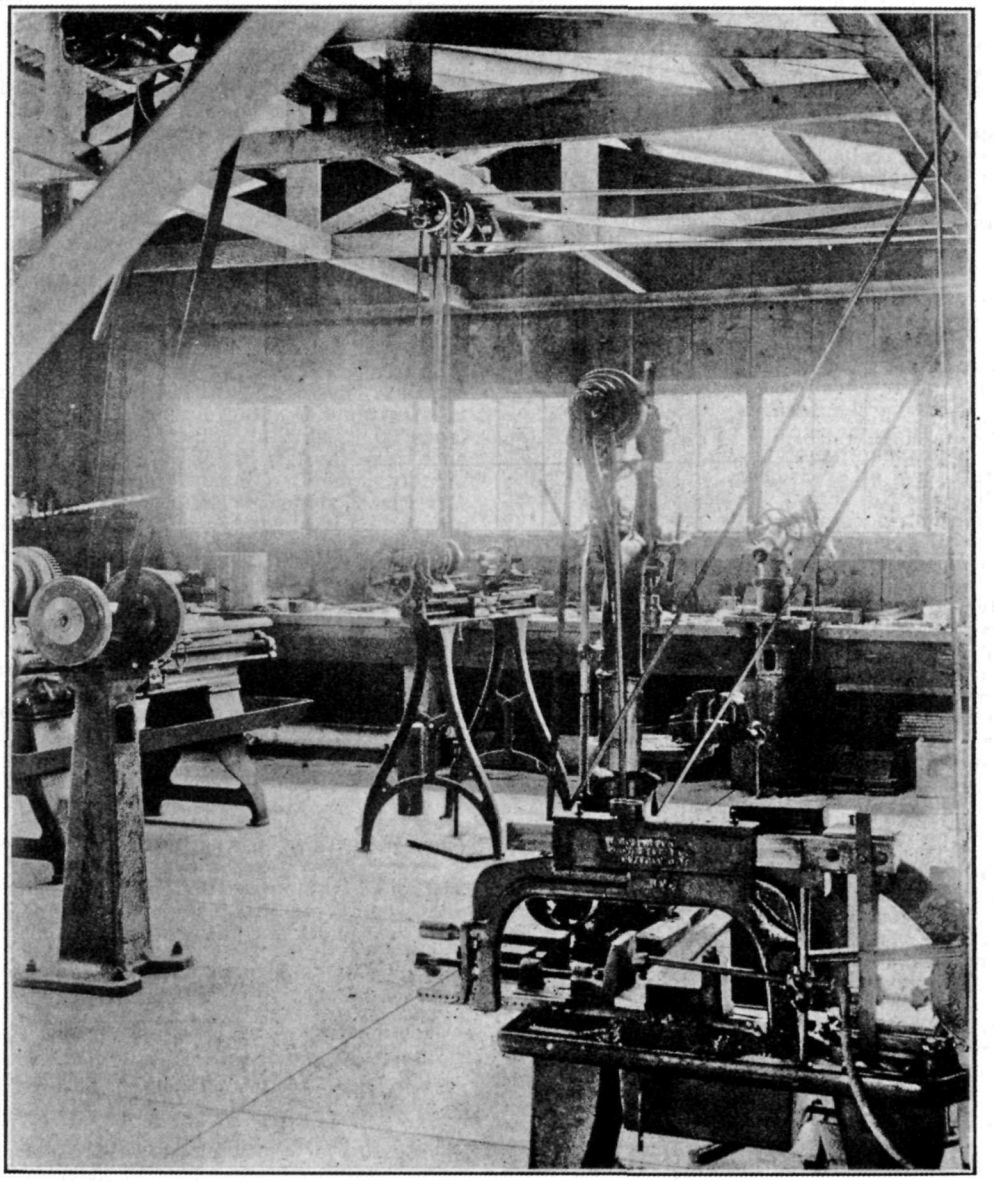
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

Conditions at Halemaumau show little change. The pit was quiet April 4, with slight steam and little variation in fume.

Crack measurements showed very slight changes. On April 6 fume was moderate at the foot of the southwest talus and the spot under the southeast wall and talus still fumed slightly. Brilliant yellow sulphur stain showed at the fume area by the southwest talus. The scar from a small slide was seen on the northeast wall. On April 7 fume at the foot of the southwest talus was dense all day and some fume was visible at the spot under the southeast wall. On April 9 fuming activity had not changed. The seismograph at the pit showed ESE tilt accompanying the earthquake at 5:50 a. m. One tremor showed E tilt

The seismographs at the Observatory recorded 52 tremors, four very feeble seisms, and two feeble seisms. One tremor at 6:25 a. m. April 5 was felt at Waimea and Puuwaawaa and had origin distance 46 miles from the Observatory. One feeble seism at 4:50 a. m. April 9 was felt at the place called "Twenty-nine Miles."

Average tilt for the week was slight NE by N. Microseismic motion was moderate during the first three days of the week, light for the next three days, and moderate on the seventh day.



Machine shop at the Hawaiian Volcano Observatory, installed by the Research Association. There are two lathes, two drill presses, a machine hacksaw, and a grinder, while in the adjacent carpenter shop are power plant, boring machine, and circular saw.

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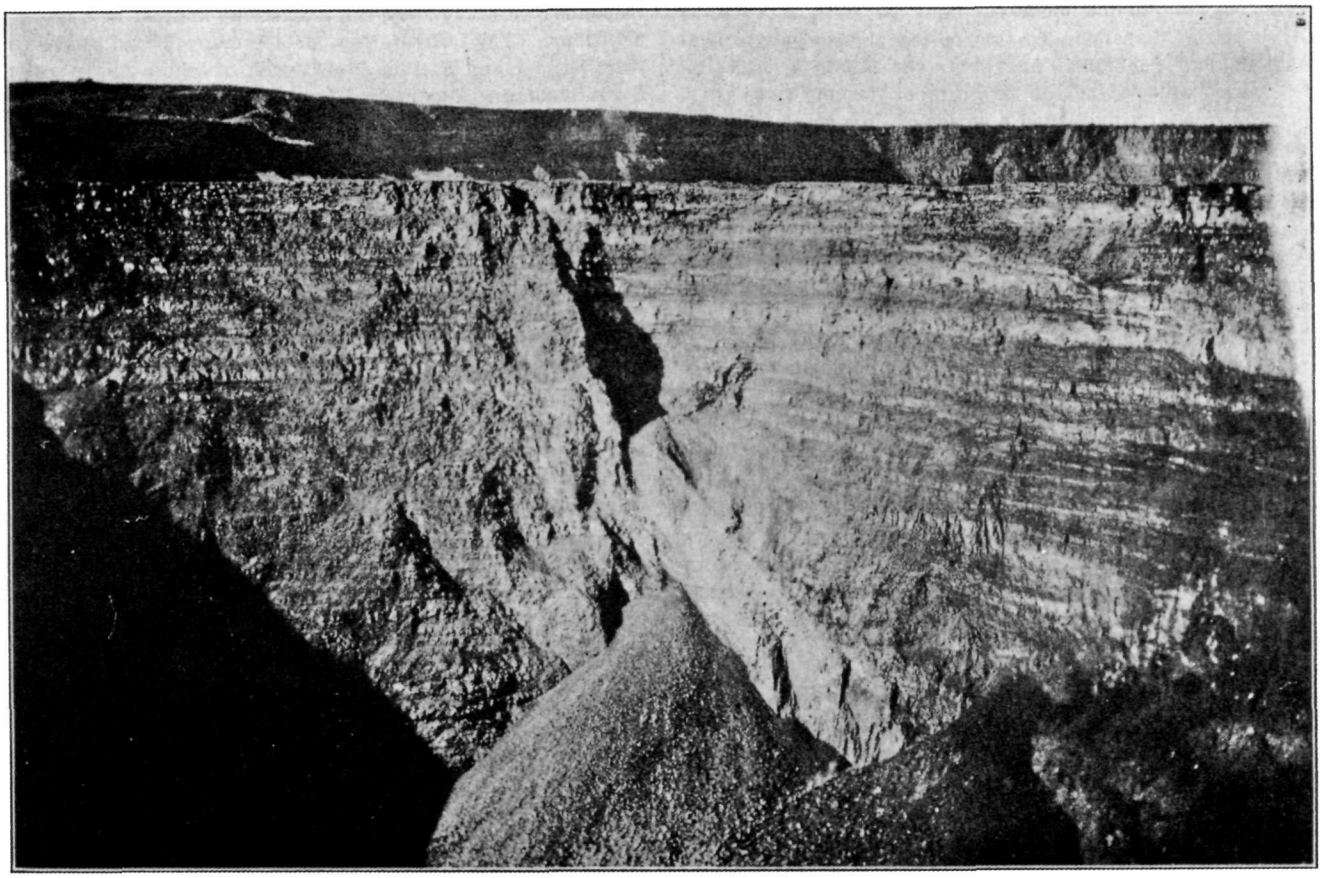


Interior of the present Halemaumau pit, showing the north corner, and behind it the cliff bounding the outer Kilauea Crater. The U-curve of white ledge at bottom is the cross section of a former pit. It shows a talus in cross section above the white ledge. The white ledge was revealed red hot by the engulfment of 1924. The horizontal layers are lava flows, all produced in the nineteenth and twentieth centuries. Photo 1927 by Wilson.

THE RESULTS OF VOLCANO RESEARCH

(Continued from Volcano Letter No. 381)

Second Part of Address by T. A. Jaggar, Annual Meeting Hawaiian Volcano Research Association in Honolulu March 31, 1932.

(3) World Volcano Stations

In 1926 a seismograph station and observatory were established at Lassen Volcanic National Park in California under Mr. R. H. Finch, who had been in Hawaii. This station has recorded hot spring temperatures and earthquakes, and has served as a base for geological studies in that interesting volcanic region. The work is being extended to other volcanoes of the northwest. Seismograph stations have been placed at two other points in Lassen Park.

In 1927 a seismograph station was established on Kodiak Island, near the Katmai group of volcanoes of the Alaskan Peninsula, and in 1929 a second station was fitted out at Dutch Harbor, on Unalaska Island in the eastern part of the Aleutian chain. In the hands of resident observers these instruments have been operated so that the seismograms are sent for study to the Hawaiian Volcano Observatory. A moderate number of local earthquakes at these stations and at Lassen indicates that some seismic activity accompanies the underground movement of volcanic magma in these places, but there is no such earthquake frequency as exists in Hawaii.

Beginning about 1918 the government of the Netherlands East Indies started a volcanologic service under their Bureau of Mines with headquarters at Bandoeng. This work has steadily grown for 15 years, a small pamphlet each month describes the temperature measurements and earthquakes and volcanic activities at several volcanoes, mostly in Java, and large, beautifully illustrated monographs in the Dutch language, latterly with summaries in English, have been published dealing with important erup-

tions of several of the great volcanoes and the volcanic islands belonging to the group. A number of small observatories are maintained.

The Japanese Empire has maintained a government earthquake investigation service since 1892, in which Professor F. Omori became the dominant figure. The motive of this service from the beginning was to find out everything possible about local earthquakes with a view to alleviation of disaster. To this end engineers. physicists, seismologists, geologists, and other specialists in universities were employed by the government, largely gave their services free, and published a series of important memoirs continuously in both English and Japanese for 30 years. Professor Omori concentrated on volcanoes during the last 15 years of his life, and his serial monographs on Asama, Sakurajima, Usu, Oshima, and other volcanoes, written in English, are among the most important of his productions. Earthquake investigation was reorganized after his death in 1923. and researches directed particularly to tilt and level changes, and to the needs of engineering, have been elaborated since the Tokyo earthquake. Professor H. Tanakadate has studied volcanoes. Seismographs of many kinds are distributed all over Japan, but a permanent volcano service has not yet been organized.

,In Italy, which established an observatory on Vesuvius in the middle of the nineteenth century, the publications about volcanic activity have been largely separate papers in scientific journals from the workers at the observatory and from seismologists and geologists in the universities. In 1924 a new series of volcanologic bulletins was started under Dr. Malladra, Director of the Vesuvian Observatory through the International Geophysical Union. Also some revival has been made of the Annals of the observatory. Mount Etna has also an observatory building on its high slopes, but the workers dwell at the university in Catania. In Naples Dr. I. Friedlaender has established at private expense a Volcanologic Institute and publishes in beautifully illustrated form a long series of volcano researches in several languages by workers all over the world. The first volume was published January 1914.

There have been a number of disasters due to earthquake and volcanoes in New Zealand, and in 1920 the writer as delegate from the Hawaiian Volcano Research Association gave a series of lectures in the universities of New Zealand on the observatory work in Hawaii and on the opportunity for continuous observation which the New Zealand volcanoes offer. The terrible earthquakes of Murchison in the South Island in 1929 and Napier in the North Island in 1931 have served to concentrate governmental attention in New Zealand on alleviation of disaster. Before these earthquakes Mr. L. Grange had been appointed to act as a volcanologic geologist and had done much mapping in the Rotorua volcanic district. Since the earthquakes, the Hawaiian Volcano Research Association has been able to assist somewhat by supplying simple seismographs for distribution in New Zealand under the government Department of Scientific and Industrial Research.

Seismologic services studying local earthquakes exist in Chile, Greece, Austria, Germany, Mexico, India, and Russia, and in some of these places some attempt has been made to begin the study of volcanoes. The Soviet has organized expeditions in Kamchatka, a little work has been done in Salvador and in the Caribbee Islands, some special expeditions have reported on Iceland and on volcanoes near New Guinea. Excellent studies have been made from the university in Athens of the active volcano Santorin and other volcanoes of the Grecian Archipelago. There are enormous volcano belts in the southwest Pacific, in Africa, the whole length of the west side of South America, and of the west side of Central America, which still await a prophet.

Three activities should be mentioned which deal with volcanoes effectively by the statistical method and by expeditions. The universities of Germany have produced Karl Sapper and F. Von Wolff. each of whom has written a textbook on volcano science. Sapper deals with geography and Von Wolff with geology of volcanoes. The Carnegie Institution of Washington through the workers under Dr. A. L. Day has sent out a series of expeditions and published monographs on Katmai, The Geysers in California. Lassen Volcano, Vesuvius, and some other places, and this work sets standards for analyses of gases, sublimates, and rocks, as well as hot waters, in accordance with critical dicta of physical chemistry. The third activity is the publication of the Geographical Society of Geneva, under th Red Cross, which has been issued quarterly since 1924, dealing with the study of calamities. as subjects of scientific prevision and alleviation (Matériaux pour l'E'tude des Calamités). This organization has had subcommittees in many countries, and the assemblage of facts has been of great value.

Before leaving world volcano stations, the recent work of the American, Frank A. Perret, a distinguished volcanologist who wrote the great monograph of the Carnegie Institution on "Vesuvius," should be mentioned. He has been living at St. Pierre in Martinique since the end of 1929, and has obtained support for a museum and research center at St. Pierre, which it is planned to make self-supporting through charges to tourists who visit the ruins of the great disaster of 1902 by thousands. This will be a private institution, for which an ideal site has been granted by the French government with construction cost covered by local contribution. The idea is a non-national institution created as a gift to St. Pierre, as a continuation of American good will. Each contributor of $1,000 or more will become a founder, and those who have started the foundation are the Carnegie Institution of Washington, Vincent Astor, and George F. Baker. It is to be hoped that the Hawaiian Volcano Research Association will be added to the list of founders, for it was Mr. Perret who started our work here in 1911, and who published on the eruption of Teneriffe in the first memoir of Friedlaender's Zeitschrift in 1914. In many respects Mr. Perret is thus the founder of modern volcanology from an experimental viewpoint.

(4) Results of Volcano Research

Two principles have been kept in mind, which are unusual in guiding the work in Hawaii: (1) Appeal to people of ordinary education in describing our results; (2) Use people in ordinary life in order to get those results. These mean, first, that the motives should be humane and not highbrow, and the work should be describable as meaning something to business men who want to know why it is done. Secondly, the harnessing of a large piece of country with observations, or instruments, or measurements, can never be done by distributing physicists permanently all over that country. The experts won't go. They prefer the council-chamber of the university. This difficulty may be met only by interesting ordinary people in a method of measuring earthquake or tremors or tiltings, so that they will send us a postcard every week. In order to do this, the method must be simple. The high-brow may sometimes

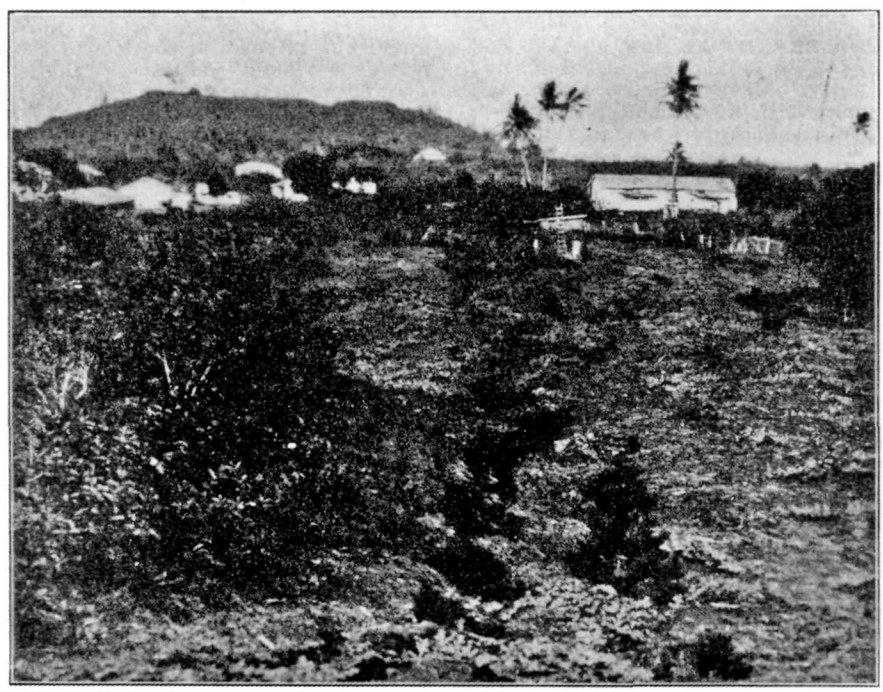
scorn simple methods. And yet Darwin's and Faraday's greatest works were done by simple methods. So it must be in compelling the earth to tell the story of how its breathings in Alaska are different from its breathings in Hawaii.

Here are a few of the facts suggested by work of the last twenty years:

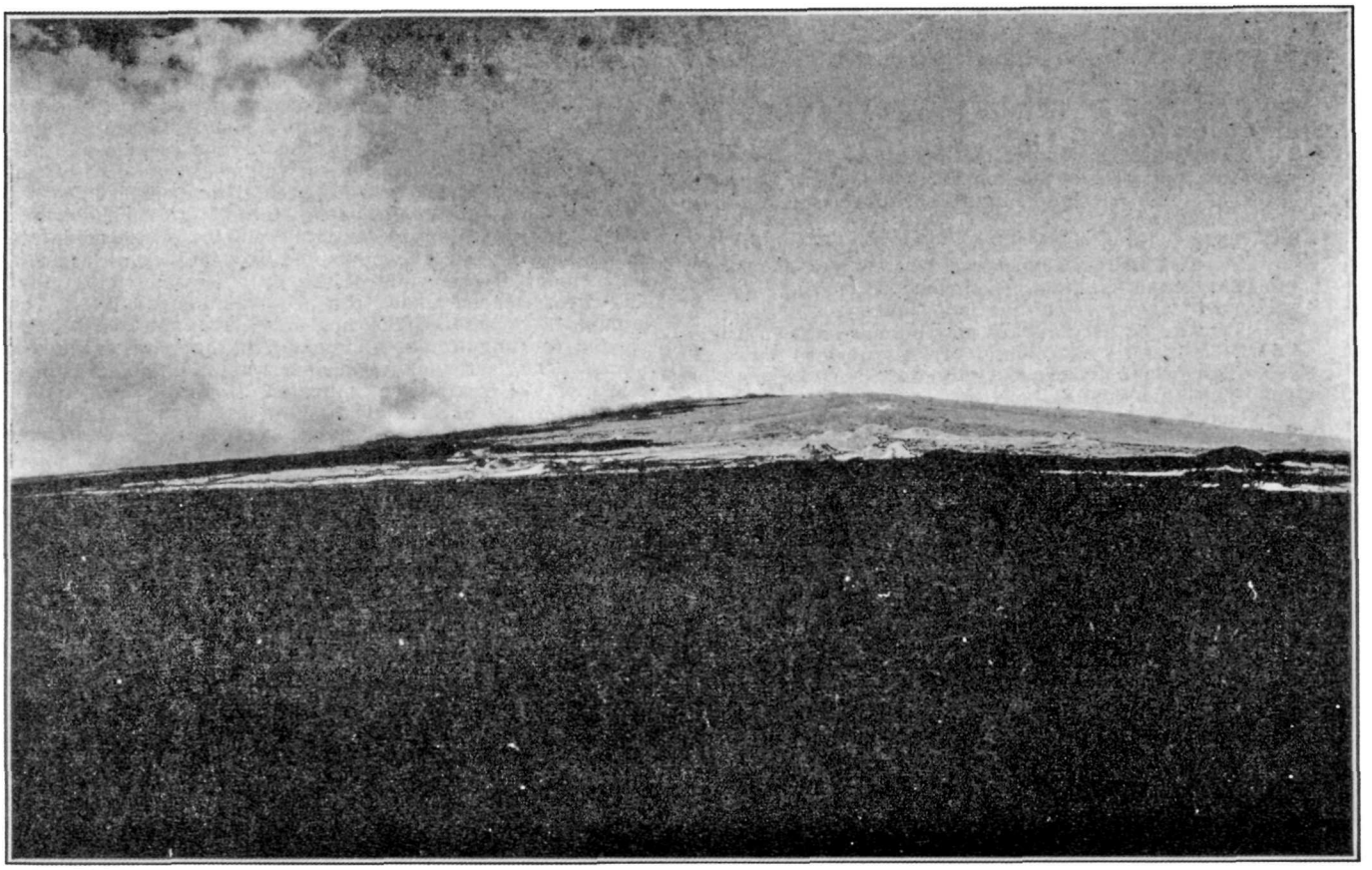
1. That volcanism everywhere has unity.
2. That gas is its prime mover.
3. That hydrogen and olivine basalt are fundamental constitutents.
4. That water is a secondary oxidation product.
5. That sulphur is concentrated at craters.
6. That engulfment is a common process.
7. That explosive eruption is secondary.
8. That major earthquakes may be magmatic in origin.
9. That magma continually presses upward.
10. That cycles are caused by yielding to pressure.
11. That this applies equally to earthquakes and volcanoes.
12. That small crust units involve short cycles.
13. That large crust units involve compound cycles.
14. That these may be of several orders.
15. That a volcanic cycle may exist at intrusions.
16. That intrusions may be studied by tilt and earthquakes.
17. That every volcano has intrusions under it.
18. That submarine outflow of lava is important.
19. That the present is a decadent time in earth volcanism.
20. That from Midway to Hawaii and along the volcanic rift, the crust has thickened and condensed.

We can think of the globe as at some time an incandescent member of the Sun's family. Up cracks as it cooled there piled up lava ridges. Our Hawaiian Territory is one such ridge. Studying the outpouring lava at Kilauea we found it divided into half-hardened, and frothy liquid, portions. We sounded the liquid and found it shallow. The half-hardened stuff was below. We took temperatures and found that the liquid was hottest above, where the most gas was burning. We found that Mauna Loa outbreaks ended with a Kilauea collapse. We found that splitting open the mountain visibly was attended by many earthquakes when lava burst up cracks. It turned out that there was local swelling of the ground. This was greatest at the pit edge. Tilt pendulums showed that it was happening farther away. It proved eventually that there are seasonal and daily tides in the lava and in the swelling of the mountain. The gases rising are mostly hydrogen, carbon monoxide and sulphur. They make flames. Water vapor, carbon dioxide and sulphur dioxide are in the greatest volume, because the burning goes deep. Boring to study ground temperature showed that hot places are due to vapor cracks. In 1924 the steam-blast eruption was preceded by a splitting of the mountain out to seashore, and accompanied by a sinking of lava and engulfment of the walls of the pit. The conviction that the lava escaped under the sea was unavoidable. The groundwater entered the hot hole and exploded. It extended the engulfment and made rhythmic geyser explosions. The last such cataclysm was in 1790. A super-cycle of 134 years was indicated, the interval between two lowerings of lava below the groundwater level for Hawaii.

With this outline for working hypothesis, it is easy to see how interesting it is to be the workers to build tilt and tremor instruments, and try to harness the crater and the island in order to interpret what is going on underground. This is what we are working on today with the instrument, designed at the Observatory, called a "clinoscope." It is a heavy horizontal iron ring. hung on wires. with a light vertical magnifying lever pointing upward in the middle. At the top is a dial. The ground tilts and the pointer wanders away from the center of the dial. This wandering each day is to be read in three cellars 400 feet back from the Halemaumau rim. These cellars are to be kept quiet and at constant temperature If the lava is swelling under the botttom of the pit as a center, the three cellars will show tilt away from the center on the clinoscope readings. If the lava is lowering they will show inward tilt. Eventually we expect to have these cellars wired so that each instrument may be called up by automatic telephone, and the pointer position will report itself electrically to the Observatory. This is the latest result of twenty years of work at the Hawaiian Volcano Observatory.



Kapoho, east point of Hawaii, looking northeast at one of the cones of the Kilauea rift zone near the sea. The fresh cracks in the foreground were produced in April 1924, when "the steam-blast eruption was preceded by a splitting of the mountain out to seashore." Photo Maehara.



Just as the Hawaiian islands form a lava ridge, so on Mauna Loa the southwest rift is a flat ridge. Here we are looking up the ridge, formed of source cones of many eruptions, from 8,500 feet elevation. These are true "fissure eruptions" and here is a vast experimental laboratory for the volcanology of the future. Photo Emerson 1923.

KILAUEA REPORT No. 1056

WEEK ENDING APRIL 17, 1932

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge.

Some fume was visible at the foot of the southwest talus on April 12. Cracks within old roped-off area at the southeast rim showed definite but very slight widening. On April 13 at 10:15 a. m. fume could be seen eastward from the southwest talus area, and slight odor of sulphur could be detected. Countless small steam vents were giving out feathery clouds in Halemaumau after rain, and steam at the larger vents was dense. Fume was also visible under the southeast wall in cracks in the new lava fill. Occasionally rocks trickled down the north wall. On the 14th fume was as usual at the foot of the southwest talus, but was not visible southeast. The northeast rim cracks showed no change On the 15th at 10 a. m. Halemaumau remained without changes. On the 17th the sulphur spot at the southwest fuming area showed increase of stain.

The seismographs at the Observatory registered 15 tremors, two very feeble seisms, and one feeble seism. Two of the tremors showed doubtful origin distances of 42 and 56 miles, respectively; the two feeble seisms, 32 miles and 25 miles; and the feeble seism, 10 miles WNW of the Observatory. This last shock awakened sleepers at the volcano, and in Honomu, Kona and Hilo at 2:55 a. m. April 17.

Microseismic motion was moderate through the week. Tilting of the ground averaged very slight to the east.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, on behalf of the section of volcanology. U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members two dollars per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Arthur L. Dean, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Walter F. Frear, Richard A. Cooke and Wallace R. Farrington.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

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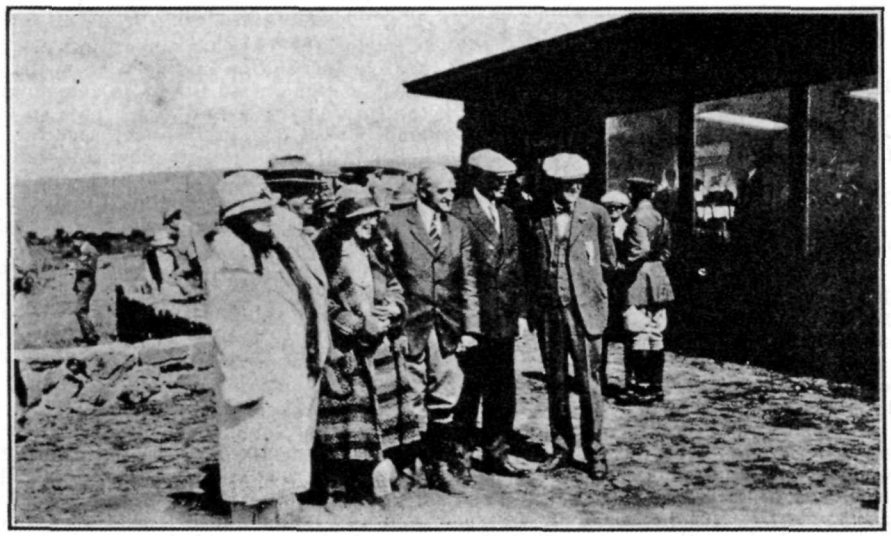
The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 383—Weekly Hawaiian Volcano Observatory, National Park, Hawaii April 28, 1932



The official party April 19, 1927, at the opening and dedication of Uwekahuna Observatory and Museum on the high western bluff of Kilauea Crater. Presented by the Hawaiian Volcano Research Association to the National Park Service. Right to left, the late Hon. Stephen Tyng Mather, Director of the National Park Service, Hon. Hubert Work, Secretary of the Interior, Volcanologist Jaggar, and Hon. Wallace R. Farrington, Governor of Hawaii.

PROGRESS OF HAWAIIAN VOLCANO RESEARCH

(Continued from Volcano Letter No. 382)

Third part of address of T. A. Jaggar, Annual Meeting of Hawaiian Volcano Research Association in Honolulu, March 31, 1932.

We have seen the growth of twenty years of volcano study in Hawaii by the observatory method, the growth of world volcano stations and some scientific results of volcano research in general. It will now be of interest to the members of this society to review the material progress of the work in Hawaii for the past ten years. The work of the first decade was outlined in the Monthly Bulletin in various annual addresses of 1913, 1915, 1916, 1917, and 1922. The year 1920 had started a new five-year program for the Association, with installation of seismographs at Hilo, Hilea, and Kona, and Dr. Omori, who had visited the Observatory with the Pan-Pacific Science Congress of 1920 had advised us to concentrate on the Mauna Loa center so as to interpret the direction, distance, and depth of the original impulses which make our local earthquakes. A second project was to do core drilling in the vicinity of Kilauea Crater for securing new light on temperatures, volcano power, the relation of volcanism to mining, underground water, and the relation of underground heat to gas. The third project was to secure publication of certain voluminous scientific papers which were ready, but unfinanced.

The Science Congress had recommended a central scientific bureau for dissemination of volcano news about the Pacific. This our Association has somewhat done by publication of the Volcano Letter. A second resolution of the Congress to the effect that the dwellers in volcano lands should be educated on the meaning of volcanoes and earthquakes, and on safeguards and insurance against them, has been promoted by the Volcano Letter, and by such magnificent work in America, Japan, the Dutch East Indies, New Zealand, etc., as is summarized in Sapper's book on Volcano Science, von Wolff's book of Vulcanism, and Freeman's book on "Earthquake Damage and Earthquake Insurance." A third resolution was that ecological studies should be carried out dealing with the rehabilitation of lava and lava soil by organisms, and this was started in Hawaii by Dr. Skottsberg under the Bishop Museum with some assistance from us, by marking ten-meter squares on lava flows of known date, and listing the lichens and other organisms found. These were to be reoccupied at future dates. Another study bearing on this subject has been published by Dr. Howard Powers of the Hawaiian Volcano Observatory in association with Messrs. Ripperton and Goto (Bull. 66 Hawaii Ag. Exper. Sta.), whereby the ash and lava soils of Kona have been specially classified for their adaptability to coffee culture. A last resolution of this Congress recommending that a station be placed on the top of Mauna Loa for combined aerology and volcanology remains still as a goal, but some progress toward it has been made by improvement of trail, and surveys for a road, by the National Park.

The year 1921 produced important material progress at the Observatory in a first shop and electric plant, in a revision of crater surveys for years back, in a beginning of monthly maps of the pit, in new crater experiments, in improved photographic apparatus, in computed curves of the lava tide investigation, in new money for an archives building and for boring, and in the discovery, by the topographers of the United States Geological Survey, of probable elevation of the rim of Kilauea Crater by from **two to three feet** between 1912 and 1921.

In 1922 the boring experiments were begun, were continued with both churn and core drills until May 1923, and were revived with air drills in 1926 and discontinued in the winter of 1927-28. There resulted 34 drill holes on

the crater floor and the crater rim of Kilauea, which are valuable assets of the Observatory for all time as places for experiment and for measurement of change in temperature and gas chemistry. The iron Archives Building was built in 1922, furniture and garages were improved, a chemical laboratory was started, and Mr. R. M. Wilson produced a first draft of "the Volcano Local System of Levels and Triangulation," which now in 1932 he is finishing in Washington in order to exhibit the important changes by land moment, precisely measured, which have occurred during activities at Kilauea Crater.

This year 1922, beginning the second decade of our work, was one of extraordinary progress for the Research Association in buildings, seismology, drilling for temperatures, and improved equipment. Machinery, tanks, cabinets for seismograms, chemical laboratory, and shop for instruments were added. Seismograms began to appear from Hilo, Hilea, and Kona. Dr. Allen came from the Geophysical Laboratory in Washington to work on the physical chemistry of the bore-hole steam at Sulphur Bank. Here an iron hut had been set up over the hot wells.

In 1923 Dr. O. H. Emerson was employed as chemist and general assistant, Dr. Jaggar was sent to Japan for three months to investigate the Tokyo earthquake, a remarkable motion picture film was obtained there, he made explorations in Tokyo, Yokohama, Kamakura, Boshu, Oshima, and Hakone, he assisted at some committee meetings of Japanese engineers and seismologists, and it was determined by the United States Government after the disaster that a plan for the new embassy should be referred to the Bureau of Standards. It is of interest to note that the earthquake-proof embassy of the United States in Tokyo is now finished. Mr. Jaggar insisted then as now that the volcano Mihara on Oshima Island, in Sagami Bay close to the seismic center of the great earthquake, one of the few volcanoes in Japan which produces lava in its crater most of the time, is a remarkably important place for a permanent observatory.

The scientific staff of the Observatory at this time consisted of Messrs. Jaggar, Finch, and Emerson. The record books were complete to 1923, and these books, typewritten in loose-leaf covers, including photographs and transcriptions of notebook sketches, were duplicated so that one set was kept in Washington. In the winter of 1923-24 the director of the station went to the eastern United States, read three papers at the American Association meeting in Cincinnati, and gave 26 lectures in Cincinnati, Washington, at Maryland University, in New York, New Haven, Cambridge, Boston, Brooklyn, Chicago, Urbana, and Philadelphia. He published articles, setting forth the work of the Association, in the National Geographic Magazine, the American Magazine, Asia, Scribner's, Popular Science Monthly, Bulletin of the Seismological Society, Monthly Weather Review, and the New York Times and Herald-Tribune. The steam-blast eruption of Kilauea occurred in May, 1924, and was admirably cared for by Messrs. Finch and Emerson, the director returning the end of May. The station was transferred to the Geological Survey July 1, 1924. Mr. Boles of the National Park Service ran levels across the disturbed area of Kapoho in Puna, which were of great value in outlining the down-dropped block of country there, which had lowered about 10 feet. It was at this time that numerous papers were published showing that tides, tilts, and cycles affected the lava of Kilauea.

Up to this time the Massachusetts Institute of Technology had continued to be a valued contributor to the Association. In later days the Institute has transferred its experimental work in geophysics to New England fields, but the highest appreciation should be expressed on behalf of the Hawaiian Volcano Research Association to this solid engineering school for bringing about the foundation of the work in 1911 which the Government and the Association have carried forward.

With the entrance of the United States Geological Survey on the work, the Government cooperation had been in progress, since the execution of a lease of the laboratory, from the Association to the Weather Bureau, April 19, 1919. Every assistance and most sympathetic collaboration was given by Chief Charles F. Marvin to volcanology while it was under the U. S. Weather Bureau. Dr. Marvin is himself a seismologist of note. The Research Association has been left entirely independent as a collaborating organization, but at all times the initiative for new methods, new discoveries, new apparatus, outside stations in Hawaii, and for publications and library, has rested with the Association. Also Research Fellows such as Dr. Romberg and Dr. Emerson, called in for studies of physics and chemistry, have been employees of the Association The regular staff is salaried by the Government, but much of the upkeep and nearly all of the improvement in buildings and apparatus has come from the Association.

During the 15 years since the work was started, the Research Association had seen grow the interest of the Congress of the United States in seismology and volcanology; the interest of scientific journals in Italy, Germany, Holland, Great Britain, France, America, and Japan, and of seismological and volcanological establishments in Geneva, Paris, Oxford, and Naples; the interest of the Carnegie Institution, the Pan-Pacific Union, the Weather Bureau, the Coast Survey, the Geological Survey, the National Geographic Society, and the universities and museums in the United States; and the establishment of bureaus and commissions on volcanoes, especially in Japan, the Dutch East Indies, the Philippines, New Guinea, New Zealand, Mexico, and Costa Rica; and it has seen fresh activity in the national and international geophysical unions and congresses.

The Bishop Museum invited Dr. Jaggar to join an expedition, in September 1924, to the Howland and Baker islands in the U. S. S. S. Whippoorwill. This was of geat interest for a volcanologist in view of Darwin's generalizations concerning atolls as representing subsidence. Howland and Baker appear to be the nucleus of an atoll, and as such show no evidence of subsidence, nor of the transition from a previous condition of fringing and barrier reefs. They appear to be accumulations on a submarine bank not significantly related to subsidence, elevation, nor retreat of the sea, but closely related to trade wind and equatorial current.

In 1925 a visit by a Congressional committee headed by Hon. L. C. Cramton of Michigan was destined to advance volcanology immeasurably. Mr. Cramton asked Mr. Jaggar to accompany him in June to Lassen Volcanic National Park and this was the signal for creation in 1926 of enlarged appropriation for a Section of Volcanology to include California and Alaska with Hawaii. Meantime Colonel C. H. Birdseye, in charge of the Topographic Branch of the Geological Survey, undertook to cooperate with volcanology by sending an engineer, Mr. J. C. Beam, for leveling, and for triangulation of the net of proposed bore holes that would determine how the temperature of the crater lava changes horizontally from place to place. In the machine shop we were experimenting with compressed air drills, and have to thank Messrs. W. F. Dillingham and Frank West of the Hawaiian Contracting Company for assistance. Leveling reconnaissance was now indicating that the edge of Halemaumau pit had gone down several feet during the explosions of 1924. Experiments were being tried in the seismological laboratory with earthquakes, with tilt recorders. and with overturning prisms for calibrating strong-motion earthquakes. Mr. E. G. Wingate was surveying Mokuaweoweo Crater, and it is impossible to express all that the Observatory owes to the late Captain A. O. Burkland, in charge of topographic mapping in the Hawaiian Islands.

In 1926 it had become the custom of the Volcanologist, to make a forecast each year, in his report to the Director of the Geological Survey, by way of experimenting with prediction. The report of December 31, 1925, stated that low earthquake frequency and accumulated tilt suggested rising lava and that location of some earthquake centers implied motion in Mauna Loa. This was confirmed by Mauna Loa breaking out April 10, 1926, and producing the Hoopuloa flow. A similar forecast for Halemaumau December 31, 1926, was followed by the outbreak in that pit in July 1927. Forecasting data are growing increasingly accurate.

General reorganization was permitted in 1926. Mr. R. H. Finch in September founding the Lassen Volcano Observatory, Mr. R. M. Wilson becoming engineer and chief assistant at the Hawaiian station, and Mr. R. B. Hodges becoming clerk and disbursing officer. Mr. Beam remained from

December 30, 1925, to May 21, 1926, tested two level lines 1,000 feet long for changes of tilt, releveled old circuits about Kilauea, surveyed the bore hole net, remapped Halemaumau, and triangulated the Wilson net. Japanese workmen were sent from station to station, on the Kilauea floor, for boring holes 10 feet deep and 1,000 feet apart at the corners of equilateral triangles. There were added to the equipment compressor, truck, and drill, some tested thermometers, one of the modern high-speed cameras, and up-to-date surveying instruments from the Survey.

Meantime the Research Association had met the Congressional increase of funds by a drive for $20,000 for an exhibition room, projection apparatus, and furniture on the top of the great western cliff of Kilauea Crater, which was duly built and turned over to the Secretary of the Interior and the Director of the National Park Service in April 1927. At the same time the Association ordered from Japan an exhibition seismograph, and the best of the mineral collections were placed in the museum. The machine shop of the Observatory was enlarged and a skilled machinist secured for one year. A tide gauge had been installed in Hilo, and the Geological Survey cooperated in securing leveling by the Coast Survey from sea-level to the top of Mauna Loa, and in measuring gravity on the island of Hawaii in the autumn and winter of 1926-27. This work was done by Engineers Simmons, Brown, and Bainbridge. In the summer of 1927 Mr. Jaggar went to Alaska, established a seismograph at Kodiak, sailed to the west end of the Aleutian Islands and back, and inspected the Lassen station. Meantime several new seismographs of a distinctive Hawaiian type, large two-component instruments. were built at Kilauea, one of which was placed in a new cellar constructed for it in Hilo. Engineer Wilson entered on new mapping of Halemaumau, improvement of wireless time service, new leveling and triangulation to determine ground movement, measuring marked fissures at Halemaumau pit, and making artificial earthquakes with an oscillating table.

The year 1928 was thus entered upon with the Hawaiian Volcano Observatory, which had been estabilshed 16 years before by the Hawaiian Volcano Research Association, as the central headquarters in the middle of the Pacific Ocean, for a Section of Volcanology of the United States Geological Survey, maintaining substations in California and Alaska, and so doing its bit, of observing active volcanoes, at the east, north, and center of the Pacific Ocean. The Volcano Letter, issued weekly, was distributing notes about the world on volcano science, particularly with reference to the Pacific. Seismograms were being studied from four places on the Island of Hawaii, and one place each in California and Alaska. The Hawaiian station was equipped with a tide-gauge, a machine shop, a number of permanent bore holes, a chemical laboratory, general laboratory, dark room, fire-proof archives building, library, and vehicles, and the needs of the public had been suitably transferred to the National Park Service by means of a museum and lecture room. Triangulation and leveling had proved elevation and distension of Kilauea Crater before 1924, depression and construction thereafter. Mapping topographically had covered the whole of the Island of Hawaii, and was nearly completed for the Territory. Marked cracks were being systematically measured around Halemaumau pit. and at Lassen by stakes at Supan's Springs. New leveling and gravity measurement had extended to the top of Mauna Loa. A project had been formulated for possible cooperation of several Government bureaus in studying the natural history of the Aleutian Islands.

The National Geographic Society was now taking an active interest, after numerous explorations in volcanic fields, from the time of the Caribbean eruptions of 1902 onward. This Society employed Mr. Jaggar in the summer of 1928 to conduct an expedition to explore and map topographically 2,500 square miles around Pavlof Bay, near an active volcano of the same name, one of the beautiful snowy cones of the Aleutian belt on the south side of the Alaskan Peninsula. This expedition was timely, as Dr. Griggs for the Society had conducted a series of expeditions near Katmai Volcano, and our Section was laying a foundation for expeditions in the Aleutian Islands, two of which has already been made, with studies of Makushin, Bogoslof, Korovin, Gareloi, and Chugul volcanoes. In the Pavlof Expedition the topographic map was made by McKinley and published by the Survey, numerous photographs and motion pictures were taken by Stewart, and the geology and volcanology were studied by Jaggar, and a preliminary report published in the National Geographic Magazine.

It had become evident at the Hawaiian station in 1924 that the tremendous slope, to depths of two or three miles in only a few miles distance east and west of Hawaii under the ocean, is an important basal part of the active volcanic system. An outflow to the west under the sea in 1877, singular waves and submarine noises during lava flows from Mauna Loa into the sea, and a probable submarine flow unperceived off the east point in 1924, all made the study of the volcanic sea bottom by new methods a fundamental part of future volcanology. Accordingly, the development of work from boats is essential. The Pavlof Expedition employed a steel amphibian boat built for the National Geographic Society which was afterwards turned over by the society to the Research Association in Hawaii. The activities of such boats were experimented with in 1927 and 1928 on the east and west sides of Hawaii, as they possess the great advantage, where laboratory work is to be considered at a permanent station, of running up the beach on wheels with all their equipment and collections into a suitable house. Their bottoms may thus be altered or mechanized for any kind of sounding, dredging, probing, or tubular bottom photography with artificial lights in shallow water, and the ordinary disadvantages, of a boat exposed to all weathers, at anchor most of the time, with its bottom fouling, are eliminated. There is very important work to be done close to shore in Hawaii in determining the escape of the groundwater through submarine fresh water springs, by bottom sampling and hydrometer tests. Such submarine springs are known in many places on the active volcanic sides of the island. where no springs whatever emerge above sea level. This is true of many of the volcanic islands of the South Pacific. where the coral reef problem is affected by fresh water, from the ground-water surface beneath the rainfall belt of a lava mountain. As the explosive eruption of 1924 was probably occasioned by lava outflow under the sea. and groundwater inflow to the hot void so created under Halemaumau, it will be seen that critical surveys of the sea-bottom near Hawaii are absolutely necessary for the progress of volcanology. Therefore it is proposed to begin with small vessels close to shore, and to develop apparatus for such volcanologic surveys. It is to be hoped that the Navy and other boating organizations of the Government will give assistance in this work. The Board of Harbor Commissioners of the Territory of Hawaii kindly permitted the Association to use a discarded warehouse at Keauhou in Kona as a shelter for the steel boat "Honukai," where this amphibian is kept for explorations on the west side of Hawaii.

Engineer R. M. Wilson was obliged to return to Washington in November 1928, and was replaced by Engineer E. M. Buckingham, who remained until July 1, 1929. His place was taken by a geologist, Dr. H. A. Powers, who came from Harvard University, and entered upon geologic mapping of the west side of Hawaii, in addition to service as general assistant at the Observatory. Mr. Wilson had completed a contour map of Halemaumau after the bottom changes of 1927. Mr. Buckingham made another after the bottom changes of February 1929. Mr. Powers as petrologist started microscopic studies of rocks from Hawaii and Alaska, and also drafted diagrams of tilt from 1913 to 1930. Mr. A. E. Jones was sent to Alaska in 1929 and established a new seismograph station at Dutch Harbor.

Experiments of 1929 at the Hawaiian station dealt with construction of leverless seismographs tested on the oscillating table, of several models of vertical-component seismographs, wherein it was attempted to make the constants equivalent to the Hawaiian-type horizontal-component instrument, and of several different sizes of shock-recorders designed as simple instruments to put into the hands of amateurs. Also mechanical devices were made the subject of experiment for securing smooth smoking of seismogram paper. For many months a seismograph was operated with a restraining bumper against the pendulum arm having in view the elimination of microseisms and tilt.

and the recording of local earthquakes only. The shock-recorders were successfully used at Puuwaawaa in western Hawaii during the extraordinary and disastrous earthquakes of September-October 1929.

In the Lassen station a new Hawaiian model seismograph was set up and the older instrument was transferred to the Loomis Museum near Viola. Messrs. Howel Willams and C. A. Anderson, in addition to Mr. Finch, were at work on problems of the geology of the vicinity of Lassen Volcano. Dr. Wentworth investigated the geology of Hawaii June-September 1929, Dr. Stone the volcanoes of Chile November-January 1929-30, and Mr. Finch attended the Java Science Congress April-June 1929. On January 12 the Director of the U. S. Geological Survey, Dr. George Otis Smith, called a meeting under the Federal Relations Committee of the National Research Council for conference on scientific cooperation in the Aleutian Islands. This was in line with recommendations of the Pacific Science Congress of 1923. Dr. Jaggar addressed the meeting, and was made chairman of a committee to further Aleutian investigations.

This brings the review of volcanologic activities centering about Hawaii up to 1930-31. The buildings of the Hawaiian station were now enlarged and rehabilitated, tilt studies on a larger scale were prepared for, the Volcano Letter was enlarged and illustrated, a course in volcanology was given annually in the summer session of the University of Hawaii, a journey to the active volcano on the island Niuafoou in Tonga, by Mr. Jaggar, secured valuable photographs and records under the Eclipse Expedition of the U. S. Naval Observatory, shock-recorders were placed there and in New Zealand, Mr. Finch explored Akutan Volcano in Alaska and tested a shock-recorder there, the first clinoscope was constructed, Professor H. S. Palmer joined Dr. Powers in studies of shore-line changes on Hawaii, and finally, beginning July 1, 1931, the Congress of the United States enlarged the funds and activities of the Section of Volcanology by adding two scientific workers.

These are Engineer E. G. Wingate and Seismologist A. E. Jones, and the motive for this enlargement of staff is largely to concentrate measurements on tilting of the ground about an active crater in relation to local earthquakes. These motions have been found significant for prediction. There is certainly such tilting around the Kilauea center, there is presumably such tilting around the Mauna Loa and Hualalai centers, and there should be generalized tilting around the outskirts of the island. The formulation of what the local motions are, in direct relation to the passage of time and the coming of activity at a definite volcanic center, and what such motions show as to location and motion of definite lava underground, is the aim of volcanology. This has led to the placing of clinoscopes, as heretofore described, in three cellars around Halemaumau pit.

The Research Association met the enlargement provided by Congress by supplying new and enlarged buildings and laboratories, and greatly increasing the facilities of the Hawaiian station. We have every reason to express our keen appreciation of the invariable assistance and cordial cooperation of Hawaii National Park. The Research Association owes a debt of gratitude to Delegate Houston, Governor Farrington and to Director Smith of the Geological Survey for bringing about our enlarged opportunities, and equally to his successor, Director W. C. Mendenhall, and to the Chief Geologist of the Survey, Dr. T. W. Stanton.

The Scientific Director of the Association takes this opportunity to express his very keen and heartfelt gratitude to the late honored L. A. Thurston, for many years our President, enthusiastic in support of everything which concerned the study and exploration of Hawaiian volcaones, and skilled as a special pleader and publicist through his extraordinary learning and memory concerning everything Hawaiian. All honor should be paid also by all students of volcanology to the gentlemen of Honolulu who from time to time have served gratuitously and loyally on the Board of Directors of this Association, and especially to the six men in recent years who have served with Mr. Thurston in making for growth of the science through business leadership, public influence, financial judgment, scientific interest, and legal advice, Messrs. Cooke, Atherton, Dillingham, Peck, Dean, and Thayer. Mr. L. W. de Vis-Norton should be especially commended for his long and painstaking service as Secretary and Assistant Treasurer, in attending to the irksome details of the work of recorder, sometime editor, bookkeeper, and correspondent, and in advising with the Scientific Director on all manner of subjects, as well as doing a large amount of literary work which has made volcano research known.

KILAUEA REPORT No. 1057

WEEK ENDING APRIL 24, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

At Halemaumau pit of Kilauea Volcano the week has shown little change. The weather has been normal of the trade-wind type, and at 9 a. m. April 18 the yellow fume patch at the west side of the floor showed thin vapor. Crack measurements about the eastern rim showed but slight widening in the measurements of April 19. The fume emitted continued thin, but is always in evidence as a bluish haze over the western half of the pit in early afternoon light. An avalanche from the northern wall of the pit about 10:05 a. m. April 21 was followed five minutes later by a much larger one which appears to have been registered somewhat as a vibration recorded on the seismographs of the Observatory two miles away. The fallen rocks overlapped the January lava floor, the roar was loud, and a dust cloud arose. There were several other slides on this day and one at 4:38 p. m. was observed April 22 at the northeastern rim.

Seismic activity registered at the Observatory was mild. One very feeble shock indicated origin distance close at hand, something over two miles, and 26 tremors were registered during the week, three of which were sufficiently defined seismically to suggest origin distances of 28, 42, and 46 miles. Microseismic motion for the week changed from moderate to light, and tilting of the ground was strong to the west with slight tendency north.

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The Volcano Letter

384

Two dollars per year **Ten cents per copy**

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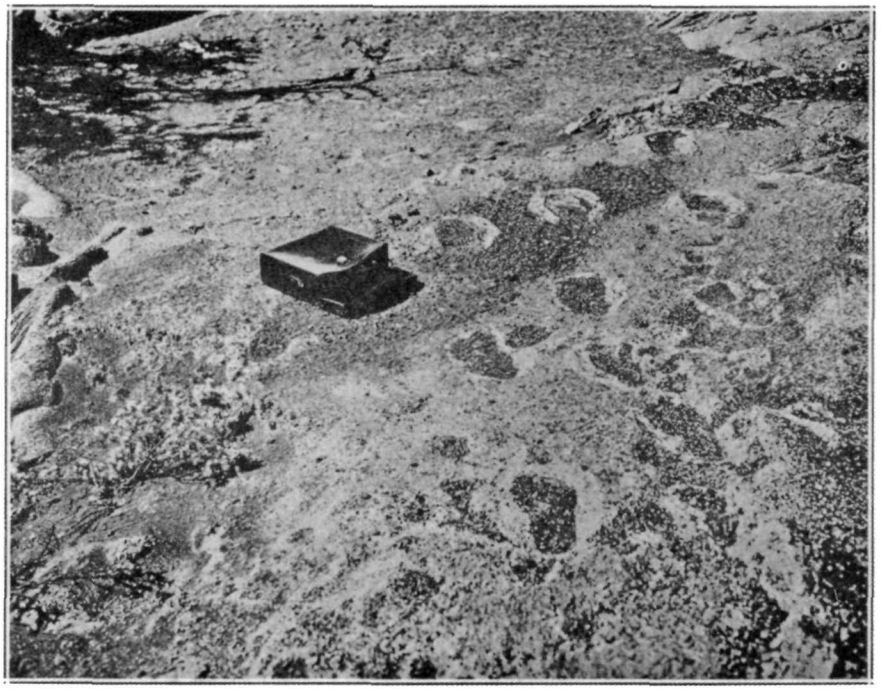


Hardened human footprints in the Kilauea ash of 1790, Kau Desert six miles southwest of the crater. The pedestrians were headed north and their bare feet squashed up the mud around the footprints. The mud solidified like cement. The pellets formed by the warm mud rains of the eruption are shown at the right. See Volcano Letter No. 273 and Bulletin Hawaiian Volcano Observatory July 1921.

PROGRESS OF HAWAIIAN VOLCANO RESEARCH

(Continued from Volcano Letter No. 383)

Appendix to Address of T. A. Jaggar, Annual Meeting of Hawaiian Volcano Research Association in Honolulu March 31, 1932.

Publications

In order that the reader of the foregoing review of twenty years of work at the Hawaiian Volcano Observatory may have some references for volcanologic reading, the following list of publications is compiled, first, to show the bulletins of the Hawaiian Volcano Observatory which contain special reviews, lists of publications, and discussions of special subjects, and second, to give references to the scientific papers by the staff which have covered the more important subjects of investigation since 1916. In Bulletin of Hawaiian Volcano Observatory Vol. IV, No. 4, April 1916, was printed a list of publications to that date.

Publications of the Observatory

First Report, Massachusetts Institute of Technology, 1912. Foundation of the Observatory, Kilauea 1909 to April 3, 1912, notes on Mauna Loa.

Second Report, Massachusetts Institute of Technology, 1917. On cyclical variations in eruption at Kilauea, by H. O. Wood.

Special Bulletin Haw'n Volc. Obs'y 1913. Scientific work on Hawaiian volcanoes.

Kilauea and Mauna Loa in 1914 (annual address), Bull. H. V. O. III, No. 4.

Hawaiian earthquake problem, H. O. Wood, III, No. 5, May 1915.

Museum, National Park, publications, etc. (documents), IV, No. 4, April 1916.

Results of six years of work (annual address), V, No. 8, August 1917.

Presidential address by L. A. Thurston (annual meeting), V, No. 10, October 1917.

Index of danger from volcanoes, Jaggar, VI, No. 1, Jan. 1918.

Composition of Hawaiian gases, Shepherd and Allen, VII No. 7, VIII No. 5, IX No. 5, X No. 8, 1919, 1920, 1921, and 1922.

Lava tube at Kilauea, Sidney Powers, VIII No. 3, March 1920.

Fossil human footprints Kau Desert, Jaggar, IX No. 7 anl No. 10, 1921.

Volcano research in Hawaii 1922 (annual address), X No. 4. April 1922.

Progress of boring experiments, X Nos. 5, 6, 7, 9, 10, 1922; XV No. 3, 1927; also Monthly Weather Review March 1924.

Aleutian eruptions December 1922, XI No. 1, Jan. 1923.

Tidal wave at Hilo, XI No. 2, Feb. 1923.

Sulphate stalactites in lava tubes, Finch and Emerson, XII No. 3, Mar. 1924.

Volume relations of explosive eruption of Kilauea, Jaggar, XII No. 12, Dec. 1924.

National standards of volcano and earthquake research (annual address), XIII No. 3, Mar. 1925.

A carbonized tree trunk in New Zealand, Bartrum, XIII No 7, July 1925.

Mauna Kea geology, Jaggar, XIII No. 10, Oct. 1925.

Southwest rift of Mauna Loa, Finch, XIII No. 12, Dec. 1925.

Viscosity of lava, Palmer, XV No. 1, Jan. 1927

Azores earthquake of August 1926, Agostinho, XV No. 2, Feb. 1927.

Opportunity for scientific research in the National Parks of America, Jaggar, address Pan-Pacific Conference, XV No. 4, Apr. 1927.

U. S. Coast Survey cooperation, Wilson, XV No. 6, June 1927.

Gravity anomalies on Hawaii, Wilson, XV No. 10, Oct. 1927 and Goranson, Amer. Jour. Sci. Aug. 1928.

Hilo seismograph station, Wilson, XV No. 11, Nov. 1927.

Review of seismic features for the year, and the Uwekahuna seismograph, Wilson, XV No. 12, Dec. 1927

Lassen Volcano Observatory, Finch, XVI No. 2, Feb. 1928.

A year of tide gauge operation, and Seismic sea waves of 1927. Wilson, XVI No. 3, Mar. 1928.

The amphibian boat "Ohiki," Wilson, XVI No. 4, Apr. 1928.

Seismic sea wave at Hilo June 17, 1928, Wilson, XVI No. 6, June 1928.

Test of Hawaiian-type seismograph, Wilson, XVI No. 8, Aug. 1928.

Magnetism of Lassen lava flows, Jones, XVI No. 9, Sept. 1928.

Aleutian geographic observatory, Jaggar, XVI No. 10, Oct. 1928.

Reviews of progress Hawaiian Volcano Research Association, Volcano Letters Nos. 2, 3, 13, 102, 139, 168, 169, 221, 225, 235.

Publications Outside of the Observatory

Volcanologic investigations at Kilauea, Jaggar, Amer. Jour. of Sci. Vol. 44, Sept. 1927.

Seismometric investigation of the Hawaiian lava column, Jaggar, Bull. Seis. Soc. Amer. Vol. X No. 4, 1920.

The program of experimental volcanology, Jaggar, Proc. First Pan-Pac. Sci. Conf. Part 2, p. 309, 1921, Bishop Museum, Honolulu.

Effects in Mokuaweoweo of the eruption of 1914, Wood, Amer. Jour. Sci. XLI May 1916.

Lava flow from Mauna Loa 1916, Jaggar, Amer. Jour. Sci. XLIII, Apr. 1917.

Notes on the 1916 eruption of Mauna Loa, Wood, Jour. of Geol. XXV, Nos. 4 and 5, 1917.

On the terms Aphrolith and Dermolith. Jaggar, Jour. Wash. Acad. Sci. VII No. 10, May 19, 1917.

Thermal gradient of Kilauea lava lake, Jaggar, Jour. Wash. Acad. Sci. VII No. 13, July 19, 1917.

Results of volcano study in Hawaii, Jaggar, Nature Vol. 101, No. 2525, March 21, 1918, p. 54.

An experiment in teleseismic registration, Jaggar and Romberg, Bull. Seis. Soc. Amer. Vol. VIII Nos. 2-3, 1918.

A New Zealand Department of Volcano Research, Jaggar, New Zeal. Jour. Sci. and Tech. Vol. III, No. 3, 1920, p. 162.

Experiences in a volcano observatory, Jaggar, Natural History, Vol. XXI No. 4, July-Aug. 1921.

The Yokohama-Tokyo earthquake of September 1, 1923, Jaggar, Bull. Seis. Soc. Amer. Vol. XIII, No. 4, Dec. 1923.

A plea for geophysical and geochemical observatories, Jaggar, Jour. Wash. Acad. Sci. Vol. 12, No. 15, Sept. 19, 1922.

Lava tide, seasonal tilt and the volcanic cycle, Jaggar, Finch and Emerson, Monthly Weather Review, March 1924, p. 142.

Seismic sea waves, Finch, Monthly Weather Review, March 1924, p. 147.

Predicting earthquakes, Jaggar, Scribners Magazine, Oct. 1924, p. 370.

Explosive eruption of Kilauea in Hawaii, Jaggar and Finch, Amer. Jour. Sci. VIII Nov. 1924, p. 353.

Tidal oscillations in Halemaumau, Brown, Amer. Jour. Sci. Feb. 1925, p. 95.

National standards of earthquake and volcano research, Jaggar, (annual address) Honolulu Advertiser, Mar. 13. 1925.

Sur le rives du lac de feu, Jaggar, L'Illustration, Paris, No. 4287, May 2, 1925, p. 428.

Aventures at volcanoes, Jaggar, Popular Sci. Mo. Mar. 1925, p. 53.

The lesson of Japan's earthquake, Jaggar, Mid-Pacific Magazine, Mar. 1924, p. 203.

An earthquake prediction at the Hawaiian Volcano Observatory, Finch, Science Jan. 9, 1925.

Seismic sequnces of the explosive eruptions of Kilauea in May 1924, Finch, Bull. Seis. Soc. Amer. Dec. 1924.

The earthquakes at Kapoho. Apr. 1924, Finch, Bull. Seis. Soc. Amer. June 1925.

Earthquake insurance, Jaggar, National Underwriter, Aug. 13, 1925, p. 10.

Earthquake insurance, Jaggar, Materiaux pour l'etude des calamites, Geneva Geog. Soc., Vol. 2, No. 7, 1925 (also Vol. 3, No. 19, 1929).

Plus and minus volcanicity, Jaggar, Jour. Wash. Acad. Sci. Vol. 15, No. 18, Nov. 4, 1925, p. 416.

Chemical significance of engulfment at Kilauea, Shepherd, ditto p. 418.

Progress of volcanology during 1924, Jaggar, ditto, p. 424.

Symposium on scientific cooperation in the Aleutian Islands, Jaggar, Bowie, Sargent, Fenner, Neumann, Ault, and Mitchell, Bull. Nat'l Resear. Counc. No. 56, Washington 1926.

The formation of aa and pahoehoe, Emerson, Amer. Jour. Sci., XII Aug. 1926.

Earthquakes and volcanoes, Jaggar, (chapter in) New Human Interest Library, Midland Press, Chicago, 1927.

Tilting and level changes in Pacific volcanoes, Jaggar and Finch;
Engulfment during Pacific explosive eruptions, Jaggar;
Volcanic relations of great Pacific earthquakes, Jaggar;
Temperature of volcano borings, Jaggar and Finch; all in Proc. Pan-Pac. Sci. Cong., in Tokyo, Nov. 1926, p. 672, etc.

Tilt records for thirteen years at the Hawaiian Volcano Observatory, Jaggar and Finch, Bull. Seis. Soc. Amer. Vol. 19, No. 1, Mar. 1929.

Products and structure of Kilauea, Stone, Bull. 33, B. P. Bishop Museum, Honolulu 1926.

Simple seismic measurements, Kirkpatrick, Science Apr. 15, 1927, p. 379.

Seismic measurements by the overthrow of columns, Kirkpatrick, Bull. Seis. Soc. Amer. June 1927, p. 95.

Sakurajima, Japan's greatest volcanic eruption, Jaggar, Nat'l Geog. Mag. Apr. 1924.

Volcano research of the U. S. Geological Survey, Jaggar, Jour. Wash. Acad. Sci. Vol. XVIII No. 19, p. 512, Nov. 19 1928.

A recent volcanic eruption near Lassen Peak, Williams, Dept. of Geology Pubs. U. of Cal., Vol. XVII No. 7, p. 241, 1928.

Relation of chemical composition to texture of groundmass in siliceous lavas, Powers, Jour. of Geol., Vol. XXVII No. 3, Apr.-May 1929.

Facts about volcanoes, Jaggar, New York Times, Sept. 1, 1929.

Amateur seismology, Jaggar, Sci. Amer. Nov. 1929, p. 411.

Graded swelling and shrinking of volcanoes, Jaggar, Proc. Haw'n Acad. Sci., Spec. Pub. 15 B. P. Bishop Museum Honolulu, p. 10, 1929.

Rainfalls accompanying explosive eruptions of volcanoes, Finch, Amer. Jour. Sci., Feb. 1930, p. 147.

Quartz basalt eruptions of Cinder Cone, Lassen, Finch and Anderson, Bull. Dept. Geol., U. of Cal., Vol. XIX No. 10, p. 245, 1930.

Geology of Kau, Hawaii, Stearns, Clark, and Meinzer, Water-Supply Paper 616, U. S. Geological Survey.

Volcanology, Jaggar, Sci. Amer. Sept. 1930, p. 176.

Hualalai earthquake crisis of 1929, Jaggar, Proc. Haw'n Acad. Sci. Special Pub. 16, B. P. Bishop Museum, Honolulu, p. 89, 1930.

Mechanism of volcanoes, Jaggar, chapter in "Physics of the earth; I, Volcanology," p. 49, Bull. Nat'l Res. Counc. 77, Washington 1931 (with bibliography).

Mapping the home of the great brown bear, Jaggar, Nat'l Geog. Mag., Jan. 1929, p. 109.

The eruption cycles in Hawaii, Jaggar, Thrum's Annual Honolulu, 1932.

Survey of the physical features that affect the agriculture of the Kona District of Hawaii, Powers, Ripperton and Goto, Hawaii Agric. Exper. Sta., Bull. 66, Honolulu, 1932.

Niuafoou Volcano in Tonga; its eruptions and its people, Jaggar, Proc. Haw'n Acad. Sci., Special Pub. 19, B. P. Bishop Museum, p. 9, 1931; also Volcano Letter Nos. 165, 312, and 318.

In addition it should be mentioned that the "Volcano Letter" has been issued weekly since January 1, 1925, and as a four-page leaflet with illustrations, replacing the former "Bulletin" since January 1, 1930. T.A.J.

KILAUEA REPORT No. 1058

WEEK ENDING MAY 1, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

No changes were observed in Halemaumau on April 25, except possible increase in sulphur stain on the floor at the foot of the north talus. Crack measurements on the 26th showed no changes. At 8 p. m. no glow was to be seen. On the 27th fume was as usual and nothing new to been seen. At 10:30 a. m. fume rose on the west side of Halemaumau conspicuously in puffs. On the 28th at 8:30 a. m. fume appeared denser at the southwest talus due to damp, cloudy morning. No change in fume observed on the 29th at 9 a. m. There appeared to have been a small slide over west end of the north sill during the night. On the 30th at 8:45 a. m. there was nothing new and fume was as usual at the southwest talus.

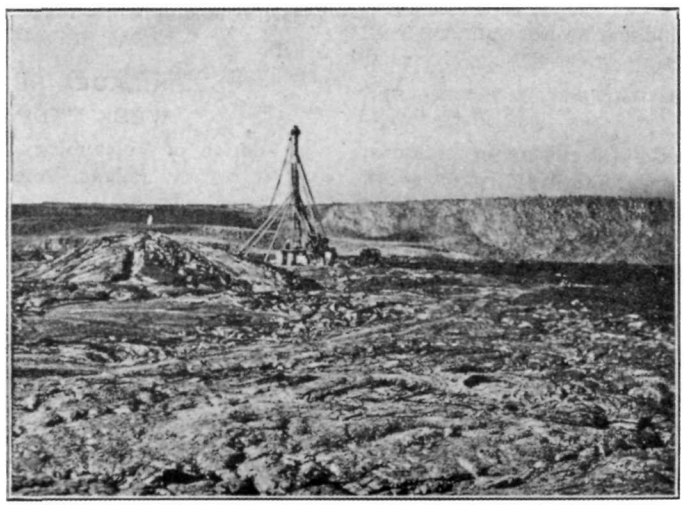
The seismographs at the Observatory recorded 13 tremors, two very feeble shocks, and three feeble earthquakes which were felt. The tremors indicated varying distances from 23 to 70 miles. The two very feeble shocks showed origin distances 6 and 16 miles. The first of the three feeble earthquakes occurred at 1:59 a. m. April 26. It was felt in Haina, Honomu, Hilo, Kamuela, Kohala, Waikii, and at the Observatory. Its record indicated distance 32 miles from the Observatory, 23 miles from Kealakekua, and 42 miles from Hilo. It is calculated to come from a point five miles below the saddle between Mauna Loa and Hualalai.

The second feeble earthquake was registered at 3:17 a. m. April 28 and was not reported felt by many. The origin was 12 miles from the Observatory. The third feeble earthquake was at 6:24 a. m. May 1, and although probably more generally felt, reports from distant parts of the island have not yet had time to arrive. Reports of perceptibility have come from Honomu, Hilo, and near the Observatory. Records indicate distances 16 miles from the Observatory and 31 miles from Hilo.

Microseismic motion was mainly moderate. Average tilting was slight SE by S.

The Observatory is getting very good cooperation from earthquake observers. Card forms will be furnished anyone willing to report felt shocks.





Churn drill at work on eastern lava field of the floor of Kilauea Crater July 21, 1922. Looking north showing Waldron's Ledge and the Volcano House in the distance. This is one of the numerous temperature wells drilled to shallow depths in the crater floor. These discovered that high temperatures are always on cracks which bring up hot vapor. See Bulletin Hawaiian Volcano Observatory 1922 and 1927.

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The Volcano Letter

No. 385 Hawaiian Volcano Observatory, National Park, Hawaii May 12, 1932

THE SUSPENSION OF THE VOLCANO LETTER

Among the reductions of governmental appropriation for the fiscal year ending June 30, 1933, is one changing the allotment to volcanology in the U. S. Geological Survey from $35,000 to 15,000. A large proportion of this concerns the Hawaiian Volcano Observatory, which is cooperatively maintained by a personnel chiefly of government employees, and by equipment and expenses, including publication, supplied in large measure by the Hawaiian Volcano Research Association.

The drastic reduction by fifty-seven per cent will permit the continuance of the Hawaiian station and a working staff only by abolishing the weekly Volcano Letter in its present form, as the publication of that periodical has been the largest item of expense from the cooperative fund furnished by the Research Association. This money will be needed to keep alive the work of the Hawaiian Volcano Observatory after July 1, 1932, and therefore it is deemed wise by the Board of Directors of the Association to take action immediately in preparing to reduce the Volcano Letter to a monthly leaflet after the issue of May 26, 1932. As before it will contain reports of the volcano observatories of the U. S. Geological Survey, and volcanologic notes.

As this crisis is a serious one for fundamental research concerning American volcanoes, all friends of volcano research are requested to rally to the support of the Hawaiian Volcano Research Association by subscribing any sum whatever, from one dollar up, and by securing new members and patrons for the Association wherever possible either firms or individuals, and anywhere in the world. The regular annual membership fee of the Association is five dollars, and necessarily the two dollar subscription for the Volcano Letter as a weekly publication is hereby abolished. After July 1, 1932, the monthly Volcano Letter will be sent only to paid up memberships and exchanges.

There will be no suspension of the work done. though the official staffs of the California, Hawaiian, and Alaskan stations will be reduced and some workers eliminated. There will be every effort to enlist new amateur workers who live near volcanoes and in land subject to small earthquakes, and who may be willing to send in official postal cards describing the happenings which come to their notice. The coming year will be an opportunity to bring to publication in scientific journals the material which has accumulated through recording twenty years of varied activities. T.A.J.

NOTICE TO MEMBERS AND SUBSCRIBERS

Honolulu, May 2, 1932.

To Members and Subscribers,
Hawaiian Volcano Research Association.

This communication is ordered by resolution of your Board of Directors on this date, to the following effect:

Resolved:

That the work of the Association shall be carried on, but that every possible avenue of economy shall be followed, including the abolition of the Volcano Letter in its present form. That the Directors approve of the proposed budget as revised for the balance of the current calendar year, with the proviso that further cuts be made, and that every effort be exerted to collect donations not yet received.

Accordingly, this letter is addressed to those who have subscribed two dollars per annum for the Volcano Letter and to regular members and patrons of the Association.

A cut of fifty-seven per cent by the Government, forces us to limit expenses to bare necessities, in order to save the Hawaiian Volcano Observatory.

After May 26, 1932, the Volcano Letter will be reduced to a monthly leaflet, but subscribers will be sent scientific papers from time to time. You are asked to accept this for the good of the cause, but two-dollar subscribers or members who except and require a weekly periodical, and who so notify the Assistant Treasurer, will have their full subscription returned.

Those able to help by enlarging their subscriptions or winning new subscribers, will be benefactors of scientific research in a time of serious crisis.

T. A. JAGGAR,
Scientific Director;
Hawaii National Park, T. H.

L. W. de VIS-NORTON,
Assistant Treasurer,
320 James Campbell Bldg.,
Honolulu, T. H.

KILAUEA REPORT No. 1059

WEEK ENDING MAY 8, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On the forenoon of May 2 Halemaumau pit showed fresh debris which had fallen since the previous day on the floor in the south bay from the wall above. Bluish fume remained constant at the sulphurous cracks at the edge of the floor west. Measurement of southeastern rim cracks showed very slight widening. Inspection at 8 p. m. revealed only a quiet pit and no glow. On May 3 at 9 a. m. the western fume was denser, probably owing to moisture content, as the weather was rainy. At 9 a. m. May 6 some fresh sliding at the south wall of the pit had added to the pile of fragments on the floor.

Progress in construction of the two tilt cellars near Halemaumau west and north shows concrete work in place at the former, and the digging practically complete at the latter

The seismographs recordel three very feeble shocks 23, 28, and 69 miles distant, the last rattling windows at Huehue in North Kona for about 15 seconds May 6 at 5:28 p. m. Twenty-one tremors were registered, one indicating distance 46 miles, and another 9 miles. Tilting of the ground was practically absent, and microseismic motion was moderate.

HAWAIIAN VOLCANO OBSERVATORY

Founded 1911

This laboratory at Kilauea Volcano is maintained cooperatively by the United States Geological Survey and the Hawaiian Volcano Research Association. It operates seismographs at three places near Kilauea Volcano, also at Hilo and Kona. The Geological Survey does other volcano investigation in California and Alaska. Persons desiring to join the Hawaiian association should address the Secretary, 320 James Campbell Building. Honolulu, T. H.

The Volcano Letter was a weekly from 1925 to 1932 (May), and is now a monthly leaflet. Readers are requested to send notes, photographs, publications, and clippings about volcano and earthquake events.

The Volcano Letter

No. 386 Hawaiian Volcano Observatory, National Park, Hawaii May 19, 1932

KILAUEA REPORT No. 1060

WEEK ENDING MAY 15, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On the forenoon of May 9, with northeasterly squalls and rain, the fume rising from the west edge of the floor of Halemaumau appeared slightly denser than before, and some odor of sulphur was detected at southeast rim of pit. In the afternoon the fume seemed dense and a few wall rocks fell. On May 11, 9 to 10 a. m. the fume was less dense, and some small sliding had taken place at the north. A slide at the south wall in the afternoon agrees in location with a slight opening of the SSE rim cracks recently measured. With damp air May 12 blue fume rose above the rim infrequently.

Experimental runs are now being made with clinoscopes for measuring tilt, in the southeast Halemaumau cellar, by E. G. Wingate.

Observatory seismographs registered one feeble local shock at 10:16 p. m. May 9, felt in Hilo, apparent distance from Kilauea to origin 14 miles. Three very feeble shocks occurred, two indicating distance 18 miles, one a possible distance of 115 miles. Twenty-six tremors were recorded. Microseismic motion was slight to moderate, and tilting of the ground was slight north.

A large distant earthquake May 14 with first preliminary at 2h 52m 57s a. m. H.S.T. (10h 30m slower than Greenwich) indicated distance 5300 miles wsw. This location checks with press report of damage and loss of life at this time in Minahassa, the northern peninsula of Celebes island, a volcanic area of the Netherlands East Indies.

TILTING OF THE GROUND FOR APRIL

The following figures show the net tilt by weeks at the Observatory on the northeast rim of Kilauea crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

March 29-April 4	1.0 second NE
April 5-11	0.8 second E
April 12-18	0.8 second NW
April 19-25	0.3 second SE
April 26-May 2	0.6 second SSW

E.G.W.

ERUPTION IN LAKE ROTORUA, NEW ZEALAND

A semi-volcanic eruption up through the bottom of the southern cove of Lake Rotorua occurred about 7:45 p. m. January 18, 1932. The place was about one hundred yards away from the shore off the mouth of the Puarenga Stream, the torrent of warm water that pours northward into the lake from the Whakarewarewa Geysers. The place is directly opposite the town of Rotorua. A column of steam, water, mud and stones was hurled up from an aperture in the solfataric shallows from 200 to 400 feet. There was little noise, and a few minutes after it occurred the surface of the lake was again smooth. The Maoris reported it the largest mud-geyser eruption since the explosion of Waimangu in 1917.

The area covered by the falling mud and stones was several acres. For more than one hundred yards along the shores of the lake, and for many yards back from the water, the ground was coated with thick slimy mud, and the point of land which projects in the direction of the vent under the lake was lengthened by 30 yards. People who happened to be on the balcony of the Ward Bathhouse had a splendid view of the outburst.

This explosion here is not the first. It is in the same general locality as two other outbursts a few months earlier, when the Ngapuna pa was startled by a sensational disruption of the flats, a native garden was engulfed and property was threatened. This area is reputed dangerous. The ground is a mass of brittle and steaming solfataric deposits, which crumble underfoot, there are many hot springs, and occasional patches of quicksand. At Whakarewarewa, a mile and a half away to the south, are the famous geysers and paint pots visited by tourists, in a verdant valley filled with boiling springs of varied aspect, and it seems likely that there are volcanic faults extending down the Puarenga valley to the lake. The whole district is highly volcanic, and the hot magma is probably not far from the surface T.A.J.

ASH ERUPTION IN THE ANDES

From the 10th to the 13th of April 1932 there were extensive steam-blast eruptions in the Andes of Argentina near the Chilean border, eight volcanoes being named, and the towns Malargue and San Rafael in Mendoza province received the heaviest ash-fall. Ash fell at Buenos Aires in Argentina 800 miles from the source, at Santiago in Chile and at Montevideo in Uruguay. In the mountain towns two to three feet of ash and sand are said to have fallen. Darkness enveloped much of the country, and earthquakes and fissures were reported, and glow from the craters. The volcanoes mentioned are the Descabezado group, Tinguiririca, Tupungato, Juncal, San Jose, Maipu and Peteroa, and probably a volcano in the Neuquen district of northern Patagonia. The volcano Quizapu in the first group has been the subject of anxious observation by the Chilean Seismological Service since April, 1929. The ash blanket covered thousands of square miles and made the mountains look as though covered with snow (Press reports.) T.A.J.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

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The Volcano Letter

No. 387 U. S. Geological Survey, Hawaii National Park May 26, 1932

KILAUEA REPORT No. 1061

WEEK ENDING MAY 22, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau, the inner pit of Kilauea Crater has shown no significant changes during the week. Measurements of cracks May 16 at the rim east and south indicated little movement. A dust cloud at the north wall at 10:55 a. m. May 17 during high wind was accompanied by no visible slide. At 4:45 p. m. the blue fume from the western sulphur spot of the bottom was plainly visible above rim of pit as seen from the Observatory. At 9 a. m. May 18 the scar from a slide was visible above the middle of the "canoe sill" in the lower northeastern wall of the pit.

The building of the tilt cellars west and north of Halemaumau has proceeded so that the western one now has the instrument chamber encased with built-up rubble, and the entrance way has been walled up on either side of the stone stairway at the approach. A heavy slab roof of concrete, separated by an air space from the inner chamber. will be built across the top The chamber is thus insulated by air spaces, and will have double doors at the entrance.

Seismic activity has been extraordinarily feeble for the week. Only three volcanic tremors were recorded, one indicating a possible origin at 120 miles distance. There has been much artificial tremor from heavy road-working machinery. One very feeble local seism occurred. A distant earthquake indicating origin 4,400 statute miles away, began at 11h 50m 43s p. m. May 20, 1932. reported location Salvador. Microseismic motion for the week was moderate, and tilting of the ground was slight to the north with tendency eastward

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The Volcano Letter will hereafter be monthly.

ERUPTION OF MERAPI IN JAVA

There are two important volcanoes named Merapi, of which one is in Sumatra. The volcano here considered is in central Java, and started a disastrous eruption November 25, 1930, and permitted a stiff, blocky variety of lava to exude from the crater throughout most of 1931. (Der Ausbruch des Merapi, by N. Van Padang, Zeitsch. für Vulk., 1931 page 135, and Bull. Neth. East Ind. Volc. Surv. 1930-1931.)

Except for the volcano on Bali named Batoer, the flowing of lava is rare in the Dutch East Indies, though the slow push upward there of andesitic domes within craters is well known.

There had been an increase of tremors from January to May 1930 at Merapi, and the temperature of the solfataras was about 600° C. in October 1930, but this was not unusual for this place. In November large and small tremors increased, explosions were heard November 23, 1930, and these continued. When the glowing lava in the crater appeared on November 25, 1930, large tremors, which had been caused by crater avalanches, came to an end.

The lava was very tough and irregular in flowing, its glow was variable, with rough blocks falling from the front, which burst and formed small clouds, that mixed with the general cauliflower clouds of the jets from the crater. This lava formed a short, stubby outflow at the crater gulch. Such sluggish flowing, with small gas concentration, continued until December 18, 1930.

The eruption had characters similar to those of Mount Pelé in Martinique, including hot blasts downward and across country, known, in Martinique as "nuées ardentes" or glow clouds. After December 18 big blasts occurred, throwing out old material mixed with fresh lava, and these emerged from a big, deep chasm or gulch in the slope of the mountain opening from the summit crater. Great avalanches, and streams of blocks rushed down, and followed valleys, along with a drifting cloud of sand, ash and gas. While the debris followed the ravines, the whirling hot sand clouds would keep their own direction, with tornado effects, and make fearful destruction.

The largest such glow-cloud blast descended the mountain on December 19, 1930, killed more than 1,300 villagers, devastated 22 square kilometers of country, and spread more than 10 kilometers from the center. The stream of debris in the valleys was 10 to 50 meters thick, and the sand covering beyond was from 1 to 40 centimeters thick.

There had been lava domes which had arisen during eruptions on the summit of Merapi, beginning in 1883, by rise of andesite lava through broken material in the bottom of a crater 100 meters deep There was renewed rise of the lava in 1888. a dome above the top of the mountain had formed in 1909. side by side with this eastern dome there arose a western dome between it and the crater wall in 1911-13, and in 1922 there came out a lava stream at the western wall crack, the source material of which made a triple dome in the crater along with two earlier ones. The sequence is vividly shown in a series of diagrams by Van Padang. In 1930 a new dome and flow were formed beside the others in November-December, and the great eruption of December 18-19 caused collapse of the older domes, but after a succession of hot blasts thick lava rose again which formed a new dome in the chasm, somewhat away from the center of the mountain. The entire description of this eruption coincides strikingly in quality with that of Santa Maria in Guatemala November 2, 1929. (Volcano Letter No. 356)

In January 1931 lava issued from various parts of the new lava dome. blocks fell noisily from the crust as the dome repeatedly burst, and the mud and debris slides in the valleys ("lahars") solidified and cooled. The rains made water explosions against dry. hot debris in the valleys just as at Soufrière and Pelée in the Caribbee Islands in 1902. The rivers carried quantities of sand. Light seen above the lava dome, which showed only fumarolic action in daytime. was indicated at night to be flame from burning gas. The smell of sulphur dioxide was strong, and temperatures of some known fumaroles, formerly 500° C., had lowered to 60° C. On the other hand, solfataric action was spread over a greater area.

On March 25, 1931. there was an older lava stream of 1930 from the gash under the summit, and a younger one emerged March 10, 1931, and increased after March 15. so that on March 19 the lava tongue was 180 meters lower than the week before. There were many small blasts, with much avalanching. and glowing spots on top of the dome marked places where lava was gushing.

Erosion was now etching rill patterns rapidly in the deep, hot, debris fills of the valleys. Mud geysers were thrown up 50 meters high where eroding streams of water made contact with gravel beds almost incandescent. Measured temperatures recorded 280° C. The fumarole activity at the head of Senowo River, where the temperature in October 1930 had been 610° C., had ceased altogether in April 1931.

Lava flowing and hot blasts continued in May and June 1931. A new local observatory was built 4 kilometers from the summit, at elevation 1,279 meters. on the northwest slope of the mountain, with a tunnel to provide safe refuge against hot blasts. In this tunnel a seismograph was placed. In July and August 1931 lava flow and avalanches continued, and at night dark red glow could be seen at the crater, where in day time vapor arose. T.A.J.

The Volcano Letter

No. 388 U. S. Geological Survey, Hawaii National Park JUNE, 1932

KILAUEA REPORT FOR JUNE, 1932

Six weeks period from May 22 midnight to July 3, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

For the week ending June 5, there were slight falls of rock during an earthquake 1:52 p. m. May 29, and a slide sent up dust at the northeast wall at 12:22 p. m. June 1. On June 6 a slide above the northwest talus at 1:10 p. m. left some new bowlders on the floor.

An event of volcanologic interest from the standpoint of experiment with methods, was the descent about 10 a. m. June 12 to the bottom of Halemaumau of Rikan Konishi, a rigger and contractor of Hilo. This was for the recovery of two dead bodies on the east talus resulting from a local tragedy. Mr. Konishi gave the preceding seven days to setting up an A-frame at the south rim, spanning the east arc with cable, and improvising a trolley. In a wooden cage strongly bound with iron, the task was completed by Mr. Konishi personally going alone to the bottom between 10 a. m. and 5 p. m. He had about fifty helpers and numerous tractors.

The specimens collected of the east edge of the 1932 bottom lava were shred pahoehoe basalt, black with brown stain, highly vesicular, glassy without visible olivine, with reddish brown glaze on inner surfaces. The grade of the talus was 34 degrees. The cage landed on the talus 250 feet above bottom. Time of collection about 3 p. m. June 12, 1932. The lava ledges at the edge of the floor were about 7 feet high, those out in the middle over 40 feet high. Temperature measured at border ledges, 15 minute exposure, 73 degrees Fahr. Temperature up talus 5 minute exposure 85 degrees: at floor edge farther north insufferably hot; at some places on the talus rubber soles were burned. The lava was curled over in shells with cavernous spaces. Mr. Konishi noticed "thin air", a difficulty of breathing, about 600 feet down: this was probably a streak of the fume with sulphuric acid gas from the solfa'ara at the west side of the floor. The Observatory is under obligation to Mr. Konishi for the specimens and the data.

Rim cracks at Halemaumau southeast, measured for the width between opposite sides with calipers, June 13 showed very slight widening at three localities. The pronounced earthquake generally felt on Hawaii about 4:52 a. m. June 14 was apparently accompanied by ESE tilt in the seismograph cellar southeast of Halemaumau. A few rocks were heard falling the forenoon of June 20. The instrument cellars for recording tilt at the pit southwest and north have been completed during the month.

T.A.J.

Earthquakes

During the last six weeks the following teleseisms were recorded on the seismographs of the Observatory. (Hawaiian standard time 10h. 30m. slow G.M.T.)

One May 26 at 5:47:50 a. m., distance 3,250 statute miles.

One June 3 at 0:15:54 a. m., wrote a very large record. It was destructive in Mexico and sea waves originating on that shore were visible in Hilo. These waves arrived in Hilo soon after 7 a. m., were about two and a half feet in height range, and 18 minutes in period. with the maxima between 7:30 and 10:30 a. m. A second series of water waves about a foot high came about 3:30 p. m. These were probably the reflections from the South American shore as the time computation is nearly correct for that path.

Fragments of teleseisms were recorded at 10:59 p. m. June 4 and 10:21:28 p. m. June 6. The latter was slightly destructive in Eureka, California, and only the P and M phases recorded. A teleseism 11:51:22 p. m. June 17 was followed between 7 and 9 a. m. June 18 by a tidal wave two to three inches high in Hilo Bay.

A teleseism June 19 at 11:13 p. m. was fragmentary, consisting of long, sinusoidal waves lasting but a few minutes. June 22 at 2:38:18 a. m. another teleseism began recording from southern Mexico. The P and M phases only were recorded. A slight ocean wave was recorded on the Hilo tide gauge after 9 a. m.

A moderate local earthquake occurred 4:51:45 a. m. June 14. Reports showed that it awakened people generally over the island of Hawaii. It was also reported from Maui. The Bosch-Omori seismograph at Kilauea was dismantled. The approximate center located by distances from two stations and by a direction from a third, was in lat. 19° 28' N., long. 155° 22' W., and about 13 km. deep. It probably occurred on the below-ground projection of the fault between Mauna Loa and Kilauea. This earthquake was estimated to be about III Rossi-Forel.

On May 29 at 1:51:27 p. m. a slight earthquake (about II Rossi-Forel) was felt at both Kilauea and Hilo. Distances from three stations placed it at 19° 21' N., 155° 17' W. and about 12 km. deep.

On June 5 at 6:53 p. m. a feeble shock was felt at Kilauea, about 9 miles away from this station.

A very feeble shock was felt on the Hamakua coast May 25 at 1:42:13 p. m. The epicenter was probably a few miles seaward from that coast.

Twenty other very feeble shocks were recorded at the Kilauea station. Ten of these occurred at distances from 3 to 9 statute miles; eight of the others occurred about 20 miles away, one at 70 and one at 150 miles away from Kilauea.

One hundred fifty-nine tremors were recorded. Due to their small size and inconspicuous phases, very few of these can be located. Some similar tremors have been reported as earthquakes from the north part of the island. In preparing to study these earthquakes a small seismograph hut was completed on June 29. It is located at Waikii telephone station on the northwest slope of Mauna Kea. It is planned that a seismograph, transferred from one of our abandoned Alaskan stations, will be placed there in October 1932.

A.E.J.

Tilting of the Ground

The following figures show the net tilt by weeks at the Observatory on the northeast rim of Kilauea crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given. The last record was in Volcano Letter No. 386.

May 3-9	0.4 second NNE
May 10-16	1.0 second NNE
May 17 23	1.1 second NW
May 24-30	0.8 second SW
May 31-June 6	0.4 second NNE
June 7-13	0.8 second NE
June 14-20	0.7 second SW
June 21-27	1.0 second N

The accumulated tilt at the Observatory since January 1, 1932 to June 27 is 14.2 seconds S. and 1.4 second W. These records are from the modified two-component Bosch-Omori seismograph which has stood in this cellar for twenty years.

E.G.W.

The Volcano Letter

No. 389—Monthly U. S. Geological Survey, Hawaii National Park JULY, 1932

KILAUEA REPORT FOR JULY, 1932

Including weekly press reports Nos. 1068 to 1071, July 3 to July 31 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, *Volcanologist in Charge*

Volcanology

A slide from the west wall of Halemaumau July 4 left a mound of debris 20 feet high on the floor, and noisy slides raised dust that forenoon. The 1932 conelet southwest had slumped. A northwest wall slide occurred 6:40 a. m. July 13, and another left a scar southeast July 16. The rock above the canoe sill in northeast wall made a slide big enough to make the 1932 lava floor dusty about July 27, and in the night following July 29 a block of the actual rim of the pit south left a wide scar down the wall, visible from the Observatory. Yellow dust and sand was left covering the western half of the floor, while the south bay showed large bowlders and smaller debris. The pit seismograph showed NW or inward tilt accompanying this slide, and two cracks back of the south rim had widened.

Fresh cracks in the ash soil of the northeast rim were occasioned by the slides of July 4. Measured rim cracks northeast on that date showed at 5 p. m. slight general opening compared with June 21. At 7 a. m. July 8 nine out of nineteen eastern rim cracks showed opening compared with July 4, but very slight. At 9:30 a. m July 12 very slight widening apart of eastern cracks continued, and at the end of the month it was found that only the two fissures back of the slide of July 29 showed significant opening, and that less than one sixteenth inch. This work is done carefully at marked and numbered places, with caliper and rule.

At the southeast Halemaumau cellar seismic movements and tilts occur quite different from those registered at the Observatory on the northeast edge of the greater crater of Kilauea. E. G. Wingate is operating this cellar, which contains both clinoscope and Hawaiian type seismograph. The following figures show weekly totals of peculiar pit tremors, sudden small jerking movements of quick period and very slight amplitude, the frequency variable on different days, and generally showing tilt, or widening apart of the seismogram lines, simultaneous with the trembling. This motion is most conspicuous on the east-west pendulum, and as the cellar is to the east of the pit, the dominant tilt which accompanies the tremors is eastward or away from the volcanic center. The action appears to be seismic, and may prove an important index of magma rising below. The new instrument magnifies about 120 times, and is more sensitive than the one in operation prior to the autumn of 1931 at this place. The frequency, or number of tremors counted, was:-

July 3 - 9	343
July 10 - 16	300
July 17 - 23	150
July 24 - 30	137

It happens that there were lower values in May, and an increase in June, so that the maximum was around the solstice (June 20), and the four weeks of July show graded decrease. This tremor frequently at the pit thus is in accord with the seismicity decrease (earthquakes) shown below by Mr. Jones. The idea that these pit tremors are creakings of the inner dome of Kilauea crater floor being pushed up by magma below, is in accord with the opening of the rim cracks, and evidence by topographic surveys which suggest that the ground is rising and that the opposite walls of Kilauea crater are spreading apart The clinoscopes have been placed in the west and north pit cellars, and their operation for a few months should throw new light on the question, is the ground tilting away from Halemaumau in all directions? During very feeble earthquakes July 16 and 17 slight east and south tilt showed on the seismograms, this being inclination away from the pit; whereas during the south avalanche of July 29, the seismographic tilt at the southeast station was northwest or inward toward the pit.

T.A.J.

Earthquakes

The following is a tabulation of the tremors, very feeble and moderate local shocks recorded by the seismographs at the Hawaiian Volcano Observatory during the interval July 4 to 31 inclusive, 1932. Hawaiian Standard Time is 10h. 30m. slower than Greenwich. The seismicity index (seis.) is the summation of weighted numbers given each type of shock, as explained in Volcano Letter No 371.

Date	tr	vf	mod	seis
July 4 to 10	37	5	1	14.75
July 11 to 17	42	2	0	11.50
July 18 to 24	22	0	0	5.50
July 25 to 31	29	2	0	8.25

The seismicity for the preceding two months was;-

Week ending	May 15	seis. 9.00
	May 22	1.25
	May 29	7.25
	June 5	8.75
	June 12	5.25
	June 19	13.00
	June 26	9.75
	July 3	14.25

The moderate shock of July 7, at 10h. 30m. 49s. p. m. was felt generally on the island of Hawaii and was reported from one locality on Oahu. Its focus was about 8 miles south of the Observatory and about 6 miles deep. It was followed on July 8 by two very feeble aftershocks, about 7 miles distant, and by 15 tremors of unknown distance. The change in earth-tilt a few hours before and a few hours after the earthquake was noticeable. Moderate NW tilt preceded and moderate S tilt followed.

The very feeble shocks, other than those mentioned above, occurred at approximate distances of 9, 9, 11, 16 18. 23, and 24 mles. The few tremors for which distances could be estimated occurred at 4, 9, 20, 34, and 40 miles. A fragment of a distant earthquake was recorded beginning 9:13 a. m. July 12, and a second one beginning 10h. 53m. 04s. p. m. July 24, with a secondary wave at 11h. 04m. 59s. p. m. Microseismic motion was light at the beginning and at the end of July, and moderate during the middle fortnight.

A.E.J.

Tilting of the ground

The following figures show the net tilt by weeks at the Observatory on the northeast rim of Kilauea crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given. The last record was in Volcano Letter 388. The total accumulated tilt from January 1 to August 1, 1932 is 12.6 seconds S., and 2.2 seconds W.

June 28 - July 4	0.6 second	N
July 5 - 11	0.4 second	SSW
July 12 - 18	1.0 second	NNW
July 19 - 25	0.6 second	NE
July 26 - August 1	0.8 second	NW

E.G.W.

Personnel

Mr. Jaggar has been engaged in editing papers for publication and in teaching volcanology to a class of fifty-six at the lecture hall of Hawaii National Park, summer session of the University of Hawaii. Mr. Finch has returned from Shishaldin volcano in Alaska to his duties at Lassen Volcano Observatory. Mr. Wingate has been resurveying the Kilauea triangulation net. Mr. Jones has been computing travel time curves for Hawaiian earthquakes. Mr. Powers has been transferred to geological surveys on Haleakala volcano, Water Resources Branch.

The Volcano Letter

No. 390—Monthly U. S. Geological Survey, Hawaii National Park AUGUST 1932

KILAUEA REPORT FOR AUGUST 1932

Including weekly press reports Nos. 1072 to 1075, July 31 to August 28 midnight.

Section of Volcanology, U. S. Geological Survey

E. G. Wingate temporaily in charge

Volcanology

A visit to the summit of Mauna Loa was made by Park rangers August 9 to 11. They discovered much steam along the upper part of the northeast rift, blue fume and steam about the central cones of Mokuaweoweo, the summit crater of Mauna Loa and the usual steam at the foot of the west wall. Another party led by Messrs. Squire and Corey of Hilo visited the summit on August 17. They reported steam and fume at Mokuaweoweo as usual. The fume over Mokuaweoweo as seen from Kilauea has occasionally been visible in late afternoon as a tenuous volute of definite outline; and several times the northern position of the sunset light has brought out the steam jets of the northeast rift. These things are not unusual in summer time.

Volcanic conditions at Halemaumau in Kilauea have been relatively quiet and inactive during the month. A small slide took place on the sixth. Only four or five rocks falls occurred during the rest of the month. A night observation trip 8 p. m. August 24 showed everything quiet and dark in the pit. The cracks on the rim of the pit of Halemaumau showed no change the first week of August. For the next three weeks six cracks consistently opened for an approximate total of a sixteenth of an inch each. The very local pit tremors have decreased in numbers, the count was 141, 203, 107, and 29 on successive weeks.

A note on Kamchatkan Volcanoes.

A very interesting communication was received from P. T. Novograblenof of the Kamchatka Museum. He describes an eruption at one of their great volcanic cones, Kluchevskaya which is nearly 16,000 feet high. There had been no eruption either in it or its parasitic cones since sometime prior to the Russian invasion of the peninsula in 1696 A. D. For a period of four months preceding the eruption of January 25, 1932 earthquakes were felt almost daily, some being almost destructive in intensity. The eruption started quietly with black fume rising some thousands of feet, above the parasitic cone at the base of the volcano. The explosive phase began two hours later and explosions recurred at intervals of six to seven hours. There were no lava flows. The eruptive products were fume, ash, sand, lapilli and volcanic bombs. Immediately after the culmination of activity on January 29 a party visited the vicinity of the cone. They reported it as growing no less than 12 meters a day. After seven days of explosive activity it quieted and gradually declined. Smoke and glow from the crater could be seen on the day and night of February 12. 1932. Karimsky volcano was the only other Kamchatkan volcano in eruption at this time.

Earthquakes

The following is a tabulation of the tremors, very feeble and feeble earthquakes recorded by the Observatory seismograph during the interval August 1 to 29. All of these are of intensity one Rossi-Forel scale. The term tremor is applied to the smallest. For weekly seismicity or seismis index see Volcano Letter No. 371.

date	tremor	v. f.	feeble	seis
Aug. 1 to 7	29	5	0	12.00
Aug. 8 to 14	23	2	1	7.75
Aug. 15 to 21	20	3	1	7.50
Aug. 22 to 28	26	9	1	12.00

One of the very feeble shocks, August 4, was felt by a person sitting on a ledge at Puu Koae in the Kau desert. A partial record of a distance earthquake began 5h; 01m; 12s p. m. H. S. T. August 11. The origin as given by the U. S. C. & G. S. was in the Aleutian Islands near Umnak Island. August 19 a shock was felt in Kona and Kohala. It recorded feebly at Kilauea. Instrumental location placed it two miles at sea near the extension of the Hualalai rift, and about three miles north of Keahole Point on the west side of Hawaii. It was about 12 miles below sea level. A feeble earthquake was felt August 23 by an observer three miles east of the Observatory. The record showed that it was followed in less than two minutes by four very feeble after-shocks, the preliminaries being too weak to indicate distance. A very feeble shock was reported felt in the same neighborhood on August 27. It was nine or ten miles from the Observatory.

The average weekly seismicity at Kilauea for the period of low values since the last lava inflow, ending January 5, 1932, has been about ten. The average for all values during the last four years has been about 80. The values for August are close to the average low for part of this year.

A.E.J.

Ground movement and Tilt

Field work on triangulation of the Kilauea net was completed early in August. Sixteen stations were occupied in the course of the survey and thirty-one triangles closed with and average error of 02".55. A complete report on the ground movements detected by this survey will be made the subject of a separate paper at a later date.

The clinoscope at the seismograph hut at Halemaumau is performing usefully, after several months of various tests. The hut is located 1,800 feet from the center of the pit, in azimuth 325 degrees, and 400 feet back from the rim. The clinoscope is housed in a seperate glass-inclosed room which has a daily range of slightly less than two degrees F. Readings are made once daily. Actual magnification of the clinoscope is about 50 times.

The 'Table of Tilt' shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinoscope readings at Halemaumau. The table represents the movement of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory from January 1 to September 1, 1932 is 10".5 South and 02".9 West.

TABLE OF TILT

Date	Observatory	Halemaumau
July 31 - Aug. 7	0".5 NNE	0".4 NW
Aug. 8 - Aug. 14	1".0 NW	0".4 WNW
Aug. 15 - Aug. 21	0".4 NW	0".5 NNW
Aug. 22 - Aug. 28	0".6 NNE	0".9 WNW

Clinoscopes of similar design to that above have been installed in the west and north tilt cellars, and are being given experimental runs. The two cellars, together with the seismograph hut, form an equilateral triangle about the center of Halemaumau.

E.G.W.

The Volcano Letter

No. 391—Monthly U. S. Geological Survey, Hawaii National Park SEPTEMBER 1932

KILAUEA REPORT FOR SEPTEMBER 1932

Including weekly press reports Nos. 1076 to 1080, August 29 to October 2 midnight.

Section of Volcanology, U. S. Geological Survey

E. G. Wingate temporarily in charge.

Volcanology

A small slide and a few rocks falls in the pit of Halemaumau in Kilauea crater were noted by observers during the last three days of August. A small slide fell from the east wall soon after daybreak September 8. A second small slide fell from over the Southwest talus slope and a few rocks fell from the east wall during that afternoon. The rim cracks back of the west wall showed widening on this day by fresh looking hair cracks in the overlying ash. Three small slides occurred after the above date and before September 18. Since then no slides large enough to be reported have occurred.

Measurements on the rim cracks under weekly observation have been taken five times, in the period covered by this report. The changes are largely confined to a few cracks that show nearly constant movement. The number of cracks that have opened a slight but measureable amount for each successive week are four, zero, six, ten, and four.

Observations and measurements of tilt at the pit during the last month seem to indicate that upward pressure is beginning to be exerted. The tilt changed abruptly from inward tilting to a direction away from the pit following the felt quake of September 7. During the last two weeks of September there began to be noticed a more or less continuous trickling of rocks from the walls, notably from the north and west, with evidences of very small sliding.

A New Map of Halemaumau

During the month of September a complete map of the pit was made by plane-table surveys on a scale of 400 feet to the inch. This is the first map of the entire pit made since the survey by R. M. Wilson in 1928. A comparison of the two maps reveals some interesting changes in the crater.

Halemaumau still retains its general circularity, though the northeast-southeast diameter is greater. The diameters at present are 3504 by 3008 feet. Avalanching from the walls has had the greatest effect on the area extending southward from the tourist lookout. The maximum amount of rim change has taken place in this area, amounting to 130 feet in one place. Other noticeable rim changes occur in the neighborhood of the old 14 ton boulder some 600 feet north of the tourist lookout, where 80 feet of the rim has fallen; along the east rim over the east talus, 80 feet; and 60 feet over the north buttress.

The general floor level has risen 280 feet, at present being 870 feet below the bronze tablet at the lookout. In area the floor has increased from 19 acres in 1928 to 88 acres, while the pit as a whole has enlarged its size only 4 acres. These figures give an approximate volume of fill, by lava extrusion, of 21,000,000 cubic yards, of which the last eruption accounted for almost 13,000,000 cubic yards.

The cone in the southwest corner of the pit is 120 feet above the floor level and the larger hummocks on the floor are from 15 to 20 feet in height.

E.G.W.

Earthquakes

The following is a tabulation of the earthquakes that were recorded during the week preceding the date below.

date	tremor	v. f.	feeble	seis.
September 4	44	8	0	15.00
September 11	19	4	1	6.75
September 18	23	7	1	10.25
September 25	36	5	1	12.50
October 2	10	5	0	5.00

These earthquakes were not larger than No. 1 Rossi-Forel scale.

During the last three days of August a swarm of thirty tremors were recorded on the seismographs of the Hawaiian Volcano Observatory. From measurements on a very few, the seismic disturbances appeared to have occurred from 30 to 60 statute miles away. Since no reports came in from other parts of the island, they probably occurred deep under the island.

A very feeble shock was felt near Kilauea at 2:45 p. m. September 6. It was about five miles away.

A feeble shock awakened people near Kilauea on the seventh at 4:38 a. m. It was also reported from Hilo. Distances and directions from the Hilo and Observatory stations indicated that the focus was under Kilauea crater and nearly under the pit.

A feeble shock, not felt, was recorded September 12 at 5:50 p. m. It was about three miles away from the Observatory. The instruments at the pit showed south and westerly tilt effects for 24 hours following the shock.

A very feeble shock was recorded September 16 at 4:51 p. m. Later, reports came in saying that an earthquake had been felt at Waikii at that time.

A feeble shock was recorded 7:32 a. m. September 24. It occurred about four statute miles from the Observatory and was well recorded on all seismographs at Kilauea. It was not reported felt. It recorded at Hilo as a very feeble shock and at Kona as a tremor.

An earthquake was felt in Kamuela at 9:38 a. m. September 27. It recorded as very feeble at the Hilo and Observatory stations. Distances interpreted from the records placed it about under Kamuela.

The seismic index (seis.), as is shown above, has not been very far from the average low between eruptions.

A.E.J.

Tilting of the ground

The 'Table of Tilt' shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinascope readings at Halemaumau. The table represents the movement of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory from January 1 to October 2,1932 is 09."6 South and 00."5 West.

TABLE OF TILT

Date	Observatory	Halemaumau
Aug. 29 - Sept. 4	0."7 NE	5."5 NNE
Sept. 5 - Sept. 11	0."4 SSE	6."9 S
Sept. 12 - Sept. 18	1."1 NE	8."2 WNW
Sept. 19 - Sept. 25	0."7 SE	17."0 S
Sept. 26 - Oct. 2	1."0 NNE	14."0 W

That the values for Halemaumau given above are not excessive is shown by spirit levels run on September 27. These levels indicate that the east rim, 400 feet from the B. M. at the clinascope station, has lowered 0.3 feet since March 5 of this year. Between April 5, the date of installation of the clinascope, and September 27, there had accumulated 01' 22."0 of tilt in the direction of the pit, which, at a distance of 400 feet, would amount to 0.12 feet. A much closer actual agreement seems to be indicated, as March 5, the date of latest comparable levels, was the culmination of a minor period of uplift of the Kilauea dome.

E.G.W.

The Volcano Letter

No. 392—Monthly U. S. Geological Survey, Hawaii National Park OCTOBER 1932

KILAUEA REPORT FOR OCTOBER 1932

Including weekly press reports Nos. 1081 to 1084, October 2 to 30 midnight

Section of Volcanology, U. S. Geological Survey

E. G. Wingate temporarily in charge.

Volcanology

Conditions at Halemaumau pit of Kilauea crater remain quiet and inactive. For the first week of the month rock trickling was quite noticeable. From the daily observations and reports of visitors it appeared that there was an almost constant falling of rocks from the walls of the pit. During the next two weeks this was unnoticeable, probably on account of the high winds that may have masked the sound of any falling rocks. For the last week of the month reports showed that there had been a small amount of rock trickling followed by two small slides from the north and northwest walls of the pit. The fume was less noticeable for the greater part of the month. Air conditions on October 26 and 27 apparently increased the visibility of the fume, which appeared in occasional puffs.

Comparison of the October measurements of the rim cracks with the measurements of the past months show that there has been a slight increase in the number opening. Each measuring point on these cracks, consists of two marked copper pins, fixed on either side of the crack. Every week the distance between the marks on the pins is measured to the nearest half millimeter or about one-fiftieth of an inch. The numbers that showed widening for the successive weeks in October were four, eight, eight, and seven, These movements are irregular and scattered among the observation points. In only one case has a crack consistently opened since September 24. Since then it has opened about a sixteenth of an inch each week until at present its total widening is about a quarter of an inch.

Earthquakes

The following is a tabulation of the earthquakes recorded by the seismographs of the Hawaiian Volcano Observatory during the intervals October 3 to 30 inclusive. The instrumental record consists only of tremors and very feeble shocks. The weekly seismicity (seis.) is the summation of weighed numbers given each type of shock as explained in Volcano Letter No. 371.

date	tremor	v. f.	seis.
Oct. 2 to 9	21	1	5.75
Oct. 10 to 16	26	1	9.25
Oct. 17 to 23	41	2	11.25
Oct. 24 to 30	41	1	11.00

Inconsistencies in the above table are due to the duration of tremors.

An earthquake was felt in Kona October 9 at 2:20 p.m. It recorded plainly on the Kealakekua seismograph a few miles away from the epicenter. It recorded as a tremor, not indicating distance, on the Observatory seismograph.

An earthquake was felt at Waikii at 6 a. m. October 27. It was about 60 statute miles from the Observatory but was not recorded. The records of all stations were searched but not a tremor could be found within an hour of that time. As the new instrument at the Waikii station was not in good adjustment it did not record the shock.

Parts of distant earthquakes were recorded on October 16 and 30. Only the long waves of these teleseisms recorded slightly. The microseisms were light on October 7, 8, 9, 28, 29, and 30; and strong on October 19. During the other days of the month the ground vibrations were of moderate intensity.

A.E.J.

The Study of Ground Tilts at the Observatory

At the very beginning of observations at Kilauea in 1913 exceptional tilting of the ground about the volcano became apparent, and with the passing of years became a subject of increasing interest and importance. The accumulation of data, obtained by measuring from a fixed datum line the displacement from day to day, of the writing pens on the seismograph seemed to point to a volcanic origin for a portion of the observed tilts. Certain eruptive periods showing a decided tilt away from the crater preceding the eruption, and the collapse in 1924 showed inward tilting to the amount of 81 seconds of arc between January 1 and July 1 of that year. In Vol. 19, No. 1, March, 1929, Bulletin of the Seismological Society of America, Dr. T. A. Jaggar and R. H. Finch have discussed, "Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory". Their work undertakes the correlation of results from precise levels and triangulation. atmospheric temperature, rainfall, seismicity, and the rise and fall of the Hawaiian lava column with the observed tilts as measured at the Observatory.

The present program of investigation is a continuation and extension of past work. It was felt that a new site for instrumental measurement was necessary as the location of the observatory proper on the outer rim of Kilauea, with earth cracks about it and a much faulted cliff in front as well as the distance (three miles) from the object of study. was not such as to obtain fully reliable records of volcanic tilts. In 1928 a one component seismograph was installed a few hundred feet southeast from Halemaumau. This instrument was in operation until December 1931 when it was dismantled to make way for the building of the first of three tilt cellars centered about the pit. Uplifts and depressions of as much as 15 feet are not uncommon about the rim of Halemaumau, and it was felt that with instrument stations located on the crater floor a short distance from the active pit it would be possible to make a much closer correlation between observed tilts and the rise and fall of the lava column.

Three clinoscopes, for direct measurement of tilt, and one Hawaiian Type seismograph are now in operation on the crater floor and measurements from seismograms at the observatory are being continued. The differential movement of benchmarks is determined by spirit levels from time to time and the horizontal angular value between two points on opposite sides of the pit is measured from the Observatory periodically. The net of triangulation and level stations about Kilauea is resurveyed at five year intervals. This net is to be extended eastward along the Puna rift and an independent net established at its eastern end. This section was the scene of disastrous earthquakes and shore line sinking in 1823, 1868 and 1924. Straight lines of sight. with intervisible marked points. spanning the fault country south of the volcano are contemplated. Records are kept, with daily and smoothed curves platted, of atmospheric temperature, rainfall and atmospheric pressure. Rainfall and temperature are also observed and platted at Halemaumau.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinoscope readings at Halemaumau. The table represents the movement of the ground. in seconds of arc, in the direction given. The total accumulated tilt at the Observatory from January to October 30, 1932 is 6."4 South and 2."1 East.

TABLE OF TILT

Date	Observatory	Halemaumau
Oct. 3 - Oct. 9	1."5 NE	9."7 N
Oct. 10 - Oct. 16	1."9 NNE	27."2 NE
Oct. 17 - Oct. 23	0."7 SE	5."5 ENE
Oct. 24 - Oct. 30	0."6 NE	6."8 SSW

E.G.W.

The Volcano Letter

No. 393—Monthly U. S. Geological Survey, Hawaii National Park NOVEMBER 1932

KILAUEA REPORT FOR NOVEMBER 1932

Including weekly press reports 1085 to 1088, October 30 to November 27 midnight.

Section of Volcanology, U. S. Geological Survey
E. G. Wingate temporarily in charge.

Volcanology

The pit of Halemaumau in Kilauea Crater remains quiet. Fume has been less noticeable than during October. Fume was present during the first three weeks but was not reported during the last week. Rock trickling has died down and there were only a few slides. Slides occurred on November 1, 4, 6, 12, 16 and 21. Puffs of fume were plainly seen November 4, 5, 6. A swarm of 11 tremors was recorded in less than half an hour, about 5 p. m. November 4. No distances could be estimated for these tremors, and as they coincided with fume and sliding at the pit, they were assumed to have occurred deep under Kilauea, rather than under Mauna Loa.

Concentric cracks around the pit have been measured every Saturday. These measurements show that the crack 100 feet north of the tourist stand continues to open. The number of cracks that widened each week were six, eight, four, and ten. The weekly average number of cracks that widened during the past month is slightly larger than the average for October. This increase has been going on ever since July when there was an average of two that widened.

Earthquakes

The following is a tabulation of the frequency of earthquakes recorded by the seismographs of the Hawaiian Volcano Observatory at Kilauea. The weekly seismicity (seis.) is the summation of weighted numbers given each type of shock, as ¼ for a minute of tremor, ½ for a very feeble shock, one for a feeble shock, two for a slight shock, and three for a moderate earthquake. These units follow roughly the numbers of the Rossi-Forel scale. The table gives number of occurrences of each type of shock:—

Date	tr.	v. f.	f.	seis.
Oct. 31 to Nov. 6.	53	2	0	14.25
Nov. 7 to Nov. 13.	30	5	1	11.00
Nov. 14 to Nov. 20.	31	1	1	9.25
Nov. 21 to Nov. 27.	27	5	1	11.25

Hawaiian Standard Time (H. S. T.) is 10h. 30m. slower than Greenwich.

Three feeble earthquakes were recorded at the Observervatory during the past month. The first was felt about two miles east of the Observatory, at 8:35 p. m. November 11. estimated distance from Observatory 30 statute miles. The second was at 2:43 a. m. November 14, distance 20 miles. not reported felt. The third was felt at Hilo and at Hawaii National Park, 4:36 p. m. November 26, distance twelve miles.

Three very-feeble shocks were felt near the volcano. The first was felt at Uwekahuna, at 11:35 a. m. November 9. The other two were felt at a location about two miles east of the Observatory at 2:28 and 2:32 a. m. H. S. T. The first was about 2, and the two later ones about 15 and 16 statute miles distant. Only one of the above six earthquakes was reported felt from more than one place or by more than one person. They were number I Rossi-Forel scale.

The preliminary of a teleseism was recorded at 6:26:43 p. m. H. S. T. November 12 Dispatches place the epicenter in the Sea of Japan.

A.E.J.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinoscope readings at Halemaumau Southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory since November 27, 1931 is 3."8 South and 7."3 East.

TABLE OF TILT

Date	Observatory	Halemaumau
Oct. 31 - Nov. 6	0."4 SW	13."8 S
Nov. 7 - Nov. 13	0."9 ESE	8."2 WNW
Nov. 14 - Nov. 20	0."8 SE	12."8 SSW
Nov. 21 - Nov. 27	2."9 NE	31."3 NNE

E.G.W.

Results of One Year's Crack Measurements

In the Monthly Bulletin of the Haw. Volc. Obs., Vol. XV, No. 7, on page 54 is the following statement by Mr. R. M. Wilson, then engineer at the Observatory, "Thinking that the steadiness in the widening of the cracks may prove interesting, 15 points for routine measurements were marked and measured along the east rim." These concentric cracks were measured in 1927-28 with some degree of regularity by Mr. Wilson. In 1929-30 the measurements were at irregular intervals.

Topographic Engineer E. G. Wingate on coming to the Observatory in 1931 extended the number of points observed and made some changes in the method of measurement to increase their accuracy. The work is done with special calipers inside of gaping rock fissures marked with paint. Routine observations were begun at weekly intervals for all points and any showing excessive movement are measured once a day or oftener. The points are also measured after any felt quakes of moderate intensity.

In the table are given the results of observations for one year. The last column shows the total accumulated movement through the year for each numbered point observed. And, though it will be noted that all except three points have shown an increase in width, the condensed table cannot show how this took place, wether by a slow gradual opening of the crack or in sudden jerks accompanying earthquakes. Actually both of these movements occurr, and in certain areas where avalanching from the walls and rim has later taken place, the movement has been accelerated up to the time of collapse.

A review of all the observations taken during the year shows two dates when a moderate quake accompanied a sudden opening of cracks. These were Dec. 7, 1931, when the opening was general but slight, and on Dec. 23, between 9:00 a. m. and 11:00 a. m., the shock preceding the last eruption accompanied moderate opening at most of the points, though some were unaffected and three indicated a slight closing of the crack.

Crack point No. 30 illustrates the several kinds of opening described. This crack is on the east side of the pit eighty feet back from the rim. The points were set Nov. 23, 1931 and the original width was 20.05 cm. This width remained unchanged until the avalanche of Dec. 7, 1931 caused increase of 0.15 cm. A slow gradual widening then commenced. amounting to 0.15 cm. at 9:00 a. m. Dec. 23, 1931. When the points were again measured at 11:00 a. m. following the quake at 10:40, the crack had widened 1.°5 cm. During the eruption December 23 to January 5. and for five weeks thereafter an opening of 1 mm per week took place. This became 2mm Feb. 1, 1932 and from that time on until the spasm of quakes and avalanching on Mar. 4. 5, and 6, it exhibited the same acceleration of movement as was noted, more strongly, at several other points: attaining a maximum widening of 1.30 cm. per week and 0.40 cm. per day. From Mar. 7 to the last date

of measurement Nov. 26, 1932 a steady increase of 0.05 cm. every two weeks has been recorded.

Lack of space prohibits a more complete analysis of these observations here. In the appended table the measurements of Dec. 23, 1931 were made three hours before the last eruption commenced, and Mar. 7, 1932 is selected for comparison, as for the preceding several days avalanching had been general, doming up of the crater rim had been observed, and a swarm of earthquakes occurred on March 5. Widths are given in centimeters.

E.G.W.

Table of Crack Measurements, Rim of Halemaumau

Widths in Centimeters.

Point No.	Nov. 23, 1931	Dec. 23, 1931	Mar. 7, 1932	Nov. 26, 1932	Total widening
16	52.95	52.65	53.15	53.75	0.80
17	64.40	64.25	64.75	65.50	1.10
18	62.65	62.65	63.45	63.95	1.30
20	68.35	70.85	71.00	71.05	2.70
5	28.80	28.70	29.00	29.65	0.85
22	20.35	20.80	21.15	21.45	1.10
10	45.00	45.15	45.70	46.10	1.10
9	91.15	91.75	92.85	94.90	3.75
11	74.75	74.65	74.65	74.65	—0.10
24	22.10	23.00	23.25	23.30	1.20
25	37.75	49.35	49.50	Fell in March	6
25 New	.....	.....	20.05	20.70	0.65
28	17.30	17.80	18.95	18.75*	1.45
30	20.05	21.70	24.20	25.20	5.15
29	46.75	48.65	49.25	49.50	2.75
27	46.90	47.40	47.60	48.00	2.10
26	60.55	61.05	61.75	62.55	2.00
33	.....	46.65	49.30	49.15*	2.50
32 1931 Dec. 9.	16.45	16.80	16.80	16.80	0.35
34	.....	83.70	85.10	86.10	2.40
31 1931 Dec. 9.	20.85	22.60	32.65	Fell in March	6.
31 New	.....	.....	12.80	12.80	0.00
35 Aug. 23, 1932	.....	.....	86.55	86.65	0.10
36 Sept. 3, 1932	.....	.....	27.30	27.00	0.00
37 Nov. 11, 1932	.....	.....	23.90	24.00	0.10

* Indicates that point was disturbed.

E.G.W.

The Volcano Letter

No. 394—Monthly U. S. Geological Survey, Hawaii National Park DECEMBER 1932

KILAUEA REPORT FOR DECEMBER 1932

Including weekly press reports 1089 to 1093, November 27 to January 1 midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

The pit Halemaumau within Kilauea crater has shown no lava activity. It is floored with lava of January, 1932 at an average depth below Tourist Lookout southeast of 870 feet. (See map on back). There is a sulphurous patch at the west edge of the floor, where most of the blue fume arises. Excessive rain December 1-2 (3.25 inches) penetrated the hot lava, caused hundreds of vapor jets, and dull thuds were heard, becoming infrequent in the course of two days, and more like distant gun shots. Sliding of debris was continuous for a day. Much of the sliding left scars at the east wall. By December 10 the sliding was inconspicuous, and the bottom was clear, but steam through the south talus keeps the rocks wet. A mound near the center of the foor is cracked and sulphur-stained. There were slides north December 14, northeast December 17, and a western slide December 19 covered part of the sulphur patch. There were other small slides toward the end of the month.

For the summit crater of Mauna Loa the National Park Service reports no changes observed about December 12.

Measurements of rim cracks about Halemaumau edge showed 10 out of 23 crack points widened for the week ending December 3, thirteen December 10, four December 17, eight December 24, and six December 31. Crack point No. 9, which had widened 3.75 centimeters during the year ending November 26, 1932, was conspicuous as widening one or two millimeters per week, but this motion ceased December 24-31 for the first time in several months (see table, Volcano Letter No. 393).

Two new crack-measuring points were marked by Engineer Edward G. Wingate December 16, making the total 25 points (see map). The number of the crack is marked on the lava with white paint, and is recorded on the map. The measuring points are upright copper pins, one on either side of the crack, with a slight cut across the head. A steel tape is used to read directly the distance between the cuts to the nearest half millimeter. Closing together of crack walls is rare, opening out is the usual movement, but highly variable. Owing to fragments in the cracks, it is natural that they should fail to close: (see wedge theory of crater fills, Bull. Hawn. Volc. Obsy. Volume XII, No. 12, December 1924, page 120). The opening of a crack is due either to tension in the floor, or to migration of the inner slab toward the pit. If it is tension in the floor. it should correspond to upward arching of the floor of Kilauea crater, that is, upward pressure under Halemaumau pit. The cracks in question are mostly back from and parallel to the line of the pit edge. In some cases several measuring points are marked at different places along the same fissure.

Earthquakes

The following table shows the frequency of local earthquakes recorded by the seismographs of the Hawaiian Volcano Observatory at Kilauea Volcano. The weekly seismicity (seis., see Volcano Letter 371) is the summation of weighted numbers given each type of shock, as ¼ for a minute of volcanic tremor, ½ for a very feeble shock (v. f.), 1 for feeble (f), 2 for slight (sl.), and 3 for moderate (mod.). One, two, and three follow roughly the numbers of the Rossi-Forel Scale. The table shows the weekly number of occurrences of tremors (not by minutes) and of each type of shock . Teleseisms or large distant earthquakes are indicated by (tel.).

Dates 1932 to 1933	tr.	v. f.	f.	tel.	seis.
Nov. 28 to Dec. 4	35	1	1	1	10.25
Dec. 5 to Dec. 11	25	3	0	1	7.75
Dec. 12 to Dec. 18	33	3	0	0	9.75
Dec. 19 to Dec. 25	21	2	0	2	10.25
Dec. 26 to Jan. 1,	19	2	1	0	6.75

The average of weekly seismicity is about 80, so that these numbers stand for weak volcanic tremor and earthquake activity. In what follows the times given are Hawaiian Standard (H. S. T.), 10h 30m slower than Greenwich. Estimate distances are from phases on the seismogram, using travel-time curves modified by local experience.

A feeble local shock at 1:34 p. m. December 3, was reported felt in Puna. The approximate epicenter was placed at sea from 30 to 40 statute miles NE of Hilo.

A feeble shock was felt in Hilo, Glenwood, and at Kilauea crater at 1:21:05 p. m. December 27. It was about four miles SW of the observatory. A field trip was made into the area of the supposed epicenter, no fresh cracks were found, although there were many cracks opened by former eruptions and earth movements.

A very feeble shock was felt in Hawi, Kohala, December 1 at 8:21 p. m. A small record was found only on the Waikii record for that time.

A very feeble shock was reported felt in Pahoehoe and Pahala 7:04 a. m. December 26. Its epicenter was apparently under the SW rift of Mauna Loa.

A very feeble earthquake was felt at Kilauea and Pahoehoe 8:55 p. m. December 27. Its epicenter was probably in the desert 11 miles to the SW of the Observatory.

No other shocks were reported. The tremors were generally less than a minute in duration. December 19 there was a 15 minute period of tremor ending in a very feeble shock about 3 miles distant. December 22 there was one 3 minute period of tremor.

A record of a teleseism was recorded beginning 8:53:44 p. m. December 3. The P and S phases were recorded, the latter being doubtful. An epicenter was given in dispatches for an earthquake in the North Atlantic on this date. The P and L waves of the Nevada earthquake were recorded here, beginning at 7:47:18 p. m. December 20. A teleseism at 3:47:40 p. m. recorded four phases fairly well. The long waves of a teleseism were recorded at 6:15 a. m. December 7.

The seismicity for December has been slightly lower than the November seismicity, however they are both very close to an average of ten, which has been the average since March 1932.

A.E.J.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinoscope readings at Halemaumau Southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory since January 1, 1932 is 7.5″ South and 3.4″ East.

TABLE OF TILT

Date	Observatory	Halemaumau
Nov. 28 - Dec. 4	1.5″ WSW	20.3″SEE
Dec. 5 - Dec. 11	0.4″ SW	9.7″ SSW
Dec. 12 - Dec. 18	0.9″ ESE	5.2″ WNW
Dec 19 - Dec. 25	0.8″ NE	16.6″ NNE
Dec. 26 - Jan. 1, 1933	2.2″ SW	5.3″ SE

E.G.W.

Postal card earthquake records

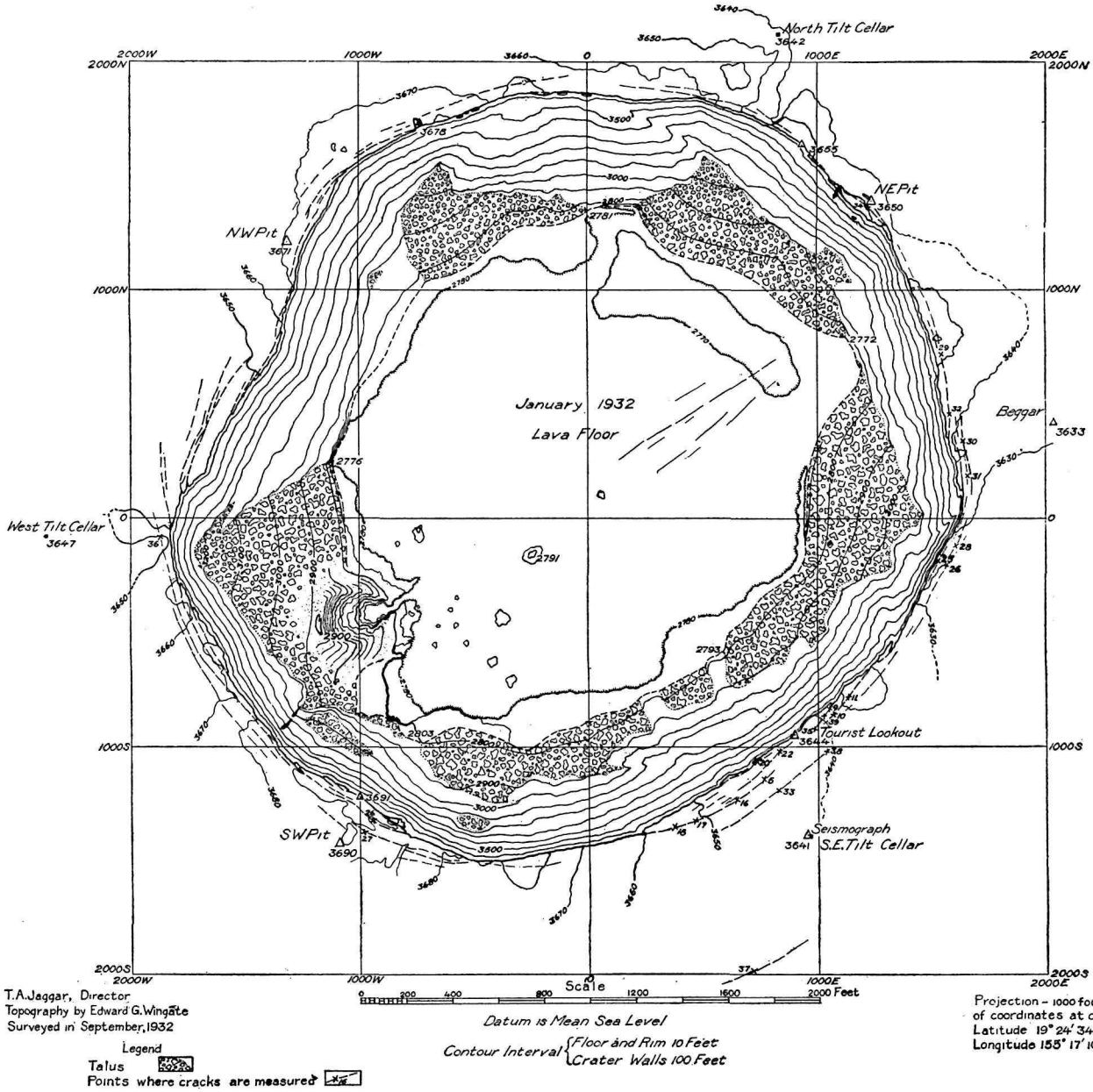
In March, 1932, special postal cards of the U. S. Geological Survey were placed at twenty-five stations on the island Hawaii, to be sent to Kilauea Observatory reporting felt shocks At the present time sixty-one card records of the new series are on file. These are of value in showing what shocks were general, and what ones were localized. A report of the results of these records will be published by A. E. Jones, seismologist. We shall be glad to supply other reporters who are interested. The following have earned the gratitude of the Observatory by sending in postals:—

L. P. Lincolu, Hookena
R. Lyman, Pahoa
J. B. Fordyce, Hawaii National Park
Kohala Sugar Co. Hawi
C. S. Ishii, Kamuela
R. Buzzard, Waikii
R. V. Woods, Kealakekua
J. B. Albert, Hilo
R. B. Hodges, Hawaii National Park
R. E. Baldwin, Hilo
R. L. Hino, Kukuihaele
Honokaa Sugar Co, Haina
Hutchinson Sugar Plantation Co. Naalehu
J. B. Oliver, Honomu
L. Loon Pahala
Hakalau Plantation Co. Hakalau
J. Johnston, Ookala
Kukuihaele Manager, Kukuihaele
E. Brumaghim, Hawaii National Park
Archdeacon Walker, Kohala
R. R. Craik, Hilo
W. Akau, Kawaihae
J. M. Ross, Hakalau

DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
HAWAIIAN VOLCANO OBSERVATORY

MAP OF
HALEMAUMAU

ISLAND OF HAWAII
KAU DISTRICT
KILAUEA CRATER
HAWAII NATIONAL PARK



T.A. Jaggar, Director
Topography by Edward G. Wingate
Surveyed in September, 1932

Legend
Talus
Points where cracks are measured

Datum is Mean Sea Level
Contour Interval { Floor and Rim 10 Feet / Crater Walls 100 Feet

Projection – 1000 foot grid. Origin of coordinates at center of map is
Latitude 19° 24′ 34″ N
Longitude 155° 17′ 10″ W

The Volcano Letter

No. 395—Monthly U. S. Geological Survey, Hawaii National Park JANUARY 1933

KILAUEA REPORT FOR JANUARY 1933

Including weekly press reports 1094 to 1097, January 1 to January 29 midnight

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Volcanology

There has been no activity on Kilauea or Mauna Loa. Small slides at Halemaumau were noted January 3, 4, and weakly at other times. Much steam developed on the pit floor due to heavy rains. Of twenty-five rim cracks measured each week about Halemaumau, slight widening was observed of only four January 7, nine January 14 about a sixteenth of an inch each, thirteen January 21, and seven January 28. It will be observed below that the seismicity was lowest the week when the most cracks opened.

Wingate has started triangulation of the eastern rift belt of Kilauea near Kalapana. Jones made the circuit of the island Hawaii on visitation of seismographs, and Jaggar started a salinity survey of the sea-water at Keauhou Bay, Kona. Hydrometer tests showed freshness conspicuous along shore and in top water near shore, while bottom water out to nine fathoms was highly saline.

Earthquakes at Kilauea

Table (see Volcano Letter December, 1932; for for seismicity index (seis) see Volcano Letter 371)

Date	tr.	v. f.	f.	tel.	seis.
January 2 to 8	24	4	0	1	8.00
January 9 to 15	30	1	1	0	9.00
January 16 to 22	16	1	0	1	4.50
January 23 to 29	32	1	0	1	8.50

No shocks were felt at the observatory and none was reported from other parts of the island. The one feeble shock recorded at 0:45 p. m. January 11 evidently occurred at sea, about 20 to 30 statute miles northeast of Hilo. It was preceded during the noon hour by four foreshocks or tremors at unknown distance. Also a very-feeble shock, about 200 miles west to southwest of Hawaii, preceded it. This very-feeble shock was probably in the vicinity of a large submarine mountain. Following these two shocks were 11 tremors, the swarm ending at 1:54 p. m. January 12. Six of these tremors indicated distances of from 37 to 135 statute miles. A second swarm of 19 tremors was recorded January 28 and 29. It is not known whether or not these earthquakes occurred on one fault line.

The two earlier teleseisms were from New Guinea and the south Indian ocean, respectively: the last is as yet unknown.

A.E.J.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory and from clinoscope readings at Halemaumau Southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory since January 29, 1932 is 8.1" South and 1.5" East.

TABLE OF TILT

Date	Observatory	Halemaumau
Jan. 2 - Jan. 8	0.8" SSW	13.6" SW
Jan. 9 - Jan. 15	0.6" SSE	21.3" NNE
Jan. 16 - Jan. 22	0.9" SE	20.1" NE
Jan. 23 - Jan. 29	1.1" SSW	4.6" E

E.G.W.

Waikii Seismograph Station

The Waikii Station on Hawaii island (mentioned in Volcano Letter 388) is in charge of the Radio Engineer of the Mutual Telephone Company in the grounds of the radio telephone establishment on the western slope of Mauna Kea. It is financed by the Hawaiian Volcano Research Association like the stations at Hilo and Kealakekua. We are indebted to Mr. A. W. Carter of the Parker Ranch for permission to install on this land, and to Mr. J. A. Balch of the Telephone Company for cooperation in the work.

The elevation is 4700 feet, the location Lat. 19 degrees, 51 minutes, 57 seconds North, Long. 155 degrees, 39 minutes, 7 seconds West. The seismograph is a two-component Hawaiian type horizontal pendulum apparatus (Bull. Hawn. Volc. Obsy. XVI, No. 8, August 1928) and was set up by A. E. Jones during October 19 and 20, 1932. The observer is Ralph Buzzard. The time service is from a Howard master pendulum clock checked by radio time from U. S. Naval Station, Pearl Harbor, Honolulu.

The piers are still settling and very little performance of earthquake registration has yet been obtained from this station. The seismograms are on smoked paper and are studied and recorded at the Hawaiian Volcano Observatory at Kilauea Volcano, Hawaii National Park.

T.A.J.

LASSEN REPORT No. 32

A report of measurements at the Lassen Volcano Observatory in California during the Calendar year 1932 indicates no crateral activity. C. A. Huff made experiments to synchronize the time markings by wired wireless on three seismographs Mineral, Viola and Harkness, work still awaiting completion. Tilting of the ground appeared to be mostly seasonal and a function of temperature.

The seismographs at Mineral recorded 83 local earthquakes as follows:—

January	3	July	9
February	2	August	15
March	2	September	2
April	0	October	13
May	6	November	5
June	20	December	6

The number of local earthquakes here registered per year has been:—

1927	266
1928	37
1929	96
1930	74
1931	38
1932	83

The indicated distance to origin of most of the local earthquakes of which the seismograms permitted measurement ranged from 12 to 20 kilometers, for the 1932 records.

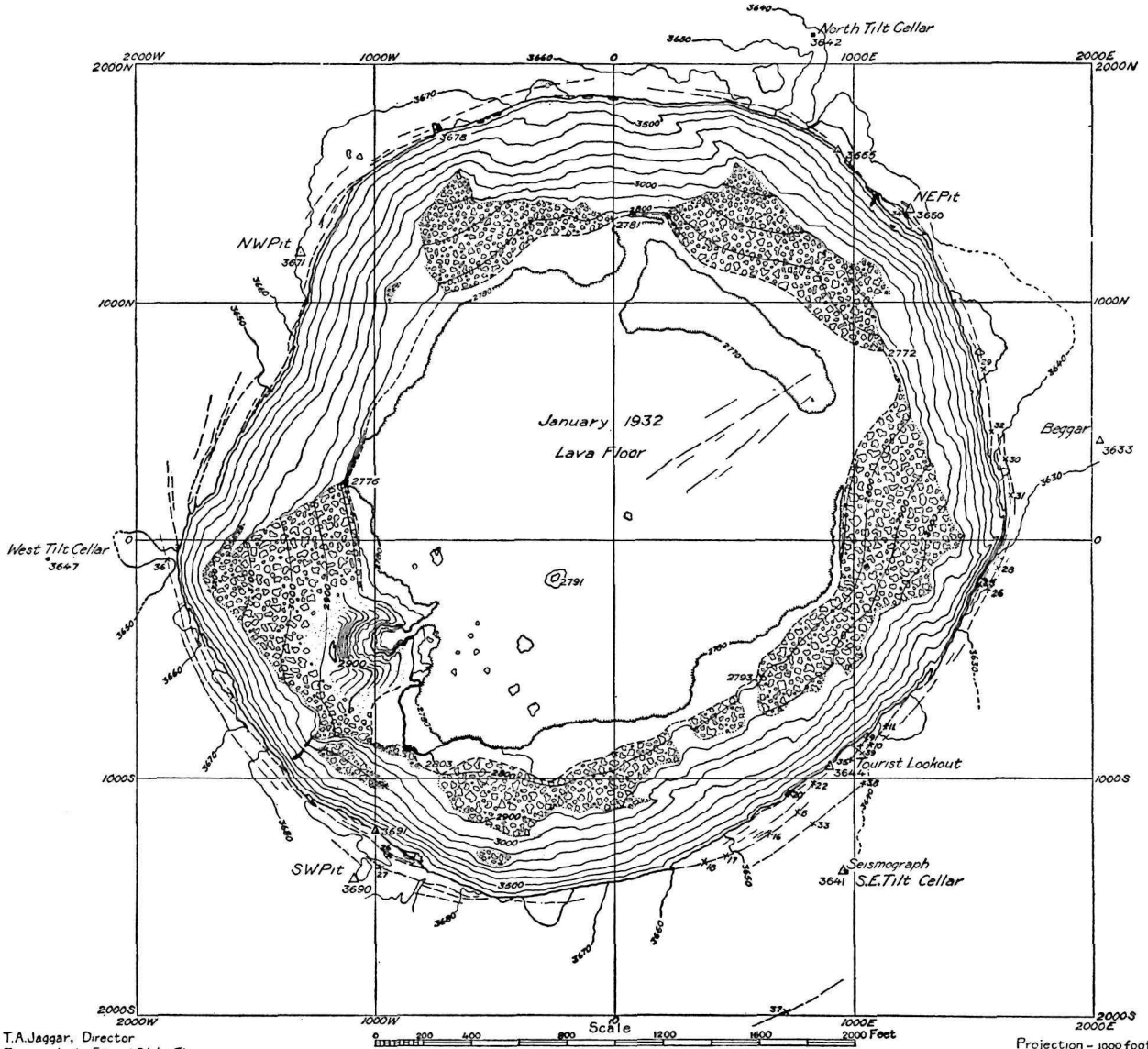
For the hot springs and steam vents, temperatures Fahrenheit measured mostly in August showed Supan's Big Steamer 192-194°, with vent enlarged toward the west, and mud ejected beyond the south rim. The New Vent of Diamond Peak gave 198°. The Lassen Crater vents 120, 142 and 146°. Bumpass Hell registered about 193°. Boiling Lake gave 124 to 148° in the water, 192 to 200° in the mud and steam vents. Terminal Geyser was 198°. Devil's Kitchen gave 196 to 200°, the big steam jet boiling with great vigor and slight overflow. Little Hot Springs Valley October 31 measured 198° imperfectly, the high velocity of escaping steam preventing proper use of thermometer. Morgan Springs gave from 148 to 202°. Supan's line of stakes showed slipping between No. 0 and No. 2 of 1.1 feet, a displacement which was distributed back to 0 between No. 2 and No. 5.

R. H. Finch

DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
HAWAIIAN VOLCANO OBSERVATORY

MAP OF HALEMAUMAU

ISLAND OF HAWAII
KAU DISTRICT
KILAUEA CRATER
HAWAII NATIONAL PARK



T.A. Jaggar, Director
Topography by Edward G. Wingate
Surveyed in September, 1932

Legend
Talus
Points where cracks are measured

Datum is Mean Sea Level
Contour Interval { Floor and Rim 10 Feet / Crater Walls 100 Feet

Projection – 1000 foot grid. Origin of coordinates at center of map is:
Latitude 19° 24′ 34″ N
Longitude 155° 17′ 10″ W

The Volcano Letter

396

No. 396—Monthly U. S. Geological Survey, Hawaii National Park FEBRUARY 1933

KILAUEA REPORT FOR FEBRUARY 1933

Including weekly press reports 1098 to 1101, January 30 to February 26 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

There is little to report for the Hawaiian volcanoes which have been apparently entirely quiet during the month of February 1933. There has been much rain which produces visible vapor plumes on the bottom of Halemaumau pit of Kilauea volcano. Rock slides from the pit wall have been rare, and the clinoscopes around the pit have generally shown little tilt, though the southeast station recorded below always shows larger tilts than the Observatory on the northeast rim of the larger Kilauea crater. The record there of 50.2 seconds January 29—February 5 checked with excessive temporary pooling of rain-water close to the hut; the rainfall was 6.16 inches in two days January 30-31.

Crack measurements around Halemaumau rim at 25 points showed five very slightly opened February 4th, eight February 11th, six opened and four closed February 18th, twelve opened and three closed February 25th. The aggregate opening for the twelve was only 1.36 millimeters.

A report of a tidal wave at Kaupoa on the west end of Molokai at night about February 14, with heavy surf flooding inland 100 to 200 feet horizontally, may indicate the aftermath of extraordinary westerly wind which produced unusual wave bombardment accompanied by very heavy microseisms at the seismographs the first part of the month. Thus it will be seen that meteorological conditions of rainfall and wind, as mentioned in this report, may produce seemingly seismic effects.

T.A.J.

Earthquakes at Kilauea

TABLE

(Numbers of tremors, very feeble and feeble local earthquakes: teleseisms or distant earthquakes: and local seismicity index described in Volcano Letter 371)

Week ending	tr.	v. f.	f.	tel.	seis.
February 5	22	1	1	0	6.75
February 12	29	2	0	0	8.25
February 19	22	4	0	0	7.25
February 26	32	2	0	1	9.00

The feeble shock at 6.17 a. m. February 4 was reported felt at Holualoa, Hakalau, Hilo and the Hawaii National Park. The location as found from three stations was about 50 statute miles due south of the observatory.

The following very-feeble shocks have been located.

9:12 p. m. January 31, was placed 15 to 20 miles east of East point. This location is given for the reason that it was not recorded at the Kona seismograph station.

11:56 a. m. February 10 was located 33 miles deep under a point half way between Kilauea and Mokuaweoweo craters.

8:24 p. m. February 13, distances from four stations, placed it in NW Kohala. The depth was possibly less than 5 miles.

Two earthquakes were felt in Honokaa. The first at 0:38 p. m. February 16 was located 23 miles deep under the peak of Mauna Kea. The second at 7:14 p. m. February 18 was located 7 miles deep under Ookala on the Hamakua coast. Both of these shocks were registered at four seismograph stations. The second was recorded as a tremor at the Hawaiian Volcano Observatory.

0:29 p. m. February 18, did not record at the Hilo station but with the aid of the Waikii record it was located 35 miles deep under a point 7 miles NE of Mokuaweoweo crater.

10:30 a. m. February 21 was located 20 miles deep under Mauna Loa.

8:00 a. m. February 22 was located about 12 miles at sea, 1 to 5 miles deep on the probable extension of the Kilauea SW rift.

Two others that could not be located were probably a short distance at sea.

Nine tremors showed some slight evidence of having originated some distance at sea. In one case as much as 500 kilometers or 300 miles away from the observatory.

A.E.J.

Microseisms

This motion of the ground appears to be prevalent throughout the world. Abnormal, large or strong microseisms have been correlated with large ocean waves or seas striking on the steeper coasts of the regions studied. In Europe the correlation has agreed with heavy surf on the coast of Norway. In North America they have been correlated with strong waves pounding the coast of Labrador. The change from light to moderate to strong and reverse is not abrupt. The transition between steps takes place slowly, often taking hours or a day to change from normal to abnormal. They have not been correlated definitely for the Island of Hawaii, but appear to vary with variations in the strength and direction of the sea waves. Ordinarily the time for a complete period, or motion of the ground to and fro, is 4 seconds, rarely it is 3 or 5 seconds.

The following inclusive dates under abnormal and subnormal give the intensity of the microseisms at this station since last published.

Abnormal	1932	Subnormal
Nov. 18, 24, 25.		May 23.
28, 29, 30.		May 28 to June 7.
Dec. 8, 10, 11.		June 11, 13, 14, 17, 18, 21.
22, 23, 24.		June 24 to July 1.
28, 29, 30		July 4 to 9.
		July 17, 18, 24.
		July 26 to 29, and 31.
		Aug 2 to 6, and 9 to 16.
		Aug. 25, 26
		Sept. 1, 2, 5, 6, 8, 15.
		Oct. 8, 9, 28, 29, 30, 31.
		Nov. 22.
		Dec. 3.

Abnormal	1933	Subnormal
Jan. 12.		Jan. 2 to 7
Feb. 4 to 7.		Jan. 19 to 30
Feb. 9 to 11		Feb. 18, 19

A.E.J.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory and from clinoscope readings at Halemaumau Southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory since February 26 1932 is 7.5″ South and 1.5″ East.

TABLE OF TILT

Date	Observatory	Halemaumau
Jan. 29 - Feb. 5	3.4″ SW	50.2″ SSW
Feb. 6 - Feb. 12	1.8″ S	9.0″ SSW
Feb. 13 - Feb. 19	1.1″ SSE	2.4″ ENE
Feb. 20 - Feb. 26	0.3″ SW	14.6″ NE

E.G.W.

The Volcano Letter

No. 397—Monthly U. S. Geological Survey, Hawaii National Park MARCH 1933

KILAUEA REPORT FOR MARCH 1933

Including weekly press reports 1102 to 1106, February 26 to April 2 midnight

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Volcanology

March of 1933 was eventful in the seismic world by producing a terrific submarine earthquake east of Japan, and the so-called Long Beach earthquake disaster in the Los Angeles region of California. Hawaii suffered from the former with a tidal wave. But the volcanoes of Hawaii remained at peace.

The first week of the month was rainy, on March 5 in the forenoon rocks were heard falling frequently from the walls of Halemaumau pit at Kilauea after heavy rain March 4, there was moderate blue fume, and numerous small jets made plumes on the lava floor of the pit. Ponds of water had accumulated on the Kilauea crater floor. A small slide fell from the east end of the north buttress at 11 a. m. March 11; there were yellow scars on the east wall and fresh debris south. On March 18 a rim block southwest showed new cracks, a slide had fallen from a shell-shaped pocket in the northeast wall of the pit, and sulphur stain had incresased on top of the inner 1932 cone. During the forenoon March 25, slides occurred at the south 9:35 a. m., west of the north buttress at 10:16 a. m., then a third was heard, and the pit walls showed fresh scars. On April 1 the walls were quiet.

The weekly measurements of rim cracks at Halemaumau gave results as follows; March 4, 7 points opened out of 25, a few slightly closed, maximum motion at a single crack a widening of 1.5 mm., aggregate opening of all 3.5 mm. March 11,15 points out of 25 opened by slight amounts. March 18, 9 points out of 26 opened by slight amounts of 1.5 mm or less. March 25, 12 points out of 26 opened, maximum single opening 2.5 mm. both ends of a rim block southeast showed slight acceleration of opening at the back of the block, and a crack back of a block southwest opened 1.5 mm. April 1, 12 points out of 26 opened 1 mm or less mostly southeast and south.

Volcanologist Jaggar visited Waikii seismograph station March 14, and Honokaa shock-recorder station conducted by Mr. Pritchard March 15, and made tests at Keauhou Kona March 19 with hydrometers and bottom samplers furnished to the Observatory by the U. S. Coast Survey. Engineer Wingate prepared ground near Kapoho and Kalapana in Puna for triangulation towers to be built by the Hawaiian Volcano Research Association, capable of enduring for thirty years of repeated tests for ground movement. An experimental earthquake annunciator was set in operation at the Observatory, capable of releasing a four-point electric indicator in a room above, for grades one, two, three and four of an earthquake intensity scale. Seismologist Jones built a non-tilt attachment for improving the seismograph registration at Waikii, where the nature of the ground has given trouble with tilting effects and other movements which obscure the true seismic motion.

T.A.J.

Earthquakes Recorded.

TABLE

Number of tremors, very feeble, and feeble local earthquakes; teleseisms or distant earthquakes: and local seismicity index described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	tel.	seis.
March. 5	17	2	0	1	5.25
March. 12	24	4	0	1	8.00
March. 19	20	2	0	0	6.00
March. 26	21	4	0	0	7.25
April. 2	31	4	0	0	9.75

An earthquake was felt at Honokaa February 27 at 8:46 p. m. H. S. T. It recorded on the observatory instruments as a tremor, and indicated a distance of 52 statute miles. This would place it under Waipio valley at the greatest possible horizontal distance.

A very feeble shock was recorded at 9:13 p. m. February 28. It has been located at lat. 19° 42.5′ N; long. 156° 05′W near Keahole Point.

A tremor recorded at 5:24 p. m. March 8 was located about 22 miles west of Keauhou Bay on the west side of Hawaii.

A very feeble shock recorded at 5:29 p. m. March 8, was located 7 miles deep under Hilina Pali (a fault scarp cliff). A second very feeble shock at 10:40 p. m. may have occurred on the same fault. It was not so well recorded at Hilo.

A very feeble shock at 10.02 a. m. March 9 was located approximately under Palima Point. It was reported felt in Pahala and in the vicinity of Kilauea crater.

A very feeble shock at 1:08 a. m. March 25 was located 13 miles deep under Napau Crater.

An earthquake felt at Kamuela at 1:55 a. m. March 28 was recorded at the observatory as a tremor. It was not recorded well enough on the other stations to be located. A second shock at 4:26 a. m. was felt as far south as Honomu. It was also reported from Honokaa, Kamuela and Waikii. Distances from two stations placed it 1 to 3 miles deep under central Kohala.

Two very feeble shocks and two tremors occurred less than 3 miles from the observatory, this would place them close to or in the Crater of Kilauea.

The teleseisms listed above were destructive near their epicenters. The location of the first near the coast of Japan was given by the U. S. C. & G. S. as at lat. 39° N long. 142° E. The arrival of the first preliminary was at 7:10:32 a. m. March 2 H. S. T. (10h 30m slower than Greenwich).

The location of the second, March 10 near the California coast was given by the Jesuit Seismological Association as lat. 32° N 118° W. Only the surface waves recorded at H. V. O. This was the Long Beach earthquake.

Microseisms were abnormal or strong March 4 & 5, they were subnormal or light March 12, and from March 21 to April 2.

A.E.J.

Tsunami or earthquake tidal wave March 2, 1933

The distant earthquake on the sea-floor about 7:10 a. m. Hawaiian time as registered at the Kilauea stations, occurred at the western edge of the Tuscarora Deep, 125 miles east of Matsushima, Japan, and near this place the ocean is more than 26,000 feet in depth. The elastic wave through the earth took 10 minutes to reach Hawaii. It registered on the seismograms at Kilauea, Kona and Hilo as a very big movement for several hours, too slow to be felt. The indicated distance was 3950 miles in the azimuth of Japan. The hour and date were 2:31 a. m. March 3 by Japan time.

It was immediately apparent to A. E. Jones, seismologist at Kilauea, and to R. V. Woods, seismograph operator for the Hawaiian Volcano Research Association at Kona on the west side of Hawaii, that a tidal wave in the Pacific ocean might occur. The Radio News Broadcast announced the Japanese earthquake as a disaster about noon March 2 in Hawaii. Radio thus confirmed the notion that the water wave should come from the west, at a time before the water wave had arrived at Hawaii. Travelling 450 miles per hour, such a wave should reach Hawaii 8½ hours after the earthquake occurred.

Mr. Jones notified the Hilo Harbormaster about 10

a. m. to look for a wave about 3:30 p. m. The sampan fleet in the river was moved out to anchorages in the harbor, the waves came at 3:36 p. m., and the range of maximum motion in Hilo was from two to three feet, on the east side of Hawaii; time within six minutes of the expectancy indicated.

Captain Woods on the west side notified American Factors at Kailua and at Napoopoo, and the Captain Cook Coffee Co. that the wave might come about nine hours after 7 a.m. The waves came at the time appointed with great force on the western side of Hawaii, the side towards Japan. They came in a series of swings of the water for hours, beginning with recession. They began about 3:20 p. m. at about ten minute intervals, and the seventh wave was reported the greatest at Napoopoo. There the water receded below mean tide eight feet, rising above mean tide 9½ feet, total vertical range 17½ feet.

The sea-bottom was left bare over wide tracts of the bays at Napoopoo, Kailua, Keauhou and even at Kaalualu at the southeast end of Hawaii. Walls washed down, boats were unmoored and capsized, houses were flooded and moved, lumber was displaced, objects were washed out to sea, damage was done to interior furniture of houses, automobile lorries were flooded so that engines were damaged by sand, and goods were washed off wharves. At Napoopoo the events of 1896 and 1923 were remembered, and cargo was removed from the wharf in expectation of the wave.

At Honolulu the tide gauge made twenty fluctuations in 4 hours, making each complete wave average twelve minutes period. The waves were noted at Kauai, at west Oahu, at Lahaina, and were somewhat damaging at Kawaihae and vicinity on the northwest shore of Hawaii. The train of waves struck Midway Island between 11:05 a. m. and 1 p. m., Honolulu beginning 2:40 p. m., the west side of the island Hawaii 3:20. p. m., and Hilo 3:36 p. m. all progressively farther from the Japanese source.

In Japan there was a great disaster in Iwate province from both earthquake and tidal wave, with reported loss of 1535 lives, 2000 wounded, 7930 houses, 1570 boats, and millions of dollars of property damage at the ports of Kamaishi, Miyako, Yamoto and Omoto.

T.A.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in a year since April 2, 1932 at the Observatory has been 2.2 seconds south, and 2.1 seconds west.

TABLE OF TILT

Date	Observatory	Halemaumau
Feb. 26 - Mar. 5	3.3″ SSW	21.4″ SSW
Mar. 6 - Mar. 12	0.9″ NE	7.5″ North
Mar. 13 - Mar. 19	2.2″ WSW	5.2″ East
Mar. 20 - Mar. 26	0.3″ NW	15.9″ NNE
Mar. 27 - Apr. 2	1.6″ SW	6.5″ NE

E.G.W.

The Volcano Letter

No. 398—Monthly U. S. Geological Survey, Hawaii National Park APRIL, 1933

KILAUEA REPORT FOR APRIL 1933

Including weekly press reports 1107 to 1110, April 2 to April 30, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

The weather at the volcano Kilauea the first week in April was stormy, with thunder, lightning and southerly wind. No crateral changes of importance were observed in the quiet Halemaumau lava pit of Kilauea, nor on the summit of Mauna Loa. There was no sliding of rocks at the Halemaumau walls. A National Park party led by Ranger Fordyce, and accompanied by seismologist Jones, went to Mokuaweoweo, the summit crater of Mauna Loa April 10-12, encountered cold weather with snow, but discovered no new solfataric activity nor steaming.

At Halemaumau April 10 there were falls of rock from the northern walls, and a small avalanche fell from the notch at the east side of the north buttress at 9:35 a. m. During heavy rain there were numerous vapor jets at cracks in the lava floor, and this continued during cessations of the rain. A large pool of water near the southeast tilt cellar did not induce visible tilt at the clinoscope. On April 17 a dusty avalanche scar was discovered, 200 feet wide, extending from top to bottom of east wall of pit. The debris had landed on talus below. The east end of the canoe sill northeast had been breaking away, and rocks fell there from time to time. On April 19 there was similar falling of rocks, while small trickling slides and rock falls continued April 20. There were a few rocks falling April 26, but none during the forenoon of April 29.

Measurement of rim cracks about Halemaumau was recorded weekly as follows:—April 8, 8 points out of 26 opened 1 mm or less, 2 cracks slightly closed. April 16, 9 cracks out of 26 made aggregate opening of 6 mm. April 17 crack point No. 11 just above the new east avalanche scar had closed 2 mm, while four other nearby points had opened each a half millimeter. April 19 a newly moving crack showing broken ground on the southwest rim was found opening a quarter millimeter per day. April 22, 14 points out of 27 opened 2 mm or less, mostly at east side. April 29, 10 points out of 27 opened, 2 slightly closed, aggregate opening with these deducted making 6.5 mm.

T.A.J.

Earthquakes Recorded.

TABLE

Number of minutes of tremors, very feeble and feeble local earthquakes; teleseisms or distant earthquakes; and local seismicity index described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	tel.	seis.
April 9	34	4	0	2	10.50
April 16	65	2	1	0	18.25
April 23	45	2	0	0	12.25
April 30	49	3	1	2	14.75

Hawaiian Standard Time is 10h. 30m. slower than Greenwich.

Spells of 5 and 16 minutes of tremor were recorded the first two weeks of the month. One tremor, recorded at the Kilauea station and at Hilo about 0.28 a. m. April 9, gave larger records as a local earthquake at the Kealakekua and Waikii stations. It was located seismometrically as at the northwestern shore of Hawaii, about 14 miles deep, under Kiholo Bay, Lat. 19° 15′ N.—Long. 155° 54′ W.

A feeble shock, felt in Hilo, at 4:10 a. m. April 16, was located as at sea a short distance WSW from Kalapana, 20 miles deep, Lat. 19° 13′ N, Long. 155° 03′ W.

A very feeble shock was well recorded at four stations at 0:11 a. m. April 30. It was located under a point a short distance out to sea, 12 miles deep, along the extension of the Kilauea SW rift zone, Lat. 19° 13′ N., Long. 155° 18′ W.

A feeble earthquake at 5:24 a m. April 30 was felt at Kilauea and located slightly south of Kilauea crater (3 miles) as 20 miles deep, Lat. 19° 22′ N., Long. 155° 17′ W.

A moderately large record of an Alaskan earthquake from Lat. 61° N, Long. 150° W. was registered on April 26. Only the surface waves of the three other teleseisms were recorded here.

Microseismic motion was abnormally large April 3 to 4; it was subnormally light on April 10, and from 12 to 30.

A.E.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in a year since April 30, 1932 is 4.6 seconds south, and 3.7 seconds west.

TABLE OF TILT

Date	Observatory	Halemaumau
April 3 - 9	2.7″ SW	24.3″ SW
April 10 - 16	0.6″ SSE	5.7″ NNE
April 17 - 23	1.3″ ENE	10.5″ NE
April 24 - 30	1.0″ SW	4.2″ NE

E.G.W.

The Volcano Letter

No. 399—Monthly U. S. Geological Survey, Hawaii National Park MAY, 1933

KILAUEA REPORT FOR MAY, 1933

Including weekly press reports 1111 to 1115, April 30 to June 4, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

No renewed lava outpouring has appeared in Hawaii. The last such activity was in Halemaumau pit in January 1932. At this pit within Kilauea crater at 8 a. m. May 6 there was trickling of rock fragments down the inner walls. On May 10 fresh scars from a slide were found on the east wall. The fall of rocks had occurred during the preceding night, and at the ends of old rim cracks on top, fresh hair cracks had developed in the soil. One rock was heard to fall in the morning. During the third week a slide fell from the west wall, where there had been little motion for several months past. Slight slides continued. June opened with only the promise based on statistics, that activities during this century have averaged once a year, and now a year and a half of quiet have gone by.

Weekly measurement of twenty-seven rim cracks around Halemaumau yielded the following results: May 6, 5 cracks opened slightly, 1 closed a haif-millimeter, net aggregate opening 3 mm, mostly southeast; May 13, 10 opened and three closed, aggregate opening 4.5 mm; May 20, 15 opened and 4 closed, aggregate opening 12 mm; May 27, 8 opened and 2 closed, aggregate opening 4 mm; on May 30 a crack on the northeast rim had opened ½ mm in three days; June 3 the weekly measurement showed 15 opened and 3 closed, making net opening 9.5 mm. All this work is directed by Engineer Wingate.

T.A.J.

Earthquakes Recorded.

TABLE

Number of minutes of tremors; very feeble and feeble local earthquakes; teleseisms or distant earthquakes; local seismicity index described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	tel.	seis.
May 7	32	4	0	2	10.00
May 14	39	3	2	0	13.25
May 21	27	5	0	0	9.25
May 28	33	6	1	0	8.00

Hawaiian Standard Time is 10h. 30m. slower than Greenwich.

The following locations of earthquake origins were derived seismometrically from measured seismograms of the four principal stations on Hawaii, Kilauea, Kona, Waikii and Hilo; 3:50 p. m. May 2 under the divide between Mauna Loa and Hualalai; 7:30 p. m. May 9, felt moderately at Puu Ulaula rest house on northeast rift of Mauna Loa, 5 to 12 statute miles deep under that part of the mountain; 6:54 p. m. May 17 a shock felt at Hakalau, on the northeast coast of Hawaii, under a point about 1 mile out to sea from that village, and 15 miles deep. A very feeble shock May 20 was located under the northeast rift of Mauna Loa. A shock 0:21 a. m. May 24, felt at Honokaa, was located on the west shoulder of Mauna Kea, Lat. 19 degrees 49 minutes N., Long. 155 degrees 37 minutes W.

Other local earthquake centers were as follows: 7:31 a. m. May 24, felt at Honokaa, Lat 20 02 N. Long 155 31 W, 3 miles deep, halfway between Mauna Kea and the ocean to the north; 7:48 a. m. May 25, very feeble, Lat 19 55 N, Long 155 35 W, under the northwest shoulder of Mauna Kea, and not over 5 miles deep; 11:38 a. m. May 27, feeble and felt at Kilauea Observatory, Lat 19 27.5 N, Long 155 27.5 W, under a point half way between Kilauea Crater and the Mauna Loa crater, 7 miles deep; 1:47 a. m. May 28, felt at Holualoa in North Kona, approximately at sea off Keauhou Bay.

The distant earthquakes, only partially recorded, beginning 8:37 a.m. May 1, and 6:00 p. m. May 4, were from unknown locations. Microseismic motion was mostly subnormally light for the month, becoming normal at the beginning of the second, and throughout the third week in May.

A.E.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in the year since May 28, 1932 at the Observatory has been 7.8″ south, and 4.0″ west.

TABLE OF TILT

Date	Observatory	Halemaumau
May 1 - May 7	1.0″ WSW	1.3″ NNE
May 8 - May 14	0.3″ SW	0.9″ SSE
May 15 - May 21	1.8″ NE	4.9″ NW
May 22 - May 28	0.8″ WNW	0.0

Halemaumau readings for May show exceptional quiet as compared with other months; the following is a comparison of net tilt by months at Halemaumau southeast, and average rim crack openings by months for the whole 27 marked crack points. If these figures show anything, it is that the crack widening lags behind the tilts. The tilt movements notably alternate between northerly and southerly.

Average crack opening	Halemaumau Tilt by months	
Jan. 0.0160 Cm	8.3 seconds	NNE
Feb. 0.0170	23.2	SW
Mar. 0.0310	18.1	NE
Apr. 0.0260	6.0	SW
May 0.0235	5.0	SW

Spirit Level Changes at Halemaumau

Levelling executed June 12, 1933 for comparison with similar measurements December 31, 1932, giving differences of elevation of points near Halemaumau relative to the datum station Spit southeast of Kilauea Crater resulted as follows; elevation of Spit 3646.93 feet:—

BM Seis June 12	plus (up)	0.02 foot
BM No. 1, Tourist June 12	minus (down)	0.05 "
BM Beggar " "	"	0.03 "
BM NE Pit " "	"	0.08 "
Crack point No. 18 " "	"	0.33 "

The accumulated tilt at the clinoscope of Halemaumau SE (BM Seis above) between December 31 and May 31 was 4.2 seconds of arc SW.

Triangulation in Puna

Field observations over the Puna Triangulation net were completed May 28th. Favorable weather aided the work, and seventeen stations were occupied between May 16 and May 28. Unchecked notes indicate a triangle closure of about 2.1 seconds for 39 triangles. A complete report on the survey will be prepared for June Volcano Letter.

E.G.W.

The Volcano Letter

400

No. 400—Monthly | U. S. Geological Survey, Hawaii National Park | JUNE, 1933

KILAUEA REPORT FOR JUNE, 1933

Including weekly press reports 1116 to 1119, June 4 to July 2, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Levels run about northeast rim of Halemaumau June 12 showed that the rim had generally lowered, less than one-tenth foot, since December 31, 1932. Weekly measurement of the 27 rim cracks at Halemaumau gave the following:—June 10, 7 points not more than ½ mm each. Two cracks forming a crescent block on the rim south and southwest, about 500 and 800 feet long, showed fresh hair fissures in the soil. June 12 similar cracks were found 100 to 150 feet back from the east and northeast rim. June 17 eleven points showed widening of 1½ mm or less, nine of these being at the east. Aggregate opening for all cracks was 7 mm. June 24 eight cracks had widened 1½ mm or less, mostly southeast, aggregate opening 5 mm. July 1 six points opened only a half millimeter each.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor, very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; local seismicity index as described in Volcano Letter 371.

Week ending,	tr.	v. f.	f	sl.	tel.	seis.
June 4	26	3	0	0	0	8.00
June 11	56	4	1	0	0	17.00
June 18	49	3	0	0	1	13.75
June 25	32	3	2	0	1	11.50
July 2	78	2	0	2	1	25.00

Hawaiian Standard Time is 10h. 30m. slower than Greenwich.

The teleseisms were only partly recorded.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in the year since July 2, 1932 at the Observatory is 4.9″ south and 2.2″ west.

TABLE OF TILT

Date	Observatory	Halemaumau
May 29 - June 4	0.3″ NE	1.4″ N
June 5 - June 11	0.4″ NW	2.7″ S
June 12 - June 18	0.8″ NNE	11.0″ N
June 19 - June 25	1.0″ NNE	10.8″ NNE
June 26 - July 2	0.9″ N	6.4″ NNE

E.G.W.

PUNA TRIANGULATION

Prof. C. Tsuboi, writing in the 'Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Vol. VI, March 1929 an 'Interpretion of the Results of Repeated Precise Levellings in the Tango District', remarks in the beginning, "In the country of Japan, from which a world-shaking earthquake originates not rarely, the scope of seismology naturally goes further beyond the study of propagation of purely elastic seismic waves and is extended to the investigation of those geophysical phenomena that are characteristic to the localities of the earthquake origin."

Similar studies were initiated by Dr. T. A. Jaggar in 1920, here in Hawaii, when he directed the work of Mr. R. M. Wilson in laying out and measuring the net of triangulation and levels about Kilauea Crater. This net was later re-surveyed by Mr. Wilson and the actual ground movements detected by this survey showed the value of applying engineering methods to the study of volcanic and seismic phenomena.

An expansion, by means of similar surveys, into known seismic belts on this island had been long contemplated, only a shortage of funds preventing an earlier beginning. The northeast rift of Kilauea, at its eastern end, was selected for the initial expansion. This section has had volcanic and seismic activity upon four occasons within the last hundred years. On the accompanying map the localities affected are shown by the date of occurrence.

The northeast rift of Kilauea is not a ridge but is a

The following locations are of local earthquakes well recorded at three or more seismograph stations on the Island or Hawaii.

Date	time	lat. N.	long. W.	depth	remarks
June 7	10;38 a.m.	19°;53′	155°;17′.5	10 mi.	not reported felt. S. of Ookala, W. of Hakalau.
June 9	4;55 p.m.	19°;26′.5	155°;42′.5	0 mi.	sharply felt. M. Loa, SW of summit, under 1851 lava flow.
June 15	6;26 p.m.	19°;36′	155°;16′	2 mi.	not reported felt. M. Loa NE rift.
June 19	7:33 p.m.	19°;12′.5	155°;25′	5 mi.	not reported felt. Kilauea SW rift.
June 20	0;32 p.m.	19°;26′	155°;16′.5	2 mi.	not reported felt. under Kilauea.
June 22	8;33 p.m.	20°;03′	155°;33′	7 mi.	felt by several. Mana, SW of Honokaa
June 25	1;15 a.m.	19°;24′	155°;15′	1 mi.	not reported felt. SE of Kilauea.
June 29	0;44 a.m.	19°;40′	155°;48′	0 mi.	moved furniture damaged stone wall. Hualalai shock.
July 2	7;47 a.m.	under Kilauea			not reported felt.

Depths are in statute miles below sea level. The microseismic motion was normal June 30 being subnormal or light during the remainder of the time covered by this report.

series of earthquake cracks, cinder cones, and pit craters, extending along the shoulder of a slope to the south and seaward, which begins at Kapoho and gradually becomes steeper to the west. Faulted cliffs appear to the westward of Kalapana. To inland, or north, there is but little slope away from the rift. The whole area is more or less densely covered with a low-level semitropical forest. At Pahoa, Kapoho, and Kaueleau are cane fields of the Olaa Sugar Co. The lava flow of 1840 followed a course eastward roughly paralleling the rift on the north. North from this flow the country rapidly changes to a grass-covered pahoehoe plain, with a thin growth of Ohia Lehua.

Reconnaissance was begun in January and together with the clearing of trails and lines of sight, the marking of stations, and the erecting of signals, consumed about four-fifths of the working time.

Existing triangulation, in this section of the Puna District, was fragmentary, being confined to four stations on the rift, with some six additional points along the shore, none of which had been determined through figures of any great strength.

The problem in laying out the new net was to get at least two stations, to the north of the rift and the last known cracks, so located as to serve, in a future re-survey, as a probably undisturbed base for computations. All of the stations along the rift, as well as those on the shore, are considered subject to change through volcanic and seismic causes. It was also desirable, with the instruments available, to hold the length of sights to a maximum of ten and a minimum of two miles. Two suitable points were finally found and are represented by the stations 'Makuu' and 'Kokoolau'.

Of the existing stations, listed in U. S. C. & G. S. Special Publication No. 156, only two were found unsuitable for use. The station 'Kamaili' was so located that no sight of sufficient length could be taken to the east, and 'Sand Hill', a cinder cone at the sea end of the 1840 lava flow, is gradually peeling off into the sea.

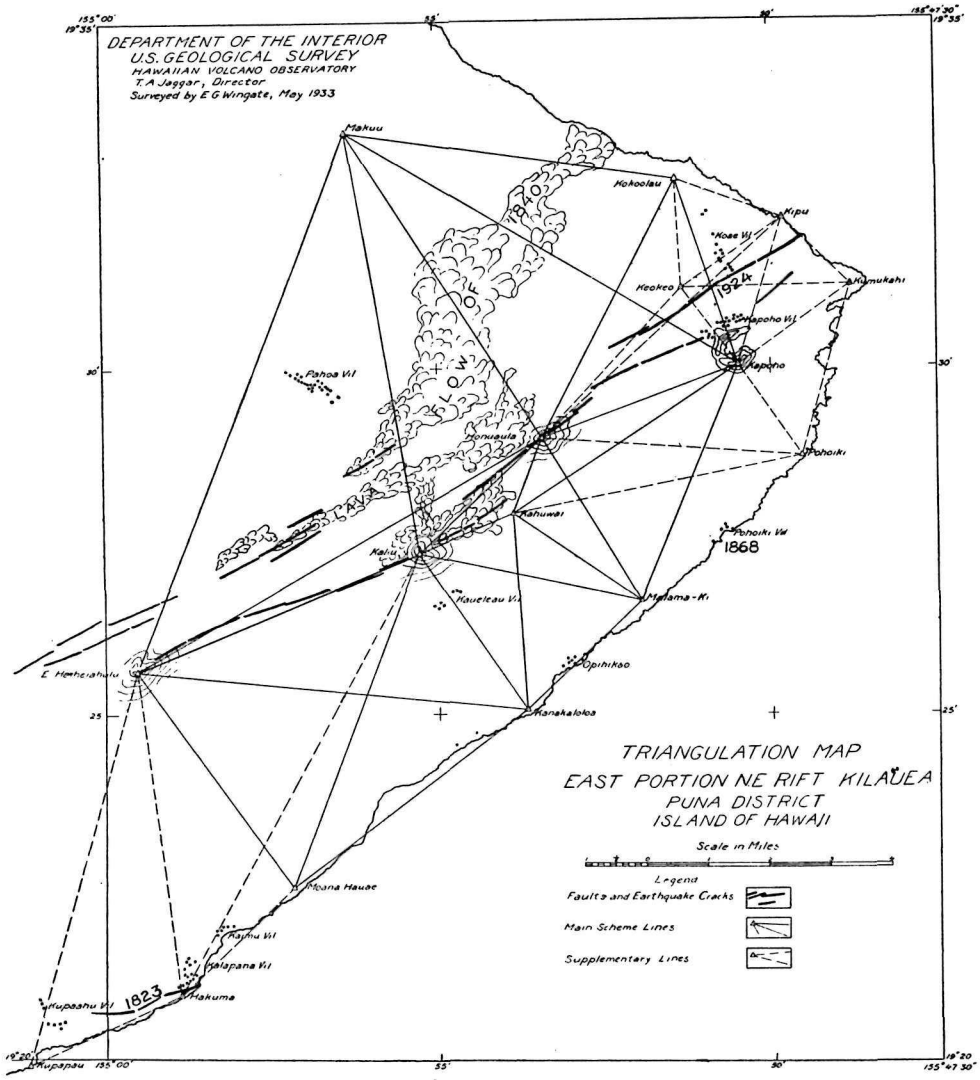
Two towers, of thirty and forty feet in height and of permanent construction, were erected under contract at stations 'Kanakaloloa' and 'Kokoolau' respectively. The observers' platform and scaffold were built around a separate, inner tripod to support the instrument.

The signals at E. Heiheiahulu, Kaliu, and Kapoho were of the new type adopted by the Hawaiian Territorial Survey and are described in 'Special Pub. No. 156' above. All other signals were 2x2 inch poles surmounted by cross targets of light weight galvanized iron, two feet square, painted in two colors, yellow and red. The signals were carefully centered by plumb line and all were erected within five days of the first observations.

The area surveyed was approximately ninety-five sq. miles and due to very favorable weather conditions all observations were completed in eleven days. A 'Berger' direction-transit graduated to 20 seconds, was used and the angles were read by repetition, six repetitions with the telescope direct, and six reversed. The horizon angle was similarly observed.

Twenty triangles in the main scheme had an average closure of 01.8 seconds, plus or minus and eighteen supplementary triangles closed with an error of 02.3 seconds, plus or minus.

The line, of existing triangulation, E. Heiheiahulu-Kaliu was adopted as a base for the present work as it appeared to be the line least subject to disturbance since last measured in 1914.



Computation of the length through the main scheme by two separate chains of triangles adjusted only within themselves gives a closure in in the order of one part in 40,000. Every line, however, in the present survey is subject to the same errors inherent in the line of older triangulation chosen as a base, which was probably of third order accuracy.

Limited funds prohibited the measurement of a base and for the same reason the existing figures about Hakuma and Kupapau were not strengthened. The total field work cost an average of $73.00 a station.

The work was greatly facilitated by the courteous cooperation of officials of The First Trust Co. of Hilo and the Bernice P. Bishop Estate of Honolulu in permitting the erection of permanent towers on their property, and of Mr. Richard Lyman of the Olaa Sugar Co., in allowing the clearing of trees from certain lines of sight. Funds for the erection of the two towers were voted by the Board of Directors, Hawaiian Volcano Research Association, without which the survey as completed would have been impossible.

Complete records of the field observations have been furnished the Hawaiian Territorial Survey and the engineer of the Bernice P. Bishop Estate.

E.G.W.

The Volcano Letter

No. 401—Monthly U. S. Geological Survey, Hawaii National Park JULY, 1933

KILAUEA REPORT FOR JULY, 1933

Including weekly press reports 1120 to 1123, July 2 to July 30, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

The data about the crater of Kilauea, in the absence of lava activity at the inner pit Halemaumau, concern observation of slides from the inner pit wall, other changes if any at the pit, measurement of rim cracks about the upper rim of the pit, measurement of horizontal angle right to left across the pit for pit rim monuments, and tilt of the ground at the pit edge in the clinoscope cellars platted with reference to one component only, the line of direction connecting the center of the pit with each cellar; this is to find out whether the ring of ground around the pit is tilting inward or outward. These measurements are under the direction of topographic engineer E. G. Wingate.

On the outer Kilauea Crater wall (Uwekahuna) about three fourths of a mile south from the summit trig station west of the crater, a small slide left a scar which was detected July 15. There were recent slides on the west wall of the summit crater of Mauna Loa discovered at about the same time. In the early part of the month gales of wind from the northeast blew clouds of dust about the lee side of Kilauea crater into the southwestern country. The age-long persistence of the trade wind is a geologic force to be reckoned with in the transport of loose ash on the island of Hawaii.

In Halemaumau July 9 a few rocks had fallen from the south wall of the pit leaving a small dusty track, and a dark red patch on the northeast wall had appeared. On July 26 there were wall slides at 11:50 a. m.. and at 0:50 p. m. The pit seismograph had shown four small quakes July 24, one of them accompanied with NNE tilt, but the walls showed no new scars from avalanches.

Measurement of rim cracks gave the following:— Out of 27 points, 8 showed no movement. 6 opened slightly, and 2 closed a half millimeter each, the area of movement being the rim southeast and south, the date July 8 for the previous week. The following week, date July 15, 12 points out of 27 had widened, 2 of them one half millimeter each, one 1 mm. Five cracks showed slight opening July 22, and 2 points on one crack showed slight closing. On July 29, six crack points showed very slight widening, two showed slight closing, the aggregate opening being 3 mm. One of the opened cracks is far back from the rim, half way between the sand spit south and Halemaumau.

The horizontal angle representing the SE-NW diameter of Halemaumau, as measured from the Observatory on the northeast edge of Kilauea crater, showed on July 28 a closing of 1.2 second since the last measurement on June 20, 1933, a period of 38 days. T.A.J.

LASSEN REPORT NO. 33.

During the first five days of July 1933, 53 earthquakes were recorded on the seismographs at Mineral. The distribution of the earthquakes by days was as follows:

July 1	3	shakes
2	5	"
3	4	"
4	39	"
5	2	"

Things had quieted down by July 8th. Several of the shakes were of sufficient intensity to be perceptible at Mineral, though more were felt in the eastern part of Lassen Park. The indicated distance from Mineral was about 10 miles.

R.H.F.

Earthquakes

TABLE

Number of minutes of tremor; very feeble, feeble and slight earthquakes; teleseisms or distant earthquakes; local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f	sl.	tel.	seis.
July 9	54	8	0	0	1	17.50
July 16	82	9	1	0	0	26.00
July 23	74	13	2	1	1	29.00
July 30	51	9	0	0	0	17.25

A feeble earthquake was felt at the Volcano House at 0:45 a. m. July 14. It was about one statute mile from the observatory.

A feeble earthquake was felt in Hilo at 3:17 p. m. July 19; as located from the records of three stations it was 25 miles deep under the Kilauea southwest rift zone, near 19° 20'N; 155° 20'W.

A slight earthquake was felt by several near Kilauea crater at 0:39 p. m. July 20. It was less than four miles from the observatory and probably under the crater.

A feeble earthquake was recorded—not reported felt—at 5:59 p. m. July 22. It was about two miles away and under the crater of Kilauea.

During the period covered by this report 25 very feeble shocks and ten tremors have been located at shallow depths, under Kilauea crater. The greater number occurred during the third week when the seismicity figure was the greatest.

The first teleseism was poorly recorded, the second was fair showing several wave arrivals.

The microseisms or ground motion was moderate or normal July 6, 10, 11, 26, 27, 28, and 29, on the other days of the month it was light or subnormal. A.E.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in the year since July 30, 1932 at the Observatory is 2.9" south and 2.1" west.

TABLE OF TILT

Date	Observatory	Halemaumau
July 3 - July 9	1.9" N	2.9" NW
July 10 - July 16	0.8" NNW	9.2" N
July 17 - July 23	0.1" WSW	2.9" WNW
July 24 - July 30	0.7" NNW	3.2" N

E.G.W.

Mauna Loa

For Mauna Loa on July 18 Messrs. Doerr and Wingate report steam seen chiefly in afternoon hours on the northeast rift 3 to 7 miles below Mokuaweoweo; no steam noticed in the north embayment of crater. A moderate amount of fume and steam came from sulphur cracks NNW of the cones of 1903. The 1914 cone was steaming strongly at the top, moderate fume issued from its vicinity, and sulphur patches were visible on the northern slopes of the cone. No fume or steam was observed at the south lunate platform. The west and northwest wall of the crater showed scars of recent rock slides, and at 12:55 p. m. a considerable slide occurred making streams of dust, with the wind blowing lightly from SW. Under clear weather conditions in still air Mr. Doerr notes that such dust might be seen from Kilauea, and it happens that on that same evening at Volcano House the volcanologist saw what looked like a faint fume cloud start above Mokuaweoweo and move slowly north, while the wind below at Volcano House was strong NE. Wingate reports that sulphur stain was seen from the east points of view at the base of, and on, the north wall of Mokuaweoweo about one half mile east of the summit trig station. The water holes examined had much less ice than during 1925-26. There was a small tremor on the Observatory seismogram about the time of the 12:55 avalanche in Mokuaweoweo.

The Volcano Letter

No. 402—Monthly U. S. Geological Survey, Hawaii National Park AUGUST, 1933

KILAUEA REPORT FOR AUGUST, 1933

Including weekly press reports 1124 to 1127, July 30 midnight to August 27 midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Two slides at Halemaumau were noticed during the first week of the month, and on one occasion some trickling of pebbles. On August 7 a small slide had left a dusty track at the top of the west wall at the big steam crack. One or two rocks were heard falling about 10 a. m. Cracks at the east platform, recently filled in, had shown dribbling in of the sand for some weeks. At 10:24 a. m. August 10 a few rocks fell from the wall at the south corner of the pit, and raised a small cloud of dust. On August 26 a somewhat fresh crack in the ash NE and N of the pit was discovered about 400 feet back from the rim.

Cracks measured at the edge of Halemaumau weekly, showed on August 5 very slight opening at 8 points out of 27, confined to the south and southeast rim area: on August 12 only 3 points had opened and 4 had closed, making the aggregate movement zero, the quietest week by measurement and observation since July, 1931: on August 19 seven rim cracks scattered along the southeast, south and southwest rims of the caldron had widened slightly, the largest amount being 1.5 mm. Two points indicated a very slight closing.

E. G. Wingate, topographic engineer, reports the horizontal angle representing the SE-NW diameter of Halemaumau, July 28—August 21, to have closed 1.7 seconds in 24 days; the angle opened 2.5 seconds August 21—August 29, in 8 days. This angle, measured from the Observatory on the northeast edge of Kilauea crater, is between Stations "NW Pit" and "Seis."

The horizontal angle representing the SSE—NNW diameter of Kilauea crater, measured from "Obsy," between "Uwekahuna" and "Spit," closed 2.5 seconds July 28—August 21, 24 days: and opened in 8 days August 21—29 by 0.3 second.

The combined tilt at Halemaumau, computed for the three clinoscope cellars, and resolved for each cellar into one component to or away from the center of the pit, shows inward tilting of 22.2 seconds July 31—August 27, a period of 27 days. This combined tilt has been computed for each day since October 11, 1932 and on August 27 showed an accumulation of inward tilt amounting to 53 seconds, for this interval 320 days.

It was shown in Volcano Letter 399 that Sta. Seis, the SE clinoscope cellar at Halemaumau had risen by spirit levelling relative to Sta. Spit outside of the Kilauea floor south by 0.02 foot on June 12,1933 relative to December 31, 1932. Levels run August 14, 1933 show that Sta. Tourist east of Halemaumau had lowered 0.13 foot relative to Sta. Seis since September 27, 1932. The distance between these bench marks is 440 feet. "Tourist" is on the rim of the pit, and "Seis" is about 400 feet back. "Tourist" is not greatly off from the line of the computed clinoscope tilt at "Seis" (to and from the center of Halemaumau). An angular depression of 53 seconds as above would at this distance give a change in elevation of minus 0.11 foot. This indicates a close agreement between measured and computed changes in elevation. In approximately this same period the horizontal angle across Halemaumau has closed 3.44 seconds.

The indication from all results is that the pit as a whole is lowering slightly at the present time. This is in agreement with the tilting of the ground for a year past, as recorded in Engineer Wingate's monthly report for the cellar of the Hawaiian Volcano Observatory on the northeast edge of Kilauea crater, the record for the preceding year each month, showing an accumulation of tilt to the southward, or in the general direction of the crater.

Measurement of vapor temperatures at eight vents of the Sulphur Bank near Volcano House with mercurial maximum thermometer, made by Wingate and Jones, on August 16, gave degrees Centigrade as follows:— 85.5, 80.0 79.0 77.0, 89.0, 94.5, 94.7, 94.6. These vents were not at the borings, where the maximum temperatures as measured several years ago were rather constant at 96.0 degrees Centigrade, or 204 degrees Fahrenheit. This temperature happens to be the boiling point of water for this elevation.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble and slight earthquakes; teleseisms or distant earthquakes; local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f	sl.	tel.	seis.
August 6	45	5	0	1	0	14.50
August 13	28	4	0	0	0	10.00
August 20	22	2	0	0	0	06.50
August 27	37	3	0	0	1	10.75

A slight earthquake was felt by Pritchard in Honokaa, by Sumner in Kapapala. Pahala, by Hutchinson Sugar Co. in Naalehu, by L. P. Lincoln in Hookena, by Fabius Paauilo, and by Hodges and others in Hawaii National Park at 11:56 a. m. July 31. It was located 19° 20′ N 155° 30′ W and 10 miles deep; nearly under Kapapala Ranch where it was felt sharply.

A small shock was felt by Mr. Sumner and others at Ohaikea, August 4.

A shock was felt at Naalehu at 4:08 a. m. Aug. 7. It recorded as very feeble on the Observatory seismographs. It was located from the records of two stations as being 2 miles northwest of Naalehu, 19° 05′ N 155° 39′ W and close to the surface.

The teleseism began recording at 9:33:25 p. m. H.S. T. Aug. 24. The secondary waves arrived at 9:44:07 p. m. The direction was Northwest and the distance 5,965 statute miles. According to press dispatches it was destructive in central China.

Microseismic motion of the ground was moderate or normal on July 31 and August 2, 3, 4, 8, 12, 14, 15, 16; it was light or subnormal on the other days of the month.

A.E.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in the year since August 27, 1932 at the Observatory is 1.5″ south and 1.3″ west.

TABLE OF TILT

Date	Observatory	Halemaumau
July 31 - Aug. 6	1.3″ N	6.5″ NNW
Aug. 7 - Aug. 13	0.4″ NNW	2.6″ NW
Aug. 14 - Aug. 20	1.2″ NNW	1.9″ N
Aug. 21 - Aug. 27	0.7″ NE	6.6″ NW

E.G.W.

The Volcano Letter

No. 403—Monthly U. S. Geological Survey, Hawaii National Park SEPTEMBER, 1933

KILAUEA REPORT FOR SEPTEMBER, 1933

Including weekly press reports 1128 to 1132, August 27 to October 1, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

In Halemaumau September 1 there had been a slide from the east corner. At 10:59 a. m. September 23, rocks fell from the north wall, and the dusty track of a moderate slide southsouthwest was seen. The northeast wall of the greater crater Kilauea showed a yellowish-orange scar from a slide, about a half mile west of the Hawaiian Volcano Observatory. On September 26 all-day inspection of the pit recorded sliding at 10:09 a. m. from the south-southwest wall, making a voluminous dust cloud and much noise. On September 30, sliding was reported as beginning in the pit between 6 and 7 a. m. Dust from slides rising from the pit was noted at the Observatory at 8:12 a. m. and 8:30 a. m. and between 8:37 and 8:45 a. m. the pit as seen from Uwekahuna was full of dusty air.

Weekly rim crack measurements around the Halemaumau border by E. G. Wingate gave:—

September 2. Six crack points out of 29 showed slight widening, two were very slightly closed.

September 9. Six points out of 29 very slightly opened, two points very slightly closed.

September 16. Twelve points widened, out of 29, one point closed. Widening not confined to any one sector.

September 23. Six scattered points widened out of 29, one point closed very slightly.

September 30. Marking nails for crack measurement had been set at three new points on September 26, on the east and northeast rim of Halemaumau.
Measurement for the week showed very slight opening of six scattered points out of 32, and very slight closing occurred at 4 points.

Mr. Wingate reports transit measurement of the horizontal angle from the Hawaiian Volcano Observatory triangulation station, to the two stations representing the southeast-northwest diameter of Halemaumau, as follows, the figures being the change of angle since the last date. Minus is a closing of the angle, or an approaching of the two walls of the pit. Plus is an opening of the angle, or a widening of the pit.

August 29 to September 5, 7 days, 0.6 second minus
September 5 to September 18, 13 days, 1.5 seconds plus
September 18 to September 27, 9 days, 0.4 second minus

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f	sl.	tel.	seis.
September 3	42	3	1	0	1	13.00
September 10	49	1	0	1	2	14.75
September 17	19	6	0	0	0	7.75
September 24	58	5	0	1	1	19.00
October 1	44	3	2	0	1	14.50

Periods of continuous tremor occurred during four weeks out of the five. This vibration has a frequency of about 100 times a minute and is indistinguishable from the tremor found on the seismograph records during the times of lava fountaining in the pit of Halemaumau.

A very feeble shock, on August 31, occurred about 10 statute miles northwest of Hilo. Lat 19 48'N, Long. 155 12'W 24 miles deep.

A feeble shock, September 2, occurred 5 miles under Pali O Mamalu. Lat. 19 2'N, Long. 155 40'W, it was not reported felt.

A slight earthquake, Sepember 7, occurred about 27 miles deep, under Wood Valley. Lat 19 18'N, Long. 155 27'W it was reported felt at Uwekahuna by Doerr, and in Hilo by M. Campbell.

A tremor. 6:13 a. m. September 11, occurred at sea a short distance off of the west coast of Hawaii, and close to the possible extension of the Mauna Loa southwest rift line. Lat. 19 02'N, Long. 155 58'W.

A very feeble shock, 7 a m. September 11, was reported felt by Mair in Pahala. It occurred 7 miles north-northeast of Wood Valley, and about 7 miles deep. Lat 19 23'N, Long. 155 28'W.

A very feeble shock Sept. 14 probably occurred under the sea a short distance of the Puna coast and south west of Kalapana.

A very feeble shock registered September 16, originated 10 miles west of Humuula.

A very feeble shock September 20, originated on the Mauna Loa northeast rift. It may have been one of many reported felt at Kapapala.

A slight earthquake September 21 apparently originated a short distance away from the Observatory, probably under the Kilauea southeast rift. It was not reported felt.

A feeble earthquake was recorded September 26, the location found was 8 miles east of Humuula, Lat. 19 42'N, Long. 155 23'W and 7 miles deep. It was felt in Papaikou, Honomu. Hakalau, Hilo. Olaa and Pahala according to reports sent in by H. Milne; J. B. Oliver; Hakalau Plantation; M. Campbell; and W. Mair.

A feeble shock was reported felt in Pahala by W. Mair. September 28. It was located 7 mi. northeast of Kapapala. Lat. 19 22'N, Long. 155 27'W and about 9 miles deep.

A very feeble shock on September 30 was approximately located under the saddle between Mauna Loa and Mauna Kea.

A fair record of a teleseism began at 11:46:11 a. m September 6, and continued for 20 minutes. It was 2,934 statute miles away from he Observatory. The other teleseisms were partial, showing only the maximum or long waves.

The microseisms were moderate September 5. 9. 16. 18, 21 22, 23, 24, and October 1; they were light or subnormal during the remaining days of the month.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater, 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outwards from and inwards toward the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a NE reading is outward, a SW reading is inward.

The total accumulated tilt in the year since October 1, 1932 at the Observatory is 1.5" north and 0.7" west.

TABLE OF TILT

Date	Observatory	Halemaumau
Aug. 28 - Sept. 3	0.9" NE	1.3" outward
Sept. 4 - Sept. 10	0.7" NE	2.6" inward
Sept. 11 - Sept. 17	1.3" NNE	0.4" inward
Sept. 18 - Sept. 24	1.1" NNE	2.6" inward
Sept. 25 - Oct. 1	1.0" NNE	0.1" inward

E.G.W.

The Volcano Letter

No. 404—Monthly U. S. Geological Survey, Hawaii National Park OCTOBER, 1933

KILAUEA REPORT FOR OCTOBER, 1933

Including weekly press reports 1133 to 1136, October 1 midnight to October 29 midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Slides from the walls of Halemaumau pit have occurred as follows for the short periods under observation daily in the forenoons, and occasional observation at other times. Slide during day preceding 10 a. m. October 6 left a scar near top of east wall, and fresh dust and small rocks scattered over the east bay of the lava floor. The southeast pit seismograph had registered the vibrations. October 6 at 9:50 a. m. a few rocks were heard falling. October 7 at 8:58 a. m. and 10:07 a. m. small slides at east corner of pit. October 9 forenoon, rocks fell infrequently. October 13 at 3:38 p. m. dust arose at east corner. October 14 new dusty appearances were seen at east talus and south wall. October 24 and 25 in the forenoons, a few rocks were heard falling. October 26 at 10:15 a. m. a small slide fell from the south wall, and one caused dust at 10:35 a. m.

Slides occurred on the west wall of Kilauea crater, about three quarters of a mile south of the museum at 4:38 p. m. October 2, and on October 8 at 10:50 a. m. and at 10:58 a. m. October 23 numerous showers caused vapor to rise from Halemaumau, mixed with some blue fume, and October 26 strong northeast wind raised clouds of dust in Kau desert. A very fresh avalanche scar was located by Wingate October 24 at the north end of the west platform inside of Alealea crater along the Chain of Craters road, with another scar nearby. This was believed related to a shock at 10:32 a. m. October 20, accompanied by a booming noise and a low rumble, felt by a construction crew near Puu Hulahula, and by others heard at 28-miles and at Halemaumau.

Weekly rim crack measurements around the Halemaumau border are reported by E. G. Wingate as follows:—

October 7. Seven crack points out of 32 opened very slightly, two closed very slightly.

October 14. Eleven points out of 32 opened, two points closed, very slightly.

October 21. Three points opened out of 32, one closed, very slightly.

October 28. Out of 32 points, four opened one-half millimeter each. Seven closed one-half millimeter each. One crack northeast showed one-half millimeter lateral movement. The closing cracks were south and southeast, the opening ones were east and northeast. The west rim showed no movement.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble; slight; and moderate earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	sl.	mod.	tel.	seis.
October 8	24	3	0	0	1	10.00
October 15	29	1	0	1	1	11.75
October 22	46	8	1	2	0	25.50
October 29	42	8	0	0	0	15.00

The indicated origin of the moderate earthquake at 3:01 a. m. October 13 was at sea, about 30 statute miles southeast of Cape Kumukahi, in Lat. 19° 15′N; Long. 154° 23′W. It was lightly felt.

The slight earthquake of October 19 at 5:37 a. m. could not be well located. It probably occurred a few miles north of the Mauna Loa northeast rift. It was felt in Hilo and Honomu.

The two earthquakes at 9:10 and 9:11 a. m. October 21 occurred at places about eight miles apart, under the southeast flank of Mauna Loa. The first at Lat. 19° 21′.5N; Long. 155° 31′.5W; and about two miles deep. The second at Lat. 19° 25′N, Long. 155° 30′W and about nine miles deep. The second could not be as accurately located as the first, owing to confusion of its waves with the waves of the first earthquake. Both were reported felt generally on Hawaii.

Six small earthquakes were felt at Kapapala ranch during the month, the observatory records were too small to indicate a distance for any of them. The same was true for an earthquake felt at Pahala and one felt at Kapulani.

The record of the teleseism beginning at 5:11:16 a. m. October 5 was fair, showing a few phases. Only the long waves of the teleseism of October 14 were recorded.

The microseisms were light on October 10, 12, 15, 16, 17, 18, 19, 20, & 29. The microseisms were moderate or normal October 2, 3, 5, 6, 7, 8, 9, 11, 13, 14, & 21. The microseisms were strong or abnormal October 4, 22, 23, 24, 25, 26, 27,& 28.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater, 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outwards from and inwards toward the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a NE reading is outward, a SW reading is inward.

The total accumulated tilt in the year since October 29, 1932 at the Observatory is 1.1″ south and 0.8″ west.

TABLE OF TILT

Date	Observatory	Halemaumau
Oct. 2 - Oct. 8	0.7″ E	2.8″ inward
Oct. 9 - Oct. 15	0.3″ NE	11.0″ inward
Oct. 16 - Oct. 22	0.3″ SW	1.3″ outward
Oct. 23 - Oct. 29	2.0″ NE	10.6″ inward

E.G.W.

The Volcano Letter

405

No. 405—Monthly | U. S. Geological Survey, Hawaii National Park | NOVEMBER, 1933

KILAUEA REPORT FOR NOVEMBER, 1933

Including weekly press reports 1137 to 1140 October 29 midnight to November 26 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology:—Kilauea

Halemaumau pit of Kilauea volcano produced a rock slide at the west end of the north sill 9:35 a. m. November 4, and another small one was heard at 10:43 a. m. Fragments of rock dribbled down the south wall 10:44 a. m. November 6. There were very heavy rains November 8-9 amounting to 6.75 inches. Pools of water remained all over the Kilauea crater floor, being lakes at the southwest valley and at the upper bench southwest. November 9 a slide occurred at noon on the south side of the pit. November 11 several hundred tons of rock had fallen from above the lowest part of the canoe sill northeast. The pieces had rolled 150 feet down the talus; at 10:07 a. m. Nov. 11 rocks fell at the northeast. About 10 a. m. Nov. 13 rocks were heard falling from the north, west and south walls; at the same hour November 16 a small slide was heard at the east, and there was fresh debris on the talus. The week ending November 26 was notably quiet.

Weekly rim-crack measurements around the Halemaumau border were as follows:—

November 4. Out of 32 points, 7 opened 1 mm. or less, 4 closed very slightly, 1 northeast crack moved laterally 1 mm.

November 11 Out of 32 points, 10 opened slightly, 4 closed slightly, aggregate result for all, an opening of 3 mm.

November 18. Out of 32 points, 9 opened, 3 closed, aggregate movement an opening of 4 mm.

November 25. Out of 32 points, 11 opened and 3 closed, aggregate opening 5.5 mm.

It will be seen that the aggregate opening gradually increased during the month.

Volcanology:—Mauna Loa

The cluster of earthquakes of October about Mauna Loa, felt especially at Kapapala ranch on the east side of that volcano, led E. G. Wingate and A. E. Jones to visit the summit crater, camping there the night of November 1-2. At Puu Ulaula resthouse the night October 31 the outdoor temperature was 31 degrees Fahrenheit. The northeast end of Mokuaweoweo was reached at 1:30 p. m. November 1.

The main crater showed puffing vapor from the 1914 cone, fume was dense at times from the solfataras of the sunken area adjacent to the 1914 cone, and the central cones of 1903 were about as usual. The summit camp was in a cavern, and ice from cracks was melted for drinking water. The east rim was explored the forenoon of Nov. 2 as far as the Wilkes Camp. The northwest and southwest walls of the crater were dusty showing some fresh scars. There was little blue fume at the central region, and possibly slightly more at the 1914 cone than in July. The Resthouse thermometer recorded 28 degrees F. at 6:10 a. m. Nov. 3. Later events proved that the dense fume and puffing vapor near 1914 cone heralded coming eruption of December 2.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	tel.	seis.
November 5	18	2	00	5.50
November 12	35	5	00	11.25
November 19	30	0	00	7.50
November 26	56	3	1	15.50

This is the only month of the year 1933 to date registering at the Observatory no felt earthquakes of the inntensities "feeble," "slight" or "moderate" for the Kilauea locality.

During the four weeks local shocks that were well recorded on more than one instrument (for location of origin) were rare.

An earthquake reported by Lincoln and Hale in Hookena district, South Kona, was felt at 7:44 p. m. November 10 It was very feeble on the seismograms, and from them appeared to be on the southwest rift of Mauna Loa in Latitude 19 degrees, 16 minutes North; Longitude 155 degrees, 43 minutes West.

A shock reported by Buzzard and registered on his seismogram at Waikii on the west slope of Mauna Kea 9:49 a. m. November 13, appeared to originate deep under that district.

A seismic movement recorded at the Kilauea observatory as a tremor, at 0:52 a. m. November 25, was reported by Archdeacon Walker as felt sharply in Kohala. The distance from the Observatory record would place it in North Kohala.

A very feeble shock registered at 5:15 p. m. November 25 was located under a point northeast of Wood Valley on the east slope of Mauna Loa, about five miles deep. Latitude 19° 22′ North, Longitude 155° 26′ West.

A very feeble shock registered 9:10 a. m. November 26, was located as near the surface of Mauna Loa about five miles north of the 1868 lava source on the southwest rift, Lat. 19° 12′ North, Longitude 155° 41′ West.

Microseisms of the month were light or subnormal October 31 and November, 16 and 21: they were strong or abnormal November 3, 25, 26. The remainder of the month they were normal.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater, 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year since November 26, 1932 is 2.2″ West and 2.9″ South, or 3.6″ SW by S.

TABLE OF TILT

Date	Observatory	Halemaumau
Oct. 30 - Nov. 5	.....0.9″ S by E	4.5″ from
Nov. 6 - Nov. 12	.....1.3″ S by W	2.5″ from
Nov. 13 - Nov. 19	.....0.6″ E by S	9.0″ towards
Nov. 20 - Nov. 26	.....1.9″ NE by E	7.0″ towards

E.G.W. and A.E.J.

The Volcano Letter

406

No. 406—Monthly U. S. Geological Survey, Hawaii National Park DECEMBER, 1933

KILAUEA REPORT FOR DECEMBER 1933

Including weekly press reports 1141 to 1145, November 26 to December 31, midnight.

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Volcanology:—Kilauea

As Mauna Loa broke out with lava eruption at the summit crater the early morning of December 2, Halemaumau pit in Kilauea crater was watched with special intentness throughout the month. Its bottom being sealed, with the lava plug of December—January 1931-32, this pit showed no sympathy with the Mauna Loa outbreak nor with the Mauna Loa cessation December 18.

In Halemaumau fresh debris lay on NE talus Nov. 27. The color of blue sulphur fume can be seen in sun-shadows. Two large newly fallen rocks were seen at the bottom under E wall December 16.

Weekly rim-crack measurements around the Halemaumau border were as follows:—

Dec. 2, 1933. Out of 32 points measured, 9 opened, 5 closed, aggregate opening 2.5 mm.

Dec. 9, 1933. Seven points opened, 5 closed, aggregate opening 1.5 m.

Dec. 16, 1933. Two points opened, 4 closed, aggregate a closing 1 mm.

Dec. 23, 1933. Eight points opened, 2 closed, aggregate opening 3.5 mm.

Dec. 30, 1933. Seven points opened, 8 closed aggregate opening ½ mm.

During the week ended December 17 levellings repeated on the old line on Kilauea floor near Halemaumau, and the horizontal angle from Observatory, measured twice across the pit, by Jones, revealed no unusual movement of the crater floor.

The minute motion of the ground measured instrumentally around Halemaumau and at the Observatory, by weeks, as shown in Earthquake and Tilt reports herewith, was as follows:—

		Obsy. Tr.	Seis.	Obsy. tilt	Hal. tilt
Week ending Nov. 26		56	15.50	1.9″ ENE	7.0″ inward
Week ending Dec. 3	(Mauna Loa eruption)	1393	360.00	1.5″ NW	15.8″ outward
Week ending Dec. 10	(Mauna Loa eruption)	345	86.00	0.3″ WSW	5.9″ inward
Week ending Dec. 17	(Mauna Loa eruption)	580	170.00	0.7″ SSW	0.0 zero
Week ending Dec. 24		20	6.50	1.1″ WNW	7.9″ inward
Week ending Dec. 31		34	12.50	1.2″ NNE	19.2″ inward

The number of minutes of tremor and accompanying local seismicity rose and fell with the Mauna Loa eruption 22 miles away. The Observatory tilt was strong and northerly or easterly (away from Kilauea crater), before and after the eruption, weaker and westerly during the eruption. The total tilt of the three clinoscope cellars around Halemaumau pit, outward away from the pit, or inward towards the pit, measured on the radial lines from the center of the pit, and disregarding other directions of tilting, yielded very interesting results. The aggregate tilting at the pit had been notably inward for many months. The week of the outbreak it was strongly outward as though the Kilauea floor swelled upward; after the outbreak it was more strongly inward, as though the sinking of the Kilauea floor followed the sinking back of the lava under Mauna Loa. This sequence is just what happened at Kilauea when the live lava in Halemaumau was visible during the Mauna Loa eruptions of 1914, 1916 and 1919.

Volcanology:—Mauna Loa

The summit crater Mokuaweoweo was split along the upper end of the southwest rift and vomited up lava at 5:43 a. m. December 2, 1933. The rift opened along a belt 15 miles long in the southwest part of the crater, the gash trending S. 27 W. from the inner basin across the south lunate platform, up the cliff to the outside country next the lava of 1851, on to the south for a half-mile about 500 feet west of the lip of the South Pit No. 1, then for a half-mile more offset 500 feet to the east, emerging from the west corner of this pit and continuing across the upland southwest to pour cascades of lava into both Pit No. 1 and the 2nd. Pit. (Lua Hohonu). The main activity of the eruption was inside the main Mokuaweoweo basin about 500 feet east of the cone of 1914.

The time of outbreak estimated is that shown by the beginning of continuous volcanic tremor at Kilauea seismographs. At 7 a. m. December 2 there were two dense white columns of vapor as seen from Kilauea Observatory about 2 miles apart, the northern one the denser and by angular measure inside Mokuaweoweo. At 9 a. m. there were 3 principal fume jets, the northern the greatest and highest, the two southern ones each double. At 7:30 p. m. the glowing columns were in number, the northern triple and most brilliant, the middle one bright, the southern one faint. The division in three corresponded to the southern-pits gash, the south lunate gash, and the inner basin gash. The southern pits went out of action the first day. After the first two hours the fume column became blue and sulphurous (absinthe red in transmitted light). Pele's hair fell in small amounts at Hookena to leeward. At 11 a. m. December 2 there were lines of moderate fountains, 200 or more feet high, along each gash at its widest part, namely; the upland SW of South Pit No. 1: the lunate at the foot of the cliff NW of this pit, just inside Mokuaweoweo; and the inner basin east of 1924 cone. There were about 35 fountains in the basin and 20 each at the two other localities. The basin fountains concentrated to a smaller number about built-up cones. These basin vents poured lava both east and west. The eastern flows became the great feature, filling the northeastern and lowest part of Mokuaweoweo basin. The western ones obliterated the pit of 1914 which had been adjacent to the cone, and filled against the western cliff of the south lunate platform. The South Pit filled about 70 feet at the base of the new cascade which poured into it from the lunate platform. The main flow area covered about a square mile the second day, and the southern pits had received a square quarter-mile additional. The southernmost rift made big upland fountains the first day, the lava cascading strongly into the south side of South Pit No. 1, and weakly into Lua Hohonu. There was liquid flooding of silvery sheets of lava the first day, but the second day there were crusted floor flows, and flocculent skins on the scarlet torrents from the main line of about 17 conelets. On this day Dec. 3 the big fountain within a horse-shoe cone at the southwest cliff sent a festooned stream in a channel down to the South Pit over the ancient black lava cascade so well known here, and also over fresh streams of the previous day. This fountain was literally in the wall-crack of Mokuaweoweo, on the west side of the South Gap.

December 3 the main fountaining was at two cone centers in Mokuaweoweo basin, and at the southwest wall; the outside southwest cracks were steaming only. The flow lava was pahoehoe of which coin specimens were made. The cones were heaped with basaltic pumice, and Pele's hair lay to leeward. Milky blue fume cirrus lay in belts across the sky, sometimes southeast, sometimes north of Mauna Loa during the next few days. There was glow over the crater at night and fume by day. December 4 the southwest wall fountain stopped. December 5 the two central fountain groups were within throne-like cone heapings 100 to 200 feet high. The steam

at the pit gashes to the southwest of Mokuaweoweo had ceased. The flows within Mokuaweoweo continued to spread north and east, against the east wall, and as far as the north lunate, and one flow had pushed west between the 1903 and 1914 cones. The eastern part of the cliff beneath the north side of the south lunate had been further obliterated by filling. A fan-like rush lava poured east from the throne-cones. This was the scene observed from air-planes day after day, the fountains of the northern cone dwindling to two small ones December 12. December 13 there was only one fountain, with occasional jets from other vents. With change of wind some Pele's hair fell along the northwest trail. The fume and glow as seen from Kilauea continued until December 17, becoming faint. Midnight December 17-18 the fountain was in action. It died down at 2 a. m. December 18, revived slightly after daylight, and thereafter went out of action. The area remained very hot and fuming with jarrings and rumbles.

The first echelon ruptures were at the top of the southwest rift of Mauna Loa, extending the action of that rift as observed in 1926, farther west and farther up, until this year's action centered in the crater itself. The eruption lasted 16 days, with no flank outbreak. Inquiry around the south end of the island December 6 revealed that the early morning earthquakes of the outbreak on December 2, felt in Hilo and Kona, were not felt at the south. The seismographic measurements show that most of the earthquakes originated to the north and east of Mauna Loa during the eruption, becoming deeper and mostly toward Kilauea at the end of the period.

If the splitting of the mountain crosses the crater and opens a flank rupture about 1936 or before, emitting lava flow, it may be along the Hilo rift, or the northwestern 1859 rift, or along the Hualalai rift. It happens that the earthquakes of December 2 this year 1933 were not felt at Puu Waawaa, where the 1929 quakes were strongest.

Toward the end of December, after summit snows about Christmas, there were hot convection puffs of rain cloud over the new lavas of the summit crater. These rose very rapidly and might easily have been mistaken for new eruption. The flows on the Mokuaweoweo floor were about ten feet high near their borders, with some breaking up of the pahoehoe surfaces, where they were pulled after congealing.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble; feeble (I, R. F.); & slight (II, R. F.) earthquakes & local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	sl.	seis.
December 3	1,393	11	3	3	360.00
December 10	345	0	0	0	86.00
December 17	580	4	0	0	170.00
December 24	20	1	1	0	6.50
December 31	34	8	0	0	12.50

The approximate origins of the earthquakes that were well recorded at more than one seismograph station, follows—

Earthquakes Preceding Mauna Loa Eruption.

November 28, a very feeble shock, located under Kilauea crater.

November 30, a very feeble shock, located a mile SW of Kilauea crater.

December 1, a very feeble shock, located on the NE rift, near Mokuaweoweo, the summit crater of Mauna Loa.

Earthquakes correlated with the Mauna Loa outbreak, on December 2.

5:55 a. m. a slight shock, about II on the Rossi-Forel scale of intensity, felt with alarm at the rest house on Mauna Loa, located at the NE end of Mokuaweoweo crater, nine miles deep. The remainder of the group appear to be less deep.

5:56 a. m. a feeble shock, about I on the Rossi-Forel scale, located about seven statute miles NW of Mokuaweoweo crater.

5:58 a. m. a feeble shock, located about one mile NE of the N end of Mokuaweoweo crater.

6:01 a. m. a slight shock, felt with alarm at the rest house, located near west rim of Mokuaweoweo crater.

6:06 a. m. a slight shock, felt with alarm at the rest house, & felt lightly in Hilo by M. E. Campbell, located three miles NE of the N end of Mokuaweoweo crater.

6:08 a. m. a feeble shock, located near the west rim of Mokuaweoweo crater.

Immediately after the first unlocated shock at 5:42 a. m. Dec. 2 harmonic or continuous volcanic tremor began. In the past, eruptions have been accompanied by this type of ground movement. The period of 0.6 seconds (100 vibrations per minute) is fairly constant, while the amplitude is variable with the size of the eruption. The spells of tremor were noted approximately as follows;

date		time	duration minutes
Dec. 2	Beginning	5:43 a. m.	244
" 2	"	9:46 a. m.	590
" 2	"	6:40 p. m.	320
" 3	"	9:00 a. m.	209
" 8	"	8:30 p. m.	80
" 10	"	8 p. m.	240
" 11	"	0 a. m.	300
" 11	"	8 p. m.	100
" 12	"	0 a. m.	150
" 12	"	7 p. m.	90

The amplitude of the waves varied from 0.8 to 0.4 microns, smaller amplitudes become unnoticeable on the records. (1 micron==0.001 m. m.)

Earthquakes During the Eruption.

Dec. 2, 7:28 p. m. a very feeble shock, located under the slope of Mauna Loa about half way between the craters of Kilauea and Mokuaweoweo.

Dec. 3, a very feeble unlocated shock was felt by M. E. Campbell in Hilo. It appeared to be about five miles from the Hilo station.

Dec. 7, a tremor, reported felt in Naalehu by the Hutchinson Sugar Plantation, was located on the Mauna Loa SW rift near the source of the 1887 flow, seven miles up the mountain from the highway.

Dec. 12, a very feeble shock, located three miles west of Kilauea crater, four miles deep under Pali O Kaoiki, a fault between Mauna Loa and Kilauea.

Dec. 14, a very feeble shock, felt in the vicinity of Kilauea crater, located near the Mauna Loa rest house and 17 miles deep.

Earthquakes Following the Eruption.

Dec. 20, a very feeble shock, located half way up the east slope of Mauna Kea from Hakalau.

Dec. 20, a tremor; Dec. 27, 3:44 a. m. a very feeble shock felt lightly at Honomu: 3:56 a. m. a very feeble shock, felt sharply at Honomu, and 4:44 a. m. a very feeble shock felt lightly at Honomu. These four were located in a group under the SE slope of Mauna Kea, half way between Hilo & the summit.

Dec. 27, a very feeble shock, felt near Kilauea, located on the Mauna Loa NE rift half way between Hilo and the summit.

Dec. 30, a very feeble shock felt in Hilo by M. E. Campbell, located six miles SE of Mokuaweoweo and ten miles deep.

Dec. 31, a very feeble shock, located five miles at sea, south of Kilauea crater.

Microseisms. Light or subnormal; Dec. 1, 3, 18, 19, 31.
Moderate or normal; Nov. 27 to 30; Dec. 2, 4, to 13, 17, 20, 21, 27 to 30.
Strong or abnormal; Dec. 13 to 16; 22 to 26.

A.E.J.

Tilting of the ground

The Observatory column shows the net tilt in seconds of arc in the direction given, computed from seismograms. The second column shows the algebraic sum of clinoscope readings for the three cellars around Halemaumau. Each reading is reduced to its radial direction from or towards the pit. As the Observatory is on the northeast rim of the larger Kilauea crater, a southwest reading is towards the crater.

The total accumulated tilt at the Observatory in the year since December 31, 1932 is 1.1" North, and 2.9" West.

TABLE OF TILT

Date	Observatory	Halemaumau
Nov. 27 – Dec. 3	1.5" NW	15.8" from
Dec. 4 – Dec. 10	0.3" W. by S.	5.9" towards
Dec. 11 – Dec. 17	0.7" SSW	0.0
Dec. 18 - Dec. 24	1.1" WNW	7.9" towards
Dec. 25 - Dec. 31	1.2" NE by N	19.2" towards

A.E.J.

The Volcano Letter

No. 407—Monthly U. S. Geological Survey, Hawaii National Park JANUARY, 1934

KILAUEA REPORT FOR JANUARY, 1934

Including weekly press reports 1146 to 1149, December 31 to January 28, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology:—Kilauea

The first week in January, 1934 Halemaumau remained quiet as before. The second week the pit showed the effects of heavy rainfall after drought. The rainfall readings for twenty-four hours preceding, at 8 a. m. were 1.37 inch January 10, 0.87 inch on January 11, 1.40 inch on January 12, and 0.29 inch on January 13, measured at Kilauea Observatory on the northeast rim of Kilauea crater. The heavy rains began the night before January 10. As seen from the west bluff of Kilauea, a dense vapor cloud appeared to be rolling out of Halemaumau pit. The actual fact was that the cloud was condensing on top in the air above the pit. The entire lava bottom was perfectly clear with no steam whatever except the usual slight vaporing from cracks under the south talus. The wind blew lightly from the northeast and the condensation of ordinary rain moisture began above the northeast edge of the pit. The big cumulus cloud above was probably assisted by nucleation from sulphur dioxide rising at the bottom solfataras. The heat from the pit made an updraft which drew in the wet air from the sides. The phenomenon showed how deceptive a so-called "steaming crater" might be anywhere on a wet day, where the observer was not in a position to look inside. This is the position of many sea-captains observing an island volcano "steaming". On a sunny day the crater in question would be clear, but the reports of two successive vessels would be for the volcano "active" and "inactive", when in fact there was no difference except the moisture in the air.

On January 11 there was the same cloud, the interior of the pit was clear, it was raining steadily. Now there were tails of steamy vapor in a horseshoe of cracks in the floor of Halemaumau SE, NE and NW where the prolonged rain had penetrated deeply to the hot region. There was clear air for eight hundred feet above the vapor jets, which had no evident relation to the cloud above the pit. The southwest inner cone, of December 1931, was not steaming. The next day January 12, with less rain, the vapor tails on the floor had stopped, and the cloud above the pit as a whole, was thin and stringy. There was drizzle, and a bright clearing sky.

On January 14 some stones were heard dribbling down the northwest inner slopes of Halemaumau. Fresh fallen rocks at the foot of the northeast talus were observed January 18. Small slides occurred later in the day, and fresh sliding occurred the morning of January 24, leaving a piece broken out of the northwestern end of the "Canoe" sill under the north corner of the pit. In the afternoon of the same day while the pit was vaporing from more heavy rains, rocks were heard falling at the north wall. Blue fume was apparent in the darkened corners of the pit in sun-shadow January 26. It is noteworthy at this time, however, that the yellow sulphur patches in Halemaumau do not show fume jets or hot air disturbance detectable with field glass, and they are not the places which steam at times of rainfall.

Weekly rim crack points, 37 in number, around the Halemaumau border, were measured for change in opening of cracks as follows:—

January 6, 1934. 7 points opened, 2 closed, summation 3 millimeters opening.

January 13, 12 points opened, 1 closed, summation 7 millimeters opening.

January 20, 3 points opened, 9 closed, summation 3 millimeters closing.

January 27, 5 points opened, 2 closed, summation 1.5 millimeters opening.

The summation of January 20 was unusual: opening by this amount is common.

Volcanology:—Mauna Loa

There were numerous thunder showers over Mauna Loa the third week in January, with calm weather preceding, and light snow fell on Mauna Loa and Mauna Kea. The recent lava eruptions in Mokuaweoweo crater, it will be remembered, were from December 2 to 17, 1933, followed by marked rain cumulus condensations due to convection on certain days. These upright clouds are still seen occasionally, especially when moisture from melting snow is present.

Ranger R. F. Lueck, National Park Service, and T. Generozza, U. S. Army, spent the night January 6 to 7 in Mokuaweoweo crater at the cone center of the December activity. Arriving at the North Bay 1:30 p. m. January 6, Lueck reports the fume had decreased in ten days 75 percent. They crossed the crater floor southward. Lueck kindly prepared the following report:—"We came to the new floor flow, which had turned west to follow the channel between the 1903 and 1914 cones. The new lava was smooth pahoehoe, broken up at the edges, where it was in contact with the old lava."

"We crossed it, the heat was quite noticeable, and this became more pronounced as we neared the base of the new cones. We finally reached them and there found a place on the fresh lava, where we thought we could spend the night in comfort and safety. Our ideas were suddenly changed, when, at 5:45 p. m. we felt a distinct shock, and at 5:48 another, of less intensity. As there was not much choice of a more suitable location, we stayed where we were."

"After we had crawled into our sleeping bags, we heard a series of rumbles, and occasional sharp cracks, which seemed to originate directly under us. The rumbling was not continuous, but came at intervals of three or four minutes. After about two hours of this, we began to think of a lot of places we would rather be than just here. At 8 p. m. we felt a shock more severe than any we had felt before, so we proceeded to leave that particular spot, as fast as our legs would carry us in the night, across the pumice beds and rough lava. We got to the edge of the new flow to the north of us, and decided to make the best of the situation, making our beds a second time, in a deposit of new warm pumice. During the night we noted several more light shocks, but none was severe enough to cause great alarm. At daylight we packed our belongings, and left for the return trip."

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending 1934	tr.	v. f.	f.	sl.	tel.	seis.
January 7	26	4	0	0	0	8.50
January 14	52	1	0	2	1	17.50
January 21	31	0	1	0	0	8.75
January 28	24	5	0	0	0	8.50

The following earthquakes were located:

A very feeble shock was felt 11:22 p. m. January 2, 1934, at Honomu, Waikii, and Kilauea. It was located under the peak of Mauna Kea, 19° 50′ N, 155° 27.5′ W, at a shallow depth, probably being above sea level.

A very feeble shock at 8:06 p. m. January 6, approximate origin 21 miles away, was probably the sharp quake reported by Lueck at Mokuaweoweo.

January 7 two very feeble quakes were recorded 15 minutes apart. The first 3 miles deep under the pit seismograph station; the other was shallow about two miles SW of Kilauea Crater in the SW rift zone.

A slight earthquake was felt 1:59 a. m. January 9 at Hookena, Kapapala, Pahala, and Kilauea. It was located under the Mauna Loa SW rift 19° 12.5′ N, 155° 44.0′ W and shallow in depth.

A slight earthquake was felt generally in Hawaii at 1:35 p. m. January 13. It was located under the sea bottom 19° 11′ N, 155° 11′ W, possibly 10 miles deep.

A tremor originated at a shallow depth about a mile SW of Kilauea crater January 16. It was recorded on the Uwekahuna and Pit seismographs and was in almost the same place as the one located November 30, 1933.

Two shocks felt at Honomu January 17 and 21 were not recorded at Kilauea. The former recorded at the Hilo seismograph station with indicated distance to origin 10 miles.

A feeble shock, not reported felt, was recorded at 9:37 p. m. January 19. It was located on the Kilauea SW rift, under the 1823 lava flow 19° 14′ N, 155° 25.5′ W.

A very feeble shock was recorded January 25. The best location found for it was four miles deep under the Kamakaia Hills on the Kilauea SW rift, about 10 miles SW of the crater.

The teleseism was one of the destructive Indian earthquakes, near Patna in the Ganges basin. It began on the record 10:31:44 p. m. January 14. In all six groups of waves were recognized, the last group beginning at 11:02:33 p. m. The waves were not large in amplitude.

Microseisms: Subnormal January, 1, 2, 12, 16, 17, 18, 19, 21, 23, 24, 25, 26, 27; normal January 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 20, 22, 28.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater, 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year since January 1, 1933, is 1.9″ west and 1.1″ north, or 2.2″ NW by W.

TABLE OF TILT

Date	Observatory	Halemaumau
Jan. 1 – Jan. 7	1.82″ ESE	15.0″ inwards
Jan. 8 – Jan. 14	1.59″ S by E	11.0″ inwards
Jan. 15 – Jan. 21	0.12″ W	2.0″ outwards
Jan. 22 – Jan. 28	2.38″ SW	15.0″ outwards

A.E.J.

The Volcano Letter

No. 408—Monthly U. S. Geological Survey, Hawaii National Park FEBRUARY 1934

KILAUEA REPORT FOR FEBRUARY, 1934

Including weekly press reports 1150 to 1154, January 29 to March 4, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Kilauea and Mauna Loa continue without volcanic outflow of any kind: the last activity was lava gushing in the summit crater of Mauna Loa December 2 to December 18, 1933. The feeble sulphur fuming at yellow patches about the border of the lava floor of Halemaumau pit in Kilauea crater has almost ceased. Small slides in the pit were observed during the casual visits, at the west 2:30 p. m. February 4, at the southwest 10 a. m. February 5, east and northwest about 10 a. m. February 6, northeast the forenoon of February 12.

Thirty-two rim crack points around Halemaumau, showed weekly change in opening of cracks as follows:—
February 3. 11 opened, 1 closed, aggregate opening 6.5 mm.
February 10. 10 opened, 1 closed, aggregate opening 9.5 mm.
February 17. 3 opened, 7 closed, aggregate closing 3 mm.
February 24. 5 opened, 3 closed, aggregate opening 2 mm.
March 3. 7 opened, 5 closed, aggregate opening 1 mm.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	sl.	tel.	seis.
February 4	100	4	1	0	1	28.00
February 11	106	2	0	1	0	29.50
February 18	41	2	1	0	1	12.75
February 25	36	3	1	1	1	13.50
March 4	74	3	0	1	0	22.00

The following earthquakes were located.

A feeble earthquake 3:14 a. m. January 30 was not reported felt. It originated 7 mi. SE of Mokuaweoweo, the summit crater of Mauna Loa, lat. 19° 24.5'N long. 155° 32' W. Two very feeble shocks 10:53 and 11:01 a. m. the same day, were close to or in Kilauea crater. A very feeble shock 2:29 p. m. February 1 originated 5 mi. west of Wood Valley, 19 ° 13'N, 155° 34.5'W. A very feeble shock 1:54 a. m. February 2 was in Kilauea crater. The Pit seismograph was disconnected for repairs during the month.

A slight earthquake was felt sharply at Kapapala ranch at 9:59 a. m. February 9. It was reported felt in Hookena, Hawaii National Park and Waikii. It was located 5 mi. SW of Wood Valley 19° 13'N, 155° 33'W. A feeble shock occurred 8:14 a. m. February 15 near or in Kilauea crater. A slight earthquake was felt sharply 3 mi. east of the observatory at 2:20 a. m. February 19. It was located a mile farther east, 19° 25'N, 155° 12.5'W. A feeble shock was felt at Kilauea crater, Hakalau and Honokaa at 5:31 p. m. February 24. The location was half way between Mauna Kea and Hualalai, 19° 46'N, 155° 42'W. and 11 mi. deep.

A very feeble shock occurred close to Kilauea crater 2:45 p. m. February 26. A slight shock was felt generally on the island of Hawaii at 10:22 p. m. March 1. It was reported from Kilauea Navy Camp, Kona, Pahala, Honomu, Hilo and Waikii. It was located 5 mi. north of Mokuaweoweo 19° 33'N, 155° 35'W.

Swarms of tremors, earthquakes barely enough to record, were noted on the following days. A swarm of 47 tremors was recorded between 8 and 11 a. m. Feb. 2. On the forenoons of Feb. 5, 6, 7 and 8 some were recorded together with suggestions of many other very faint tremors too small to be certain of. A swarm of 28 tremors was recorded during the middle of the day of Feb. 28.

A small teleseism began recording at 11:43:01 p. m. Jan. 30. The preliminary waves only were recorded. A small fragmentary record of a teleseism was obtained beginning at 5:41:51 p. m. Feb. 13. A fair record of a teleseism began recording at 8.03:30 p. m. Feb. 23, other waves began at 8:11:19 and 8:20:56. The maximum waves came at 8:22:19 p. m. It appeared to be 3,800 statute miles away.

The microseisms were normal Jan. 29, Feb. 1, 2, 3, 5, 9, 10, 18, 20, 21, 25. Mar. 1 & 4, they were strong or abnormal Feb. 11 and Mar. 2, they were subnormal during the rest of the period under consideration.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year since March 1, 1933 to March 1, 1934 is 2.7″ west and 3.8″ north.

TABLE OF TILT

Date	Observatory	Halemaumau
Jan. 29 – Feb. 4	1.2″ NE by E	17.0″ from.
Feb. 5 – Feb. 11	2.3″ SW by S	25.0″ from.
Feb. 12 – Feb. 18	2.1″ SW by W	10.0″ from.
Feb. 19 – Feb. 25	0.8″ SW by W	23.0″ towards.
Feb. 26 – Mar. 4	1.0″ S by W	00.0″

The pit tilt figures are somewhat unreliable, for during the period Feb. 2 to 25, a concrete ceiling was put in. The clinoscope was temporarily disconnected and though the connections were not changed, it is unlikely that it was replaced in the same position that it would have reached if undisturbed.

The temporary timbering in the clinoscope chamber must have had a large effect also. The figures are tentative. It is notable that the tilt away from the pit started January 19, 1934 with a net of 17″ at the end of January, so that the net tilt away from the pit of 29″ for the February interval may not be all artificial.

Correction. Tilt Jan. 1–7 should read 4″ inwards, not 15″ inwards.

A.E.J.

The Volcano Letter

No. 409—Monthly U. S. Geological Survey, Hawaii National Park MARCH, 1934

KILAUEA REPORT FOR MARCH, 1934

Including weekly press reports 1155 to 1158, March 4 to April 1, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

There has been no lava activity on the surface of the Mauna Loa—Kilauea volcanic system of the island Hawaii during the month of March. The summit crater of Mauna Loa, Mokuaweoweo. which was spouting basaltic lava December 2 to 18, 1933, has been under observation, as the National Park force are preparing a rest house or camp on the northern rim of the crater. The rangers report that the blue sulphur fume, at the source cone of December inside the main Mokuaweoweo floor towards the south, has definitely increased, the last visit being noon March 23.

On the Kilauea east rift, or Chain of Craters, there was a rumor of noises heard by workmen the afternoon of March 24 in the direction of Makaopuhi pit. There were a few tremors recorded on the seismograms of the Kilauea station at about the same time. The field was examined by A. E. Jones March 28. and inspection of the Chain of Craters revealed no sign of recent slides.

Small slides in Halemaumau pit of Kilauea Crater occurred as follows:— At 8:42 a. m. March 13, at the northeast wall, started perhaps by strong and gusty northeast wind. At 1:25 p. m. March 19. making dust rise at the west. During the forenoon of March 24, at 10:56 a. m. at the north corner of the pit. On April 1 at 10:24 a. m. at the north corner, and fresh dust lay on the talus at the northeast corner.

The thirty-two rim crack points around the edges of Halemaumau for weekly measurement of opening or closing, yielded the following changes when measured on Saturday forenoons:—

March 10. 5 opened, 2 closed, aggregate opening 1.5 mm.
March 17. 6 opened, 6 closed, aggregate opening 2 mm.
March 24. 3 opened, 1 closed, aggregate opening 1.5 mm.
March 31. 7 opened, 0 closed, aggregate opening 3.5 mm.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; and numbers of very feeble earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	tel.	seis.
March 11	48	2	1	13.00
March 18	35	2	2	9.75
March 25	33	2	1	9.25
April 1	19	5	0	7.25

The following very feeble shocks were located, none was reported felt.

One 0:34 a. m. March 10, 9 miles at sea off Cape Kumukahi. Lat 19° 37.5′ N. Long. 155° 43′ W.

One 1:56 a. m. March 10, under a fault scarp 2 miles SE of Ainahou. Lat 19° 19′ N. Long. 155° 11′ W.

One 5:09 p. m. March 11, 2 miles east of Kalalua crater on the Kilauea east rift. Lat. 19° 25′ N. Long. 155° 03′ W.

One 11:40 a. m. March 13, under SE edge of Kilauea Iki crater. Lat. 19° 25′ N. Long. 155° 15′ W.

One 8:09 p. m. March 18 under SE edge of Kilauea crater. Lat. 19° 24.5′ N. Long. 155° 16′ W.

One 3:01 a. m. March 24, between Makaopuhi crater and the cliff to the south. Lat 19° 20′ N. Long. 155° 10′ W.

One 4:11 a. m. March 29, on the Mauna Loa SW rift, 10 miles at sea. Lat. 18° 58′ N. Long. 155° 55′ W.

One 1:46 p. m. March 30, north of Pauahi crater on the Kilauea east rift. Lat. 19° 23′N. Long. 155° 13′ W.

The records of the teleseisms were poor, usually preliminary waves followed by L waves.

One began at 1:27:07 a. m. March 5.

One began at 4:43:40 a. m. March 12, reported by press in Utah, Wyoming and Idaho.

One began at 2:51:14 a. m. March 13.

One began at 1:43:47 a. m. March 24 with secondary waves following at 1:51:11 a. m., estimated distance 3600 miles, located in Pacific Ocean near the Solomon Islands.

Microseisms were subnormal March 5, 6, 7, 8, 10, 11, 13, 14, 17, 18, 19, 20, 21, 22 and April 1.

Microseisms were abnormal March 25, 26, 27, 28, 29, and 30. They were normal or moderate during the rest of the period under consideration.

A.E.J.

Tilting of the Ground.

In the Table of Tilt below, the second column shows the net tilt by weeks, as computed from the seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater 2.2 miles from Halemaumau.

The third column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year April 1, 1933 to April 1, 1934, is 1.8″ east and 4.0″ north.

TABLE OF TILT

Date	Observatory	Halemaumau
Mar. 5 to Mar 11	0.7″ SSW	3″ towards
Mar. 12 to Mar. 18	0.7″ NE	14″ towards
Mar. 19 to Mar 25	2.1″ SW by S	4″ from
Mar. 26 to Apr. 1	1.2″ NE by E	16″ towards

A.E.J.

The Volcano Letter

No. 410—Monthly U. S. Geological Survey, Hawaii National Park APRIL 1934

KILAUEA REPORT FOR APRIL 1934

Including weekly press reports 1159 to 1162, April 1 to April 29, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

No significant changes have been observed, in the craters of Kilauea and Mauna Loa during April, which suggest any immediate activity of lava. In Halemaumau pit of Kilauea volcano, a small fall of rocks at the northwest wall occurred 8:40 a. m. April 11, another at northeast wall 8:30 a. m. April 12, trickle slides moved down the northwest buttress inside the pit at 9:18 a. m. April 21, again at 10:15 a. m. northeast, and at 10:38 a. m. stronger at the top of the northwest buttress; dust arose again at 1:15 p. m. April 25 a northwestern slide again occurred, at 10:12 a. m.

The thirty-two rim crack points marked, around the edges of Halemaumau, for weekly measurement with steel tape, showed the following weekly changes as measured Saturday forenoons:—

April 8. 7 opened, 7 closed, aggregate result zero.
April 15. 5 opened, 6 closed, aggregate closing 1.0 mm.
April 22. 12 opened, 1 closed, aggregate opening 7.5 mm.
April 29. 12 opened, 4 closed, aggregate opening 5.5 mm.

For Mauna Loa, Ranger R. F. Lueck was in Mokuaweoweo crater April 29 for six hours. He visited the cones at the center of eruption of December last. He is familiar with this center from previous visits (Volcano Letter, January, 1934). Where at this center during his January visit he could smell sulphur strongly, there was now in April no more blue fume nor odor at the December vents. The 1914 cone, however, west of the rifts of 1933 in the bottom of the greater crater, was making blue and yellow fumes, as before. Lueck reported that a cone six miles down from the summit along the northeast rift belt of the volcano was steaming from its crater. This cone lies east of the National Park trail below the usual steaming places, and no steam had been noticed there on previous trips.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	sl.	tel.	seis.
April 8	15	4	0	0	0	5.75
April 15	25	5	2	1	1	12.75
April 22	18	1	0	0	0	5.00
April 29	18	2	0	0	0	5.50

The following local earthquakes were located.

A very feeble shock at sea on the Kilauea east rift, at 5:46 p. m. April 3. Lat. 19° 40'N. Long. 154° 37'W.

A very feeble shock a short distance north of Kilauea crater at 7:34 p. m. April 6. Lat 19° 28'N. Long. 155° 14'W.

At 2:06 a. m. April 9, a moderate earthquake felt in Kohala, felt lightly in Hilo and in Maui. It recorded as very feeble at the observatory and was located at the north end of the island Lat. 20° 09'N. Long. 155° 53'W.

At 8:21 a. m. April 9, a second shock in central Kohala. It was less widely felt, but recorded as feeble at the observatory; Lat. 20° 06'N. Long. 155° 43'W.

A very feeble shock at 2:38 a. m. April 11, 12 mi. at sea, S by E of Cape Kumukahi, Lat. 19° 16'N. Long. 154° 40'W.

A very feeble shock at 0:01 a. m. April 12 was located in Kilauea crater Lat. 19° 24.8'N. Long. 155° 16.5'W.

A feeble shock at 9:14 a. m. April 14 was located 10 miles north of Mokuaweoweo, Lat. 19° 37.5'N. Long. 155° 37'W.

A slight earthquake at 7:51 p. m. April 14, was felt in Olaa and Hilo. It was located 10 miles at sea on the east rift, Lat. 19° 37.5'N. Long. 154° 43'W.

A very feeble shock was felt in Hawaii National Park at 10:25 p. m. April 15. It was located 3 miles SE of the Volcano House, Lat. 19° 24.5'N. Long. 155° 14'W.

A very feeble shock at 1:06 a. m. April 24 was located near Waiohinu near the south end of the island, Lat. 19° 02'N. Long. 155° 38'W.

The teleseism was partly recorded, the records showing first or P wave only, beginning at 11:57:10 a. m. April 15.

Microseismic ground motion was normal April 4, 9, 11, 12, 13, 14, 15, 18, 20, 21, 26, 27, and 28, and subnormal the remainder of the month.

A.E.J.

Tilting of the Ground.

In the Table of Tilt below, the second column shows the net tilt by weeks, as computed from the seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater 2.2 miles from Halemaumau.

The third column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year April 29, 1933 to April 29, 1934 is 5.3" N. and 2.1" E.

TABLE OF TILT

Date	Observatory	Halemaumau
Apr. 2 to Apr. 8	0.8" SW by S	3" towards
Apr. 9 to Apr. 15	0.6" SW by S	2" from
Apr. 16 to Apr. 22	0.3" E by S	8" from
Apr. 23 to Apr. 29	0.3" West	1" towards

A.E.J.

The Volcano Letter

No. 411—Monthly U. S. Geological Survey, Hawaii National Park MAY, 1934

KILAUEA REPORT FOR MAY 1934

Including weekly press reports 1163 to 1167 April 29 to June 3, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Slides in Halemaumau pit of Kilauea crater occurred as fol'ows:—a thin dust cloud rose high and straight at northeast side 3:20 p. m. May 3; trickle slides at northeast wall 9:20 a. m. May 8, and thereafter during the day; the strongish earthquake of 10:09 a. m. May 10 left fresh red fragments on lower northwest talus, and there was a break in the wall just above. On May 11 fragments trickled down the northwestern wall as shown by the noise in that region at 9:05 and 9:12 a. m. The earthquakes of 3:23 and 3:25 p. m. May 13 were followed by a slide at Halemaumau at 3:38 p. m. leaving scars at top of west and north wall.

On May 14 at 8:20 a. m. with notably still air and rainy weather, Halemaumau showed vapor rising from the southeast and west walls, from the southwest talus, in voluminous jets up the south talus, at the wall about the southwest rift tunnels. and all along the upper rim cracks, east and west, outside of the pit.

In contrast to this. vapor was notably absent up and down the walls and taluses north and northeast, and no vapor jets whatever rose from the lava floor of the pit, nor from the 1932 cone at the southwest margin of the floor. The walls of the pit were dark red with moisture. This vapor distribution seems to indicate that the release of atmospheric moisture from underground is entirely outside the lava plug.

On May 20 it was noticed, that the tension cracks in the 1932 floor of Halemaumau all radiate from the region of the southwest cone. These include the border cracks, which are notably absent around the northern sides of the floor. The effect is as though strain of uplift were in progress under the 1932 cone. Yet for the last ten months 59% of the tilting at the three tilt cellars around Halemaumau has been inward, measured in seconds, reduced to radii from the center of the pit. The tension cracks are rather a relic of 1932, than anything related to present stress.

Weekly measurement of opening and closing of thirty-two rim crack points around the edges of Halemaumau, showed the following changes Saturday forenoons:—

May 5. 10 opened, 4 closed, aggregate opening 3.5 mm.
May 12. 8 opened, 3 closed, aggregate opening 4.5 mm.
May 19. 5 opened, 13 closed, aggregate closing 4.5 mm.
May 26. 4 opened, 7 closed, aggregate closing 3.0 mm.
June 2, 14 opened, 3 closed, aggregate opening 7.0 mm.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, slight, and moderate earthquakes; teleseisms or distant earthquakes: and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	sl.	mod.	tel.	seis
May 6	21	4	0	0	0	1	7.75
May 13	21	3	2	1	1	0	14.75
May 20	11	1	0	0	0	1	3.25
May 27	5	1	0	0	0	0	1.75
June 3	18	1	0	0	0	0	5.00

A tremor at 1:07 p. m. April 30, recorded at both Hilo and Observatory stations, was located about 55 statute miles east of Cape Kumukahi (east point of Hawaii) Lat. 19° 32'N. Long. 153° 59'W.

A very feeble shock at 8 p. m. May 9, was 10 miles deep under Mauna Loa, Lat. 19° 30'N. Long. 155° 30'W.

A moderate to strong quake began at 10:09:05 a. m. May 10 on the Observatory seismograms and was followed by aftershocks at 10:39 a. m. and at 0:34 p. m. The main shock was described at Hakalau as being very strong leading to flight from houses. Honomu and North Kohala reported it as very sharp, and sharp. Hookena and Kapapala reported it moderate, Holualoa and Puuwaawaa as small. Honokaa thought it rather strong. Hilo had objects fall and old paint crack off ceilings, there was some alarm. It was reported felt on the island of Maui. It dismantled some seismographs on Hawaii. The location found was 17 miles deep under the NE section of Mauna Loa. Lat. 19° 38'N. Long. 155° 23'W.

The first aftershock at 10:39 a. m. was felt in Hakalau, it was located 27 miles deep under the SE section of Mauna Loa. Lat. 19° 27'N. Long. 155° 26'W. It registered as very feeble at the Observatory.

The second aftershock at 0:34 p. m. recorded as feeble, was from the shore line of Hawaii to the south of Kilauea, Lat 19° 15'N. Long. 155° 18'W., and probably 4 miles deep. It was reported felt very slightly at Kilauea and Hilo.

Two small quakes were well recorded on the Kona seismograph at 7 p. m. on May 10 and at 11:20 p. m. May 11, but were not well recorded elsewhere.

A slight quake was felt at Kilauea, Hilo and Honokaa at 3:23 p. m. May 13. It was located 14 miles deep on the rift dividing Mauna Loa and Kilauea at Lat. 19° 22.5'N. Long. 155° 22.5'W. It was followed by an aftershock, felt in Kilauea and Hilo, at 3:25 p. m. It was about 2 miles deep under the SW section of Mauna Loa, Lat. 19° 13'N Long. 155° 39'W.

A very feeble shock at 6:30 p. m. May 15 may have occurred under the Mauna Loa SW rift.

Ten very small shocks (tremors and very feeble) occurred under the Kilauea crater during the five weeks covered here.

A small record of a teleseism began at 6:13:56 p. m. May 3, a second began at 11:50:25 a. m. May 14. Both were located by the U. S. Coast and Geodetic Survey. The first Lat. 61°N. Long. 148°W. near Prince William Sound, Alaska; the second Lat. 59°N. 150°W. near Kenai Peninsula, Alaska.

Microseismic motion of the ground was subnormal most of the five weeks, normal intensity was reached only on May 10 and 12.

A.E.J.

Tilting of the Ground.

In the Table of Tilt below, the second column shows the net tilt by weeks, as computed from the seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater 2.2 miles from Halemaumau.

The third column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year June 3, 1933 to June 3, 1934 is 1.8" E and 4.5" N.

TABLE OF TILT

Date	Observatory	Halemaumau
Apr. 30 to May 6	1.3" NE by N	2" towards
May 7 to May 13	0.4" NW by W	4" towards
May 14 to May 20	1.5" SW	1" towards
May 21 to May 27	0.1" S	4" from
May 28 to June 3	0.5" SE by S	2" towards

A.E.J.

The Volcano Letter

No. 412—Monthly U. S. Geological Survey, Hawaii National Park JUNE, 1934

KILAUEA REPORT FOR JUNE, 1934

Including weekly press reports 1168 to 1171
June 3 to July 1, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

At Halemaumau pit of Kilauea Volcano there was no new motion nor sign of lava activity. It is of interest to note how the pressure ridges around the edges of what was the lava lake of 1932 (January), now the floor of the pit, show three stages of shrinkage of the lake. There is the ridge around the edge of the floor, outlining the large lake of December 1931. Then there is a narrow ridge across the floor from the northwest to southeast, marking the first stage of diminution. Lastly there is an innermost rampart with hummocks inside, just in front of the big southwest cone, which contained the last fountaining source of the lava. What liquid lava receded must have finally sucked down the vent under the cone, and so made the slumping of crusts which are now seen in tumbled condition on the floor and at the cone.

Measurements of vapor temperatures by Jaggar, at cracks near Halemaumau, June 1, 2, 3, and 5 gave the following figures in degrees Centigrade (35° C. equals 95° F., and 88° C. equals 190° F.):—

Southwest, over Kau Desert rift line, 54, 57 and 64 degrees C.

West, near big steam crack, 58 and 67 degrees C.

East, north of tourist outlook, 50 and 55 degrees C.

One hundred feet back of this from the pit, 70 to 75 degrees C.

Near road terminus houses, southeast, 35 to 48 degrees C.

Near flag northwest of pit, 51, 53, 56, 58 and 64 degrees C.

Whitened 1919 lava half-mile north of pit, 74, 83, and 88 degrees C.

Whitened 1894 lava southeast of Halemaumau, 82 to 88 degrees C.

These figures show temperatures lower than January 1925 for cracks near the pit (See Volcano Letter 301). The high temperatures in cracks more remote are as usual. The implication is that deeper cracks are found, tapping deeper and hotter vapor, towards the border of the greater Kilauea crater. Probably at the border of the inner fill of Halemaumau, now inaccessible, there are very hot places. These would correspond with the old "postal card crack," which was at the border of a Halemaumau fill of 1894, a "wall-crack," destroyed by overflow in 1919 and by collapse in May, 1922.

Slides in Halemaumau during June were:—

5:30 p. m. June 8, from the notch to the east of the north buttress.

June 14-15, large fresh fall of rocks found, making a broad gray streak on the east talus.

9:42 a. m. June 23, small and continuous slide on north side of lower buttress at the southeast wall, lasting some minutes.

10:57 and 11:21 a. m. June 30 over the middle of the north sill.

Weekly measurement of opening and closing of thirty-two marked rim-crack points, around the edges of Halemaumau, showed the following changes Saturday forenoons:—

June 9. 7 opened, 3 closed, aggregate opening 3.0 mm.
June 16. 6 opened, 5 closed, aggregate opening 0.5 mm.
June 23. 8 opened, 5 closed, aggregate opening 3 mm.
June 30. 9 opened, 7 closed, aggregate opening 1.5 mm.

T.A.J.

EARTHQUAKES

TABLE

Number of minutes of tremor; numbers of very feeble, and moderate local earthquakes as registered at Kilauea; teleseisms or distant large earthquakes; and local seismicity index (see Volcano Letter 371)

Week ending	tr.	v. f.	mod.	tel.	seis.
June 10	15	1	0	0	4.25
June 17	102	3	0	0	27.00
June 24	51	2	0	0	13.75
July 1	32	6	1	1	14.00

The following successive local disturbances began at the times indicated, and the epicenters as shown were located from seismograms; when possible, the depth of the source is indicated. The location of epicenters is based on four main seismograph stations. Kilauea, Hilo, Kona, and Waikii. The intensity is that recorded at Kilauea instruments.

May 16 at 6:29 p. m. very feeble, Lat. 19° 01'N, Long. 155° 38'W.

May 20 at 6:14 p. m. tremor, Lat. 19° 49'N, Long. 156° 13'W on the extension of the Hualalai rift.

June 5 at 8:59 a. m. very feeble on the NE Mauna Loa rift, nearer Hilo than Kilauea.

June 15 at 10:50 p. m. very feeble, Lat. 19° 42'N, Long. 155° 22'W, 6 miles deep under SE slope of Mauna Kea.

June 25 at 2:30 p. m. very feeble, Lat 19° 36'N, Long. 155° 20'W on the northeast Mauna Loa rift.

June 26 at 7:07 p. m. moderate, Lat. 19° 12'N, Long. 155° 05'W, a few miles at sea south from the Puna coast, felt at Honokaa, Hilo, and Kilauea.

June 27 at 7:01 a. m. very feeble, Lat. 20° 02.5'N, Long. 155° 18'W, under Hamakua coast, felt in Honokaa.

Other very feeble local earthquakes at Kilauea crater were two in number June 12, and one each June 19, 23, 26, and 28.

The distant large earthquake was incompletely recorded beginning June 28 at 10h:06m:43s; p. m.

Microseismic motion was subnormal, becoming normal June 4, 19, 24, and 25.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending July 1, 1934 was 3.3″ N and 1.6″ E of the position July 1, 1933.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
June 4 to June 10	0	3.3″ towards
June 11 to June 17	0.9″ NE by E	2.0″ towards
June 18 to June 24	0.9″ NNE	0.6″ towards
June 25 to July 1	0.9″ W by N	72.8″ towards (Earthquake 26th)

A.E.J.

The Volcano Letter

No. 413—Monthly U. S. Geological Survey, Hawaii National Park JULY, 1934

KILAUEA REPORT FOR JULY, 1934

Including weekly press reports 1172 to 1175
July 1 to July 29, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Slides in Halemaumau during July were:—

At 1:15 p. m. July 5, north side, making dust cloud, leaving fresh break in wall over west end of Canoe Sill, and leaving fresh debris on the talus.

10:20 a. m. July 7, small slide north.

9:33 a. m. July 19, small slide north.

2:36 p. m. July 20, slides from east and north walls started by an earthquake. The shock was felt by an observer standing on the southwest rim, a swaying motion. This was Mr. Twigg Smith, who immediately saw a considerable slide at the east corner of the pit, and a smaller one at the north buttress. Dust rose above the pit. Rocks were still falling at the east at 3:05 p. m. The earthquake origin was probably under the southeast part of Kilauea crater. The pit instruments were partly dismantled, and the cracks used for measurements were somewhat changed.

10:15 a. m. July 21, slide at northwest talus.

Afternoon, July 21, slide made a dust cloud.

8:40 a. m. July 22, a few rocks sliding north.

1:45 p. m. July 24, a few rocks heard sliding.

National Park workers at the summit crater of Mauna Loa reported disagreeable fumes in the west part of the crater, and on July 22 two noises like blasts about twenty seconds apart, to the eastward.

Weekly measurement of opening and closing of thirty-two marked rim-crack points, around the edges of Halemaumau, showed the following changes Saturday forenoons:—

July 7. 8 opened, 3 closed, aggregate opening 5.0 mm.

July 14. 4 opened, 4 closed, aggregate opening 1.5 mm.

July 21. 11 opened, 4 closed, aggregate opening 4.5 mm.

July 28. 6 opened, 8 closed, aggregate closing 1.0 mm.

Crack point No. 37, about 800 feet back from the southeast rim of Halemaumau, and extending northeast along the wall-crack of Kilauea crater against the "Sand Spit" where the Volcano House road emerges on the lava floor, has been opening extensively. It has made marked cracks in the paving of the road, and in the mortared stone coping. This was observed by A. E. Jones June 25. The total opening is 15 mm. (0.6 inch) April 14 to August 4, 1934. This crack had opened slowly during the previous half-year, but it suddenly began rapid weekly movement after April. (For position see map Volcano Letter 395).

T.A.J.

EARTHQUAKES

TABLE

Week ending.	Minutes of tremor.	very feeble earthquakes	Slight earthquakes	Distant earthquakes	Local * Seismicity.
July 8	24	8	0	1	10.00
July 15	12	2	0	0	4.00
July 22	25	1	1	5	9.25
July 29	14	2	0	1	4.50

* For local seismicity see Volcano Letter 371.

The following successive local disturbances began at the times indicated, the epicenters as shown were located from seismograms; when possible, the depth of the source is indicated. The location of epicenters is based on four main seismograph stations, Kilauea, Hilo, Kona, and Waikii. The intensity is that recorded on the Kilauea instruments.

July 5. 2 20 a. m. very feeble, Lat. 19° 17'N. Long. 155° 35'W, 22 miles deep under the SE flank of Mauna Loa.

July 5, 3:15 p. m. very feeble, Lat. 19° 33'N, Long. 155° 23'W, 3 miles deep under the Mauna Loa NE rift.

July 20, 2:36 p. m. Slight, felt strongly by visitors near the Pit of Halemaumau, felt slightly at the NE end of Kilauea, occurred under the SE rim of the crater. Dismantled the Pit seismograph, only recorded as a small tremor on both the Hilo and Kona seismographs.

July 20, 1:30 a. m. Felt at Kapapala Ranch. Lat. 19° 24.5'N, Long. 155° 27'W, 4 miles deep.

The teleseisms were recorded as follows;

July 6, 0h:27m:02s. p. m. the secondary waves began at 0:32:45 p. m. It's origin was 41.5° N 124.9° W (Jesuit Seis. Ass.) off the coast of Northern California.

July 17, 3:17:50 p. m. secondary waves at 3:27:15 p. m. Its origin was 16° N, 84° W, (USC&GS) in northern Panama.

July 18, 9:19:31 a. m. secondary waves at 9:26:14 a. m. Origin 14° S, 168° E, (USC&GS) near the New Hebrides.

July 18, a fragment of a distant earthquake began recording at 9:30 p. m.

July 20. 7:57:17 p. m. secondary waves at 8:04:48 p. m. Origin 3,700 miles away.

July 21, 0:20:29 a. m. secondary waves at 0:29:52 a. m. 4,900 mi. to origin.

July 27, 11:14:08 a. m. secondary waves at 11:23:36 a. m. 4,985 mi. to origin.

Microseismic ground motion was normal July 6, 18, 19, 21 and 27 and was subnormal the other days of the month.

A.E.J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending July 29 is 3.8″ N and 1.8″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
July 2 to July 8	0.5″ North	3.0″ from
July 9 to July 15	0.8″ N by W	5.4″ towards
July 16 to July 22	1.4″ N by W	64.3″ from * (quake)
July 23 to July 29	1.2″ ENE	4.0″ from

* Local earthquakes have caused the SE clinoscope to change 73″ towards the pit June 26 and 64″ from the pit July 20. What portion of these changes represent actual tilt is uncertain.

A.E.J.

The Volcano Letter

No. 414—Monthly U. S. Geological Survey, Hawaii National Park AUGUST, 1934

KILAUEA REPORT FOR AUGUST, 1934

Including weekly press reports 1176 to 1180

July 29 to September 2, midnight

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Slides in Halemaumau during August were:—

At 9:10 a. m. August 4, south wall, a small slide.

9:12 a. m. August 4, north wall.

On the previous day August 3 a small slide was reported northwest about 10 a. m.

About 11 a. m. August 12, small slide at the north.

At 9:25 a. m. August 19, an avalanche at the north.

At 1:15 p. m. August 19, another similar slide.

At 10:30 a. m. August 25, slide at the north.

Weekly measurement of opening and closing of thirty-two marked rim-crack points, around the edges of Halemaumau, showed the following changes Saturday forenoons:—

August 4. 6 opened, 4 closed, aggregate opening 2 mm.

August 11. 7 opened, 11 closed, aggregate closing 2.0 mm.

August 18. 9 opened, 7 closed, aggregate opening 2.0 mm.

August 25. 7 opened, 6 closed, aggregate opening 1.0 mm.

September 1. 7 opened, 1 closed, aggregate opening 3.0 mm.

No excessive movement occurred at Crack No. 37, described in July Volcano Letter.

August 30 temperature readings were made on the Kilauea floor north of Halemaumau. A new trail for the purpose has been built by the Hawaii National Park. Heat is at vapor vents. These vents are persistent deep crackings, which assert themselves up through surface flows. Similar temperatures are found over definite areas. Presumably deep cracking has let down rain water and brought up vapor. The mapping of these areas is important, and their changes of temperature may possibly bear on forecast. Hitherto the data of forecast for eruption are elusive, except where based on statistics, or phenomena only a few hours before the event.

In a whitened area north of Halemaumau, in 1919 lava, maximum temperature was 86° Cent; heavy grass and moss grew in the wet vapor. The 1924 ash has assisted vegetation everywhere. Farther north opposite Uwekahuna trail, the temperature was 45° C., also 1919 lava with less vegetation. In 1894 lava near the big lava dome northeast of Halemaumau, a whitened area showing lichens and grass gave 79° C. The whitening is due to insoluble sulphates. On the Volcano House trail farther east, whitened cracks cutting both 1894 and 1921 lava gave 85° C. A big steam hole farther northeast on the line between Halemaumau and the north side of Kilauea Iki gave 89° C (the boiling point of water for this elevation is about 97° C.) This was 1894 lava, the cracks showed blue-green algae in the openings, the rock was rusty and covered with salts, and a reddish belt of these cracks extended east-northeast away toward the outer walls of Kilauea crater, in a sharply marked zone radial to the Halemaumau center. The larger steam-holes that show vapor on a sunny day are very hot. Along the telephone line east of Halemaumau in 1894 lava. the maximum temperature was 63° C.. the ground showing some whitened cracks and grass. The temperature of the air was 26°C.

A. E Jones was in charge of a party under Hawaii National Park July 30 to August 3, to map the lava floor of the summit crater of Mauna Loa, as left by the eruption of December 1933. The floor was flagged and a revised topographic map made with plane-table. The helpers were John Mahaiula, Fred Pestana, Louis Braz and Torao Nishimoto. The new summit rest-house was occupied and was found a protection against cold. The four days on the summit were generally clear and comfortable. The temperature was 32° F. at sunset and 20° F. at daylight. The crater was quiet, sounds of falling rocks were heard occasionally, and the 1933 lava was shell pahoehoe. Near the eruption vents the rock was hot enough to be uncomfortable, the shell lava broke easily and in places was dangerous, and sulphurous fume was locally strong. The results of mapping show the new lava field in the eastern half of the main Mokuaweoweo bowl to be two miles long by three-fourths mile wide and 100 feet thick; the source cones at the southwest are 100 feet high. The depression contour basins of the crater are now at the north and southeast. The new lava heap is thus an elongate dome highest at the southwest athwart the crater sink, with its axis northeast-southwest.

T.A.J.

EARTHQUAKES

TABLE

Week ending.	Minutes of tremor.	Very feeble earthquakes	Slight earthquakes	Distant earthquakes	Local * Seismicity.
August 5	11	4	0	0	4.75
August 12	14	3	0	1	5.00
August 19	12	1	1	0	5.50
August 26	18	2	0	0	5.50
September 2	11	4	0	0	4.75

* For local seismicity see Volcano Letter 371.

The following successive local disturbances began at the times indicated, the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on four main seismograph stations, Kilauea, Hilo, and Kona. Waikii did not return any records for days when earthquakes ocurred. The intensity is that recorded on the Kilauea instruments.

July 30. 0:23 a. m. very feeble, Lat. 19° 40′ N. Long. 155° 45′ W; under Hualalai.

July 30. 4:18 a. m. very feeble, Lat. 19° 20′ N. Long. 155° 14′ W; under Ainahou Ranch.

July 30. 3:28 p. m. very feeble, Lat, 19° 22.5′ N. Long. 155° 17′ W; under the south slope of Kilauea 1 mile from crater.

July 31. 0:06 a. m. very feeble, Lat. 19° 22.5′ N. Long. 155° 13′ W; 1 mile deep under Heake crater, one of the chain of craters.

August 7. 10:19 a. m. very feeble, Lat. 19° 32′ N; Long. 155° 32′ W; 5 miles deep under Mauna Loa NE rift, near summit. Felt in Hilo.

August 11. 2:38 p. m. very feeble, Lat. 19° 18′ N. Long. 155° 28′ W; 1 mile deep under SE flank of Mauna Loa, near Wood valley.

August 16. 2:08 a. m. slight, Lat. 19° 38′ N. Long. 155° 15′ W; 5 miles deep uder Mauna Loa NE rift. It was felt in Hilo and Honomu.

August 25. 2:08 p. m. very feeble, Lat. 19° 25.3′ N. Long. 155° 16 5′ W; 1 mile deep under Kilauea crater.

August 28. 5:51 p. m. very feeble, Felt by several on Kilauea crater rim, probably centered under crater.

The long waves of a teleseism began recording at 5h:30m:40s. p. m. August 6.

USC&GS reports it as occurring near the New Hebrides, Lat. 14° S. Long. 168° E.

Microseismic ground motion was normal (20 to 30 microns) July 30 and 31, and was subnormal (8 to 20 microns) August 1 to September 2.

A.E.J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending September 2, 1934 is 1.9″ N and 2.7″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
July 30 to Aug. 5	0.7″ NNW	0″
Aug. 6 to Aug. 12	0.4″ WNW	1.0″ from
Aug. 13 to Aug. 19	0.8″ ENE	6.9″ towards
Aug. 20 to Aug. 26	1.2″ ENE	5.6″ towards
Aug. 27 to Sept. 2	0.5″ N by E	1.2″ towards

A.E.J.

The Volcano Letter

415

No. 415—Monthly U. S. Geological Survey, Hawaii National Park SEPTEMBER, 1934

KILAUEA REPORT FOR SEPTEMBER, 1934

Including weekly press reports 1181 to 1184
September 2 to September 30, midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Halemaumau pit of Kilauea Volcano broke into lava eruption in its bottom about 2:44 a. m. September 6. On the preceding day there were slides before and after noon, and the seismograph SE of Halemaumau registered southwesterly tilt the afternoon of the 5th. This was the first real premonitory symptom.

Sept. 6 tremor spasms began 1:07 a. m. a few minutes apart, and shocks close to the pit accompanied the outbreak, the feeble shock at 2:44 a. m. being followed by the continuous tremor of fountaining, and by the bright glow of inpouring lava and clouds of fume. The fountaining places began at the edge of the 1932 floor north, northwest and west. The first two were at the base of taluses, the third a crack back of the west buttress. Here the lava squirted up in 25 jets along a horizontal line halfway up the wall of the pit. These jets cascaded down the wall in ribbon cataracts. They poured over the large west talus and went out of action by 6 a. m. The northwest fountains were several hundred feet high like jets from hose nozzles, covering up the northwest talus with pumiceous lava. The northern line of fountains trending E-W about 600 feet was quickly submerged under the spreading lake, and became a lake center destined to survive. Between 3 and 4 p. m the northwest fountains went out of action, making a great diminution in fume volume and the eruption adopted stability of action at the northern fountains, followed by gradual dwindling for thirty days.

Sulphurous fume of absinthe red color in transmitted light boiled up several thousand feet the first twelve hours. With it went fragments of basaltic pumice, but nothing resembling ash. The reflected fountain light was yellow-green to orange. The noise was a rumbling and a rushing of gas. Hundreds of whirlwinds swept up clouds of dust west and southwest of Halemaumau, the trade wind being from the northeast. Pumice fragments up to 30 cm. fell on the ground outside of the pit.

At 4 a. m. Sept. 6 there were 30 jet fountains. At 8 a. m. the new bottom pool covered the entire 1932 floor 60 feet deep. Its area was 90 acres and its volume 9 million cubic yards. Only the top of the 1932 border cone was still emergent. Ten main vents persisted until 6 a. m. along the cascade crack, the cascades being 300 to 400 feet high, and there were two or three subordinate cascades, on an extension of the crack which opened on the north side of the west boss.

Northeast and southwest of the pit, the broken ground exhibited new breaks in the ash soil. At noon Sept. 6 the north fountains had dwindled and the northwestern ones were very violent. The lake was covered with a bright-line pattern and black silky skins. There were straight lines of bubble fountains along the meeting belt of surface currents. A bench and rampart of crusts developed around the lake, wider at the taluses, where the submerged slope was flatter. The tremor diminished when the violent northwest fountaining stopped rather suddenly, between 3 and 4 p. m., and only thin blue fume was left arising from the northern interior fountains.

Sept. 7 there were 8 fountains, the larger one making blast-like detonations, flinging up lava 300 feet, and emitting brown puffs. Tremor increase rang the annunciator bell at the Observatory two miles away. The lake diminished to a northern circle around the fountains 1200 feet in diameter. Sept. 9 the floor had shrunk and lowered 10 to 20 feet, and the inner lake was smaller, at the NNE side of the floor. There was a slump scarp all around. A few slides occurred. The lake Sept. 10 measured about 1000 feet east-west by 400 feet north-south, and was defined by a border rampart over which went overflows. The lake became an oval plateau on top of a terraced heap. Spatter banks formed behind the two bigger fountains east and west, showing that the lake was shallow as usual. Only the fountains were over wells. September 11 overflows poured out of the lake heap on all sides. Sept. 12 islands of crust and spatter began to form near the eastern fountains. Detonations came from the wells from time to time as the vents clogged. Five sulphur patches appeared on the taluses. Sept. 15 there were five principal fountains and a line of islands from NW to SE across the lake. Sept. 16 the western fountain was dominant, with a cone and crater about it. There were ten fountains, six islands and a peninsula.

Sept. 20 the floor measured 2700 by 2200 feet. The lake pool measured 744 by 390 feet. This pool stood 38 feet above the floor, and the highest grotto heap of its banks stood 136 feet above the pre-eruption floor of 1932 immediately under it. The average 1932 floor level was 2796 feet above sea-level, while the average 1934 new floor level is 2874 feet. This makes the average thickness of the new layer 78 feet.

Overflows built up the new lake heap against the north wall of the pit. Ten cracks gradually developed in the outer floor radial to the lake. The overflows appeared to be a stiff viscous pahoehoe Always the streaming was outward from the west fountains as source well, and sometimes the east fountains exhibited a well of inward cascading downward. Evidently a convectional circulation was being established, and the sinkhole well tended to explode with detonations. The lake remained brimming full and the fume remained thin.

Sept. 20 a new feature back of the border slump scarp at the edge of the greater floor of Halemaumau was the welling up of trickle flows glowing red, evidently following the "wall-crack" between the talus and the new cake of 1934 fill. This was the first time after the early days that any glowing lava had appeared from a source away from the lake. These trickle flows at 11 a. m. rose along the base of the east talus, and at 2:30 p. m. they rose along the base of the south taluses. The next day September 21 the west talus developed the same kind of trickle flows along its base. These risings at the floor edge were favored by freedom of percolation of the lava among talus bowlders, but the trickle flows extended to places under the rock walls of the pit. In no case did they cascade over the slump scarp inward, but rose as a dike between the floor cake and the outer funnel. In each case their appearance was marked by extra pressure at the lake, accompanied by overflows. The band of border extrusion was 20 feet wide in places. Sept. 22 during a big overflow from the lake southwest, wall-crack trickle appeared along the small talus heaps west-northwest.

Sept. 22 detonation spells from both east and west walls of the lake recurred from time to time, usually when the east fountain had been transformed into a sinkhole grotto Big bursts of gas and flame came up. The phenomenon of downpouring would last from 10 to 20 minutes. Then the pot would resume ordinary fountaining with outward streaming. Harmonic tremor greatly increased during detonation spells. September 23 the west fountain had become a pool in a raised craterlet, from which a cascade poured southward into the lake.

This craterlet made noisy high explosions emitting brown fume bursts. Four avalanches were observed at the north wall of the pit. About 2 p. m. the lake drained out almost completely through the eastern sinkhole, leaving an empty saucer 20 or more feet deep, with the western source quiet, and explosions at the sinkhole Then the liquid poured in again. The duration of these drainages was from a half-hour to two hours, increasing until October 1 in duration and violence at intervals of about six hours. Eventually the detonations were heard three miles away.

The elevation above sea-level of the lake Sept. 20-21 was 2882 feet, of the floor, 2844 feet, of the floor edge 2860 feet. The spatter heaps stood 26 to 28 feet above the lake. The depth of the pit from the Tourist Stand southeast (B. M. 3644 feet) to the lake plateau was 762 feet, and to the mean level of the bottom 770 feet. The highest spatter heap at the lake stood 71 feet above the lowest part of the floor.

The last week of the month was characterized by the six-hour intervals between explosive drainages of the lake, and by swelling up of the edges of the floor. Probably the whole floor was swelling by intrusion. This accounts for the drainages, and agrees with the earlier wall-crack trickle flows. Apparently the pulsations of lowering the lake basin—all overflows had now ceased—were occasioned by inflow of the liquid under the shell of crust forming the floor of Sept. 7-8. The floor was lifted and the lake went down. The lake heap was thereby abolished. The explosions

were due to clogging of the gases in the increasingly viscous lava of the wells, unable to fountain freely with artesian well action, when by reason of recession the effervescent fluid was trying to fountain at the bottom of a shaft. Failing to overflow, the wells became gun barrels. With each detonation an umbrella-shaped fling of stiff lava would shoot up 400 feet, the roofs of the grottoes would be blown to pieces, and fragments would clatter down all over the surrounding surfaces. Finally the explosive spells would be followed by complete quiet for a half-hour. Then the liquid would quietly recover in the wells, and restore the lake to a period of four or five hours of quiet streaming.

The drainages tended to come after noon and after midnight, and usually once in between. Sept. 25 a band of red glow showed around the floor edge of Halemaumau, indicating that wall-dike intrusion was still in progress. Sept. 26 this disappeared, but a week later it reappeared. The detail of a sinking spell of the lake was as follows. At 9 a. m. the west fountain cone was cascading over its flank; at 11 a. m. the lava had lowered 25 feet from the lake, both east and west fountain wells were cannonading vertically, long squirts of viscous melt were sent up 200 feet, the intervals between detonations or hisses were from five to ten seconds, then the lava pooled in the wells and came back with quiet fountaining at 12:15 p. m. The explosions gradually lessened, a fan-shaped flood from the west fountain met an expanding puddle from the east fountain in mid-lake, the new liquid overriding the foundered crust that formed the floor of the lake.

September 28 there were still some overflows from the lake. An elephant-back ridge 25 feet high was revealed swollen and crevassed, in the edge of the new floor at the foot of the east talus. Instead of welling up the wall-crack, the under-lava was now blocked in that direction, and so was lifting the floor instead. The floor which had been 15 feet below the slump-scarp, was now 25 feet above it.

Another survey by T. A. Jaggar September 29 showed the average floor border at elevation 2860 feet as before; the inner floor 2881 feet instead of the former 2844 feet. The lake had lowered slightly from 2882 to 2879 feet elevation. The summits of the lake heap now averaged 2903 feet, where on September 21 they stood at 2909 feet. The length of the lake, now narrower and irregular, had increased from 744 to 812 feet. Its width decreased from 390 to 360 feet. The relative height of the lake heap above the floor remained about 75 feet for its maximum relief above a valley in the floor southeast of the lake basin. The east cone was its highest point, elevation 2910 feet. The relief of the floor is much greater than is apparent as seen from above. The cones about the fountains were 20 to 30 feet above the full lake.

Sept. 29 the lake made small overflows, overhanging grottoes surmounted the two fountains, gradual drainage until noon was followed by intense explosions at both wells, lasting until 1:30 p. m. The explosions demolished the arched grottoes. There was repose until 2:00 p. m. Then the wells quietly filled from below with red puddles covered with gray skin. The lake basin was refilled from both wells by torrents cascading downward over the slag-heaps of the ridge. The lake area was being converted into several ponds. Sept. 30 there was a forenoon drainage; at 8 p. m. the west fountain started lowering and exploding, while the eastern one was giving vent to a voluminous river of lava, which stopped flowing at 8:30 p. m. Then its source the east well gave vent to explosions 400 feet high, the smaller shots coming 20 to the minute. The west pot exploded sending fiery spray 600 feet high, the maximum to date; the detonations were heard 2.2 miles away and rattled iron roofs. The well seemed empty, but the gushes occasionally brought up great sheets of lava; splashes stuck on the pit wall a third of the way to the top. The greater explosions came about every 8 minutes. Cessation followed as usual. By night five glow spots showed along the edge of the floor east.

Weekly measurements of rim cracks around Halemaumau, 32 in number, gave:

Sept. 8. 14 opened, 12 closed, aggregate opening 24 mm.
Sept 15. 11 opened, 6 closed, aggregate opening 6 mm.
Sept. 22. 10 opened, 2 closed, aggregate opening 5.5 mm.
Sept. 29. 8 opened, 6 closed, aggregate opening 2.5 mm.

By measuring the cracks the forenoon of the eruption Sept. 6, a movement of opening of 20 mm. had already taken place, involving 12 opened and 11 closed; 12 mm. of the opening was at Crack No. 37, a deep border fissure of the Kilauea crater floor southeast, which had cracked the road paving. The differential movement was down to the northwest, and up to the southeast. This movement had been in progress for some months (See July Volcano Letter).

The tilt movements at the three clinoscope cellars around Halemaumau accompanying the eruption, were inward towards the pit at the north and southeast cellars, and away from the pit at the west cellar. This amounted to more than 100 seconds at the west and southeast cellars, but the instruments were dismantled, so that the values are indefinite. The north cellar registered 22 5 seconds south since the previous day, (Sept. 5-6).

The tilt at these cellars after the eruption proceeded was recovery at the southeast and west cellars, and continuance in the same direction at the north cellar. The west cellar recovered 21 seconds to the ENE; the southeast cellar 7 seconds to the SE; and the north cellar continued 5 seconds to the SW, between Sept. 6 and Sept. 10. The tilting movements were more normal after September 10. This was the first demonstration of the effect of eruption on these tilt cellars. The instrument pivots are not yet proof against earthquakes. T. A. J.

EARTHQUAKES.

TABLE

Week ending.	Minutes of tremor.	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Local * Seismicity.
Sept. 9	4,878	9	1	1	1,725.
Sept. 16	10,080	1	0	0	2,565.
Sept. 23	10,075	3	2	0	2,808.
Sept. 30	9,885	0	0	0	2,763.

* For local seismicity index see Volcano Letter 371.

Note, Some of the tremor was very feeble in amplitude and was weighted accordingly.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on three main seismograph stations, Kilauea, Hilo, and Kona. No earthquakes were recorded at Waikii. The intensity is that recorded on the Kilauea instruments.

September 6, 1:07 to 2:44 a. m. several very feeble shocks and tremors occurred that were near or in the crater; they preceded the eruption in Halemaumau. At 2:21 a. m. a slight earthquake (2 Rossi-Forel) was felt by several persons living on the rim of the crater. It was located in the creater near Halemaumau. lat. 19° 25′ N long. 155° 17′ W and very near the surface of the crater floor. At 2:44 a. m. a feeble earthquake (1 Rossi-Forel) occurred. It was located near the south rim of Kilauea near the surface, in lat. 19° 23.5′ N long. 155° 16.7′ W. All of the above shocks immediately preceded the out-flow of lava in Halemaumau, and were supposedly caused by the breaking of the crust under the strain of trapped volcanic gas and magma.

September 17. 11:56 a. m. a feeble shock was felt at the Observatory and at Honomu. It was located at 19° 02′ N, 155° 13′ W. 11 miles deep.

Sept. 22. 9:44 a. m. a feeble shock was felt at the Observatory and at Kapapala ranch. It was located 11 miles deep under Hilina Pali, at 19° 15′ N. 155° 20′ W.

September 23. 1:49 a. m. a very feeble shock occurred probably one of seven felt at Kapapala ranch. It was located 9 miles deep under Palima Point on the Kilauea SW rift. 19° 11.5′ N. 155° 27′ W.

No teleseisms were noticed on the seismograph records. Any small records would have been obscured by the large continuous "Harmonic Tremor" generated by flowing lava in Halemaumau.

This tremor had a period of 0.6 seconds and represented a ground movement of from 6 to 48 microns during the early hours of the eruption. Towards the end of the month the fluctuations in amplitude became more marked, dropping at times to less than one micron, at other times becoming as large as 15 microns, all with the same period. These spells were coincident with spells of explosion that recurred at 6 to 7 hour intervals during the last week of the month. (Sept. 24 to 30).

Microseismic motion of the ground was normal on the following days of the month, September 6, 7, 8, 12, 14, 19, 21, 24, 26, and 30, and subnormal the rest of the month. A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the Pit.

At the Observatory the total accumulated tilt in the year ending September 30, 1934 is 0.4″ S and 1.4″ E.

TABLE OF TILT

Date 1934	Observatory		Halemaumau	
Sept. 3 to Sept. 9	2.0″	SW	120.″ ?	towards
Sept. 10 to Sept. 16	1.4″	ENE	0.4″	towards
Sept. 11 to Sept. 23	1.0″	NNE	2.6″	from
Sept. 24 to Sept. 30	1.2″	NNE	6.0″	from

A. E. J.

The Volcano Letter

416

No. 416—Monthly U. S. Geological Survey, Hawaii National Park OCTOBER, 1934

KILAUEA REPORT FOR OCTOBER, 1934

Including weekly press reports 1185 to 1188
September 30 to October 28 midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Oct. 1 at 9 a. m. the west fountain pot started exploding and the lake drained. At 10:46 a. m. the liquid returned by overflow of the east fountain well. Another spell in the evening sent the glowing spray almost up to the pit rim 770 feet high. The noises were heard 3.5 miles away. This ended the detonating phase of activity. Oct. 2 the west fountain was overflowing its cone with seven streams, then the east fountain sent out a torrent 100 feet wide, then a middle fountain sent a stream northward to a new pool, which there overflowed the lake basin and reached the base of the north wall of the pit. After noon the wells lowered to weak bubbling fifty feet down. At seven in the evening heavy fume was rising from the wells.

Oct. 3 three quarters of the lake basin had become a slag-heap, with the north pool a depression in its flank 300 feet long. The middle fountain and the north pool were actively liquid. There were nine smoke holes. At night three pools were outlined by glow. Streaming showed there were tunnels to outlets east and west from the west pot. At the outer edges of the floor there was glow in cracks east, south and southwest. Intrusive lava was welling up along the edges of the floor cake. October 4 the middle fountain noisily jetted up diagonally like a hose, supplied the north pool, and kept the pit luminous at night, but this was the end of illumination. The east pot was a smoke hole, the east pool was dark at night, only a trickle remained at the west pool, and the floor margin glow was less. October 5 the lake area had collapsed, there was fume, streaming continued in the north pool, and blowing noise was audible. Around the edges of the floor there was conspicuous swelling from intrusion, especially northeast. Oct. 6 and 7 the central cone became a whitened fuming heap, the north pool was liquid underneath and showed crusts cracking and foundering in the melt, and the west cone had ceased fuming. Thuddung noise was heard in the western part of the swelling floor, prolonged wall-slides began at the north, and the steaming lessened at the taluses.

The last moving lava in Halemaumau was seen Oct. 7, and the last day of eruption was October 8. On Oct. 8 at 10 a. m. hisses were heard from the middle fume cone. At 11:25 there was prolonged wall-sliding north, and dust arose through a rim crack NNE. About 1 p. m. there were two north slides. Sliding all day occurred at west end of Canoe Sill. At 11:30 a. m. there was a slide east of Southwest Tunnel. At 11:43 a. m. there was a slide at top of West Talus. At 8 p. m. there were 11 glow spots along the east and south wall crack of the floor, and 12 about the lake area.

Oct. 9 at 7:17 a. m. a big avalanche took away the upper edge wall slab NNE of Halemaumau. The lake basin and the northern and eastern taluses were fuming. Out to the edge of the floor from the lake area there are left ten radiating tension cracks. There was a slide N. at 9:06 a. m., a big fall of fresh rock from the lower wall lay on the floor SE, and a few fresh bowlders lay on the floor NE. During the next week the taluses showed dry hot places at the bottom, 11 places on the northeastern half of the floor showed blue fume, and border swellings had cracked into chasms at the edge of the floor east, west and south. The solfatara at the base of the east talus increased its fuming. At the end of the month there was no visible shrinking down of the floor, there was wall-crack heat everywhere, slides were few, snapping was heard, spots of white and yellow staining appeared, especially at the base of the WNW wall cascade and on the NW pumice bank left against the talus by the big fountains of Sept. 6. A curved line of stain on the floor in front of this outlined and buried front of the talus cone.

Weekly measurements of rim cracks around Halemaumau, 32 in number, gave:—

Oct. 6, 11 opened, 3 closed, aggregate opening 5.5 mm
Oct. 13, 7 opened, 4 closed, aggregate opening 3.0 mm
Oct. 20, 9 opened, 5 closed, aggregate opening 3 mm
Oct. 27, 10 opened, 5 closed, aggregate opening 2.5 mm

A levelling circuit from South Sandspit as base by Jones Oct. 17-25, showing changes since July 2, 1934, in elevation of rim of Halemaumau, relative to the south rim of Kilauea Crater, revealed the following facts, presumably correlated with the outbreak of September that was concentrated at the north side of the Halemaumau bottom:—

Elevation to maximum of 1.28 feet within a stretch of the north rim 1800 feet long.

Depression to a maximum of 0.5 foot northwest and northeast of the pit, along a thousand feet of the rim on each side of the elevated tract.

The rest of the rim shows diminishing depression southward to a line of no change 400 feet SSE of the pit.

The north tilt cellar was involved in the elevated area to an elevation of 0.69 foot; its disturbance at the time of the outbreak was much less than that of the other two cellars in the slightly depressed areas. T. A. J.

EARTHQUAKES

TABLE

Week ending	minutes of tremor	very feeble earth-quakes	feeble earth-quakes	moderate earth-quakes	distant earth-quakes	local * seismicity
Oct. 7	5,091	5	0	0	0	1,252.
Oct. 14	64	2	0	1	1	20.00
Oct. 21	23	4	1	0	0	8.75
Oct. 28	63	2	1	0	0	17.75

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on three main seismograph stations, Kilauea, Hilo, and Kona. The intensity is that recorded on the Kilauea instruments.

October 3. 1:50 p. m. very feeble, lat. 19° 18′ N. long. 155° 26′.5 W. 21 miles deep under Kaoiki fault.

October 8 to 9 numerous tremors and very feeble shocks correspond with avalanching of Pit walls.

October 12. 5:45 p. m. a shock was felt at Honokaa, not recorded at Kilauea.

October 13. 7:14 p. m. moderate. Felt generally over the island of Hawaii. 19° 28′ N 155° 30′ W. 44 miles deep under the central part of Mauna Loa.

October 18. 0:20 a. m. feeble, felt generally on Hawaii. 19° 30′ N. 155° 40′ W. 39 miles deep, under central part of Mauna Loa. Followed at 1:41 a. m. by a very feeble shock from near the same place. 19° 30′ N. 155° 42′ W.

October 27. 7:47 a. m. feeble, felt near Kilauea crater. 19° 56′ N. 155° 38′.5 W. 23 miles deep.

The preliminary waves of a teleseism began recording at 5:20:09 a. m. October 10, the secondary waves began at 5:26:34 a. m.

Microseismic motion of the ground was normal October 9, 10, 11, 12, 16, 17, 18, 21, 22, 23, 24, 25, 27, 28, and was abnormal October 15: Other days subnormal.

The 5,091 minutes of tremor in the table represents the closing week of the lava inflow, and has about half the value of other weeks. (See Volcano Letter 415.) The explosive sequence that began in Halemaumau 9:15 a. m. October 1 made at first a record similar to a small earthquake record, later records were obscured by tremor. The last detonation at 9:57 a. m. was felt at Hawaiian Volcano Observatory 2 miles away. The harmonic tremor almost disappeared after October 1, its amplitude always stronger at the stations nearer the pit, and showing direct relation to the visible lava fountaining. A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending October 28, 1934 is 1.0″ N and 1.7″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
Sept. 30 to Oct. 7	1.2″ NE	9.1″ from
Oct. 8 to Oct. 14	0 6″ N by W	23.3″ toward*
Oct. 15 to Oct. 21	1.4″ ENE	21.3″ from
Oct. 22 to Oct. 28	0.6″ NE by N	2.2″ toward

* Disturbance following quake of October 13.

A. E. J.

The Volcano Letter

No. 417—Monthly U. S. Geological Survey, Hawaii National Park NOVEMBER, 1934

KILAUEA REPORT FOR NOVEMBER, 1934

Including weekly press reports 1189 to 1193
October 28 to December 2, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Slides in Halemaumau during the month had the following characters:

At 9:50 a. m. October 29 a block fell noisily southeast.
Pebbles fell at the new lava cascades November 1.
Between 8:30 and 10 a. m. November 3, intermittent sliding north.

November 4 this continued.

Week ending November 11, sliding at the west end of the Canoe sill north, notching the wall and making a sandy talus below; the buttress east of the SW tunnels caved away. This made pink dust on the floor.

11 a. m. November 13, a slide northeast sent up dust.
November 20 the sandy top of the north talus, after many slides recently, had changed its shape.

Fume in the pit was noted as follows:—

October 30, 9 fume places and 3 sulphur spots.

November 4, fume from pit as whole rose in thin bluish clouds.

November 11 fume had increased north.
November 12 solfatara at East Talus had lengthened southward. Ten places were fuming.

November 20, a dry day, the central fume patches of the 1934 lava lake area could not be seen; only 7 places counted.

November 22, after more than 1 inch of rainfall, 20 places showed vapor, but none at the lava lake site. On the Kilauea floor southwest over the rift belt, noisy purring at the vapor vents.

December 2, after 3.66 inches rain at Halemaumau gauge, pit was full of vapor, hundreds of steam plumes on the bottom, clockwise whirls indicated small tornadoes.

November 3 fresh hair cracks in soil appeared at pit rim NNE. Cracks of the intrusion ridges around edge of 1934 floor had widened November 11. Stain at the southeast ridge was increasing. Hot dry belts marked the bases of the talus cones, and bright yellow sulphurous stain was increasing at base of WNW wall. The stained area of pumice on top of northwest talus changed from yellow to white under rain washing; it was probably alum. The talus ESE and SSW steams after rainfall.

It is remarkable on the Kilauea floor southwest and northwest of Halemaumau how by condensation the puffing vapor vents have made areas green with tufty grass in the 1924 sand and gravel.

Weekly measurement of opening and closing of 32 marked rim crack points, around the edges of Halemaumau, showed the following changes Saturday forenoons:—

Nov. 3, 9 opened, 3 closed, aggregate opening 4 mm
Nov. 10, 7 opened, 7 closed, aggregate opening 0.5 mm
Nov. 17, 12 opened. 3 closed, aggregate opening 5 mm
Nov. 24, 7 opened, 3 closed, aggregate opening 3 mm
Dec. 1, 5 opened, 4 closed, aggregate opening 0.5 mm

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Distant earthquakes	Local * Seismicity
Nov. 4	9	1	0	2.75
Nov. 11	11	0	0	2.75
Nov. 18	29	1	0	7.75
Nov. 25	15	2	0	4.75
Dec. 2	11	2	1	3.75

* For local seismicity index see Volcano Letter 371.

During the five weeks period, only one shock has been approximately located. The Hilo and Kona records of the other shocks were too small to be of value in making a location. The very feeble shock at 5:53 a. m. November 12 was on the Kilauea SW rift. 19° 13′ N. 155° 24′ W.

The preliminary waves of a teleseism began to record about 3:43:54 p. m.; what may have been either secondary or long waves began to record at 3:54:47 p. m. The maximum waves at 3:58 p. m. were very large.

Microseismic motion of the ground was normal November 1, 2, 4, 11, 13, 14, 22, 25, 27, 28, and abnormal October 29, 30, 31, November 3, 5, 6, 12, 21, 23, 29 30, December 1, 2, and subnormal the other days of the month.

A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending December 2, 1934 is 1.9″ N and 1.1″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
Oct. 28 to Nov. 4	0.5″ N by W	10.9* toward.
Nov. 5 to Nov. 11	0.4″ N	2.5″ from
Nov. 12 to Nov. 18	0.7″ E	2.0″ from
Nov. 19 to Nov. 25	0.5″ ENE	4.9″ from
Nov. 26 to Dec. 2	0.5″ WSW	18.7″ from.

A. E. J.

The Volcano Letter

No. 418—Monthly U. S. Geological Survey, Hawaii National Park DECEMBER, 1934

KILAUEA REPORT FOR DECEMBER, 1934

Including weekly press reports 1194 to 1197
December 2 to December 30, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Slides in Halemaumau were as follows:—

December 16, 9:25 a. m., a fall of rocks at west lava cascade

December 30 about 10 a. m., rocks fell occasionally northeast

Fume in the pit was noted as follows:—

December 10, 9 a. m., 7 places fuming around northern edges of floor. The place of densest fuming was at base of east talus.

December 16, dry sunny day, about 9:30 a. m., vapor visible only at east talus.

Week ending December 23. Fume continues moderately dense at east talus.

Week ending December 30, blue fume from the four northern and eastern talus slopes, where they make contact with the new lava floor. The solfatara making densest steam and fume was at the base of the east talus. where there was in September the largest swelling in the floor due to intrusion. The fume separates itself from the steam and rises to fill the air in the upper part of the pit, while the water vapor dissipates. This fume shows best when the sunlight is behind it; it is thin. December 17 strong northeast wind was blowing clouds of dust over the Kau desert, and making whirls counterclockwise on the western edge of the pit. Thirteen places around the floor showed vapor after rain, but the bases of the taluses showed dryness due to excessive heat below. Vapor rose from high cracks in the western wall.

December 30 six fuming places were counted as visible.

December 10 stain had begun to appear at the wall-crack extrusion against the talus SSE, and the slope showed wet streaks steaming. A snapping noise was heard from the floor. December 16 the base of the WNW cascade had been growing increasingly bright yellow, probably with sulphur stained sulphates, and had extended its stain out on the floor. December 22 new rocks had fallen on the floor east. December 30 during the visit one snap in the floor like a detonation was heard about 9:50 a. m.

Weekly measurements of 32 rim cracks about Halemaumau, for changes of opening and closing as exhibited Saturday forenoons, resulted as follows:—

Dec. 8, 8 opened, 5 closed, aggregate opening 2.5 mm
Dec. 15, 9 opened, 6 closed, aggregate opening 2.5 mm
Dec. 22, 16 opened, none closed, aggregate opening 11.0 mm
Dec. 29, 3 opened, 3 closed, aggregate opening 0.5 mm

The general situation in the Halemaumau bottom is a pause in hot lava deeply crusted since the eruption of September, which had filled in over the 1931-32 floor by something over 90 feet for an average. The yellow sulphates and hot fume around the border, the swollen and cracked floor, the hot dry bases of the talus slopes, and the cracking noises, all indicate that the mobile paste is still there.

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
Dec. 9	8	2	0	0	4.50
Dec. 16	19	7	0	0	8.25
Dec. 23	12	6	1	0	8.00
Dec. 30	15	2	0	1	4.75

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; no epicenters could be found. The intensity is that recorded on the Kilauea instruments.

December 22. 1:55 a. m. very feeble, was felt lightly near Kilauea crater.

December 22. 0:46 p. m. feeble, was felt lightly near Kilauea crater. It was reported as stronger at Kapapala Ranch.

December 24. 9:27 a. m. very feeble, was felt at Hakalau.

The long waves of a teleseism began recording at 3:39 a. m. Dec. 30.

Microseisms were subnormal December 14, 29, and 30; they were normal December 13, 15, 22, 24, 25, and 26; and they were abnormal the rest of the period.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending December 30, 1934 is 1.3″ N and 2.8″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
Dec. 3 to Dec. 9	0.7″ NE by N	8.2″ toward
Dec. 10 to Dec. 16	0.6″ NE by E	0.2″ from
Dec. 17 to Dec. 23	1.4″ E	10.1″ from
Dec. 24 to Dec. 30	1.0″ E	6.3″ toward

A. E. J.

The Volcano Letter

No. 419—Monthly U. S. Geological Survey, Hawaii National Park JANUARY, 1935

KILAUEA REPORT FOR JANUARY, 1935

Including weekly press reports 1198 to 1202
December 30, 1934, to February 3, 1935, midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

VOLCANOLOGY

The general situation in the Halemaumau pit bottom for the month of January shows much volcanic motion centering about Kilauea. The lava floor of September, 1934, is hot and uneasy, snapping noises are heard, the tilts about the pit are rather strong and in new places, the hot fume is increasing at the west edge of bottom of pit, and new cracks have appeared near the rim.

Slides at Halemaumau

January 1, forenoon, a few rocks heard falling at the north. January 2, after the strongish earthquake of 6:47 a. m. originating under Kilauea, slides were started, and the pit was watched, but no excessive sliding was reported. January 8, a collapsed rim crack south of Halemaumau indicated recent motion. January 13, at 10 a. m., a slide occurred southwest. January 14, at 9:37 a. m. rocks fell at the east. January 18, at 2:15 p. m., and at 2:30 p. m. lasting a half-minute, slides were reported. January 21, at 9:05 a. m., a fall of rocks occurred near the SW tunnels. January 22, at 9:30 a. m., after a faint booming noise, a few rocks fell, and at 10:09 a. m., a moderate slide occurred south, after other noises. Seven slides occurred in one half hour period. January 26, the excessive sliding on the SSW wall made a streak of dust to the bottom, where fresh debris lay on the south talus and floor; the falls had started 100 feet below the edge. January 27, small slides at the SSW wall occurred twice in the hour 8:40 - 9:40 a. m. January 29, a few rocks fell prior to 10 a. m. January 31, between 9 and 9:20 a. m., a few rocks fell NW and E. A track of a recent slide lay on NW wall through the middle of the 1934 lava cascades. February 3, in the forenoon dust rose from east wall; the slides there were renewed 12:40 p. m., 12:50 p. m., dwindling to 1:05 p. m.; slight sliding occurred continuously 1:30 to 2:30 p. m. The location was above the east talus. There was some sliding at south wall also.

Sounds in Halemaumau

January 1, a clanking noise was heard twice, seeming to come from the 1934 lava lake cup. January 14, at 9:40 a. m. a snap was heard toward the north. January 18, two cracking sounds were heard after 2:30 p. m. January 22, at 9:02 a. m. a loud boom was heard, a faint sound at 9:30, and dull sounds from the east end of the lake cup came at 9:41; at 9:45 a dull sound seemed to come from the bottom of SE wall; again at 9:56 from the SW bay; and from the NW part of the floor at 9:58 a. m.; slides occurred during this half-hour. January 25. One snap was heard NW. January 27, eleven snapping noises were counted between 8:43 and 9:02 a. m., averaging one every 1.7 minutes. The sound is like the blow of an underground hammer. The south wall was sliding slightly. January 31, 9 to 9:20 a. m., some dull thudding noises were noted, and a hissing noise was heard from the SW bay.

Solfataras, at Halemaumau

January 1, five fuming places were noted, at the E, NE, N, and NW taluses, and at the Yellow Solfatara, a vent at the northern base of the west cascades of 1934. January 8, with very heavy rains, there were thousands of steam jets on the hot floor, but not at the lake cup. The heaviest steam jets were at the Yellow Solfatara, and at NW and E taluses. January 10, after more rains, the fume over Halemaumau appeared dense. January 14, after rain, 19 places were steaming or fuming inside the pit. There were hot dry places at the base of talus slopes, which are heaps of broken bowlders extending down under the 1934 lava fill to a depth of 600 feet, and these are porus filters for hot gas. January 17, at noon, with strong southwest wind, the fume from the pit did not show. The vapor jets on the outer floor of Kilauea crater at the north, during such wind, are nucleated by invisible fume from the pit, and show scores of white jets. January 21, the yellow solfatara was strongly fuming. January 25, the heap of sulphur-stained sulphates at the Yellow Solfatara had increased and been washed by rain, and fume was still more voluminous. The solfataric bank on the NW talus showed pink, red, yellow, white and gray salts, with vapors presumably rotting the 1934 pumice, suggesting the Red Solfatara of 1921. January 29, with southwest wind blowing, both fume and vapor were moderate in amount in Halemaumau.

The cracks in the floor of Halemaumau, and elsewhere, were observed as follows:—

January 2, after the earthquake, the cracks and swellings of the floor showed some new features. January 11, new cracks were reported at the tourist stand SE. January 12, cracks were reported newly breaking the curb masonry 450 feet back from the rim of Halemau SE. January 19, this crack in the masonry at the pit measured 3 mm. January 21, the radial cracks on the floor southeast appear widening. One cross-crack has formed in the south floor. The marginal ridge in the floor all around exhibits large gaping cracks. January 25, eleven cracks radial from the cup were counted on the eastern half of the floor, and five or six more are on the western half.

Weekly measurement of 32 marked rim cracks around Halemaumau, resulted as follows:

Week ending forenoon

Jan. 5,	15 opened,	3 closed,	aggregate opening	12 mm.
Jan. 12,	8 opened,	5 closed,	aggregate opening	1.5 mm.
Jan. 19	12 opened,	1 closed,	aggregate opening	7 mm.
Jan. 26,	5 opened,	7 closed,	aggregate closing	0.5 mm.
Feb. 2,	14 opened,	2 closed,	aggregate opening	8 mm.

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Moderate earthquakes	Distant earthquakes	Local * Seismicity
Jan. 6	72	10	1	2	26.00
Jan. 13	26	3	0	0	8.00
Jan. 20	14	3	0	0	5.00
Jan. 27	18	5	0	1	7.00
Feb. 3	29	4	0	0	9.25

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on three main

seismograph stations, Kilauea, Hilo and Kona. The intensity is that recorded on the Kilauea instruments.

Dec. 31, 1934, at 10:40 p. m. very feeble, was SW of Kilauea crater lat. 19° 21′ N long. 155° 19′W 12 mi. deep. It was reported felt near Kilauea crater.

Jan. 2, 1935, at 6:47:17 a. m. moderate, was under the Uwekahuna rim of Kilauea crater. 19° 25.5′ N 155° 17′ W. 2 mi. deep. Reports indicated that it was felt generally over the island of Hawaii, objects fell in Hilo, and a landslip was started in Halemaumau.

Jan. 8 at 2:09 p. m. very feeble, was near Kulani cone 19° 31′ N 155° 17′ W.

Jan. 13 at 1:33 p. m. very feeble, was 3 miles ENE of the Observatory 19° 26′ N 155° 13′ W and 4 mi. deep.

Jan. 17 at 11:35 a. m. very feeble, was probably at sea SE of the island, near 19° 15′ N 155° 0′ W.

Jan. 17 at 10:58 p. m. very feeble, was near Wood Valley, 19° 20′ N 155° 30′ W. It was reported felt at Kapapala Ranch near the epicenter.

Jan. 19 at 5:49 a. m. a tremor, was in Kilauea crater, probably near Byron's Ledge.

Jan. 21 at 0:02 a. m. very feeble, occurred 35 miles deep under the east slope of Mauna Kea, 19° 44′ N 155° 22′ W. It was reported felt along the NE coast of Hawaii.

Jan. 27 at 7:23 p. m. very feeble, was 30 miles deep under Puu Ulaula rest house on the Mauna Loa NE rift zone, 19° 31′ N 155° 29′ W.

Jan. 29 at 4:01 p. m. very feeble, was probably under the summit crater of Mauna Loa.

Jan. 29 at 6:41 p. m. a tremor, was probably near the Kealakekua Bay fault. It was felt and well recorded in Kona.

Jan. 30 at 9:51 p. m. very feeble, was probably on the chain of craters 7 miles SE of Kilauea.

Feb. 3 at 4:21 p. m. very feeble, was 2 miles ENE of Kilauea crater, 19° 26′ N 155° 14′ W, near the epicenter of Jan. 13.

The preliminary waves of a teleseism began recording at 8:16:50 a. m. Dec. 31, 1934. The secondary waves were missing, the long waves were missing, the long waves began to record at 8:32:08 a. m. It was about 3,400 statute miles distant.

The preliminary waves of a teleseism began at 2:58:12 a. m. Jan. 1, 1935. The secondary waves began at 3:03:49 a. m. It was about 2,500 miles distant.

The long waves of a poorly recorded teleseism began at 9:08 p. m. Jan. 22. The distance was unknown.

Microseisms were abnormal Jan. 2, 3, 4, 5, and Jan. 17 to Feb. 3. They were normal Jan. 6, 7, 9, 10, 12. 13, 14, 15, and 16; and subnormal the remainder of the time.

A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea Crater; at Halemaumau, the readings from each clinoscope, and the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending February 3, 1935 is 2.3″ N and 0.2″ W.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
Jan. 6	0.8″ N 28° E	23.6″ S 28° E	28.1″ S 16° W	160.0″ N 20° W	185.0″ toward*
Jan. 13	1.7″ S 66° W	7.3″ S 71° W	7.7″ N 12° W	3.4″ S 4° E	2.9″ toward
Jan. 20	2.2″ S 52° W	2.3″ S 26° W	2.8″ N 25° W	33.6″ S 17° W	20.4″ from
Jan. 27	1.4″ S 55° W	5.1″ N 86° E	1.9″ N 58° W	4.3″ S 3° E	4.4″ from
Feb. 3	1.0″ S 3° W	6.3″ N 25° E	2.2″ N 23° E	9.2″ N 4° E	5.3″ toward

* Southeast station dismantled by earthquake of January 2, 1935.

A. E. J.

The Volcano Letter

No. 420—Monthly U. S. Geological Survey, Hawaii National Park FEBRUARY, 1935

KILAUEA REPORT FOR FEBRUARY, 1935

Including weekly press reports 1203 to 1206
February 3 to March 3, 1935, midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

The month has produced local shakings close to Kilauea, some easterly tilt which suggests tumescence and is abnormal for this season, and small slides from the walls of Halemaumau pit. Many small earthquakes at the Halemaumau seismograph, are mere tremors at the Observatory near Volcano House.

Slides at Halemaumau

February 4, occasional rock falls all day, including one in SW corner of the pit at 5:09 p m. February 5, the scar of this slide was obvious, and rocks were falling there at 9 a. m. Other falls of rock were heard NE, the East wall and talus had been changed. About 7 p. m. a slide was reported. Feb. 6, rocks were heard falling NE and SW. Feb. 9, all the sliding areas appeared freshly disturbed, fallen stones lay on the 1934 floor SE, and the scar of a fresh slide marked the wall halfway up, at the east Feb. 10, at 9:30 a. m. rocks fell at the S wall, and along the swollen monoclinal ridge at the margin of the 1934 lava floor, fallen bowlders lay on the crest of the arched crust in several places. Opposite all the talus slopes there is now fresh fallen debris on the 1934 floor, as result of caving wall matter since the eruption, and at the base of rock walls SE, NE and W NW. Feb. 12, at 9 a. m. a slight rock fall occurred S. After 3:25 p. m. rock slides SE occurred for 30 minutes. At 3:30 a cloud of dust arose from the wall, at 3:40 a larger mass of rock fell from a thin-layered zone near the top, sending a cloud of dust over the floor, and this was followed by rocks slipping for 10 minutes. There were four slides in a half-hour, leaving fresh cracks in the soil back of the edge of the pit, fresh dust on the floor, and a scar on the wall. Feb. 14, about 9 a. m. a tremor and slides were reported, accompanied by the opening of a crack in the floor. Feb. 16, a few rocks fell. Feb. 17, debris had been added to the bases of the east and south taluses, and the eastern floor appeared more swollen and cracked near the east solfatara. Feb. 18, at 9:05 a. m. there was a southern fall of rocks, and at 10:43 a. m. an avalanche fell from half way up the NE wall to the small talus heap. Feb. 25, at 8:52 a m. a fall of rocks occurred NE. Feb. 27, at 11:50 a. m. a small noisy slide fell from the NW buttress. March 1, at 2 a. m. a slide occurred E S E.

Other Phenomena

Feb. 12, there were vaporings at south talus and wall, at west talus and the cascade wall, at the wall west of southwest tunnels; voluminous fume rose from the Yellow Solfatara NW, and there were many small fume jets at the floor edge under the NNW talus. It was a misty forenoon of high humidity after moderate rain, but for no obvious reason the northwest region had suddenly developed excessive vapor and fume, and these had diminished in the east part of the Halemaumau floor. February 17 in cold dry weather hot vapor and fume were very slight, but they had developed at the small NE talus. The vapor and fume certainly fluctuate with the rainfall; during very heavy rains about February 23 deuse clouds of vapor rose from the pit, originating in the symmetrical semi-circle of five fuming talus slopes around the lava-lake oval, or cup, which was the last active pool of lava of October 1934. In the morning light of February 25 the floor cracks around the edges appeared to have increased their gaping, and the crescent of stain in front of the NNW talus—the site of the pumice bank of the largest fountains of September 6, 1934—had definitely become a depression. There is an arc of cracks in front of it, and the floor still farther in front is a plateau; everywhere the floor is a swollen plateau above the wall-valley. The cracks at the edge of the floor plateau are tensional chasms, parallel to the strike of a monoclinal bend which dips down to the floor margin.

Rim Cracks

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau resulted as follows:

Week ending forenoon:

Feb. 9, 7 opened, 3 closed, aggregate opening 2.5 mm.
Feb. 16, 10 opened, 2 closed, aggregate opening 5.0 mm.
Feb. 23,* 16 opened, 4 closed, aggregate opening 9.0 mm.
Mar. 2,* 9 opened, 4 closed, aggregate opening 3.5 mm.

* Measured partly Feb. 24, because of heavy rains.

Noises

Thudding noises from the bottom of Halemaumau were heard at 8:58 a. m. and 9:02 a. m. February 12, a clanking was heard at the base of east wall at 10:10 a. m. Feb. 17, and a snapping noise NE at 11:05 a. m. that day, and again Feb. 25 at 8:40 a. m. T. A. J.

EARTHQUAKES

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Distant earthquakes	Local * Seismicity
Feb. 10	28	6	1	0	0	11.00
Feb. 17	15	0	1	0	0	4.50
Feb. 24	46	5	1	0	1	15.00
Mar. 3	67	4	0	1	0	20.75

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated The location of epicenters is based on three main seismograph stations, Kilauea, Hilo, and Kona. The intensity is that recorded on the Kilauea instruments.

Feb. 4 at 7:45 p. m feeble, occurred under the west wall of Kilauea crater, under Uwekahuna. Reported felt near Kilauea crater.

Feb. 5 at 0.20 a. m. very feeble, occurred under the NE wall of the crater near the Observatory.

Feb. 11 at 3:59 a. m. very feeble, occurred under Mauna Loa, lat. 19° 26′ N long. 155° 28′ W 16 miles deep.

Feb. 15 at 6:12 p. m. very feeble, occurred 2 miles SE of Kilauea crater.

Feb. 20 at 9:27 a. m. feeble, occurred near the junction of the SW rift and the SW crater wall.

Feb. 21 at 1:21 p. m. very feeble, occurred in the crater, east of the Pit.

Feb. 21 at 8:56 p. m. very feeble, occurred outside of Kilauea crater near Keanakakoi crater.

Feb. 26 at 2:10 a. m. slight, occurred 5 miles deep under N rim of Kilauea.

Feb. 27 at 1:11 p. m. very feeble, near Keanakakoi crater.

Feb. 28 at 5:39 p. m. very feeble, reported felt at Naalehu, located on the Mauna Loa SW rift, near 19° 10′ N 155° 45′ W.

Mar. 3 at 11:11 p. m. tremor, near SW wall of Kilauea crater.

Feb. 22 the preliminary waves of a small teleseism began recording at 6:43:58 a. m. the secondary waves began at 6:50:20 a. m.

Microseismic motion was abnormal Feb. 11, 12, 13, 14, 15, 16, 17. normal Feb. 4, 6, 18, 20, 21, 24, 27, 28, Mar. 1 and 2. and subnormal during the other days of the period.

A. E.J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the readings from each clinoscope and the resultant of radial tilts for the three clinoscopes, towards or from the center of Halemaumau Pit.

At the Observatory the total accumulated tilt for the year ending March 3, 1935 is 3.5″ N and 4.1″ E.

TABLE OF TILT

Week ending	Observatory station	Halemaumau Clinoscope Stations			
		North station	West station	SE station	Resultant
Feb. 10	1.3″ S 38° E	1.7″ S 70° W	2.8″ N 5° E	3.5″ N 43° E	1.7″ toward
Feb. 17	0.9″ S 80° E	3.2″ S 52° W	3.3″ N 81° W	5.9″ N 18° E	9.3″ toward
Feb. 24	0.2″ N 40° E	2.6″ N 68° E	5.1″ N 8° E	19.8″ S 9° E	20.5″ from
March 3	1.8″ S 39° W	2.0″ S 75° E	3.1″ S 86° W	14.7″ S 6° W	8.0″ from

A. E. J.

The Volcano Letter

NO. 421—MONTHLY U. S. Geological Survey, Hawaii National Park MARCH, 1935

KILAUEA REPORT FOR MARCH, 1935

Including weekly press reports 1207 to 1210
March 3 to March 31, 1935 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

The same processes of fuming, snapping, and avalanching from the walls, have continued in Halemaumau pit.

Slides at Halemaumau

March 4, at 9 a. m.; March 5, at 9:10 a. m.; March 6, a few rock falls after 9 a. m. and a slide at northeast corner 9:28 a. m.; March 7, a few rocks falling between 9:20 and 9:30 a. m.; March 8, rocks heard falling about 9:05 a. m.; March 10 debris on the bottom southeast, was in two new places. These are the incidents observed during a half-hour visit to the pit each forenoon.

March 16, debris at the west showed that a slide had occurred. Another slide scar appeared southeast, and other slides had occurred over the east bay, and at the NNE. March 23, at 9:02 a. m. a noisy avalanche reached the floor and sent up dust, at the south corner of the pit; the disturbance broke the rim, where fresh cracks in the soil were found, parallel to the edge of pit, fifteen feet back from the verge, and extending lengthwise more than a hundred feet. Another slide there at 2:25 p. m. made a similar dust cloud, and the noise was heard at a distance. Two other small slides fell from the west and north walls during the next half-hour.

March 28, slides were heard at 9:40 and 10:20 a. m. March 31, it was evident from the Pit seismograms, and from the dust over the south end of the pit floor, that a large slide had fallen at 8:15 p. m. March 30. The scar was from a point 100 feet below the top of the SSW wall, the same area that had been "working" lately. Cracks were widening in the soil above. The disturbance on the Halemaumau seismogram was much larger than on the Observatory record.

Miscellaneous Phenomena

Rainfall reached 7.5 inches in the four days preceding March 6, at the Halemaumau rain-gauge. Vapor plumes on the hot pit floor occasionally united into a dense cloud. At 9 a. m. March 8, an unexplained hissing noise seemed to be at the SW bay, and lasted about 3 seconds; earlier two dull thuds were heard NW and W. There had been five records of pit shocks on the Halemaumau seismogram, during the preceding 24 hours. The day before this there were one or two little shocks. On March 5, there were 8 small earthquakes on the Halemaumau record, only one of which was recorded at the Observatory two miles to the northeast, and that as a mere tremor.

The heavy rains tended to disturb the tilt instruments. However, there is always more intense volcanic tilting, and seismic activity, at the Halemaumau instruments, than at the northeast edge of Kilauea crater where the Observatory stands. This shows how important it is, in volcanology, to study seismically the innermost focus of a crater, in equipping with seismographs such a place as the summit crater of Mauna Loa. That particular crater must be so equipped very soon.

The radial floor crack at the bottom of Halemaumau, trending east, appeared to have widened March 16. The sulphur at the Yellow Solfatara northwest had so increased March 21 that the stain extended out on the floor, and its fume column was noticed at stations behind buttresses on the west rim of the pit, where it had been invisible before. March 25 about 8:40 a. m. two dull detonations were heard about five minutes apart. Three more were heard to the east of the pit between 9:20 and 9:30 a. m.

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of

March 9, 7 opened, 4 closed, aggregate opening 2.5 mm.
March 16, 19 opened, 0 closed, aggregate opening 13.5 mm.
March 23, 10 opened, 4 closed, aggregate opening 5.0 mm.
March 30, 11 opened, 5 closed, aggregate opening 3.0 mm.

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Distant earthquakes	Local * Seismicity
March 10	22	2	0	6.50
March 17	20	4	0	7.00
March 24	16	2	0	8.00
March 31	20	6	0	8.00

* For local seismicity index see Volcano Letter 371.

The following local very feeble disturances began at the times indicated; the epicenters as shown were located from the seismograms; when possible the depth of the source is indicated. The location of epicenters is based on three main seismograph stations, Kilauea, Hilo, and Kona. For crateral earthquakes, stations at Uwekahuna and Halemaumau are used. The intensity is that recorded on the Kilauea instruments.

March 5 at 5:31 a. m. located one mile deep under the southwest end of Kilauea crater.

March 9 at 1:58 a. m. located half a mile deep under the east side of Halemaumau Pit.

March 20 at 4:48 p. m. felt at Puuwaawaa, but not recorded well enough to be located.

March 24 at 11:29 a. m. felt at Uwekahuna, located 5 miles deep under that wall of Kilauea crater.

March 25 at 0:20 a. m. 3 miles deep under the southwest rift zone, 1 to 2 miles from Kilauea crater.

March 26 at 5:52 p. m. 1 mile deep, 2 miles southwest of Uwekahuna.

March 27 at 0:38 p. m. 1 mile deep under Kaoiki fault, lat. 19° 26′ N, long. 155° 20′ W.

March 28 at 11:48 p. m. 3 miles east of the summit crater of Mauna Loa, lat. 19° 27′ N, long. 155° 34′ W.

March 29 at 2:59 a. m. reported felt in Hilo, not well located.

Microseismic motion of the ground was abnormal March 4, 13, and 16; normal March 7, 14, 15, 18, 19, 20, 22, 24, 25, and 29; and subnormal during the remaining days of the month.

A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; at Halemaumau the readings from each clinoscope and the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the Pit.

At the Observatory the total accumulated tilt in the year ending March 31, 1935 is 1.1″ N and 0.6″ E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
March 10	1.4″ S 55° W	2.5″ N 67° W	5.1″ N 82° W	8.7″ S 48° W	6.2″ from
March 17	0.7″ N 67° E	3.3″ S 53° E	1.6″ North	12.8″ N 9° W	12.1″ toward
March 24	2.9″ S 50° W	1.3″ S 68° W	0.9″ S 86° W	4.2″ N 6° E	4.9″ toward
March 31	1.5″ S 12° W	1.8″ S 65° W	3.0″ N 11° E	6.4″ N 50° E	4.9″ toward.

A. E. J.

The Volcano Letter

No. 422—Monthly U. S. Geological Survey, Hawaii National Park APRIL, 1935

KILAUEA REPORT FOR APRIL, 1935

Including weekly press reports 1211 to 1214
March 31 to April 28, 1935 midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

VOLCANOLOGY

The month of April at Halemaumau pit was chiefly remarkable for the partial obliteration of the black, solidified lava cascades of September 6, 1934. This was achieved by avalanching, the upper wall NW falling away April 20, and the rim slab was completely removed in front of the West Steamhole. This west steam crack has been a landmark on the edge of Halemaumau since 1924, sending up white clouds of vapor always visible. The enlargement of the pit by engulfment of the rim rock in front of this crack, for a width of 20 feet lengthwise of the margin for 250 feet, leaves the western wall of the former steam crack merely part of the pit wall. The steam is gone. A few small steam cracks extend from here northward, back of the edge of the pit. The thudding noises in the floor have notably decreased since February.

Slides at Halemaumau

April 2 at 5:07 p. m. a noisy slide fell from the north wall, and coursed through the notch to the talus below, some of the bowlders reaching the floor. April 4 at 11:20 a. m. a small slide fell from the south notch which has been recently working. April 5 the pit was quiet between 5:10 and 5:45 p. m., but at 5:46 a moderate slide fell from the southeast wall north of the Tourist Lookout; this was followed by small slides NE and SSW. April 6 at 9 a. m. the rim of Halemaumau above the SSW scar revealed fresh cracking in the surface of the 1924 ash drifts and in the rock below, for 20 feet back from the edge. The length of the fresh breaks was 165 feet. The block of rim appeared ready to fall. April 7 at 9 a. m. there was slight dribbling of stones down the west wall, and there were southern slides later.

April 8 there was small sliding west and south at 9:30 a. m. April 10 at 9:15 a. m. a moderate slide fell from the southeast wall. April 16 a large slide about 1:30 p. m. fell from the NW buttress athwart the lava cascade locality and above the Yellow Solfatara. April 17 at 8:55 a. m. there was a small slide at the east corner of the pit.

Small quakes accompanying slides were recorded April 18. The next day April 19 slides five times made very feeble earthquake records on seismograms, and a still larger number of tremor records at Halemaumau. Seismograph records of slides thereafter became less frequent.

The working of the cascade rift northwest reached a climax of avalanching at 5:50, 5:53 and 5:55 a. m. April 20, largely sweeping away the black ribbons of lava cascade from the wall. What was left was almost covered by fresh dust. The cascade remnants are at the talus south of the scar (West Talus) and at the Yellow Solfatara on the north of it. There were several small earthquakes during the forenoon. A big slide at 9 a. m. fell over the northern end of the cascade, the larger rocks reaching the floor before the finer material. Marked crack No. 36 at the western rim had opened a little. The air in the pit was charged with vapor and fume, and some dust. A slide at 9:02 a. m. fell from three quarters of the way up the wall, over the north end of the lava cascades.

At 9:50 a. m. April 20 there was a small slide WNW. A small quake rang the annunciator at the Observatory at 1:36 p. m., and four minutes later dust arose from the north side of Halemaumau. There was continuous western sliding all day, with avalanches noted at 3:05, 3:15, and after 6:00 p. m. Rock trickling at the west continued all day April 21.

It was this April 20 crisis that destroyed the big west-rim steam crack, as described in the first paragraph above. The new talus below is large, widening the big west talus northward for 250 feet, and piled above the floor 200 feet. The west talus has been widened farther by recent tumbles of rock east of the SW rift caverns in the wall, so that the whole debris slope is now twice as wide as in August 1934 at the elevation now represented by the bottom contour. Two cascades of solidified lava remain on the main talus cone, as produced on September 6th.

Rocks continued to dribble down the western wall, with few intermissions, until April 28. April 22 slides on that scar were noted at 11:13, 11:17, and 11:25 a. m. and later, making dust clouds. April 23 small slides fell from the NW buttress at 8:50, 9:30 and 9:48 a. m. April 24 at 11:05 a. m., rocks fell at the northeast. April 25 rocks were falling on both east and west sides of Ha'emaumau. At 10:45 a. m. a large block fell, from 75 feet below the rim, at the east. At 12:47 p. m. a large slide was heard at the Observatory, and sent up a cloud of dust. April 26 at 8:50 a. m. there were steady small slides SSW and NW. April 28 rocks were falling more or less continuously at the western scar, making a noisy avalanche at 8:52 a. m. One slide was heard at the east. At 2:25 p. m. a slide at the northeast wall sent up a thick cloud of dust, followed at 2:32 p. m. by two smaller clouds.

Miscellaneous Phenomena

Fumes rose from the Yellow Solfatara in variable amounts. There are four other fuming places at the north and east edges of the floor. April 20 fume was more conspicuous at the NNW talus than at the East talus. During the small WNW slide of 9:50 a. m. that day there was hardly any fume at the East talus; ten minutes later it puffed fume. April 26 white vapor was variable at the three taluses W, S, and SE.

Levelling

Spirit levelling at the Halemaumau rim April 25 by A. E. Jones, using as base the bench-mark at the southern gravel ridge of Kilauea crater (Spit), determined that points on the rim of Halemaumau, since April 3, 1935, had been elevated about 1 cm. or less.

The eruption of September 1934, by this datum, (Volcano Letter 416) had shown elevation 39 cm. of the north rim, and depression each side of the raised area. This April lift is the first movement of elevation since the eruption.

Thus during the week prior to April 3, the levelling of that date had shown lowering of from 1 to 3 cm. since March 27. On March 27 there had been lowering in the 5½ months since October of from 4 to 7 cm. This makes the April 25 elevation a distinct change of habit, probably indicative of renewed lava pressure.

Rim Crack Measurements

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau pit, resulted as shown in the tabulation that follows.

This indicates a notable disturbance of the entire pit by the breakdown on April 20 of the western wall, followed by quiet. A similar crack-opening, aggregating 13.5 mm., affecting 19 cracks, occurred on March 16, during the avalanching of that month. There were other maxima January 5, February 2 and February 23. These were the months of snapping noises and of numerous slides. They were also months of lowering rim.

Week ending forenoon of

April 6, 12 opened, 6 closed, aggregate opening 6.5 mm.
April 13, 11 opened, 3 closed, aggregate opening 5.0 mm.
April 20, 16 opened, 1 closed, aggregate opening 12.0 mm.
April 27, 7 opened, 5 closed, aggregate opening 2.0 mm.

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Distant earthquakes	Local * Seismicity
April 7	61	2	0	16.25
April 14	44	1	0	11.50
April 21	38	8	0	13.50
April 28	55	1	0	14.25

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of these three very feeble shocks is based on the main station at Kilauea Observatory and two subsidiary stations around the crater. The intensity is that recorded on the Kilauea instruments.

April 3 at 9:34 a. m. 4 miles deep under Kilauea southwest rift zone; lat. 19° 23′ N, long. 155° 19′ W.

April 20 at 1:10 a. m. 2 miles deep under Kaoiki Pali rift, 19° 21′ N, 155° 18′ W.

April 20 at 5:53 p. m. 1 mile deep under Waldron's ledge, part of the east rim of Kilauea crater.

April 22 at 0.18 p. m. an earthquake was felt at Hakalau, it recorded as a tremor at the Observatory.

Miscroseisms were normal April 10 to 14, and subnormal the remainder of the period. A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea Crater; at Halemaumau, the readings from each clinoscope, and the algebraic sum of radial tilts for the three clinoscope cellars, towards or away from the center of the Pit.

At the Observatory the total accumulated tilt in the year ending April 28, 1935 is 2.4″ N and 0.7″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
April 7	0.6″ S 60° E	1.1″ N 7° E	0.3″ N 20° W	4.8″ S 71° E	8.9″ from.
April 14	0.8″ N 39° E	5.9″ N 84° E	4.2″ N 36° W	2.6″ N 32° E	0.2″ toward.
April 21	1.1″ S 66° W	7.9″ N 38° E	0.9″ N 66° W	12.2″ S 67° E	17.4″ from.
April 28	0.8″ N 86° W	1.7″ S 12° W	1.9″ S 31° W	1.1″ N 32° E	3.1″ toward.

A. E. J.

The Volcano Letter

No. 423—Monthly U. S. Geological Survey, Hawaii National Park MAY, 1935

KILAUEA REPORT FOR MAY, 1935

Including weekly press reports 1215 to 1219
April 29 to June 2, 1935 midnight
Section of Volcanology. U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

The month of May was like April in making critical changes in the wall of Halemaumau by avalanching, but transferring the sliding activity to the south and east corners. The opening of rim cracks also reached a maximum about the middle of the month, followed by immediate diminution.

Slides at Halemaumau

The first week was notable for much sliding from E and S. walls of Halemaumau. April 29, following 8:15 a. m., the SSW scar was sliding, and a stain of dust extended across the floor from it NE. The rim block at the top fell at 9:16 a. m., making a noisy avalanche. This was followed by trickling of small stones NW, and one rock fall NE. At 12:35 p. m. April 29 a small slide fell W, and a large one ESE at 12:45 p. m. On April 30 the SSW scar had extended farther west. May 1, from 1:40 to 3:30 p. m. with snapping sounds at intervals of five to 10 minutes, small slides occurred N, and two larger ones there at 3:15 and 3:20 p. m. After dribbling slides in various places on May 2, a heavy dust cloud arose at 5:10 p. m. from a slide at the NE wall. At 9:30 a. m. May 3, a noisy fall of rocks stripped the east buttress, and this was followed by numerous slides there, north and south of the buttress during the next two days. From such slides a small balanced pinnacle was left on top of the buttress at 11 a. m., May 3, and by the next day this had fallen. On May 4, avalanches occurred here at 9:47, 10:02, and 10:10 a. m., and 6:40 p. m. A large avalanche here May 5, about noon, set up a thick dust cloud.

The following slides were noted during the second week: May 6, 9:15 a. m. NE, 9:36 SW and NW, 9:45 NE; a dust streak extended out on the floor from this place. At 9:58 there were slides W and NW, and again for five minutes after 10:05 a. m., making a continuous dribbling of gravel and much dust. Similar dribbling slides SW and NE occurred 8:45 a. m., May 7. May 10 there was small sliding at the SSW and W scars. May 11 the same thing was going on at 8:45 a. m., and with the strong wind continuous dust arose from these western slopes. At 12:25 p. m., a strong landslip sent up much dust ENE. At 6:00 p. m., a strong slide occurred W. Slides May 12 were at 8:50 a. m. W, 9:38 a. m. E, 9:58 W, and at 12:50 p. m., a large dust cloud rose above the west side of the pit and spread out so as to fill the whole pit.

The avalanching declined during the third week. May 13 rocks were falling SW. W and NE.; at 9:38 a. m. an avalanche fell near the SW trig station, west of the SSW scar, where there have been recent opening of cracks and engulfing of the ash soil. It was obvious that this rim block was about to fall. At 12:45 p. m., May 13 an avalanche sent up dust NE, loud noises were heard in the pit at 1:30 and 2:30 p. m., and that these were the roars of avalanches was verified by one occurring May 15, about 5:40 a. m., so loud that it was heard at Volcano House. At 7:20 a. m., May 15, there was another roar and at 7:54 a. m., a big avalanche fell at the eastern edge of the SSW scar. The stage was now set for the falling of the rim block at the western edge of this scar, and this happened at 12:41 p. m., after minor preliminary slides, the shock shaking the seismographs, sending up thick dust, and making a loud roar heard at a distance. This event brought to a close the active working of that part of the Halemaumau rim.

The fourth week ending May 26 was relatively quiet. The only slides noted occasioned dust clouds seen May 20, at 9:55 a. m., and at 3:25 p. m., and on May 21 at noon and at 4:25 p. m.

The week ending June 2 produced spells of more than 15 minutes at a time when no rocks could be heard falling. May 27 at 10:24 a. m., there was a slide at the SSW scar and at 10:25 a. m. a slide fell NW. May 28 to May 31, the pit was quiet, except for a few rocks heard falling but not seen at 9:50 a. m. on the last date.

Halemaumau Floor Solfataras

On May 7 the fume vents at the edge of the floor were active NW and NE, and at 9 a. m. May 9, though the atmosphere was dry there was much fume from the three solfataras NW, N and E. May 28, about 8:45 a. m., five northern vents were fuming, thudding noises were heard twice, and fume was in greatest volume at the Yellow Solfatara NW where it came up puffing. May 30, at 9:10 a. m., after a rainy night, all five fuming places were puffing. May 31, at 9:50 a. m., after only slight rainfall, the five fuming places were inconspicuous.

Changes In Halemaumau Floor

The May avalanching spells built two new talus cones under the SSW scar, and made a pink stain of dust extending out on the floor. At the lower part of the gulch that extends down the wall along a crevasse at the east, above the large eastern talus cone, vapor rises from the wall itself. Here a buttress of fresh grey rock hangs out toward the pit, in the middle part of a new eastern scar. Big bowlders had extended the eastern talus, but none had been able to surmount the marginal ridge of the floor. The marginal valley here is very deep. The chasms in the top of this ridge lengthwise, and the five eastern radial cracks extending across the floor from the lake basin of 1924, appeared more widely open than ever. It is worthy of note that the talus slopes north and northwest, which were the scene of sliding activity in October, 1934 after the eruption, have not been in motion in 1935.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau pit, resulted as shown in the tabulation that follows.

Week ending forenoon of

May 4, 11 opened, 3 closed, aggregate opening 6.5 mm.
May 11, 6 opened, 3 closed, aggregate opening 6.5 mm.
May 18, 12 opened, 6 closed, aggregate opening 5.0 mm.
May 25, 5 opened, 3 closed, aggregate opening 2.0 mm.

A large crack in the actual rim of the pit near the southwest trig station opened 23.5 cm in 14 days from April 20 to May 4. T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
May 5	71	9	0	0	22.50
May 12	38	11	0	0	15.00
May 19	41	6	0	0	15.25
May 26	12	1	1	0	4.50
June 2	34	3	0	1	10.00

* For local seismicity index see Volcano Letter 371.

During the first week of May three slides in the Pit were large enough to record on the Observatory seismographs. During the second week five slides made very feeble records, with only one recorded during the third week.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on the smaller network of seismograph stations, Kilauea, Uwekahuna, and Halemaumau. The intensity is that recorded on the Kilauea instruments.

May 13 at 1:46 p. m. beginning of a series of five very feeble shocks, not reported felt, lasting until 2:01 p. m. Only two could be located. The second of the series was

located about a mile south of Kilauea crater, not over two miles deep, Lat. 19° 23′ N, Long. 155° 17′ W. The third of the series could only be approximately located, two and a half miles west of Kilauea crater, Lat. 19° 25′ N, Long. 155° 20′ W. They were not recorded on the Hilo and Kona instruments.

May 23, at 1:37 a. m. a feeble shock was felt near Kilauea crater. It was located a mile west of Uwekahuna and five miles deep, Lat. 19° 25.5′ N, Long. 155° 18′ W.

The long waves of the destructive earthquake in Baluchistan began recording at 11:57 a. m. H.S.T. May 20.

Microseismic motion of the ground was normal April 29 and subnormal the remainder of the period. A.E.J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea Crater; and at Halemaumau, the readings from each clinoscope, and the resultant of radial tilts for the three clinoscopes, towards or from the center of Halemaumau Pit.

At the Observatory the total accumulated tilt in the year ending June 2 is 3.6″ N., and 0.5″ W.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
May 5	1.6″ S 64° W	2.8″ N 54° E	5.0″ N 87° W	7.0″ N 45° W	1.7″ from
May 12	1.0″ N 16° E	2.0″ N 15° E	6.8″ N 36° W	5.8″ S 83° E	9.3″ from
May 19	0.6″ West	3.8″ N 19° E	1.8″ S 62° W	2.4″ N 29° W	2.6″ from
May 26	0.9″ N 30° E	3.8″ N 69° E	1.4″ S 25° E	5.4″ N 28° E	1.1″ toward
June 2	1.0″ S 77° W	1.0″ S 80° W	1.6″ S 83° W	2.8″ S 27° E	2.2″ from.

A. E. J.

ERRATA

Following Sept. 11, 1934, Volcano Letter 415, the resultant tilt at Halemaumau should be as follows;

1934		1935	
Sept. 16	0.8″ from	Jan. 6	165.″- toward
23	1.2″ toward	13	1.1″ toward
30	1.3″ from	20	22.5″ from
Oct. 7	7.9″ from	27	7.1″ from
14	11.0″ toward	Feb. 3	7.7″ toward
21	11.1″ from	10	1.7″ toward
28	8.2″ from	17	3.1″ toward
Nov. 4	2.0″ toward	24	18.2″ from
11	7.1″ from	Mar. 3	14.2″ from
18	12.6″ from	10	4.2″ toward
25	1.4″ toward	17	12.1″ toward
Dec. 2	28.0″ from	24	3.1″ toward
9	0	31	6.7″ toward
16	1.1″ toward.	Apr. 7	8.9″ from
23	5.7″ from	14	4.3 from
30	7.8″ from	21	18.9″ from
		28	2.0″ toward.

A.E.J.

The Volcano Letter

No. 424—Monthly U. S. Geological Survey, Hawaii National Park JUNE, 1935

KILAUEA REPORT FOR JUNE, 1935

Including weekly press reports 1220 to 1223
June 2 to June 30, 1935, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

The month of June at Halemaumau pit of Kilauea Volcano was not remarkable for any important events until after the solstice when a very marked increase of earthquake frequency occurred along with notable sharp earthquakes at the end of the month. The press reports Vesuvian activity in Italy and earthquakes in Mexico.

Slides at Halemaumau

At 9:50 a. m. June 3, gravel was falling at the NW scar, and it was evident that some additional pieces of the rim slab had fallen there, and a remnant pinnacle appeared ready to fall. This is equally the case at the middle of the SSW scar, where a column on the rim is hanging out in unstable equilibrium. June 6, at 10:56 a. m. a noisy slide was heard. June 8, at 10:50 a. m. a moderate slide fell E, recording as a tremor on the Halemaumau seismograph. June 9, at 6:36 a. m. an eastern avalanche occurred, and at 9 a. m. the rock wall ENE was scarred and working. There was a fresh wet scar high up, and fresh red debris on the talus. At 12:52 p. m. a slide occurred above the E talus.

The second week produced repeated slides from the east buttress. At 9 a. m., June 14, and again at 9:05, avalanche dust arose. A visit at 9:15 showed that the slide was at the east wall; from the buttress there at 9:25 a large slide fell. At 3:30 p. m., June 15, and at 5:30 p. m., June 16, dust clouds arose.

This eastern sliding was replaced by avalanches on the opposite side of the pit during the third week. The west wall sent up dust June 17, at 4:15 p. m. and 5:00 p. m. This was at the WNW scar which had been quiet of late. Noisy slides were heard 9:50 a. m., 2 p. m., and 2:55 p. m. June 21, while a party was running levels around the pit.

The week ending June 30, stirred the walls considerably owing to large numbers of earthquakes. Slides were almost continuous the afternoon of June 28. and it was evident that the earthquake of 9 a. m. that day had dislodged a slide SSE. At 9:30 a. m. there was a slide NE, at 11:57 a. m., one N. June 29, at 4:35 p. m., a dust cloud arose NNE. June 30, at 11:55 a. m. a slide occurred NE, and dust arose above the pit at 3:10 p. m.

This northeast sliding was accompanied by fresh soil cracks observed 100 feet back of the northeast rim of Halemaumau for a length of 50 feet on June 29; and new breaks in the dirt occurred inside of old cracks NNE; this phenomenon was observed also along the WNW edge of the pit.

Halemaumau Floor Solfataras

June 3, at 9:50 a. m., there was a trace of thin rising fume at the north corner of the 1934 lake cup. Fume was abundant at the Yellow Solfatara NW. June 9, this place was fuming, and fumes were visible at the four other vents north and east. With increasing northeast wind and clear dry weather this fuming from the five vents at the NW, NE, and E edges of the floor continued on June 10. At the west rim of the pit sulphur dioxide could be smelled presumably from the bright yellow solfataras NW and NNW. On days when the relative humidity become lower both the vapor vents and the yellow solfataras produced clouds less dense. The odor of sulphur dioxide along the west rim of the pit was noted by the levelling party June 21. June 22, heavier fume than usual was observed issuing from the NW solfatara at 10:30 a. m.

The earthquake week at the end of the month disturbed the cracks around Halemaumau and increased the odor of sulphur gases from the floor fumeroles. Most of this came from the Yellow Solfatara northwest. The disagreeable odor of hydrogen sulphide was noticed in the early afternoon of June 28 and a little the next day.

Tilt Cellar Effects

The three tilt cellars around Halemaumau showed no unusual tilts after the earthquake of June 25, but their disturbance after the earthquake of June 28 was marked. The boom of the western clinoscope was moved 19 mm SSW, that of the northern instrument 14 mm E. and at the southeast station the movement was 17 mm NW. Two days later this southeast station had accumulated an additional tilt of 57 mm. before it settled down, always with northwesterly or westerly trend. One millimeter equals approximately two thirds of a second. Northwesterly tilt at the southeast station means a tipping of the ground in the direction of the center of the pit, or in the direction of the northern rift of Mauna Loa. It should always be remembered that these tilting results after earthquakes are only approximate, as a shock disturbs the instrumental adjustments, and also the block of ground may be fractured locally whereon the instrument stands.

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of

June 8, 8 opened, 7 closed, aggregate opening 0.5 mm.
June 15, 12 opened, 3 closed, aggregate opening 5.5 mm.
June 22, 14 opened, 3 closed, aggregate opening 9.0 mm.
June 29, 11 opened, 4 closed, aggregate opening 9.5 mm.

Levelling

Spirit level determination of elevation changes around the rim of Halemaumau was made by A. E. Jones, June 4, 21, and 28. The base used was the bench mark at the southern gravel ridge of Kilauea Crater ("Spit"). Results showed that the NW trig station on Halemaumau rim had relative-lowered, or Spit B.M. had raised, between April 25 and June 4, 1 cm. or less; a reverse movement (NW up or Spit down) June 4 to June 21, 0.5 cm.; original movement (NW down or Spit up) June 21 to June 28, 2 cm. In this direction the total NW down or Spit up was 2.5 cm. or less since April 25 (see Volcano Letter 422).

Referring to the movement as NW station lowering, as was done in the Volcano Letter for April, and in other communications, this lowering of the crater floor is a continuation of movement in this direction since the eruption of Kilauea in September 1934, but is in contrast to the elevation of April 1935. The strong earthquake shock of June 28 may have been partly responsible for the sudden lowering of the crater floor between June 21 and 28. Levelling was in progress at the time of the quake, and was stopped by rain before a check could be made. It must be borne in mind that it is quite probable that the change of level of the eruption was a depression of the southern fault block under Spit relative to mean sea-level, and that the change of level since has been an elevation of that fault block relative to the crater floor. T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Moderate to Strong earthquakes	Distant earthquakes	Local * Seismicity
June 9	40	1	1	0	0	11.50
June 16	53	2	0	0	0	14.25
June 23	134	5	0	0	0	36.00
June 30	143	9	0	2	1	47.25

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on five stations Kilauea, Hilo, Kona, Halemaumau, and Uwekahuna. The intensity is that recorded on the Kilauea instruments.

June 5, at 6:55 a. m., a feeble earthquake was felt at both Kilauea crater and Honokaa. It was located 15 miles

deep under the Kona side of the island, lat. 19° 28′ N, long. 155° 48′ W.

June 6, at 9:46 a. m., a tremor was recorded, it was larger on the Kona seismogram. It was tentatively located on the seaward extension of the Hualalai rift, in lat. 19° 50′ N, long. 156° 10′ W.

June 16, at 4:35 p. m., a very feeble shock was recorded from the Kaoiki rift about 19° 20′ N, 155° 25′ W.

June 25, at 0:45 a. m., a moderate earthquake dismantled the Observatory seismograph. It awakened people quite generally on south half of the island. The source was two or three miles deep under the north rim of Kilauea crater. 19° 26.5′ N, 155° 16.5′ W.

June 27, at 8:14 a. m., a very feeble shock was felt in north Kona and Puuwaawaa. It appeared to be located near Kailua Bay, 19° 40′ N, 155° 00′ W.

June 28, at 9:00:19 a. m., a moderate to strong earthquake began to record on the Observatory seismographs. The strong motion seismograph was the only instrument on the island not dismantled. The secondary wave did the dismantling. Some damage was caused in Hilo. The selected location was on the Mauna Loa northeast rift, 19° 36′ N, 155° 11′ W and five miles deep. It was felt generally on Hawaaii.

Microseisms were normal 5, 6, 18 and 28, and were subnormal the remainder of the period.

The preliminary waves only, of a teleseism began recording at 1:02:05 p. m., June 24. No location has been reported of it. A.E.J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the readings from each clinoscope and the resultant radial tilts for the three clinoscopes, towards or from the center of Halemaumau Pit.

At the Observatory the total accumulated tilt in the year June 30, 1935, is 3.0″ N and 2.7″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
June 9	0.8″ S 20° W	1.4″ N 82° W	2.8″ N 89° W	7.0″ S 34° W	5.6″ From
June 16	1.3″ N 45° E	1.4″ S 70° W	2.4″ S 92° W	9.2″ N 18° E	3.2″ toward
June 23	0.6″ N 65° E	2.2″ N 63° E	6.8″ N 37° W	2.8″ S 70° E	7.6″ from
June 30	2.5″ N 80° E	24.3″ N 75° E	26.8″ S 32° W	118.″ N 60° W	96.″ toward.

A.E.J.

The Volcano Letter

No. 425—Monthly Department of the Interior, National Park Service JULY, 1935

KILAUEA REPORT FOR JULY, 1935

Including weekly press reports 1224 to 1227
June 30 to July 28, midnight
HAWAII NATIONAL PARK

E. G. Wingate, Superintendent
T. A. Jaggar, Volcanologist

The month of July at Halemaumau Pit of Kilauea Volcano showed high frequency of earthquake shocks, continued rock slides from the pit walls, and heavy fuming of the solfataras adjacent to the floor of the pit during the first two weeks, but thereafter the pit became very quiet.

Slides at Halemaumau

July 1, slides were reported at 11:55 a. m. and 5:40 p. m. July 2, there were two or three small slides during the day. July 6, the SW wall was making slides at 9:45 a. m. July 7, dust clouds from slides occurred at 11:00 a. m., 1:20 p. m., 3:00 p. m., and 3:25 p. m. There was very large slide at 5:50 p. m. The slide registered as tremors on the Observatory seismograph. Between 8:00 and 9:00 p. m., small slides were noted at intervals of about 9 minutes.

July 8, dust clouds indicated slides at 9:45 a. m., 10:37 a. m., and 10:45 a. m. July 9, at 8:55 a. m., 10:10 a. m. and 1:05 p. m. Small slides were practically continuous the morning of July 9. July 10 dust clouds arose at 1:07 p. m. July 11 there were rock slides at 9:10 a. m.

July 15 and July 20, dust caused by slides covered a large part of the lava floor of Halemaumau, especially NE, W, and N on July 20. Scars have been produced on the N Buttress by slides on July 15. Slides were reported at the following times:

July 16, at 12:53, 1:00, 1:38, 1:43, and 2:05 p. m., mostly E and NE. Very large slides on this day fell from the E wall at 11:00 a. m. and 4:30 p. m. July 17, another slide occurred here at 9:40 a. m. July 20, rocks fell from the N. Buttress at 11:25 a. m., the cloud resembling steam. July 21, there was a slide at 9:45 a. m.

The last week of the month, the pit was quieter, though the numbers of local seismic disturbances were more than 100 weekly throughout July. This was of interest as the numbers greatly decreased during the following month, and had been small before the solstice in June.

As shown by the earthquake report, increased frequency of earthquakes which originate away from Kilauea probably stimulates sliding; on the other hand, the disturbance of the pit occasioned by heavy sliding, itself makes tremors at the instruments. Most tremors are Kilauea phenomena and may be caused not only by slides in the pit, but also by lava movements under the pit. We have not yet devised any method of proving conclusively cause and effect, in the relations between tremors and slides.

Halemaumau Floor Solfataras

Fuming at the NW Solfataras increased slightly with puffs at 12:45 p. m. July 1, and at 2:00 p. m. July 2 fume filled the pit with heavy blue haze. At 12:30 p. m. July 6, sulphurous odor was noted and again the evening of July 7. These phenomena continued July 9, July 11, and July 13, and a small area of yellow sulphur had appeared at the E edge of the floor. By July 20, the fume had decreased. After heavy rainfall July 24, much vapor rose from cracks on the floor.

Tilt Cellar Effects

At the beginning of the month large tilt values continued to be recorded at the SE and W tilt cellars near Halemaumau. Following the earthquake shock of July 4, the W cellar registered about 6 seconds tilt NE, and the SE station about 12 seconds W.

On July 6, the SE cellar again registered a large tilt of 20 seconds W, without the stimulus of any unusual earthquake.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau Pit resulted as follows:—

Week ending forenoon of					
July 6	6 opened,	4 closed,	aggregate opening	2.0	mm.
July 13	9 opened,	7 closed,	aggregate opening	2.5	mm.
July 20	6 opened.	5 closed,	aggregate opening	0.0	mm.
July 27	19 opened,	2 closed,	aggregate opening	11.0	mm.

T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
July 7	105	6	0	0	31.25
July 14	136	8	1	0	42.00
July 21	136	1	1	0	35.50
July 28	119	3	0	1	31.25

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indictated. The location of the earthquakes are based on the main station at the Kilauea Observatory and two subsidiary stations located around the crater. More distant earthquakes were located with the aid of seismograms from stations at Hilo and Kealakekua.

July 4, at 10:02 p. m., slight earthquake under Kilauea southwest rift zone; lat. 19 degree 25′ 54″ N, long. 155 degree 17′ 57″ W, 1.7 miles deep.

July 5, at 9:44 p. m., very feeble earthquake between Keanakakoi and Lua Manu craters; lat. 19 degree 24′ 19″ N, long. 155 degree 15′ 39″ W, .0.9 miles deep.

July 8 at 4:21 p. m., moderate earthquake, some doubt as to the exact location but known to have been centered about 3.6 miles deep in the vicinity of Makaopuhi crater, probably along the southeast rift.

July 10 at 9:49 a. m., very feeble earthquake reported felt in Kona district and 31.4 miles from Kilauea. Thought to be located on S. W. rift of Mauna Loa.

July 10, at 6:47 p. m., very feeble earthquake reported felt in Kona district and 59.5 miles from Kilauea. Thought to be located on sea bottom west of Kealakekua.

July 12, at 4:32 a. m., very feeble earthquake 2.5 miles S. W. of Halemaumau in rift zone; lat. 19 degree 22′ 45″ N, long. 155 degree 18′ 36″ W 2.5 miles deep.

July 12, at 8:30 p. m.. feeble earthquake reported felt at Kapapala Ranch where a window pane was broken and a noise like the report of a gun was heard. Located in S. W. rift zone 16.5 miles from Hawaiian Volcano Observatory; lat. 19 degree 15′ N. long. 155 degree 25′ W, 74.0 miles deep.

July 13, at 2:56 p. m., very feeble earthquake reported felt at Summer Camp on S. E. rim of crater. Probably located between Lua Manu crater and Keanakakoi about 1.2 miles deep.

July 16, at 5:10 p. m., a feeble earthquake, beneath ocean, 20 miles S. S. W. of Kilauea, 11.0 miles deep.

July 24, at 6:35 p. m., a very feeble earthquake 0.6 miles north of the north rim of Kilauea crater; lat. 19 degree 26′ 27″ N, long. 155 degree 16′ 9″ W, 5.4 miles deep.

July 26, at 1:51 p. m., very feeble earthquake probably centered in S. W. rift zone about 5 miles from Halemaumau.

The distant earthquake of July 28 which began to record at 9 h: 16 m: 40s p. m. originated 2,775 miles southwest of Hawaii near or in the Tonga Deep.

On July 31 at 9:01 a. m. and 9:35 p. m., 15 and 20 minutes respectively of harmonic tremor began to record.

Microseismic motion was subnormal during July except on the following dates: July 7, 8, 10, 17, 20 and 26 when it was normal and July 14 to 16 inclusive when it was abnormal.

H. H. Waesche.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea Crater; and at Halemaumau, the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending July 28 was 1.1″ N and 4.2″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
July 7	0.7″ N 24° E	2.4″ N 47° W	19.67″ N 18° E	74.5″ N 84° W	51.55″ toward
July 14	0.3″ S 27° E	4.9″ N 37° W	0.75″ S 31° W	51.8″ N 50° W	58.00″ toward
July 21	1.1″ N 45° E	1.2″ S 66° W	1.1″ N 56° W	4.4″ N 69° E	0.94″ from.
July 28	0.8″ N 20° E	0 0	3.96″ N 87° W	4.4″ N 37° W	8.23″ toward.

H.H.W.

The Volcano Letter

No. 426—Monthly | Department of the Interior, National Park Service | AUGUST, 1935

KILAUEA REPORT FOR AUGUST, 1935

Including weekly press reports 1228 to 1232

HAWAII NATIONAL PARK

E. G. Wingate, Superintendent
T. A. Jaggar, Volcanologist

During the month of August at Kilauea Volcano, there was steady decline in local seismicity, but a flurry of local movement occurred in the middle of the month.

Slides at Halemaumau

July 31, 10:50 a. m., a few stones were heard falling near N Buttress, and a similar movement of rocks and dust occurred there August 2, 10:45 a. m. August 7, 5:52 p. m., a slide occurred at the N, and a fresh scar streaked the N Buttress. More N Slides occurred August 8 and August 9 about 10:00 a. m. The N Buttress was again making slides at 2:55 p. m., August 12, and on August 15, a large slide fell at the W at 6:30 a. m. followed by others at the same place at 9:33 and 11:50 a. m.; and at 2:00 p. m., a large slide at the S occurred, another at the N Wall and a small slide occurred SW. August 19, 9:36 a. m. a noisy small slide fell at the N Wall and rocks were slipping at the W Wall. August 20, 9:10 a. m., there was a small slide N and others at the same place, sending up dust. August 21, 9:05 and 10:18 a. m. August 23, fresh talus appeared on the E floor. August 26, new rocks had fallen on the N floor and on August 30, at 12:40 p. m., a slide at the N sent up pinkish dust; gravel was slipping on that wall the next morning. September 1, 9:00 a. m. a snapping noise was heard, and a slight fall of stones occurred at the W five minutes later.

Halemaumau Floor Solfataras

August 3, the sulphur spot E had enlarged and become a brighter yellow. August 7, a new sulphur stain was observed at the foot of the NE talus. During rainy, foggy weather, August 10, there was much fume from the solfataras and vapor from the walls. A fume puff was observed 3:15 p. m. August 12, and on August 13, in the morning, the NW yellow solfatara was puffing vigorously but owing to dry weather fume did not show elsewhere. During afternoons, blue fume became conspicuous at the pit with sunlight in the background, and similarly fume showed over Mokuaweoweo at time of sunset. August 23, the E sulphur spot appeared larger and August 29 calm weather made the fume conspicuous; this continued September 1. as the fume appears heavy and settles. A crack at the NW border of the floor appeared to have widened during the last few months.

Measurement of Halemaumau Rim Cracks

Weekly measurements of 32 marked rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of

August 3 10 opened, 3 closed, aggregate opening 2.0 mm.
August 10 6 opened, 9 closed, aggregate closing 2.0 mm.
August 17 8 opened, 6 closed, aggregate opening 1.5 mm.
August 24 10 opened. 4 closed, aggregate opening 2.5 mm.
August 31 14 opened, 3 closed, aggregate opening 7.0 mm.

Levelling

Spirit level determinations were run around the rim of Halemaumau August 15, 1935 by H. H. Waesche. Result shows that crater floor of Halemaumau had lowered 1.2 cm. since July 2. As shown by graphic method, the rate of lowering is about the same as between June 28 and July 2. With the exception of a slight upward movement of the crater floor in April, downward movement has been continuous since the eruption of September 1934. By downward movement is meant the relative lowering with reference to the S gravel ridge of Kilauea Crater (Bench Mark "Spit"). Total lowering has been 8.5 cm. or less since October 1934.

T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
August 4	133	0	0	0	33.25
August 11	123	3	0	1	32.25
August 18	113	1	1	1	30.75
August 25	86	9	0	0	27.00
September 1	49	6	0	0	15.00

* For local seismicity index see Volcano Letter 371.

The fol'owing successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The locations of the earthquakes are based on the main station at the Kilauea Observatory and two subsidiary stations located at other points around the crater. More distant earthquakes were located with the aid of seismograms from stations at Hilo and Kealakekua.

August 9 at 8:40 a. m. very feeble earthquake under Kilauea S. W. rift zone, 1.5 miles S. W. of Halemaumau; lat. 19 degree 24′ N, long. 155 degree 18.5′ W.

August 11 at 7:12 p. m. very feeble earthquake about 1.2 miles deep and between 2 and 3 miles N. E. of the Volcano Observatory.

August 17, at 12:04 a. m. a slight earthquake felt in Volcano district by many and reported felt in Pahala, Hilo, Hakalau and Hookena. Location on Mauna Loa N. E. rift, 21.7 miles deep; lat. 19 degree 34′ N, long. 155 degree 25.2′ W.

August 20, at 1:23 p. m. a very feeble earthquake thought to have originated in area in S. W. portion of Kilauea Crater.

August 22, at 6:11 a. m. a very feeble earthquake probably located in Kilauea S. W. rift zone, 1.8 miles S. W. of Halemaumau.

August 22, at 8:12 a. m. a very feeble earthquake probably located in Kilauea S. W. rift zone, 0.8 miles S. W. of Halemaumau.

August 23, at 1:28 a. m. a very feeble earthquake probably located 1.7 miles S. W. of Halemaumau in S. W. rift zone.

August 23, at 5:13 a. m. a very feeble earthquake probably located 1.7 miles S. W. of Halemaumau in S. W. rift zone.

August 23, at 6:32 p. m. a very feeble earthquake probably located 2.1 miles S. W. of Halemaumau in S. W. rift zone.

August 24, at 8:20 a. m. a very feeble earthquake located 2.3 miles S. W. of Halemaumau in rift zone 2.5 miles deep; long. 155 degree 18.8′ W.; lat. 19 degree 23′ W.

August 27, at 3:15 a. m. a very feeble earthquake located ½ mile S. E. of Halemaumau near Keanakakoi 3.2 miles deep; lat. 19 degree 24.2′ N, long. 155 degree 16.7′ W.

August 27, at 2:23 p. m. a very feeble earthquake located 1 mile S. E. of Halemaumau about 1 mile deep; lat. 19 degree 24.1′ N, long. 155 degree 16.3′ W.

August 29, at 7:59 a. m. a very feeble earthquake 2.7 miles S. E. of Halemaumau and 3.5 miles deep; lat. 19 degree 22.7′ N, long. 155 degree 15.4′ W.

August 29, at 11:46 p. m. a very feeble earthquake probaly located 3.7 miles S. E. by S. from Halemaumau.

The surface waves of a distant earthquake began recording at the Volcano Observatory at 9 h: 30 m: 05s: p. m.. August 10.

The preliminary waves of a distant earthquake began recording at 3h: 23m: 51s: p. m., August 16. It was 3,660 miles from Kilauea and was located at or near New Caledonia.

Microseismic motion was subnormal during the month except on the following dates, August 5, 8, 13, 14, 15, 19, 20 and 24 when it was normal.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at the Volcano Observatory, northeast rim of Kilauea; and at Halemaumau, the algebraic sum of radial tilts for three clinoscope stations towards or from the center of the Pit.

At the Observatory the total accumulated tilt in the year ending September 1, was 0.74″ N and 1.5″ E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
August 4	0.93″ N 24° W	1.19″ S 29° W	1.79″ N 80° W	4.31″ N 82° W	2.37″ toward
August 11	0.55″ S 46° W	4.83″ N 71° W	6.17″ N 50° W	3.40″ N 56° E	4.54″ from.
August 18	0.77″ N 15° W	4.78″ S 78° W	4.41″ N 55° W	19.86″ N 53° W	15.93″ toward
August 25	0.76″ N 3° E	1.48″ S 62° W	3.64″ N 75° W	3.24″ N 48° E	1.92″ from
September 1	0.24″ W	1.00″ N 28° W	7.45″ N 36° W	4.54″ S 5° W	7.93″ from

H.H.W.

The Volcano Letter

No. 427—Monthly | Department of the Interior, National Park Service | SEPTEMBER, 1935

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR SEPTEMBER, 1935

Including weekly press reports 1233 to 1236

September 1 to September 29, 1935, midnight

HAWAII NATIONAL PARK
Edward G. Wingate,
Superintendent

KILAUEA VOLCANO
T. A. Jaggar,
Volcanologist

VOLCANOLOGY

During the month of September, the seismicity declined, this being influenced by the amount of local tremor. At the time of equinox, the week ending September 22, there was distinct increase in seismic frequency and intensity. All but two of the earthquakes of the month were located near Kilauea. The excessive tilt at the SE clinoscope station for the third week is not trustworthy, as earthquakes derange these instruments. Halemaumau pit has been quiet.

Slides At Halemaumau

Slides from the wall of the pit have been noted as follows:—

September 3 at NW wall, 2:40 and 2:55 pm.
September 4, at E bay, 9:37 am.
September 7, large slide NE wall 1:05 pm.
September 7, NE wall, followed by continuous dribbling, 2:09 pm.
September 8, E wall, 1:30 pm.
September 9, NE wall, small slide, 4:45 pm.
September 10, N wall, small slide, 9:45 am.
September 11, E wall, slight slippings, 9:00 am.
September 17, N corner, 11:45 am.
September 17, large dust cloud, 11:55 am.
September 19, small slide E wall, 9:00 am.
September 20, numerous slides N corner, 9:30 am.
September 21, dust cloud and noise, N edge 1:45 pm.
September 21, dribbling on N and W slopes, 2:30 pm.
September 25 light dust cloud E, 10:00 am.

The slides of the first week removed a piece of rim rock NE and made a straight narrow scar down the wall, midway between the E and NE taluses; some fresh debris lay underneath.

Halemaumau Solfataras

In rainy weather, September 2, the walls were wet, and 14 vaporing places were counted. There were dry places on 8 talus slopes. Heavy blue fume arose at the NW Solfataras, and much steam came out of the W wall. On September 9, at 10:00 am, the solfatara at base of E talus was fuming, and fume elsewhere was not seen; at 10:45 am, however, the E fume had disappeared, but the NW Solfatara was smoking variably. For some reason these two places puffed fume interchangeably. September 21, it was apparent that the sulphur patch at edge of floor ESE is growing brighter yellow. September 22 at 8:40 am, with light southerly wind, the blue fume from NW Solfatara rose conspicuously.

Measurement Of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

Week ending forenoon of—
Sept. 7, 12 opened, 4 closed, aggregate opening 6.0 mm.
Sept. 14, 7 opened, 2 closed, aggregate opening 4.0 mm.
Sept. 21, 3 opened, 7 closed, aggregate closing 1.5 mm.
Sept. 28, 11 opened, 2 closed, aggregate opening 6.0 mm.

T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
Sept. 8	65	4	0	1	22.00
Sept. 15	40	8	0	2	14.00
Sept. 22	50	7	2	3	18.00
Sept. 29	38	8	0	1	13.50

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms. The depth of focus is indicated whenever determinations were possible. The locations of the earthquakes are based on the main station at the Kilauea Observatory, and the two subsidiary stations at Uwekahuna and Halemaumau respectively. More distant earthquakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The latter net is primarily for locating earthquakes originating on the Island of Hawaii outside of Kilauea area.

September 5 at 10:29 am, very feeble, located under or near Halemaumau.

September 6 at 4:26 pm, very feeble. probably located on SE slope of Hualalai; 19° 36.5′ N; 155° 48.2′ W. Reported felt at Puuwaawaa Ranch.

September 9 at 5:06 am, very feeble, located 0.6 mile deep under SE portion of Halemaumau, 19° 24.5′ N; 155° 17.5′ W.

September 15 at 5:34 pm, very feeble, probably located under NE rift of Mauna Loa near the summit Crater.

September 17 at 10:06 pm, very feeble, located 1.6 miles SSW of Pit seismograph station and 1.7 miles deep. 19° 23.1′ N; 155° 17.7′ W.

September 19 at 9:07 am, very feeble, located 3 miles deep in the Puna rift zone between Lua Manu and Puhimau Craters. 19° 23.9′ N; 155° 15.4′ W.

September 19 at 9:10 am, very feeble, located 4.7 miles deep, 0.2 miles N of Devils Throat in the Puna rift. 19° 23.0′ N; 155° 14.2′ W.

September 20 at 2:31 am, very feeble, located 5.0 miles deep, 1.2 miles east of Halemaumau 19° 24.7′ N; 155° 16.1′ W.

September 20 at 3:59 pm, feeble, located 1.1 miles deep under east rim of Halemaumau. 19° 24.6′ N; 155° 17′ W.

September 21 at 10:31 pm, very feeble, located 5 miles deep, 3.8 miles SSE of Pit seismograph under Kalanaokuaiki Pali. 19° 21.2′ N; 155° 15.9′ W.

September 23 at 8:08 pm, very feeble, located 0.8 mile N of the Pit seismograph. 19° 21.0′ N, 155° 16.9′ W.

September 26 at 2:27 pm, located 0.6 mile deep under SE rim of Halemaumau. 19° 24.5′ N; 155° 17.1′ W.

September 28 at 4:09 am, very feeble, probably located under SE rim of pit.

Distant earthquakes were recorded as follows: September 8 at 7:58 pm, surface waves only, location 58° N; 139° E in the vicinity of Northern New Guinea. September 11 at 3:44 am (preliminary waves); location near Japan; 44° 5′ N; 147° E. September 15, at 4:06 am, long waves only, location, 28° S; 113.3° W, about 2000 miles W of Peru in the Pacific Ocean. September 19 at 3:28 pm; preliminary waves, location 4,510 miles from Kilauea immediately south of Australia and west of Tasmania, 40° S; 140° 5′ E. September 19 at 7:22 pm, surface waves only location in vicinity of the Admiralty Islands, 0° N; 146° E. September 22 at 11:18 pm, surface waves only, location 0.5° N; 141.5° E, in vicinity of Northern New Guinea. September 24, at 11:58 am, location 50° N; 129° W, off Coast of British Columbia.

Microseismic motion was slight during the month except on the following dates, September 12, 14, 16, 17, 23, 25, and 28 when it was normal. It was strong September 29.

H.H.W.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for three clinoscope locations towards or away from the center of the Pit.

At the Observatory the total accumulated tilt for the year ending September 29, was 0.4″ N and 1.1″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
Sept. 8	0.3″ S 65° E	3.59″ N 45″ W	2.38″ N 55° W	1.45″ S 33° E	4.57″ from.
Sept. 15	0.84″ N	0.90″ S 69° E	2.44″ N 78° W	2.59″ N 64° W	2.22″ toward
Sept. 22	0.15″ N	3.09″ S 35° W	3.58″ N 22° E	32.4″ N 59° W	33.20″ toward
Sept. 29	0.20″ S 45° W	3.51″ N 48″ W	4.62″ N 47° W	1.26″ N 82° W	3.23″ from

NOTE: SE Pit Clinoscope adjusted September 21. Had probably been partially dismantled since earthquake of June 28, rendering results between those dates doubtful.

H.H.W.

The Volcano Letter

No. 428—Monthly Department of the Interior, National Park Service OCTOBER, 1935

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER, 1935

Including weekly press reports 1237 to 1240

September 29 to October 27, 1935 midnight

HAWAII NATIONAL PARK
E. G. Wingate
Superintendent

KILAUEA VOLCANO
T. A. Jaggar
Volcanologist

VOLCANOLOGY

A large group of exceptional earthquakes, moderate to strong, occurred on September 30 and October 1, originating under the rift system of Mauna Loa at estimated depths of 17 to 30 miles. In view of the lava flow of Mauna Loa that was to come in November, it is interesting to note that the strongest shock was felt all over Hawaii and its epicenter was located seismometrically under the NE slope of Mauna Loa, near where the Humuula Flow finally came forth. These earthquakes disturbed the Halemaumau walls, made avalanches and opened rim cracks excessively owing to the long swaying movement. Most of the centers were under Mauna Loa. The total number of disturbances for the week ending October 6 was 178. The spasm of 11 shocks the middle of October was quite different and centered at Kilauea. Except for the slides started by earthquakes, Halemaumau pit was quiet. Horizontal angles measured across pit and crater notably opened September 25 to October 30, the Halemaumau rim slightly lowered relative to the southern gravel spit, and tilt of the clinoscope stations around Halemaumau which lately had been away from the center, changed to a tilt towards the center in July and August.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows:—

September 30, large avalanche cloud, with two smaller ones following it, 9:45 am.

September 30, noisy slides made by the night earthquakes

October 1, smaller slide N wall. 1:20 am.
October 1, W side of pit after 6:00 am.
October 2, NW dribbling slides 10:35 am.
October 3, N wall dribbling slides, 9:30 am.
October 3, NE slide, 5:15 pm.
October 4, NE floor covered with dust, early morning.
October 5, NE slides, 10:32 and 11:00 am.
October 7, NE dust clouds, 4:45 pm.
October 8, dust clouds from slides leaving stones on E floor, 2:55 and 3:50 pm.
Octcober 17, small slides, SW 12:20 and 12:50 pm.
October 18, small slide NW. 12:15 pm.
October 22, rocks heard falling WNW, 9:50 am.

Halemaumau Solfataras

At 10:40 am, September 30, fume rose from yellow spot at E edge of floor. With 5 inches of rain in 2 days, October 12-13, the fuming vapor was dense at the Yellow Solfatara NW. White salts appeared at the vents of the 1934 Lava Cascades, and during heavy rain showers the forenoon of October 12, dense vapor clouds appeared there, and tails of vapor rose all over the floor.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

Week ending forenoon of

October 5, 17 opened, 5 closed, aggregate opening 21.0 mm.
October 12, 12 opened, 7 closed, aggregate opening 6.5 mm.
October 19, 8 opened, 5 closed, aggregate opening 2.0 mm.
October 26, 14 opened, 3 closed, aggregate opening 8.0 mm.

After the earthquake spasm of the first week, in some places soil had fallen down the measured cracks and hair cracks in the dirt appeared, showing the effects of disturbance of rim blocks by the earthquakes. T.A.J.

Crater Angles and Levelling

The horizonal angle measured from the Volcano Observatory between SE and NW rims of **Kilauea Crater** showed sharp closing of 4″, July 30 to August 3 and opening 0.8″, August 9 to 29. The angle closed 1″, August 29 to September 21, and opened an equal amount October 9. Opening continued, adding 4″ more October 9 to October 30, the angle on that date reading 38° 30′ 16.2″.

The angle across **Halemaumau** from SE to NW rim stations, changed similarly to the one across Kilauea Crater. It closed 3.0″ to a record dow value of 16° 14′ 27″, August 29 from its reading of July 30. From that date, there was steady opening 2.4″ to October 30.

Spirit levelling between Spit B. M. in the southern rim region of Kilauea Crater, and the NW station B. M. of Halemaumau, shows relative lowering of NW station. The amounts of lowering are as follows:

July 2 to August 13, 12.0 mm; August 13 to September 18, 1.0 mm; September 18 to October 18, 4.0 mm.

H.H.W.

EARTHQUAKES

TABLE

Week ending	Tremors	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Moderate earthquakes	Local * Seismicity
Oct. 6	142	27	3	2	4	69,00
Oct. 13	36	2	0	0	0	10.00
Oct. 20	33	10	1	3	0	20.25
Oct. 27	30	3	0	0	0	9.00

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated and the epicenters were located from seismograms. The depth of focus is indicated wherever such determinations were possible. The locations of these earthquakes are based on the main station at the Kilauea Observatory, and the two subsidiary stations at Uwekahuna and Halemaumau respectively. More distant earthquakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The latter net is primarily for locating shocks originating on the Island of Hawaii outside of the Kilauea Area.

September 30 at 8:28 am, very feeble, located 0.8 miles deep under SE rim of Halemaumau, 155° 17.1′ W; 19° 24.5′ N.

September 30, at 10:35 pm, very feeble, located 25 miles deep on NE rift near Summit Crater of Mauna Loa, 155° 31.6′ W; 19° 31.4′ N.

September 30, at 10:36 pm, moderate, felt generally on the Island of Hawaii. It was located 30 miles deep under the SW rift of Mauna Loa 155° 39.5′ W; 19° 22′ N.

September 30, at 11:58 pm, moderate to strong, felt over entire Island of Hawaii, located under NE slope of Mauna Loa about midway between Puu Ulaula and Humuula Sheep Station and 17.4 miles deep, 155° 26.3′ W; 19° 38.7′ N.

October 1, at 12:02 am, moderate, generally felt as a continuation of the preceding one, location undertermined, but focus was probably under the Mauna Loa rift system.

October 1, at 12:10 am, feeble, felt slightly in NE sections of the Island of Hawaii, location undetermined but probably under Mauna Loa, like preceding quake.

October 1, at 12:34 am, slight, associated with this same series of Mauna Loa disturbances.

October 1, at 12:54 am, slight, felt in Kilauea Area and NE section of Island of Hawaii, located half way between Mokuaweoweo and Hilo about 25 miles deep under the Mauna Loa NE rift zone; 22 miles NE of the summit Crater 155° 24.5′ W; 19° 34.4′ N.

October 1, at 10:22 am, moderate, reported felt in Hilo and in the Kilauea district, located under the NE rift

zone of Mauna Loa 15 miles SW of Hilo 155° 19.2′ W; 19° 38.3′ N.

Between 10:30 pm, September 30 and midnight October 1, there were 23 very feeble earthquakes associated with the disturbance centered under the SW and NE rift zones of Mauna Loa.

October 4, at 5:33 am, feeble, located 30 miles deep under SW rift of Mauna Loa about 6 miles SW of Summit Crater, 155° 38.2′ W; 19° 23.5′ N.

October 5, at 1:49 am, feeble, reported felt strongly at summit rest house of Mauna Loa. Also felt at Waiohinu, Naalehu and Honuapo, located approximately under NE edge of Mokuaweoweo.

October 11, at 7:37 am, very feeble, located 1.3 miles deep under Halemaumau 155° 17.1′ W; 19° 24.5′ N.

Octcober 15, at 4:53 pm, very feeble, located 2.8 miles deep near the Devils Throat in Kilauea SE rift zone 155° 14.4′ W; 19° 22.9′ N.

October 15, at 6:35 pm, feeble, located 3.7 miles deep 3.2 miles S of Halemaumau 155° 17.′ W; 19° 21.5′ N.

Octcober 15, at 7:20 pm, slight, located 1.8 miles deep near Cone Crater, Pit Craters and Puu Koae in Kau rift zone of Kilauea 155° 19.0′ W; 19° 21.5′ N.

October 15, at 8:09 pm, very feeble, located 4 miles deep and 3.3 miles SW of Halemaumau in Kau rift zone 155° 18.8′ W; 19° 22.1 N.

October 15, at 8:09 pm, slight, located 3.8 miles deep and 3.4 miles SW by W from Halemaumau 155° 19.7′ W; 19° 22.8′ N.

October 16, at 12:07 am, slight 1.3 miles deep and 0.5 mile NW of Puu Ohale 155° 17.3′ W; 19° 21.6′ N.

October 20, at 5:01 pm, very feeble, located 1.2 miles under east rim of Halemaumau 155° 17.0′ W; 19° 24.5′ N.

October 25, at 11:45 pm, very feeble, located 0.7 mile deep under Crater of Kilauea 0.2 mile NE of Pit seismograph station 155° 16.9′ W; 19° 24.4′ N.

No distant earthquakes were recorded during the month.

Microseismic motion was normal October, 1, 2, 5, 6, 7, 10, 11, 14 to 17 inclusive, 20 and 24; light 8, 9 and 21 to 23 inclusive; and strong September 30, October 3, 4, 12, 13, 18, 19 and 25 to 27 inclusive. H.H.W.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at the Volcano Observatory, NE rim of Kilauea Crater; and at Halemaumau, the algebraic sum of radial tilts for two* clinoscope locations towards or away from the center of the Pit.

At the Observatory the total accumulated tilt for the year ending October 27, was 1.12″ S and 1.25″ E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit Resultant
October 6	1.87″ N 32° E	14.75″ N 27° W	41.80″ N 8° W	27.69″ toward
October 13	0.9″ S 77° E	3.28″ S 79° W	8.42″ N 19° E	1.42″ toward
October 20	0.17″ S 44° E	6.57″ S 27° W	4.21″ S 39° W	4.56″ from
October 27	0.64″ S 82° E	2.98″ N 59° W	2.43″ S 51° E	4.80″ from

* N Clinoscope dismantled September 30. Discontinued until changes made in design. H.H.W.

THE VOLCANO LETTER

No. 429—Monthly, Department of the Interior, National Park Service, November, 1935

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaii Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR NOVEMBER, 1935

Including weekly press reports 1241 to 1245
October 27 to December 1, 1935 Midnight

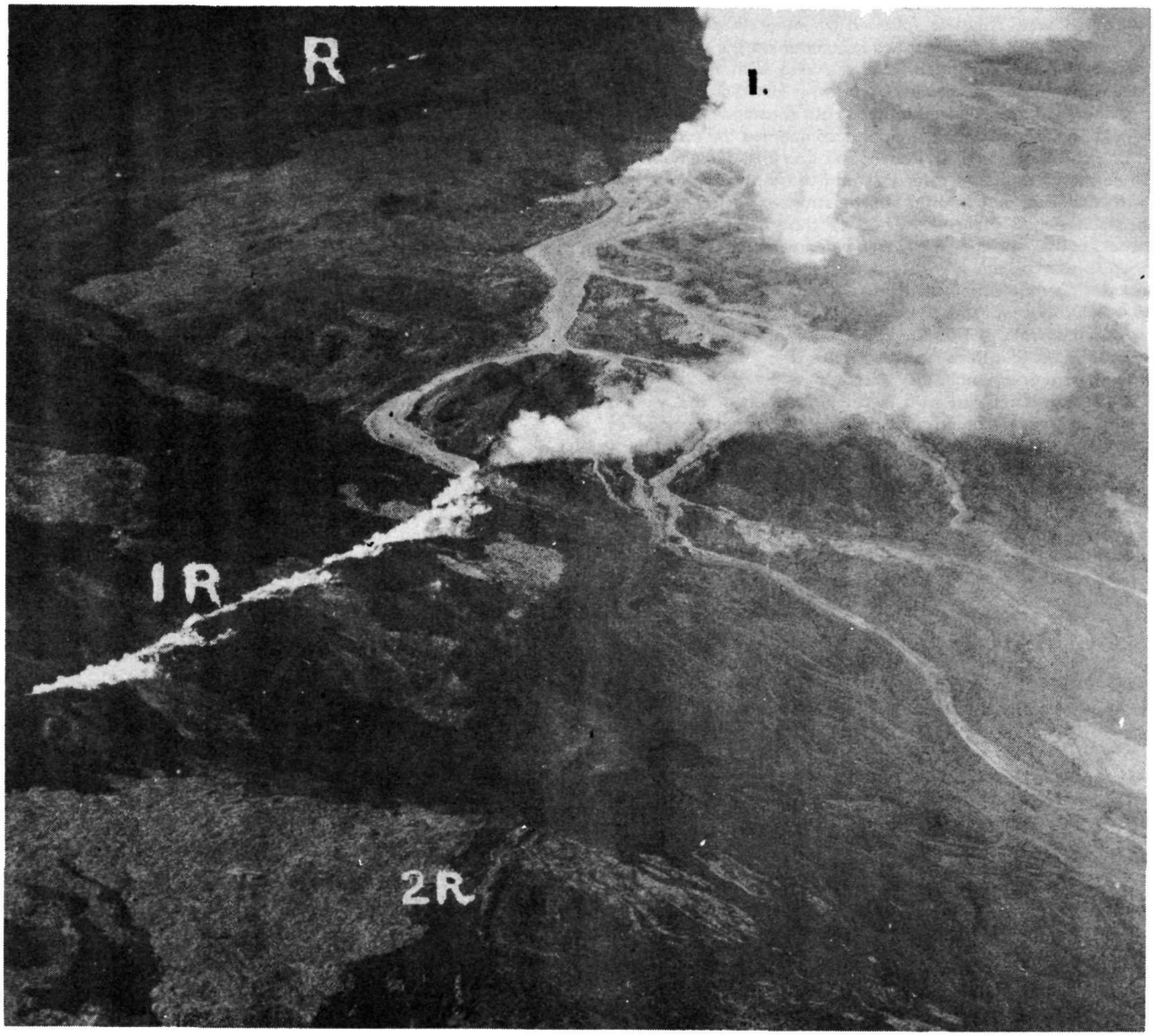


FIGURE 1. Airplane view November 22, 1935. Mauna Loa looking south. Showing northeast rift R; new rift fountaining and sending lava streams of aa north; (1) is a fountain; (1R) is the steaming lower end of new rift. (2R) is branch rift receiving a cascade of lava at a smoking pit below and to the right of (1). Probably (2R) developed into the flow outlet 2, Figure 6, about November 27.—By permission Fleet Air Base, Pearl Harbor, U.S. Navy.

VOLCANOLOGY

There were three reasons for expecting in 1935, an outbreak from Kilauea or Mauna Loa; and the preponderant evidence of recent years indicated it was likely to be Mauna Loa. The first is that the average interval between Hawaiian eruptions since 1924 has been 1.26 years, and the last oubreak was in 1933. The second is that the average cycle is 11 years, and the last cycle culminated in 1924. The third is that Mauna Loa had a summit crater eruption in 1933, which pointed to a coming lava flow on the north side in about two years.* Therefore it was not unexpected that Mauna Loa lava erupted from a north rift on November 21.

*The Coming Lava Flow, by T. A. Jaggar, March, 1934, Honolulu. (Published by Hawaiian Volc. Res. Ass'n.)

The Observatory headquarters at Kilauea had shown exceptional Mauna Loa earthquakes October 1, with an echo of Kilauea earthquakes, October 15. The month of November showed about 50 local seismic disturbances per week for the first three weeks. Then an earthquake strongly felt occurred at 1:11 am November 21 under the NE rift of Mauna Loa, slightly felt even in Honolulu. This was followed by minor shocks, and another group of minor earthquakes accompanied the Mauna Loa outbreak at 6:20 pm the same day. Along with this, tremors appeared which became continuous, but this lasted only two days; thereafter, the tremors were numerous but spasmodic. It is probable the period of continuous tremor accompanied the continuous rush of gas fountaining at the Mauna Loa rift. Halemaumau, the inner pit of Kilauea Crater showed little that was sympathetic with the Mauna Loa outburst. The stronger earthquakes dislodged slides, and there was evidence that the fumaroles became less active, and that the Kilauea steam cracks showed lower temperatures. The crack measurements around the pit showed more opening than usual, but this is a common effect of earthquake disturbance.

Fresh filaments of basaltic spun glass, or Pele's hair, from the Mauna Loa fountains nineteen miles away, fell all over Kilauea Crater on November 22.

In general, it may be said that the location of the Mauna Loa outbreak was indicated seismometrically by the earthquakes of October 1, and November 21; that the approach to the outbreak was forecast by the seismic conditions within these two intervals of 51 days and of 19 hours; and that the larger earthquake of the first group indicated a depth of seventeen and a half miles, while that of the day of the outbreak showed a depth of five miles or less, this difference implying a splitting movement from below upward, which the seismological travel-time data located at the point of outbreak.

Kilauea Observations

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows:—

October 31, dust on NE floor, and gravel slipping from NE wall, 9:00 am.
November 1, rocks fall at NE and W scars, 8:38 am.
November 2, slides at NW wall, 10:45 am.
November 4, noisy slide at E wall, introduced by a small one, 10:00 am.
November 8, NE slide sent up dust, 2:20 pm.
November 16, small rock fall at NE talus, 9:30 am.
November 20, new scar of slide 150 feet below NW edge.
November 21, rocks dribbling down W wall, and N wall showing disturbance owing to earthquake of 1:11 am, observed 10:00 am.
November 22, rocks dribbling N wall 9:54 am.
November 22, noisy slide falling from point 200 feet below SE edge, 2:15 pm.
November 23, dust from slide at N wall, and trickles of debris moving down N talus, 10:00 am.
November 24, rocks dribbling continuously W wall, and small slide there 9:25 am.
November 24, slide W wall, 9:55 am.
November 25, slide making dense dust cloud, W wall 10:55 am.
November 27, slide made dust, 8:40 am.
November 28, two slides made dust clouds W, 1:35 pm.
November 30, slide W, 10:36 am.
November 30, noisy slide with thick dust NW, 11:09 am.

Halemaumau Solfataras

Observations of the sulphurous fumaroles around the edges of the Halemaumau floor, and of the vapor cracks, have been as follows:—

November 16, heavy fume at sulphurous spot E, in rainy weather, 9:30 am.
November 17, after heavy rain, vapor at all the solfataras, at other places on floor and walls, and at N side of 1934 lava lake basin. Cumulus over W side of Halemaumau, due to heat convection or nucleation from sulphur fume.
November 18, no fume detected, an unusual condition; some vapor places, 9:00 am.
November 23, no fume visible, 10:00 am.
November 23, faint puff of fume started at Yellow Solfatara NW, 10:57 am, and became normal 11:30 am.
November 25 to December 1, fume NW solfatara very slight.

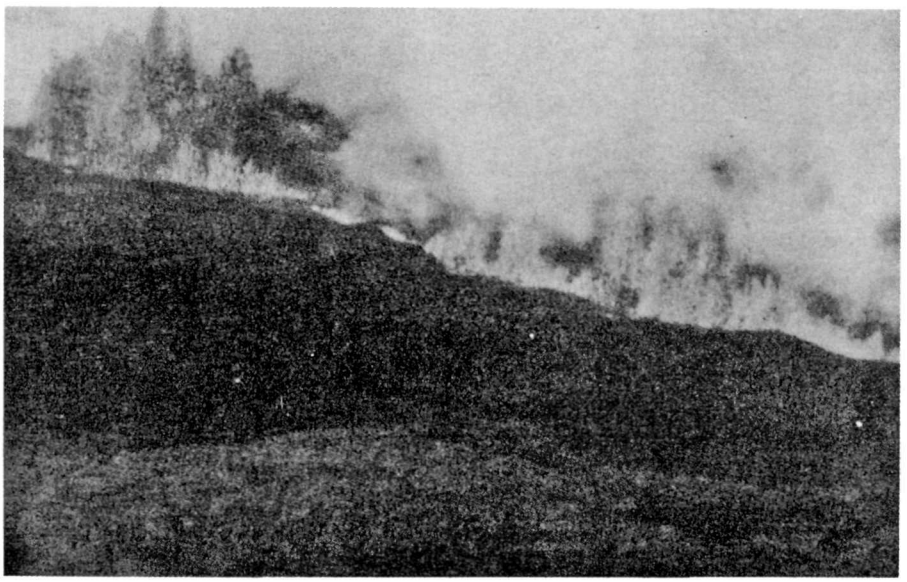


FIGURE 2. Rift fountains in sheets. Maximum 500 feet high. November 22, looking southwest, 2 pm., elevation 12,000 feet, airplane view. After 19 hours of eruption, northeast rift of Mauna Loa. Liquidity high, continuous scarlet froth jets.—By permission 11th Photo. Section, U.S. Army.



FIGURE 3. Lowest series source fountains northeast rift, 250 feet away, 150 feet high. Mauna Kea in background. November 23, 1:30 pm. Liquidity dwindling after 43 hours of eruption. Cones building, fountain jets spasmodic. —Photo by Wingate.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

Week ending forenoon of

Nov. 2,	12 opened,	1 closed,	aggregate opening,	8.0 mm
Nov. 9,	9 opened,	5 closed,	aggregate opening,	3.5 mm
Nov. 16,	7 opened,	6 closed,	aggregate opening,	2.0 mm
Nov. 23,	20 opened,	1 closed,	aggregate opening,	20.0 mm
Nov. 30,	15 opened,	3 closed,	aggregate opening,	11.5 mm

The unusual opening of cracks noted November 23, followed the numerous unusual earthquakes of November 21, occasioned by the Mauna Loa eruption, which produced swaying disturbance of upright slices of the Halemaumau rim. This caused rocks to settle in the cracks, and so is different from gradual warping movement. —T. A. J.

Crater Angles and Levelling

Measurement with precision transit from the Observatory on NE rim of Kilauea across the crater between the SE and NW trig stations, on the edge of Kilauea Crater, showed a closing of 0.8" between October 30, and November 8. This angle measured again comparing November 8 with November 21 showed a closing of 3.3". Measured again, comparing November 21 with December 9, the angle opened by 2.4".

Measuring from the Observatory across Halemaumau pit from its SE rim station, to its NW rim station, showed similar changes. This angle closed 1.3" between October 30 and November 8. It closed 1.2" between November 8 and November 21. It opened 1.4" November 21 to December 9.

Spirit levelling, using Spit B.M. on the southern rim region of Kilauea Crater as a base, showed the NW station B.M. on the rim of Halemaumau to have been relatively stationary, comparing October 18 to November 26. This last date was the fifth day of the Mauna Loa eruption. —H. H. W.

MAUNA LOA OBSERVATIONS

Earthquakes

A moderate earthquake at 1:11 a.m. November 21 was felt generally from Hawaii to Honolulu, and strongly at Kapapala on the east side of Mauna Loa. Seismographic evidence located the origin less than five miles deep under the NE rift of Mauna Loa about 5 miles from Mokuaweoweo Crater. A felt earthquake of less intensity, followed by feeble ones, and tremors, occurred at 6:35 p.m. November 21, marking the visible beginning of a lava eruption on the NW side of this rift.

Rift Gushing

Light, gas-charged foaming incandescent lava opened cracks, extending from the north bay of Mokuaweoweo, where a pool of lava collected, to an old red cone 4 miles from Mokuaweoweo at elevation 11,453 feet above sea level. This line of cracking is on the NW side of the Mokuaweoweo Trail, which was invaded by the spill of the new lava only at one or two places along the upper stretches, relatively close to the summit crater. The upper two miles of the spurting cracks quickly became sealed the first night of the eruption leaving a line of small conelets, and small flows of pahoehoe lava. The next two miles NE by E became a place of large fountains, playing up in sheets along the crack, and sending floods of lava, pahoehoe above turning into aa below, down the Mauna Loa slope, in a direction nearly north towards Puu Koli.

These floods originated all along the two miles of opened crack, made braided streams, which distributed about islands of old lava on the slope to the north, changed from the smooth glassy pahoehoe to rough aa a mile or so from the vents, and united below into two main elongate torrents. Approximately the east flow travelled about 8 miles, and the west one about 7 miles in the course of the next two days, but their exact locations will not be known until this wild area of very rough ancient lavas is surveyed. The west flow went well below the treeline, as seen from airplanes the forenoon of February 22. Roughly the eastern flow was towards Mauna Kea and the western one was towards Kohala (Figure 9).

There were seven principal vents that made lava jets along the rift, each jet surmounted by gushing sulphurous fume that rose into the upper atmosphere, ginger brown in transmitted light, milky bluish in reflected light. The streamers made high cirrus, which lingered all day in the upper air. The drift of the upper wind the first day strewed Pele's hair over Kilauea. The first night there were high clouds, the glow was brilliant, and was seen from many NW localities, all the way to Honolulu.

Inspection 9:30 to 11:00 a.m. November 22 by airplane, was made by Mr. Jaggar and Mr. Waesche, flying at 11,500 feet elevation over the new flows and along the SE side of the belt of rift fountains. The field of activity was photographed from the air by Army and Navy photographers (Figures 1 & 2). Five main ribbons of liquid lava flowed in rather straight streams from the two miles of open rift, and these diverged from a wide river of lava that poured along the rift northeastward. This river divided around the old red cone, the northern branch pouring away down the slope, the southern one, after half encircling the cone, cascading into a newly opened crack on the NE side of the cone which was an extension of the rift. Beyond this point to the NE the crack was marked by many jets of white steam for perhaps a half-mile.

About a half mile west of this red cone (11,453 feet) there are some old cinder heaps on the map, and a profound pit. A branch of the rift river flowed northward about 2,000 feet to this pit and made a large cascade into it, disappearing into the depths of the mountain. Very hot fume puffed up from the pit where the bright orange melt disappeared into the void, and there was a similar gush of fume at the other cascade, by the cone.

The biggest fountains, guided by the upright planes of the gaping rift, squirted up as sheets, very narrow NE-SW, semicircular and scalloped in plan and profile, as seen from the SE. They shot up 200 to 300 feet, in about 10 main jets of scarlet molten slag, for a length of several thousand feet along the crack between elevation 11,600 feet and 11,900 feet. This region produced the effect of a flat, scalloped wall of fire with the jets continuous, like the squirting of water from a hose, (Figure 2). The detail of the rift that had opened at the base of the fountains

indicated a wall, higher on the SE side of the crack than on the NW side, where the torrents poured away down the mountain slope. Great quantities of fume rose from the fountains and the crack, and the splitting of the mountain was not confined to a single crack. With the wind blowing from the eastward, the sharp definition of the larger crack that gave vent to the fountains was very marked, the wall in plan taking the form of a series of cusps between the fountains, and of crescent bays where each larger fountain group stood. On the SE side of the line there was almost no outlying breakage or steaming. On the NW side, however, the new fractures forked in places, and the photographs show that an important secondary rift extended to the NE from the big cascade pit, with a tendency to curve northward, farther down the mountain. This crack distinctly diverges from the steam crack below the red cone. It seems likely that this fissure leads toward the lower flow vent, that later became important, (Figure 1).

The intensity of the fountaining along the open part of the crack was greatest at the NE when seen the forenoon of November 22, but angular measurement had indicated the brightest fountains farther SW the previous night. Toward the end of fountaining about November 28, the vent on the rift which persisted longest was at the SW end of the active belt, at about the 12,000 foot contour. This was destined to become a smoke hole over a concealed lava pit beneath, that acted as reservoir, within the mountain, for the Humuula lava flow of December. The increasing viscosity of the fountaining lava was very marked November 23-24, (Figures 3-4).

Upper Rift Lava Flows

The lava flows of the upper rift during the week from November 21 to November 25 were so rapidly and violently stirred into crystallization, at first, that the lava turned to aa clinker a short distance from the rift. The fountains as usual built up enclosing cones of spatter, and from breaches in the cones, pahoehoe flows poured in places along the rift belt on the SE side. The earlier photographs of November 22 show the torrents on the NW with dark clinker on each side, and with the peculiar surface pattern, of a dark line of lagging crusts up the middle of each stream; and more rapid flow along the bright glowing overhang of the stream margins. The result is a pattern of bright line crescents with the horns pointed downstream. This is exactly the opposite of the pahoehoe stream pattern, where in plan the horseshoe toe of the festoons points downstream, and the greatest drag, or restraint of the surface skin, is at the stream margin.

The fume column above the fountains was more than 5,000 feet high and above this stood a mushroom of rain cumulus. Along the crack uphill were fiery fuming vents of declining fountains, remnant from the first outbreak. Probably the first of these was the vent in the NW corner of the north bay of Mokuaweoweo. It is of interest to note that this eruption, breaking out in that bay, continued the splitting of the mountain northeastward, from where the crater outbreak left off, in December 1933.

The pattern of the flows which developed on this mountain slope to the north, appeared like that of the earlier ones which are numerous on this declivity. The braided torrents of glowing liquid were from 30 to 50 feet wide, near their sources, and these became narrower farther down the mountain and the rapidity of their forward motion became less. The front of each flow several miles down the mountain exhibited a widening into delta-shape, with dark cherry-red stream in the middle, covered with ragged sprouts and bowlders, and the actual front a glowing wall tumbling forward very slowly. Strong heat rose from the flows, and caused the airplanes to lurch violently. The odor was the usual foundry smell. The middle ribbon of liquid lava was bright orange near the source, the flow in the stream appeared liquid and rapid, within banks of its own clinker which formed fringes and tongues, of varying widths, on either side. These border fields appeared granular with many bowlders. All the torrents united into one about two miles from the source. Below this, the flow divided into two streams with one branch headed toward Mauna Kea, and the other toward Puu Koli. It is probable that these forked above the source heap of the 1843 Flow.

During the following week the pahoehoe lava of the fountains extended itself over the aa lava of the earlier flows, and also built up heaps along the rift line, the source fountaining becoming concentrated to a single cone. Probably there was flowing under the crust of the stream along the rift, and of some of the streams down the northern slope.

Detail of Upper Rift Fountains

H. H. Waesche and S. H. Lamb obtained night views of the upper fountains along with C. K. Wentworth, November 24. Fountaining activity extended for three-quarters of a mile along the fissure, with conspicuous fountain-built cones at each end. The large lower fountain had eight active centers, throwing spatter upward 100 to 300 feet. The cone was about 750 feet long, with a lava river at its base southeast, taking its origin in other cones southwest of it; this was pahoehoe flowing rapidly within a field of aa. At the upper limit of the active belt, there were three fountaining vents, the largest a truncated cone vomiting a very fluid lava from its northeast side which fed the flow pouring along the rift. The action was violent, sometimes flinging up material 400 feet, and the cone was 200 feet across and 75 feet high. A

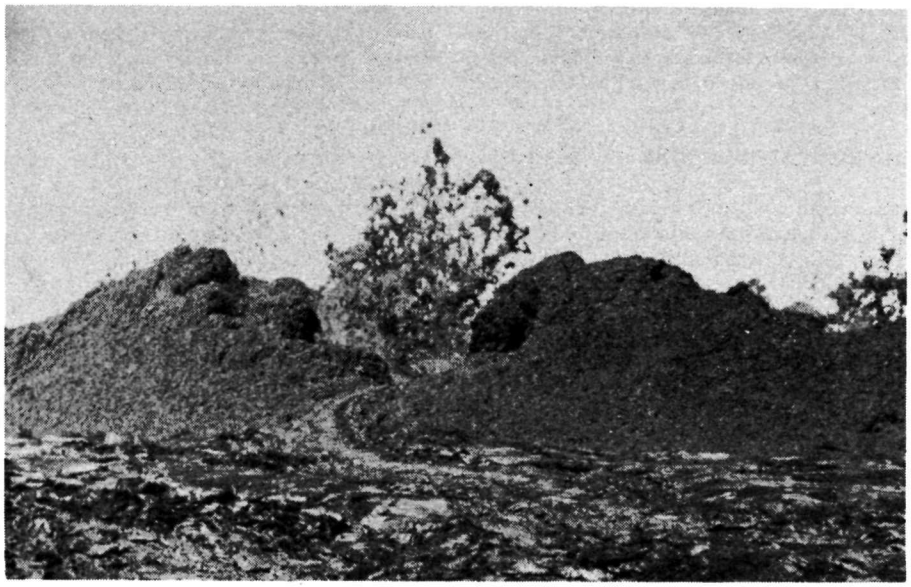


FIGURE 4. Detail of northeast rift fountains November 24, 7 am., showing overflow of pahoehoe lava from the cones. Liquidity low, viscous heavy slag after 60 hours of eruption. Looking northwest.—Photo by C. W. Carlsmith.



FIGURE 5. Mauna Loa from the north at Humuula evening November 24. To be compared with Figure 6. (1) is the rift fountain area, and long aa flows to the right. (2) later developed a flow source elevation about 9,000 feet. (3) was the flow front November 29. The glow spot between 2 and 3 lights a cloud behind Huluhulu hill. Its meaning is not clear.
—Photo by Hilo Photo Supply.

vent 75 feet NNE of this one emitted gas burning with a blue flame, occasionally jetting up in blasts with yellowish flames, at intervals of from three to five minutes. Seventy-five feet farther NE a spatter cone flung out filaments and gushes of viscous lava, building up the cone rapidly to the size of the larger ones within three hours. There were many vents farther NE flinging out incandescent cinders and showing blue flames or gas blasts. One large vent erupted with a roar at intervals of twenty minutes. Along the course of the flow there was a lava cascade. Crust on the flow would lift like a trap-door and emit rapidly cooling aa. The noise of the fountains was like surf on a rocky coast-line, and the gas vents made prolonged coughing exhausts. This entire history closely resembles that of the 1919 fountains. (See Bulletin Hawaiian Volcano Observatory, October, 1919, pages 131 and 155).

Development of Humuula Flow

As is usual with Mauna Loa outbreaks, the chief characteristic of the first week at the line of fountains, impelled up through the rift by gas-effervescence, was the rapid decline of heat and gas pressure, and the concentration of all activity to one vent (Figures 2, 3, 4). Apparently the rift opened quietly on the west side of the Dewey Crater of 1899, and a flow more than a mile long was reported there the morning of November 24. Then on November 27 there came the report of a light-colored flow originating at elevation 9,000 feet, at a fuming channel in the north side of the mountain midway between the 1899 Flow and the 1843 Flow. The area of this slope of the mountain is vast, and what really happened is obscure. Certain it is that *a flow appeared, with a line of smoke at its source, about elevation* 8,500 feet, Longitude 155°, 29.5′ west, Latitude 19°, 35.5′ north. Seen from the air, this place had two north-flowing pahoehoe lava channels emerging directly from under the skirt of an old flow. The larger channel had sulphur-stained fume vents along its bank, and inspection at night from Humuula sheep station, 8 miles away, showed bright spots here suggesting small standing fountains. The pahoehoe poured down these channels, spread out and changed into delta-shaped aa fronts, and as the flow progressed, these tended to force each new front farther westward than its predecessor.

The net effect of this, between November 27 and mid-December, was to make great fields of aa lava widening from above downward in the direction of Humuula station, and gradually overlapping the lava flow of 1843, the source being above elevation 8,500 feet, and the wide-spread frontal region in the vicinity of the 6,800 foot contour.

Decline of Upper Rift Fountains

H. S. Palmer and W. O. Clark spent the night November 27-28 at the rift cone, elevation 12,000 feet. There were three most active vents, behind a rampart 500 feet long and about 100 feet high, the NE one being the most energetic, and discharging great quantities of gas-carrying incandescent clots up into the air. The biggest of these were six inches across, sometimes falling outside the rampart and rolling down. Spindle and ribbon bombs were flung up, and others shaped like a dumbbell. The bombs generally followed parabolic trajectories but sometimes they took irregular, wavy paths. At the east end of the heap stood a beehive cone 50 feet high, surmounted by a glowing hole 25 feet in diameter, which discharged tremendous clouds of fume, believed to be steam and sulphur dioxide. The general level of activity was fairly constant with some increasing force about once an hour. There were pulsatory discharges at intervals of from one to five seconds with surf-like noise. The odor was of sulphur-dioxide when the gas came toward the observers, and there were some light drizzles.

This clotted activity reduced to a single vent, with the new pahoehoe lava flow stationary but hot, adjacent to the active cone, was succeeded on November 28 by a sinking away of the fountains so that the surf-like noise was replaced by explosive detonations at intervals, this process flinging out lava spatter and bombs. No glow or flinging out of material was seen at the upper rift source after December 1, but the fume continued to rise there charged with much white vapor. It was evident from the lowering of the lava in this craterlet, and from the explosions during the closing phases of its activities, that the rift underneath communicated directly with the 9,000 foot source of the Humuula flow farther down the mountain; and it did not seem likely that that source was a tunnel leading from the upper cone through new surface flows, as no glow whatever remained in the upper region. This makes it probable that the rift makes a long bend for six miles NE, and then north, under the shell of old lavas, and opens at the lower locality to give rise to the flow. The lower source is more than 3,000 feet below the base of the rift cone, and may be an old tunnel.

It is of interest to note that Ranger Kenneth Williams who was stationed at the upper rift and described the explosive recession of the lava in spells between November 28 and December 1, compared the action to the sinking spells of the lava in Halemaumau, described as "explosive drainages" in September and October 1934. (See Volcano Letter, of those months.)

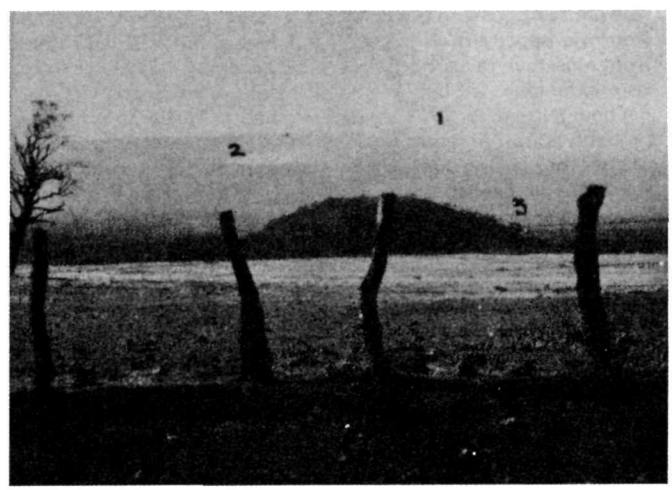


FIGURE 6. Mauna Loa looking south from Humuula, November 30, 7 am. (1) rift cones: (2) flow source: (3) flow front of aa lava. Sheep pasture and Huluhulu hill in foreground. The glow spot of Figure 5 corresponds to the middle flow region of Figure 6. The upper flows of Figure 5 had now ceased action.
—Photo by Jaggar.

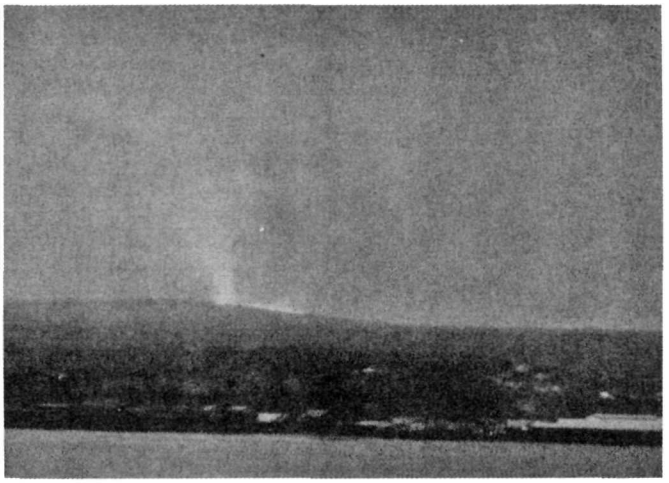


FIGURE 7. Hilo and Mauna Loa eruption, November 22, early morning light. Shows the high fume cloud, the fountains on northeast rift, and the upper flows of the first day sweeping northward. These flows stopped after five days. —Photo by Maehara.

Progress of Humuula Flow

The phases of this eruption had now been (1) Earthquakes of November 21. (2) Summit rift gushing November 21-26, producing short-lived lava flows. (3) Development of Humuula Flow, November 27-December 1, along with subsidence of upper rift lava.

From the hills east of Humuula, November 23, could be seen at night a meandering aa stream headed northwest, and joining a branch headed farther west between Puu Koli and the 1843 Flow, (Figure 5.) November 25, the west branch was visited by Naturalist Doerr, and Park Architect Sager and the live aa of 1935 was found on the west side of the 1843 Flow. The front, of the rough broken lava was 15 to 25 feet high, the end of a lobe moving only a few feet per hour, on top of ancient bushy country where falling incandescent bowlders occasionally set fire to shrubs. The main flow showed glowing areas 10 or 12 feet across. The cooler solidified rocks on top kept rolling down, to be over-ridden by the advancing paste, with a continual cracking noise. An eastern flow some miles away showed heat waves in the air rising above it. That night this east flow was dull and the extreme front of the west flow glowed. The latter came from the 12,000-foot rift.

November 28 the east or Humuula Flow developed a bright new phase of gushing at the 9,000-foot vents, and the west flow from the upper rift went out of action November 29. The new front was four miles north of Humuula on old pahoehoe lava; its middle lobe, fed by a medial stream, pushed ahead 120 feet per hour, November 29. The front as a whole was variable, making probably a half-mile per day. Sometimes the progress would increase, the glowing bank would increase in height, huge bowlders would topple over the front impelled forward on the upper surface of the delta-shaped plateau, and there was steady tinkle of falling debris down the 18-foot wall. Red hot blocks fell out with a musical ringing noise. The pasty swelling forward of the mass was distinctly visible. The behavior was like a caterpillar tractor. When a spell of increased thrust arrived, the front glowed more brightly, the tinkling noises were more continuous, the top of the bank piled up to heights of 20 to 25 feet, and larger fragments fell more frequently.

The flow as seen from Humuula was now like a snake in four meanders, and it had stopped to fan out at the bends. The front visited was 2,000 feet across, and a stream 50 feet wide and dark cherry-red in color occupied a canyon of its own making in the background, to spread in lobes as it fed the delta. The canyon appeared to have cascades of lava as one looked up the mountain, all the other bright places vanishing around bends in a shimmer of heat, and a dark line up the middle of the river marked the characteristic choked zone of rafts and crusts, which come tumbling along on the surface of aa liquid, and occasionally hit bottom.

The front of the flow produced flames, and smoke of the burning sparse vegetation; there were very large bowlders of lava on top of the delta plateau, sometimes 10 feet across and made of pahoehoe lava, where the stream had brought down rafts and thrust them into the lobes. The brightness of glow at the front was a direct measure of the activity of motion. Dust was made by the incessant flow of coarse and fine material down the frontal wall, and there were explosions in old caverns of lava under the flow, where the gases of burnt vegetation mixed up with air and ignited. Such explosions were not conspicuous outside of the front. The progress in 6 days was 0.4 mile per day.

On November 30, the aa front was widening eastward and was less bright and active than on the previous day. As one looked up Mauna Loa from Humuula, the source of the flow was seen to be at the tip of an inverted V of new lava, which meandered back and forth within the V, the swings of the meanders becoming wider towards the front (north). This V-pattern is of the same quality as that of the 1843 Flow, and of most of the flows which originate at a single vent and then widen out in a flat region below. The source of the 1935 flow showed two sulphurous smoking spots sending up a quantity of blue fume, and at night these places were very bright as though they were standing fountains of lava. In a straight line with them just below were several white steam jets, which suggested a crack, producing water vapor from its downhill extension, as in the case of the summit rift, (See figure 6). All this time the summit rift cone sent up dense fume clouds and at night the glow there was growing fainter. This was the time of the lowering lava in the shaft, and of the explosions.

—T. A. J.

EARTHQUAKES TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Moderate earthquakes	*Local Seismicity
Nov. 3	41	7	1	0	0	14.75
Nov. 10	37	4	0	0	0	11.25
Nov. 17	44	4	0	0	0	13.00
Nov. 24	3281	8	2	2	1	835.75
Dec. 1	157	5	0	0	0	41.75

*For local seismicity index see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations located at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant of these quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. All the disturbances began at the time indicated and whenever determinations were possible, the depth of focus is given.

November 1, at 6:23 pm, very feeble, located in vicinity of the S rim of the Crater of Kilauea.

November 1, at 6:34 pm, feeble, located 0.8 mile under N rim of Halemaumau. 19° 24.7′ N; 155° 17.2′ W.

November 1, at 7:40 pm, very feeble earthquakes in the same location as the one preceding.

November 7, at 5:36 am, very feeble, located 4.6 miles deep and 3.2 miles west of the Volcano Observatory. 19° 25.9′ N; 155° 18.6′ W.

November 17, at 1:52 am, very feeble, located 12 miles deep and 8 miles NW of Humuula Sheep Station. 19° 48′ N; 155° 32.5′ W.

November 18, at 3:04 pm, very feeble, located approximately under NE edge of Mokuaweoweo.

November 20, at 5:57 am, very feeble, located 4.5 miles deep and 1.8 miles W of Halemaumau. 19° 24.9′ N; 155° 18.8′ W.

November 20, at 11:52 am, very feeble. Probable location on NE rift of Mauna Loa halfway between Hilo and the summit crater, Mokuaweoweo.

November 21 at 1:11 am, a moderate earthquake was gen-

erally felt on the Island of Hawaii and was reported felt at Waikiki on the island of Oahu, and at Hana on the island of Maui. It was most strongly felt at Kapapala Ranch where the shock lasted one and a half minutes, made a noise like an explosion, knocked objects from shelves, broke one window, knocked over bottles and cause a tube of tooth paste to fall into a wash basin. In the Kilauea area, people were generally awakened, pheasants called, and in one case books were reported knocked from shelves. The seismographs at all stations were dismantled. Location in NE rift of Mauna Loa five miles SW by W from the rest house at Puu Ulaula and an equal distance NE by E from the center of Mokuaweoweo Crater. This quake was evidently caused by the opening of the NE rift in this vicinity resulting in the Mauna Loa eruption which started seventeen hours later. The depth of the quake is uncertain but is estimated to be not more than five miles and was probably less. 19° 31′ N; 155° 31.5′ W.

November 21, at 6:35 pm., there was a slight earthquake which probably marked the visible beginning of the Mauna Loa eruption. Preceding this shock, there were fourteen minutes of harmonic tremor, interrupted by a very feeble quake at 6:33 pm. Following this there were 3 more minutes of harmonic tremor. The tremor was interrupted by another slight earthquake at 6:42 pm. At 6:45 pm there was a feeble earthquake with its origin indicated as being at the NE edge of Mokuaweoweo Crater. Another feeble quake followed at 6:49 pm, located approximately 6 miles W of Puu Ulaula on Mauna Loa NE rift. A very feeble earthquake occurred at 6:58 pm. Harmonic tremor continued until midnight November 24. Tremors continued with a decreasing rate of frequency until the end of the month. The locations of these disturbances were approximately along the NE rift of Mauna Loa from the NE edge of Mokuaweoweo to a point approximately four miles SW by W from the rest house at Puu Ulaula. None of the shocks associated with the Mauna Loa outbreak was reported felt.

The harmonic tremor had a period of 0.6 second. The amplitude varied but indicated a ground movement at the Observatory of between 1 and 10 microns the first three days of the fountaining activity. Afterwards the tremors became intermittent with a decrease of both frequency and intensity.

November 24, at 2:46 pm, very feeble, 0.6 mile deep and 0.5 mile east of Tourist Stand on SE rim of Halemaumau. 19° 24.5′ N; 155° 16.6 W.

November 27, at 12:30 am, very feeble, 9.5 miles deep and 4.8 miles NW of Puu Ulaula on N slope of Mauna Loa. 19° 33.7′ N; 155° 32.0′ W.

November 27, at 6:15 pm, very feeble, located 1.1 miles deep 0.4 mile SW of Pit seismograph station. 19° 24.2′ N; 155° 17.2′ W.

November 29, at 1:48 pm, very feeble, located 0.5 mile SW of Pit seismograph. 19° 24.0′ N; 155° 20.6′ W.

No distant earthquakes were recorded.

Microseismic motion was normal, November 1, 2, 8, 11 to 13, 16 to 22, 25 to 27, 29 to December 1, inclusive. It was strong the remainder of the month except November 14, 15, 23 and 24, when it was light. —H. H. W.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope locations towards or away from the crater of the Pit.

At the Observatory the total accumulated tilt for the year ending December 1, was 1.3″ S and 3.85″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit resultant
Nov. 3	0.15″ E	1.04″ E	7.78″ N 11° E	6.22″ toward
Nov. 10	0.32″ S 41° E	5.13″ N 5° W	2.30″ S 55° E	2.12″ from
Nov. 17	0.83″ S 45° E	5.36″ N 5° W	12.96″ S 78° W	5.51″ toward
Nov. 24	1.83″ N 45° E	3.28″ N 75° W	14.90″ N 47° E	1.20″ from
Dec. 1	0.91″ N 70° E	1.88″ N 59° W	8.26″ N 30° E	1.75″ toward

H. H. W.

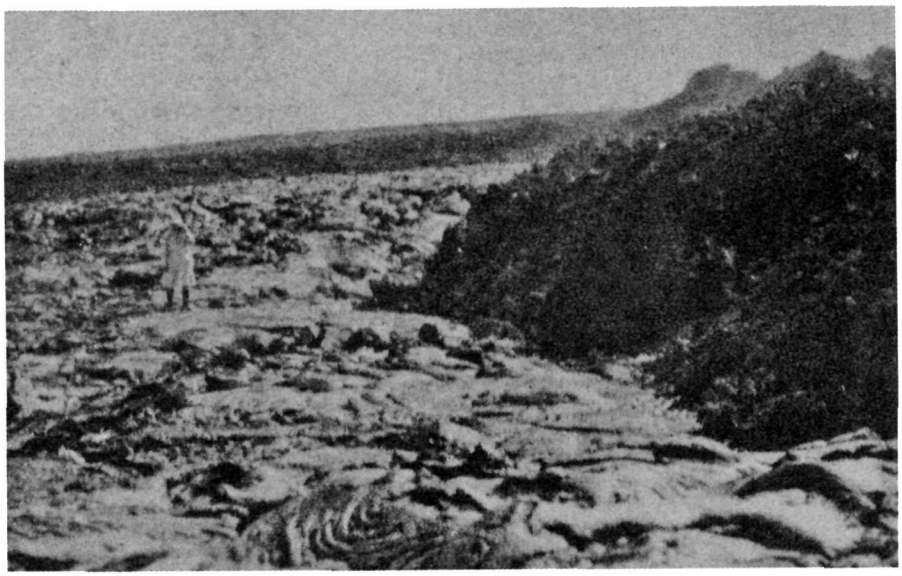
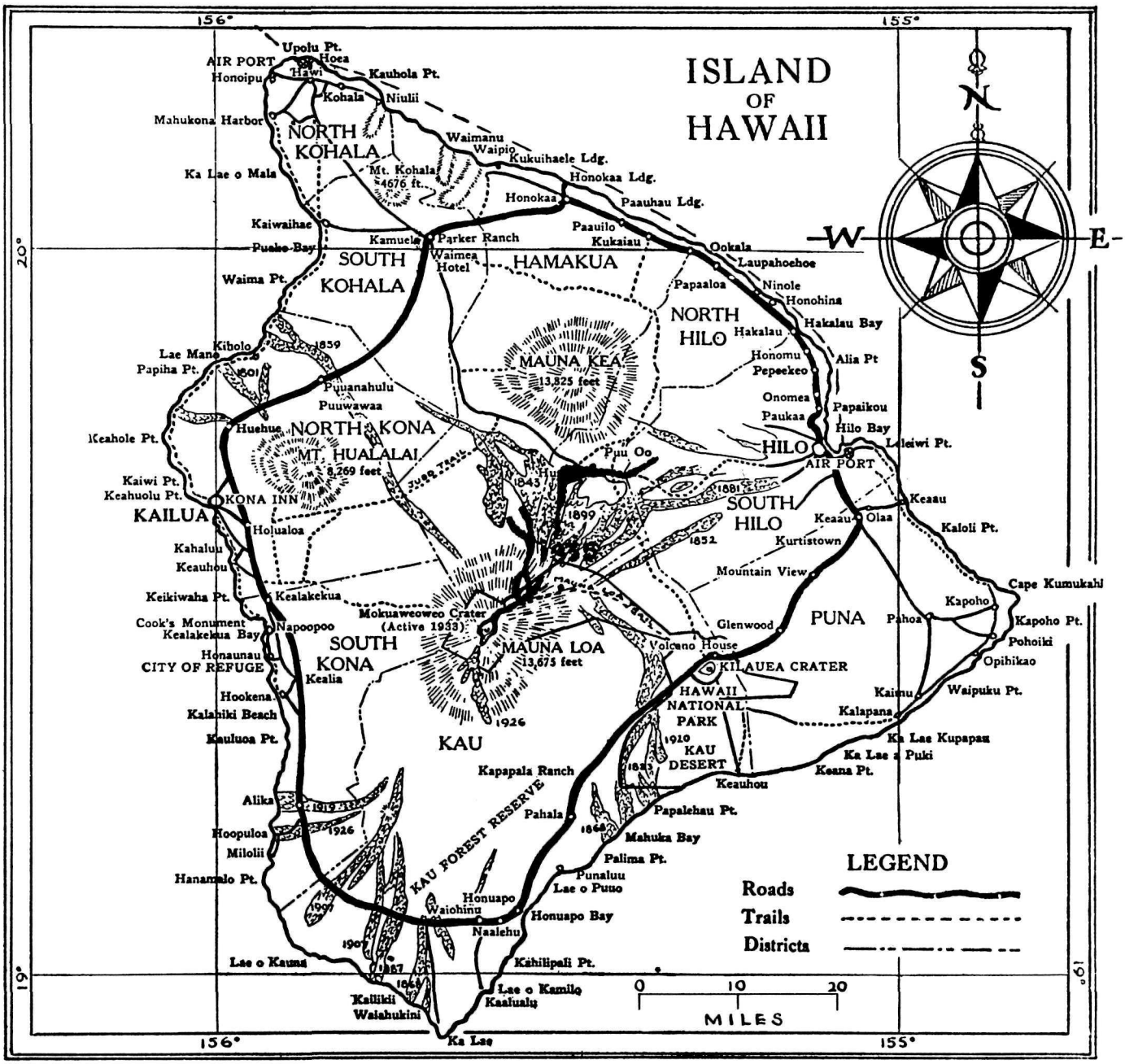


FIGURE 8. Front of glowing aa lava, 18 feet high, moving over old pahoehoe, right to left, at a rate 120 feet per hour. Looking east, 3.3 miles southwest by south from Humuula Station, 11 am., November 29. This was one of a succession of lobate fronts that moved north northwest from the 9,000-foot source, down the north slope of Mauna Loa—Photo by Jaggar.


ISLAND
OF
HAWAII
N
S
E
W
156°
155°
20°
19°
Upolu Pt.
AIR PORT
Hoea
Honoipu
Hawi
Kaubola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH KOHALA
Waimanu
Waipio
Kukuihaele Ldg.
Ka Lae o Mala
Mt. Kohala 4676 ft.
Honokaa Ldg.
Honokaa
Paauhau Ldg.
Kaiwaihae
Puako Bay
Kamuela
Parker Ranch
Waimea Hotel
SOUTH KOHALA
HAMAKUA
Paauilo
Kukaiau
Ookala
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH HILO
Hakalau
Hakalau Bay
Kibolo
1859
Lae Mane
Papiha Pt.
1801
MAUNA KEA
13,825 feet
Honomu
Pepeekeo
Alia Pt
Puuanahulu
Puuwawaa
Onomea
Paukaa
Papaikou
Hilo Bay
Keahole Pt.
Huehue
NORTH KONA
MT. HUALALAI
8,269 feet
Puu Oo
HILO
AIR PORT
Leleiwi Pt.
Kaiwi Pt.
Keahuolu Pt.
KONA INN
KAILUA
1843
1881
SOUTH HILO
Keaau
Olaa
Kaloli Pt.
1899
1852
Kurtistown
Holualoa
Kahalulu
Keauhou
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Mokuaweoweo Crater
(Active 1933)
Glenwood
PUNA
Pahoa
Kapoho Pt.
Cook's Monument
Kealakekua Bay
Napoopoo
SOUTH KONA
MAUNA LOA
13,675 feet
Volcano House
Pohoiki
Honaunau
CITY OF REFUGE
Kealia
KILAUEA CRATER
Opihikao
Hookena
HAWAII NATIONAL PARK
Kaimu
Waipuku Pt.
Kalahiki Beach
Kalapana
Kauluoa Pt.
1926
KAU
1920
KAU DESERT
Ka Lae Kupapau
Ka Lae a Puki
Kapapala Ranch
1823
Keana Pt.
Keauhou
Alika
1919
Pahala
Papalehau Pt.
1926
1868
Hoopuloa
Mahuka Bay
KAU FOREST RESERVE
Palima Pt.
Milolii
Punaluu
Hanamalo Pt.
Lae o Puuo
Honuapo
Waiohinu
Honuapo Bay
1909
Naalehu
1907
Kahilipali Pt.
Lae o Kauna
1867
1868
Lae o Kamilo
Kaalualu
Kallikii
Waiahukini
Ka Lae
LEGEND
Roads
Trails
Districts
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MILES

THE VOLCANO LETTER

No. 430—Monthly, Department of the Interior, National Park Service, December, 1935

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR DECEMBER, 1935

Including weekly press reports 1246 to 1249
December 1 to December 29, 1935 Midnight

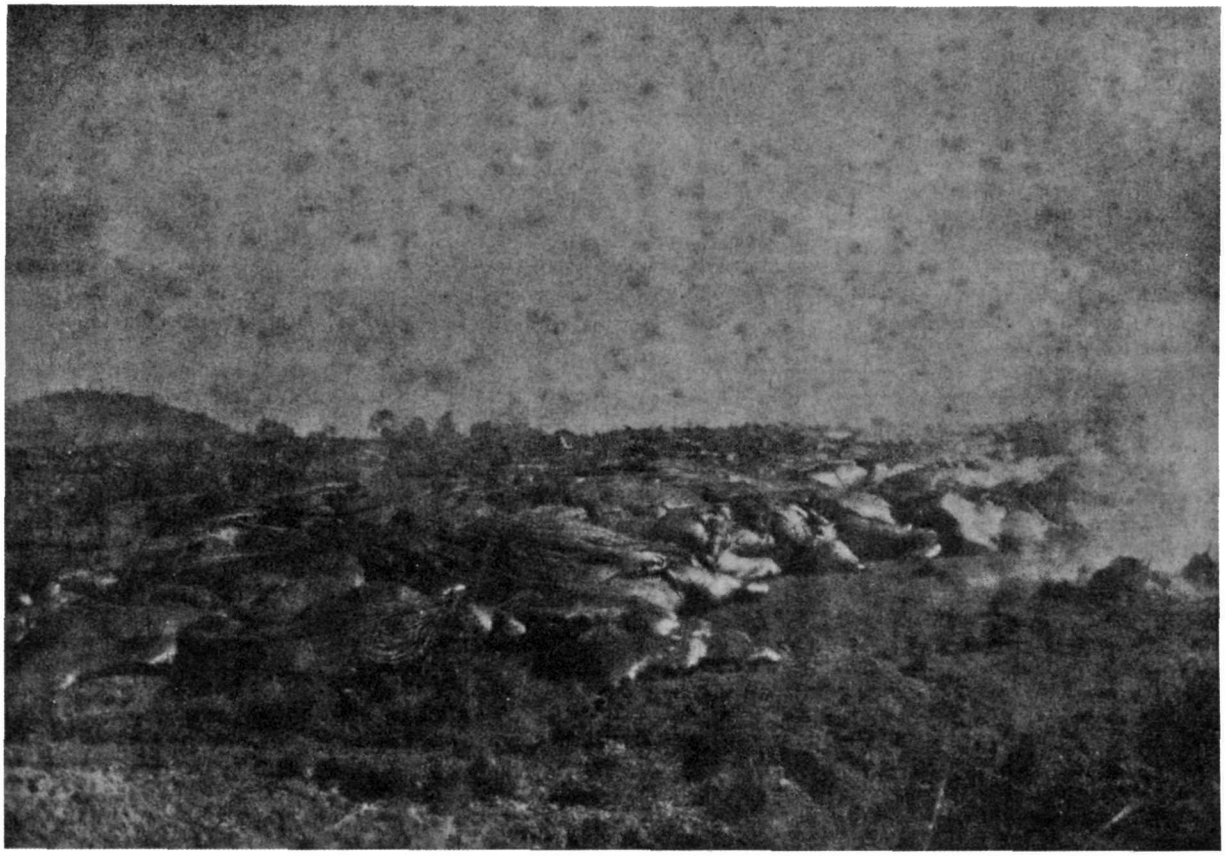


FIGURE 1. December 21. Pahoehoe flow at Humuula, advancing towards Hilo. Bronze in general color with glowing, cherry-red "toes."

VOLCANOLOGY

The release of gas, of molten lava, and of heat achieved in great quantities by the outflows of the Mauna Loa eruption in December, which continued throughout the month, reacted at Kilauea in a pronounced decrease in numbers and intensity of tremors and earthquakes. The weekly local seismicity declined from 30.50 to 4.25. This did not mean a decline in the volume of Mauna Loa outpouring, for seventy per-cent of the earthquakes located were Kilauea shocks. It appears rather to mean that a free release of thermal energy for the whole volcanic system, if continued through open vents, reduces the local seismicity. Thus we find the average weekly seismicity for October 27, for November 20, (disregarding the excessive figure for the week of outbreak, due to continuous tremor) and December 14. This tendency has been observed in other eruptions and suggests that abortive eruption or intrusion accounts for times of high seismicity.

A correspondence between the release of heat at Mauna Loa and an observed lowering of temperature at Kilauea was noted. The time when blue fume disappeared at the northwestern Yellow Solfatara in Halemaumau, November 18, three days before the Mauna Loa outbreak, was characterized by cooling of the bath steam in the Observatory ground. By December 18, sulphur fume reappeared at the pit and the vapor temperatures became hot again at the Observatory.

An observation worth recording reported by A. M. Brown of Keahou Ranch is the following:—

On July 22, 1935 at 4:30 am, along the Puu Oo trail, on the east slope of Mauna Loa about elevation 5,000 feet, between Keahou Ranch house and Keawewai Camp, in old pahoehoe lava, five persons noted hot places in the ground.

Kilauea Observations

Slides of Halemaumau

Slides from the wall of the pit have been noted as follows:—

December 5, continuous small sliding from W, NW, and N walls, 10:05 am
December 13, slides occasioned by slight earthquakes 9:31 am
December 13, dust rose from NW side at 12:49 and 12:55 pm
December 19, rocks were dribbling at E wall, 9:50 am
December 21, fresh scar observed on NE wall 10:00 am
December 22, avalanche dust arose NE, 12:55 pm
December 26, small slide E wall 9:58 am
December 26, noisy slide and dribbling of rocks at N wall, 10:03 am
December 27, small slide NE wall, 9:45 am
December 28, small slide N wall, 10:23 am

Such slides during the inspection hour indicate the average conditions.

For the last two weeks of the month, volcanic conditions at Kilauea were unusually and increasingly quiet.

Halemaumau Solfataras

Observations of the sulphurous fumaroles around the edges of the Halemaumau floor, and of the vapor cracks, have been as follows:—

December 3, almost no fume visible at NW Solfatara, fumes strong, from new sulphur spot SE, 10:20 am
December 5, fume normal at all vents, 10:05 am
December 13, new sulphur spots noticed SE 9:30 am
December 19, abundant fume in pit, apparently increasing at border crack SE 9:50 am

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

Week ending forenoon of

Dec. 7,	6 opened,	3 closed,	aggregate opening 4.0 mm
Dec. 14,	17 opened,	1 closed,	aggregate opening 14.0 mm
Dec. 21,	8 opened,	3 closed,	aggregate opening 5.5 mm
Dec. 28,	6 opened,	7 closed,	aggregate opening 1.0 mm

—T. A. J.

Crater Angles

The horizontal angle measurement from Observatory showed a closing of the angle between SE and NW rims of Kilauea Crater, 1.0" comparing December 9, to December 19, and showed no change comparing December 19 to January 9, 1936.

The same kind of measurement across Halemaumau pit from the Observatory showed a closing of 2.2" between December 9, and December 19, and an opening of 1.2" between December 19 and January 9, 1936.

HAWAIIAN VOLCANO OBSERVATORY REPORT
Week Ending December 8, 1935

The northern flow of the current Mauna Loa eruption continued its advance during the week. The front of the flow moving to the north and west has reached a point within two miles of the Humuula Sheep station. All forward motion of the main flow had apparently stopped however, by December 7. The glow from the aa river feeding the flow was reported to be quite bright on the evening of December 7, showing that fresh lava was still being fed to the stream. At several localities the channel was probably being blocked by cooling lava as small flows issued from the stream and flowed for short distances from the side of the main flow. The upper source fountains have ceased all visible activity although a glow was still noticeable at that point from the north side of the Island, December 7. No glow at that point has been visible from the Observatory this week although heavy fume columns were visible during the day until December 6. Cloudy weather has prevented observation since that date but the fume was greatly diminished when last observed.

Little or no fume was visible at the N.W. solfatara of Halemaumau December 3, at 10:20 am; at the same time the fume from the comparatively new sulphur spot at the S.E. edge of the floor of Halemaumau was rather strong. The weather was rainy and the wind was moderate from the Northeast. Fume was apparently normal from all vents in Halemaumau at 10:05 December 5. Small slides occured from the west, northwest and north walls at this same time.

116 local seismic disturbances were registered on the Observatory seismograph of which 112 were tremors, one was a feeble earthquake and three were very feeble earthquakes. The feeble earthquake occurred at 9:13 pm, December 4 and was 2.4 miles from the Observatory probably under Halemaumau. It was reported felt at the C.C.C. Camp. The very feeble earthquakes were, December 2, at 7:55 am at a distance of 17.8 miles; December 3, at 6:30 am at a distance of 19.4 miles; and December 7, at 12:31 am at a distance of 2.4 miles. Those of December 2 and 3 were probably associated with the Mauna Loa eruption. Seismic index for the week was 30.50. Microseismic motion was normal but increased to strong on December 8. Tilting of the ground at the Observatory was slight S by E.

Measurement for the week of 32 crack localities around Halemaumau, December 7, showed that 6 had opened and 3 had closed for a resulting aggregate of 4.0 millimeters opening.

One hundred and sixteen local seismic disturbances were recorded at the Volcano Observatory during the week.

At 9:13 pm, December 4, a feeble earthquake was registered. The shock was apparently centered 2.4 from the Observatory under Halemaumau. The Pit seismograph was dismantled and the quake was reported felt at the C.C.C. Camp.

The following very feeble earthquakes registered.

December 2, at 7:55 am, at a distance of 17.8 miles
" 3, at 6:30 am, " " " " 19.4 "
" 7, at 12:31 am, " " " " 2.4 "

A total of 112 tremors were recorded for the week.

Seismic indices (0 to 12 miles: :1.50) (0 to 66 miles: : 1.00) Weekly 30.50.

Tilt—Dec.	2	61	184	M
"	3	62	185	M
"	4	62	182	M
"	5	62	182	M
"	6	65	180	M
"	7	68	174	M
"	8	64	168	St

63	179	63	179
59	178	-17	000

4 S 1 E Slight S by E tilt 46 179 To compare with next week.

Of 32 crack points measured December 7, 6 opened, 3 closed for an aggregate opening of 4.0 millimeters.

HAWAIIAN VOLCANO OBSERVATORY REPORT
Week Ending December 15, 1935

The Mauna Loa eruption continued, with the front of the flow changing to pahoehoe, or glassy liquid lava, a half mile from the cones immediately west of Humuula. The pahoehoe has come down the lava channel overriding the aa fields. December 9 the aa front was three quarters of a mile from the foot of Mauna Kea and at 8 p.m. the pahoehoe began spilling out the west side of the front. The upper lava rivers were voluminous and

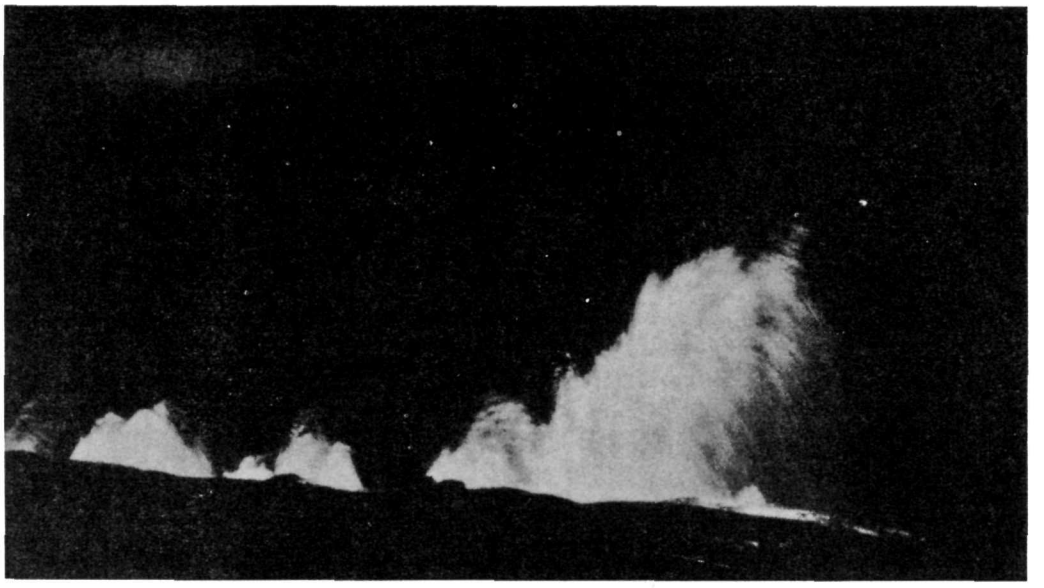


FIGURE 2. November 23, 7:00 p.m. Great fountains over rift-line. Right-hand fountain is approximately 400 feet high. —Photo by Wingate.

brilliant. The rift cones smoked, and the 9000-foot source made a line of smoke holes. December 10 the front slowed, but above there was dusty aa in motion. December 11 the front stopped. From Kilauea and Hilo there was smoke seen at the rift cones and glow above the lava flows. December 12 there was slight revival of the pahoehoe front which stopped the next day. December 14 the piling heaps of pahoehoe at the 9000-foot source appeared to make scattered flows westward. December 15 new aa fronts moving west from the heap and the big lava rivers of the middle slopes of the mountain increased in size.

Halemaumau has shown nothing of importance. A slight earthquake there December 13 at 9:30 am made some sliding. New sulphur spots were noticed southeast. Measurement December 14 of the 32 marked places on cracks around Halemaumau indicated that 17 had opened, 1 had closed, result in aggregate opening of 14 mm.

Assistant Naturalist H. H. Waesche reports 55 local seismic disturbances and one distant earthquake. The distant large earthquakes indicated origin 3780 miles away and began at 8:47 pm December 14.

A slight earthquake of 9:31 am December 13 was felt strongly at Halemaumau and a feeble shock 2:33 pm December 14 indicated origin 18 miles away from Kilauea, the distance of the Mauna Loa rift source of the present eruption. Very feeble earthquakes were registered December 10 at 6:09 am and 6:19 pm, distances 19 and 20 miles, December 11 at 1:36 pm distance 32 miles and December 13 at 9:31 am, distance 2 miles. Forty-nine tremors were recorded. Seismis index for the week was 17.25. Miscroseismic motion was strong. Tilting of the ground at the Observatory was slight NE.

Fifty-five local seismic disturbances were recorded at the Volcano Observatory during the week.

At 9:31 a.m., December 13, a slight earthquake was registered. The shock was centered under Halemaumau, 2.4 miles from the Observatory. It was felt by a few around the National Park Headquarters area and strongly by several on the rim of Halemaumau. The E.W. component of the Pit seismograph was dismantled.

A feeble earthquake registered at 2:33 pm, December 14. Its distance was 18.3 miles and was probably associated with the Mauna Loa eruption.

The following very feeble earthquakes were recorded.

December 10, at 6:09 am, at a distance of 18.9 miles
" 10, at 6:19 pm, " " " " 20.2 "
" 11, at 1:36 pm, " " " " 31.9 "
" 13, at 9:31 am, " " " " 2.4 "

There were a total of 49 tremors. The preliminary waves of a teleseism began recording at 8:47 pm, December 14. Distance 3,780 miles.

Seismic indices (0 to 12 miles: :1.50) (0 to 66 miles: : 3.50) Weekly 17.25.

Tilt—Dec.	9	47	164	St		
"	10	49	169	St		
"	11	49	175	St		
"	12	46	180	St		
"	13	41	182	St		
"	14	37	184	St		
"	15	36	186	St		
	44	177	Tilt this week		44	177
	46	179	Tilt last week		0	-13
	2N	2W	Slight NE tilt		44	164

To compare with next week.

Of 32 crack points measured December 14, 17 opened, 1 closed for an aggregate opening of 14 millimeters.

HAWAIIAN VOLCANO OBSERVATORY REPORT
Week Ending December 22, 1935

The Mauna Loa lava flow bent eastward toward Hilo December 22, creating a crisis. December 16 the brown fume arose densely at the rift sources, and glow of the pahoehoe streams was visible at Hilo and at Kilauea. These streams December 17 revived the front opposite Humuula. December 19 this pahoehoe lava moved northeast 1800 feet, and spread out in a sheet east of the 1843 flow, one-half mile south of the stone wall extending west from Puu Huluhulu at Humuula.

December 20, just on the solstice, with a spurt forward, the liquid overflowed the wall for one-half mile, fronting Puu Huluhulu within one-quarter mile. December 21 the forest and grass lands were burning on the flat south of Humuula sheep station. December 22 the pahoehoe lava passed Puu Huluhulu, between that hill and Mauna Kea, flowed eastward more than a mile, with a front 200 feet wide, and tended by reason of slope and stirring to change to aa lava. The progress had been one-quarter mile per day; it suddenly changed to one mile or more a day, draining the large lake which had accummulated in the saddle between Mauna Loa and Mauna Kea. The source heaps on the north flank of Mauna Loa were now brilliant with a meandering pahoehoe stream of liquid fiery lava, and soon the lava field closed around the Huluhulu hill, and sent a second stream on its south

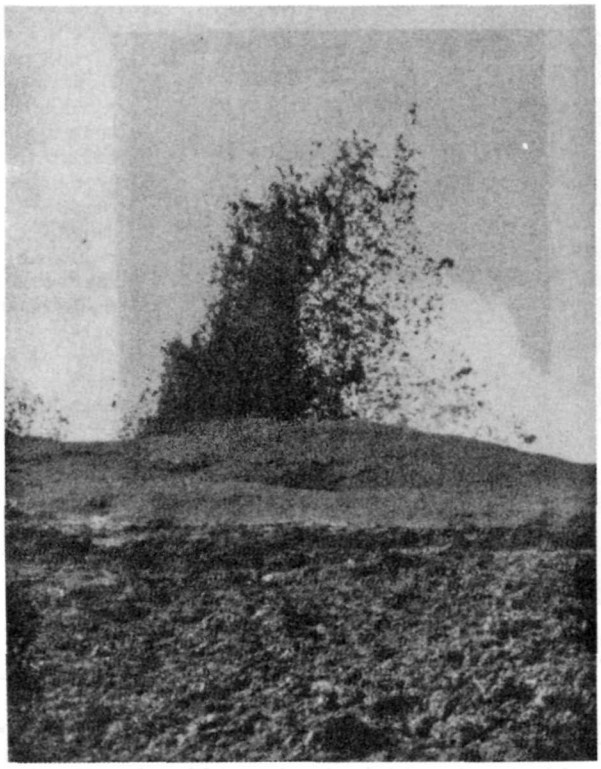


FIGURE 3. November 23, 2:00 p.m. 250-foot fountain over vent in lowest series. —Photo by Wingate.

side to join the main east-flowing river of slag. The flow-source about 9000 feet elevation, exhibits, from the air, a channel 40 feet wide emerging from under dead flows above, with smoking grottoes or vents, and silvery splashes of distributary pahoehoe make a widening feather-pattern down the mountain north, into which the glowing river disappears under gleaming crust. This flow source led into the rift belt southward, toward Mokuaweoweo at 13,000 feet where the eruption began on November 21. At elevation 11,000 to 12,000 feet, the 1935 cones and chasms of the rift belt sent up brown fumes in seven columns, densest at the big new cone. The cone lies at the southern end of the active cracks, which form a zone 3 miles long.

The eruption thus has three centers: The main summit crater shaft, the secondary smoke shaft within which the lava has lowered and the flow vent which siphons the liquid out at a single point. The liquid crusts and pours in tunnels down the mountain under its crust, distributing to numerous fronts. It is necessary to keep the upper smoke shaft and the lava vent separately in mind—they are six miles apart—in order to understand future developments.

At Halemaumau pit of Kilauea volcano trivial slides were observed December 21 and December 22. The reduction of blue fume at the Yellow Solfatara noted November 18 just before the Mauna Loa outbreak, was accompanied by cooling of the bath steam in the Observatory grounds. Both visible sulphur fume at the pit and steam temperatures at the Observatory, had returned to normal December 18.

Measurement of 32 marked crack localities, around Halemaumau pit, for the week ending December 21, showed that 8 opened and 3 closed, making aggregate opening of 5.5 mm.

The seismographs show approximately 31 disturbances, of which 29 were very feeble shocks and tremors. Feeble earthquakes occurred about 12:54 pm December 17, and 5:23 am December 20. Formal seismometric report will be made in January.

HAWAIIAN VOLCANO OBSERVATORY REPORT
Week Ending December 29, 1935

The Mauna Loa eruption continued to eject dense vapor and fume from the sulphur-stained rift cone at elevation 1,200 feet. December 23, the lava flow was 2 miles east of Humuula, about 200 feet wide, changing from pahoehoe lava to aa lava The stone wall drowned under a lake of lava, south of Humuula, tended to reappear as the lake level sank. Explosions were common in old cavities along the lava fronts. This had occurred from the time vegetation made carbon monoxide gas, and the liquid lava penetrated cracks and pockets under the soil, where mixtures of gas and air were ignited. In some places hundreds of feet from the lava front, bluish flaming gases of charred grass roots, shot up through sandy hollows. The explosions disrupted old rock surfaces, and made cannon-like detonations. December 24, smoke and glow at the saddle between Mauna Loa and Mauna Kea were plainly visible from Hilo. The aa flowed more slowly. December 25, a tongue of the front reached Puu Oo ranch, reaching the wall at 11 am; it had been wholly within the Parker Ranch. December 26, the front increased its speed locally to 800 feet per hour. The average progress was one mile per day on a grade 157 feet to the mile, steeper to the east. At this rate, the flow would have been in the Kaumana road of Hilo on January 9. The widest parts of the flow reached a breadth of 2000 feet, where there was a spreading out on flat places.

The volcanologist recommended bombing the source at elevation 8500 feet on Mauna Loa, to break up the stability of the flow tunnels, and to divert the flowing at the source region. This was done by U. S. Army bombing planes December 27, after the officers were shown the target, from the air. Six tons of T.N.T. explosive were detonated about the vent and channel. Fresh incandescent streaming there was seen December 28, and dusty aa flows in motion immediately below on the mountain slope were detected December 29 and later. At the front fifteen miles away down the lava stream, 33 hours after the bombing, the front stopped moving for a half-day in Puu Oo ranch. Apparently the violent release of lava, of gas and of hydrostatic pressure, at the source, robbed the lower flow of its substance, and of its heat.

At the lower front there was only side and frontal spilling of viscous channel lava thereafter. The total forward motion December 28 was approximately 1000 feet, and December 29, 500 feet. In the pooled pahoehoe lava of the divide at Humuula, fresh puddles of glistening slag welled up through cracks. The night following the bombing, the glow of the middle lava channels had been very brilliant, probably occasioned by drainage of the tunnels and over flowing of clogged canals.

At Halemaumau pit of Kilauea volcano conditions have been unusually and increasingly quiet. There were small slides at the east and north walls of the pit 9:58 am and 10:03 am December 26, at the northeast wall 9:45 am December 27, and at the north wall 10:23 am December 28, during inspections.

Measurement of the 32 rim crack localities around Halemaumau, for the week ended December 28, showed that 6 had opened and 7 had closed, resulting in aggregate opening of 1.0 mm.

H. H. Waesche, Assistant Geologist, reports as follows for the seismographs at Kilauea crater:—

For the week ending December 22, there were 21 local seismic disturbances, of which 18 were tremors, and 3 were very feeble earthquakes. The latter were at 12:13 am December 18, distance of origin 11 miles, 2:52 pm December 22, distance undetermined, and 6:35 pm December 22, distance 1.6 miles, Seismic Index was 6:00, microseismic motion was strong, and tilting of the ground at the Observatory was moderate SW by W.

For the week ending December 29, there were 17 local seismic disturbances, all tremors. At 4:31 pm December 27, a distant earthquake began recording, distance not evident. Weekly local seismic index was 4.25. Microseismic motion was strong. Tilting was moderate W by N.

JOURNAL MAUNA LOA ERUPTION DECEMBER, 1935

December 1

At 4:30 pm Mauna Loa showed three very slight puffs at rift source as seen from Observatory; Humuula reports glow of flow and aa progress still strong, but only smoke was seen at rift cone where glow has ceased. The flow was pushing its front NNW about a half-mile per day toward the 1843 pahoehoe.



FIGURE 4. December 21. Pahoehoe advancing through forest land and forming tree-molds by solidifying around the tree-trunks which are then burned away—leaving perfect casts of themselves in the rock.
—Photo by Maehara.

December 2

Strong white cauliflowers of fume rose at the rift source, and rumbling was heard there. The front of the Humuula Flow and its medial river were very bright and reported moving 150 feet per hour with the front migrating westward from its position of November 29.

December 3

At the resthouse on Puu Ulaula, elevation 10,000 feet NE side of Mauna Loa, a rushing noise could be heard underground along with rumbling in the direction of the 1935 fissure. The flow was reported to be overlapping the eastern belt of 1843 pahoehoe. It was said to be two miles nearer Humuula than on November 29. From eastern parts of the island, the bright glow had shifted from the source region to the flow region, so that from Kilauea and Hilo it stood as a broad band of light on the clouds, back of the lower northeastern Mauna Loa slope.

December 5

Two or three new lobes were moving west from the flow and the front progressed rapidly along the 1843 Flow overlapping the middle aa of that year. Seen from the air, the smoking source region of the flow, at elevation 8500 feet, appeared to be streams emerging from under the crust of an older flow.

December 6

The conspicuous feature of this day was the bright glow at night over the flow region, while the fume at the upper rift cone rose in great volume with ginger-red color and dense volutes.

December 7

The brightness of the Humuula Flow was occasioned in part by the development of floods of pahoehoe lava moving down the medial river channels of the main aa stream. When this happened, the front of the aa moving north, had spread into a wide delta about 2 miles south of the Omaokoili Hills, and its lateral spreading had checked its forward motion. It is probable that at this time side streams were making out from the source heap. The glow from the aa river was bright this evening, showing that fresh lava was still coming down, but small flows were issuing from the sides of the main aa flow. Glow was still seen occasionally at the upper rift conelet.

December 8

The source heap of the Humuula Flow was now developing pahoehoe lava veneering over its upper slopes and spreading down the big aa channel that led to the front.

December 9

The upper rift cone had now settled down to steady ejection of sulphurous fume clouds. The aa front of the Humuula Flow was three-quarters of a mile from the foot of Mauna Kea. From Humuula, the big flow was seen to be fed by a bright meandering river zig-zagging down the mountain, with its wide front west of the position of November 29, and 1.9 miles farther north. The front lay in the 1843 aa. About 8:00 pm the main feeding river began spilling pahoehoe lava at a position on the west side of the front; this was very brilliant, in contrast to the somber red of the aa river.

December 10

A visit to the front this day discovered a field of shallow slabby pahoehoe of thick porridge-like consistency, moving along the aa front eastward to within 200 yards of where that front lay on the eastern marginal strip of 1843 pahoehoe. The 1935 aa made occasional cavings along its front and showed red glow in cracks. Its wall was 20 feet high. The pahoehoe was spreading out vigorously on the 1843 aa, but it did not quite reach the eastern band of 1843 pahoehoe. Many pasty toes of lava were progressing, perhaps one-quarter mile per day as a whole, and the entire front was about one-half mile wide in an EW direction. The surface of the aa fields sloped down to where the river of pahoehoe swept in a curve from the west side of the front. This river then spread out eastward at the base of the aa wall. There was thus a narrow pahoehoe delta about 5 feet high, in front of the much higher and wider aa delta. The feeding river af pahoehoe coursed down the west side of the upper aa fields.

Looking from the summit of Puu Huluhulu at 3:00 pm the summit rift conelets of 1935 were seen to have their greatest development at the upper end where heavy fume rose in four jets. Farther to the left (NE) were three other faint vapor jets among small cones. On the mountain slope below were the floods of lava of November, with islands of old light-colored lavas amid the new dark streams. At the source of the active flow, in the direction of Pukauahi two-thirds of the way up the mountain, could be seen a line of blue smokes from separate vents trending apparently NNW, and the belt of aa streams meandered from that point, towards Humuula in three stretches, respectively, NNW, NNE, and NNW with bends between. The whole field at this time was mostly aa except for some silvery gleam of pahoehoe in the source region, and below, where a narrow band of the frontal pahoehoe made a fourth meander stretched eastward. Portions of the dull red river that occupied the main channel were visible in places where the bends of the channel made the gorge visible to an observer at the north. There were several places where aa was

in motion at tumbling fronts, which may be described as moving lobes at the meander elbows, particularly on the east side of the flow as seen from this position. These places sent up dust and also made some smoke, probably due to burning vegetation. They represented the eastern corners of successive deltas of aa which overlap in plan from SE to NW from about elevation 7,200 feet on the mountain. The second of these aa fronts made a huge wall more than 50 feet high and this was caving and making dust.

The process of the interior progress of an aa delta is exhibited by some of the vertical airplane photographs. These show wide medial streams and frontal outlines in plan like a feather to which the stream is the quill. On flat ground, these streams thicken, pile up, show transverse wrinkling and distinct marginal lobes are formed in plan, and slump terraces are developed at the front of the lobes. A large lobate feather of this kind may have a plexus of streams down the middle with wrinkled surfaces and a large number of delta lobes, like separate leaves. These recall the miniature deltas formed on low tide flats by rills. The pahoehoe pattern is altogether different, a delicate tracery like frost on a windowpane, with a tendency to overlapping "lobster claws" from uphill downward.

As a whole, it appeared that the pahoehoe was pushing its way down the mountain on the west side of the series of aa deltas. It was clear that at this time a very critical change had occurred, just as in 1843 the pahoehoe lava had come later than the aa, and poured down the mountain over the middle of it on the upper steep slope, and at the sides of the aa field below.

December 11

The new pahoehoe front of the Humuula Flow became quiet and relatively stationary. There was much river action in the upper parts of the flow and dusty aa was seen in motion. A series of panchromatic photographs was taken with color filters, of the flow, from the lower Omaokoili Hills. These pictures show how inconspicuous the pahoehoe was at this time in comparison to what it became later.

From Kilauea and Hilo smoke was seen at the rift cones and glow above the lava flow area.

An investigation of the location of the first two 1935 lava flows of November 21-24, obtained by questioning observers living at Humuula station makes it seem probable that this pair of flows lay on the west side of the present Humuula Flow. The easternmost of the two is overlapped by the western meanders of the present flow. On November 23, this eastern aa of the first pair may have come down the general line of the 1843 source well to the west of the smoking source streams of November 27-28. Numerous photographs taken from Humuula at this time suggest this arrangement. The observer at Humuula noted a very definite development at this last place on November 27 and sketched it as making new smoke where smoke had not been seen before. This new smoke was noted by both Mr. Wingate and Mr. Jaggar, on their arrival at Humuula November 28, after previous visits.

December 12

From Kilauea four fume columns appeared above the upper rift and no glow was seen at night. At Humuula there was revival of the pahoehoe front.

December 13

The glow and fume continued at the Humuula source and lava channel, the progress of the pahoehoe front was comparatively quiet, and an earthquake was felt at Kilauea.

December 14

The upper slopes along the course of the Humuula Flow showed glowing areas more scattered than before, suggesting pahoehoe flow over the western side of the heap. The pahoehoe front was glowing but not progressing. Smoke continued at both the rift source and the flow source and glow was reported but doubtful at the rift source. Another earthquake was felt, originating at the Mauna Loa sources. Seen from Kilauea, dense fume arose at the upper rift source in the afternoon.

December 15

The glowing stream of the channel of the Humuula Flow appeared bigger to observers at the ranch and the pahoehoe front was motionless. A new aa flow or branch in the middle of the flow region was reported to be moving on top of earlier aa flows in the direction of the upper 1843 aa westward from the middle stream of the Humuula Flow.

This may have meant that some of the new pahoehoe developing in the upper reaches of the flow had spilled over sideways and speeded up so as to be stirred into making aa. This would account for the lack of progress at the extreme front.

December 16

At this time, glow as seen from Kilauea appeared back of the lower part of the northern Mauna Loa profile. Wingate at Humuula reported revival of the pahoehoe front from the eastern side of the front of December 10 and progressing over the old aa between the 1843 Flow and Humuula station.

December 17

The pahoehoe front was reported to be 200 feet wide, proceeding toward the high stone wall of the sheep pasture, which extends west from Puu Huluhulu. The source of the flow was reported to be smoking, fiery, and the stream channels active. Wingate estimated the smoke source of the Humuula Flow to be at elevation 8,500 feet. From Kilauea at 5:00 pm the rift source showed a dense ginger-colored cloud rising with seven stems, a mushroom shape above and standing 2,000 feet above the rift.

December 18

On this day rangers Murray and Waesche explored the region immediately NW of Puu Ulaula resthouse for about 3 miles. From the large cone there at elevation 10,126 feet which is in line of the curved rift believed to extend northward to the flank outlet, which forms the source of the Humuula Flow, Waesche reported that the lava flows of November 21-22 were a considerable distance to the west. From that cone the smoking flank source heap of the Humuula Flow appeared very far away to the north over interminable fields of old aa. This observation is of great interest, in that it indicates the upper lava flows chose a path mostly west of the 1843 source.

One mile west of this old red cone, Waesche reports reaching the east side of an aa flow, probably 1935. From the top of it a ridge cut off his view westward. The only pahoehoe seen was up the mountain. The aa on December 19 was cold and quite accessible.

Comparing these facts with the data in the Army and Navy airplane photographs of November 22, it appears certain that the smoking source on the mountain flank, elevation 8,500 feet, of the Humuula Flow, was not in the track of the floods of lava of November 21-22 which made the two long streams in the direction of Puu Koli.

On the night of December 17-18, the glow over the Mauna Loa profile seen from the east appeared farther up the mountain than before and dense brown fume rose high in calm air from the upper rift source.

December 19

The flow was brilliant, the upper rift source fume was dense, and there was strong pahoehoe advance NE 1,800 feet over the old aa in the saddle between Mauna Loa and Mauna Kea to within a half-mile of the stone wall. The pahoehoe front was about a quarter-mile wide, spreading out in a sheet east of the 1843 Flow. The progress of the front changed for a time from spreading eastward to spreading westward. The wall of aa behind the pahoehoe and around the front of which the pahoehoe had executed an encircling movement from west to east between December 13 and December 19, was in motion, dropping rocks over its front with clinking noises. New appearance of pahoehoe lava was reported higher up the aa flow near the front of November 29 on the east side of the flow belt. A heavy pall of smoke 2 to 3 miles wide was rising in the evening at the upper rift cones. Soldiers visiting that region reported that they could not approach the cones because of irrespirable sulphur fume. The fume in the upper atmosphere made milky cirrus clouds. This intense development of sulphurous fume from the pit where the summit fountains had been, was entirely different from December 1914, and from December 1933, when the fountaining persisted at the upper vents until the end of the eruption. In 1935, the fountaining was far down inside the shaft and this concealed pit was acting as a

reservoir to the flank flow, just as Halemaumau had acted as a reservoir to the Kau Desert flow of 1920.

An unconfirmed report from one observer in Hilo mentioned two glow points seen from there at the upper rift the evening of December 18, which were called "fountains."

December 20

It was now evident that an extremely critical advance of the flow was in progress. The topographic map showed that the ground of the saddle under Humuula station slopes eastward towards Hilo. The solstice was producing sudden and rapid increase of lava pressure.

At markers placed at the front 8:00 pm December 19, the flow had moved northward 400 feet at 6:30 am December 20. On this day with a spurt forward, the liquid lava overflowed a half-mile of the stone wall, and the eastern side of the front was within one-quarter mile of Puu Huluhulu.

At 4:00 pm a visit was made to the pahoehoe front of the flow at the stone wall. The lava was pouring over it and into the hollows of old aa. It appeared to be a normal heavy pahoehoe, progressing toward the trees and grassy land at the base of Mauna Kea, and at this time approximately a third of the stone wall was being overwhelmed at elevation 6,575 feet above sea level. This stone wall extends 1.8 miles between Puu Huluhulu and the southernmost of the Omaokoili Hills. The middle and eastern portions of the wall were gradually covered. The wall was a massive structure of carefully piled lava slabs, about 3 feet thick and 6 feet high. The flow piled against it on the southern side, usually without knocking it down, until cascades of lava overtopped the wall and filled the space on the northern side. These cascades then fed flows which united in a pool on the northern side. All these pools merged and advanced toward the vegetation in the saddle. This vegetation was at the edge of a former flow from Mauna Loa consisting of both aa and pahoehoe, with large craggy domes, gorges, and forest trees north of the wall in the western part of the area, while towards Puu Huluhulu at the edge of the old lava there were open fields. All of this tract was destined to be invaded by the new pahoehoe, which cascaded into the chasms and burnt the forest at the west, and spread over the grassy lands at the east.

December 21

The development of pahoehoe had been very rapid over the source heap and the upper parts of the flow during the preceding week. The flow as seen from the Mauna Kea slope was now silvery pahoehoe on top in four large meanders, which sent out two tongues to the west over the 1843 aa. This silvery surface, reflecting the light from the sky, was in marked contrast to the earlier condition when the Mauna Loa slope was photographed December 11 and all the aa fields were dead and lusterless, of dark reddish-brown color, the only glossy pahoehoe being at the source, and on the crust of the main stream.

There was now a liquid sea of this silvery lava which had spread over a large area of the ancient aa fields immediately below Humuula station. This big lake on this day expended its energies of forward progress by penetrating the fields and low rocky hills and burning the vegetation WNW of Puu Huluhulu for a width of front of three-quarters of a mile, with its eastern limit about one-quarter of a mile from Puu Huluhulu. Estimates of progress at different lobes of the front showed the glowing paste progressing in one place 10 feet in 10 minutes, in another place 20 feet in 15 minutes, these meaning forward movement of from 60 to 80 feet per hour. The flow as a whole moved more slowly, but in detail there were places that were swift cascades, where the new fill overtopped ancient obstructions and rushed forward.

Some of the energy of the flood at this time was being expended in spreading out a mile or so south of the saddle in the region SSW of Puu Huluhulu among ancient flows which were almost horizontal. Individual tongues actually flowed backward or to the south in this country, at the southern edges of the lake of lava, and there was backing up of the lake also to the west as far as the slope would permit. The 1843 Flow, however, obstructed the new lava in that direction, where the older flow had partially encircled the wooded hill there which is 6,823 feet above sea level. Th backing of the lake soon reached its limit, and the greater stream which was pressing forward around the earlier aa front from the west pushed eastward into the saddle between Puu Huluhulu Mauna Kea where it found a pronounced valley leading down in the Hilo direction. Another stream from the SE tongues of the lake area found a similar grade eventually on the south side of Puu Huluhulu, that led it cascading NE into the same valley.

On this day another photographic panorama was made to show the contrast in the gleaming smooth-topped flow up to the source from the conditions of December 11.

A development which always accompanies the invasion of vegetation by pahoehoe lava, where the old ground under the root system is cavernous, was the exploding and flaming of carbon gases, supplied with oxygen of the air in the region adjacent to the front. The explosions became numerous and noisy, and in many places blocks of rock were flung up in heaps where mixtures of carbon monoxide and air were ignited in ancient lava caverns by flames or by penetrating tongues of melt. Another phenomenon, more unusual, was the presence of burning gases making wandering blue flames, or banners of yellow flames, in sand pockets sometimes 50 to 100 feet away from the lava front, in a grassy pasture. Apparently the carbon gas was generated by charring of the deep sod. This penetrated cavernous spaces or cracks under the field, and remained sufficiently free from contamination by air to escape and burn without explosion. Such flames were later seen burning in the hollows of the new lava, where it overlay masses of carbonized vegetation.

The lake area of the flow had a depth of 7 to 10 feet, was moderately flat on top, and the stretch of stone wall left its mark as a straight line through these portions of the flow where the wall was covered. This was due to some molding effect where the cascades over the wall left a scar on the final lava field.

December 22

The flow passed between Puu Huluhulu and Mauna Kea, found a steeper slope and progressed eastward more than a mile with a front 200 feet wide and tended by reason of slope and stirring to develop internal crystallization and so to change to aa or clinker lava. The progress, which had been of the order of one-quarter mile per day on the flat land, now suddenly changed to more than one mile a day, and this started draining the large lake which had accummulated in the Humuula saddle. The speed of progress was augmented when the second stream on the south side of the Huluhulu Hill joined the main east-flowing river of slag.

The Mechanism of Aa and Pahoehoe Lavas

There were now three distinct centers of activity requiring attention, in order to understand the Mauna Loa Flow. There was the smoking rift crack about elevation 11,500 feet, beneath which the internal lava was boiling in a pit. There was the source vent on the north flank of Mauna Loa, whence the Humuula Lava Flow poured down to the saddle between Mauna Loa and Mauna Kea. This flow source was 6 miles north of the upper rift and its smoke shaft. The third active area was the new drainage from Huluhulu Hill to the front of the lava flow, a steadily progressing mass of clinkery paste covered with huge bowlders, and fed by glowing torrents of slaggy melt which tended to crust itself over from the source downward to the broken dam at the Humuula lava lake. This melt was essentially a foam impelled both by gravity and by hot gas expanding within it. The tunnel system created by its crust made a pipe leading from elevation 8,500 feet down the slope of Mauna Loa to elevation 6,500 feet. Here the pipe bent sharply eastward at a right angle, and vomited out its content in an open river. Down to this point, the froth stream secreted a glassy skin over itself as a roof; this is pahoehoe lava.

Such a torrent in a tunnel, makes an adjusted pressure system connected with the foam column in the shaft, inside the mountain. The open pit at the top of this shaft sends up sulphur smoke and other gases, from the summit rift craterlet, which had been fountaining with the hot froth at the beginning of the eruption. The froth had lowered in the vent, and was now fountaining internally.

This statement exhibits the relationship of the upper vent to the lower flow vent. When the pahoehoe stage is reached, the adjusted pressure system above referred to, means an equilibrium of gas-heated foam holding a certain level in the shaft, and flowing foam in the pipe system which pours down the crusted-over river under both hydrostatic pressure and gas-pressure. A man with hob-nailed boots might possibly have walked eight

miles on top of the pahoehoe stream from the flow vent to Humuula and avoided any liquid. The main lava river was flowing in a tunnel.

This arrangement is closely similar to the overflow of an uncorked champagne bottle if one imagines a small pipe leading from the neck of the bottle and the uncorking controlled by a stop-cock instead of a cork. The foam might then be allowed to rise in the neck and overflow through the pipe, while the liquid being converted into foam always remained below the neck. So the magma in the mountain is the liquid below the foam with gases escaping from solution. The foam we call lava is frothing molten glass. It differs from champagne in that the gases react chemically to release heat and make the foam more fluent than the mother-liquid below, and in that it solidifies in cold air.

When the flow gathered speed down the valley east of Humuula station, by reason of suddenly breaking the dam beside Huluhulu Hill, the liquid under the crust, of the lake area, rushed out into the open and down the slope with a rapidity which stirred it into the "sugaring" condition, known as aa lava. There was at this point a sudden quasi-new eruption; a quasi-new vent broke out so to speak, from under a sensitively adjusted cover to a steeper slope beyond. The flow down this slope towards Hilo was thus a third repetition, on a small scale of the breaking out of November 21 from under the heavy ancient cover we call Mauna Loa Volcano, and of the second on November 27 from the flow source crack in the mountain flank. As in that case, the new gushing made skins over itself (pahoehoe) just below its point of escape at Huluhulu Hill, but below that it crystallized into clinker, with a dark-red river in the middle, and would make no more glassy skin over itself, until a new adjustment was reached by pooling in some hollow below, when the Huluhulu pahoehoe would push down the river and overtake the aa with a skin.

The process by which such an adjusted skinning over of a lava with a glassy crust comes about is as follows:—

The gas-charged melt of a vent is stirred and rapidly crystallized both by boiling or effervescing and by rapid flowing. If it rapidly flows with gases rising from within it, it is heated on top by the gases, it is heated within by crystallization, and it is cooled and solidified, chiefly on the bottom, by contact. The hot gases incessantly escape without forming bubbles, and the solidification proceeds from the bottom upward. This solidification is free to take forms of sprouting determined by crystal groupings, and no time is allowed for the separating out on top of a glassy foam. Such glassy foam is formed in enormous quantities near the vent, and makes the basaltic pumices, Pele's hair, Pele's tears, and heavy ropy folds of coarse pahoehoe which is always characteristic of the source region of any flow. A short distance away, the highly stirred crystallizing material pours out from under this tangle of glassy membranes, and the solidifying from there to the lower end of the first streams proceeds by the aa process.

When the gas stirring becomes less, and the rate of flowing becomes slower, whatever may be the causes of the change, glassy bubbles are free to form and rise to the top. These make a layer of many membranes of glass which stretch themselves over the expanding and advancing liquid. When this happens, there is no longer a heating on top by reacting, escaping, and oxidizing gas, and a cooling only at the bottom, with an eternal sprouting upward in a clinker, such as is characteristic of aa; but the cooling proceeds from above downward, and a glassy crust confines the melted stuff within. In this condition we have exactly the same liquid melt inside tending to crystallize, but it fills a pipe. This pipe itself imposes a continuous restraint by pressure, on the escape of gas from solution; and the eternal formation of new glassy membrane over the liquid, pushing out as toes under the skirt of crust at the front, imposes a restraint by pressure on the speed of flow of the liquid. These two restraints enforce a relatively constant adjusted pressure and the vesicular crust now has the effect of a heat and gas insulator and keeps the melt inside from losing too much gas—and gas is its main heating agent—and from radiating heat and so losing its liquidity. By keeping the gas in, it keeps the source of its auto thermic action. All these adjustments bring about the formation of a tunnel system, with liquid lava running through the pipe, and the pipe continually strengthened by layers of glaze added as interior coatings. As the gas does not escape, except through flaming cupolas near the vent, which have fountains inside, the whole system preserves the heat of reaction between the gases, and so a lava tunnel may be at brilliant yellow heat, even when the liquid river inside has lowered somewhat, and through windows is sucking in oxygen to unite with the gases, and also with the glazes, to keep the temperature high.

To return to the Humuula Flow: the transition from the aa stage of the first week of December, to the silvery pahoehoe crust covering the whole course of the flow the third week of December marked a gradual change in these adjustments of internal heating to external cooling. A highly critical point is reached whereby clinker sprouting and solidifying from below, is replaced by vesicular glassy crusting and solidifying from above. In general, the conquest of a flow by pahoehoe crust proceeds from uphill downward along the course of the river channel. In like manner, if the aa lava flow toward Hilo from Humuula station were to reach another pahoehoe adjustment, it would be by the pahoehoe skins and crusts spreading down the channels and mastering the front of the flow as had happened when the Humuula lake was the front.

There are three important corollaries to this heat argument, namely (1) pahoehoe and aa lavas are exactly the same substance. (2) The internal liquid or paste under any pahoehoe crust is quite competent to become aa lava if allowed to flow in the open. (3) The only mechanism which could carry a lava flow 30 to 50 miles on a flat grade is pahoehoe tunnel-making, for that insures retention of heat and liquidity.

A fourth experimental corollary of the pahoehoe argument is this:—

If an artificial disturbance like blasting is applied to the outside of the tunnel system near the vent, after pahoehoe adjustment had been attained, the stream inside under pressure would flow out into the open, without restraint of gas, and without restraint of flow. There would be immediate cooling and solidifying of the remnant material within the tunnel, after what remained liquid in the downhill system of tubes had poured out, and there would be nothing to keep up the supply.

A second possible result of such blasting might be this:—

If the stream suddenly released near the source vent were a foam torrent close to the hydrostatic level of the foam inside the shaft reservoir of the mountain, the gushing might drain the reservoir below that level, the flow would stop, cool, stiffen, back up, and seal the cracks from which it came, and the "small tube in the side of the neck of the bottle" would thereby be shut off. Rising of the foam thereafter in the shaft might pass this level, but newly solidified hot lava is an unbreakable plug. The reservoir shaft would continue its internal fountaining and external puffing of gas, until the gas release and heat radiation which determines the duration of an eruption were ended. Eruption would end, as all eruptions probably end, by an act of viscous intrusion somewhere inside the mountain. The blasting would have accomplished an interruption of the frontal progress of the flow, and also plugging of the flow vent.

December 23

The revived flow east of Humuula station travelled more than a mile turning into an aa stream with aa fields in front and at the sides. There was some slumping of the lava lake around the stone wall. In the evening a brilliant torrent was cascading around the south side of Puu Huluhulu, this joined the main river farther east, the front of which was some 2 miles from this hill. Flames burst through the marginal lava, there were big explosions in old caverns, and the large lake in the saddle was nearly black as seen at night.

The actual time when the flow passed Puu Huluhulu was the morning of December 22. There are now many explosions in old pahoehoe caverns not only at the borders of the pahoehoe near Humuula, but also at the lower aa front as the flow approached the wall which separates the Puu Oo lands, from the Parker Ranch, to which Humuula sheep station belongs.

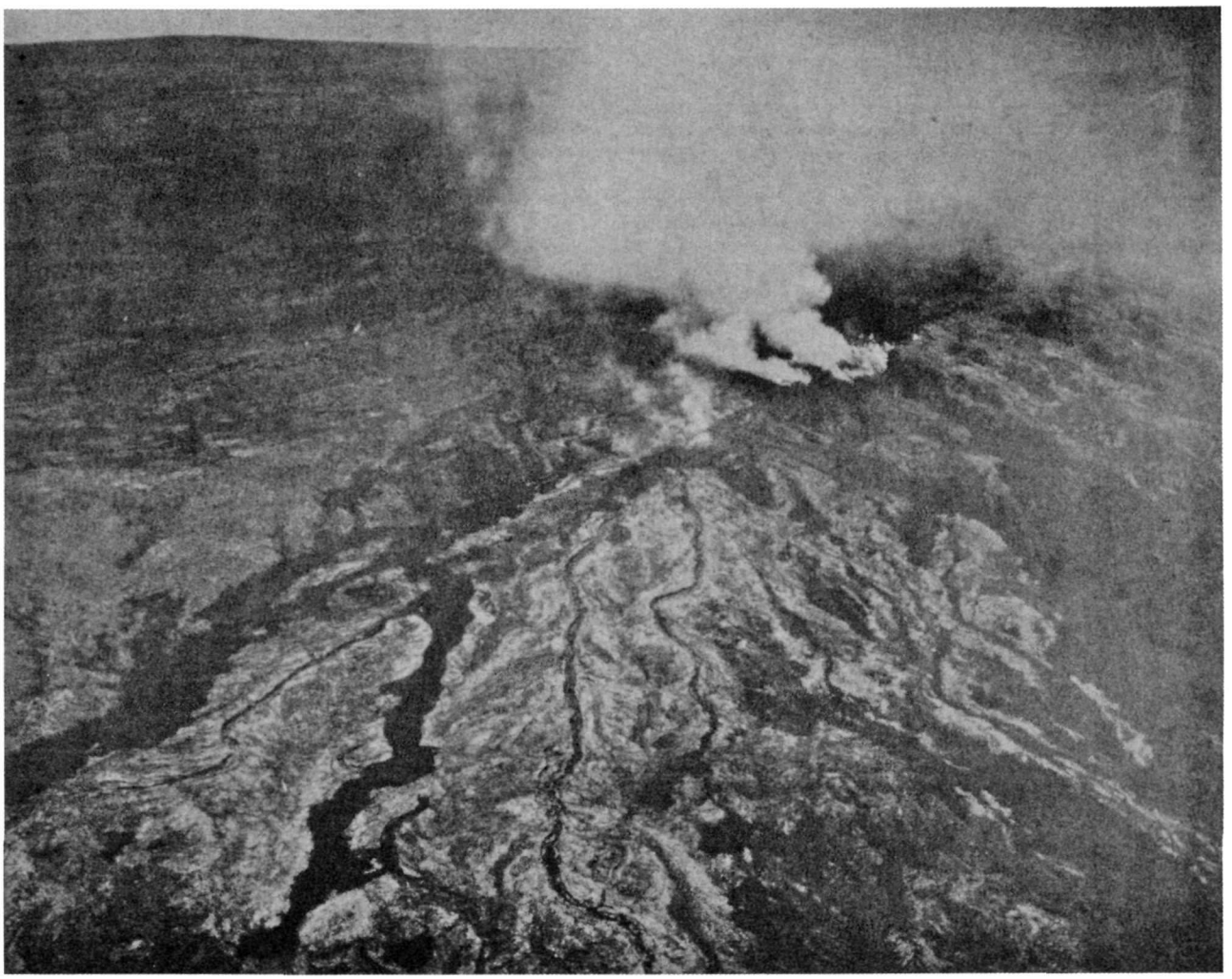
THE VOLCANO LETTER

No. 431—Monthly, Department of the Interior, National Park Service, January, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY, 1936



The top crater and well smoking at 12,000 feet.—December 27, 1935.

VOLCANOLOGY

As was anticipated, the operations carried out during the last week of December, 1935, by the bombing of certain selected localities upon the mountain-flank, thus venting the heavily gas-charged lava flowing within roofed tunnels, hastened the conclusion of the Mauna Loa eruption. While the actual bombing took place on December 27 with immediately recognizable results in the form of gushing of aa lava from the channel in the lower flow December 30 to January 2—the forward movement entirely ceased upon the latter date. The most marked features of the period subsequent to the bombing—in addition to the gushing referred to—comprised lateral overflow to northward of the main stream at an elevation of 5,750 feet: and sudden spillings from the medial channel at the front itself. These ranged in width from 50 to 200 feet—and pushed forward at speeds varying between 75 and 1400 feet per hour. The last forward movement ceased during the early morning of January 2 at Long. 155° 21′ west: Lat. 19° 42′ north, at a point 600 feet inside the Forest Reservation Fence. At this spot, a finger of pahoehoe, 50 feet wide, pushed slowly forward and then ceased to move. The great Mauna Loa lava flow had definitely ended.

It cannot be claimed, however, that the eruption has come to a close. During the entire month there has been continued emission of smoke and fume at the rift cone northeast of the summit crater at the 12,000 foot level. As long as this continues there is, undoubtedly, moving lava within deep cracks and the mountain is still in actual eruption.

Routine observation reports of this section during the month were as follows:

January 3 to 5. Fume with vapor at the cone which was heavily encrusted with sulphur. Fume and smoke rising from the cooling flows in various places.

January 10 to 11. A wide band of brown fume-changing on January 11 to a thin, upright column.

January 14. Faint fume visible from Observatory, and again on January 17, rising in a thin dark column in definite puffs, brown in color. Marked increase in fume density on January 18.

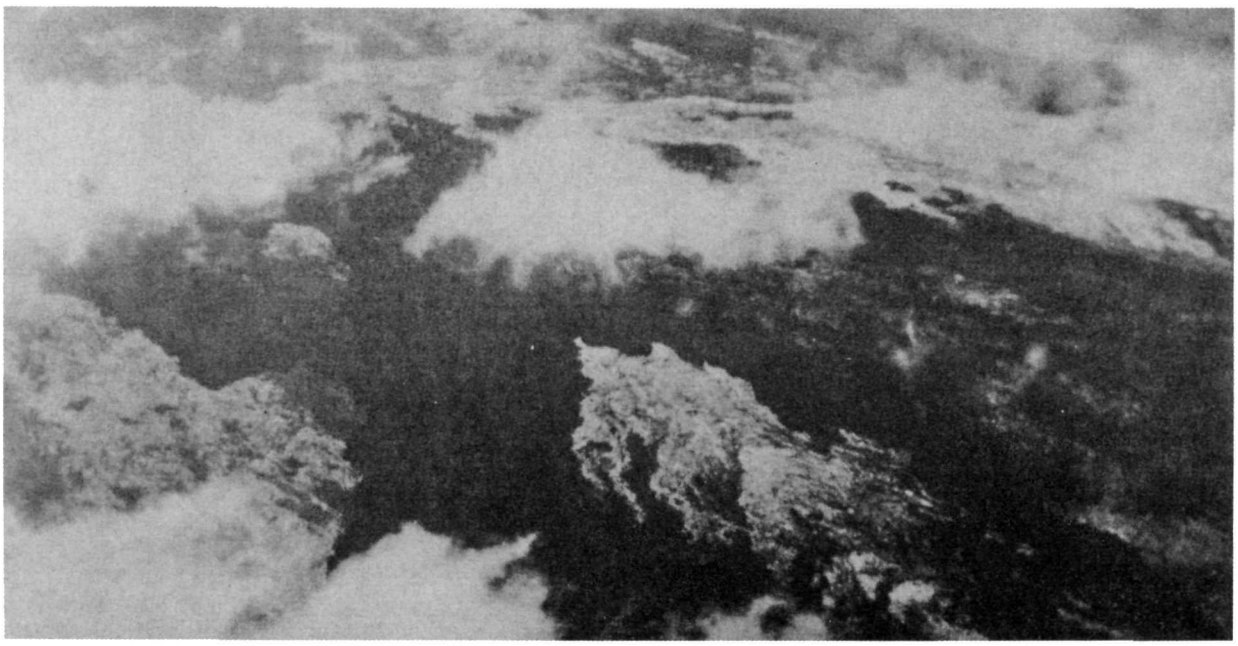
January 19. A report from a party of five observers visiting the cone on this date, stated: "Glassy black Pele's tears (droplets of lava spatter) were found on the ground near the trail. The conelet was climbed at the S end of the new crater in the large lava hill. Dark smoke puffed up from the shaft at the bottom of the crater with a purring noise, and spells of greatly increased pressure occurred, when it came with a roar. When the wind veered, the sulphur gas was unbearable. Within the cone there was yellow sulphur and greenish coatings. On the outer flanks the sulphur was brilliantly yellow, especially at the S. The outer lava was warm and brittle."

January 26. Fume from the upper rift continues unabated, making a brown cloud—and hangs in the upper atmosphere in thin wisps of bluish-white color.

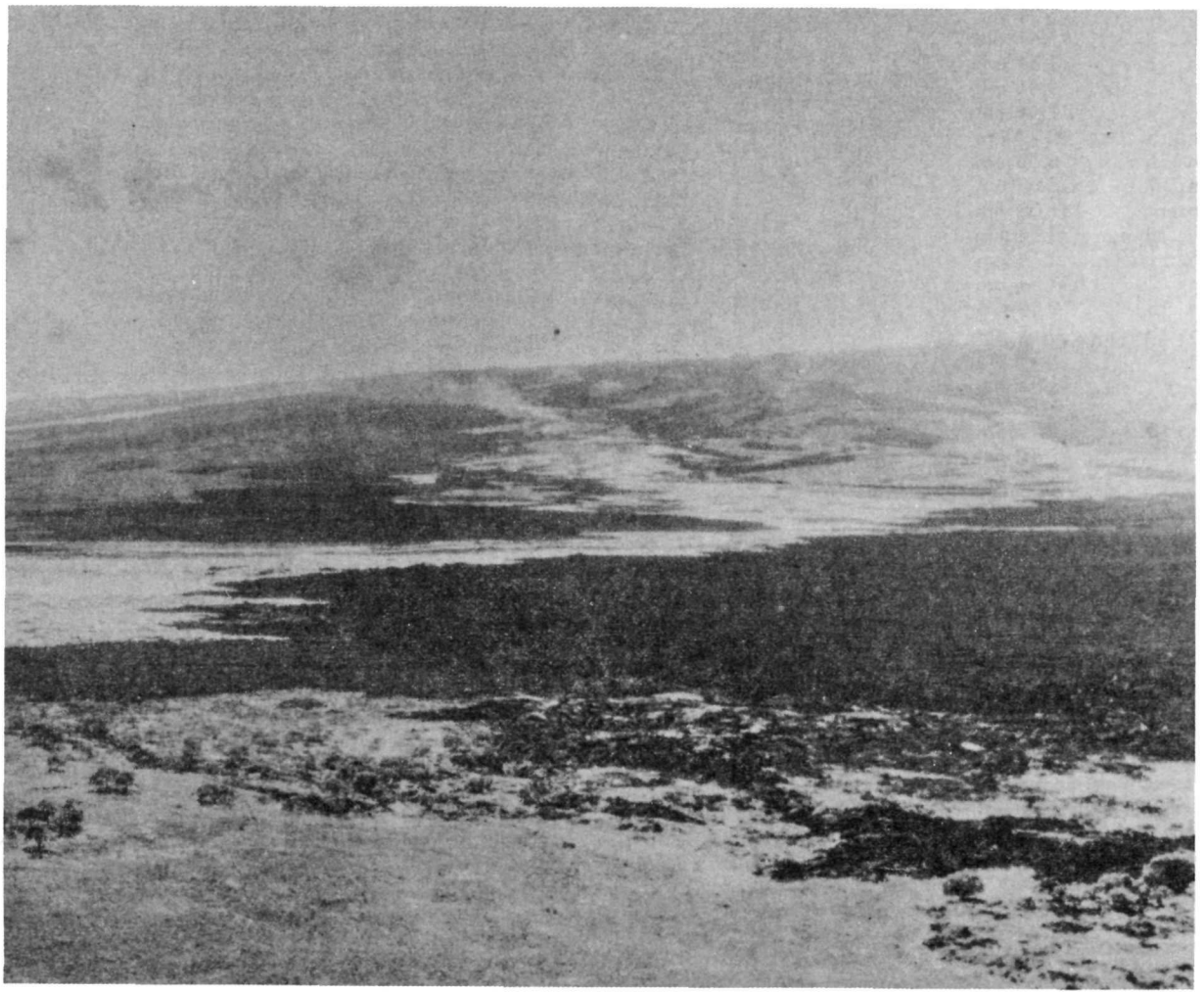
January 30. The Mauna Loa activity is not yet finished. The rift cone continues to send up jets of sulphur fume showing bluish under overhanging clouds. The mountain above 9,700 feet is heavily covered with snow.

KILAUEA OBSERVATIONS

Halemaumau on January 1 showed no sign of fresh slides. Blue fume rose at the yellow solfatara NW. On January 2 and 4 slope gravel was in motion WNW and at the north wall. Unusually dense fume was rising on January 7 at 3:30 pm and avalanche dust was observed on January 9. A slide occurred at the west wall at 9:32 am January 16 and fume from the SE edge of the floor was rising on January 18. In calm weather on January 21, blue fume, mostly from the yellow solfatara NW, filled the pit, producing an odor of spicy sulphur. With a moderate NE wind on January 24-25 the fume was inconspicuous. Earlier west wall sliding, 10 am January 30, developed into a large slide at 11:05 am—followed by another at 11:25 am between the northwest talus and the yellow solfatara. At noon on this date there was an eastern slide and freshly fallen rocks thereafter lay upon the southeast floor.



The lava stream is seen flowing diagonally at upper right.—Dec. 28, 1935.



The target source on the mountain slope.—December 29, 1935

Crack Measurements

Measurements of the 32 places marked on concentric cracks around Halemaumau, resulted as follows:

Week ending January 4. 11 opened. 3 closed. Aggregate opening for the week 9.5 mm.

Week ending January 11. 15 opened. None closed. Aggregate opening for week, 13.5 mm.

Week ending January 18. 7 opened. 6 closed. Aggregate opening for week 6.0 mm.

Week ending January 25. 11 opened. 1 closed. Aggregate opening for week 11.5 mm.

Week ending February 1. 7 opened. 4 closed. Aggregate opening for week 6.0 mm.

Seismic Observations

During the month of December, there was a total of 196 minutes of tremor and 15 earthquakes were recorded. Of these latter, ten were very feeble, two were feeble, one was slight and two were distant. Local seismicity was 14.5.

The epicenters of local earthquakes were determined as follows:

December 2, at 7:55 am, very feeble, located 13 miles W of the Volcano Observatory and 6 miles S of Puu Ulaula, 19° 26.8′ N; 155° 28.0′ W.

December 4, at 9:14 pm, feeble, located 1.1 miles deep under Kilauea Crater 0.4 mile E of Pit seismograph station, 19° 24.4′ N; 155° 16.7′ W.

December 10, at 6:19 pm, very feeble, probable location under Kilauea SW rift 14 miles SW of Pit seismograph station.

December 13, at 9:31 am, very feeble, located 1.6 miles deep and 0.4 mile E of Pit seismograph station. 19° 24.3′N; 155° 16.7′ W.

Seismic Observations

During the month of January, 138 seisms were recorded of which, 111 were tremors and 27 were very feeble earthquakes.

The very feeble shocks were:

Dec. 30	1.04 am	Estimated distance		12 miles
Jan. 2	2.47 pm	"	S	25 "
Jan. 3	7.34 am	"	"	Uncertain
Jan. 3	9.41 am	"	"	20 miles
Jan. 4	11.44 am	"	"	14 "
Jan. 5	10.27 am	"	"	2 "
Jan. 6	6.00 am	"	"	2 "
Jan. 7	8.06 am	"	"	2 "
Jan. 7	11.08 am	"	"	2 "
Jan. 8	4.32 am	"	"	25 "
Jan. 11	2.14 pm	"	"	2 "
Jan. 12	7.54 pm	"	"	20 "
Jan. 15	9.59 pm	"	"	2 "
Jan. 16	10.15 am	"	"	6 "
Jan. 16	1.14 pm	"	"	3.5 "
Jan. 16	11.43 pm	"	"	2.4 "
Jan. 17	1.11 pm	"	"	49 "
Jan. 18	1.45 am	"	"	62 "
Jan. 19	11.31 pm	"	"	24 "
Jan. 22	5.27 pm	"	"	20 "
Jan. 23	5.15 pm	"	"	2.7 "

An analysis of these distances shows that shocks recorded at distances up to six miles from the Observatory were under—or adjacent to Kilauea Crater. All others, with the exception of those on January 17-18, being Mauna Loa earthquakes. The increase in recorded shocks from Mauna Loa during the week ending January 5 is indicative of increased friction within the mountain as the internal lava became blocked. Mauna Loa distances for the 1935 vents approximate 19 miles. It is noteworthy that no larger shocks occurred during the month to point to the sealing of the rift and the end of the eruption. Local seismic indices (1), microseismic motion (2), and tilting of the ground at the Observatory for the month (3) were

Week ending	(1)	(2)	(3)
Jan. 5	7.75	Strong	Slight SW
Jan. 12	8.75	Moderate	Moderate E
Jan. 19	7.50	Strong to Moderate	Slight SE
Jan. 26	10.00	Moderate to Light	Slight SW
Feb. 2	7.25	Light to Strong	Slight WNW

The increase of microseismic motion during the week ending February 2 was coincident with marked barometric depression and unusual cyclonic storm.

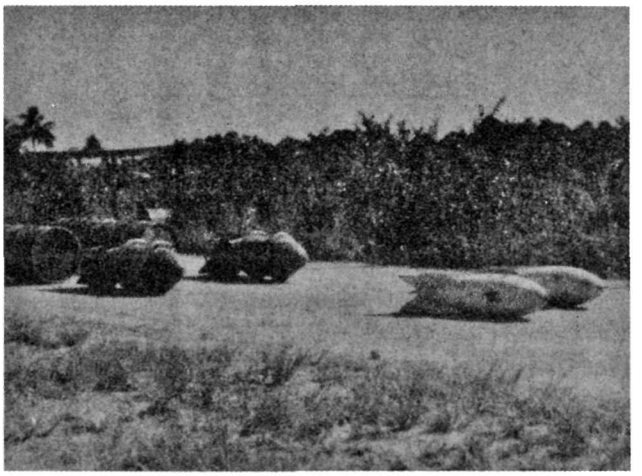
THE BOMBING OPERATION AT MAUNA LOA

A brief account of the actual bombing operation—an event that has aroused widespread interest in many parts of the world, will be of interest here. As was stated in the December issue of the Volcano Letter, there was nothing in the earlier phases of the flowing of Mauna Loa lavas to cause apprehension of damage other than to certain sections of pasture lands belonging to ranches situated at relatively high altitudes. Much of the elevated terrain at the junction of the slopes of Mauna Loa and Mauna Kea consists of lava covered land, rocky and sterile, intermingled with grassy pasture areas, not of particularly great agricultural value. As long as the flows were confined—in the main—to this area, they would spread slowly across it and would be harmless. This condition was maintained until the solstice on December 21 when a sudden change took place with the commencement of the draining of a large lake which had accumulated in the saddle between the two mountains. Upon the following day, the pahoehoe lava passed Puu Huluhulu and flowed eastward for more than a mile with a front 200 feet wide, tending to change to aa. The front of this flow almost immediately commenced to pour into a pronounced valley leading directly towards Hilo on the sea coast—and it was speedily apparent that a serious crisis might be developing.

It is of value at this point to recall the three distinct centers of activity: (1) the smoking rift crack at elevation 11,500 feet, beneath which the internal lava was boiling in a pit; (2) the source vent on the north flank of the mountain (some 6 miles north of the upper rift crack) from which the Humuula flow was being fed, and (3) the new activity caused by the draining of the Huluhulu lake. This presented an onward moving mass of clinkery paste carrying huge bowlders upon its surface—consistently fed by glowing torrents that tended to crust over and form roofs—thus creating tunnels from the source downwards and forming a pipe leading down the side of the mountain. Through this tunnel, the slaggy melt was moving—impelled both by gravity and by hot gases expanding within it. Even though there might be breaks, or windows in the roofs of such tunnel



Bomb dropped into flowing channel, throwing molten lava high into the air. The picture shows the wide expanse of Pahoehoe lava in foreground. —Photo by Maehara, December 27, 1935.



TNT bombs, bomb pointers, gasoline for planes.—Photo by Maehara

systems—these would merely act as flues through which oxygen would be sucked—to unite with the gases and maintain the temperature of the flowing mass. It was through such a tunnel as this that the main stream was now advancing at the rate of more than a mile a day travelling upon a down grade of 157 feet to the mile.

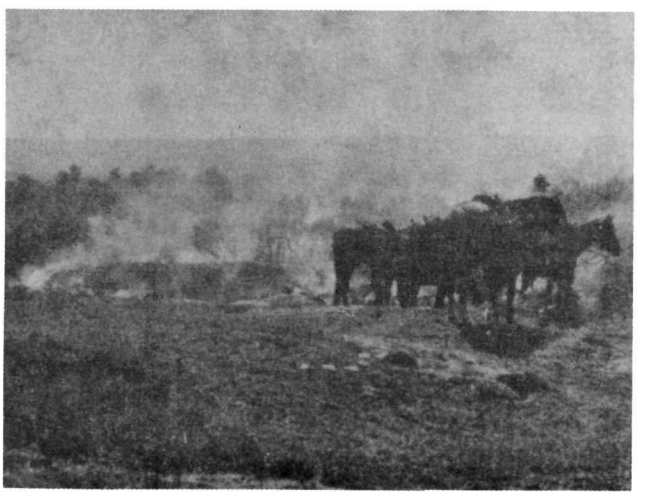
It was abundantly obvious that a continuance of this flow would constitute a danger, not only to the sources of Hilo's water supply—but also the city itself. Even discounting the probability of an acceleration of the rate of travel as the flow reached a steeper grade to the eastward, the front would be in the Kaumana road of Hilo by January 9th, and would have an almost unobstructed path down towards the city upon the seashore. When it is remembered that the flow was spreading out upon flat places to a breadth of 2000 feet it will be seen that the situation had become serious and presented a marked change from the conditions prevailing prior to December 21. It must be remembered also that there were other indications of danger other than those more apparent upon the surface. The structure of the mountain itself beneath the upper layer of surface rock, particularly under the lower levels, is honeycombed with tunnels and tubes of earlier lava flows. That the lava was making its way under the ground through such passages, was evident from the cannon-like detonations that were constantly occurring—hundreds of feet in advance of the main flow. These were due to the penetration of live lava into such tunnels, igniting mixtures of gas and air and shattering the old rock surface.

Under such conditions therefore, it had become imperative to take action, and the volcanologist sought assistance from the United States Army with a view to bombing the source at the 8500 foot level, and by thus breaking up the stability of the flow tunnels to spread and divert the flowing throughout this region.

On December 23, the matter was taken up through Major Hugh Gilchrist, Commander of the Kilauea Military Camp—and an urgent appeal was forwarded by airplane to Colonel Daniel Van Voorhis, Department Chief of Staff at Fort Shafter in Honolulu. The response was immediate. Upon the same day, an army amphibian, carrying a pilot, an engineering officer and a bombing officer was dispatched from headquarters under orders to fly over the area and to report upon return to Colonel Delos C. Emmons, Department Air Officer, upon December 24. Colonel Emmons accompanied by Lieut. Col. Virgil L. Peterson, Commander of the 3rd Engineers flew over the lava flows—and the U.S.A.T. Royal C. Frank was ordered to proceed immediately to Hilo with a supply of 600 lb. TNT high-explosive bombs. It had been decided that the occasion was of considerable urgency and that all possible cooperation should be accorded by the Army. Several reconnaissance flights were made upon this day—accompanied by the volcanologist—the course of the various flows was carefully mapped and a large number of vertical photographs taken in order that the targets might be indicated in the precise localities where bombing would be likely to be of the greatest value. The general situation at this time was that the main easterly flow was twenty miles in length with its front within five miles of the Hilo water supply—and only fifteen miles from the city itself. If it followed the natural contour of the ground it would undoubtedly reach Hilo.

Fourteen army planes arrived from Honolulu during the day and all arrangements were made for the operation, twenty officers and twenty-seven enlisted men being detailed to carry out the details involved. The ships were ten bombardment aircraft, two amphibians and two observation planes. Officer personnel comprised Lt. Col. Duncan, Maj. Lucas V. Bean, Maj. Roscoe C. Winston; Capts. Maurice C. Bisson, Joseph J. Ladd, Lewis R. Parker, Clarence P. Kane, Ford J. Lauer, Charles F. Born, Walter A. Fernander; 1st. Lieuts. Byram A. Bunch, William C. Beard, Charles E. Fisher, William C. Capp, David N. Crickette, Dale E. Altman, N. F. Coddington, Christian H. Clark; 2nd Lieuts. John C. Armstrong and Travis Hatherington. To these gentlemen fell the honor of being participants in the first experiment of its kind in the history of science.

It was decided by Col. Emmons that, owing to their dangerous cargo, the planes would not fly over Hilo, but would head out to sea until the proper altitude had been reached—and then circle in towards the mountain, passing over the sparsely populated Puna section on their way to the saddle land. Arrived over their targets and from a position at least three thousand feet above them—the bombs would be dropped. Arrangements were made for the posting of guards to divert traffic and spectators were warned to keep away from the vicinity. All was now in readiness and, favored by magnificently clear weather, the planes took off early on the morning of December 27. Taking off from the Hilo airport at intervals of ten minutes, seven Keystone bombers were employed, each carrying a pair of 600 lb. TNT bombs and two 300 lb. sighting bombs. The volcanologist, from his chosen post of observation upon Puu Oo Hill, had an uninterrupted view of the entire operation which was spectacular and impressive. Amid the thunder of shattering explosions, masses of rock and sheets of glowing lava were hurled in all directions, many of the great bombs, dropped from planes travelling at high speed, plunging directly into open channels through which molten lava was flowing, while others crashed upon the roofs of tunnels, blowing them open and releasing the melt imprisoned within, causing it to gush upwards and commence spreading immediately.



The Puu Oo flow moving 800 feet an hour.
—Photo by H. Shipman, December 25, 1935.

From the airport, at which interested crowds had gathered, the roar of the explosions could not be heard, but gigantic columns of black smoke, rising one after the other, were clearly seen, the great plumes drifting steadily off upon the prevailing trade-wind. The undertaking was continued until six tons of bombs had been dropped—and was entirely successful, the violent release of gas, of lava, and of hydrostatic pressure at the source, robbing the lower flow of its substance and heat. During the following night, there was greatly increased glare as seen from Hilo—this being occasioned by the draining of the tunnels and overflowing of clogged canals.

On December 28, fresh incandescent streaming was observed about the vent and channel. Thirty-three hours after the conclusion of the bombing, the front of the flow, fifteen miles away down the lava stream in Puu Oo ranch, stopped moving entirely for a half-day. At the lower front there was only side and frontal spilling of viscous channel lava and the total forward motion was approximately 1000 feet, dwindling to 500 feet on December 29. In the pooled pahoehoe lava of the divide at Humuula—fresh puddles of glistening slag were observed welling up through cracks. During the next two days there was slight gushing of aa lava from the channel in the lower flow, but by early morning of January 2 all motion at the front had definitely come to an end and the former crisis had ceased to exist.

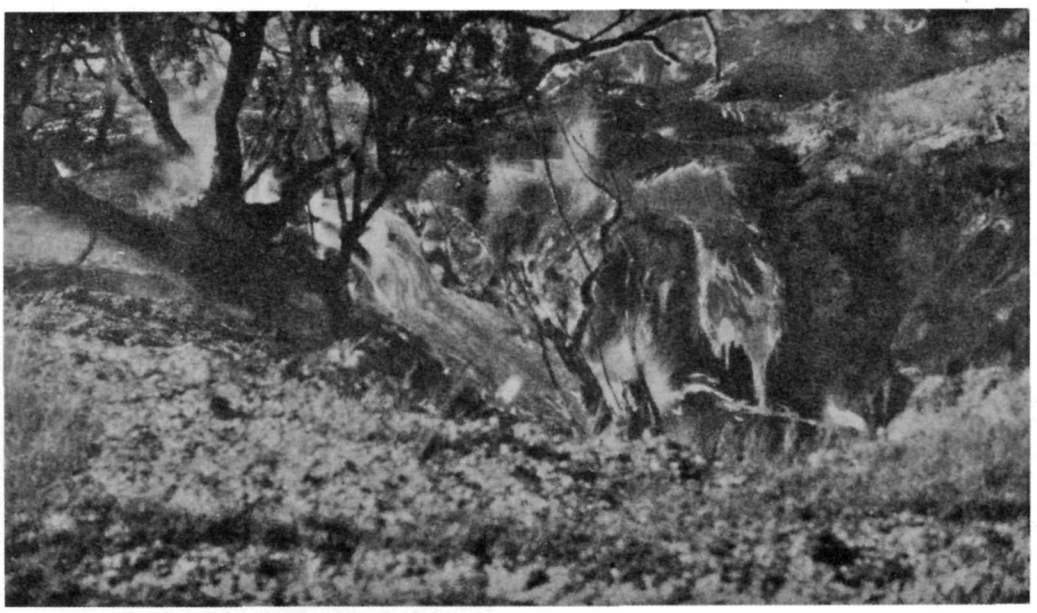
Thus, terminated the first experiment of its kind in attempting to curb one of the most destructive forces of nature—and thus also was afforded a happy exemplification of the results that may be obtained by the cooperation of one branch of science with another. It is entirely permissible through the medium of this publication, publicly to acknowledge the high appreciation of the extremely courteous and valuable help rendered by the Army Air Service upon this occasion and to express profound admiration of the almost miraculous accuracy with which the task was performed. That it has aroused world-wide interest is gratifying, for it is obvious that further research along similar lines may prove of incalculable value to those who live in active volcano lands and are at all times under the shadow of possible menace.

NATIVE SUPERSTITION

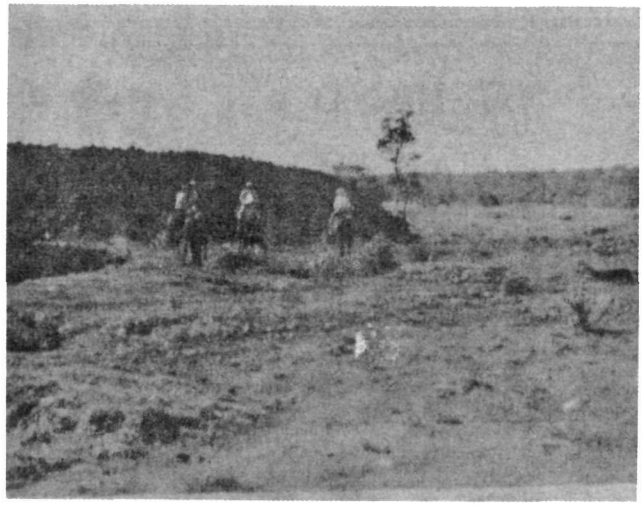
It may not be out of place as a matter of general interest, to comment upon the reaction of the older generation of native Hawaiians to the bombing of Mauna Loa. For countless generations, belief in Pele—the Polynesian goddess of fire, played an important part in the lives of the Hawaiian people.

Legendary lore is filled with stories of the doings of this mythical deity who lived in turn within the craters of the various islands, forsaking them in succession until she finally established her habitat in the depths of Halemaumau, the firepit of Kilauea—and under Mauna Loa. Indubitably, very many of the older natives still cling to their belief that the fiery floods pouring down the mountain are the visible effect of some insult offered to the dangerous goddess, and many are the efforts made upon such occasions to propitiate her in order that her anger may be stayed. The island of Hawaii, upon which these two great active volcanoes are situated, abounds in legends of Pele, and it cannot be gainsaid that many startling rumors of her appearance in human form in various places upon the mountain sides have been closely followed by lava outbreaks, although this has by no means been a natural corollary.

It was certain that many objections would be raised by older Hawaiians to any project of bombing Mauna Loa lava flows. They maintained that the goddess had her own reasons for being out on the mountain in the midst of her fiery torrents, and predicted dire catastrophe if her plans should be hampered by the unbelieving white man. They recalled an ancient legend of Pele and her bitter enemy, Kamapuaa—who, after many centuries of warfare during which the latter fought Pele's fires with water, endeavoring to drown her—came to an agreement under whose terms the goddess agreed never to destroy lands upon the northern side of the Wailuku river which runs through Hilo—if her enemy would undertake to protect the lands on the southern side from floods. Confident that this agreement would be kept—the Hawaiians predicted that any attempt to bomb the flows would anger the goddess who would immediately vent her wrath upon the city and cause widespread destruction. This feeling was widely shared and considerable strength was given to it by the fact



Illustrating the thick, pasty consistency of the Pahoehoe lava flowing through the forest.—Photo by Maehara, December 21, 1935.



The front dead —January 4, 1936.

that the flows did not immediately stop after the bombing operations. On the morning of December 28—considerable native excitement was caused by an aged Hawaiian who declared that he had seen an immense image of the goddess, with bulging eyes and streaming hair hovering over the flow region.

Perhaps the most interesting, and amusing, reaction was the declaration of an aged native, Keala Nuionaahienaena Kaha Kanianikaipo, more familiarly known as Ben Amina, who described how he, personally, had stopped the flow by direct supplication to the goddess. This gentleman claims direct descent from the goddess herself and his story—as told to the Hilo Tribune-Herald on January 8, six days after all movement of the flows had ceased, is well worth quoting.

"It was like this," he said. "I heard from my friends that the Army planes were going to throw bombs on Mauna Loa on December 27th to stop the flow. I shook my head because I knew Pele's life would be endangered by these bombs. I knew she would become angry and seek vengeance upon us. I was ready to do anything to stop this mad experiment, but my family prevented me. The bombing took place but the lava flow still continued. I was feeling desperate because I knew Pele too well. So, on December 31 at 4:30 p.m. I went up the road with four witnesses, Joe Pacheco, John Medeiros, Tony Reach, and William Rocha, all of Hilo, and gave the Hawaiian prayer which would melt Pele's heart. They were with me all the time I prayed to the fire-goddess.

"I faced the mountain and the huge column of smoke, raising my hand and beseeching Pele to hear my prayer. Then I called to her that I was her descendant who wanted to save my friends and the people of the island from this awful fate. I told her she had had a wonderful Christmas on Mauna Loa and that she was now celebrating New Year's Eve in her home of fire. I begged her to stop the flow on New Year's morning—beseeching her 'Pau, pau, pau (stop, stop, stop.) ' "

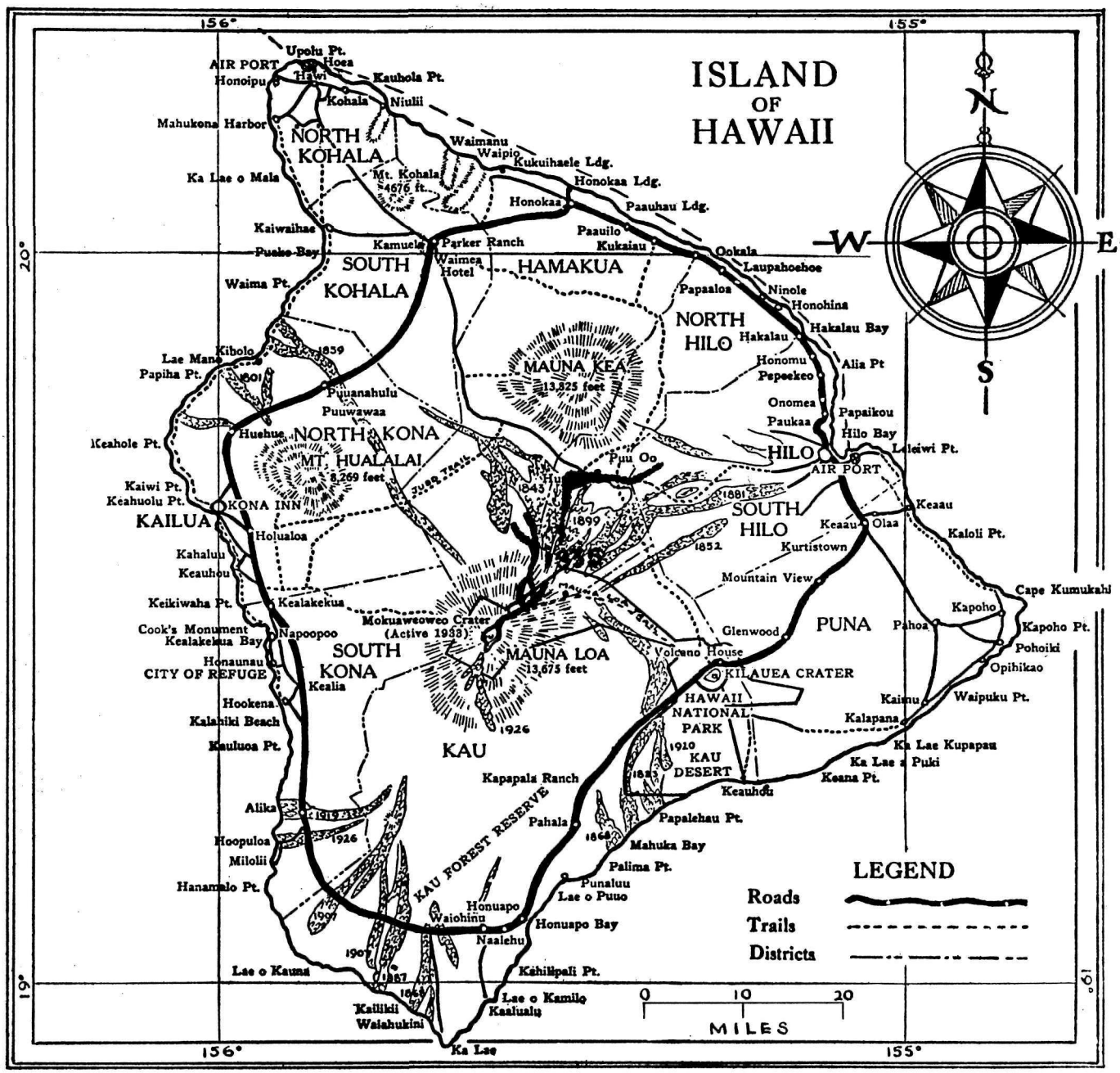
He stated that he sat in front of his home all night, keeping a close watch upon the mountain, and praying to Pele throughout the vigil. "At one o'clock in the morning," he said, "just an hour after the New Year was heralded, the mountain grew dark and no light could be seen. Pele had answered my prayer and I am grateful."

Hilo at large heard the news that the flow had stopped, on New Year's Day. Amid the general feeling of relieved tension, old Ben sat and chuckled, convinced that he was the one who stopped it.

Such beliefs may appear strange to those who are familiar with the development and progressiveness of these islands. But they are founded upon centuries of faith in a vast assemblage of gods and goddesses and they do not die out easily.



The man in foreground points with his stick to a place where an explosion from beneath the ground has disrupted the surface. Such explosions were frequent in advance of the flows; were violent and dangerous.
—Photo by Jaggar, January 4, 1936.


ISLAND OF HAWAII
N
S
E
W
156°
155°
20°
19°
Upolu Pt.
AIR PORT
Hoea
Hawi
Honoipu
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH KOHALA
Waimanu
Waipio
Kukuihaele Ldg.
Ka Lae o Mala
Mt. Kohala 4676 ft.
Honokaa Ldg.
Honokaa
Paauhau Ldg.
Kaiwaihae
Puako Bay
Kamuela
Parker Ranch
Paauilo
Kukaiau
Ookala
SOUTH KOHALA
Waimea Hotel
HAMAKUA
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH HILO
Hakalau
Hakalau Bay
Kiholo
1859
Lae Mana
Papiha Pt.
1801
MAUNA KEA 13,825 feet
Honomu
Alia Pt
Pepeekeo
Puuanahulu
Puuwawaa
Onomea
Papaikou
Paukaa
Hilo Bay
Keahole Pt.
Huehue
NORTH KONA
MT. HUALALAI 8,269 feet
Puu Oo
HILO
Leleiwi Pt.
AIR PORT
1843
1881
Kaiwi Pt.
Keahuolu Pt.
KONA INN
1899
SOUTH HILO
Keaau
Olaa
KAILUA
Holualoa
1852
Kaloli Pt.
Kahaluu
Kurtistown
Keauhou
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Cook's Monument
Kealakekua Bay
Napoopoo
Mokuaweoweo Crater (Active 1933)
Glenwood
PUNA
Pahoa
Kapoho Pt.
Honaunau
CITY OF REFUGE
SOUTH KONA
MAUNA LOA 13,675 feet
Volcano House
Pohoiki
Opihikao
KILAUEA CRATER
Kealia
Hookena
HAWAII NATIONAL PARK
Kainu
Waipuku Pt.
Kalahiki Beach
1926
Kalapana
Kauluoa Pt.
KAU
1910
KAU DESERT
Ka Lae Kupapau
Ka Lae o Puki
Kapapala Ranch
1823
Keauhou
Keana Pt.
Alika
1919
Pahala
Papalehau Pt.
Hoopuloa
1926
1868
Mahuka Bay
Milolii
KAU FOREST RESERVE
Palima Pt.
Hanamalo Pt.
Punaluu
Lae o Puuo
Honuapo
1907
Waiohinu
Honuapo Bay
Naalehu
1907
Lae o Kauna
1887
Kahilipali Pt.
1868
Lae o Kamilo
Kaalualu
Kailikii
Waiahukini
Ka Lae
LEGEND
Roads
Trails
Districts
0 10 20
MILES

THE VOLCANO LETTER

No. 432—Monthly, Dept. of the Interior, National Park Service, February, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR FEBRUARY, 1936

VOLCANOLOGY

Conditions at Kilauea

The month at the Halemaumau Pit of Kilauea produced no notable changes. Conditions were extremely quiet. A moderately heavy slide occurred about February 13, piling fresh debris upon the floor and leaving a scar upon the NE wall. On February 16, the SE wall showed the mark of a slide and rocks were dribbling from the West and NE walls. Some cracks on the floor appeared to be widening. On February 18, rocks were falling from the N wall which appeared dry. Small slides from this wall and the NE wall occurred upon the following day.

Mauna Loa Observations

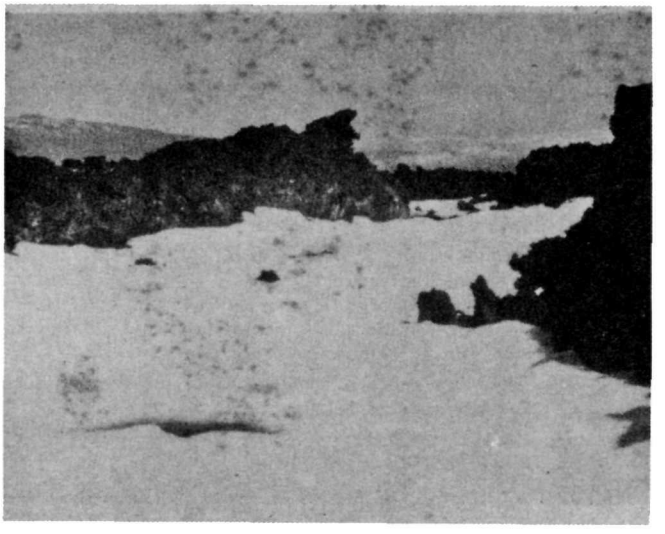
Fume was still rising in puffs from the rift source at 12,000 feet as the month of February drew to a close. As long as this puffing continues it cannot be said that the eruption has ended since it is obviously due to continuance of lava action within the pit from which it comes. From the eastward, or Hilo side, this fume is not often now discernible as it is blown southwestward by the prevalent tradewind. Occasionally however—in still air—more particularly about the time of sundown it may be seen rising as a thin column by observers near the city.

The Observatory upon the rim of the Kilauea Crater, being situated many miles to the south-south-east, is more favorably located and, provided the mountain is unobscured by cloud, the fume may generally be seen. On February 6, it was visible at noon, and on the 9th, it stood as a large yellowish milky cloud about 900 feet above its base. At the base, it was more dense and appeared to be puffing steadily. The mountain was covered with snow at this time and the cold would have condensed water vapor—but there was more sulphur smoke than steam in this cloud. At 5 pm on February 6, an opalescent fume cirrus was left by this cloud in the upper atmosphere: it lay in a sheet to the west of the zenith, bluish in color and with rainbow hues on its edges. On February 10, light fume was visible in the morning, both from Kilauea and from Hilo. A southerly wind on February 14 made brown fume visible all day: a tall, slender brown column was seen at 7 am on February 15, and milky fume against the western sun was reported by a Hilo observer on the following day.

On February 18 the smoking rift cone was visited by Seismologist H. H. Waesche of the Kilauea Station. He reported that, accompanied by D. McClellan he reached the NE cinder cone after crossing lava of the present eruption. "This was found to be black shelly pahoehoe with aa on its outer edges and gave off almost no heat when crossing over it. In fact, in many places, unmelted snow was lying upon its surface. The cone itself was from 50 to 75 feet in height—composed of black cinders and ash—and was about 750 feet in length—with a width, at its base, of approximately 150 feet. No fuming or steaming areas were found in or upon it—but considerable heat, accompanied by the familiar foundry-like odor emanated from the interior. Upon the SE slope and towards the SW end of the cone were areas of sulphur deposits associated with white salts. Two openings in the NW flank—one about the center of the cone's length—and the other towards the SW end had served as outlets for lava flows which had streamed away northwards.

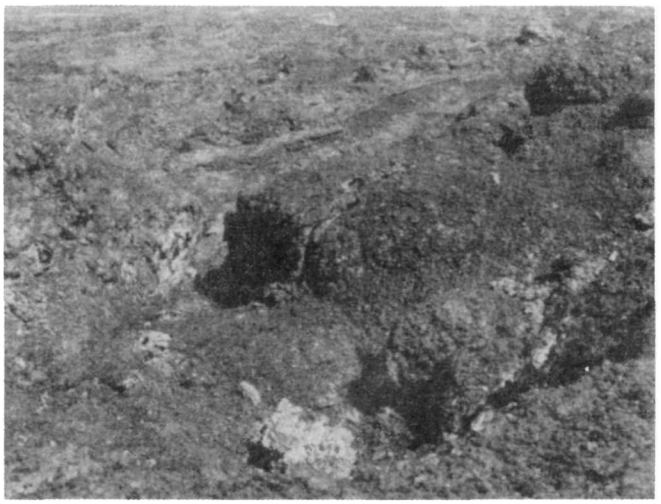
"The SW cone was next visited from its northern side—more of the 1935 lava being crossed in order to reach it. This lava also was black and more or less shelly pahoehoe with occasional patches of aa. It was warm in places but for the main part was cool enough for snow to remain unmelted. Immediately to the NW of both cones there was much pumice and fine cinders—mixed with the rounded glassy droplets known as Pele's Tears and with pieces of irregularly shaped lava glass from one-half to three-quarters of an inch in diameter.

"Immediately adjacent to the SW cone and to the northeast of it was a large spatter cone some 75 feet in height and 100 feet in diameter at its base. From an orifice at its summit a large volume of fume was steadily pouring. With a moderate NE wind it was possible to approach from the northern side. No pulsation in the fuming process was observed—neither was there any marked force in the volume either from the spatter cone or from a cinder cone further to the SW which also fumed steadily. It was possible to reach the brink of the throat of the cinder cone by use of a handkerchief held over the nose. This cone was between 75 and 100 feet high and about 250 in diameter in the direction of the rift. Although in climbing the



Looking NE along former lava stream which originally flowed from SW cone along base of NE cone, February 18, 1936.

cone progress was made over a large snowbank, the cinders underfoot were distinctly warm. The fume clouds were bluish-white in color and the strong odor of H^2SO^3 was strong and unpleasant even through the folds of the protecting handkerchief upon which yellow sulphur stains were left where they had been deposited by fume associated with air breathed through the material.



Opening in NW rim of NE cone through which lava stream flowed during activity, February 18, 1936.

"Along the base of the cone and more particularly to the SW, large areas of sulphur were forming and fume was rising from these places and from numerous spots of a similar nature though of smaller size along the flanks of the cone. Where new lava lay beneath such areas it had become soft and of a rotten texture. The largest sulphur deposit was at the SW end of the cone where the latter was superimposed upon the rift, which lay open towards the SW and was emitting steam. There was no sound of internal noises and no vibrations were felt. We crossed the rift to the SW of the cone and made our way back to the trail, passing through moderate fume strongly impregnated with sulphur."

SEISMOLOGY

During the month of February there were 12 seisms of which two were feeble earthquakes, nine were classified as very feeble, and one was a record of a distant shock. These produced a total of 89 minutes of tremor. Their distribution was as follows:

Feb. 4. 2 miles deep: 0.7 miles S of pit seismograph: feeble. A Kilauea earthquake.

Feb. 5. 21 miles deep: 5.0 miles NW of Puukoli. North slope of Mauna Loa: feeble, but reported felt in Hilo and at Kilauea Military camp.

Feb. 12. 4.6 miles deep: 1.5 miles SW of pit seismograph: SW rift zone of Kilauea: very feeble.

Feb. 12. 5.0 miles deep: 0.8 miles WNW of pit seismograph: vicinity of Kilauea Rift Cones: very feeble.

Feb. 13. 1.9 miles deep: 0.2 miles N by E of KoKoolau Crater: very feeble.

Feb. 21. 3.5 miles deep: 3.5 miles E of Kilauea Iki Crater: very feeble.

Feb. 27. 2.8 miles deep: 0.5 mile N of Pauahi Crater in Kilauea SE rift zone: very feeble.

Mar. 1. Very feeble—located probably in Kilauea SW rift zone about 1.0 mile SW of Halemaumau.

The epicenters of the above local disturbances were determined from the seismograms of instruments operated at stations of the Hawaiian Volcano Observatory. Kilauea earthquakes were located by means of the main station located at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant earthquakes were determined with aid of seismograms from stations at Hilo and Kealakekua. The depth of focus is given wherever possible.

16 minutes of harmonic tremor began recording at 10:19 am on February 13. On February 26, two spells of harmonic tremor were recorded. The first commenced at 2:41 pm and lasted 6 minutes, and the second, lasting 13 minutes, began at 3:08 pm.

The preliminary waves of a distant earthquake began recording at 2:29 am on February 15. Its estimated distance from the Volcano Observatory was 5735 miles.

Microseismic motion was strong February 3 to 9 and on February 29. It was normal February 10 to 12, 15, 19 to 28, and March 1, and light on February 13, 14 and 16 to 18, all dates inclusive.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope locations towards or away from the Pit.

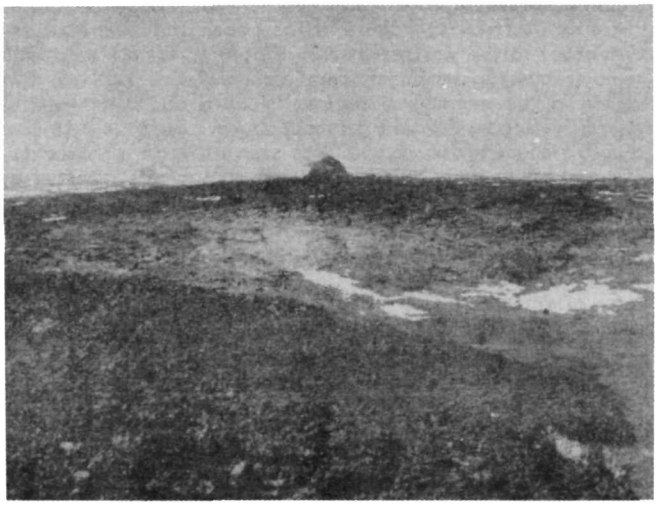
Week Ending	Observatory	Halemaumau West	Clinoscope Southeast	Stations Pit Resultant
Feb. 9	1.31"S.44°W	8.20"N.34°E	8.62"S. 7°W	8.56" *
Feb. 16	1.46"S.57°W	2.09"S. 76°W	5.38"N.57°E	2.41" *
Feb. 23	0.87"S.29°W	3.87"N.43°W	3.01"S. 81°E	4.29" *
Mar. 1	0.80"S.45°E	3.58"S. 70°W	7.94"N.	2.89" †

*—from. †—toward.

The total accumulated tilt at the Observatory for the year ending March 1, was 0.37"S and 0.40"W.

RETROSPECT

Now that the outbreak of Mauna Loa is ended, it may be interesting to look back a few years and compare the precise predictions then made, with what actually happened in 1935. Such retrospection will, at least, show the value of consistent study and uninterrupted compilation and maintenance of record, since—in just the same way as a small



View of Spatter cone and SW cinder cone as seen looking to SW from the NE cone, February 18, 1936.

acorn may develop into a mighty oak, so the true picture of what is likely to occur in connection with individual volcanoes—can only be gained by taking most careful note, through many years, not only of major happenings, but of even the most infinitesimal and, to the layman, seemingly unimportant movements far below the surface of the ground. *It is a truism that the most important part of the work of* volcanology is the correct interpretation, not of the outward manifestations of an eruption—but of the calm periods when the earth seems to be in a complaisant mood. For it is during such periods that vigilance is most necessary in order that no least movement may be overlooked. The faintest stirring of the calm evening air may be the precursor of the cyclone: the most minute tremor beneath the ground may be the forerunner of increasingly greater movements that may end in a disastrous earthquake, or an eruption with accompanying lava flow.



Spatter cone and SW cone as seen from N, February 18, 1936.

Inhabitants of volcanic lands may be subjected to four different classes of disaster. These are: 1. Explosion and volcanic blast: (2) Lava flow: (3) Earthquake, and (4) Tidal wave. All of these four have happened in Hawaii. There was a great explosive eruption of Kilauea in 1924: Lava flows from Mauna Loa in 1881 threatening Hilo, in 1926, destroying Hoopuloa—and a large number of other flows in very recent years: earthquakes, notably in Kau in 1868, in Puna in 1923 and at Puuwaawaa in 1929: tidal waves in Puna in 1868, and at Hilo in 1877 and again in 1923. As each of these is represented by damage in this century—the topic is a live one.

Speaking before the Hilo Chamber of Commerce on June 9, 1931, Dr. T. A. Jaggar, Director of the Hawaiian Volcano Observatory, called attention to the possibility of disaster to Hilo and urged that precautionary action and organization be taken and established. He said, in part:

"Hilo is peculiar among cities in the world in that it is squarely in a volcanic belt, but happens to have been largely spared until now. So far as strong earthquake is concerned this is equally true of Honolulu, for both of these places are liable to a terrific earthquake, when everybody will be surprised just as the living generation was surprised at Charleston, Santa Barbara and San Francisco. They will be surprised in Hawaii, because the earthquake interval overlaps several generations, and in Hawaii in the 18th century, before the coming of the white man, earthquakes made no impression upon grass houses.

"Hilo is definitely committed to future lava flows. The years 1801, 1843, and 1859 sent flows northwest, two of them building new land in the sea, from Hualalai and Mauna Loa. *The years* 1852, 1855, 1881, *and* 1899 *sent flows towards* Hilo. The flow of 1881 reached Waiakea, and that of 1855 reached Kaumana. The years 1868, 1887, 1907, 1919 and 1926 have sent flows at short intervals to the southwest from Mauna Loa, always in different places, three of them reaching the shoreline, and all of them destructive of ranches, or roads, or villages, or all three. Earthquakes, destructive and dangerous, came in a swarm in October, 1929, shifting the area of underground activity of the enemy from Kahuku to Hualalai, and **suggesting that the north side of Mauna Loa as the center of it all, will probably be the sector where he will concentrate his artillery for the next attack.**

"Apart from these dates, history indicates that Mauna Loa will average activity about every four and a half years, so that we are now on the verge of a new outbreak. There are pros and cons that argue for long intervals in some parts of the century, but we know too little to apply them here. **The fact is inevitable that Hilo will look up some evening and see what resembles a bright star on the northeast rift line of Mauna Loa, and a flow will start, following the hollows among the flows of 1852, 1855, and 1881 in the direction of the valley of the Wailuku River.** After it has been going for a month, we shall know whether it is likely to keep going for a year. It begins with rapid aa flows, the source cones make pahoehoe, the aa ceases, then the pahoehoe slowly tongues out from above, past the earlier aa extremities, and, pushing through tunnels to spreading leaf-like fronts, the pahoehoe may creep through the forest downwards for many months. This would invade and dry up the Hilo water supply. **The lava would be fed through a source tunnel up around the nine thousand foot level, forking out into many tubes down below.** If a flow once got started between the 1855 and the 1881 flows, or on the north side of the 1855 flow, it would pour down the line of the waterfalls of the main valley of the Wailuku, as it has done in prehistoric times in

the past, and as it did in 1881. The waterfalls were made by many lava dams. The visible tributaries are mostly from the north, those from the south being buried under lava and flowing underground. On this course, the lava would pour straight down through Piihonua, and the fate of Hilo would depend upon how long the tunnel supply of pahoehoe kept on flooding at the source.

"Just at this point could be applied the project to stop a lava flow advocated by the late honored L. A. Thurston, **and only at this point.**

"No aa flow in its early and rapid stages could be arrested. **A pahoehoe flow in the later stages of an eruption, by reason of the tunnel mechanism, could be blown up at the source tunnel about the nine thousand foot level, or just below the source cone so as to dam the lava stream with rock and force it to start afresh.** The eruption would continue as before, with the lava starting to flow anew out of the blocked channel over the surface of the country by a slightly changed course. If the previous pahoehoe flow took five months to get down near the Hilo level, the renewed flow 30 miles up the mountain would require as much or more, and the city would be given five months respite. The main source would go out of action in that time, and Hilo would be saved.

"If **the 1855 or the 1881 situations were exactly repeated, this diversion of the flow at the source could be done.** It could not possibly have been done for Hoopuloa or Alika. The 1855 flow lasted 15 months, the 1859 flow ten months, and the flow of 1881, nine months. Such durations are quite possible now—for the tunnel flows on the Kilauea floor in 1919, lasted seven months, and so did the Kau Desert flow in 1920. Contemplation of these possibilities is thoroughly sound economics for this community."

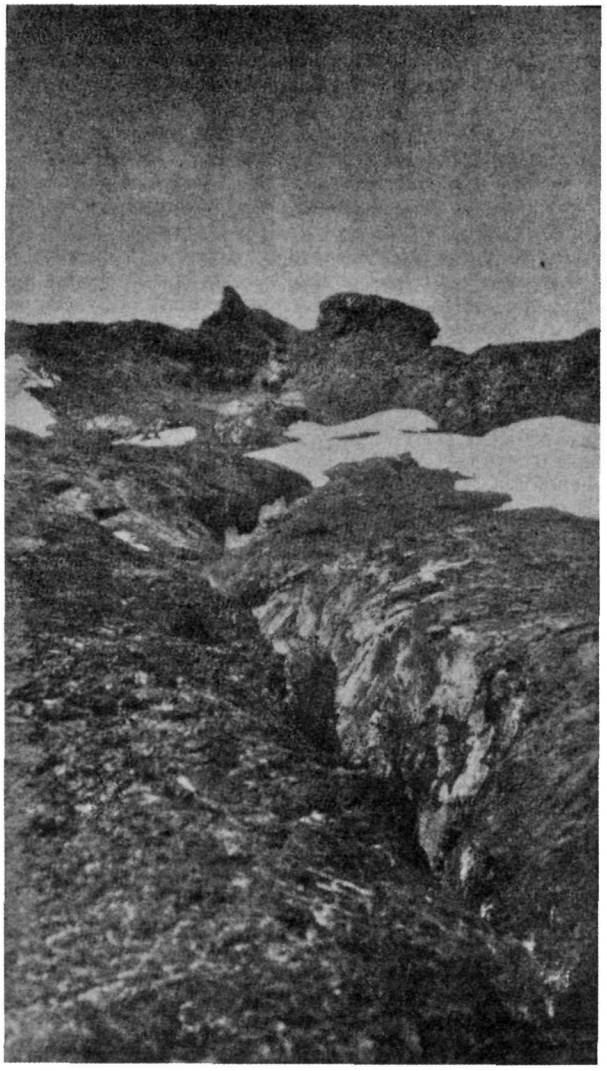
The foregoing predictions were made in 1931. Let us, in the light of them, look at what happened in 1935.

On October 1st of that year exceptional Mauna Loa earthquakes were recorded—followed by smaller ones, and by 50 seismic disturbances per week for the first three weeks of November. Warnings were issued by the Observatory that an outbreak along the northeast rift line of Mauna Loa was imminent. At 1:11 am on November 21, a heavy earthquake occurred under this rift line. The quake of October 1 was located at 17½ miles below the surface: that of November 21 was less than 5 miles down—clearly implying a splitting movement from below upward. At 6:25 pm on November 21, another earthquake—followed immediately by smaller ones, occurred, and the people of Hilo looked up and saw the bright light on the northeast rift line. The great lava flow had commenced.

By mid December, the main flow had definitely swung in the direction of Hilo and was headed for the valley of the Wailuku River. It was being fed through a source tunnel at an elevation of 8,500 feet, forking out into many tubes below around the 6,500 foot level, and the danger not only to the water supply of Hilo but to the city itself, was clearly apparent. It was therefore necessary to blow up the source tunnel in order to secure the result whose possibility had been outlined in the speech of 1931. This was done on December 27, with entire success. The details have been fully covered in the January issue of the Volcano Letter.

It was during the same speech in which these predictions, later so accurately borne out, were made, that Dr. Jaggar touched upon the topic of organization for preparedness, in order that, should disaster occur, suffering might be reduced to a minimum. Alluding to the terrific earthquake in the North Island of New Zealand in February of that year, he said:

"Let us look at what has happened at Napier. Wherever you were, in your car, on the road, standing indoors, standing outdoors, suddenly there comes a tremendous crash like an explosion and down you go. Everything goes down, houses,



Rift looking SW from SW cone February 18, 1936.

bridges, gulches, cliffs, fires start, road fills crack open, automobiles fall into the cracks, wharves are all down, some of the shipping is grounded, the breakwater has settled out of sight in places. In other words, the enemy has hit Hilo with a Big Bertha. The railway is out of commission, emergency telepones are called for as the wires are all down, the water mains have burst, the sewage is interrupted, the fire engines are pinned in their houses, the roads are interrupted by landslides. More than all, the people are struck dumb with shock, and until a warship arrives, to which this sort of thing is all in the day's work, the population is dependent on whatever leaders happen to be soldiers.

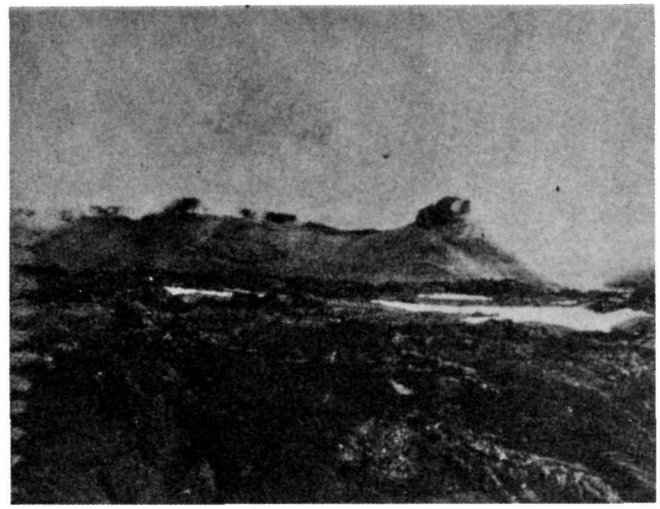
"Rescue parties are organized to dig out the wounded, portable cranes are in demand. Explosives must be used to demolish tottering masonry, which is likely to kill more people with the thousands of aftershocks that are coming along. Temporary wireless is one of the first requirements as the radio masts are down. Airplanes are summoned to rush anaesthetics and medical supplies, for these things have given out. They have to be carried by air. A large number of tents are needed for temporary hospitals, and the roads interrupted by slides and cracks are not immediately available for carrying

people to towns which suffered less. Sea transportation is organized as fast as possible by wireless, but that takes some time. The water supply being cut off, it is necessary to get in a chlorinating plant, organize a road survey immediately, and start work on pipes for an auxiliary water supply from a place where fresh water is available. The contents of the banks are laid wide open as well as many other valuable safes and cash drawers, and martial law is immediately organized by soldiers and constables who understand such things, a ring of pickets is run around the city, looters are shot on sight by marine guards. The jail prisoners are called out for digging, and do heroic work of rescue. Many motorists are caught in gorges and gulches and search parties have to be organized to seek them. The post office department is entirely disrupted and a quick reorganization is called for, as inquiries begin to pour in by mail as soon as any partial organization has been made; people inquire for the safety of their relatives. All lights go out at the very beginning and the organization of a temporary lighting plant and the cleaning up of wires is of first importance when the darkness of night settles over ruins, where work has to continue with the aid of flares, and where valuables have to be guarded.

"Necessarily the Navy and shipping are of great use, and there were three ships which reached Napier. A small, compact, efficient, relief committee was found to be the first requirement at Napier and the organization of an information bureau to answer inquiries. Within a week when outsiders arrive to bring relief, there is need of quarters to correspond with the destroyed hotel, and there is need of increased wharf facility. Free meals have to be organized with the relief funds. Now there is need for a card record of hospital cases, of which there were 2,200 at Napier. The stoppage of the sewers and the bad water supply made it necessary to get together as many trucks as possible as soon as the road gangs had opened a way to get out of the district, and 5,000 people evacuated from Napier and Hastings to a neighboring town which had not suffered, Palmerston. Palmerston organized itself to receive the transport of refugees. There was an acute clothing shortage, and notices had to be placed in newspapers of other towns instructing the public what to send, for they sent too many groceries and too little clothing. The loss at the central towns was of the order of $15,000,000. Fire insurance was simply not paid, for the situation was just the same as at San Francisco and Tokyo, and companies when they do write



View of fuming SW cone taken from South. Distance about ¼ mile, February, 18, 1936.



SW Cinder cone Mauna Loa eruption of November 1935, as seen from N. February 18, 1936.

risks involving conflagration always reinsure with other companies. Only when earthquake is specified, and fire resulting from earthquake, and when these risks are paid for, can there be any expectation of restoration by insurance. **After the event** in all these cases, San Francisco, Tokyo, and Napier, insurance companies wrote earthquake risks. This is always done without any logic, on the part of the owners seeking insurance, who try to save the horses after the barn is burned down. Then after 45 or 50 years when there is real danger, everybody has forgotten it, insurance has been withdrawn, the building code has been relaxed, and it all happens over again. Such is human nature."

Dealing with the important subject of organization for preparedness Dr. Jaggar said:

"Every city should have a small committee of far-seeing men accustomed to administer discipline, representing commerce, public health, police and national guard, transport, and statistics. These people should have a clean-cut war problem with map of the city, just as war problems are worked out by General Staffs. The needs in time of disaster may be small or big, local or general, but the big possibilities should be looked at so that nobody will be surprised. The needs are:

(1) Organization of discipline and communication.
(2) Organization of rescue.
(3) Organization of relief.
(4) Organization of relief funds.
(5) Organization of camp for refugees.
(6) Organization of rebuilding.

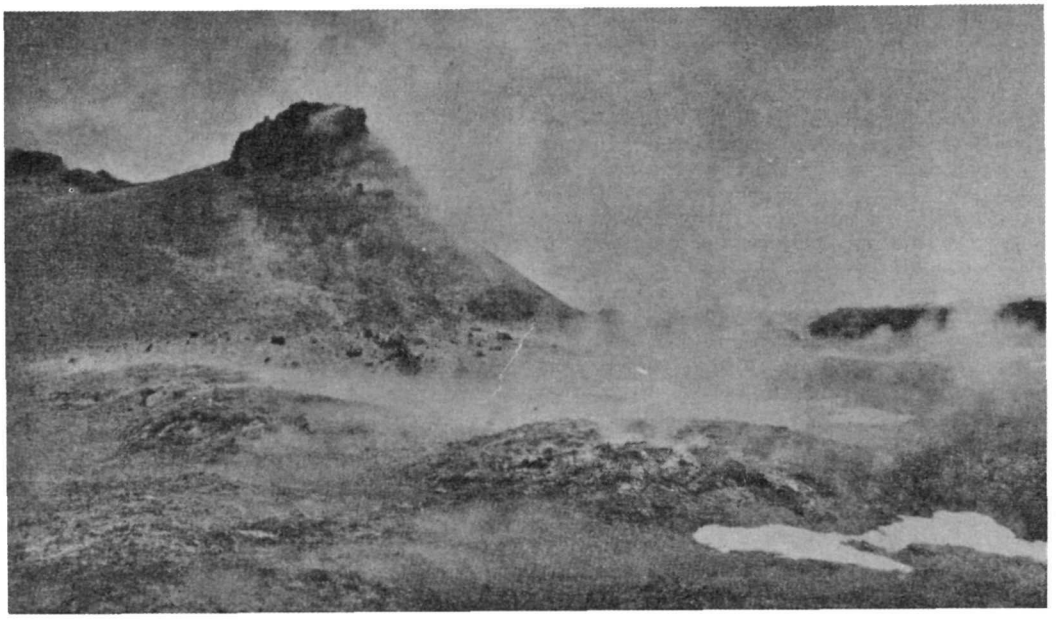
(1) Discipline and Communication

"This in Hilo would naturally fall to the Police service and the National Guard, and the communication side of it would call for the assistance and representation of the Naval and commercial wireless. Public Health agencies would be needed right away, and a representative of everybody possessing motor trucks.

(2) Rescue

"This calls for large forces of laborers and truckmen, the National Guard to protect property, Boy and Girl Scouts to act as messengers, all the auxiliary police available, and all the resources of the Red Cross, including everybody who has had any nurse training.

(3) Relief



SW end of cone showing major sulphur forming area, February 18, 1936.

"The prompt selection of camp grounds, creation of sanitation, and finding of auxiliary water, light if the main sources are destroyed, and assembling of food supplies have to be governed by circumstances. This sort of thing is best directed by some one familiar with organizing a camp on military lines and capable of enforcing martial law. There are needed food supplies, tents, surgical supplies, washing appliances, utensils, fuel, stoves, and competent cooks. Don't say 'get them at the hospital.'

"The natural reaction of a committee is to say, 'We have camp supplies in the armory, surgical things at the hospital, and trucks in the county stables.' Remember that for the extreme crisis contemplated, all three may be toppled over and burning, or under a laval flow, with 500 people dead, 1500 needing hospital treatment, and 5,000 homeless. The thing to face is the extreme possibility, the resources in water and supplies of Olaa and Hamakua, evacuation by sea to Maui or Kona, the place for a sanitary refugee concentration camp.

(4) Relief Funds

"There have been cases of disaster where relief funds have been misapplied. One of the first things to happen when a catastrophe is announced is for subscriptions from elsewhere to pour in. The Red Cross is the proper center, with reputable financiers to act as custodians of money.

(5) Refugee Camp

"Supposing Hilo partially destroyed under some great calamity, it is a matter of debate where to put a relief camp. The requirements are access to transportation, good water, supplies of food and clothing, policing, and communication by telephone and radio. If the wharves at Hilo were not destroyed or buried under lava, the place might be Waiakea or the airport. If a lava flow came through that side, the place would have to be in Hamakua."

WHAT MAY BE LEARNED FROM TILT

Tilting of the ground as recorded by the slow and persistent wandering of the recording pens of the seismograph bears an important relation to the whole problem of the movement of lava columns underground and therefore to the problem of forecasting of possible surface outbreaks.

Study of the records made at the Hawaiian Volcano Observatory during many years has shown that tilting away from the pit of Halemaumau has, as a whole, been correlated with rising of the lava column, while tilting towards the pit has usually marked retirement of the lava or has been pronounced at times of general collapse. The tilt at the Observatory appears to have a normal annual range of about 10 seconds of arc towards the pit (southwest) during the first half of the year, and a recovery during the second half. This, however, may not be strictly due to volcanic causes. Changes of temperature in the instrument room itself: of the ground upon which the Observatory stands, or of the face of the cliff near the buildings may produce tilting effect and so account in part for this annual change, though experiments have shown that it certainly is not a purely local movement. Volcanic conditions undoubtedly produce tilt, and these volcanic tilt effects are superimposed upon the tilts produced by other causes.

Quantitative measurements of the uplift and depression of the Kilauea dome have been made upon many occasions by means of precise spirit levels, and horizontal movement detected by a careful retriangulation of a network of stations about the pit also connected by precise levels. Such levels run in 1912, 1920, and 1927 have amply demonstrated the value of spirit levels as a means of detecting even small amounts of vertical displacement. The net of triangulation stations about Kilauea was first established in 1920 and connecting levels were run during the same period. Final adjustment of both surveys by the method of least squares was made by the computing section of the Geological Survey in Washington. D.C.

The resurvey of this net in 1927 and 1928 correlated most satisfactorily in its results with the general breakdown and depression of the Kilauea dome during the seven year period from 1920. Horizontal movement was shown to be a general pull-in of all points towards Halemaumau as a center.

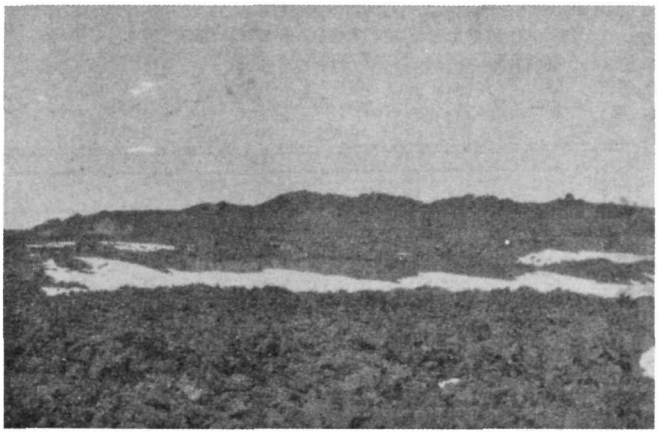
Similar repetitions of surveys have been made upon an extensive scale by the Japanese government in earthquake-stricken provinces, and the area along the San Andreas rift in California has been retriangulated by the U.S. Coast and Geodetic Survey. The results of these measurements, as of those in Hawaii—clearly demonstrate the amount of displacements of the earth's crust which took place during periods of disturbance. Some of these displacements were extremely small and required the most accurate of modern engineering methods to detect: also, the surveys were made after the greatest movement had occurred. But the lesson to be learned is that by applying the same methods at regular intervals it may be possible to predict the likelihood of earthquake—or what more closely concerns us in Hawaii, the rise of the Kilauea or Mauna Loa lava columns.



Rift looking toward SW base of SW cone, February 18, 1936.

The measurements in California or Japan have been concerned partly with earthquakes of tectonic origin, and as these are caused by continued long strain and warping of the earth's crust over a number of years until the breaking point is reached, it follows that periodic surveys of known active fault areas may be of the utmost value, in the prediction of approaching disturbances. Here in Hawaii it would be necessary to correlate such measurements with data from the seismograph or tilt-meter and to continue it through two or more active phases since the actual tilt of the ground from day to day is small and not perceptible except by magnification. However, cumulative tilt is undoubtedly a measurable quantity, and since accumulated tilt away from the Halemaumau pit has been shown generally to precede an active period, it is logical to assume that measurements of the relative change in elevation of established bench-marks together with the measurement of the horizontal angular change between such points would give a more firm basis for prediction.

With this end in view, new stations were established about the rim of Halemaumau. One of these adjoins the pit seismograph cellar—the others forming a rough square spanning the crater, and being triangulated for any immediate emergency. Horizontal angles were observed by a repetition with a Berger transit graduated to 20 seconds. Each angle is observed 12 times, six times in a clockwise direction, three settings made with telescope direct, and three reversed, both verniers being read. The angle is then measured in a similar manner but in a counter-clockwise direction, the mean of the 12 readings giving the correct angular value free from instrumental errors. Horizon closures are made the same way. Particular care must be given to the centering of the instruments over their respective marks.



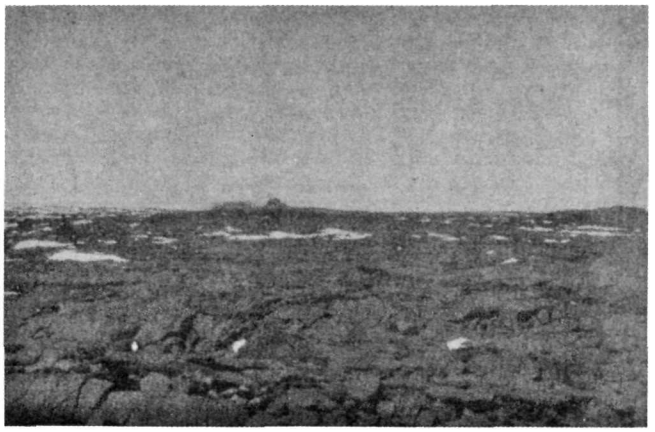
View of SE cone Mauna Loa, February 18, 1936, as seen from S.

The measurement of rim cracks around Halemaumau has in the past proved of scientific interest, as well as of value to the public in marking off weak or dangerous sections about the pit. This precaution is highly necessary as Halemaumau is the main attraction to all visitors to the Hawaii National Park and is reached directly by automobile from Hilo—the seaport city on the coast at the foot of Kilauea mountain. As one of the world's most stupendous windows into the molten heart of the globe, it attracts thousands of visitors throughout the year, any unusual activity causing an influx of tourists and island people whose safety must be carefully considered.

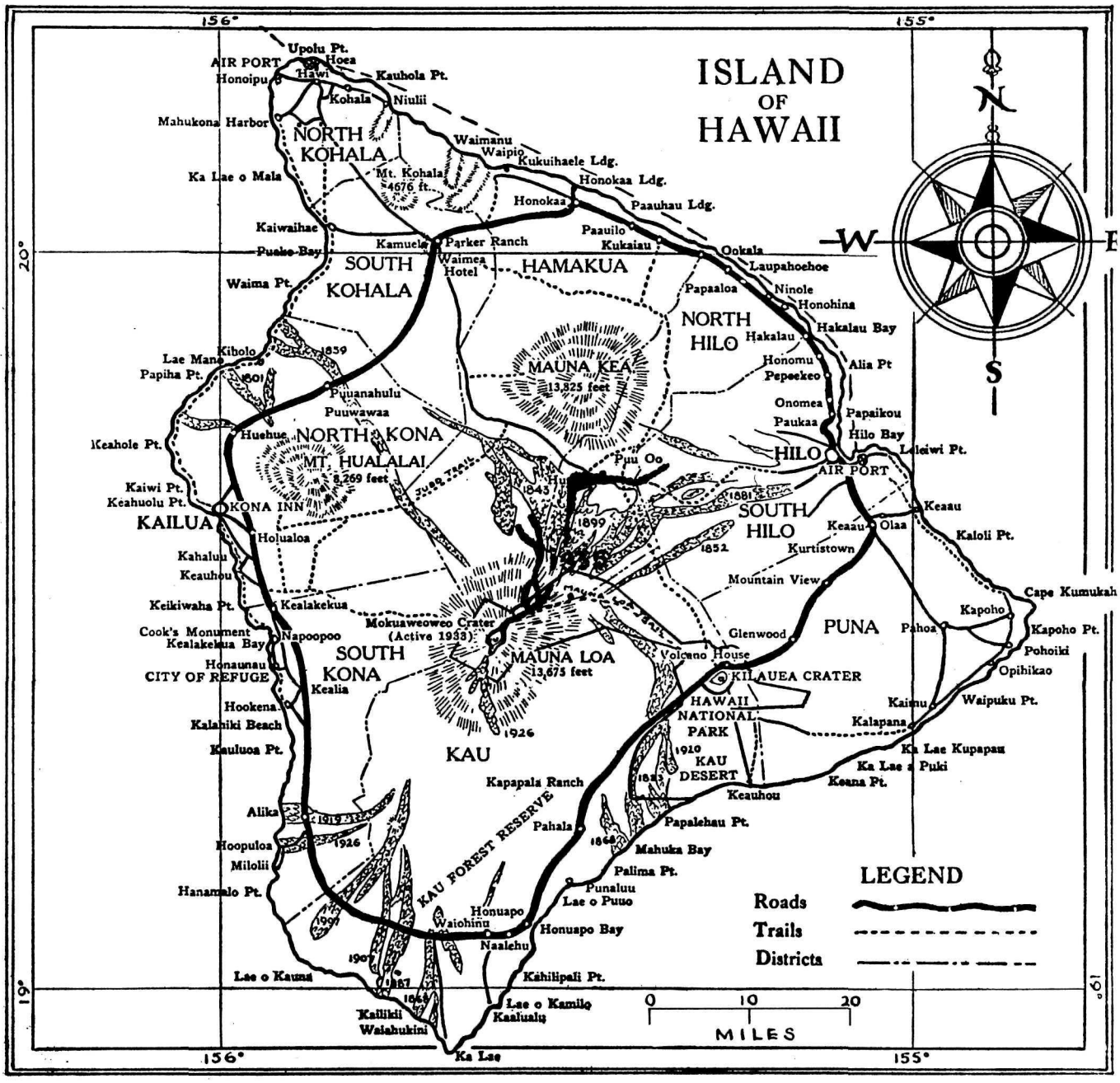
Measurements of rim cracks however, are not always meticulously accurate, instrumental errors amounting to as much as two or three millimeters having occurred, owing to the uncertainty of exact points of measurement as well as to the inaccessibility of some of these points. Measurements must be made from new points as may become necessary and new methods of measuring must also be devised. Tumescence of the Kilauea dome as the result of rising lava has its effect upon the more deep-seated fractures, the lifting of the lava column upon various occasions causing a widening of the superficial rim cracks with sections breaking off and avalanching into the pit.

But as a part of the complicated, process of volcano study, observation of the tilting of the ground is a highly important factor.

E.G.W.



General view from SE of fountain area of Mauna Loa eruption, February 18, 1936. SW cone is to left and NE cone to right.


ISLAND
OF
HAWAII
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156°
155°
20°
19°
Upolu Pt.
AIR PORT
Hoea
Hawi
Honoipu
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH
KOHALA
Waimanu
Waipio
Kukuihaele Ldg.
Honokaa Ldg.
Ka Lae o Mala
Mt. Kohala
4676 ft.
Honokaa
Paauhau Ldg.
Kaiwaihae
Puako Bay
Kamuela
Parker Ranch
Waimea
Hotel
SOUTH
KOHALA
HAMAKUA
Paauilo
Kukaiau
Ookala
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH
HILO
Hakalau
Hakalau Bay
Lae Mano
Kibolo
1859
Papiha Pt.
1801
MAUNA KEA
13,825 feet
Honomu
Alia Pt
Pepeekeo
Puuanahulu
Puuwawaa
Onomea
Papaikou
Paukaa
Hilo Bay
Keahole Pt.
Huehue
NORTH KONA
MT. HUALALAI
8,269 feet
Puu Oo
HILO
AIR PORT
Leleiwi Pt.
1843
1881
Kaiwi Pt.
Keahuolu Pt.
KONA INN
KAILUA
1899
SOUTH
HILO
Keaau
Olaa
Kaloli Pt.
Holualoa
1852
Kurtistown
Kahaluu
Keauhou
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Mokuaweoweo Crater
(Active 1933)
Cook's Monument
Napoopoo
Glenwood
PUNA
Pahoa
Kapoho Pt.
Kealakekua Bay
SOUTH
KONA
MAUNA LOA
13,675 feet
Volcano House
Pohoiki
Honaunau
CITY OF REFUGE
Kealia
KILAUEA CRATER
Opihikao
Hookena
HAWAII
NATIONAL
PARK
Kaimu
Waipuku Pt.
Kalahiki Beach
1926
Kalapana
Kauluoa Pt.
1910
KAU
DESERT
Ka Lae Kupapau
Ka Lae o Puki
Kapapala Ranch
1823
Keauhou
Keana Pt.
KAU FOREST RESERVE
Alika
1919
Pahala
Papalehau Pt.
1868
Hoopuloa
1926
Mahuka Bay
Milolii
Palima Pt.
Punaluu
Hanamalo Pt.
Lae o Puuo
Honuapo
1907
Waiohinu
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Naalehu
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LEGEND
Roads
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MILES

THE VOLCANO LETTER

NO. 433—Monthly, Dept. of the Interior, National Park Service, March, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR MARCH, 1936

VOLCANOLOGY

Activity at Halemaumau during March was marked by increased seismic activity the middle of the month followed by a sudden decrease the latter part. Numbers of slides from rim walls increased as did the size of individual slides. The peak of seismic activity was reached the afternoon of March 12, when three feeble earthquakes within one hour's time shook the Kilauea District. Their location was apparently under the East Rim of the Crater S of Kilauea Iki. The significance of the shocks of the second and third weeks of March and the quiet of the fourth week is probably a sinking of the deep lava under Kilauea as a reaction from similar sinking under Mauna Loa. This period of activity was closed with a feeble earthquake, March 21. Much of the seismic activity of the third week was the result of unusually heavy sliding of Halemaumau walls thus producing a large number of tremors on the Observatory record. Large sections of the NE rim fell into the Pit greatly increasing NE talus accumulations on the edge of the lava floor. A section of the rim bounded on the NE by one of the regularly measured cracks disappeared between March 15 and 22. This was discovered March 22, when making the regular rounds of crack measurements and the SW side of the crack was found to be missing. The distance from the former crack to the previous edge of the Pit was about thirty-five feet. The length of this section may have been two hundred feet. It is interesting to note that this excessive rim sliding is at the NE side of the Pit which is thought to be in the vicinity of the emergence of Crater rifts from the NE. The receding lava column suggested in the review of the earthquakes, may have caused movement in the rift region thus precipitating sections of the Pit walls in this weakened zone. Nearby Crack No. 46 opened considerably. Excepting these two cracks, it was noticed that an abnormal number of other concentric cracks had closed. An analysis of this condition further tends to confirm the supposition that lava was receding below Kilauea and Mauna Loa. Reference to records of 1935, show that heavy sliding occurred during the latter part of March and continued into April and May. At that time the SSW wall of the Pit was in the active center of avalanching. As was true of the same

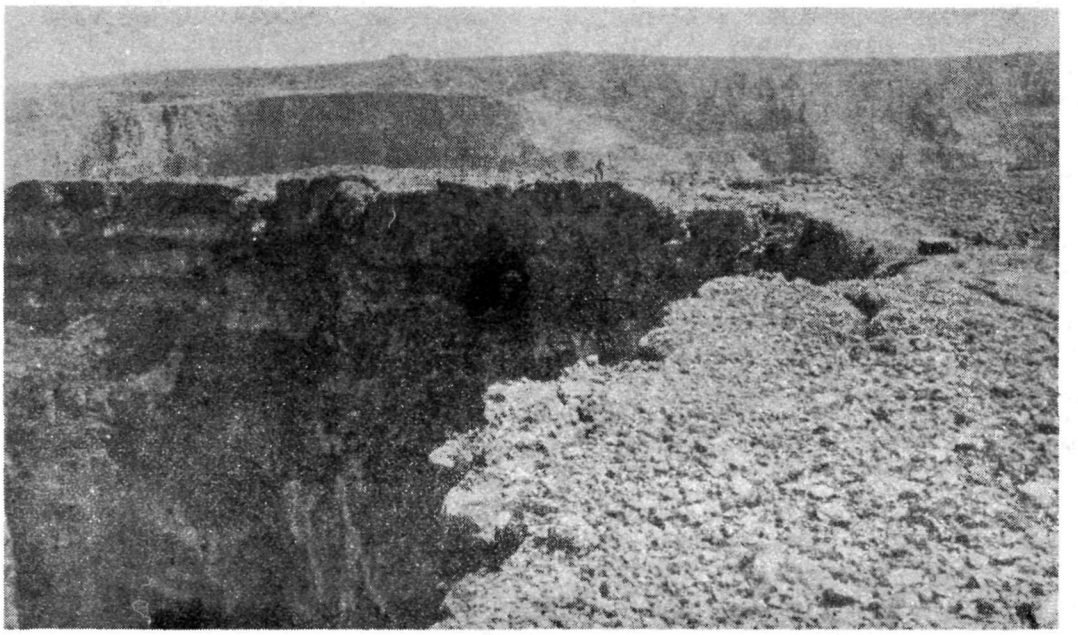


Fig. 1. Section of Rim of Halemaumau showing bay largely formed by the falling of masses of wall rock. Note figure of man for comparison with Fig. 2.

phenomena this past month, last year seismic activity increased in a manner similar to this year because of tremors resulting from heavy rock falls. The 1935 series of slides were to the west of the point of emergence of the Kilauea SW rift at the Pit. The points of greatest avalanching were at opposite ends of the Pit but both were associated by proximity to the main crater rift system. The occurrence of each at approximately the same time of year may be of significance demonstrating possible annual lava movements or pulsations of like nature.

Fume from the yellow solfataras around the edge of the floor of Halemaumau continued emitting bluish fumes with apparently little change throughout the month. Fuming was reported as very light at 9:50 am, March 29. The day was clear and a moderate wind was blowing from the NE.

Fuming of the source cones of the 1935 eruption at 12,000 feet on Mauna Loa has died down considerably as no fume was observed from the Observatory after the first week in March.

The summary of these events in each case tends to show a lowering of the lava column and or pressures under Mauna Loa because of:—

1. Earthquake shocks and high seismicity followed by a sudden drop in seismicity;
2. Slides in Halemaumau from probable lowering of Crater floor;
3. Closing of more than the usual number of cracks and,
4. The disappearance of fume on Mauna Loa as seen from the Observatory.

KILAUEA OBSERVATIONS

Slides at Halemaumau

Slides at Halemaumau have been noted as follows:—

March 7, small slides from N wall at 9:58 and 10:35 am.

March 4, at 9:46 am, small slide from N wall and from fresh dust on floor probable slides from SE and NE wall within last 24 hours.

March 13, fresh scar about 500 feet below NE rim, fresh talus at foot of wall and fresh dust on floor seen at 9:48 am, indicate large slide during preceding night.

March 17, at 10:13 am, slide from NE wall about 200 feet below rim.

March 18, sliding from NE wall noted as follows: loud noise of falling rocks indicating large slide heard at Pit seismograph station at 9:56 am; 10:06 am, small slide; 10:10 am, heavy slide followed by another small one at 10:14 am. A very heavy slide occurred about two-thirds of the way up Pit wall at 3:20 pm. This was followed by a larger one at 3:32 pm, leaving a large apse like embayment at same point as 3:20 slide. Continuous trickle of small rocks interrupted by large sliding bowlders from time to time was observed between 3 and 3:45 pm.

March 19, continuous trickling of rocks from NE wall about 9:30 am.

March 20, much noise and trickling of rocks from NE wall at 9:58 am.

March 22, small slide from NE wall at 9:48 am. Dust cloud over Halemaumau as seen from Observatory at 4:36 pm indicated sliding.

March 23, rocks trickling from NE wall at 9:57 am; noise and trickling of rocks from NW wall 10:05 am; dust clouds at 12:40 pm and 12:51 pm seen from the Observatory indicate moderate slides in the Pit.

March 25, slide from NE wall at 9:40 am.

March 29, small slide from NE wall at 9:50 am.

Halemaumau Solfataras

Observations of the sulphurous fumaroles around the edges of the Halemaumau floor, and of the vapor cracks have been as follows:—

March 17, fume very slight, 10:13 am. Weather: light NE wind with rain and high humidity.

March 20, strong fume from yellow solfatara below Tourist Lookout 9:58 am. Lt. SE wind, heavy fog and mist, and high humidity.

March 29, fume very slight at 9:50 am from all solfataras. Weather clear, moderate humidity and wind was moderate NE.

Note:—Weather is an important factor in observations of fume as all the variable factors may influence its appearance so that the same amount of fume may appear different depending upon immediate meteorological conditions. That is to say, that for a given amount of fume, it appears to increase with an increase of humidity which of course increases directly with fog and rainfall. Thus, the greater the percent of moisture in the air, the greater the volume of fume seems to be. The lower the temperature, the greater the fume, and temperature also affects humidity. The lower the temperature the greater the relative humidity. Wind direction and strength will affect air currents in the Pit, thus at times disseminating the fume more or less rapidly as the case might be so that the location of the vent may be protected from the wind one day and not the next. There is always more fume visible on a quiet day than on a windy day. From this it can readily be understood that for comparative results on fume visibility care must be taken to consider weather conditions at the time of observation.

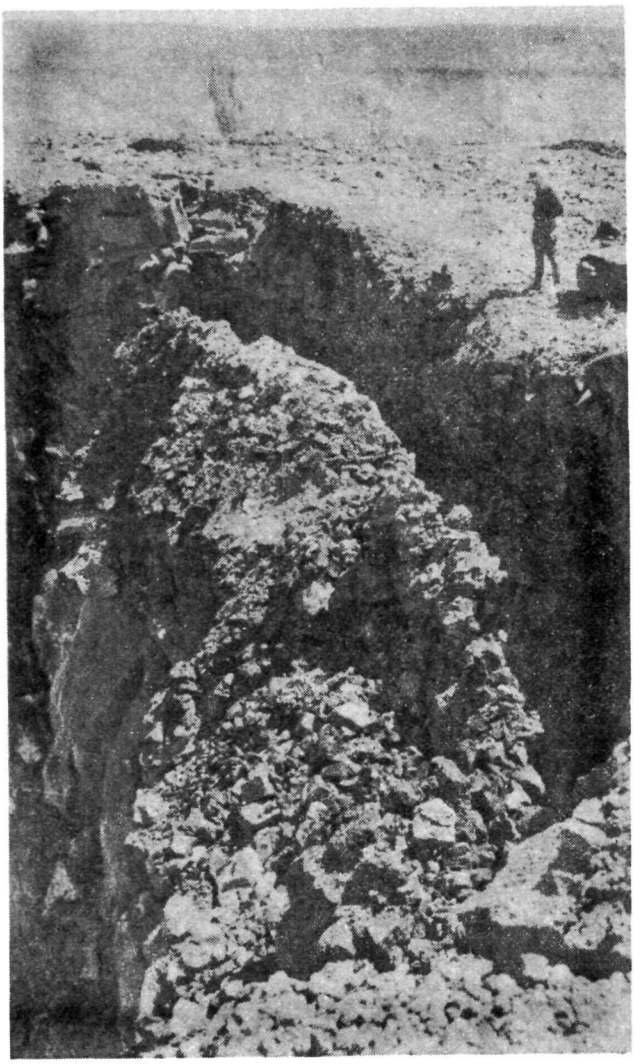


Fig. 2. Detail of condition of rim as shown in Fig. 1, in front of observer illustrating probability of further collapse.

Measurements of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

	Opened	Closed	Aggregate Opening
March 7.....	16	0	21.0 mm.
March 14.....	14	0	54.5 mm.
March 22.....	4	8	6.5 mm.
(31 cracks as No. 34 had disappeared)			
March 28.....	13	2	14.0 mm.
(31 cracks)			

Cracks No. 46 and No. 34 combined, contributed 10.5 mm. of the total amount for March 7, and 47.5 mm. of the total for March 14. As previously stated Crack No. 34 was eliminated by sliding during week preceding March 22.

Crater Angles

The horizontal angle measurement across Kilauea Crater and Halemaumau for March 16, taken from the Observatory, compared with similar measurements for February 20, showed closing of the angles in all cases. Between SE and NW Rims of Kilauea there was closing of 4.2". Between the SE and NW Rims of Halemaumau there was closing of 0.8". Accompanying this marked closing of the Crater angles there was much sliding of rock from the walls of Halemaumau.



Fig. 3. Rim Crack #46 at point where weekly measurements are made. This crack has continued opening of 4.5 millimeters per week for the past two months.

SEISMOLOGY

Earthquakes

Table

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Distant earthquakes	Local * Seismicity
Mar. 8	31	4	0	0	1	9.75
" 15	22	5	0	3	0	14.00
" 22	52	7	1	0	0	17.50
" 29	26	4	0	0	0	8.50

*—For local seismicity see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station located at the Observatory and the two subsidiary stations located at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and, whenever such determinations were possible, the depth of focus is given.

March 3, at 1:36 am, very feeble, probable location under N rim of Halemaumau, Kilauea Crater.

March 5, at 7:31 am, very feeble, located 1.6 miles deep and 1.8 miles E of Pit Seismograph Station. 19° 24'.4N; 155° 15'.4W.

March 6, at 5:33 pm, very feeble, probable location under SW rim of Halemaumau.

March 9, at 2:15 pm, very feeble, probable location under SE portion of Kilauea Crater.

March 10, at 12:59 pm, very feeble, probable location under E slope of Hualalai volcano.

On the afternoon of March 11, there were three slight earthquakes all of which were sharply felt in the Volcano District by many people. The first one of the series began at 4:15 pm; it was located 1.1 miles deep on the East rim of Kilauea Crater and 0.6 mile S of Kilauea Iki; 19° 24'.5N; 155° 15'.1W. The second shock followed at 4:54 pm, and was located 1.5 miles deep and 0.7 mile S of Kilauea Iki, 0.6 mile E of the E rim of Kilauea Crater; 19° 24'.4N; 155° 15'.0 W. The third shock at 4:55 indicated the same location as the preceding. Very feeble shocks registered on the Observatory seismograph at 4:19 pm and 4:49 pm. They were apparently associated with the disturbances which caused the heavier shocks.

March 21, at 3:50 pm, a feeble earthquake began to record. The probable location was deep under the west slope of Hualalai Volcano.

March 22, 5:44 am, very feeble, located 35 miles under Mokuaweoweo Crater of Mauna Loa. 19° 26'.5N; 155° 35'.8W.

March 23, at 8:19 am, very feeble, probable location, deep under Kilauea Crater.

March 25, at 2:34 am, very feeble, located 3.0 miles deep and 1.2 miles E of Puhimau Crater in SE Kilauea Rift zone. 19° 23'.8N; 155° 14'.0W.

Several spells of harmonic tremor occurred during the month. Sixteen minutes of such continuous tremor began recording on the seismograph at 7:05 am, March 8. Four minutes were recorded beginning at 5:04 am, March 17, and on March 24 at 11:58 pm, an eleven minute spell began, lasting until 12:09 am, March 25. These tremors were similar in every way to those accompanying volcanic outbreaks of Mauna Loa and possibly are caused by lava movements underground.

The surface waves of a distant earthquake began to record at 8:06 pm, March 4.

Microseismic motion of the ground at the Observatory was light March 9 to 11, and 26 to 29, inclusive. It was normal March 2, 4 to 8, 12 to 15, 17 to 19, inclusive and was strong the remaining days of the month. —H.H.W.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE Rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope locations, towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending March 29, was 3.37″N and 2.88″E.

Table of Tilt

Week ending	Observatory	Halemaumau West	Halemaumau Clinoscope Stations Southeast	Pit resultant
Mar. 8	2.12″N 77°E	10.79″N 60°E	3.58″N 29°W	2.63″†
Mar. 15	0.76″N 13°E	3.73″N 33°E	1.64″S 64°W	0.19″†
Mar. 22	2.84″S 54°W	24.95″S 37°W	2.09″S 75°W	9.35″†
Mar. 29	0.12″W	8.75″N 16°W	7.36″S 89°W	0.80″§

† from. § toward. —H.H.W.

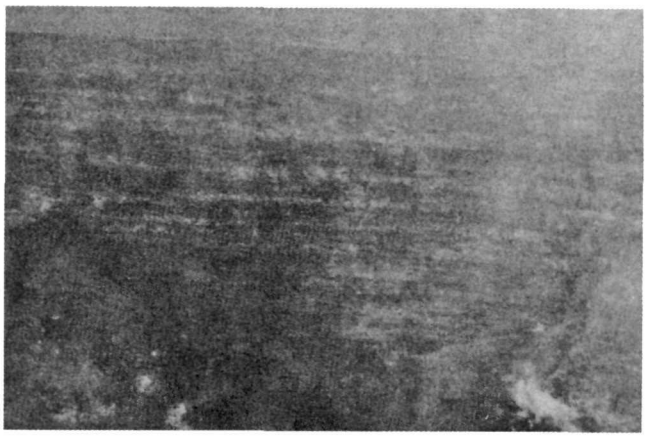


Fig. 4. Cascade of 1934 flow showing conditions prior to the heavy avalanching of 1935.

A TRIP UP THE 1935 MAUNA LOA FLOW

On the morning of March 1, 1936, Dr. T. A. Jaggar and H. H. Waesche of the Volcano Observatory left Kilauea for an exploration of the Mauna Loa flow of November-December 1935. The objective was to be the source vent at about 8,500 feet elevation on the N slope of Mauna Loa. This locality was of added interest because it was the scene of the bombing operations of December 27. The night was spent in the Forest Reservation west of Puu Huluhulu.

At 8:00 am, March 2, approach to the edge of the flow was made as nearly as possible by car. The weather appeared unfavorable for the expedition as it was raining heavily and there were no signs of a change. To attempt the trip over still warm lava flows would have been dangerous as steam or fog would be created, lowering visibility to a point where travelling would be slow and directions uncertain. This situation caused abandonment of the trip for the day. However, exploration of the pahoehoe in the vicinity about one mile west of Puu Huluhulu was made. From this area, a tongue of pahoehoe, hitherto unnoticed was seen extending about a mile to the west. It had stopped about two miles southwest of Puu Huluhulu and immediately S of the Omaokoili Hills. It was of interest in that this lobe had evidently been stopped by 1843 aa and thus dammed, was prevented from moving farther to the west and consequently caused a filling in of all the low areas of the Humuula Ranch land before finally extending itself eastward and then advancing rapidly toward the upper source of the Hilo water supply. The new pahoehoe, although formed in the third week of December was still warm and in some places quite hot. The hotter spots may have been localities of greater thickness of lava or may have been caused by chemical reactions still progressing, particularly within the remains of buried vegetation. Cooling had contracted the lava so that many cracks had been formed and some were emitting fume or vapor or both which was depositing sulphur and white salts along their surfaces. In some cases the red color indicating selenium was seen. The fuming hot spots seemed to be more common near the edge of the lava bordering the grass lands thus supporting the idea that some of the heat was possibly the result of chemical activity between the lava and covered vegetation. The trace of a former stone wall was crossed. The location of the wall could readily be followed along its former line. In some places this wall had been pushed over by the force of the advancing lava but more often the pahoehoe had frozen on the S side of the wall thus strengthening it so that the lava was either locally diverted or forced to build up to the height of the wall and then cascade over. Where this latter had happened the wall was completely invisible but was marked by a change in the character of the lava along its course. Where the lava had been diverted, the wall was visible on the N but usually buried on the S side. The exploration was continued until the main river channel of the flow was reached about two miles SW of Humuula. It was decided that the frozen surface of this river would make the best path of travel in reaching the source vents and would be so used when the weather permitted. At this point, the river channel was about thirty feet in width and its surface was more or less corrugated as seen in the photograph with the corrugations running in the direction of flowage. As the weather still showed no signs of change, the party returned to the car and back to Waimea Hotel.

The weather seemed very unfavorable again on March 3, so that continuation of the trip was postponed until March 4. On this date however, it was decided to make the hike up the flow even though the weather still was not too favorable. The start was made from an edge of the flow near Puu Huluhulu. The pahoehoe here was the typical billowy type and was comparatively dense so that at no time did it give way under foot as is so often the case with shelly pahoehoe usually encountered near source vents. After walking about a mile the



Fig 5. Talus slopes in Spring of 1935 covering cascade shown in Fig 4.

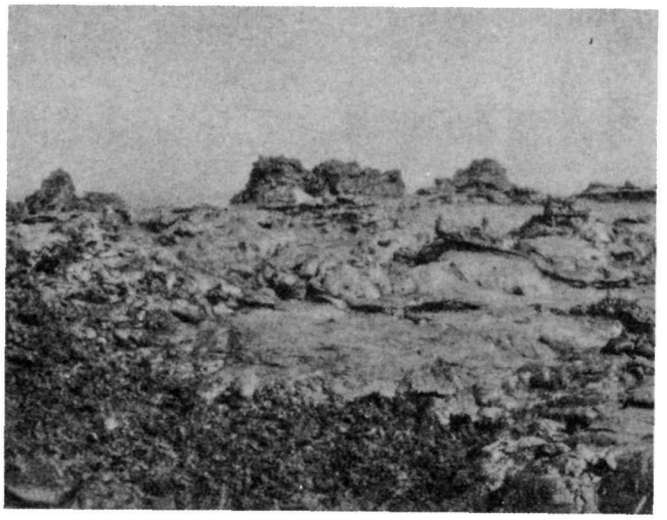
frozen surface of the former meandering lava river was encountered. The river varied in width from a few feet in some places to as much as one hundred and fifty in others. As is true of rivers of water, the lava river was narrower and straighter on steeper grades whereas it meandered and was wider on the more level portions. It had built up more or less natural levees at each side, 5 to 25 feet high, making the flow higher than its surroundings. The pahoehoe on each side of the river was much broken and contorted and in some places the location of the actual river was not identifiable because of the broken condition of the surface of the entire flow. Hiking was comparatively easy. Along the river course there were to be seen interesting peculiarities such as cascades

and as shown in accompanying photograph, the frozen design of a former cascade with a whirlpool at its base. The boundary to the east was either 1935 aa, pahoehoe of the 1899 flow or very old light brown pahoehoe. To the west the river boundary was either 1935 aa or aa of 1843, mostly the latter. The 1935 pahoehoe as seen along the river was either black or bronze in color and billowy as it had been at the start of the hike.

After climbing up grade for about five miles, the slope became steeper. From this point on, the river's course was marked by frequent yawning holes of various shapes and sizes from a few feet to thirty. They connected with a lava tube below. The lava tube was apparently the location of the former very active liquid stream which had fed the front of the flow far below during the height of the activity. Its floor was five to possibly fifteen feet below the surface of the river. Intense heat poured from practically all, making exploration either very difficult or impossible. The holes were the result of the caving-in of weak portions of the tube roof. After hiking about seven miles from the starting point, a place was found where the roof of the tunnel had caved in leaving a pit about fifty feet long and about thirty feet wide. At each end the openings of the tube were seen. The one to the north was too hot to be approached but the one to the south was cool. Camp was made in this cooled portion of the tube. The floor was covered with slabs of material which had fallen from the ceiling. In many places slabby portions of the roof seemed most precariously perched and ready to fall at any minute. Lunch was partaken of and then the hike continued about two miles farther up the flow. A point was reached where the going was difficult as the lava became broken and slabby with many patches of aa. The main source vent was still to be seen between one and two miles farther along. To the SW could be seen fume and steam rising from a distant portion of the 1935 flow. In the immediate vicinity and on up to the main source vent, bluish fume made the air somewhat hazy. It was at this locality that depressions and craterlets showed an interesting variety, showing characteristics of eruptive activity, such as might be caused by bombing and in other cases, collapse seemed to be the cause. In all cases there had been fresh outpourings of smooth pahoehoe as seen in photos No. 1 and 2. No. 2 shows a typical depression and No. 1 shows the downstream flow of pahoehoe which had welled out of the depression. It was at first thought that these might be bomb craters. Later determinations showed this to be incorrect as the locality was not one of those bombed. After abandoning attempted continuation of the exploration for that day because of rain, camp was made in the tunnel at the place previously mentioned. During the night booming sounds with a slight jarring motion of the lava issued from the flow. These were apparently caused by more rapid cooling of the lava at night with consequent shrinkage.

On the morning of March 5, the main lava river was left in favor of a small more easterly arm of pahoehoe which led directly to the lower bombing locality. This locality consisted of a large heap of lava both pahoehoe and aa through which ran a channel, the former path of the main lava stream and the target of the army bombers. The floor of the channel was about thirty feet below the surface and was about fifteen to twenty-five feet in width. Observation of the channel could be made through much elongated openings or windows along its course. Wherever one of these windows was discovered, large amounts of pahoehoe and lava veneer surrounded it apparently having flowed from the vent at a very late period of the eruption. As this region was a part of the bombed area further discussion of its nature will be left to future articles concerning the results and other data related to the unique experiment of bombing a lava flow.

The uneventful hike back to Puu Huluhulu ended a most interesting and profitable trip up the still hot course of the river which fed the main Mauna Loa flow of 1935.



Pahoehoe which had flowed from craterlet of picture below.

LASSEN VOLCANO — CALIFORNIA

Attention has been drawn to Lassen Park at this season by the large number of earthquakes recorded in this area. Many of the newspaper reports have been exaggerated and without scientific foundation. Speculation and prediction have been rife and those not familiar with the situation may be led to believe that the volcano is about to burst forth into cataclysmic activity. Under those conditions, an impartial description of the present status of Lassen Peak as a volcano, so far as can be determined from its features and activities, may be of value.

Since the 1917 activity of Lassen Peak, more than thirty constantly active fumaroles have been present on or near the summit. These fumaroles are located in and around the 1915 and 1917 craters and consist of steam issuing from fissures in the dacite. Some H_2S and SO_2 gas is present but is usually just barely noticeable. Sulphur deposits are present around some of the vents but there are no evidences of recent sulphur deposition. There are no hot springs, mud pots, or other solfataric features present, and the steam vents may not be noticed by the casual observer, especially on a warm, dry day when the steam is quickly evaporated and dissipated.

Observers in the vicinity of the base of the peak have noticed an unusually large amount of steam coming from these fumaroles this spring. Jets of steam, probably two or three hundred feet high are observed frequently from Manzanita Lake, four miles from the summit. On several occasions clouds, perhaps partly composed of steam, have been seen hovering over the craters on quiet, moonlit evenings. These phenomena have not been unknown in the past, but they are much more frequent this spring.

In an effort to ascertain the cause of this seemingly unusual activity, Park Naturalist Swartzlow and the writer recently climbed to the summit of Lassen Peak. The craters were carefully inspected and special attention was given the fumaroles. So far as could be determined, there are no new steam vents present and the known fumaroles are not emitting excessive amounts of steam. Having inspected the area under various conditions more than 100 times during the past three summers, the writer feels qualified to state that there are no obvious reasons for believing that Lassen Peak or its fumaroles are more than usually active. In fact, on several damp, cold days last season, there was much more steam visible than on the occasion now referred to.

The writer also inspected the hot springs at Bumpa's Hell to see if they were unusually active. They were reported to be excessively violent this year and it was thought that there might be some connection between the recent earthquakes



Showing one of the craterlets.



Cascade and whirlpool in lava river of 1935. Mauna Loa Flow.

and their activity, since they are probably located on a fault which may be active. However, the hot springs, mud pots and fumaroles seemed to be normal in action. Since features of this kind are probably dependent upon surface water, they are naturally more active when the snow is melting rapidly in the spring and early summer than later when the supply of water is small.

The appearance of an unusual amount of steam from the fumaroles this year is probably due to atmospheric conditions. During the past six weeks, the weather has been unusually cold and damp and there has been little wind. Such conditions prevent the rapid evaporation and dissipation of steam and increase its visibility so that the normal quantity appears much greater.

One cannot say that Lassen Peak will not erupt tomorrow because no one can see what is transpiring below the surface and our seismographs are poor indicators of subterranean activity. However, there have been no surface indications that any unusual activity is present or is about to begin.

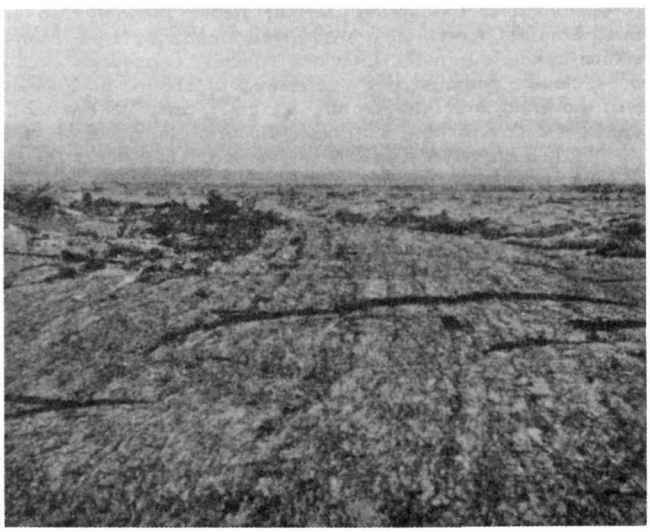
—By Russell Farmer, Ranger Naturalist.

HOW TO MAKE A SIMPLE SEISMOGRAPH

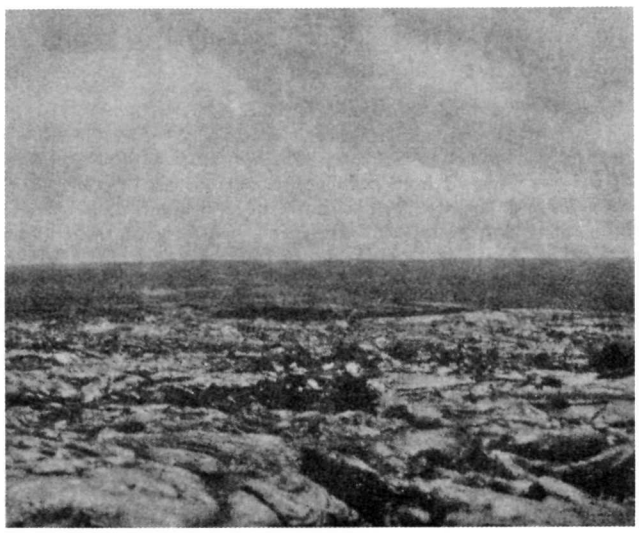
From time to time the Hawaiian Volcano Observatory receives inquiries from students and other interested persons upon the method of construction of a simple earthquake-recording instrument that—while not possessing the refinements and high magnification common to costly apparatus, shall, nevertheless, show practical results for ordinary purposes of daily observation.

Since such inquiries have become increasingly frequent during the past few months and it has been impossible to reply to all of them in full detail—we here present a brief working plan from which, with a little patience and ingenuity, a satisfactory seismograph may be constructed, using only the most simple of materials and avoiding the necessity of outlay upon expensive equipment.

The seismograph in most common use is a horizontal pendulum. Figure 1 shows the hanging part of such a pendulum which anyone can make for himself. There is here shown a clock on the wall which is a good timepiece made by the Howard Company in Boston, Mass. This is fitted with electrical contacts closing the circuit of a four-cell dry battery for about



Lava river of 1935. Mauna Loa Flow.



Looking upstream. 1935 Mauna Loa Flow.

two seconds every minute and about six seconds every hour. It is a weight-driven pendulum regulator with eight-day movement. The electrical contacts on the minute and hour are for marking the time continuously on the smoked paper which covers the drum of the seismograph, so that any hour or minute may be identified on the paper for discovering the time when an earthquake has marked the paper.

On the left is shown a concrete post in a basement room with an upright hollow or groove cast at the bottom where the post rises from a concrete table or pier. It is better to have the cylinder as shown hanging from an isolated post than to hang it from the wall. We have tried both plans for

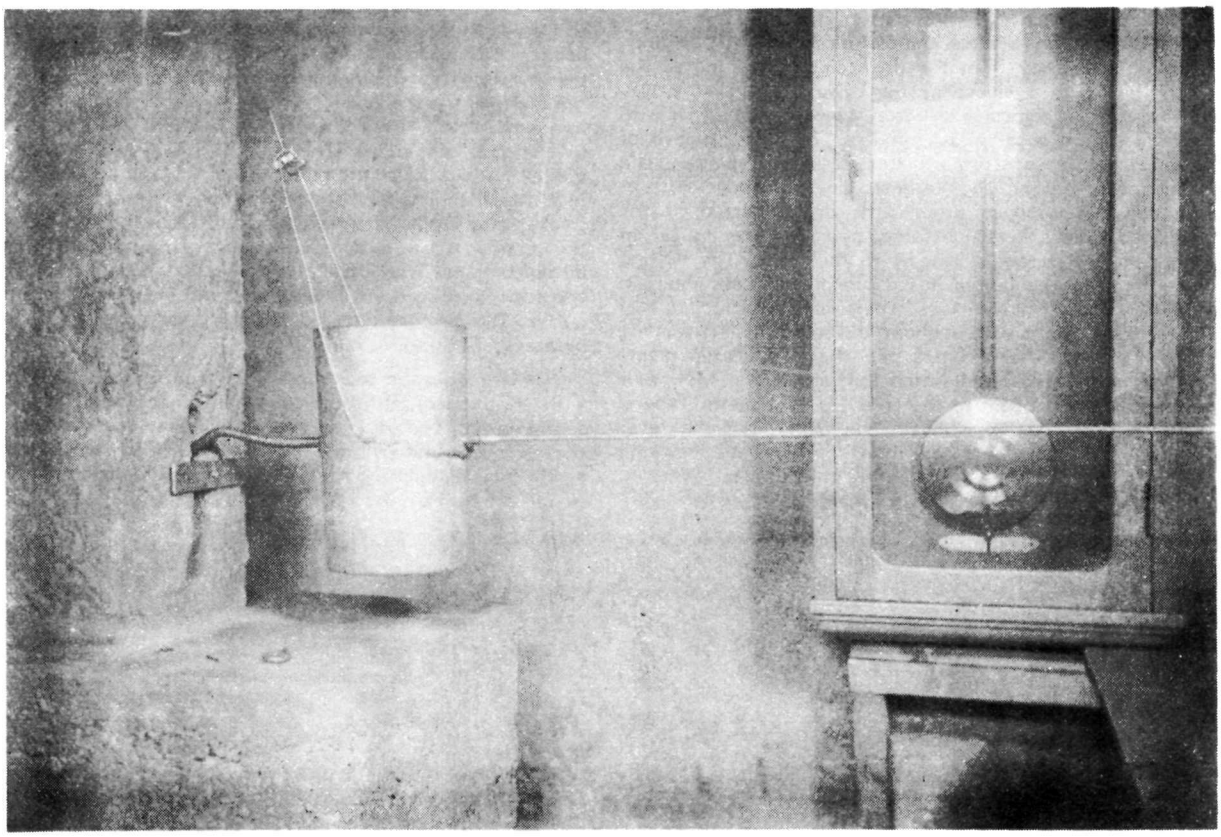


Fig. 1. Showing concrete pier and post—heavy mass suspension and boom and the Howard Clock.

different instruments at the Hawaiian Volcano Observatory. As the hanging cylinder is very sensitive to the slightest tilt given to its supports, walls are not desirable. The upper part of the concrete wall of a cellar on the outside of the building is heated by the sun for some parts of each day. The heating expands the wall and it cools at night, thereby contracting. The seismograph is so sensitive, magnifying earth motion some two hundred times in case of a horizontal displacement, that the distortion of the wall under expansion and contraction will cause the writing pen to swing sidewise an inch or more in the course of a day. This causes the lines to interfere and interlace with each other. A certain amount of normal tilting of the ground is to be expected in the course of each day anywhere, and it is likely to be exceptionally big at an active volcano. Therefore we do not want any tilting due to solar heating of the house. What tilting we get, measured by the swinging apart or the close approach of the lines, should be indicative of what the actual ground is doing under the whole country, and therefore is measurable for the particular two directions in which a single horizontal pendulum swings.

The dimensions of the cellar shown in the picture are ten by ten feet, and the general plan of the instruments followed the lines of the Omori seismograph. The concrete post, ten by ten inches square, stands 27 inches high above the pier which is 18 inches high above the floor and two feet square. The cylinder consists of a cast-iron container holding nine circular lead discs, which make the whole weigh 225 pounds. The lead discs are each bored and threaded in the center to take a large screw-eye, so that the container can be handled by one man by lifting the discs out or putting them in separately.

An iron rod, bigger near the post, and smaller at its outer end, passes horizontally through the middle of the heavy mass or cylinder. This protrudes 52 inches from the center of the cylinder. The bit end of the rod is bent and lies in the niche at the base of the post, supported by a short hinge of spring-steel wire. This wire hinge is terminated by metal balls in two slots cut with a hack-saw. One of these slots is in the flat iron strap shown pinned across the niche, the other in the bent end of the rod. The heavy cylinder is supported by a stirrup hanging from a piano wire which is made fast to a simple adjustable bolt in two angle irons pinned to the top of the concrete post. For these attachments to the post it is convenient to use expansion bolts, which are readily put in holes drilled in the concrete. The adjustments of the upper attachment of the piano wire permit of winding it up to lift the mass, and of moving it right and left to bring the outer end

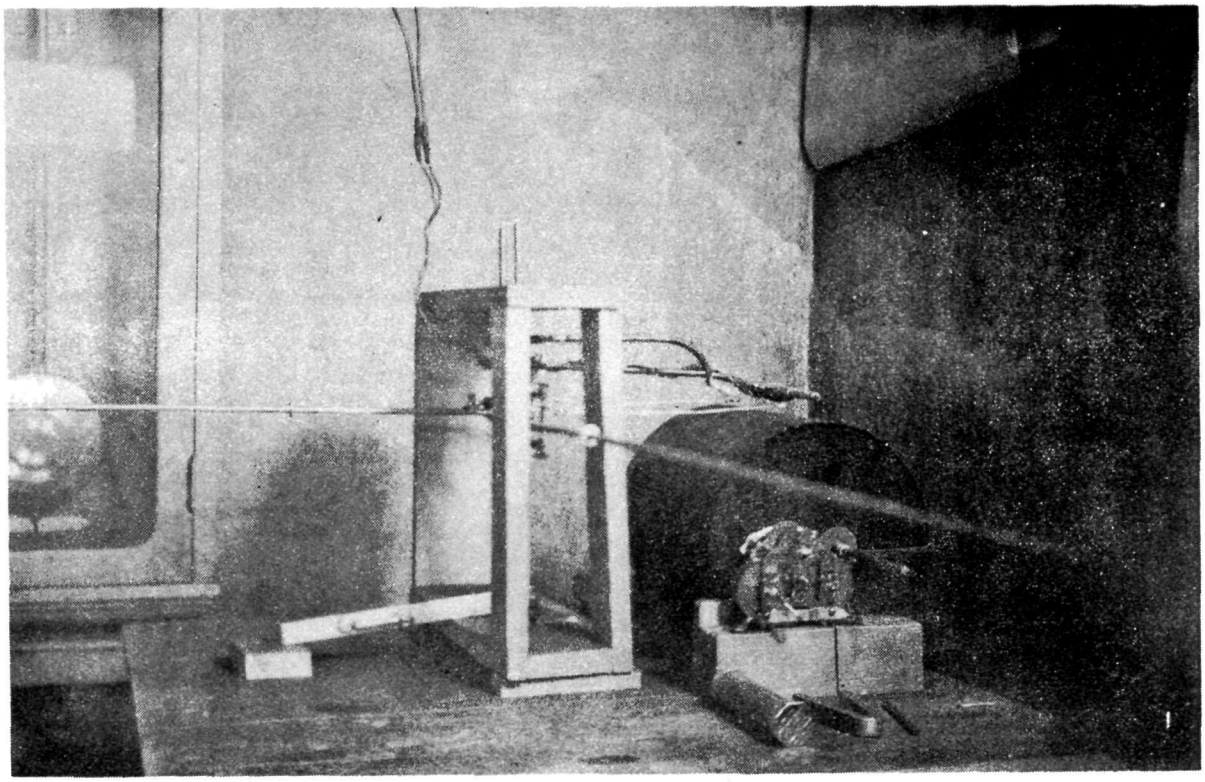
of the rod or boom to a medial position.

From all this there results a mass hung like a door with a boom protruding out from it, designed to record those oscillations or tilts of the earth at right angles to the plane of the suspension. The boom is braced by fine steel wires extending from its outer end to the cylinder. If the boom points to the east, the inertia of the mass registers the north-south earthquakes. Another similar pendulum is hung north-south to record the east-west components of the motion. Under each pendulum the system is damped, or prevented from free swaying on its own account, by sheet-aluminum vanes attached to the boom, protruding downward into a metal tank of automobile oil, so that with swinging of the pendulum, the vanes move edgeways in the oil. The little oil tanks, four or five inches square, not shown in the illustration, are supported by a removable stand in front of the pier.

The registering mechanism is shown in Figure 2. The recording drum is built on a steel spindle threaded with ¼-inch worm at the end away from the drive clock. This moves the drum lengthways in a sleeve at the driving end. The drive-clock is a Seth Thomas two-barrel power movement with rotation of spindle once in 30 minutes. The inner sleeve of the drum is set by a screw on the clockwork spindle. The worm end of the drum spindle rests on knife-edge wheels. Glassine paper is wrapped around the drum, pasted at the ends, smoked over a kerosene lamp, and the drum is set in place with the set-screw locking it to the clock. The writing lever-pen from the pendulum has a hinged stainless steel tip which rests on the smoke surface. The lever pens are made of aluminum. They are pivotted about a vertical axis near the end of the booms. The pen tips and the levers have pivots made of standard clock and watch balance staffs. Motion is transmitted from the boom to the lever by light metal T-bars, with the ends of the cross-bar in the boom and the lever respectively. The drum ends are made of ply-wood and the surface of pasteboard. The pen tips are magnetized, lifted to make a gap in the written line on the smoked paper every minute by an electro-magnet connected with the time-piece on the wall. The drum surface moves 30 mm. to the minute. The static magnification of the boom is five and of the writing lever forty, making the total 200. A marker pen attached to the plate supporting the drum and lever system, is made to write a line for a few minutes once a day on the side of the smoked paper, to be used as a datum line for measurement of wandering of the pendulums under tilting of the ground.

The free period of the pendulums is adjusted to seven seconds by moving the upper support of the piano wire in and out from the posts. The pen tips are laid back with a horseshoe magnet when the drum is changed. The change of paper is made once a day and the seismogram removed is passed through a bath of very dilute shellac and denatured alcohol, which fixes the smoke image of the line written by the pens. In the second photograph there is shown the second boom vanishing into the foreground, connected with the second pen by its T-bar impinging on an angle piece in the lever at right angles to the lever. In this way both pens, north-south and east-west, write during the day bands of lines side by side on the same paper. The paper is 12½ by 38 inches. Each line is interrupted by its minute and hour marks, the operator indicates the time of the starting mark by scratching it in the smoke, and simple counting for the succeeding hour marks on the smoke is all that is needed for timing an earthquake autograph that may appear. The light pasting of the ends of the paper on the drum is easily separated by a slender paper-cutter. The seismogram is dated and marked with its location before shellacking.

It will readily be seen from this account that any amateur with mechanical aptitude can build for himself a sensitive seismograph, and he can learn all about the technique of the science if he will consult the back files of the Bulletin of the Seismological Society of America, the headquarters of which are at Stanford University, California.



Feb. 2. Recording end of simple seismograph, showing booms of both north-south and east-west pendulums, pivot connections with writing levers, straight-wound electric magnet for marking time and the driving clock and drum, the latter with smoked paper.

THE VOLCANO LETTER 434

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Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL, 1936

HAWAIIAN VOLCANO OBSERVATORY

A signal honor was conferred upon Director T. A. Jaggar early in the month in the form of an invitation from the Royal Society of London, England, to assist a scientific party it was sending to the island of Montserrat in the British West Indies to study an alarming earthquake crisis in progress there and to make necessary preparations for the protection of the population in the event of a possible volcanic eruption upon that island.

Permission was secured from the Secretary of the Interior and Dr. Jaggar sailed from Hilo on April 11 to connect with a vessel from Honolulu a week later, expecting to be away for at least two months. A complete report of this expedition will be published in a later issue of the Volcano Letter.

While in Honolulu, Dr. Jaggar delivered an illustrated lecture upon the recent eruption of Mauna Loa and the successful bombing experiment. The attendance was so overwhelming that many hundreds of people were unable to obtain admission and



Seismograph Hut southeast of Halemaumau. Thermometer shelter, rain gauge, bench mark, trig station, and in the hut both tilt-meter and two-component seismograph. Shows T. A. Jaggar, volcanologist, and H. H. Waesche, seismologist.

the lecture was accordingly repeated a few days later—also to a capacity crowd.

With Assistant Geologist Waesche absent on annual leave to the Orient, the Observatory was reduced to a skeleton staff and no more than usual routine operations could be carried out. These consisted, in the main, of the care of the seismographs with changing of the records: measurement of rim cracks and tabulation of all changes—and the usual compilation of meteorological data. The weekly reports, reading and study of the seismograms, preparation of other data and all correspondence were handled by Superintendent E. G. Wingate.

Repair and boxing of seismograph parts for transmission to Lassen National Park and the University of Hawaii was attended to during the month.

MAUNA LOA OBSERVATIONS

With Kilauea remaining quiet, attention was concentrated upon Mauna Loa throughout April. Blue fume rising from the source region of the recent eruption was plainly visible under favorable atmospheric conditions. Towards the latter part of the month, fume was observed in increased volume and density. A Navy aviator reported the source cones as smoking profusely and covered with brilliant sulphur deposits.

On the night of April 28 there were many unconfirmed reports of activity at the source cones—but since the seismographs indicated no activity at this time, it is probable that the reports owed their origin to the reflection of a brush or cane fire upon an overhanging blanket of cloud.

There was, however, some indication of increased activity during the week ending April 26th. This consisted largely of tremors—of which several were noticeable for their duration. Three spells, occurring on April 20, were of 12, 18 and 25 minutes duration respectively.

On April 15, a slight to moderate earthquake occurred at 8:28 a.m. It was felt more or less strongly in the Kilauea section —also at Olaa Village near Hilo, and at Hookena in South Kona on the west side of the island. It was sufficiently strong at the Kilauea Observatory to dismantle the east-west component of the Bosch-Omori seismograph—but no reports of damage were received.

Review of the seismograms from the Hilo, Kona and Kilauea stations indicated the epicenter as east of the summit crater of Mauna Loa and south of the recent eruption source about 15 miles from the Observatory. All other earthquakes occurring during the month were classed as very feeble or feeble.—E.G.W.

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Moderate Earthquakes	Distant Earthquakes	Local* Seismicity
April 5	41	5	0	0	2	12.75
" 12	28	3	0	0	0	8.50
" 19	18	7	1	1	1	12.00
" 26	86	6	0	0	1	24.50
May 3	20	3	0	0	0	6.50

Epicenters of the following local disturbances were determined by means of seismograms from the station operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and, whenever such determinations were possible, the depth of focus is given.

April 1 at 11:13 am, very feeble, probable focus in vicinity of Cone Peak, about 1.6 miles SW of Pit seismograph.

April 4, at 4:24 am, very feeble, located 2.5 miles deep under SE rim of Kilauea Crater and 0.8 mile SW of Keanakakoi Crater. 19° 23.9′ N; 155° 16.4′ W.

April 5, 9:31 pm, very feeble, located 1.1 miles deep and 2.0 miles SE of the Volcano Observatory under S edge of Kilauea Iki. 19° 24.6′ N; 155° 18.4′ W.

April 9, 10:40 am, very feeble, located about 8.0 miles deep off the Hamakua Coast in the vicinity of Pepeekeo. 19° 49.5′ N; 155° 5.5′ W.

April 10, 7:21 am, very feeble, probable location under Kilauea Crater.

April 11, 9:50 pm, very feeble, thought to be located in vicinity of Pahala.

April 13, 6:46 am, very feeble, located 1.6 miles deep and 1.8 miles S of the Observatory under SE rim of Kilauea. 19° 24.4′ N; 155° 15.8′ W.

April 13, 6:59 pm, very feeble, probable location 1.5 miles SW of Pit seismograph in Kilauea SW Rift zone.

April 14, 2:13 am, very feeble, located 1.8 miles deep and 1.0 mile NE of Pit seismograph. 19° 24.8′ N; 155° 16.3′ W.

April 15, 6:03 am, very feeble, located 0.6 mile under Kilauea Crater and 1.4 miles SW of the Observatory. 19° 25.2′ N; 155° 18.7′ W.

At 8:27 am, April 15, a moderate earthquake occurred which was generally felt on the Island of Hawaii. Definite reports were received from Olaa, Hookena and the Hamakua district. It was felt rather strongly in the Volcano district. The east-west component of the Observatory seismograph was dismantled. Its origin was determined to be 18 miles under the SE portion of Kilauea Crater. 19° 24.0′ N; 155° 15′ W.

A feeble earthquake which occurred at 12:30 pm, April 15, was located 8.0 miles deep and 3.8 miles SSE of the Pit seismograph under Pali Kalanaokuaiki.

April 15, 6:47 pm, very feeble, located near the surface of Kilauea Crater floor and 0.7 mile ENE Pit seismograph. 19° 24.6′ N; 155° 16.4′ W.

April 16, 3:38 pm, very feeble, probable location under NE section of Kilauea Crater.

April 17, 7:44 pm, very feeble, located 0.9 mile deep under Kilauea Crater and 0.4 mile N of Keanakakoi Crater. 19° 24.6 N; 155° 16.0′ W.

April 20, 1:24 pm, very feeble, probable location about 1.0 mile SW of Volcano Observatory in Kilauea Crater.

April 23, 1:08 pm, very feeble, probable location 0.9 mile W of Pit seismograph in Kilauea SW Rift zone.

April 25, 3:11 pm, very feeble, located 1.1 miles deep and 2.0 miles SE Pit seismograph in the vicinity of Ahua Kamokukolau. 19° 22.0′ N; 155° 15.7′ W.

April 26, 9:22 am, very feeble, located 8.5 miles deep and 1 mile SE of Makaopuhi in Kilauea SE Rift zone. 19° 21.5′ N; 155° 10′ W.

April 27, 3:47 am, very feeble 8.0 miles deep under ocean floor 5 miles NW of Hoopuloa. Reported felt at Hoopuloa. 19° 15.5′ N; 155° 57.4′ W.

April 29, 8:29 am, very feeble, probably located 2.0 miles SW Pit seismograph in Kilauea SW Rift zone.

May 2, 7:09 am, very feeble, probable origin under Mauna Loa SW Rift about 8.0 miles from summit.

Spells of harmonic tremor began recording at the Observatory as follows: March 30, 4:46 am, for a duration of 17 minutes; April 5, 11:22 pm, 4 minutes, and on April 20, at 5:00 am, 9:30 am, 1:21 pm, 1:26 pm and 6:24 pm for 25, 5, 3, 14, and 11 minutes respectively. This represents the greatest amount of harmonic tremor within the same time limits since the first three days of the Mauna Loa eruption in November, 1935.

Microseismic motion of the ground at the Observatory was

* For local seismicity see Volcano Letter 371.

strong April 6 and 7, it was moderate March 30, April 5, 8, 9, 14, 15, 17, 18 and April 27 to May 3, inclusive. The remainder of the month it was light.

Four teleseisms, or distant earthquakes, were recorded during the month. Preliminary waves began to register at 3:51 pm, March 31, for the first of the series. The origin was 5380 miles from Kilauea. The reported location was 46 miles below the ocean floor, N of the Celebes Island. 2.5° N; 123.5° E. The secondary waves of the second teleseism began recording at about 8:30 pm, April 1. Its location was undetermined. The preliminary tremors of a teleseism began recording at 6:47 pm, April 18. The estimated distance from the Volcano Observatory was 3745 miles. The reported location was in the vicinity of the Solomon Islands. 9° S; 15.6° E. The secondary waves of the last recorded teleseism of the month began at 1:01 pm, April 23. The reported location was in the vicinity of the Aleutian Islands. 50.5° N; 17.8' E, 62 miles deep. H.H.W.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Hale-



Measuring a crack locality on Halemaumau rim with steel tape over permanent metal studs in the rock.

maumau the algebraic sum of radial tilts for two clinoscope locations towards or away from the Pit.

At the Obseravtory the total accumulated for the year ending May 3 was 4.13" N and 2.66" E.

TABLE OF TILT

		HALEMAUMAU CLINOSCOPE STATIONS		
Week Ending	Observatory	West	Southeast	Pit Resultant
April 5	0.76"S 70°W	2.62"N 42°W	2.66"S 5°E	3.59" from
April 12	0.60"S 47°W	3.87"S 85°W	9.72"N 2°E	3.58" toward
April 19	1.50"N 14°E	1.49"N 48°W	6.16"N 24°E	2.04" toward
April 26	2.48"S 66°W	6.38"N 20°W	5.22"S 55°W	1.49" from
May 3	1.10" N 66°E	4.41"N 74°W	6.54"N 9°W	1.66" toward

H.H.W.

UNIVERSITY OF HAWAII SUMMER SESSION

The Summer Session of the University of Hawaii this year changes its Volcano School to a program of research only. This is in charge of Dr. Thomas A. Jaggar, Professor of Volcanology in the Graduate Division. As volcanologist in the national park Dr. Jaggar has developed a number of experimental problems during the last twenty-five years. One is the location underground of earthquake centers, produced by some kind of impact or jolt. Another is the possible gradual change, or sudden change, from time to time, in such gases as those at the Volcano House sulphur bank. Both of these things, if measured and interpreted promptly, and more accurately, may indicate the coming of eruptions. The foretelling of eruptions is one important result of volcano study.

Accordingly in August, two investigators from the Physics Department of the University will start using new instruments at Kilauea. The shops of the Volcano Observatory have been renovated for their use. A University Laboratory has been arranged in a special building. The workers are Assistant Professor Stanley S. Ballard, specialist in spectroscopic work, and Instructor Iwao Miyake, skilled in electrical instruments.

Dr. Ballard will collect the Sulphur Bank gases, and also the gaseous products in Kilauea Crater at certain localities. The collection will be with pumps and tubes specially designed to exclude outside air, which tends to be sucked in when steam condenses in ordinary vacuum tubes. The object is to design field apparatus which will be effective in retaining pure volcanic gas, after collecting such gas not only at solfataras, but even at flame vents in lava where gas is burning. There is no such lava available now, but many experiments may be made in preparation for such active periods as last December. The tubes of gas will be carried back to Honolulu laboratories. There the gas will be carefully subdivided into numerous samples for use in discharge tubes, in partial vacuum, illumined by an electric discharge. These will be photographed for the spectrum of rare gases. This work is done with a large quartz prism spectrograph.

It is planned to make negatives of numerous gases, and if results are satisfactory, to establish a new routine at the Observatory. This will consist in collecting the gases at regular intervals and sending them to Honolulu to see if there is any change. It is also hoped to obtain for the Observatory a small model spectrograph which may perhaps be used in the field for direct recording of gases. The object of all the work is to start a movement for more precise use of the spectroscope in volcanology.

The work of Mr. Miyake is based on experiments started more than a year ago under the direction of Assistant Professor Willard H. Eller at the University of Hawaii. His experiments were designed to record the exact time in fractions of a second of blasting explosions at Moiliili quarry. Then an electrically equipped seismograph was set up at the Physics Laboratory some distance away recording the exact time that the earthquake shock from the explosion reached the University. According to the difference in times of the quarry measurement and the university measurement, the rate of travel of the earth wave could be discovered. Mr. Miyake has been improving the apparatus for doing this kind of exact work electrically.

It is now proposed that he bring his apparatus to the Volcano Observatory where thirty or forty actual seismic disturbances occur every week. The seismologic work of the earthquake investigators at the Observatory has taught how to locate earthquake centers approximately. We need to know exactly how fast and in which direction the earth waves travel for a Mauna Loa earthquake, a Kilauea earthquake and others. It may be possible with simple apparatus buried in the ground to compel an earthquake wave passing a place five miles away to send a wireless message to the Observatory and record its time on an Observatory chronograph. If the same earthquake when it reaches the Observatory makes another record on the same chronograph, the time of travel for the five miles will be known. It is hoped by electrical work of high precision to discover the travel times of different kinds of earthquake waves. The Volcano Observatory is a natural laboratory for this work, because it has many movements of tilting and trembling all the time.

These investigations will continue until the end of September, and Dr. Jaggar and Mr. Waesche will bring to bear the resources of the Observatory records on the two kinds of work. The University of Hawaii has recently published four papers from the Volcano Observatory by Wilson, Jones, Powers and Wentworth on ground movement, seismology, soils and geography of Hawaii. The appointment of Professor Jaggar brings the resources of the Kilauea laboratories and their large accumulation of unstudied records within the orbit of a research university graduate school. This contact of National Park and University to make available the natural resources of the nation to scholarship and education, is along the lines of what other national parks are doing.

THE INFLUENCE OF VOLCANIC RESEARCH IN HAWAII

The by-products of the popularity of our volcanoes have been the National Park and its improved roads; the Mauna Loa road and camps; the military recreation camp; the Chain of Craters road; the Haleakala road and Park; the Hilo-Volcano road; the Uwekahuna Museum; the projected Hilo-Kona road; increased tourist visitation effects of this on Island business; the coming expansion of the National Park and its road system; the pleasure visitation of Mauna Loa and Kilauea by airplanes; the gradual opening of Mauna Loa to visitation and science; the completion of topographic maps of the whole island; science guiding the police, the ranchers to safety, and the public to sight-seeing, through ten lava crises. All of these things we have seen grow up during the last twenty-five years.

What Did the Science Do?

It measured continuously the materials and the movements coming forth out of the three active volcanoes Kilauea, Mauna Loa and Hualalai. Having this experience led in part to the **social** benefits enumerated. The latest of these is the **social** contract with a British presidency, another volcanic island, seven thousand miles away.

Larger Meaning of Measuring the Earth

The following are results of measuring the earth's powers: Boulder Dam, the Panama Canal, the Tennessee Valley Authority, the Mississippi Flood Control, the Great Lakes Drainage Project, the Golden Gate Bridge, Earthquake Insurance, Earthquake-proof construction. Geophysical prospecting for oil. Finding radium, caesium, selenium, tungsten, vanadium, uranium, rhodium, fluorine, helium and nitrogen. Prospecting the soil for its real meanings, a far cry from the days of guano and Chilean nitrate. Developing the air drill, the Diesel tractor, the new explosives for moving mountains. Tying up the earth in roads, pipe lines, telefer wires and aqueducts such as the world never

dreamed of. Penetrating fogs. Steering by sea-bottoms. Mapping by airplanes And traversing Antartica by the tools of modern science.

All of this is the work of that man of science called the engineer. He has become utterly **Social.** He has a fine ethics like the physician. This is because his responsibility is for public safety, and for justifying a **measurement** of the earth that he has made for service. It makes him sober, to know that he has the responsibility of serving **socially** a million people in the future.

There is a still larger social aspect to the sciences of the Earth. We hear much of extravagance, of colossal expenditure, and the question "Who is going to pay for it all?" But pay for it in what? If the labor of the nation is doing it, and the result is doing the nation good, why not look back and say "Who has ever paid for the free franchises, free farms, free rights of way, and free public utilities of the American people? Who has ever paid science for improving the earth for man's occupancy? What modern men of science ever work for profit?

Is anyone now asking who will ever pay the great inventors for the extravagance, the colossal expenditure in blood and brain and spirit, of Jesus, Lincoln, Goethals, Walter Reed, Gorgas, Darwin, Faraday, Pasteur or Curie?

Do we realize that one man or woman somewhere and somewhen, produced a future billion dollars, in prospecting the Earth with his brain, for each great engineering and social achievement, among such constructive discoveries as those I have enumerated, like the Boulder Dam or the rare metals? For the Boulder Dam is just as much a discovery as the North Pole, and requires a hundred times more courage and brains.

The bonded debts of the world can never be repaid in coins. Money is the blood of youth and the labor of men. The earth furnishes some raw material and power for blood and labor to use. There is no other wealth than the good-will of men, and the self-sacrificing measurements of progressive learning, in economizing happily the energies of men. The energies of men are banded together to discover moral power and earth power. By moral we mean "MORES," improved human habits. This is the whole of education.

The Earth is yielding much to the chemist. It is not being made to yield enough of its resources to the engineer. Our sea-bottoms are not mapped, our deserts and mountains are almost untouched, our oceans are not working for us, our sunlight is not yet running our cars and planes. We live too much in city laboratories. There is here a gigantic field for the employer of labor.

Science is not yet extricating Society from its foolish city congestions: and sending MEN out in vast employments, to discover THE EARTH, with the new **social** tools of modern physics and engineering. Here is a chance for the benefactors of mankind to rethink social science. T. A. J.

THE VOLCANIC AREA OF BUFUMBIRA, UGANDA

The following excerpts and paraphrasings from "The Volcanic Area of Bufumbira" by A. D. Combe and W. C. Simmons,



The west tilt cellar on Kilauea crater floor, housing clinoscope pendulum for daily readings.

published in 1933 by the Geological Survey of Uganda, shows many striking similarities to descriptions of Kilauea at various times.

The volcano Nyamlagira is in about 1° 25' south latitude and about 29° 12' longitude east of Greenwich in Belgian territory. The summit is 10,026 feet above sea level. It rises gently to a height of about 5,000 feet above its base. The mountain has been built by the piling up of successive lava flows apparently of large volume and in a very fluid state.

The caldera or crater depression is over a mile in diameter and it is surrounded by a vertical wall from 200 to 300 feet high, which is breached on the northwest side by a gap between 500 and 600 yards wide. The main part of the floor of the depression is formed by a flat terrace with a general crescentic outline and possibly 800 yards in width over its widest part. The breach in the caldera wall is on a level with this terrace, and thus one can walk onto it from the slopes of the mountain without climbing down. This terrace is in part bordered by a narrower one from 100 to 150 yards in width and about 100 feet lower. From the lower terrace there is a descent of perhaps 100 feet to an irregular elliptical depression which occupies the greater part of the southern portion of the caldera, the floor of which is covered with ropy and pahoehoe lava. It is on this that the pools of liquid lava are situated. On the south-east side of this depression there is a direct drop from the upper terrace and on the southern side a direct descent into it from the high wall surrounding the caldera as a whole. In the southwest corner of the depression there is a pit from 150 to 200 feet lower with an irregular elliptical outline, vertical sides, and perhaps from 250 to 300 yards across. The floor of this pit is the lowest part of the caldera. The southwest side of the pit is formed by the main wall of the caldera which is there from 400 to 450 feet high, while the west side descends directly from the upper terrace.

At the time of Combe's visit nine centers of activity could be seen. The largest was a pool of boiling lava, perhaps 70 yards in width, from the surface of which jets of lava, probably caused by the escape of juvenile gases, issue at frequent intervals. The rim of the pool has been built up above the level of the adjacent floor. The others have built up small cones from which large volumes of steam and sulphurous gases are given off. Liquid lava was seen in several of these cones. In many places jets of gas and steam issue through the surface of the ropy lava. At the time of his visit small intermittent streams of liquid lava issued from under the solid ropy rock and dropped over the steep wall into the lowest part of the caldera. These did not reach the bottom in a liquid state, but became partly solidified and dropped as lumps of scoria which have formed a large pile along the base of the wall resembling the ash heap of a power plant.

A striking feature of the structure of the volcano is that the wall surrounding the caldera, the terraces and the sides of the lowest depression are formed by a homogeneous lava in horizontal layers. The edges of the layers present a generally jagged surface cut off vertically, which suggests that they have been broken off by subsidence within the caldera. In many places large strips and blocks have broken away from the edges of the terraces. Over the floor of the terraces lines of fumaroles issue from fissures, the gases of which appear to be mainly of steam and sulphurous types, but in one place there was a strong smell of sulphuretted hydrogen. Native sulphur has been deposited adjacent to some of the fumaroles.

It is quite clear that the present-day caldera has been formed by the direct subsidence of the upper part of the volcano. The mode of origin of the flat layers of homogeneous rock, none of which exhibits columnar structure, is not so clear.

No recent flows have been derived from Nyamlagira itself that reach any considerable distance down the mountain side, for the lower slopes are clothed with dense forests.

On the whole the activity of Nyamlagira appears to have been rather quiet, but that violent explosions have taken place is indicated by the large number of bombs and ejected blocks, some of which are as much as two feet in diameter, scattered over the slopes of the mountain and over the upper terrace.

The lavas of Nyamlagira are mainly medium-grained leucite-basanites in which porphyritic crystals of plagioclase, augite, and a brownish olivine are set in a holocrystalline groundmass.

One of the fundamental tenets of science is that like causes produce like results. Nyamlagira is a volcano which, like Kilauea and Mauna Loa, yields chiefly basic, fluid lavas. Consequently the resulting volcano and volcanic structures and topography are much alike.

The matter abstracted above regarding Nyamlagira reads very much like various descriptions of Kilauea written during the nineteenth century.—H. S. Palmer.

EARTHQUAKES IN UNITED STATES

It is not generally realized how wide has been the range of seismic disturbances in what now comprises the United States of America. Practically every state in the Union has recorded earthquakes within the last hundred and sixty years and Indian tradition constantly refers to such occurrences in earlier times. Students of the geology of the North American continent can point to abundant evidence of many great upheavals that have occurred within comparatively recent geologic time.

Probably the greatest earthquake of modern times in North Amrica was the catastrophic series of shocks that commenced early on the morning of December 16, 1811, and affected an area extending from Cairo, Missouri, along both banks of the Mississippi River through Arkansas to the vicinity of Vicksburg in the south. While the greatest destruction occurred within these limits, the effects were felt over an area of 50,000 square miles while the vibrations were clearly perceived by persons in upper Canada as well as in Detroit, Washington, and Boston. This actually means that the shocks of this great earthquake were felt over a million square miles, half of the area which became the United States of today.

We take the liberty of reviewing a most interesting account of this great disaster by Thomas Ewing Dabney, appearing in a recent issue of the magazine section of the New Orleans Times-Picayune. The gifted pen of the author has conjured up a vivid picture of the occurrence.

"Trees," he says, "began to move on a windless day, then clashed together like flailing clubs. High bluffs leaned forward, poised in fearful dignity, bowed into the river with enormous splashes. Waves of earth rolled over the land; rose higher and higher and burst. Back flowed the Mississippi; waterfalls raced above its surface, cast their roarings into the chaos.

"The shocks began soon after 2:00 a.m. on December 16. The crash of falling chimneys, the groaning and creaking of house timbers and the noise of overthrown furniture drove the inhabitants of New Madrid outdoors. A horrible darkness pressed down from the sky; strange odors released by the breaking earth filled the air. Daybreak came with dreadful rumblings; the ground rose and fell so that one could not stand erect. Forests fought and fell; a welter of sound rose from the tortured rivers."

Throughout that day and the next, the shocks were incessant but steadily decreasing in intensity. There was a savage renewal on January 23, 1812, followed by two weeks that were almost normal. But there was a renewal of the upheaval on February 7 and for many days after that the earth was shaking constantly. The shocks gradually ceased, but for more than twelve months afterwards recurrences kept the people in a state of alarm.

"One observer who attempted a systematic record counted 1,874 shocks between December 16, 1811, and March 15, 1812. This count was made in Louisville, far away from the main disturbance. Unfortunately no record was kept in New Madrid where, as one man said, 'the world seemed to be blowing up with loud explosions.'

"Passengers on the river steamer New Orleans which visited the devastated areas, described the enormous changes which had taken place.

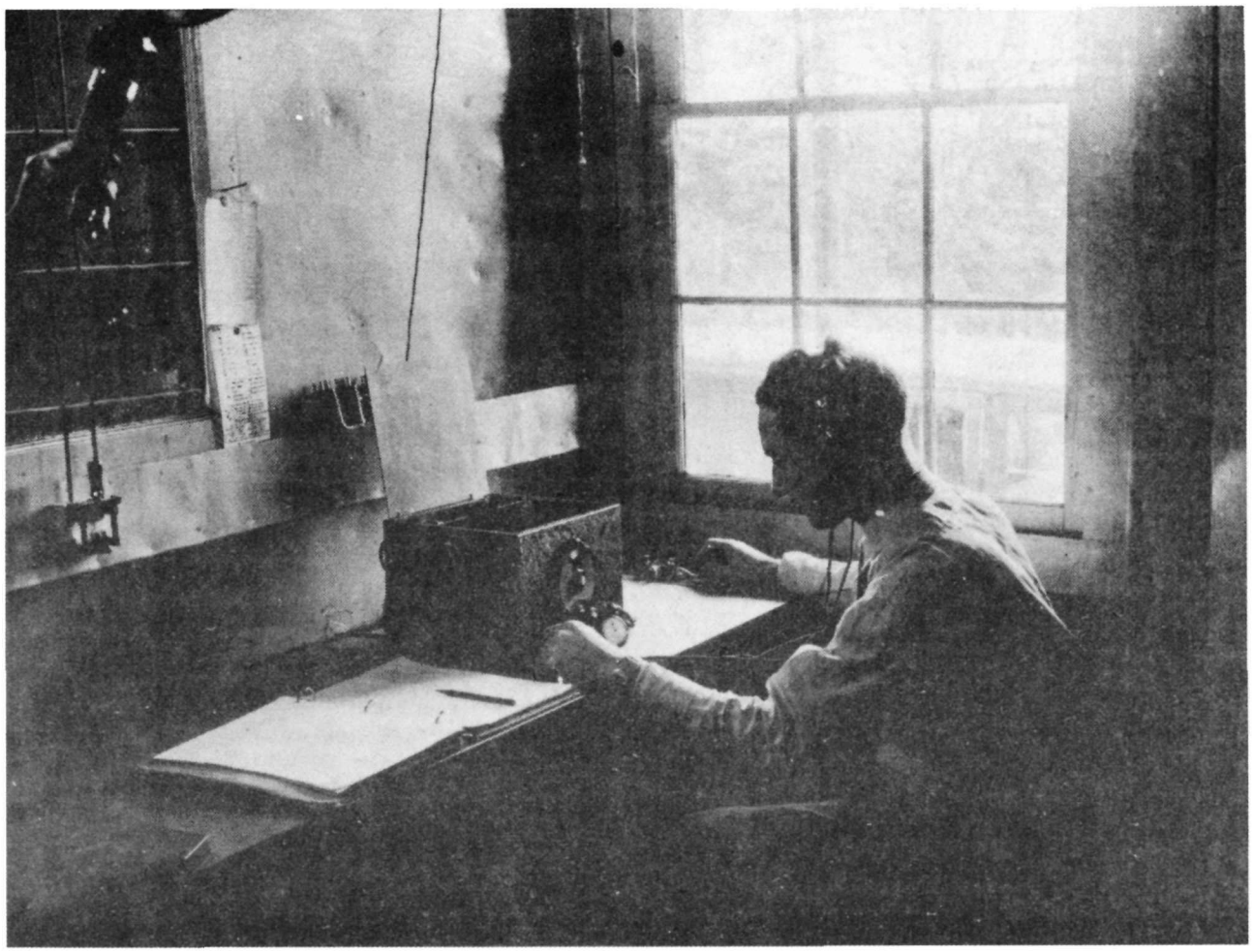
"New Madrid itself, they found, was practically destroyed. Much of the town had been swallowed by the river and the houses on higher ground had collapsed. Further down the river, the prosperous agricultural community of Little Prairie (the Caruthersville of today) had become a desolate waste of sand and water spewed up from the splitting earth. The whole channel of the Mississippi River appeared to be up-tilted so that the water ran backward towards its sources for more than an hour and until the current broke its way through the upthrust material, the river was a crazy thing. One account speaks of a great waterfall six feet high and half a mile wide, apparently formed by the water being violently sucked into some chasm in the river's bottom. The same narrator speaks of another fall of the same character eight miles below New Madrid.

What are now called the "sunken lands' 'of western Tennessee, southwestern Missouri, and northwestern Arkansas covering hundreds of square miles were made in this subsidence to which Reelfoot Lake also owes its origin.

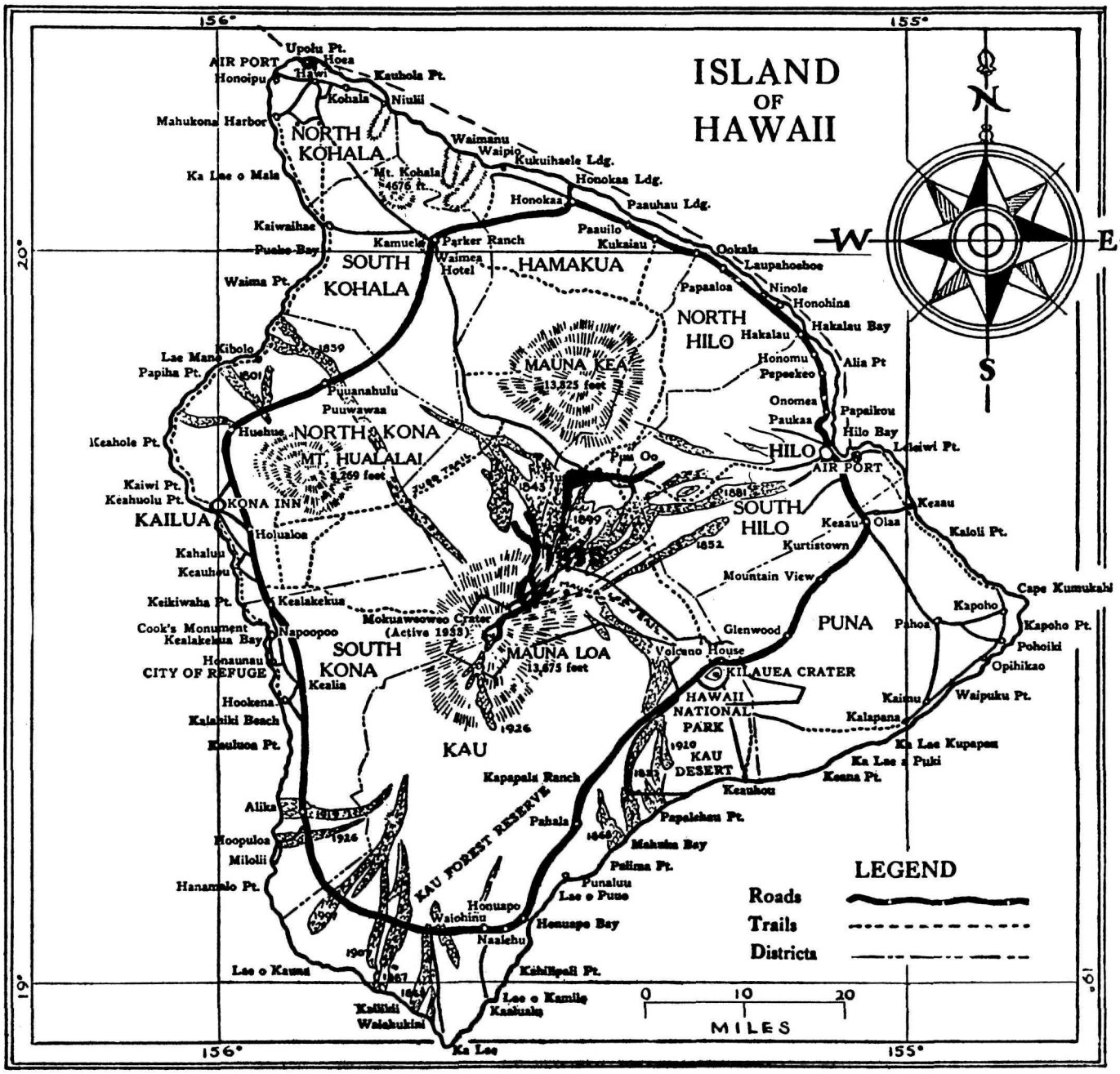
In other sections, land was raised and navigable streams went dry. A fifteen-mile stretch or territory in southeast Missouri, once a part of the flood plain, was raised nearly twenty feet. There was widespread fissuring, due to the opening of the earth after the main wave-motion had swept through the surface strata. Mr. Dabney tells us that some of these openings were several hundred feet long and were so numerous that in some sections men felled trees against the direction of the movement and clung to them to prevent being engulfed. It is worthy of note that while many of these fissures were twenty feet in width, their depth was shallow and reached only to the quicksands underlying the surface alluvium. Through many of these fissures tremendous ejections of sand, water and carbonaceous material took place, burying the fertile land. At one place the skull of the long extinct musk ox was thrown out on the surface and was later placed in the Museum of Natural History in New York.

The loss of life, owing of course, to the scanty population, was astonishingly small. Should such a shock occur in these present days of closely crowded people and tall buildings, most of which are anything but earthquake proof, the loss of life would be almost too appalling to contemplate. Congress passed an act allowing the sufferers from the disaster to locate on an equivalent amount of land in any other part of the public domain open to entry. But after a year of frequent earthquake shocks, the survivors had become so accustomed to them that of the five hundred certificates issued only twenty were located by the original claimants in person.

Mr. Dabney, in his able article, has made a valuable contribution to American literature on this important subject.—deV-N.



Short wave radio set in Volcano Observatory for receiving time signals from Washington and imprinting them on seismograms through a telegraph key.


ISLAND
OF
HAWAII
N
S
E
W
156°
155°
20°
19°
Upolu Pt.
AIR PORT
Hoea
Hawi
Honoipu
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH
KOHALA
Waimanu
Waipio
Kukuihaele Ldg.
Ka Lae o Mala
Mt. Kohala
4676 ft.
Honokaa Ldg.
Honokaa
Paauhau Ldg.
Kaiwaihae
Kamuela
Parker Ranch
Paauilo
Kukaiau
Pueko Bay
Waimea
Hotel
SOUTH
KOHALA
HAMAKUA
Ookala
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH
HILO
Hakalau
Hakalau Bay
Kibolo
1859
Lae Mano
Papiha Pt.
1801
MAUNA KEA
13,825 feet
Honomu
Pepeekeo
Alia Pt
Puuanahulu
Puuwawaa
Onomea
Papaikou
Paukaa
Hilo Bay
Keahole Pt.
Huehue
NORTH KONA
MT. HUALALAI
8,269 feet
Pua Oo
1843
HILO
AIR PORT
Leleiwi Pt.
Kaiwi Pt.
Keahuolu Pt.
KONA INN
1881
SOUTH
HILO
Keaau
KAILUA
Holualoa
1899
Keaau
Olaa
Kaloli Pt.
Kahaluu
Keauhou
1852
Kurtistown
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Cook's Monument
Kealakekua Bay
Napoopoo
Mokuaweoweo Crater
(Active 1933)
Glenwood
PUNA
Pahoa
Kapoho Pt.
Honaunau
CITY OF REFUGE
SOUTH
KONA
Kealia
MAUNA LOA
13,675 feet
Volcano House
KILAUEA CRATER
Pohoiki
Opihikao
Hookena
Kaimu
Waipuku Pt.
Kalahiki Beach
HAWAII
NATIONAL
PARK
Kalapana
1926
Kaulusa Pt.
1919
KAU
DESERT
Ka Lae Kupapau
Ka Lae o Puki
Kapapala Ranch
Keauhou
Keana Pt.
Alika
Pahala
Papaleheu Pt.
Hoopuloa
1926
Mahuka Bay
Milolii
KAU FOREST RESERVE
Palima Pt.
Hanamalo Pt.
Punaluu
Lae o Puue
Honuapo
Waiohinu
Honuapo Bay
Naalehu
Lae o Kauna
Kahilipali Pt.
Lae o Kamilo
Kaalualu
Kaalualu
Waiakukini
Ka Lae
LEGEND
Roads
Trails
Districts
0 10 20
MILES

THE VOLCANO LETTER

No. 435 — Monthly, Department of the Interior, National Park Service, May, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

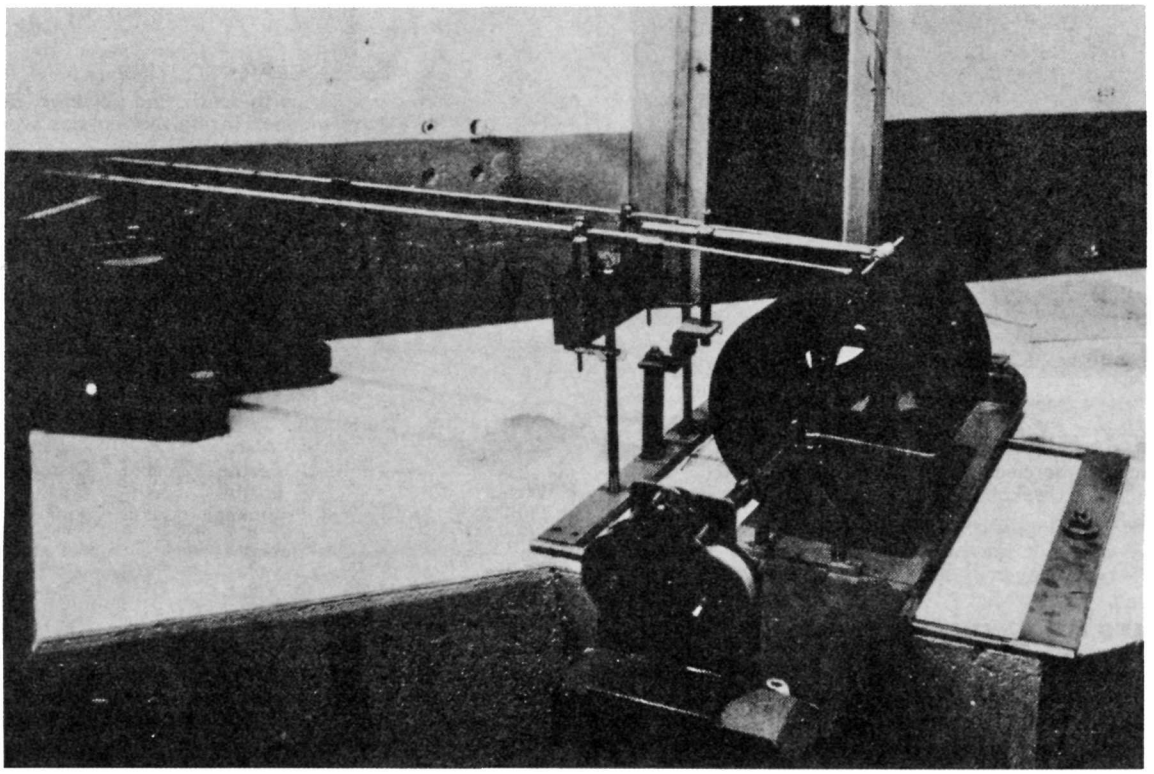
HAWAIIAN VOLCANO OBSERVATORY REPORT FOR MAY 1936

HAWAIIAN VOLCANO OBSERVATORY

Routine work at the Volcano Observatory was ably carried on during the month by H. Yasunaka, who at times was assisted by Asao Okuda, carpenter and mechanic, both Volcano Research Association employees. This work consisted of caring for seismographs, changing of records, recording meteorological data, recording tilt at clinescope stations and caring for the Observatory grounds, buildings and equipment.

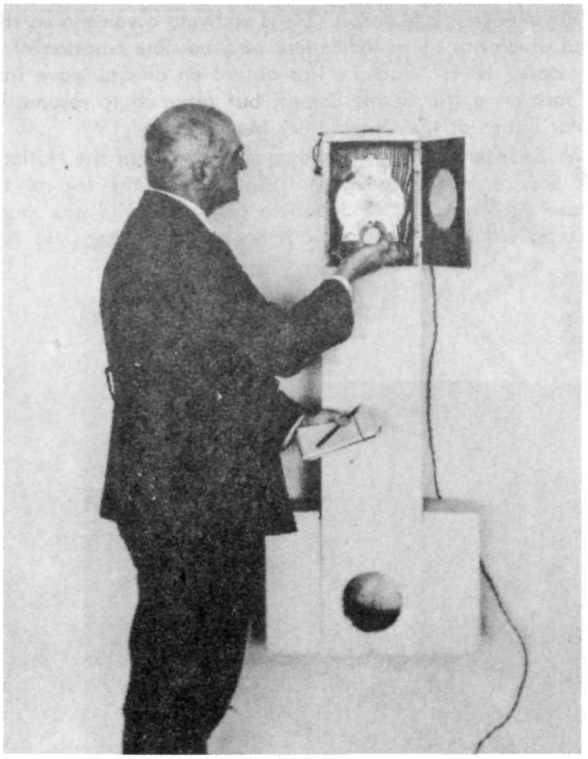
In the absence of both Volcanologist T. A. Jaggar and Assistant Geologist Waesche, weekly reports were written by Superintendent Wingate. Dr. Jaggar is on an expedition to the island of Montserrat in the West Indies by invitation of the Royal Society of London. He is studying a volcano on that island which has given indications of a possible eruption at an early date. H. H. Waesche was absent on annual leave from the park on a trip to the Orient, but returned to resume his regular duties at the Observatory May 23.

M. S. Seger, Associate Landscape Architect of the National Park Service, accompanied Mr. Waesche on the trip to the Orient. An inspection of Japanese national parks was made, including visits to the volcanic parks of Aso, Unsen and Fuji.



Strong-motion seismograph with low magnification to record those earthquakes that are too big for the other instruments.

Other parks visited were Inland Sea and Nikko. A visit was made to the national park headquarters in the Home Office Building in Tokyo, where members of the administrative staff were met. Dr. Tamura of the Japanese National Parks presented Mr. Waesche with a bomb from the summit of Mt. Fuji. This is a "sister rock" to the one presented to Ambassador Grew, in ceremonies in Tokyo, as a present from the Japanese national parks to those of the United States. The Mt. Rainier rock was part of the exchange of courtesies of this nature between Mt. Rainier National Park and the Japanese National Parks. Sakarajima Volcano was visited. Inspection was made of the seismological institute of Tokyo Imperial University as well as the seismological research department of the same institution. In addition to Japan, China, Manchukuo and Korea were visited.



SEISMOGRAPH ROUTINE 1
Checking the clock time against a stop-watch, Uwekahuna Seismograph.

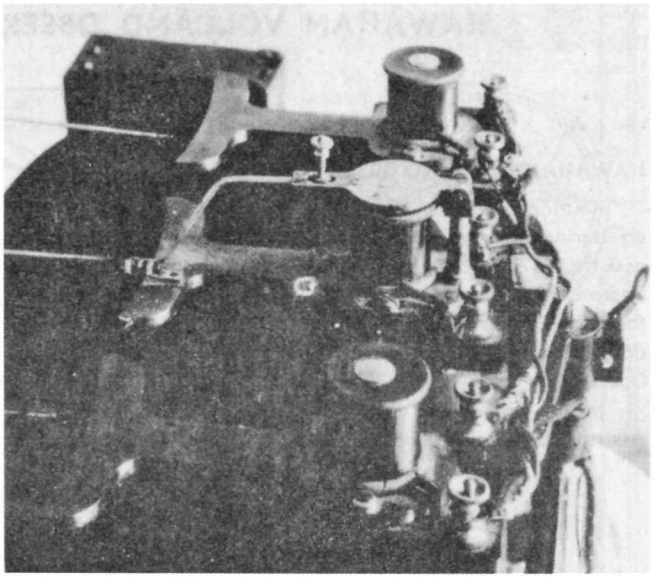
KILAUEA AND MAUNA LOA OBSERVATIONS

Kilauea and Mauna Loa have both been quiet throughout the month. As late as May 16 fume was reported seen at the rift cones of the 1935 eruption of Mauna Loa. Sulphur deposits around the cones were said to be increasing. No fume has been noticed the latter part of the month. Fuming at the sulphur spots in Halemaumau continues about the same. Slides have been few and small.

Seismic activity has been comparatively moderate. There were feeble earthquakes May 2, 7 and 26, none of which was reported felt. All other disturbances were classed as very feeble or as tremors. Spells of continuous tremor of 5 minutes duration were reported for May 8 and 9. Most of the disturbances for the month originated in the Kilauea area.

Crack measurements showed abnormal opening of No. 46 on the NE rim of Halemaumau near the point where a large section of the rim disappeared into the pit in March.

Addition was made to the Observatory equipment of a Leitz precise level.



SEISMOGRAPH ROUTINE 1a:
The pens for east-west, north-south, and up-down, pendulums. The spools are electro-magnets lifting the pen-tips every minute.

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant Earthquakes	Local* Seismicity
May 10	19	4	1	0	7.75
" 17	22	3	0	0	7.00
" 24	41	3	0	1	11.75
" 31	39	9	1	1	15.25

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at the Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and whenever such determinations were possible, the depth of focus is given.

* For local seismicity, see Volcano Letter 371.

May 6, 8:55 pm, very feeble, located 0.6 mile deep in Kilauea Crater, 1.0 mile SW of the Observatory. 19° 25' 2N; 155° 16' 2W.

May 7, 6:51 am, very feeble, located 1.9 miles deep in Kilauea Crater near SE rim. 19° 24' 7N; 155° 15' 9W.

May 7, 8:07 am, feeble, located 0.4 mile deep in approximate center of Kilauea Crater 1.5 miles SW of the Observatory. 19° 24' 9N; 155° 16' 5W.

May 10, 6:57 pm, very feeble, located 1.2 miles deep under W portion of Kilauea Iki. 19° 25' 0N; 155° 15' 1W.

May 14, 4:42 pm, very feeble, located 1.6 miles deep under SE rim of Kilauea Crater and 0.4 mile W of Keanakakoi Crater. 19° 24' 2N; 155° 16' 3W.

May 14, 9:04 pm, very feeble, located 1.2 miles deep and 0.6 mile S of the Twin Craters and 1.2 miles E of Kilauea Crater rim. 19° 25' 4N; 155° 14' 6W.

May 16, 6:35 am, very feeble, probably located under S rim of Kilauea Crater.

May 21, 2:31 pm, very feeble, probably located in Kilauea Crater.

May 21, 2:46 pm, very feeble, located 1.7 miles deep and 0.4 mile N of Keauhou Ranch House. 19° 26' 6N; 155° 16' 9W.

May 25, 10:46 am, very feeble, located 1.1 miles under Waldron Ledge, NE rim of Kilauea Crater. 19° 25' 5N; 155° 15' 5W.

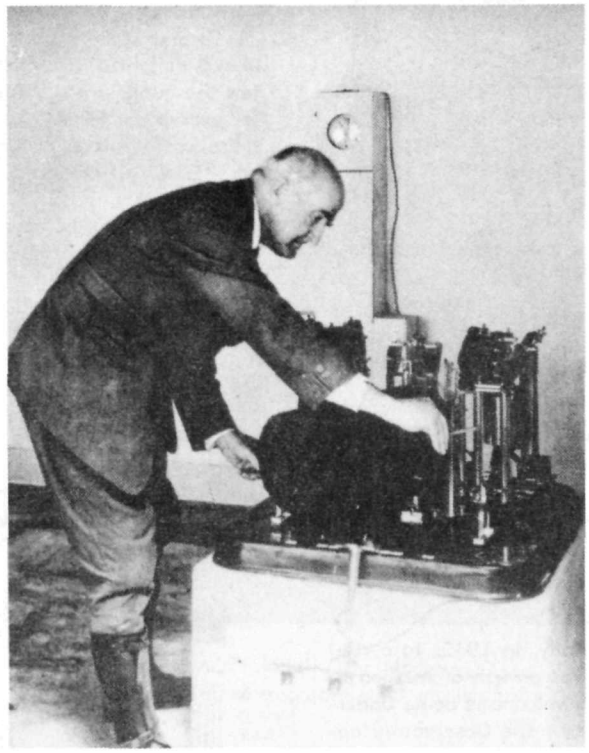
May 26, 11:48 am, feeble, located 1.4 miles deep under Waldron Ledge. Same as preceding quake.

May 28, 3:09 am, very feeble, located 9.0 miles deep in the Hilina-Kapukapu Fault system, 3 miles N of Keauhou Point. 19° 19' 3N; 155° 14' 8W.

May 30, at 6:19 am, very feeble, probably located in NE rift of Mauna Loa.

The preliminary waves of a teleseism began recording at 4:45 pm, May 19, and the indicated distance from the Observatory was 3630 miles. The reported location was in the vicinity of the Solomon Islands 7° 7S; 159° 6E. On May 28, at 8:35 am, the secondary waves of a distant earthquake began to register. The reported location was about 900 miles off the SW coast of Honduras. 9°N; 103° 5W.

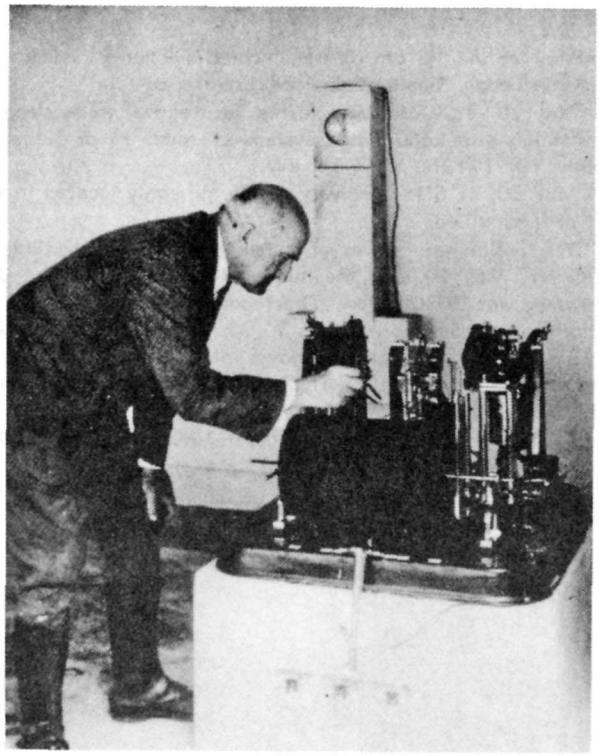
Microseismic motion was moderate, May 10, 11, 15, 19; the remainder of the month it was light.



SEISMOGRAPH ROUTINE 2
Removing the drum covered with smoked paper.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations West	Southeast	Pit Resultant
May 10	0" 83 N 27°E	4" 77 N75°W	4" 47 N 36° E	2" 87 from
" 17	0" 57 N 54°W	5" 19 S 78° W	2" 27 N 30°E	4" 25 from
" 24	0" 85 N 4°W	1" 01 S 23°W	2" 27 N 5°W	1" 33 toward
" 31	1" 24 S 82°W	2" 21 N 58°W	5" 57 S60°W	1" 14 from H.H.W.



SEISMOGRAPH ROUTINE 3
Installing a fresh drum and pulling over the pen points with a horseshoe magnet.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 31, was 4" 20N and 1" 9E.

THE METHODS OF THE HAWAIIAN VOLCANO OBSERVATORY

From trying everything experimentally, in 1912, to a routine of measurement in 1936, there was growth of method at Kilauea in the effort to discern what a volcano is doing underground. One of the impressive results of the Observatory approach to volcanoes, is the failure of underground lava to announce its intentions. Newcomers to volcano science always think a hot crack at the edge of a live crater will get hotter when an eruption is impending. They solemnly measure with a thermometer. The eruption comes and goes, and nothing whatever happens to their hot crack.

Or it may be earthquakes. The lava gushes up in the bottom of the pit, and immediately the tremors may become fewer than before. Or the shakes temporarily flare up, if measured very close to the crater, and then die away before the eruption ends.

The idea that a beautiful fever chart would show everything, before the disease breaks out, is a dream doomed to disappointment. Lava is there all the time. It is a substance which suddenly releases thermal and kinetic energy, apparently from great depths. But **how,** chemically and physically, this release proceeds, is still a mystery.

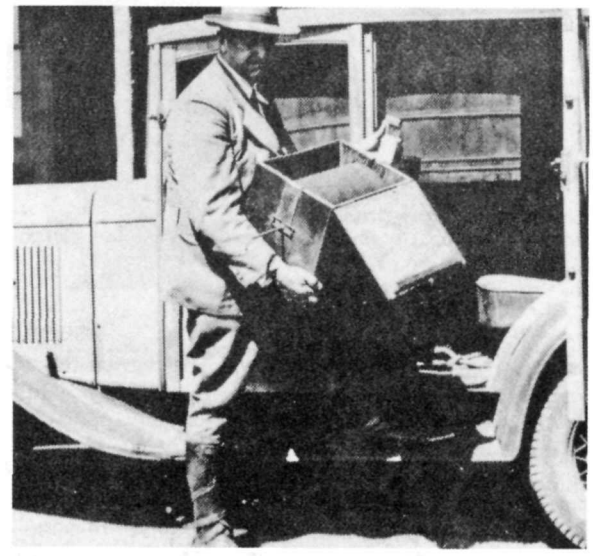
The mere finding out that the lava is there all the time is a real discovery. It is proved by the sudden geysering of gas and red hot froth at the edge of a plug in the pit bottom, when a new eruption begins. By experimental drilling into Kilauea crater we found places growing hotter downward. By watching the walls of the pit when a big cave-in occurred, we found red hot avalanches 600 feet down. And when a thick new flow cools off, we find the under parts stay hot for years.

Comparing the dull times when the lava in the pit was sluggish but liquid, and the dull time now when it is crusted and hard, there is no essential difference in behavior: sulphurous hot gas always rises, the rim cracks move, the earth tremors increase and decrease, and the top of the mountain is a flexible shell that tips inward, or tips outward. Always the ground is **alive,** and very different from the terra firma of Honolulu.

Four things, weather, earthquakes, slow movement, and gas emission are the things we set ourselves to measure after twenty-five years of Observatory work. First, the measured changes of the weather. We must know what weight of rainwater loads the mountain, what pressure and temperature of the air may make changes in the rock, and how wind and storm and sunshine may deceive us in viewing steam or vapor from cracks.

Second comes the locating of earthquakes. This looked like a delightful prospect in 1912. We would find out who felt the quakes most. We would make a nice little instrument for everybody. Then Kona would tell us the December quake there was of Grade 2, Kohala would have Grade 1, Hilo would show Grade 6, and Kilauea would be Grade 8. Ergo, Kilauea was strongest, and Kilauea lava made the shake.

But nothing like that happened. When it came to **feeling,** people in one end of Hilo town felt quakes that nobody noticed in the other end. With a magnifying seismograph in Hilo and at Kilauea, Kilauea got many tremors that did not show at all in Hilo. When a nice little earthquake was felt in Kohala, Kona, Hilo and at Kilauea, all at the same hour, and surely the same shock, nobody felt it more strongly than anybody

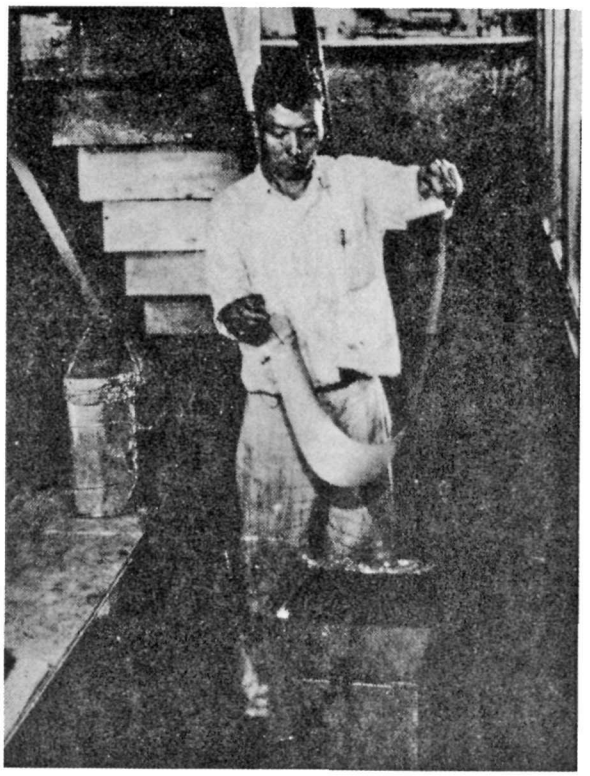


SEISMOGRAPH ROUTINE 4
Carrying case for drum, transported by car to be changed, and the record varnished.

else: it seemed to have been felt equally all over the island. This was most disconcerting. It raised such baffling questions as "What **is** an earthquake, anyway?" And so we were led to phases, and compression, and angle of emergence, and vertical component, and depth of origin. And to the question, what **is** an origin? Is it a snapping open, or a scraping slip, or a closing bump?

The entire science of seismology was painfully reviewed and investigated and experimented with; complicated seismographs were set up and discarded and tried anew; at Kilauea, Hilea, Kona, Puu Waawaa, Waikii, Honokaa, and Hilo. Trials of simplified shock recorders were made. The telephone was used to send the same time-keeping to different stations. Wireless was installed to get the same time-signal to each station. Some instruments were made to write with a beam of light on photographic film. And all of this had a **geographical** motive, to peared above ground, was done on Mauna Loa in 1935. This was the result of careful studies for two decades by faithful seismologists. But we are still far from knowing exactly what an earthquake is.

The third quest of the Observatory concerns finding out what is the secular strain under which a volcano is laboring. Not only does the ground shake, but it rises and tilts. This involves a long engineering program, again harnessing an island. Kilauea Crater has been proved to move more, through a period of twenty years, than Hilo. The movements up and down were big, before and after the pit exploded in 1924. They were up before, down afterward. The mountain swelled for ten years, then its top was let down suddenly. At the same time the lava was withdrawn, water must have rushed in below, and steam gushed out. Probably the lava flowed out under the ocean.



SEISMOGRAPH ROUTINE 5
Fixing the smoked seismogram with varnish bath.

cover the whole island. The result was a deadlock, for the whole island had to be covered with skilled physicists, an obvious impossibility. The workers were faithful amateurs, but a seismograph properly requires a highly trained scientist.

So the Observatory muddled through, getting a result here and a result there, and an improving list of earth movements. The dream of 1912 faded away. The harnessing of an island with amateurs is still awaiting a suitable instrument. Three stations have been maintained at corners of a triangle. Theoretical seismology has improved, and the routine is shown in the accompanying photographs. The horizontal pendulum three-component seismograph, with smoked-paper records, is still used, and the earth has written thousands of autographs. The locating of a place underground, where an outbreak ap-

All of this story from 1912 to 1926 was told by R. M. Wilson in engineering language, "Ground Surface Movements at Kilauea Volcano," (University of Hawaii Research Publications No. 10, 1935, 56 pp. with maps and charts). The work has been done repeatedly by levelling, tide gauge reading, triangulation, setting up nets of flags, bench marks and towers across the volcano, and by comparing the results of 1897, 1912, 1922, 1927 and other times.

This has been supplemented by the pendulums of the Observatory, writing on smoked paper, from day to day, many years. This writing showed tilting of the ground away from Kilauea very strongly after 1918. And there was strong tilting back again towards the crater in 1924. The Volcano House rose bodily about two feet during the years before 1924. It

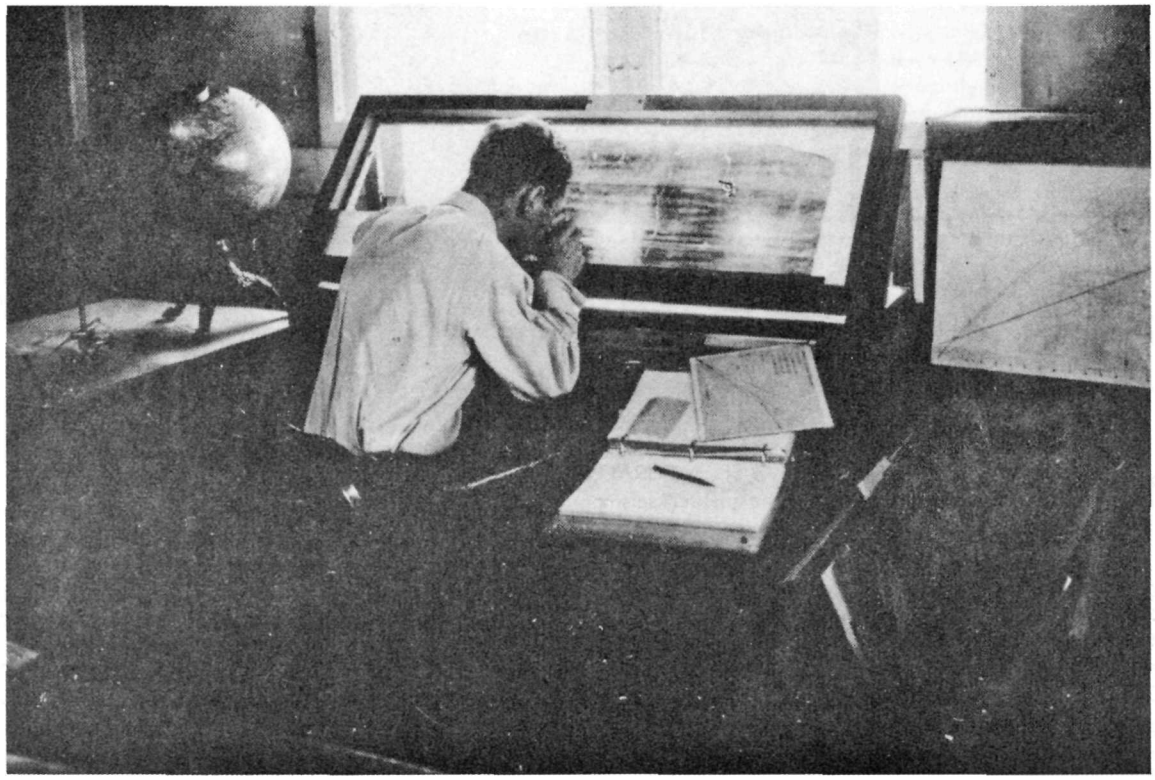
sank as much after the lava collapsed in 1924. And the edge of the inner pit Halemaumau sank **thirteen feet,** and the walls on opposite sides of the crater **approached each other.** This was proved by measuring horizontal angles with a transit, in the triangulation.

All of these laborious discoveries might have applied equally to the great crater on the summit of Mauna Loa, if men and means had been available, before and after the eruptions of Mauna Loa in 1914, 1916, 1919, 1926, 1933 and 1935. What Wilson began at Kilauea has gradually been added to by the weekly and monthly measurements at the Observatory, with level and transit. This was set in motion by E. G. Wingate, who succeeded Wilson as topographic engineer. Some of our illustrations show the surveying instruments used to line up the changing geometry of the crater.

The fourth and most elusive high ambition of the Hawaiian Volcano Observatory, in its methods of studying the chemistry and physics of the inner earth, deals with the emission of gases, especially hydrogen. To collect new or "juvenile" gas from live lava, to trap and analyze it, to develop a technique that can be applied at any sulphurous volcanic vent or actual flame, is the volcano student's dream. Whenever the mighty fountains play above a gushing rift on Mauna Loa, there are flames. When the gushing stops, there are steam jets and sulphur and selenium and alum. The so-called "solfataric" mild activity (Sulphur Bank) of quiescent volcanoes, is still **in communication by gas ducts** with potentially live lava below. We see such gases on the sun, and both volcano and sun yield free hydrogen. Free hydrogen at high temperature is not to be trapped. No laboratory container will restrain it. At lower temperature it has been trapped at Kilauea, in small percentages. Its oxide, water vapor, appears in large percentages. The lower the water vapor, the higher the hydrogen. This ratio leads to the suspicion that if spectroscopic or other method could find out, what is the Hawaiian gas before it vanishes in flame, we might discover hydrogen to be the prime mover of all volcanism. It is certainly a primary element in all chemistry, and in astro-physics: and water vapor is nothing more than burned hydrogen.

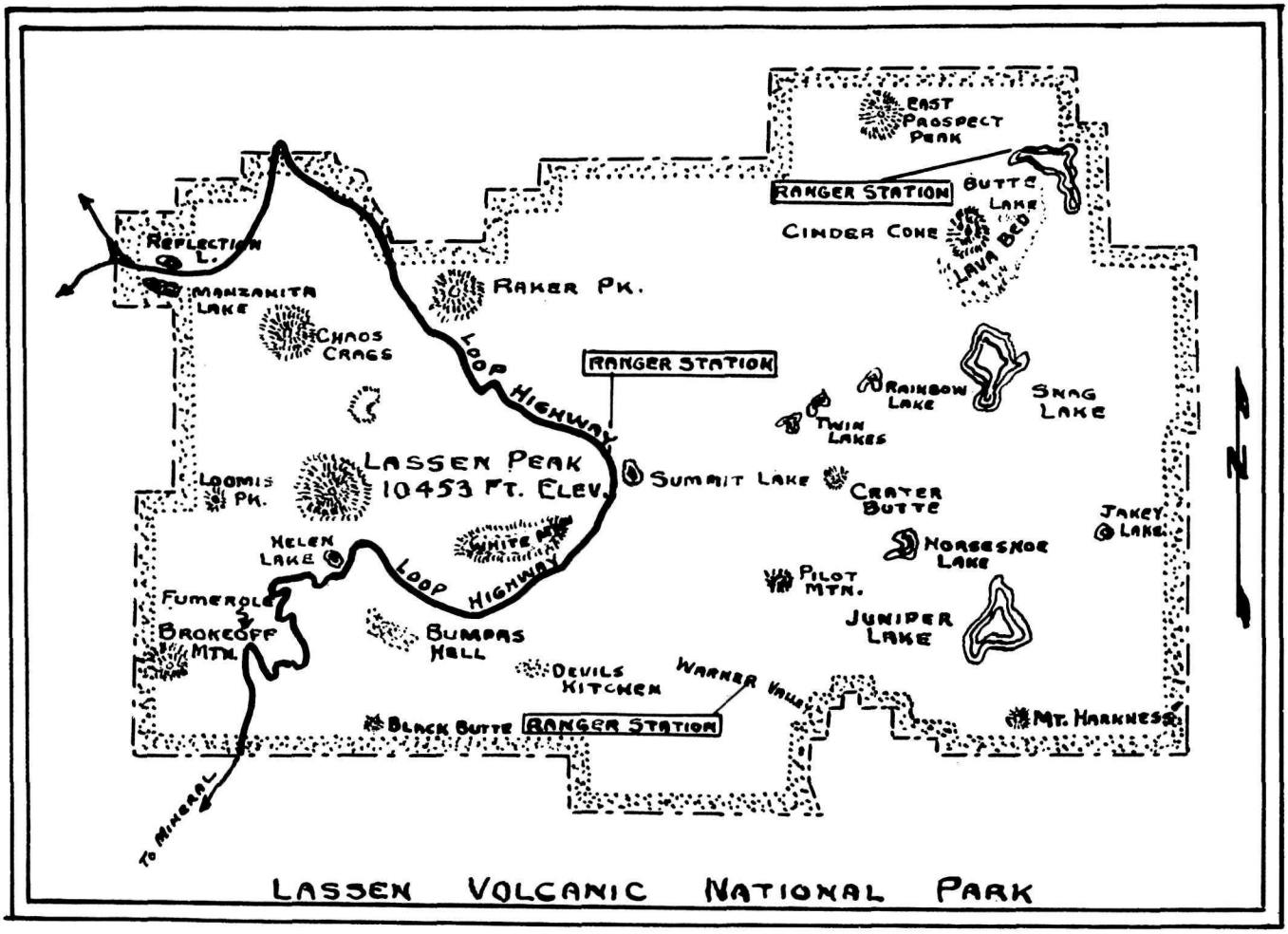
The methods of attacking the gas problem are illustrated in some of the photographs. Vacuum tubes are thrust behind a flame, or into a sulphurous crack, and the tip is melted or broken deliberately. The glass is sealed and the contained gas carried to a laboratory for analysis. This work is now being improved by special researches by the Physics Department of the University of Hawaii; in which the spectroscope will play a part.

The illustrations appearing in this issue of the Volcano Letter show the seismograph routine; other apparatus in regular daily use will be shown in succeeding issues. T. A. J.



SEISMOGRAPH ROUTINE 6

Studying and measuring the seismogram, calculating the epicentral location, and entering in record book.



EARTHQUAKES IN LASSEN VOLCANIC NATIONAL PARK DURING MAY, 1936

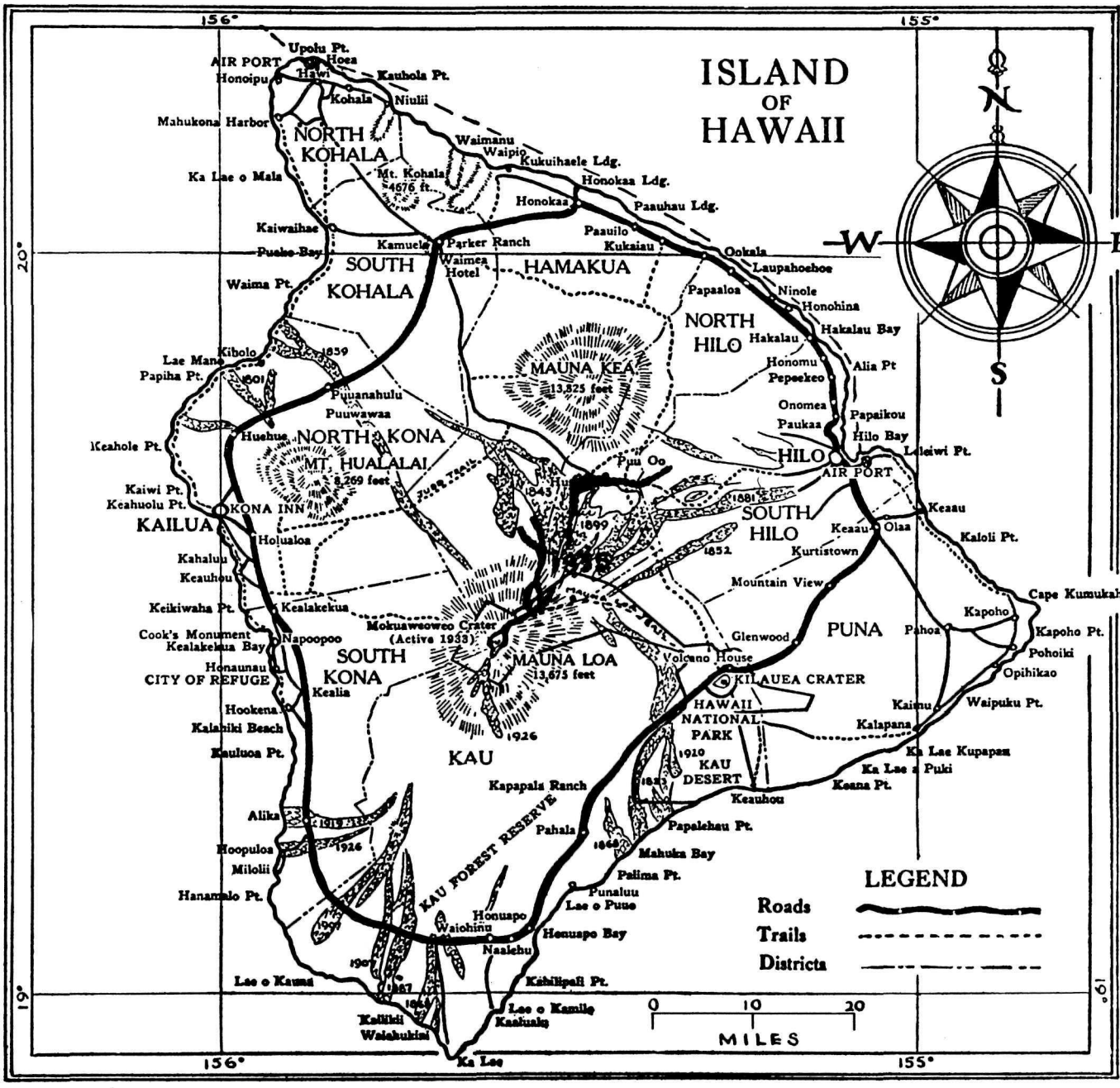
Carl R. Swartzlow
Park Naturalist

More earthquakes occurred in May, 1936, than in any previous month. The shocks were all of low intensity. Only four were of No. 5 intensity, according to the McAdie Scale, and the rest were less severe.

The earthquakes were accompanied by considerable tilt during the periods of greatest activity.

With a few exceptions the epicenters were located within the park boundaries. Most of the shocks did not center under Lassen Peak as many people believed but were located along fault zones in the eastern part of the park. The Warner Valley fault zone was the center of greatest activity, with some minor shocks felt in the Butte Lake District.

The hot spring activity has remained practically normal throughout the month. On April 30, four columns of steam rose from the crater of Lassen Peak to a height of between 200 and 300 feet, but activity on the peak has been normal since that day, although a little abnormal activity was noted in Bumpas' Hell early in the season. Conditions in the Devil's Kitchen in Warner Valley have been normal during the period of observation.


ISLAND OF HAWAII
N
S
E
W
156°
155°
20°
19°
Upolu Pt.
AIR PORT
Hoea
Honoipu
Hawi
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH KOHALA
Waimanu
Waipio
Kukuihaele Ldg.
Ka Lae o Mala
Mt. Kohala 4676 ft.
Honokaa Ldg.
Honokaa
Paauhau Ldg.
Kaiwaihae
Paauilo
Kukaiau
Kamuela
Parker Ranch
Pueko Bay
Waimea Hotel
SOUTH KOHALA
HAMAKUA
Ookala
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH HILO
Hakalau
Hakalau Bay
Kibolo
1859
Lae Mane
Papiha Pt.
1801
MAUNA KEA
13,825 feet
Honomu
Pepeekeo
Alia Pt
Puuanahulu
Puuwawaa
Onomea
Papaikou
Paukaa
Huehue
NORTH KONA
Keahole Pt.
MT. HUALALAI
8,269 feet
Hilo Bay
HILO
Leleiwi Pt.
AIR PORT
Puu Oo
Kaiwi Pt.
Keahuolu Pt.
KONA INN
1845
1881
SOUTH HILO
Keaau
KAILUA
1899
Keaau
Olaa
Kaloli Pt.
Holualoa
1852
Kurtistown
Kahaluu
Keauhou
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Mokuaweoweo Crater (Active 1933)
Cook's Monument
Kealakekua Bay
Napoopoo
Glenwood
PUNA
Pahoa
Kapoho Pt.
Pohoiki
Honaunau
CITY OF REFUGE
SOUTH KONA
MAUNA LOA
13,675 feet
Volcano House
KILAUEA CRATER
Opihikao
Kealia
Hookena
HAWAII NATIONAL PARK
Kaimu
Waipuku Pt.
Kalahiki Beach
Kalapana
1926
Kauluoa Pt.
KAU
1920
KAU DESERT
Ka Lae Kupapau
Ka Lae a Puki
Kapapala Ranch
1823
Keana Pt.
Keauhou
Alika
1919
Papalehau Pt.
Pahala
1868
Hoopuloa
1926
Mahuka Bay
Milolii
KAU FOREST RESERVE
Palima Pt.
Hanamalo Pt.
Punaluu
Lae o Puuo
Honuapo
Waiohinu
Honuapo Bay
1907
Naalehu
1907
Lae o Kauna
Kahilipali Pt.
1887
1868
Lae o Kamilo
Kailikii
Kaaluaku
Waiahukini
Ka Lae
LEGEND
Roads
Trails
Districts
0
10
20
MILES

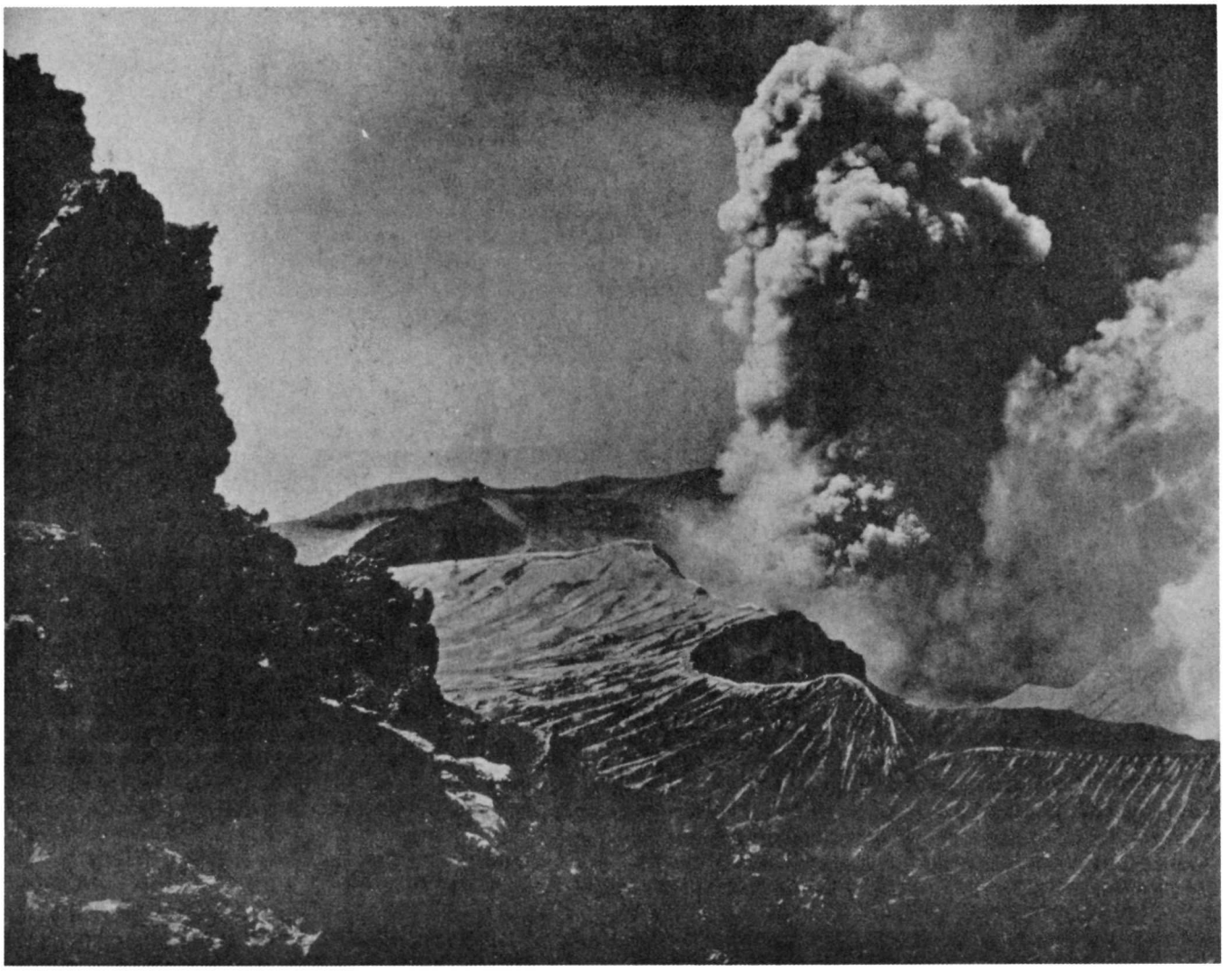
THE VOLCANO LETTER

No. 436—Monthly, Department of the Interior, National Park Service, June, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JUNE, 1936



Naka-dake Crater, Pit No. 2, of Mount Aso Volcano, Japan

REPORT OF VOLCANO OBSERVATORY FOR JUNE, 1936

The normal schedule of routine activities has been carried on at the Volcano Observatory during the month. Regular records have been kept of daily activities and of observations of Mauna Loa and Kilauea. The usual daily trips to the seismograph stations and tilt stations for observations have been made. Daily meteorological records have been kept.

The Volcanologist, Dr. Jaggar, is still absent on a scientific expedition studying conditions at Montserrat for the Royal Society of London.

Mauna Loa and Kilauea have been quiet throughout the month. June 14 ended a week of exceptional quiet at Kilauea, during which no rock slides from the walls of Halemaumau were reported. This is the first time that such has been the case for over a year. Active sliding was again resumed the

week of June 28. A party accompanied by Ranger Murray made a trip to the summit of Mauna Loa June 13 to 16. They report that there had been considerable activity in the NE section of Mokuaweoweo, the summit crater, during the November, 1935, eruption. The trail, one-half mile below the crater, was covered by a new lava flow. Fuming, though greatly diminished, was continuing at the source cones at the 1200-foot elevation and deposits of sulphur were reported large around their base. All trails and markers in the NE portion of Mokuaweoweo have been obliterated. The summit rest house was unharmed.

Seismic activity has been moderate and fairly consistent as shown by the numbers of disturbances for the successive weeks of 32, 32, 21 and 32. Of these one was a feeble quake on June 4, 26 were very feeble shocks and the remainder was made up of tremors. Three minutes of continuous tremor began at 11:26 P.M. June 2. On the morning of June 30 at 3:59 twenty-eight minutes of continuous tremors began recording. Most of the disturbances are of Kilauea origin.

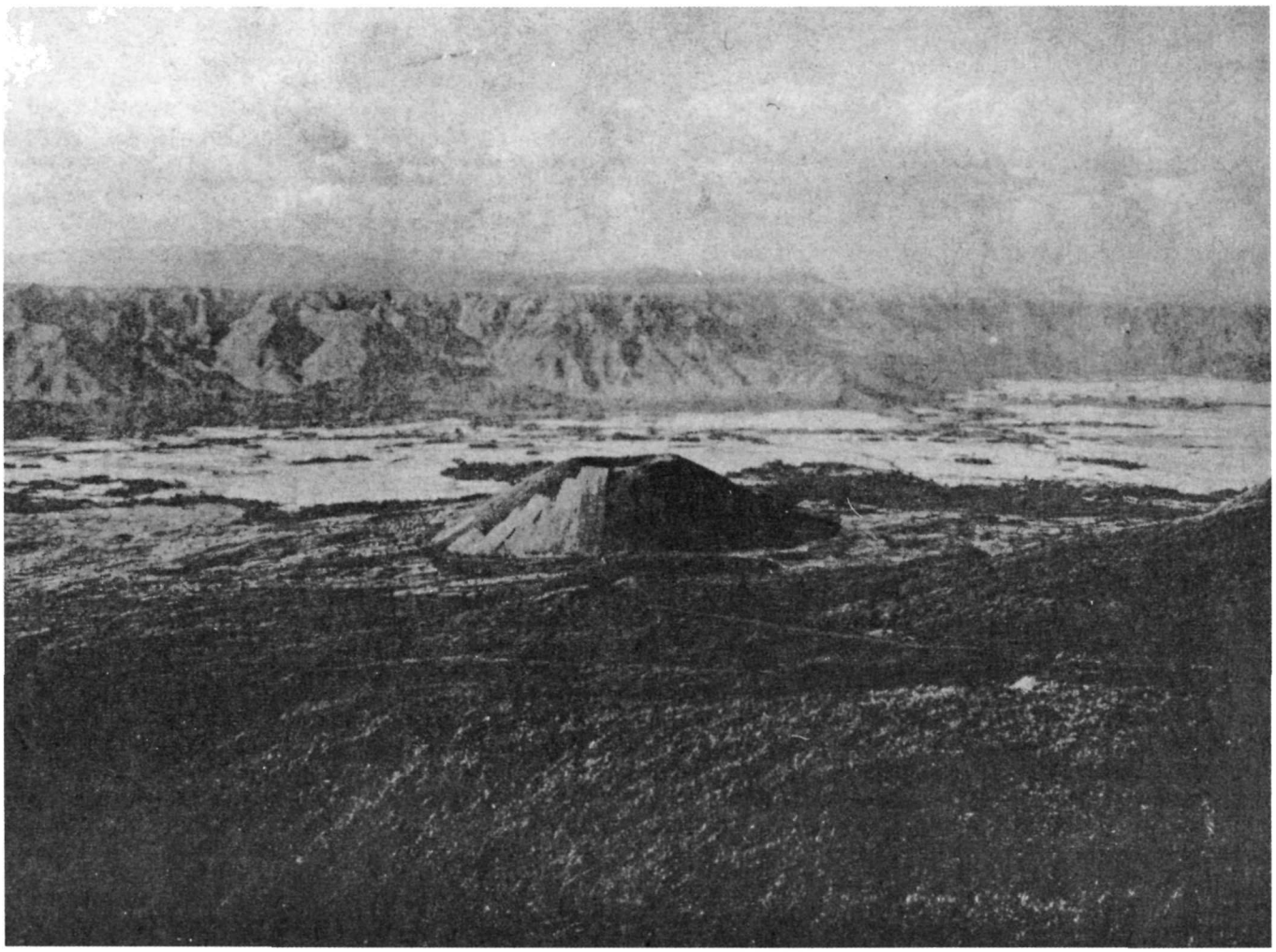
Crack measurements around Halemaumau for the month showed very little change except number 46, located on the NE rim, which has consistently opened at an abnormal rate of 4.5 millimeters per week.

Mr. F. Chase of the Department of Geology, Harvard University, visited the Park on June 10-17. He spent considerable time studying at the Observatory and made a trip to the summit of Mauna Loa. He had been two years in Australian gold mining work and was returning to Cambridge to resume his duties there.

TABLE

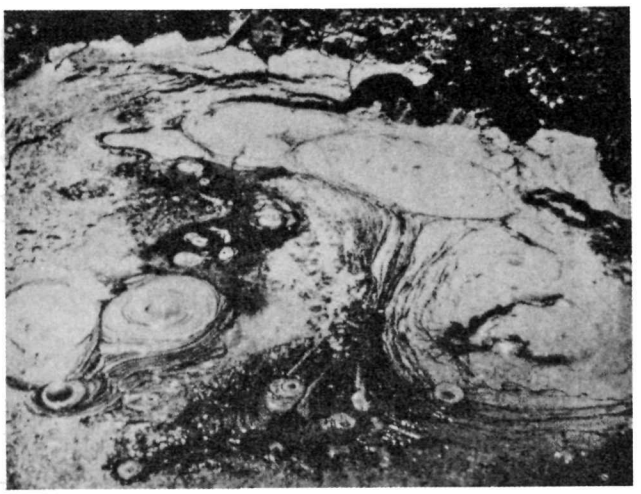
Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant Earthquakes	Local* Seismicity
June 7	25	8	1	1	11.25
" 14	28	4	0	0	9.00
" 21	17	4	0	0	6.25
" 28	23	9	0	0	10.25



View of Mount Aso Crater, Japan

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of the seismograms from stations at Hilo and Kealake-



Boiling Mud at Hot Springs, near Beppu, Japan

kua. The disturbances began at the times indicated and whenever possible determinations of depth of focus have been made.

June 1, 6:33 pm, very feeble, probable location in Kilauea Crater.

June 1, 7:53 pm, very feeble, located 2.5 miles SSW of Pit seismograph station in Kau Desert. 19° 22' 3N; 155° 18' 0W.

June 3, 8:13 pm, very feeble, located 1.5 miles deep in Kilauea Crater 1.0 mile SW of the Volcano Observatory. 19° 25' 2N; 155° 16' 1W.

June 4, 1:21 pm, very feeble, located 2.5 miles under SE rim of Kilauea Crater 19° 24' 7N; 155° 15' 8W.

June 4, 3:18 pm, very feeble, located 1.8 miles deep in Kilauea Crater, 1.0 mile SW of the Volcano Observatory. 19° 25' 2N; 155° 16' 1W.

June 4, 3:21 pm, feeble, located 3.0 miles deep in Kilauea SW Rift zone 0.4 mile west of Halemaumau in vicinity of the Rift Cones. 19° 24' 6N; 155° 22' 8W.

June 5, 4:09 pm, very feeble, located 1.2 miles under Pit Seismograph in Kilauea Crater. 19° 24' 3N; 155° 17' 0W.

June 7, 9:53 pm, very feeble, located 0.8 mile deep under SE rim of Kilauea Crater. 19° 24' 5N; 155° 15' 9W.

June 7, 11:28 pm, very feeble, located 1.2 miles under N rim of Kilauea in vicinity of Kilauea Military Camp. 19° 26' 3N; 155° 16' 8W.

June 11, 5:05 pm, very feeble, located 1.4 miles deep in Kilauea Crater 5.0 miles SW of the Volcano Observatory. 19° 25' 6N; 155° 16' 0W.

June 14, 8:31 am, very feeble, probably located in Kilauea SW Rift zone 8 to 9 miles SW of Halemaumau.

June 17, 12:55 am, very feeble, located 1.4 miles S of Pit seismograph and 1.9 miles deep. 19° 23' 2N; 155° 18' 0W.

June 18, 12:03 am, very feeble, located 2.5 miles under W rim of Kilauea Crater 0.7 mile SW of Uwekahuna. 19° 25' 1N; 155° 18' 0W.

June 22, 2:37 am, very feeble, probable location in vicinity of Hilina Pali.

June 23, 7:19 am, very febele, probable location in Kilauea Crater.

June 25, 8:34 pm, very feeble, located 3.7 miles deep and 1.1 miles SW of Puu Ohale. 19° 20' 9N; 155° 17' 7W.

June 25, 8:37 pm, very feeble, located 3.1 miles under NW rim of Kilauea. 19° 25' 9N; 155° 17' 4W.

June 26, 6:57 am, very feeble, located 1.6 miles deep and 0.3 mile S of S rim of Kilauea Iki. 19° 24' 6N; 155° 15' 1W.

June 26, 9:25 am, very feeble, probable location in NE portion of Kilauea Crater.

June 26, 2:54 pm, located 1.6 miles deep and 0.8 mile S of Twin Craters. 19° 24' 4N; 155° 14' 2W.

The surface (L) waves of a distant earthquake began recording at the Observatory at 11:02 pm, June 2. The reported location was off the Coast of British Columbia. 40° 7N; 125° 5W.

Three minutes of continuous tremor registered, starting at 11:26 pm, June 2.

Microseismic motion was moderate, June 2, the remainder of the month it was light.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending June 28 was 5".08 N and 0".74 W.

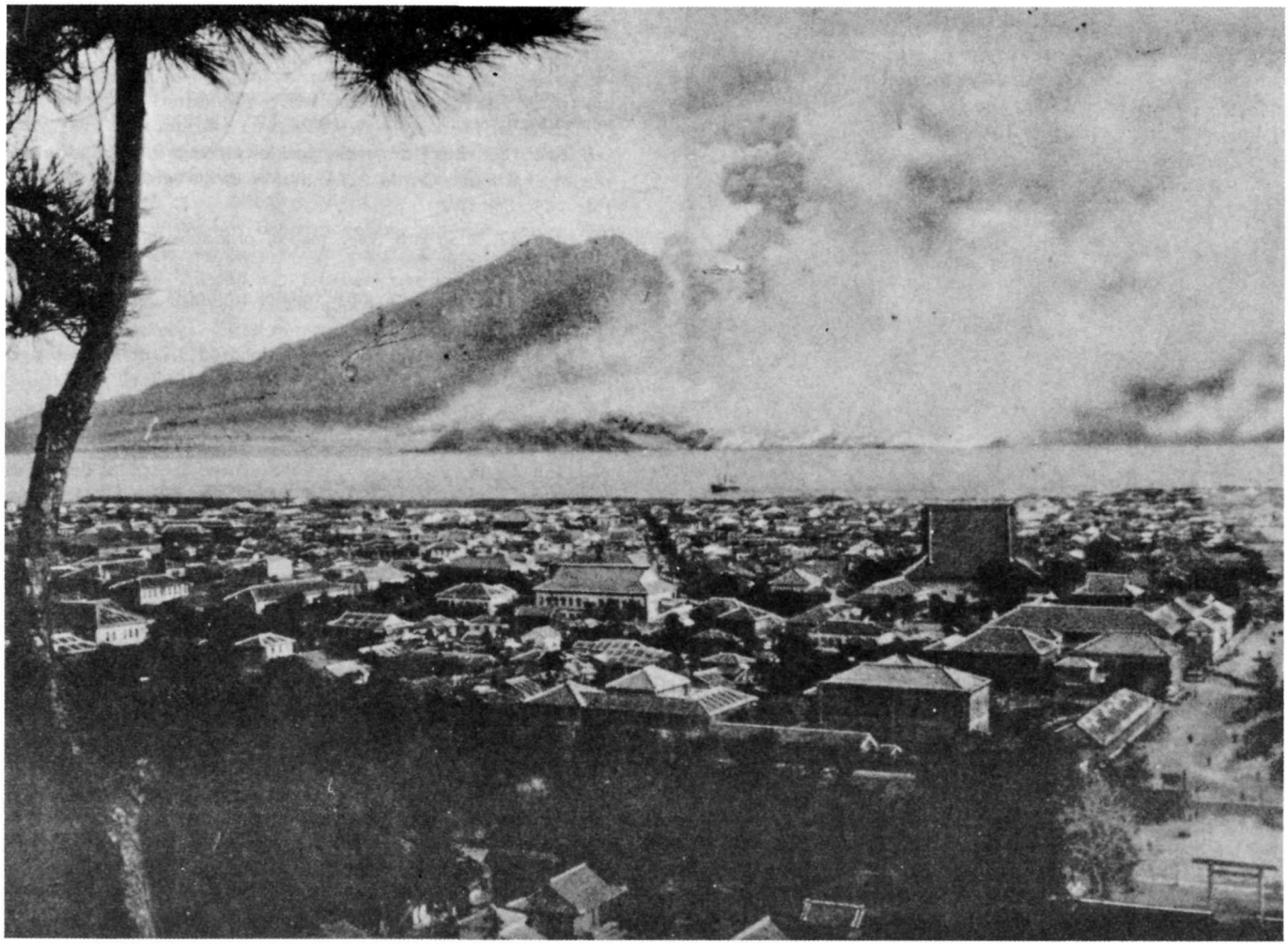
H.H.W.

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory June 9, compared with similar measurements March 16 and April 15, showed little change across Halemaumau but indicated opening across the crater from rim to rim in a NW-SE direction. March 16, to April 15, Halemaumau showed opening of 0".11 and April 15, to June 9, it closed 0".52. Across the Crater there was an opening of 0".75, and April 15 to June 9, an opening of 2".18.

TABLE OF TILT

Week Ending		Halemaumau Clinoscope Stations		
	Observatory	West	Southeast	Pit Resultant
June 7	1".00 S 40°W	6".59 S 65°W	7".52 N 10°W	0".34 toward
" 14	0".29 N 59°E	3".10 N 38°W	6".19 S 9°E	7".11 from
" 21	0".75 N 33°E	4".26 S 40°W	6".71 N 2°E	2".22 toward
" 28	0".92 N 19°E	5".96 N 79°W	1".94 S 83°W	4".69 from



View of Sakurajima, Kagoshima in Foreground, 1914 Eruption

NOTES ON JAPANESE VOLCANOLOGY, AND ON SEISMOLOGICAL RESEARCH

H. H. Waesche

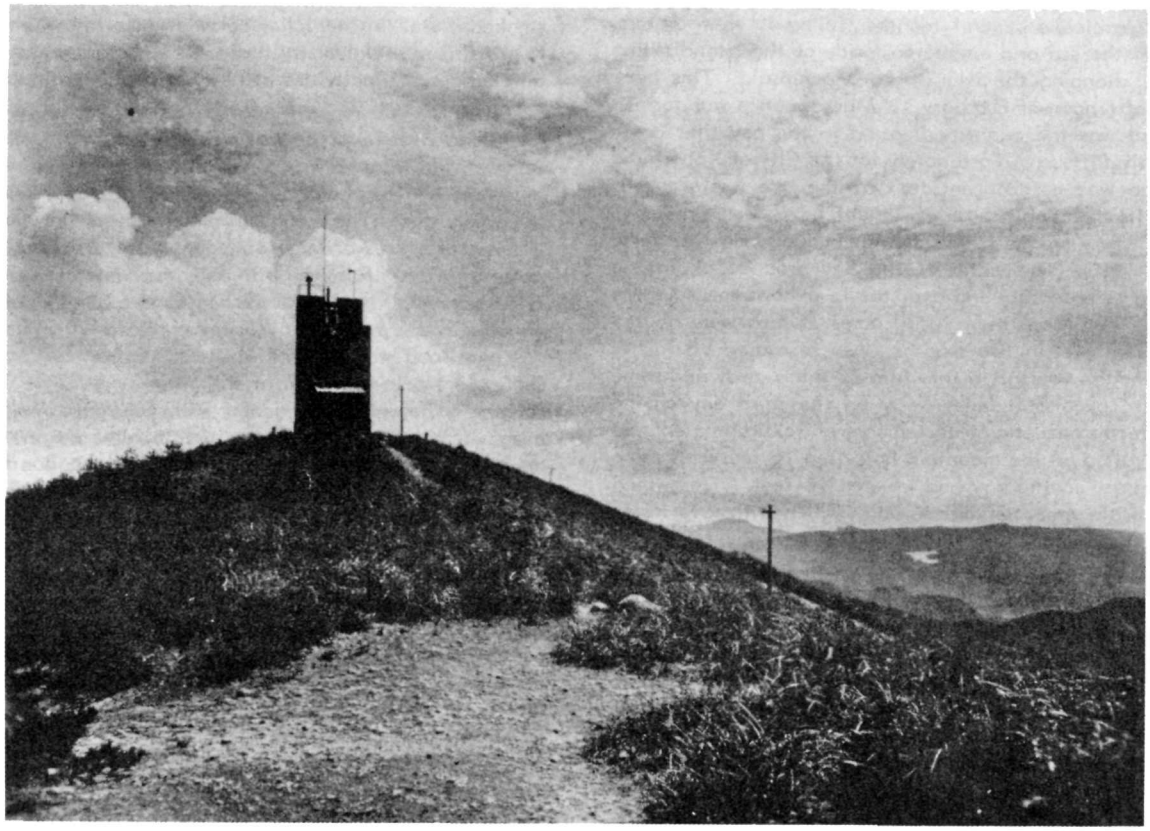
Cherry blossoms, temples, and volcanoes are three things that every visitor to Japan becomes conscious of as soon as his ship docks at one of the Empire's many ports. He may not see the cherry blossoms as they are a seasonal exhibit only, and a visit could be made without seeing any of the shrines or temples, but evidence of volcanic activity, either past or present, cannot be overlooked. Volcanoes are a part of the everyday life of all the Japanese. Volcanism is a major motif in their art, it enters into religion, and even in their play at various hot-spring resorts or "spas," as they are called. Fujiyama is known the world over for its grace and symmetry of form. This dormant volcano is exhibited in practically all *Japanese arts and being sacred it influences the thought of* the entire country. It is probably the typical volcano. Volcanic eruptions, destructive and otherwise, have been a part of the history of Japan from its very beginning. There are many volcanoes which are periodically active, such as Asama, Mihara (Oshima), Aso, and Sakurajima among the more famous, and others at scattered localities from Hokkaido in the North to Kyushu in the South. Anyone interested in volcanology and its related subject, seismology, will find both well represented in their many phases in the "Land of the Rising Sun."

H. Waesche, Assistant Geologist at the Hawaiian Volcano Observatory, and Merel S. Sager, Associate Landscape Architect of the U. S. National Park Service, visited Japan during April and May, 1936. Trips to the volcanic areas of Mt. Fuji, Beppu, Sakurajima, Mt. Aso and Unzen were made during their stay. They also visited the Department of Geology, and the Research Institute of the Tokyo Imperial University. Acknowledgment is made of the many courtesies extended and helpful information given by Dr. S. Tsuboi of the Department of Geology, Dr. M. Ishimoto of the Research Institute, and Drs. *Imamura and Matuzawa of the Seismological Institute.* The trips to the National Park Areas were made most enjoyable and profitable through the very kind assistance of Dr. T. Tamura, of the Japanese National Park Association, his assist-

ant Mr. Kato, and the local directors of the several parks, as well as local prefectural officers. All contributed toward making the trip one of outstanding value.

The morning of April 17 was spent inspecting Hot Springs in the vicinity of Beppu. This city is one of the most famous of Japan's 1200 spas. It is located on the east coast of the Island of Kyushu bordering the famous Inland Sea. Here in a volcanic area of about twenty square miles are found over a hundred thermal springs and fumaroles exhibiting a variety of characteristics. They are known as "Big Hells" or to the Japanese as jigoku. Associated with many of the hot springs are smaller areas several feet in diameter of boiling mud similar to the "paint pots" seen in Yellowstone. These latter are noisily and continuously agitated by escaping steam. The largest of the hot springs is known as Umijigoku and is thought to be over 400 feet in depth and has a temperature of 195° F. at the surface. The water of one spring visited possessed a bright red color which appeared to be caused by the presence of iron, evidently in the form of ferric oxide. Articles of clothing and other materials dipped in the red water and stained were valued souvenirs by many visitors. The name of this spring was Chinoikejigoku or "blood pond." Most of the fumaroles produced sulphurous odors. No native sulphur deposits were observed, however. A popular novelty along the seacoast at Beppu is the so-called "sand bathing." Hot springs bubble up through the sand beaches where the bathers bury themselves in the sand and take a modified turkish bath.

The next stop after leaving Beppu was made at the city of Kagoshima in the southern part of the Island of Kyushu. This city is located on the shores of Kagoshima Bay. In the Bay and two miles east of the city, towering 3,500 feet above the water, is Sakurajima, one of Japan's mightiest volcanoes. This cone marks the scene of the greatest eruption in the annals of the Island Empire which took place beginning in January, 1914. It is of interest that this eruption was expected, and the local residents being thus warned were prepared, with a consequent loss of life of only 35 people and some millions of dollars in property damage. Warnings concerning the possibility of an explosive eruption were made as early as 1909 following rather violent earthquakes in the vicinity. In 1913 violent eruptions began at Kirishima Volcano some thirty miles to the north of Sakurajima. The last two eruptions there occurred on November 8 and December 9, consequently expectations at Kirishima were high when January 9 arrived, but nothing happened. However, at Sakurajima an outburst of earthquake swarms transferred suspicions to that vent. Four hundred and seventeen earthquakes were recorded at Kagoshima between 4 am January 11 and 10 am January 12, after which the main eruption began. The morning was cloudy so that the activity was not visible until after 10 am when the



Meteorological Observatory on Sokojio Unzen, Japan.

clouds dissipated. At that time a swelling balloon of black smoke in the middle of the mountain was seen rising from the ground where an hour before there had been orange orchards and cultivated, terraced fields. The column of smoke went up some 30,000 feet in the air and then bent eastward, strewing dust all over Central Japan. A smaller column arose on the east flank of the mountain having started ten minutes after the western one with which it later merged. There were booming concussions, flashes of lightning and in the lower part of the cloud, being thrown to great heights were ashes, sand and bombs. At night these latter were seen to be red hot. At 6:29 pm a violent earthquake shook Kagoshima and it was in the destruction caused by this shock to buildings and in landslides that most of the casualties resulted. This shock was recorded on seismographs in Europe. It was followed by lava emissions. Their flow continued several months, filling in new craters, pouring into the sea and on the east side of the Island filling in a strait, changing the Island into a peninsula. This happened the afternoon of February 1. Much pumice was formed and so great was the quantity floating in the bay that boats traveled with difficulty. Fortunately for the City of Kagoshima the eruption was not concentrated at the one western vent pointed in its direction as its fate might have been similar to that of St. Pierre on the Island of Martinique when Mt. Pelee erupted in 1902. The water of the Bay around Sakurajima was warmed considerably and near the lava flows measured as high as 138° F. More than 4,000 acres of lava were poured out above sea level in two months. Ash measured 70 inches in depth near the volcano, a thin film 30 miles away and some even fell in Tokyo 600 miles away on the third day of the activity. Precise geodetic measurements of Sakurajima showed that an elevation on the mountain had risen 10 feet whereas a point submerged in the bay had lowered 10 feet. This would seem to indicate that the volcano had swollen with lava inside while the surrounding land had subsided with the release of pressure and emission of lava.

On April 18 of this year Sakurajima was quiet when visited. In the early morning a moderate cloud of fume or vapor was seen rising from the summit crater. This was obscured by clouds shortly before noon. A boat trip was made to the tip of the most westerly lava flows from Kagoshima. The party landed on a beach composed of pumice. The lava was of a rough fragmental nature, black in color, very similar to the aa of Hawaii. It is said to be a hypersthene-hornblende andesite. The flow at this locality was piled up probably two hundred feet in thickness. Reports said that the eastern flow was 300 feet above sea level in localities formerly covered by 200 feet of water. The upper slopes of the volcano were bare of vegetation, were light reddish in color and seemed composed of soft materials of the nature of ashes and cinders. Sakurajima is of the usual conical shape much like the volcanoes of the Cascade Range of the Northwestern United States. Although not now active in a spectacular way it is an inspiring sight.

Leaving Kagoshima by train, the City of Kumamoto was reached the evening of April 18. The night was spent at the Tsukasa Inn. Early the next morning the party, consisting of Mr. Matsumuro, Director of Aso National Park, Mr. Goto, the Assistant Director, and a Japanese policeman by the name of Jiro Kurageno, left Kumamoto for Mt. Aso Volcano. Mr. Matsumuro left the party after going a few miles out of Kumamoto. The policeman went along as translator, being the only Japanese of the group who could speak English. At Bochu a bus was taken for the point of greatest activity. The bus was a very sumptuous one including swivel chairs as in a railway parlor car. Besides the driver there were two Japanese girls, one who described the places of interest in sing-song Japanese and another who translated it into English. The latter girl's name was Sumi Araki formerly of Honolulu, Hawaii, and spoke excellent English. She is now employed by the Great Aso Motor Bus Company in charge of the other girl employees and as a translator for foreign visitors. The bus used was one which had been especially built the preceding year for the exclusive use of Prince Takamatsu when he was a visitor to Mt. Aso. At the summit Mr. Henry K. Haraguchi, owner of the park concessions, was the party guide. The road from Bochu to the summit was finished five years ago, having been built by the Imperial government, and is now operated by the National Parks Association of Japan. It is about nine miles long and at no point is the grade more than 1:12. At the end of the road, which was about one-half mile from the active crater, there was located a seismograph station. Here there was an instrument of moderate magnification registering on a smoked drum. In the valley below Aso, toward Kumamoto, the Kyoto Imperial University has an observatory where studies of all changes and activities at Aso are being continuously made.

The Aso Volcano is the largest of a chain of vents extending along a zone of crustal weakness from Mt. Kuju to the east to Mt. Unzen to the west. This zone of weakness is supposed to be a continuation westward of the depression zone of the Inland Sea. The mountain proper covers the major part of the two provinces of Higo and Bungo and its base extends 30 miles E-W and 28 miles N-S, including some 700 square miles. It consists of a "somma" which attains a height of 3,200 feet above sea level, topped by an oval crater, 10 miles wide and 15 miles long, the floor of which is sunk an average of about 1,600 feet below the rim of the outer slope. The wall of this caldera is nearly perpendicular with talus accumulated at its base. This huge crater is thought to have originated by depression, as have those of Hawaiian volcanoes, due to the outflow of immense volumes of lava. The caldera is attained from Kumamoto on the west through the Futaye Pass cut into the rim to a depth of over 2,000 feet. Another pass known as the Tateno Break occurs to the south of Futaye Pass. Breaks in the rim walls along fracture zones aided by water erosion are supposed to be responsible for these two gaps. Rising near the center of this huge crater, said to be the largest in the world, are the central cones called the "Five Peaks of Aso." The most important of these is one known as Naka-dake, the scene of current activity. Standing west of Naka-dake is the highest cone, Taka-dake, rising a mile above sea level and around 3,600 feet above the floor of the caldera. Surrounding these central cones are the plains extending to the crater wall which are known as the "atrios." The part to the north of the cones is the Aso valley and to the south is the Nango valley. These atrios, consisting of volcanic ash, sand, lapilli and gravel, form a fertile soil on which lives a population of some fifty thousand people including 11 villages. The stratification of the materials composing the crater floor suggests the existence of a former crater lake, which was later drained through the passes previously mentioned.

Naka-dake possesses a series of five pits composing the summit crater. These are numbered consecutively from north to south and share honors as centers of activity with the number 1 pit having the majority to its credit. Number 3 pit is next in frequency of eruptions. Number 4 pit was active 10 years ago and continued intermittently for several years. In 1926 number 2 pit was described as a small kettle-shaped depression, at times filled with water and never very active. At present this is a large depression and the center of activity. It broke out with an explosive eruption in 1934 which was the largest in 150 years. Bombs and boulders were thrown over three hundred feet in the air and literally peppered the ground for several square miles around the vent. Much ash and cinders were ejected but no lava flows. A huge column of

smoke now billows above the vent, rising high in the air and easily visible almost the entire trip from Kumamoto to Bochu. Viewed from the rim of the pit, it is seen to be rushing out with considerable force and is accompanied by loud roaring sounds below. Evidently this cloud of fume is composed principally of steam with considerable sulphur fumes, as shown by the amber color in reflected light and bluish in transmitted light. This pit is now over 3,000 feet long by 1,500 in width and is about 450 feet from the rim to the throat of the funnel-shaped aperture from which issues the huge cloud of vapor. The throat is supposed to be about 35 feet across. Occasionally incandescent material is visible below. Number 1 pit is about 400 feet, number 3 about 250 feet and number 4 about 475 feet in depth. Their floors are dotted with fumaroles and solfataras. Historical records indicate that Naka-dake has erupted between 60 and 70 times. These have always consisted of emissions of mud flows, ashes and fragmental materials but never any trace of a lava flow.

The rocks of Mt. Aso are petrographically classed as andesites and are comparatively basic, many of them containing olivine or angite or both. The olivine-bearing rocks are found in the central cones and are younger than hornblende-bearing rocks found on the outer slope of the crater.

Aso Volcano is without doubt one of the most interesting sights to be seen in Japan today. It is apparently putting on an excellent and impressive performance at all times whether of a violent nature or otherwise. Five hundred thousand visitors annually are reported to look into the awesome depths of the rumbling pit. As is true of Mihara and Asama, Aso seems to be an attractive spot for those Japanese suffering from suicide manias. An average of 200 of these unfortunates is reported to make the leap from the rim of number 2 crater per year.

The next volcanic district as a part of the Japanese itinerary was that of Unzen, also a National Park and a very popular hot springs resort, catering mostly to foreigners. It is located on the Shimabara Peninsula, western coast of the Island of Kyushu and is the western terminus of the volcanic chain of which Mt. Aso is a part. The group of mountains at Unzen consists of a central cone called Fugen-dake and associated peaks of Kunimi, Myoken, Takaiwa and Kinugasa. The whole mound consists of a more acidic type of rock than was found on Mt. Aso.

Within historic times there have been several recorded eruptions at Unzen. One is reported to have started in 1657 A.D. and marks a period of activity lasting for more than 20 years. Others occurred in 1663 and 1664. The most eventful activities started with a series of earthquakes in the winter of 1792. On the morning of February 9 that year, Fugen-dake erupted with loud explosions, throwing heavy smoke clouds, mud and rocks. Lava broke out in the valley of Anasako February 25, overwhelming the village of Semboki. This lasted several months. A heavy earthquake shock on March 11 was followed by over 300 slighter shocks that night and over 100 during each of the next two days. Around April 1 a huge landslide following earthquake shocks occurred on the southeastern part of Mea-yama, a mountain on the seacoast south of Shimabara. About one-sixth of the entire mountain mass slid into the sea, producing severe tidal waves. Two villages were completely buried under the debris. The portion of this huge mass which slid into the sea gave rise to between two and three hundred islets of which many still exist. Today these are called "Ninety-nine Islands" and are partly covered by vegetation. The boat which runs from Misumi to Shimabara affords excellent opportunity to see the scar left by the slide and the islands which resulted. Whether this was really a volcanic explosion or not is a moot question. Casual observation from the boat suggested structural failure rather than volcanic activity. Various phases of diminished activity continued until February, 1793. Eruptions of this nature are of interest in exhibiting, specifically, relationship to a marked degree of volcanic activity and seismic activity. Other than a heavy earthquake in December, 1922, and minor shocks from time to time no further evidence of activity except hot-spring and fumarolic emissions has occurred.

In the recently erupted flat dome of Obiyama, past volcanic activity is indicated by numerous hot springs and fumaroles. This is the famous spa district of Unzen where are located the many hotels for the thousands of visitors who come from all over the world annually. The springs are usually acidic and contain sulphur compounds. Near the vents, siliceous sinter and deposits of sulphur are being built up. The spa is 2,200 feet above sea level. A nine-hole golf course is located at the foot of Mt. Myoken.

An excellent view of the surrounding country may be had from the summit of Kinugasa-yama. This mountain, over 3,000 feet above sea level, is the location for a meteorological station under the control of the Nagasaki Prefecture. Here are housed various instruments such as barometers, anemometers and thermometers. In a separate building is an Omori seismograph and quarters for an attendant. Unzen posseses a charm deserving of its great popularity.

The supreme expression of volcanism in Japan, at least to the popular mind, is the world-famous Mt. Fuji. Rising to a height of over 12,000 feet above sea level, it is usually surrounded by clouds and during most of the year there is a mantle of gleaming snow on the upper portion. Wherever Japanese art has gone, there also has gone Fuji. It is the very symbol of Japan itself and as previously mentioned is held in sacred veneration by the Japanese people. It well deserves this consideration. Its perfect cone is considered the classic type shape for a volcano of the explosive type. When the weather is favorable, Mt. Fuji may be seen from Yokohama, where visitors from North America first land, from Kamakura, parts of Tokyo and from the main line railroad between Yokohama and Kobe.

Mt. Fuji is characterized by a long, gentle slope of similar inclinations on all sides except the southern, where there is an explosion crater. Halfway up the inclination is 17° and at the summit it is 34°. A typical summit crater is found at the top of the mountain which is a funnel-shaped depression, 720 feet deep and 1,970 feet in diameter at the uppermost level.

Mt. Fuji has been active several times within history. In 800 A.D. a lava stream flowed down the Katsura-gawa and eached the Enkyo bridge following a violent eruption. In 864 A.D. two great streams of lava poured down the northern slope. The last major activity occurred in 1707 when a large explosion took place on the southeastern flank, producing the Hoeisan Crater. No lava was emitted but great quantities of bombs were thrown out. This was followed by small explosions in 1708 and 1792. The volcano seems dormant at present although reports mention fumaroles on the east side and on the top, none of which are very active. Numerous spas and hot springs dot the countryside around Fuji, however, of which some of the best known were visited at Myanoshita and in the Hakone District. One of these, visited May 9, 1936, known as the "Big Hell," was emitting quantities of sulphurous vapors, was surrounded by sulphur deposits, and was of comparatively high temperature. At Myanoshita, waters from the hot springs are run into very imposingly appointed baths at the Fujiya Hotel for the use of guests. Dr. Tamura of the National Parks Association presented a bomb from the summit crater of Mt. Fuji to H. H. Waesche. This was a sister rock of the one

presented to Mt. Rainier National Park in the United States as an exchange of goodwill between the respective countries. They were both brought down by Mr. Kato, Landscape Architect of the Japanese National Parks. The bomb was oval-shaped and about seven or eight inches in maximum diameter. Like other Fuji rocks it is of an andesitic composition. One of the best views of Fuji is obtained from Nadao Pass to the south, reached by bus from the Fujiya Hotel at Myanoshita.

On May 11 a visit was made to the Tokyo Imperial University. Dr. Tsuboi, the head of the Department of Geology, was host to the party. Activities of the Geology Department were discussed and results exhibited. Geological work was in progress on the Mount Fuji region and much areal mapping had been done. Instruments used for petrographical and mineralogical work were inspected. The department was up to date in all respects and seemed to be carrying on an extensive as well as progressive program of research with emphasis on the geological phases of volcanism, earth movements and structures, petrography and mineralogy. There was a large collection of thin sections of rocks from all parts of Japan. Everything was being carried on with the customary Japanese thoroughness.

Dr. Ishimoto, Director of the Earthquake Research Department, next took charge of the visitors. He has a large, well-equipped department with many seismographs of various types. Most of them were modified Galitzins of the accelerometer type, having a vibration period in some cases as long as 0.7 second. One vertical instrument had a pendulum extending three stories up to the roof of the building with a period of 7.0 seconds. Photoelectric recording was the preferred method, although many instruments utilized very thinly smoked drums. In all cases the drums were rotated by means of synchronous motors. They made in most cases four revolutions per hour. A few seismographs used no timing. Instrument magnification ran from 100 to 500 and on low magnification instruments from 2 to 10. The time marks were recorded on the drums by means of electrical solenoids which jarred the frames, thus widening the pen's trace at that instant and were controlled by master clocks. Tilting of the ground in Tokyo is given considerable attention because of its possible value in earthquake predictions following observed tilts of blocks between fault lines. One very interesting tilt instrument consisted of a long horizontal pipe partially filled with water and buried several feet in the ground. The open end of the pipe was faced with glass where the water level could be seen. Regular daily micrometer measurements of the changes in level of the water were taken and from them tilt calculations made. This seemed to be quite practical for tilt measurements in one plane and had the advantage of being earthquake proof. One laboratory room was used for testing seismographs and accelerometers with a standard rocking machine. Various types of harmonic motion could be produced in this manner with known values, making possible the determination of instrument peculiarities and characteristics. A similar instrument is in the shop at the Hawaiian Volcano Observatory and has been used for tests on instruments now in use. A great deal of attention is given to initial movement determinations. Both vertical and horizontal instruments are used. Models of glass representing the disturbed area are made, with small silk threads showing deformation of the earth near the focus as indicated by interpretation of initial earth movements at a number of localities.* All the instruments at the Earthquake Research Laboratory are located one to two stories below the ground level for better control of variable conditions, such as temperature changes and in order to reach a good rigid sub-stratum. Gravity determinations of localities on the earth's surface is a source of much active research along with the seismological studies.

As guests of Dr. Ishimoto, luncheon was enjoyed at the faculty restaurant in the company of Drs. Tsuboi and Imamura, as well as the host. After luncheon Mr. Sager called at the Architectural Department while H. Waesche accompanied Dr. Imamura to the laboratories of the Seismological Institute, of which he is Director Emeritus. The Institute is an older organization than the Earthquake Research Institute. It was previously under the direction of the late Professor Omori, world-renowned seismologist, and is now directed by Dr. T. Matuzawa. Possibly the work of the two organizations overlaps. The primary interest of the Seismological Institute, though, seems to be the study of the cause and effect of earthquakes with their possible prediction of occurrence in mind. Here they are interested in what happened in Tokyo and Yokohama in 1923 and what can be done to prevent recurrence of such catastrophes. More attention is given to local shocks. The Earthquake Research Institute, on the other hand, is more interested in the theory of wave propagation, physics, and mathematics of seismology. The day was concluded with Drs. Matuzawa and Imamura conducting the remainder of the party through their laboratories. It was noticed that an instrument identical to the one in use at Uwekahuna was in operation. Many old obsolete seismographs were on display as well as various other instruments of a seismological nature. Pictures of earthquake destruction were plentiful. Seismology is taken seriously in Japan—and it should be, with the occurrence of such catastrophes as some of the past earthquakes have caused. These two seismological research institutions are working day and night to learn more about one of Japan's principal problems. Knowledge is not a guarantee of protection but it will go a long way toward making Tokyo a safer place in which to live, and prediction of earthquake activities more reliable.

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* From the Proceedings of the Imperial Academy, Vol. VIII (1932), No. 2, Sur le Mécanisme de la Production des Ondes Sismiques au Foyer: Existence d'une Source Quadruple au Foyer; and Vol. XI (1933), Part 2, la Deformation de la Croûte Terrestre et al Production des Ondes Sismiques au Foyer, par Mishio Ishimoto.

THE VOLCANO LETTER

No. 437—Monthly, Department of the Interior, National Park Service, July, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY, 1936

VOLCANOLOGY

A fresh scar was found on July 1 on the west end of the north wall of Pauahi Crater in the Chain of Craters. Other scars representing recent slides were noticed in Makaopuhi, along with an increase of fuming and sulphur stains.

The week ending July 12 was peculiar in that no rock slides were reported from Halemaumau. Fumes continued to issue from the west floor solfatara, and a more intense puff of fume than usual rose over the NW rim of pit July 11, 10:15 am.

Measurement of 32 marked concentric cracks around Halemaumau, showed changes each week from the week before, as follows, with certain notable openings of Crack No. 46, which is about 150 feet back from the ENE rim:

Six days ending July 3, 6 opened, 4 closed, aggregate opening 5.5 mm. Crack 46 opened 4.5 mm.

Eight days July 11, 13 opened, 2 closed, aggregate opening 11.0 mm. Crack 46 opened 5.5 mm.

Week ending July 18, 7 opened, 5 closed, aggregate opening 5.5 mm. Crack 46 opened 4.5 mm. Fresh cracks opened on the ENE rim.

Six days ending July 24, 7 opened, 1 closed, aggregate opening 9.0 mm. Crack 46 opened 6.0 mm.

Eight days ending August 1, 7 opened, 3 closed, aggregate opening 10.5 mm. Crack 46 opened 8.5 mm.

Thus through five weeks the aggregate openings have been 5.5, 11.0, 5.5, 9.0 and 10.5 mm, and crack 46 has opened 4.5, 5.5, 4.5, 6.0 and 10.5 mm, these facts showing progressive increase of yawning open of cracks northeast.

Rock Slides in Halemaumau

June 29, new dust on floor and scar on wall 400 feet below Crack No. 29, NE. At 12:45 pm a NE slide made dust cloud visible for 5 minutes.

June 30, 3:50 pm, small slide. Others occurred at 5:35 pm, 6:18 pm, 6:25 pm and 6:30 pm, all NE.

July 2, 8:55 pm, SW wall, 9:10 pm, NE wall.

July 13, two large slides sent up dust 3:20 and 3:24 pm.

July 18, 9:58 am, noise of rocks falling at SE wall.

July 20, avalanche scar NE.

July 21, noon and 3 pm, dust from slides NE, followed by dribbling slides.

July 22, more scars, small slide 9:37 am, a larger one 1:19 pm, and others 3:43 and 4:30 pm.

July 23, slides from NE wall 9:13 am, 9:52, 10:01, 10:07 am. Northeast chasms on the edge were widening.

July 24, dust clouds from slides 8:15 am and 1:24 pm.

There appear to have been increases in sliding northeast, along with the opening of cracks.

All of this means that a portion of the northeast wall of Halemaumau is "working," whether because of movement on the deep rift blocks, or because of lava motion, cannot yet be told. T.A.J.

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant Earthquakes	Local* Seismicity
July 5	29	9	2	0	2	20.75
" 12	18	7	0	0	0	8.00
" 19	38	12	0	2	1	22.25
" 26	45	4	0	0	0	13.25
Aug. 2	44	3	0	0	0	18.50

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and, whenever possible, determinations of depth of focus have been made.

June 30, 7:28 am, very feeble, located 4.0 miles deep and 0.5 mile SW of Pit Seismograph. 19° 24' 0N; 155° 17 3W.

July 1, 2:31 pm, feeble, located 15.0 miles deep and 3.0 miles SW of Halemaumau in Kilauea SW Rift zone. 19° 22' 3N; 155° 18' 6W.

July 1, 2:32 pm, feeble, same locality as preceding quake and both reported felt in Hilo.

July 2, 12:47 pm, very feeble, probable location in rifts 2.3 miles west of Pauahi Crater.

July 3, 6:27 am, very feeble, located 4.0 miles deep and 1.6 miles S of Pit Seismograph, 1.0 mile west of Ahua Kamokukolau. 19° 22' 9N; 155° 17' 1W.

July 3, 1:25 pm, very feeble, located 1.8 miles deep in Kilauea Crater. 19° 24' 7N; 155° 16' 3W.

July 5, 7:04 pm, very feeble, 1.3 miles deep and 0.7 mile E of Pit Seismograph in Kilauea Crater. 19° 24' 4N; 155° 16' 4W.

July 6, 7:41 pm, very feeble, located 0.9 mile deep in Kilauea Crater, 0.5 mile W of Byron Ledge. 19° 24' 9N; 155° 16' 1W.

July 9, 8:48 am, very feeble, probable location under E portion of Kilauea Crater.

July 12, 6:22 am, very feeble, located 2.0 miles deep in Kilauea Crater. 19° 24' 7N; 155° 16' 3W.

* For local seismicity definition, see Volcano Letter 371.

July 12, 3:46 pm, very feeble, located 15.0 miles deep under N slope of Mauna Kea, 4.0 miles below summit. 19° 52' 6N; 155° 26' 5W.

July 15, 5:16 pm, very feeble, probable location in Kilauea Crater.

July 15, 9:40 pm, very feeble, located 1.7 miles deep and 0.5 mile S of Kilauea Iki. 19° 24' 4N; 155° 14' 9W.

July 15, 11:12 pm, very feeble, located 1.5 miles under SE rim of Kilauea Crater near Keanakakoi Crater. 19° 24' 4N; 155° 16' 2W.

July 15, 11:39 pm, slight, located 1.6 miles deep under S rim of Kilauea Iki. 19° 24' 7N; 155° 14' 9W. Reported felt in the Kilauea Area and in Hilo by several persons.

July 16, 4:14 am, very feeble, located 0.9 mile under Byron Ledge E rim of Kilauea Crater. 19° 25' 1N; 155° 15' 7W.

July 18, 6:21 am, very feeble, located 1.7 miles deep under NE rim of Kilauea Crater. 19° 25' 8N; 155° 16' 0W.

July 18, 8:24 am, slight, located 2.8 miles deep under SE portion of Kilauea Iki. 19° 24' 9N; 155° 14' 8W. Reported felt by several persons at Military Camp and at the Volcano House.

July 18, 12:45 pm, very feeble, probable location SE portion of Kilauea Crater.

July 20, 8:50 am, very feeble, located 1.8 miles deep, 3.3 miles SW of Pit Seismograph and 2.0 miles W of Aloi Crater. 19° 22' 0N; 155° 15' 3W.

July 23, 6:41 pm, very feeble, probable location Mauna Loa NE Rift, about 5.0 miles from Summit Crater.

July 25, 4:41 pm, very feeble, probable location under E slope of Hualalai about 5.0 miles from summit.

July 27, 4:58 pm, very feeble, probable location under Mokuaweoweo, Summit Crater of Mauna Loa.

The preliminary waves of a distant earthquake began recording at 4h 45m 14s HST, June 30. Newspapers reported quake as being 4100 miles NW of Pasadena, California. The distance from the Volcano Observatory was 3190 miles. Reports from the Central Station of the Jesuit Seismological Association gave the location near N portion of Japan Trough off the S end of the Kamchatka Peninsula. 51° 0N; 161' 1E. The preliminary waves of a distant earthquake began recording at 8h 37m 4s, HST, July 5. The estimated distance from Kilauea was 5650 miles. Reported location was the southern extremity of the Philippine Trough, N of Moluccas. 4° 0N; 124° 9E. The preliminary waves of a distant quake began recording at 12h 55m 45s, HST, July 13. Its estimated distance from Kilauea was 6480 miles. Reported location, in Chile Trough off the N coast of Chile.

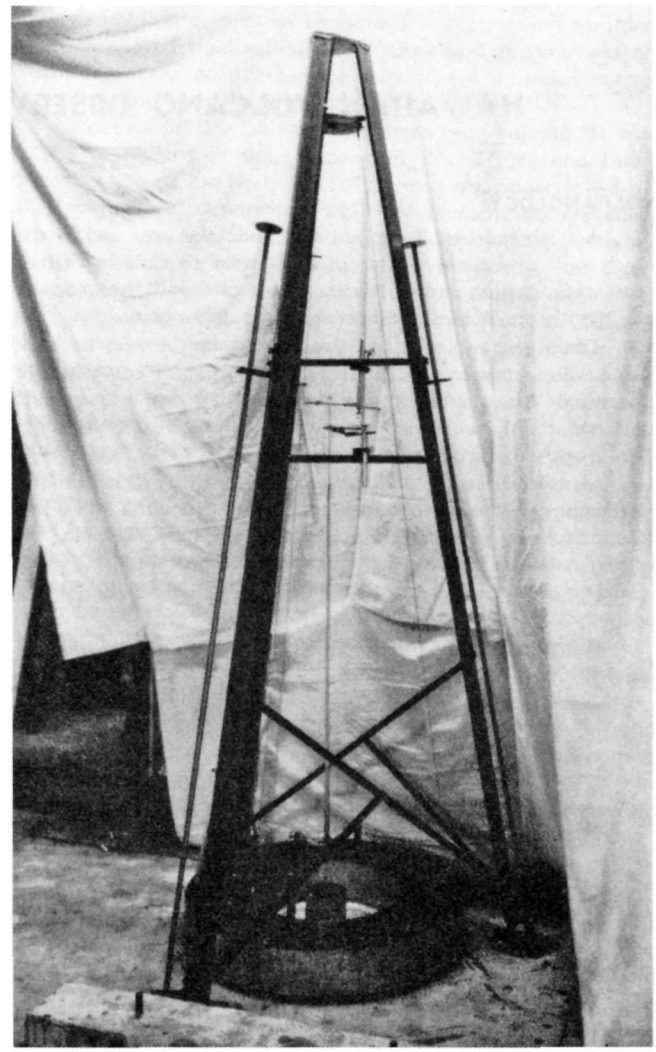
At 3:59 am, June 30, 28 minutes of continuous tremor began registering. At 7:38 pm, July 19, three minutes of continuous tremor began. 24 minutes of tremor began at 11:31 am July 30.

Microseismic motion of the ground at Kilauea was moderate July 15, 17 and 18; the remainder of the month it was light.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts tor two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 2, was 4" 35N and 1" 81W.



The tiltmeter or clinoscope designed by Wingate and Jaggar, and installed in the three cellars around Halemaumau. A heavy ring weight in oil moves when the ground tilts the tripod. The top of the boom is pointing to a disc marked in directions and distances from a center. The reading of the bottom surface of the disc is made daily with a mirror. The adjusting rods on the tripod bring the boom back to center.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit Resultant
July 5	0".76 N 16°W	5".22 N 83°W	3".73 N 4°E	2".15 from
" 12	0".39 N 15°W	3".23 S 60°W	3".92 N 29°W	0".90 toward
" 19	0".12 N 3°E	0".36 N 49°W	2".43 N 36°E	0".51 toward
" 26	0".30 N 28°W	9".24 N 64°W	1".20 S	8".87 from
Aug. 2	0".86 N 51°E	3".04 S 86°W	5".83 N 18°W	2".54 toward H. H. W.

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, July 24, compared with similar measurements June 9, showed slight closing across Halemaumau and slight opening across the Crater from the SE rim to Uwekahuna on the NW rim. The amount July 6 was a closing across Halemaumau of 0".83 and an opening across the Crater of 0".4. Between July 6 and July 24, the Halemaumau angle opened 0".41 and the Crater angle opened 0".84.

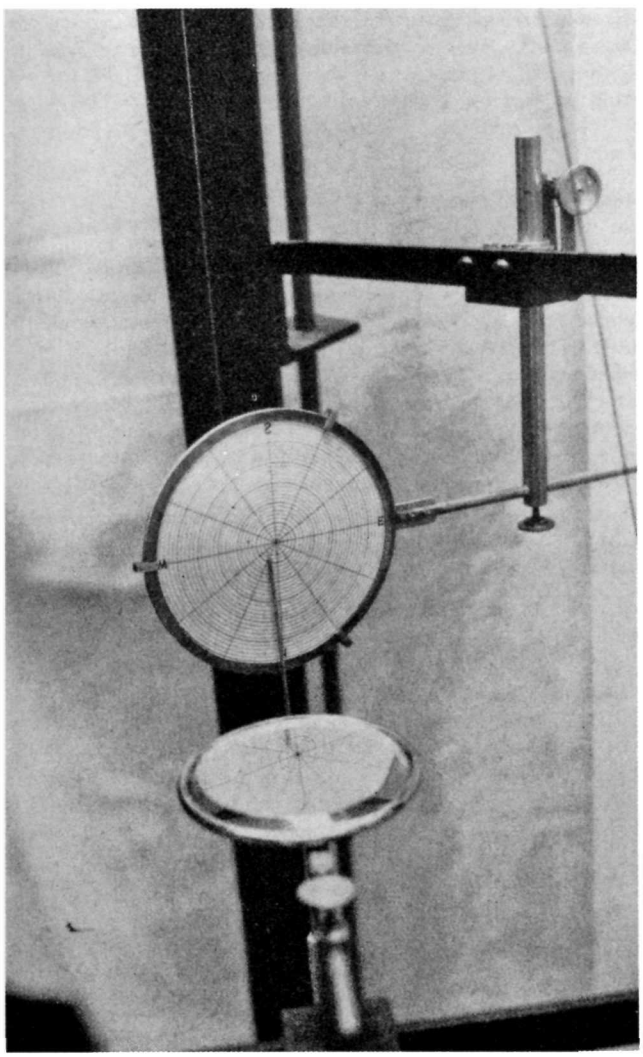
H. H. W.

MORE ABOUT VOLCANO OBSERVATORY METHODS

Tilt Measuring Instruments

We have seen in the May number and in the pictures of the April number, how the Hawaiian Volcano Observatory makes seismograms, measures cracks, receives time signals, collects gases, watches the weather, and surveys the land to prove its rising and falling, swelling and shrinking, and the spreading apart of the cliffs of the Crater.

Here and in Japan, the study of earthquakes has led the workers increasingly to watch the tipping or tilting of a piece of ground. Just what does this mean? It obviously does not mean that the ground was level before. It means that a plumb-bob, hung on a thread and allowed to come to rest, has its thread making a certain definite angle with the surface of the ground at any place. If the ground tilts between January and July, the thread will make another angle, in another direction, when the weight is hung over that same place.



Mirror and dial of Hawaiian Volcano Observatory clinoscopes.

What we need, then, is a weight hanging in one place from a support over a level floor, and a device for measuring the angle that the thread makes with the floor. If the floor were really level, the thread would be at right angles to it with reference to all points of the compass.

But no floor is level. We are not measuring in degrees but in seconds, and a second is one-thirty-six-hundredth part of a degree. A tilt of two seconds would be a disturbing event for the foundation of an astronomical telescope used for measuring the position of the stars. Imagine, then, how an astronomical telescope would fare, when the edge of Kilauea Crater tips eight seconds in two days!

Sometimes these tippings are sudden and are accompanied by earthquakes. This means that the mountain block where our level floor is built has suddenly shifted and our floor is no longer level. At other times the motion is more gradual as though the shell of the mountain were bending like a bow. There are many possibilities. The man of science must think of all these possibilities and select the one that fits best. We had a little seismograph station in February, 1929, at the southeast edge of Halemaumau, the inner pit of Kilauea Crater. The instrument was a pendulum hinged against an upright post like a door with the plane of the hanging at right angles to a radius of the pit. The outer end of the boom attached to the hanging weight wrote a line on smoked paper driven by clockwork. If the ring formed by the upper edge of the pit were lifted, the ground would tilt away and the boom would move away from the pit, and the line on the paper would move with it. On the other hand, if the mountain under the pit should shrink, the pit edge would lower and the door-like weight would swing toward the pit.

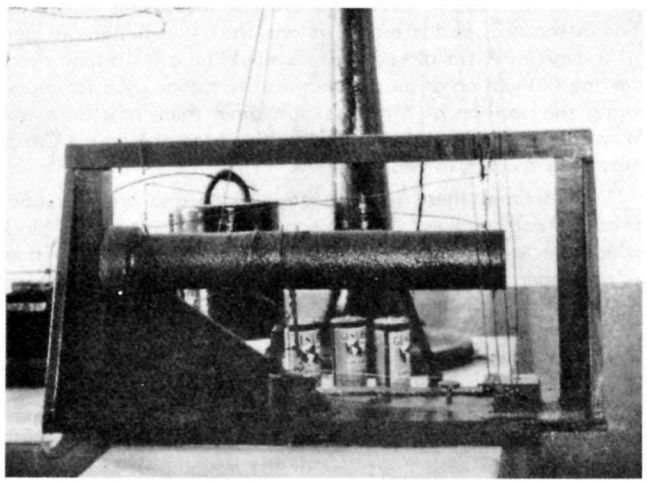
The main purpose of such an instrument is to write a zigzag when an earthquake occurs. But its second purpose is to measure tilting of the ground by the position of the line on the moving paper, with reference to a fixed mark on the instrument. It measures tilt in one line of direction only, and that is the line at right angles to the hanging plane.

On February 19, just before midnight, this instrument showed sudden tilting, accompanied by small earthquakes, straight away from the center of the pit, and the moving of the boom away from the pit increased, and kept it up for two hours. Then molten lava gushed up in the bottom of the pit, and the eruption lasted a day and a half. When the eruption ceased, the tilt pendulum moved back towards the center of the pit, and a trembling which it had registered while the lava fountains were operating, rather suddenly ceased.

This splendid demonstration of a relationship between tilt and eruption, the whole pit swelling before the eruption began, and the whole pit sinking when the eruption ended, at once suggested the importance of having two more instruments on other sides of the pit. Thus the idea of a special "Clinoscope" was born.

We proceeded to build the "Clinoscopes" in the Observatory shops. This tilt meter is shown with its parts in the accompanying pictures. It seemed desirable to make it show both direction and angular amount of the change in position of a weight hanging vertically from a single piano wire, so a heavy ring-shaped weight was hung from a seven-foot tripod in a bath of automobile oil, and a magnifying boom or lever was led vertically upward from the space in the middle of the

ring. A sharp point at the top of this lever nearly touches a horizontal circular card, which is ruled in points of the compass and in concentric circles. A mirror makes it convenient to read the bottom surface of the card and see where the sharp point lies. By centering it every day, after seeing how far and in what direction it has migrated, we can tell the direction and the amount of tilt of the floor of the cellar where the tripod is placed. The three cellars are at the points of an equilateral triangle around the pit and are built to avoid change



Earthquake Annunciator: Heavy cylinder hangs on wires. Connecting needle magnifies the motion. Tip makes mercury contact and rings bell.

of temperature. Each instrument is read every morning, and the findings are entered in the Observatory records.

The results of running these instruments for some years have not shown that all eruptions in the pit behave on the three sides the way the 1929 eruption behaved on the one side. The principal discovery made with the Clinoscope is that the Kilauea Rift Belt goes across the pit in a straight line and the tipping is right and left with reference to that belt. It is not "all around" with reference to the center of the pit on radial lines. This is very interesting. It means that the circular pit is only a detail of a linear crack. For tilt measurements the crack is the important thing, the blocks on each side of it lifting or tilting away from or towards the crack. We know where the crack crosses, and both the western and northern cellars are on the Mauna Loa side of the crack, while the cellar near the Tourists' Stand is on the ocean side of the crack.

The Clinoscopes are unfortunately not earthquake-proof. This gives us a great deal of trouble because fifty or sixty earthquakes and tremors occur every week. The large earthquakes certainly derange the delicate pivots. Any slightest derangement of a pivot makes the record erroneous where there is such high magnification. We are now redesigning the instruments and hope to make them entirely earthquake-proof, the reading to be done with a microscope without using any pivots. We ought to have a larger number of these instruments around the outer rim and inner floor of Mauna Loa Crater, and also around the rim of the larger Kilauea Crater, and at some distance away on the radiating highways.

An Earthquake Annunciator

Three of our pictures show respectively a rough hanging cylinder in a wooden frame, a very sensitive long needle under the cylinder balanced horizontally about a vertical axis, and a common electric bell annunciator showing four numbers just as used in the office of a hotel to show signals from four bedrooms.

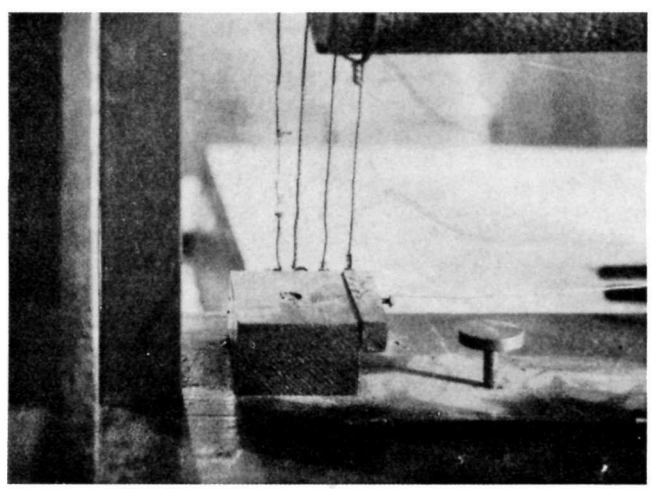
The hanging cylinder is in the seismograph cellar of the Observatory, the annunciator bell is in the seismologist's room above. The object of the device is to notify the seismologist when four different sizes of weak earthquakes occur, all in the class too feeble for him to feel. The bell rings, notifies him that an earthquake is going on, and he may take action accordingly.

The cylinder is a very heavy piece of shafting hung to swing from a beam in an east-west direction. It is appropriately connected with the short arm of an aluminum lever, the long needle. The magnification is about one hundred. This is like the magnification of our sensitive seismographs. The tip of the long arm of the lever, when an earthquake moves the beam back and forth, makes contact electrically with four drops of mercury spaced out in a line, progressively farther from the tip. If the earthquake is big enough to reach number four mercury drop, the number four arrow of the annunciator dial springs sideways and points to the figure four. The same with the other numbers.

This annunciator proved unexpectedly useful during the eruption of Halemaumau Pit, two miles from the Observatory, in September, 1934. The little cone on the floor of the pit became violent with gas explosions every few hours. These explosions were rhythmical. Every time they began, a tremor impulse or shock was sent through the earth to the distant Observatory, and the annunciator bell started ringing with a rhythm exactly accordant with the explosions. Thus a record could be kept by an observer sitting quietly in the Laboratory of the recurrent spasms of explosions at the Pit, two miles away.

Meteorological Instruments

There is little to be said about the thermograph, rain gauge, or the maximum and minimum thermometers, except that their showings have been recorded here for twenty-five years. The Observatory has been a volunteer station of the United States Weather Bureau. The wet- and dry-bulb thermometers, which Mr. Waesche is shown swinging in the breeze, attached to an instrument called the Hygrodeik, is for registering the moisture of the air; the relative humidity at the edge of Kilauea Crater is very high owing both to the climate and to the innumerable steam cracks.



Earthquake Annunciator: Tip of needle opposite four mercury cups. These are for four different intensities of earthquake motion.

Crack Movements at Halemaumau

This subject has already been illustrated on page three of the April issue, but it is just now an appropriate time to show another picture of a special caliper built for measuring the extremely large cracks on the edge of the pit.



Earthquake Annunciator: Bell and numbers record by arrows earthquake intensities 1, 2, 3 and 4. This notifies the seismologist what the seismographs are doing when he does not feel the quake. Shows also timepiece and mercurial barometer.

For several months, as indicated in the reports, we have had excessive movement at crack number forty-six, which lies some distance back from the northeast edge of the pit and this is merely an extension of a crack emerging at the edge of the pit as in the photograph. A section of the rim bounded by one of the regularly measured cracks, fell in between March 15 and March 22, 1936, and in our March issue we illustrated some of these cracks. The aggregate opening of all cracks on March 14 was more than 54 mm. This is excessive, and these movements of cracks at times have yielded very useful data for the National Park Service. The change will come gradually or suddenly and some portion of the rim of the pit may become dangerous and have to be roped off.

Just before the eruption of February, 1929, described above, there was such a disturbance at the eastern margin of Halemaumau so that the entire Tourists' Stand had to be changed in position and a new station built.

There appears to be a complicated relation between local earthquake, tilting of the ground, rise and fall of the pit rim, and the avalanches which fall from the walls of the pit. The complication concerns the question of whether the avalanching and the cracking make the local earthquakes or whether the local earthquakes make the avalanching and the cracking. Both kinds of relations have been discovered on different occasions. T. A. J.

DES MOINES SEISMOLOGICAL STATION

Editor's Note: We are privileged this month to publish a brief account of the only earthquake-recording station in America, designed, constructed and operated by a woman. To Mrs. M. M. Seeburger, a talented scientist from whose facile pen comes the article which follows, and to whose patient study and steadfast work seismology is indebted, we tender respectful esteem and cordial appreciation.—Ed.

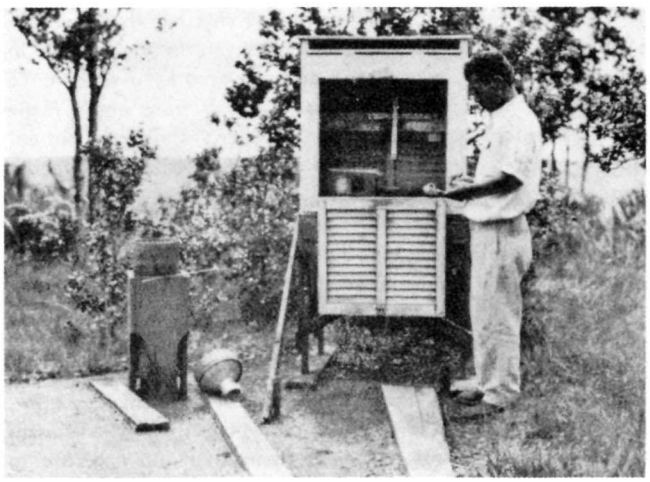
The establishment of the Des Moines Seismological Station was the outgrowth of a number of years of study of volcanic activity by the writer. Inspired by annual visits to the Lassen Observatory in California, where the Hawaiian-type instruments were in use and the laboratories at Pasadena and Berkeley, where various types of optical instruments were developed and operated, the writer's interest in seismology grew, and plans were made to establish a station in Des Moines with teleseismic instruments sufficiently sensitive and accurate to supply needed records in the midwest area, where stations are far apart.

The instruments were designed and built by the writer, the first component being started in operation December 20, 1934, and the second March 15, 1935. They are modified Bosch-Omori in type, and record on smoked paper, one drum being used for both components. The period is 9 seconds and a magnification of 15 was used until this month, when it was increased to 25. A 24-kilogram heavy mass is used, this being adjustable along the pendulum. A pivot is used for the lower suspension and a fine piano-wire suspension at the top of the upright is adjustable back and forth for change of period and from right to left to correct tilt.



Weather Recording: Swinging wet-bulb and dry-bulb thermometers for relative moisture content of the air.

The magnifying system is a new device, designed to reduce friction, which is the great problem in lever magnification. A steel rod, attached to the end of the boom by a three-way adjusting device, ends in a U-shaped fork, having a needle eye at the end of each tine. The fork moves in the same plane as a clock wheel, mounted on a pinion, working in polished bearings in a frame, the wheel being mounted between the two ends of the fork. A groove is cut in the rim of the wheel. A fine silk thread, knotted at one needle eye, passes around the groove in the wheel, thence through the other needle eye and back to the steel rod, where it is kept at unvarying tension by a tiny weight. A 17 cm. recording arm of .006 aluminum is



Weather Recording: Thermograph, rain gauge, maximum thermometer, minimum thermometer.

riveted to the wheel, ending in a fork with an arbor set in polished bearings. The arbor carries the balanced stylus which has just enough weight to remain on the smoked paper. When a movement occurs the fork with the silk thread turns the wheel, oscillating the recording arm and resulting in the variation from the straight line which records the earthquake's message.

Oil damping is used. Time control is provided by a regulator clock closing a circuit every minute and lifting the stylus by means of an electromagnet. Time is checked twice a day by radio signal.

Records are sent to the United States Coast and Geodetic Survey and the Jesuit Seismological Society. During 1935, the first year of operation, 29 earthquakes were recorded at the Des Moines station, varying in distance from the Nebraska earthquake, March 1, 1935, 250 miles distant, to the December 26 shock near Sumatra, 9,700 miles distant. From January 1 to September 1, 1936, 20 shocks have been recorded.

The Seeburger family home offered a good location for the station, being located on a street undisturbed by heavy traffic. A special room was provided, with no windows, and well insulated to keep temperature as nearly uniform as possible. The cement work and casting of lead cylinders was done by the writer, assisted by her husband, who is city solicitor of Des Moines, and a high school son. The assistance of a machinist and a jeweler was required for some parts of the mechanism. Designing, experimenting, and final construction of the instruments required about a year's work.

ADVENTURES AND METHODS IN STUDYING WEST INDIAN VOLCANOES

The bombing of Mauna Loa December 27, 1935, was followed by the stoppage of the lava flow before it damaged Hilo. The preparation for this engineering job was twenty-four years of recording and experimenting on Kilauea and on Mauna Loa. The action taken was not suddenly inspired, but was methodically thought out sixteen years earlier. The coming of this particular 1935 eruption of Mauna Loa was published early in 1934 for time, place, possible direction, earthquake accompaniments, preparedness, and method of airplane attack.

The volcano excelled itself in coming to time. Predicting is the test of right interpretation of physical processes. At Hawaiian Volcano Observatory mere descriptions and photographs of eruptions gradually gave place after the first six years of work to systematic measurements of earthquakes, tilts, tremblings, gases, and temperature. The effort was always to see what lava is doing underground. Photographing and describing it above ground during eruptions, and comparing the earth motions during eruptions, gave information of what lava is and how it may be acting underground all the time. Gradually the non-erupting times became very interesting as pointing to the places and depths where lava was working its way upward.

This has all led to the investigation of three main projects which in scientific terms may be described as locating earthquake centers underground, measuring the year to year elevation or sideways motion of the ground, and measuring the ejection of matter, either lava or gas, or both. There is always gas being emitted, but not always lava. Sometimes the lava takes it out in lifting the mountain by swelling inside.

When I had opportunity in the spring of 1936 to visit Montserrat in the West Indies, which had been violently shaken by many earthquakes, I had these principles in mind. There was no observatory on Montserrat, but some good earthquake observers had made lists of shocks, and some agricultural chemists had studied the sulphur banks in the craters.

The West Indian volcanic adventures of the last few years have come on several different islands along a curved line of several hundred miles of active volcanoes. They are like the Hawaiian Islands in being thirty or forty miles apart, and long ages past they poured out black lava. But now they are shoving up stiff lavas which are more crystalline and contain more silica. These masses underground react violently with water, the way Kilauea did in 1924. The result was the terrible eruption of Mont Pelé in 1902, which sent out a downward blast of scalding steam and destroyed 26,000 people in St. Pierre. The day before this the volcano Soufrière in St. Vincent made a similar eruption with similar destruction. Mont Pelé during the next year sent up a stiff plug of siliceous lava from its crater. Soufrière did not do so, but filled its crater with a lake of hot water which gradually cooled off during the decades since. Mont Pelé renewed its eruptions in 1929 after twenty-four years of quiet and again increased its height by thrusting up a central plug.

It was just after this last event, which came to an end in 1932, that Montserrat started making a nauseating smell of sulphurous gases in its crater, which is 146 miles northwest of Mont Pelé. It is the same kind of a crater, with several valleys containing sulphur banks, and boiling springs and steaming chemicals. These are all the products of lava somewhere below and the reaction of its acid gases with the rocks of the island and with water. Immediately thereafter, Montserrat started to shake. About every six months in 1934 and 1935 the swarms of earthquakes increased in number and vio-

lence, and most of the churches were shaken down. The morale of the people was upset, for everyone remembered the scalding hot blasts of Mont Pelé.

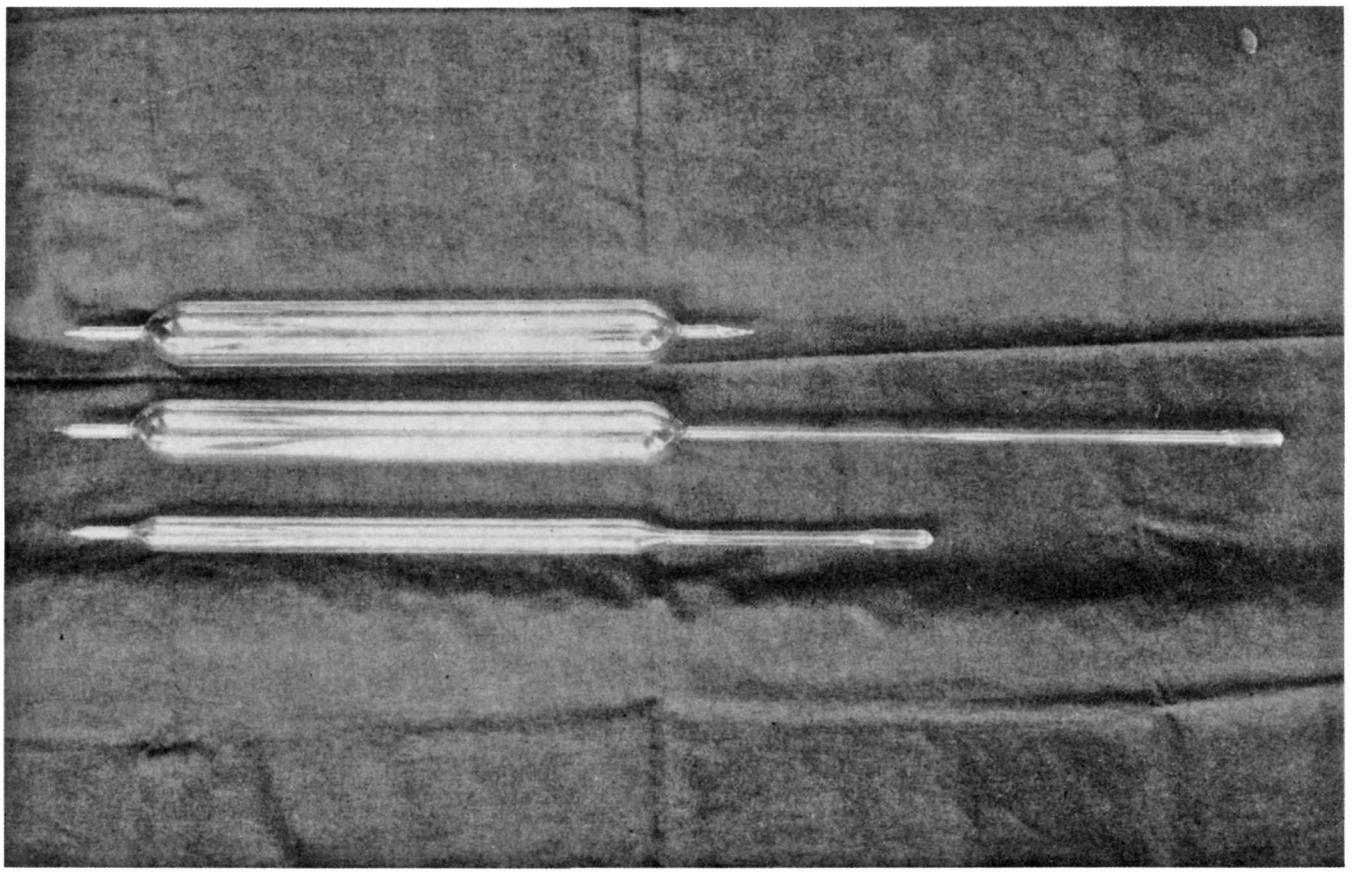
The shift of activity in 1902, 111 miles from St. Vincent to Mont Pelé in 17 hours, and the shift of activity of a different kind, 146 miles from Pelé to Montserrat in a year in 1933, shows that we have to deal with something like the shifts of activity from Kilauea to Mauna Loa, and also such changes from outside eruption to inside heaving, as we had in 1929 when Kilauea stopped erupting and North Kona started shaking. Here are shifts in Hawaii from one place to another, for much shorter distances, than the distances in the West Indies. But the kinds of action are much the same, with due allowance for a different kind of lava.

After making such allowances it is evident we can apply our three methods in the West Indies, if we locate earthquake origins, measure slow motions of the ground, and measure the kinds and temperatures of gases. All of these things are measurable there all the time. The chemistry of the hot solfataras, and there are scores of them in the West Indies, is very interesting and very significant. But before any predicting can be done it is essential to combine the changes in gases and the changes in sequences of earthquakes. This means we must know what the little earthquakes were in numbers and intensity during the quiet time before the crisis developed. For this same time we must know what the gases were and how hot they were before the nauseating and excessive gaseous emission became conspicuous. These are just the facts that we do not possess, in the absence of an observatory. The same thing was true in 1901, the year before Mont Pelé and Soufrière erupted.

What methods, then, should be recommended for understanding any such active volcano? Clearly the measurement must be repeated and continuous. The little earthquakes, the changing elevation of the ground, and the gases, must be measured every week or month or year, and the measurements entered in a record book. Montserrat appears now to have quieted down. What place in those ten or twelve active volcanoes, in those eight or nine islands, along those 350 miles of curved volcanic crack, is now going to do something unusual in 1937 or 1938 or 1939, following upon the shift from Martinique to Montserrat?

There have been many difficulties and disappointments in studying Kilauea and Mauna Loa. There are enormous difficulties and disappointments for the Dutch engineers in studying with airplane and otherwise the many volcanoes that destroy human beings in densely populated Java. But these Hollanders remained manfully at their posts in the jungle amid poisonous reptiles and poisonous gases, and they are getting results. This kind of work of the Geographical Engineer is growing more important, all the world over, because men must know the power and the materials of the earth that is their home.

T. A. J.



Vacuum tube styles for breaking or melting the tip in a gas-hole or volcanic flame: and one tube which has been sealed with gasoline torch.



Use of caliper for measuring large cracks at Halemaumau. The crack is equipped with copper studs and, after setting, the caliper opening is measured with steel tape. An improved caliper is made with arc and clamp.

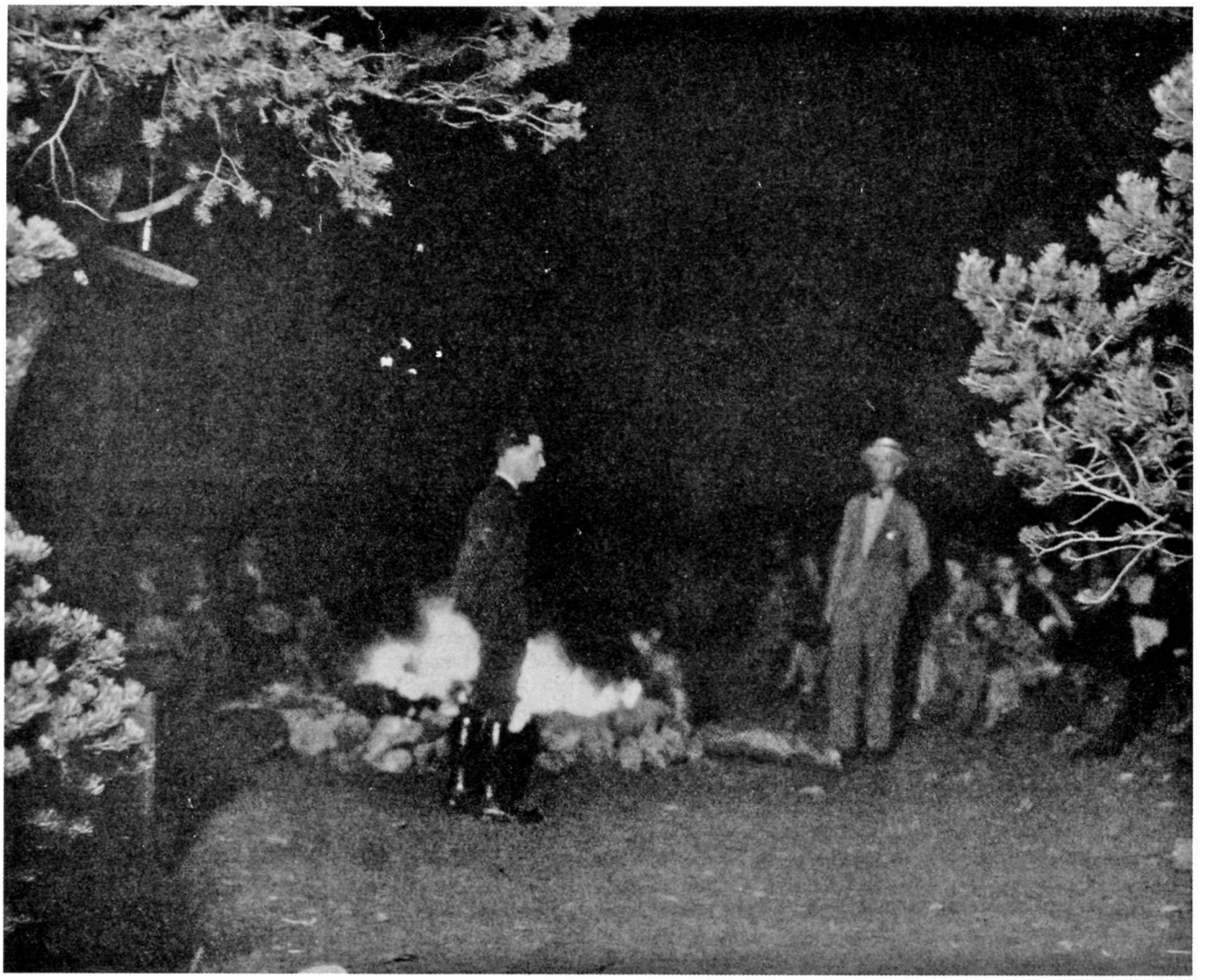
THE VOLCANO LETTER 438

No. 438 monthly **Department of the Interior National Park Service** **August 1936**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR AUGUST, 1936



Campfire Lecture. Grand Canyon, Arizona.

SCIENCE IN THE NATIONAL PARKS

The opening of the Uwekahuna Museum at Kilauea April 18, 1927, was the occasion for an address by the writer to the delegates of the "First Pan-Pacific Conference on Education, Rehabilitation, Reclamation, and Recreation," which met in Hawaii at the call of Secretary of the Interior Dr. Work. Mr. Stephen T. Mather, Director of the Park Service, attended this meeting and the subject of the talk was the geographical

opportunity that the Parks offer for experimental studies by measurement of geologic processes (Bulletin Hawaiian Volcano Observatory, April, 1927).

The present address was delivered to the University of Hawaii Summer School at Kilauea, June 20, 1935, in order to outline the growth of educational work in natural science in the National Parks (which has been greatly added to in the last few years), and to show how the several volcanic Parks may add important data to the science of volcanology that is being studied experimentally at Kilauea and Mauna Loa.

It was in 1872 that Yellowstone region was created the first National Park on earth "set apart as a public park or pleasuring ground for the benefit and enjoyment of the people; the preservation from injury of all natural features; and their retention in their natural condition."

The National Park Service as a great organization under the Department of Interior was established August 25, 1916, and owes its original solidity and growth very largely to Stephen T. Mather who was its guiding spirit until January 28, 1929. The idea of creating free nature guides for travellers began at Yosemite in 1919 and this became the Division of Research and Education under Dr. Harold C. Bryant in 1930. A large growth in numbers of Naturalists and Ranger Naturalists attached to the Parks took place during the formative period, and the importance of visual education and photographs* was accented after 1923.

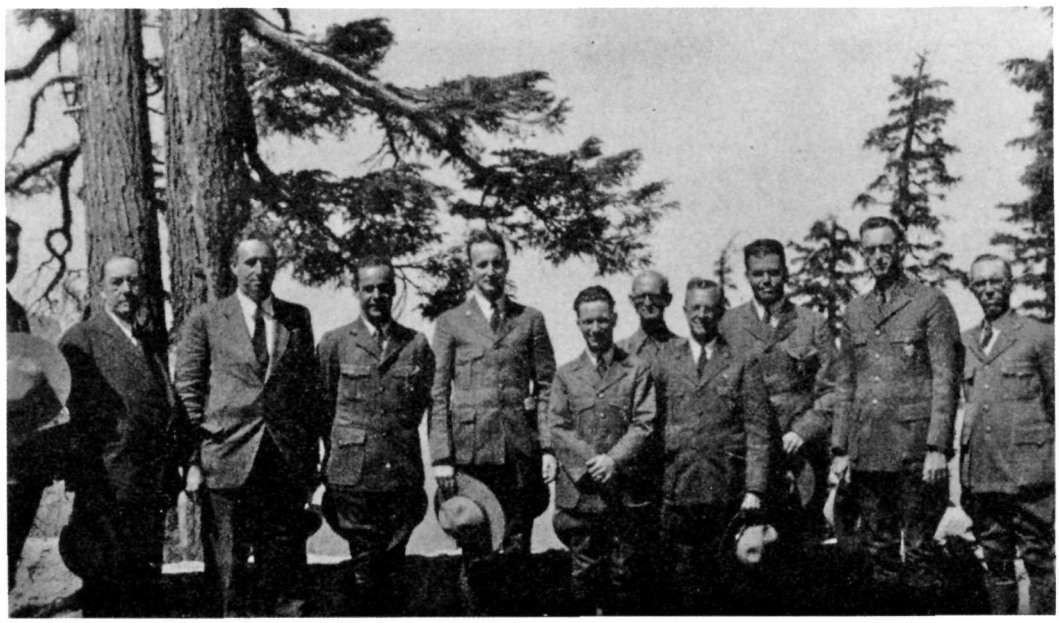
A committee on the educational problems in the Parks made an extended study of the question of developing museums in close proximity to the places where the exhibits came from. There were many places where the actual landscape spread out before the traveller gave life and reality to these exhibits. And there were many other places, like our footprints of the old Hawaiian natives in the Kau desert, where the whole significance of a specimen depends on seeing it in its natural environment. Hence arose the "trailside museum" where a group of fossils or crystals or objects of organic life may be both preserved from harm and seen in their natural relations under advantageous lighting.

The committee on the study of educational problems consisting of Messrs. Merriam, Bryant, Atwood, Bumpus, Kellogg, and Oastler made critical studies of such Parks as the Yellowstone, the Yosemite, Crater Lake, and Lassen; with the assistance of the American Association of Museums, the American Library Association and the Rockefeller Foundation.

From 1924 on, a field school of natural history had been established in the Yosemite. The expenses of the visiting committee of educators were provided after 1928 by the Laura Spelman Rockefeller Memorial which also supplied $118,000 for Yellowstone Museums, near Old Faithful and at Mammoth Hot Springs.

The report of the committee in 1929 pointed out the necessity and the advantage of further research in science as a service to the visiting public, and as service to educators and investigators, "to increase the general and special knowledge of the phenomena represented in the Parks."

In 1928 a trailside museum was built at Yavapai Point in the Grand Canyon. In 1929 the Museum at Yosemite was built. The Loomis Museum was accepted as a gift from private donors at Lassen.



A Group of Educators and Park Officials at Crater Lake in 1934.

Archeological museums were now springing up in Parks having remains of Cliff Dwellers and Indians, the cooperation of the Smithsonian Institution had been secured, fish culture was in progress, the preservation, feeding and study of animals in their native habitat had become a large branch of the work, and to this the Biological Survey contributed, as did the Bureau of Forestry to the protection of National Park Forests.

In 1930 at Craker Lake a memorial was built to Congressman Sinnott of Oregon. This is a rough stone observation station, inside the rim of the crater, with mounted field glasses, specimens and relief map, all in a commanding position with parapet overlooking the lake. An archeological museum was built at Mesa Verde, and an Indian museum at Acadia (Mount Desert).

At this time several Parks had adopted the practice of conducting automobile caravans from place to place in the care of trained naturalists, and the cooperation in research by government bureaus had become a regular practice. In the cliff dwellings of the southwest, Dr. A. E. Douglas, who had developed the science of interpretation of tree-rings in relation

to sun-spot intervals and the climatal changes that affected trees, applied his knowledge to the beam cores of the cliff dwellings, so as to determine their age.

In 1931 lectures and field trips had become the first aim of the Naturalist Branch, a Chief Historian was appointed to cover history and archeology, and Dr. Bumpus succeeded Dr. Merriam as Chairman of the Educational Advisory Board. The Fishing Bridge Museum and Trailside Shrine at Obsidian Cliff were built in Yellowstone Park. At Dinosaur National Monument in Utah an actual fossilized skeleton of a large extinct reptile was excavated in relief by the American Museum of Natural History in its natural site.

Three-year studies of wild life conditions were begun, particularly in the Yellowstone; and for the elk, a cooperative survey was made for the migration routes, the life history and the forage requirements. The Biological Survey, the Forest Service, and the Montana Fish and Game Commission collaborated in this.

In 1932, the native Indians were employed to show their arts and crafts. A ranger-naturalist at the Grand Canyon accompanied privately operated airplane flights. In Acadia a sunrise breakfast caravan was led to the top of Cadillac Mountain, and in the Yellowstone an evening caravan was led to suitable places for stalking game with the camera. Informal campfire talks to five hundred people at a time were held in the Yosemite and the Yellowstone.

The use of the National Parks by university classes was increasing; the principal subjects of investigation being the group relations to each other of plants and animals, and the geology. Graduates of the Yosemite Field School are now serving as ranger-naturalists in other Parks. Thus the Park Service becomes a University for training its own men.

In pure science, cosmic ray investigations have been made in Hawaii and at Mount McKinley. In the Yellowstone, and the Absaroka Mountains to the east of it, university groups of highly trained specialists have investigated the origin of granite, and the geology of the Rocky Mountains.

In 1933 the Emergency Conservation Program was at work in numerous C. C. C. Camps of the National Parks, and the preservation of historic sites was one of the activities of the Educational Board. Sea caravans of motorboats were added as a new feature at Acadia, to study sea-life. Indian pageants were organized, a wayside museum of archeology was built at the Grand Canyon, and a wayside exhibit of the life history of the beaver was established at Yellowstone. In two lookouts there, long-range telescopes were set up. Botanic gardens have been created at Yellowstone and Crater Lake, and a new garden was presented to Yosemite Park.

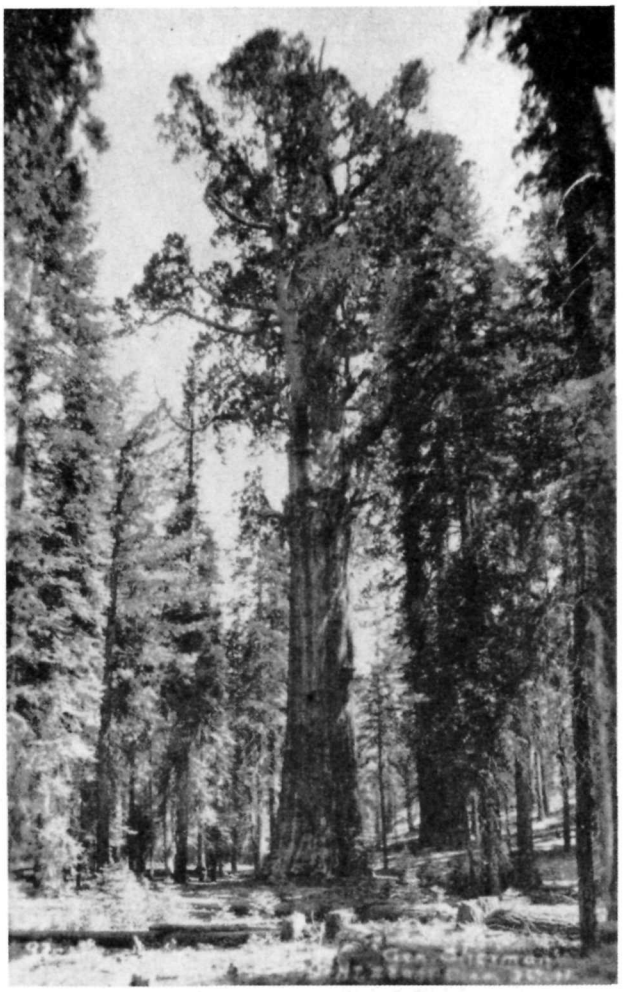
As examples of the utilization of cooperative research in the National Parks, we have had out here in Hawaii Dr. Meinecke of the Bureau of Plant Industry, and Drs. Day, Shepherd and Allen of the Carnegie Institution. Dr. Wetmore, ornithologist of the Smithsonian has taken a great interest in the Parks and has also been to Hawaii, and the Biological Survey has contributed the work of Drs. Palmer and Murie. Dr. Hommon of the Public Health Service has studied Park problems, and Dr. Hazard of the Bureau of Fisheries. In history Dr. Leland has called in the Council of Learned Societies and a group of leading historians for the numerous battlefields and other places related to the history of the country. So it is with the prehistoric sites where ancient man lived and worked and tilled the soil. The universities of Michigan and California have collaborated in studies of the Teton Range, a National Park in the Rocky Mountains immediately south of the Yellowstone.

National Park Science in Hawaii

The foregoing outline sketches the growth of public interest in the many branches of natural and human science that are related to the preservation forever of large tracts of natural wilderness, or smaller ones of historic land.

The tendency of industry is to tear the land to pieces for raw materials, agriculture, transportation or construction and congestion of cities.

The National Park idea has in some measure preserved the natural frontier which our forefathers met in their restless march seeking freedom and wealth. There is still a frontier and a restless march. The tools of the primitive American frontier were the axe, the plow and the rifle. The tools of the new frontier are the airplane, the radio, and the chemical bal-



Sequoia National Park. General Sherman Tree.
Height, 280 ft.; Diameter, 36½ ft.

ance. By the ever-widening range of these new tools, which look outward to the universe, and inward to the core of the earth, the frontier of the human spirit today knows no boundary.

The outlook of the Hawaiian Volcano Observatory on its frontier, hewing its way with metaphorical axe and plow and rifle to a visionary palace of science on the top of Mauna Loa Volcano, differs somewhat in its aim of education and research from most of the enumerated activities above outlined.

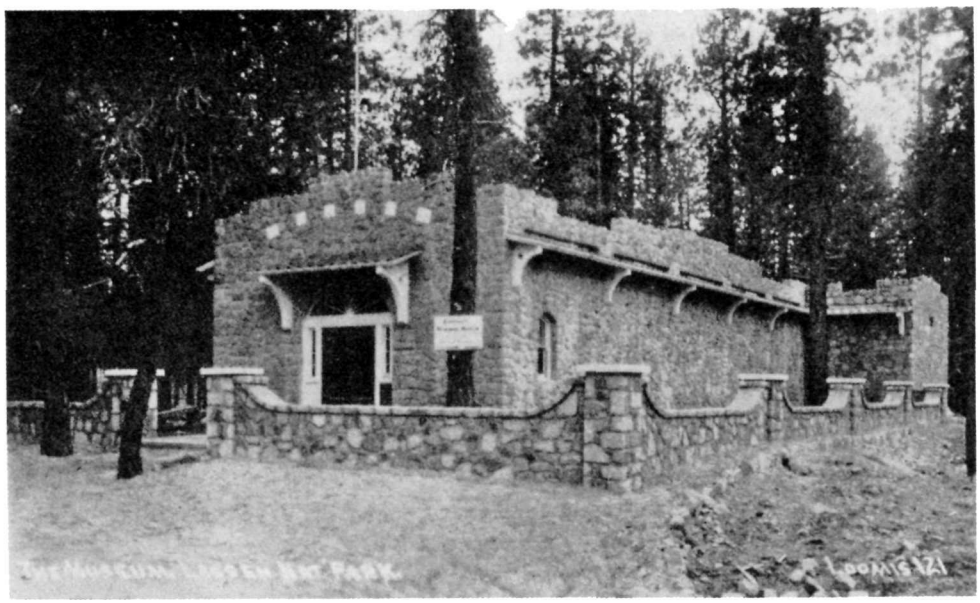
The word "research" means searching over again, and the historical viewpoint is conspicuous in the attitude of scholar-

ships. How did the elk and buffalo originally live? How did the beaver behave when undisturbed by man? How did the cliff dwellers live? How was that battle fought? How did those mountains grow? How did the dinosaur behave? How does the undisturbed trout breed and meet his enemies? How did the tree rings vary in the seventeenth century? What were the customs of the original Indians? How did the primitive forests grow?

It is a curious and inevitable trait of education and scholarship that the past is more detailed and elaborated than the present and the future, in current methods of research.

In contrast to this, the activities of the present are studied in the chemical laboratory, the growth of living cells in the microscope, the interaction of plants and animals on land and sea; and the effect of planting of gardens and forests and the culture of fish and insects.

The seismologists look inward at the shells of the globe for



Loomis Memorial Mission, Lassen Volcanic National Park.

echoes from distant big earthquakes; and the magneticians and gravity physicists do the same with the compass needle and the pendulum.

The day to day changes, and the statistics of the present are used by laboratory and field science, and the widely distributed National Parks are very valuable for these sciences, whenever a variety of latitudes, elevations or climates affects the process that is being studied. Science goes to the beach when it has to study sea-life, and it goes to the mountain top when it has to study effects of elevation. The Middle Ground, between University and Universe, is apt to be neglected.

On the other hand, the astrophysicists study the universe, and the ultimate atomism of physics, but frankly acknowledge little interest in the earth, the moon and the planets. The earth is chiefly a nuisance, because of the disagreeable optical properties of its atmosphere.

These investigators are studying the light which left distant bodies in space hundreds of thousands or millions of years ago, and so they also are intensely interested in the past. Their observatories have the great advantage of being close to universities, and it is only occasionally that the hardship of an expedition is necessary for such an event as an eclipse. The frontier of the outer universe is the field of their restless march, and their tools are the telescope, the spectroscope, and the electro-magnet.

A part of science, therefore, leaps from the university microscope or electroscope, to the observatory telescope, in studying pinpoints of light. It leaves the study of the earth, the study of the great rough frontier, of the mountains, the rivers, the ice, the sea-bottoms and the volcanoes, to the great rough corporations and their engineers, who handle great rough bodies of labor in tearing up the earth for raw materials and for power.

But what of the earth itself, and its great and small natural processes on the surface, where man dwells, at the present day? And what of the future results of those same processes, many of them quite within the range of man's prediction, that will sweep his cities with hurricane, flood, drought, dust, insect plague, famine, fire, earthquake, blizzard and tidal wave?

The mathematical quantitative study of a point of light under a lens, and the explanation of the past by its aid, is so much more orderly than fighting the battles of the earth frontier; that the pure sciences of the interaction of the atmosphere with the earth, are somewhat left to engineers, and governments, and commerce.

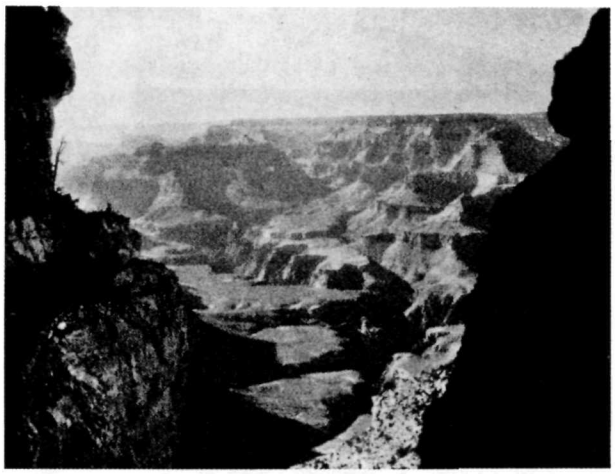
In relation to the looming bulk of those things in the economy of mankind, there is no adequate field science today of the inorganic processes, of oceans, rivers, shorelines, glaciers and earth movements.

The Hawaiian Volcano Observatory has stood for this field science of Experimental Geonomy from the time when it was first proposed in 1909. The object was to keep a diary of active volcanoes, and by patient effort to decipher their habits, to discover the swelling and shrinking of the land, the cycle of outbreaks, the location of centers of small localized earthquakes, and the peculiarities of lava when it pours forth. The island was treated as a working model of process. This followed a resolution of 1907 recommending the foundation of earthquake and volcano observatories, passed by the Geological Society of America.

In the same way the Mississippi might be treated as a model of river process, all the way from Yellowstone and Rocky Mountain National Parks to the delta in the Gulf of Mexico.

And the laboratory should be called an observatory, because its function is to observe and record forever.

The result of twenty-five years of work in Hawaii has been to show that the Hawaiian volcanoes are always predicting their own coming events. Sensitive instruments tell what is happening underground. Earth movements and earth chemis-



Grand Canyon, Arizona.

try never cease. There are some discovered emanations, in gases and wave movements; there are probably many undiscovered ones which are telling the times and places of future eruptions.

There is great importance to comparison with different places. Such different volcanic places are the Yellowstone and the northwestern volcanoes, the hot steam region north of San Francisco, the Aleutian Islands, and Arkansas Hot Springs. How do the undeciphered emanations there differ from the Hawaiian ones? And what difference do they predict for intrusion of lava underground, in contrast to the occasional and relatively rare extrusion, in places like Hawaii and Japan?

And so for the other processes of the earth, the making of new rock, the uplift of the land, the sweep of the waters, the rotting of the mountains, and the settling of the rubbish, we need never leave the National Park System to establish observatories of the behavior of the earth.

Glaciers are to be found in Glacier Park, Rainier and Mount McKinley. Mountains are rotting in different ways in the Great Smokies, the Grand Tetons and Yosemite. Rivers are telling their story in all of these, as well as at Platt, Hot Springs, Yellowstone and Grand Canyon. Volcanoes offer a variety at Lassen, Crater Lake, Rainier, Katmai, Craters of the Moon, Yellowstone and Hawaii. And sea-bottoms in great variety are close to Hawaii, Acadia, Katmai, Sitka and Olympus.

All of these places contain superb opportunity for establishment of permanent geonomical observatories. Here lie the mysteries of possible deciphering of the great powers that dwell in our own earth; which from second to second and minute to minute is being altered as man's habitation by the hot forces within it, and by both the hot and cold forces of its own interaction with water and air.

T. A. J.

Photographs herewith kindly supplied by Assistant Geologist H. H. Waesche.

VOLCANOLOGY

The month of August, at Halemaumau Pit of Kilauea Volcano, produced more slides and a widening of eastern cracks at the edge of the pit. Otherwise nothing of external happenings was conspicuous for the Hawaiian volcanoes during this month. The third week of the month was most active seismically and showed the highest weekly index per month, of local seismicity, since April, the sequence being for the weeks ending:

May	31,	Seismic	index	15.25
June	7,	"	"	11.25
July	19,	"	"	22.25
August	23,	"	"	45.50

In the main this index is made up of tremors, and this summer these tremors have been greatly affected by slides from the walls of the pit. The total number of slides for the month, however, counted during daily forenoon visits and by dust cloud at other times does not accord with the above table of seismicity maxima:

Number of slides May	12
June	6
July	26
August	6

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows:

August 6. Dust on floor of pit seemed to concentrate around the floor crack.



Columnar Sections of Natural Rocks and Fossils of Grand Canyon in Yavapai Museum.

August 9. Moderate slide NE wall 9:25 a.m., apparently from gaping outcrop of Crack No. 29.

August 18. Moderate slides 9:35, 9:42 and 10:42 a.m. NE wall under Crack No. 29. A little farther north some dis-

tance back is Crack No. 46, which has been opening. Still farther north Crack No. 34 caved in completely on March 22. This high part of NE wall, between E and NNE taluses, was getting ready to fall.

August 31. Moderate slide 8:03 a.m. under Crack No. 29, sending up thick dust cloud, leaving fresh scar, and thin dust on floor beneath.

August 31. Small slide same place 12:18 p.m.

lava cascades NW. These places are on a diagonal of the pit at right angles to the rift belt.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of:

August 8, 9 opened, 3 closed, aggregate opening 9.5 mm. Crack No. 46 opened 6.5 mm.



Mountain Lion. North Rim, Grand Canyon, Arizona.

Halemaumau Solfataras

There has been no notable change in the places at the edge of the floor, where yellow sulphur and white sulphates are depositing and blue fume rises, varying in visibility with the humidity of the air. The most conspicuous places are under the Tourists' Stand SE, and at the north end of the 1934

August 15, 6 opened, 4 closed, aggregate opening 8.5 mm Crack No. 46 opened 7.0 mm.

August 22, 11 opened, 2 closed, aggregate opening 14 mm. Crack No. 46 opened 7.5 mm.

August 29, 8 opened, 2 closed, aggregate opening 12 mm. Crack No. 46 opened 8.0 mm.

T. A. J.

EARTHQUAKES

Table

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Slight Earthquakes	Distant Earthquakes	Local* Seismicity
August 9	84	5	0	0	23.50
" 16	17	6	0	0	7.25
" 23	140	19	1	1	45.50
" 30	47	7	0	1	15.25

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, determinations of depth of focus have been made.

August 3, 10:36 pm, very feeble, probably located in Kilauea Crater.

August 7, 8:21 pm, very feeble, probably located near Puu Huluhulu, Chain of Craters Rift.

August 8, 7:13 pm, very feeble, probably located about 0.8 mile SW of center of Halemaumau.

August 8, 9:51 pm, very feeble, with location same as preceding quake.

August 10, 3:12 am, very feeble, probably located in SW rift zone of Kilauea, 0.9 mile W of Pit seismograph.

August 13, 12:25 pm, very feeble, probably located in vicinity of Kamakaia Hills about 10 miles SW of the Observatory.

August 16, 7:38 am, very feeble, probably located about 10 miles W of Hilo. Reported felt by several at Waimea Hotel.

August 18, 4:54 pm, very feeble, located 2.2 miles deep in Kilauea SW rift zone near Puu Koae. 19° 21′ 8N; 155° 19′ 3W.

August 18, 10:39 pm, very feeble, located 1.4 miles deep under Byron Ledge, SE portion of Kilauea Crater about half the distance between Keanakakoi and Kilauea Iki Craters. 19° 24′ 5N; 155° 15′ 6W.

August 19, 10:28 am, very feeble, located 1.9 miles deep in west portion of Kilauea Crater. 19° 25′ 2N; 155° 17′ 4W.

August 19, 11:05 am, very feeble, located 0.7 mile deep and 1.2 miles S of Pit Seismograph Station. 19° 23′ 3N; 155° 17′ 0W.

August 20, at 6:23 am, a slight earthquake occurred. It was probably of very shallow origin under SE rim of Kilauea Crater. The shock was not reported felt. 19° 24′ 2N; 155° 16′ 1W.

August 20, 9:41 am, very feeble, probably located under N rim of Kilauea Iki.

August 20, 6:04 pm, very feeble, located 2.4 miles deep in rifts 0.3 mile N of Ahua Kamokukolau. 19° 23′ 2N; 155° 16′ 3W.

August 21, 8:36 pm, very feeble, located 3.3 miles deep in rifts 0.9 mile SE of Ahua Kamokukolau. 19° 21′ 5N; 155° 15′ 4W.

August 24, 1:56 am, very feeble, located 6.2 miles deep in Chain of Craters rift near Devil's Throat. 19° 22′ 8N; 155° 14′ 5W.

August 24, 2:17 am, very feeble, located 2.3 miles deep and 0.3 mile NE of the Observatory. 155° 15′ 5W; 19° 26′ 1N.

There was a marked increase of seismic activity during the week of August 16-23. Many of the locations of the very feeble earthquakes of the month were difficult or impossible to make because of the lack of definite demarkation of phases. In most cases they waxed to maximum amplitude with little change from the initial type of movement. In this respect they resembled enlarged tremors.

At 8:34 pm, August 21, the preliminary waves of a teleseism began recording at 8h 33m 31s pm. Its reported location was in Formosa. 22° 3N; 121° 5E. The distance from Kilauea was 5,265 miles. Another teleseism registered its preliminary waves at the Volcano Observatory beginning at 10h 59m 6s am, August 26. Its estimated distance from Kilauea was 3,155 miles.

Periods of continuous tremor registered as follows: beginning at 9:32 am, August 4, 4 minutes; at 11:16 am, August 9, 30 minutes.

Microseismic motion of the ground at Kilauea was light for the entire month of August.

H. H. W.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 30, was 4″ 67N and 0″ 25E.

H. H. W.

* For local Seismicity definition, see Volcano Letter 371.

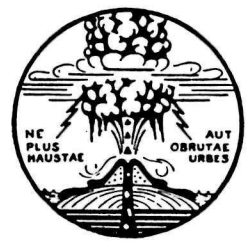
CRATER ANGLES

Measurement of Horizontal angles across Kilauea Crater from the Observatory, August 18, compared with similar measurements July 24, showed a slight closing both across the Crater and Halemaumau. From July 24 to August 7, there was closing from the SE rim of Kilauea to Uwekahuna of 2″.5 and across Halemaumau from the Pit seismograph to the NW BM, closing of 1″.25. From August 7 to August 18, the Crater angle opened 1″.00 and the Halemaumau angle opened 0″.67.

H. H. W.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit Resultant
August 9	0″.15 N 4°E	3″.28 W	10″.63 S 18°W	8″.42 from
August 16	1″.02 N 40°E	4″.53 S 54°W	4″.47 N 34°W	0″.99 from
August 23	0″.38 N 20°E	5″.39 N 45°W	4″.21 S 25°W	5″.37 from
August 30	0″.55 N 17°E	5″.00 N 75°W	4″.57 N 15°W	0″.41 from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THE VOLCANO LETTER

No. 439 monthly Department of the Interior National Park Service September 1936

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

The succession of numbers of this journal in the autumn of 1936 will deal with the sequence of special studies, by the Volcanologist, that led to the bombing operation on Mauna Loa during the great lava flow that reached South Hilo District in December 1935.

The present number describes the summit crater eruption, the like of which is always followed by a flow from the flank.

The October number will print the Annual Address of March 1934 that showed the reasons for expecting that flow within two years at the north: with more illustrations of the 1933 eruption.

The November number will describe the Kilauea eruption of September 1934, with illustrations of that extraordinary cascading eruption of Halemaumau, keeping up the precedent of averaging one eruption a year for the Hawaiian system in the recent eleven-year cycle 1924-1935.

The December number will reprint, by permission, an article from "The Military Engineer", describing concisely the exact facts concerning the 1935 eruption, the bombing, and the stoppage of the flow towards the city of Hilo, with illustrations.

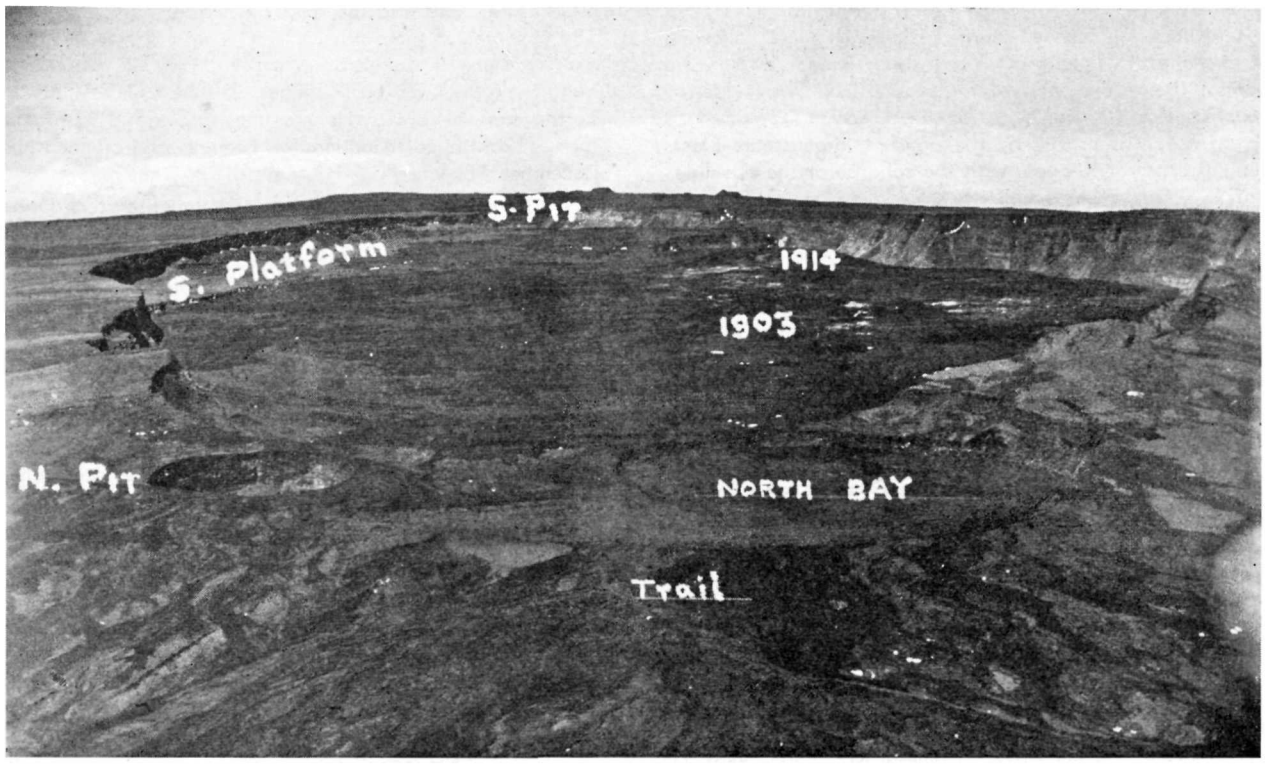


Figure 2. Mokuaweoweo from an airplane January 20, 1925, looking SSW. Condition before the 1933 eruption. Photo by 11th Photo Section, A.C., Wheeler Field, T. H. Elevation 14,600 feet (4450 meters).

SUMMIT OUTBREAK OF MAUNA LOA DECEMBER, 1933

T. A. Jaggar

Sequences Preceding 1933

Eruptive cycles of the Hawaiian volcanic system have indicated[1] that a complete eruption of Mauna Loa, and disregarding Kilauea, consists usually of one or more preliminary summit crater eruptions. These lead to one or more concluding lava outflows from an established rift that cuts across the mountain from southwest to northeast, with a slight bend at the summit crater.

The lava outflows so led up to, and occurring some years

after the crater outbreak, themselves begin with a summit gushing. This takes place a few days before the establishment of the flank outlet, which may be 6 to 12 miles (10 to 20 kilometers) from the central caldera.

The last complete cycle for Mauna Loa, preceding the one which is the subject of this paper, started in 1914. It began with an eruption of liquid lava, in the large summit sink-crater Mokuaweoweo, making a brilliant display at a fountaining cone, and flooding the crater floor from November 25, 1914, to January 11, 1915, a period of 48 days.

The later flank outflows, down the southwest rift of the mountain, were in 1916 and 1919; these came in May-June and September-November, and lasted respectively 17 days and 56 days.

The completion of a cycle for Mauna Loa may not be judged without taking account of Kilauea. Kilauea frothing lava spurted and subsided in sympathy with the two outbreaks of Mauna Loa 1914 and 1916. After the Hawaiian Observatory had plotted this sympathy, the 1919 outbreak induced us to publish the expectation of sudden subsidence of Kilauea, which was then flooding, as soon as the Mauna Loa outbreak was finished. This was verified and the lowering occurred in Halemaumau pit of Kilauea volcano 600 feet (180 meters) in one morning, November 28, 1919. The lava in the pit immediately recovered and rose nearly to the top in 24 days,[2] a lift of 560 feet (171 meters). Such sympathy appears in the Halemaumau pit only when the crateral pipe has free liquid lava in evidence within it. When it is plugged the sympathetic movements can only manifest themselves by seismic action.

As Kilauea proceeded during the four years following 1919 to make three flank outflows, while Mauna Loa stopped its action, the repose interval for Mauna Loa had evidently arrived. That an 11-year cycle for the Hawaiian system ended in May 1924, was proved by the unusual large steam-blasts and engulfments at Kilauea, with the collapse of the pit Halemaumau.

The platted curve of rise and fall of lava for both volcanoes[3] makes a complete 11-year cycle for the system, between 1913 and 1924.[4]

This brings us to the new cycle for Hawaii, which began with the return of a short-lived inflow of spurting liquid lava on the bottom of the cup of talus in Halemaumau pit, in July, 1924. Just as in the case of the last cycle when Kilauea had resumed vigorous activity in 1914 and was followed by the Mauna Loa eruption of 1916, so this inflow at Kilauea of 1924 was followed by the gushing of Mauna Loa in April, 1926. This began its outbreak at the south pit of the summit caldera Mokuaweoweo, then spread down the southern flank and the lava emerged at about 8,000 feet elevation, to pour into the sea at the village Hoopuloa. The eruption lasted 25 days.[5]

This eruption of Mauna Loa was followed by small gushings in the bottom of Halemaumau pit, each adding a layer 60 or more feet (about 18 meters) deep, in July 1927, January 1928 (thin), February 1929, July 1929, November 1930, and December 1931.

[1] The Hawaiian Volcanic Cycle. Volcano Letter No. 325, March 19, 1931. Volcanic Cycles and Sun Spots. Volcano Letter No. 326, March 26, 1931. The Peak of the Volcanic Cycle. Volcano Letter No. 330, April 23, 1931. Beginning of the Volcanic Cycle. Volcano Letter No. 332, May 7, 1931. When the Pit Lava Sinks. Volcano Letter No. 324, March 12, 1931. Copies of the references in this paper may usually be obtained by addressing the Hawaiian Volcano Observatory.

[2] Bulletin Hawaiian Observatory, Vol. VII, No. 11, November 1919, pages 166 and 169. Page 166 is from the press report issued before the collapse.

[3] Lava Tide, Seasonal Tilt and the Volcanic Cycle, by Jaggar, Finch and Emerson. Monthly Weather Review, March 1924, Fig. 4. Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory, by Jaggar and Finch. Bulletin Seismological Society of America, March 1929, Fig. 3, page 41.

[4] The Eruption Cycles in Hawaii, by T. A. Jaggar. Thrum's Annual, Honolulu, 1932, pages 83 to 93, chart on page 84.

The Outbreak of Mauna Loa, 1933

The earthquakes associated with this eruption have been described by Jones in Journal Washington Academy of Sciences Vol. 24, No. 10, October 15, 1934. A cluster of notable shocks in October, 1933, felt strongly at Kapapala Ranch on the east side of the mountain, led to an investigation of the summit crater by E. G. Wingate and A. E. Jones, Nov. 1-2, 1933. The main crater showed puffing vapor from the 1914 cone[6] on the floor, fume was dense from the sunken area around it, and the western walls of the crater were dusty with fresh avalanche scars. There was nothing remarkable about sulphur fumes or vapors elsewhere. Later events proved that the dense fume and puffing vapor near the 1914 cone in the southern part of the main bowl of the big crater heralded at just that place the coming eruption of December 2.

The summit crater of Mauna Loa was split along the upper end of the southwest rift (see map of Hawaii November Volcano Letter 1935, and later), where frothy lava gushed up, at 5:43 a.m. December 2, 1933. The rift opened along a belt about two miles (three km.) long in the southwest part of the crater, trending south 27° west from the inner basin. The cracks crossed the south inner platform, extended up the cliff to the outside country, and then on to the south for a half mile (one km.), about 500 feet (150 meters) west of the lip of the South Pit. The breakage was then offset 500 feet (150 meters) to the east, a crack emerging from the west corner of this pit and continuing across the upland to the southwest, so that cascades of lava were poured both into the South Pit of the main crater, and into the next pit to the south, Lua Hohonu.[7] The gushings of these outside cracks were short-lived, and the main activity of the eruption which continued, was inside the main Mokuaweoweo basin, about 500 feet (150 meters) east of the cone of 1914. Here a line of gigantic fountains was formed, continued in action for 16 days and stopped gushing December 18.

The physical measurements at Kilauea crater, during the activity of Mauna Loa, were of considerable interest. Halemaumau pit had its bottom sealed with the lava plug of December-January, 1931-32, so that no liquid lava, to rise or fall, was observable at the time of the Mauna Loa eruptions of the last cycle. The weekly measurement of marked rim cracks around Halemaumau, and precise levellings during the week ended December 17, comparing Halemaumau rim with the southern gravel spit, and the readings of horizontal angles across the pit from the Observatory, measured twice during the month, revealed no unusual ground surface displacements.

The tremors, tilts both at the Observatory and Halemaumau, and the total local seismicity, showed striking changes accordant with the period of the Mauna Loa eruption.

The number of minutes of tremor for the week preceding the eruption, as measured at the Kilauea observatory, was 56, whereas for the week ending December 3, the day after the outbreak, the number was 1393. For the next two weeks, the weekly frequency of tremors dropped off to 345 and 580. Thereafter the figures were low and normal, the numbers of tremors per week being 20 and 34 for the last two weeks of December. It thus appears that the number of tremor spasms, or minutes of tremor, increased suddenly from figures counted in tens, to figures counted in hundreds, for the three weeks of the eruption.

[5] Bulletin Hawaiian Volcano Observatory, April 1926, with illustrations in May to December numbers, 1926. See also Volcano Letter, Nos. 68 to 72, April 15 to May 13, 1926.

[6] Effects in Mokuaweoweo of the Eruption of 1914, by H. O. Wood. Amer. Jour. Sci., May 1916.

[7] Geology of Kau District, Hawaii, by Stearns, Clark and Meinzer, Water Supply Paper 616, U. S. Geol. Surv., 1930, maps.

It is customary at the Hawaiian Volcano Observatory to compute local seismicity in terms of minutes of "tremor", unfelt or "very feeble" earthquakes, slightly felt or "feeble", felt or "slight", generally felt or "moderate", and "strong" representing earthquakes that are alarming. The grades feeble, slight, moderate and strong correspond to I, II, III, IV, of the Rossi-Forel scale. The local seismicity index for any week is obtained by adding together the frequency numbers of arbitrary weights, corresponding each to one unit of each type of earthquake. The tremor unit is ¼, the very feeble shock is

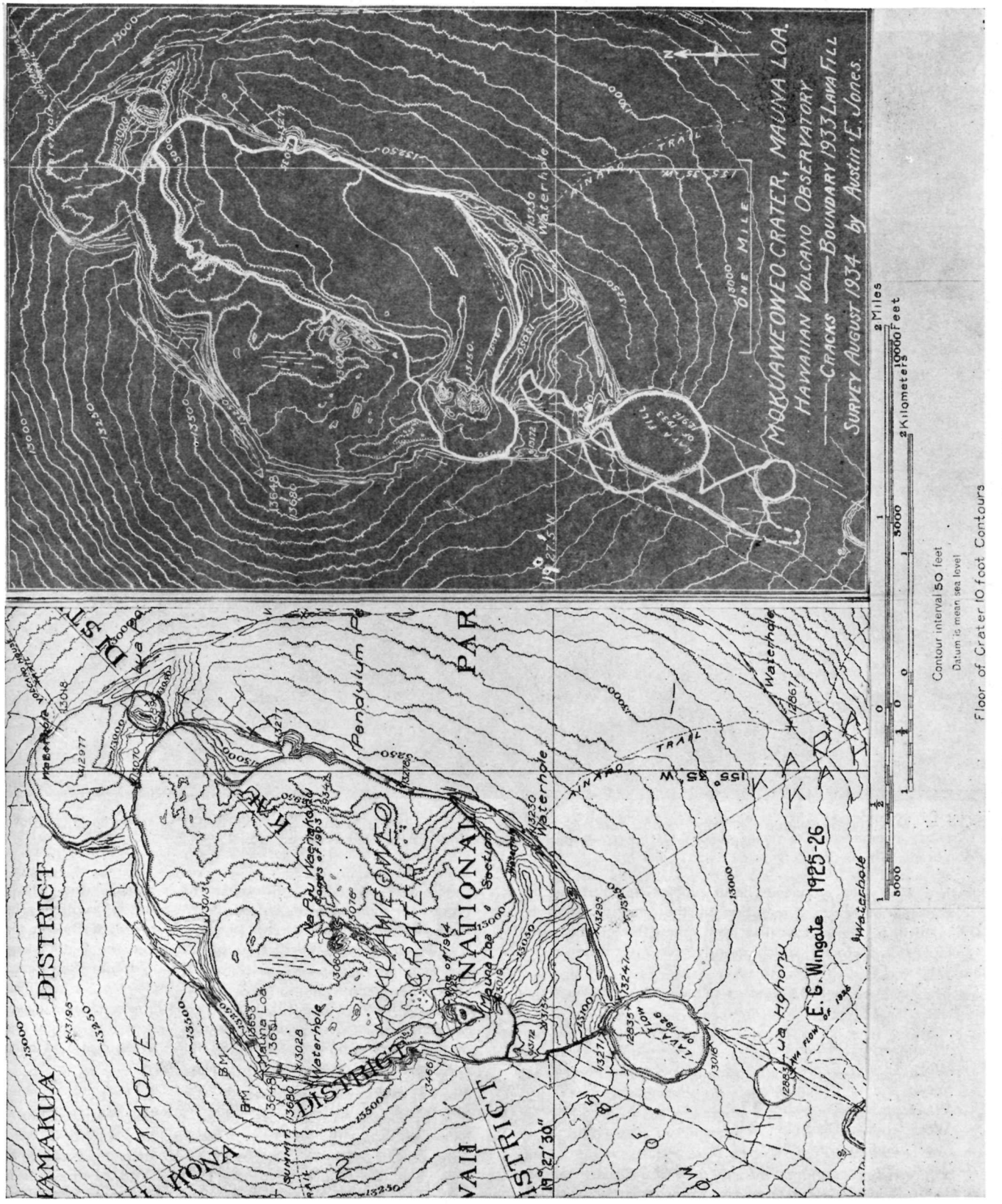


Figure 1. Maps of Mokuaweoweo before and after 1933 eruption.

½, feeble is 1, slight is 2, moderate is 3, and strong is 4. When a tremor lasts less than a minute it is evaluated as a single tremor unit; when it is continuous the unit is the minute of

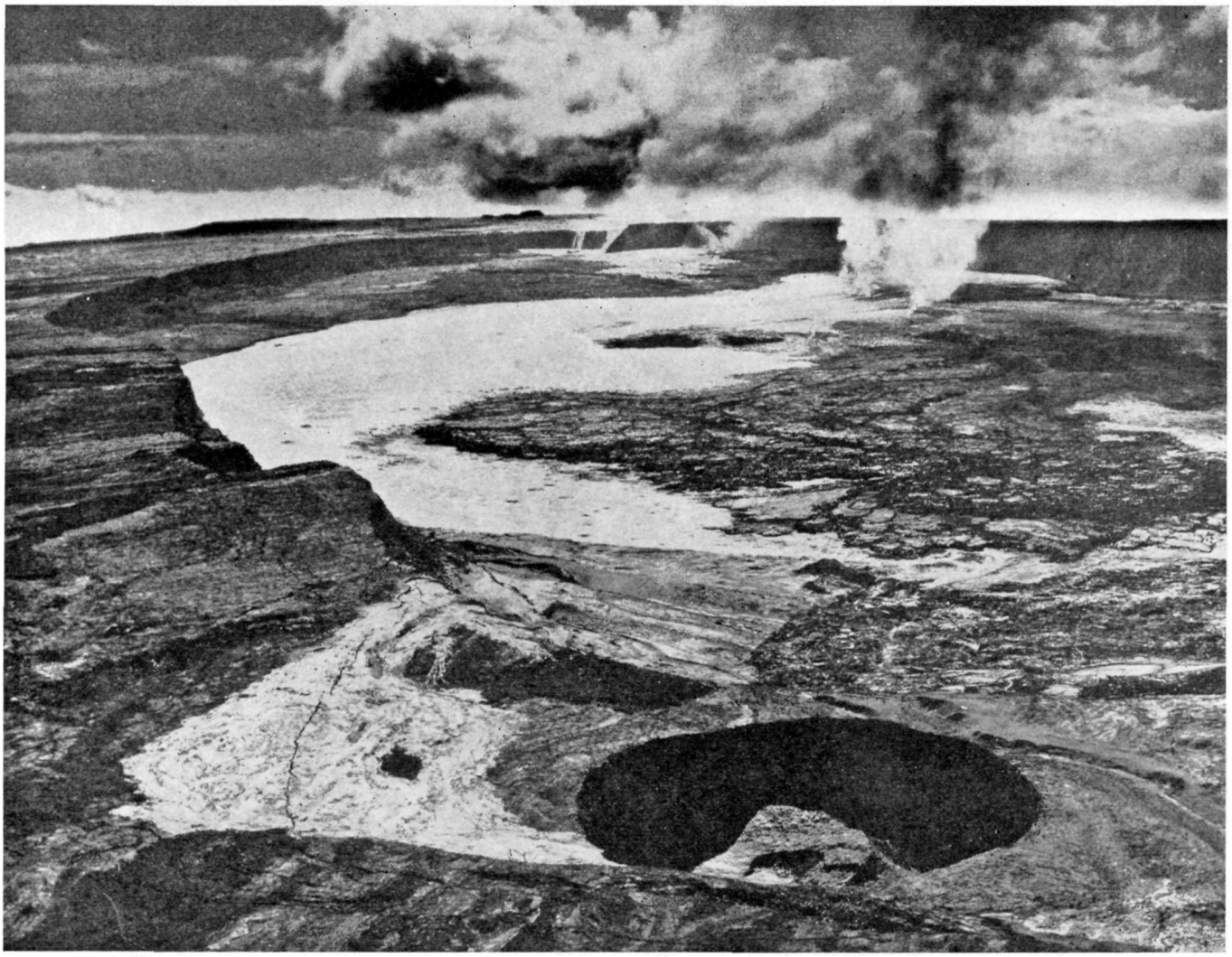


Figure 3. Mokuaweoweo eruption from 14,250 feet, 11 a.m. December 2, 1933, looking SW. North Pit in foreground, old lava gleaming to left of it. By permission Fleet Air Base, Pearl Harbor, U.S.N.

duration. If a week produced one of each of the six types the local seismic index, or summation of the weights would be 10¾. It will readily be seen that continuous tremor, measured in minutes, is a factor which greatly raises local seismicity values.

These values in 1933 were as follows, the eruption starting December 2:

	Seismicity
Week ending November 26	15.50
Week ending December 3	360.00
Week ending December 10	86.00
Week ending December 17	170.00
Week ending December 24	6.50
Week ending December 31	12.50

Tilting of the ground, measured at the Observatory on the northeast rim of Kilauea crater, was strong and northerly or easterly (away from the crater), before and after the Mauna Loa eruption, weaker and westerly during the eruption. The total tilt of the three clinoscope[8] cellars around Halemaumau pit, outward away from the pit, or inward toward the pit, measured on the radial lines from the center of the pit, and disregarding other directions of tilting, yielded interesting results. The aggregate tiliting at the pit had been notably inward for many months before the Mauna Loa eruption. The week of the outbreak it was strongly outward as though the Kilauea floor were swelling upward. After the outbreak it was **more** strongly inward, as though the sinking of the Kilauea floor followed the sinking back of lava under Mauna Loa. This sequence, for the lava fill, is just what happened at Kilauea, when the live lava in Halemaumau was visible during the Mauna Loa eruptions of 1914, 1916 and 1919; and the Mauna Loa crater is 22 miles (35 km.) away WNW.

[8] Volcano Letter, Nos. 382 and 392.

Maps of Mokuaweoweo Crater

In Figure 1 maps are shown of Mokuaweoweo crater before and after the 1933 eruption. The first is by E. G. Wingate, as mapped in the summer of 1926, after the eruption of that year. Contour intervals are 50 feet (15.24 m.) outside the crater, 10 feet (3.05 m.) within the crater floor. The lowest point of the main bowl showed elevation 12,934 feet (3942 m.) before the eruption, 13,035 feet (3973 m.) after the filling of 1933. The bottom of the South Pit showed elevation 12,835 feet (3912 m.) before the eruption, 12,912 feet

(3936 m.) after the filling. The eastern side of both bowls had been depressions before the eruption, but the fills made them relatively flat or level. The heavy outlines on the second map, a survey of August 1934 by A. E. Jones, indicate the two areas of fresh lava north and south. The northern area was fed by the north-south line of big cones approximately 100 feet (30 m.) high that built themselves up on a crack immediately east of the cone of 1914. This source made big floods of lava over the entire eastern side of the main bowl north of the southern lunate platform. These floods also filled the depression adjacent to the 1914 cone and made a new fill against the high western wall of the crater for a third of a mile (one-half kilometer).

The southern area of 1933 outbreak includes the two pits and the cracked upland west of them. A big fountain formed a cone at the foot of the bluff just north of the South Pit and sent a cascade for many hours into that pit. It is this cascade which produced and lies northeast of the small island mapped in the southern area of lava, shown on the northern side of the South Pit. The surface area of the southern lava tract is one square kilometer (0.39 sq. mi.) and of the northern tract three square kilometers (1.16 sq. mi.). The total volume produced in this eruption was of the order of 68 million cubic meters (2400 million cu. ft.).

1 sq. km. = 1 million sq. meters.

Max. thickness in pits southern area = 24 meters.

Mean thickness in south area = 8 meters—thin at the west.

Max. thickness in north area = 31 meters.

Mean thickness in north area = 20 meters counting the cones and west fill.

Area south = 1,000,000 sq. meters.
x 8 = 8,000,000 cu. meters.

Area north = 3,000,000 sq. meters.
x 20 = 60,000,000 cu. meters.

Add N & S = 68,000,000 cu. meters.

Progress of the Eruption

The estimated time of outbreak, 5:43 a.m., December 2, 1933, is that shown by the beginning of continuous volcanic tremor at the Kilauea seismographs. At 7:00 a.m. December 2 two dense white columns of vapor were rising, and by 9:00 a.m. there were three jets, the northern the largest and highest, the two southern ones each double. After the first two hours the white vapor columns became bluish and sulphurous, and these when seen in transmitted light were absinthe red. Filamentous glassy lava, or Pele's hair, fell in small amounts at Hookena 22 miles (35 km.) to leeward, west-southwest. There is reason to think that the division of the fume columns in three corresponded to the opening of three principal gashes on the rift belt. These are respectively the southern gash connecting the two outlying pits, the gash immediately west of the South Pit, and the gash inside the big crater offset still farther to the west and extended to the north. By 7:30 p.m. December 2, when the glow of the fountains at the base of each fume column could be seen, the glowing columns were three in number. The northern one was triple and very brilliant, representing three gigantic fountains east of the 1914 cone within the big crater. The second one was bright and stood over the big fountain at the southwestern border of the big crater, building a cone which vomited up a cascade that streamed down into the South Pit. The southern glow column was faint, and represented the last gushings of the southern gash after fourteen hours of action. The region near the southern pits went entirely out of action by the end of the first twenty-four hours.

Figure 2 shows a lengthwise view of Mokuaweoweo taken before the eruption from an army plane in 1925 at elevation 14,600 feet (4430 meters), looking from the region of the northeast rift towards the southwest rift cones in the distance.

The whole bowl of the caldera is exhibited for comparison with Figure 3, which shows the activity of the first forenoon of 1933 eruption. The line of fountains crosses the southern part of the large cauldron, cuts the northwest cliff-block of South Pit, and extends into the upland beyond, sending cascades of incandescent lava into the South Pit and the pit farther south. The three fume patches represent three principal fountaining areas, the first and largest just east of 1914 cone; the others north and west of South Pit, the floor of which has a new lava fill. Vast floods of pahoehoe in the picture are filling the depression near the cone of 1914, and also the basin of the east side of the main crater.

On the first day, December 2, there were about 35 fountains in the main basin, and 20 each at the two other localities. The basin fountains concentrated to a smaller number about built-up cones. These basin vents poured lava both east and west, but the eastern flows became the great feature. The western ones obliterated the pit of 1914, and made a fill against the western cliff of the south lunate platform. The South Pit outside of the main basin received a fill about 21 meters deep (70 feet) at the base of the cascade through the gap. The main flow area covered about 3 square kilometers (1.16 square miles) the second day, and the southern pits had received a quarter as much. The southernmost upland fissure made big fountains the first day, the lava cascading strongly into South Pit, and feebly into Lua Hohonu.

In the main crater there was liquid flooding of silvery sheets of lava the first day, but on the second day there were crusted floor flows, and flocculent skins appeared on the scarlet torrents of the main streams. On this day the outside southwestern cracks were steaming only. The flow lava of the crater was pahoehoe, but the cones were heaped with basaltic pumice, and Pele's hair lay on the ground to leeward. Milky-blue fume cirrus lay in belts across the sky during the next few days. There was glow over the crater at night, and a fume column by day. December 4 the southwest wall fountain stopped. December 5 the two central fountain groups were within throne-like conical heapings more than 100 feet (30 meters) high.

Figure 4 is a remarkable picture of lava-flow pattern. It shows a half-mile (0.6 kilometer) of the spouting rift inside Mokuaweoweo. It is the forenoon of December 3, when the fountains along the crack, about eighteen in the photograph, had built pumice cones. The jets were 100 to 400 feet (30 to 120 meters) high, and show indistinctly as light patches, for the camera was directed downward. The 1914 cone was smoking violently but still intact behind the second of the two larger fume columns. The left-hand or southern end of this particular fault-block rift crack, one of the echelon of cracks that erupted, is drowned under its own flood. This lake of lava spread to the western crater wall, in a local basin that had been left in 1914. The erupting crack is itself faulted down in the foreground, bounded by a higher block in the background west, and so building crescent half-cones on the step, and the lava flows away from the rise.

This last feature is highly significant of an age-long trend in the active rifts of Hawaii. They are breaking down in steps away from the summit. The same step-down to the east appeared in the 1926 eruption 3 kilometers (2 miles) south of here. The larger fault blocks of both Kilauea and Mauna Loa are sliding toward the southeastern bay of the island for the Kau district, and toward Kealakekua Bay for the Kona district. Something similar is going on in a northern embayment of Mauna Loa, on the Mauna Kea side. Probably dikes under-

ground form three hard ribs on the southwestern, northeastern and northwestern rifts, and between these, the weight of the flanks of the dome breaks it on slipping planes.

The foreground of the photograph shows the great rivers of golden pahoehoe which filled the eastern half of Mokuaweoweo with 30 meters' depth (100 feet) of new lava. The two main fume columns are over the two persistent fountaining heaps, destined to build up cones 80 to 100 feet (25 to 30 meters) high and to envelop the 1914 cone as shown on maps, Figure 1.

The peculiar flocculent pattern of the surface of the liquid rivers is occasioned by the forming and rending of skins of solidification. Each of these skin belts may be traced to its fountain source, the wider ones to the bigger cups, and the contact of skin against skin produces lines longitudinally like the medial moraines of a glacier. Each skin belt tends to wrinkle in festoons of ropes, with convexity down-stream, so that the lines are occasioned by the meeting of the curtains at the frictional drag, where each festooned crescent flows more slowly at the sides. The writer had opportunity to inspect this scene from an airplane, and this was the first time in the history of Mauna Loa when its summit eruption was repeatedly so inspected, by regular passenger planes. By this method far more could be determined in a few minutes, concerning the progress of the eruption, exploring from an airport 65 km. (40 miles) away, than through days and weeks of camping trips, wherein only a small part of the field could be seen at one time.

The flows within Mokuaweoweo proper continued to spread against the east wall; the eastern part of the cliff on the north side of the south lunate platform became obliterated (See Figure 2). Airplanes carried visitors day after day to watch the fan-like rush of lava pouring eastward from the two cone-filled gashes in the crater. The fountains of the northern gash, by December 12, had dwindled to two small ones. December 13 there was only one fountain, with occasional jets from other vents. The fume and glow as seen from Kilauea continued until December 17, becoming faint. The last fountain died down at 2 a.m., December 18, revived slightly after daylight, and thereafter went out of action. The Mokuaweoweo crater area remained very hot and fumy with many jar-rings and rumblings.

A party visiting the crater January 6 to 7, 1934, found that the new lava was somewhat broken up in places near the fronts of the flows. There was much heat about the new cones, rumbles and sharp cracking noises were heard during the night, coming at intervals of three or four minutes, and a few sharp earthquake shocks were felt.

During the mapping expedition, July 30 to August 3, 1934, the new summit resthouse of the national park was occupied by Mr. A. E. Jones and his men, and gave much protection against the cold. The temperature was 32° F. at sunset, and 20° F. at daylight. There were occasional sounds of falling rocks, much of the new shell-lava broke easily and was dangerous to walk on, the lava near the vents was hot enough to be uncomfortable, and sulphurous fume was locally strong.

The results of mapping show the new lava field in the eastern half of the main Mokuaweoweo bowl to be over three kilometers (nearly two miles) long, and something more than one kilometer (0.6 mile) wide, with a thickness of 30 meters (100 feet). The source cones are 30 meters (100 feet) high; the lower basins of the crater are now at the north and at the southeast. The new lava heap is an elongate dome, highest at the southwest in a ridge athwart the crater sink, with its longer axis northeast-southwest.

Hawaiian Volcano Observatory Report for September 1936

VOLCANOLOGY

During the month of September the number of slides from the ENE wall of Halemaumau Pit at Kilauea Volcano increased. Eighteen were reported as compared with six for August.

The following tabulation shows the relation for the month between local seismicity, number of reported slides, and aggregate opening in millimeters of the measured cracks:

Week	Seismicity	Number of slides	Aggregate crack openings
First	7.00	0	10.5 mm.
Second	12.50	3	13.5 mm.
Third	24.75	6	17.5 mm.
Fourth	20.25	5	14.5 mm.
Fifth	27.75	4	28.0 mm.

It is evident that these phenomena as a whole increased during this month that ended with the fortnight that followed the equinox. The crack opening was much larger than August, but not the seismicity.

Slides at Halemaumau

The NE rim of Halemaumau had been roped off, owing to the menace of crack opening and of slides, and the latter from the wall of the pit have been noted as follows:

September 7, Rocks were heard dribbling down the NE wall 9:12 a.m.

September 9, Moderate slide from E rim, near Crack No. 31, 9:50 a.m.

September 9, Rocks dribbling NE 9:58 a.m.

September 14, Large fresh scar over dust on floor, 150 feet below rim, under Crack No. 29. Rocks there were still in motion during forenoon visit.

September 15, Slide under NE rim 10:50 a.m.

September 16, Dribbling rocks NE 1:40 p.m.

September 19, Rocks in motion NE 9:30 to 11:00 a.m. Central part of NE talus had been increased with debris falls from fresh scar above.

September 25, Big noisy slide ENE at 9:42 a.m., and a new scar had appeared 100 feet below ENE rim near Crack No. 29. Rocks dribbled down wall throughout forenoon visit.

September 26, Small slide E wall 10:04 a.m.

September 26, Another at same place 10:24 a.m.

September 29, Small rocks fell WNW wall 9:40 a.m., and a larger slide had left a scar there 300 feet below rim.

October 1, Large dust cloud arose ENE rim, 2:20 p.m.

October 3, Small slide NE rim 11:00 a.m.

Halemaumau Solfataras

September 19 fume was rising from SE and NW Solfataras at edge of floor. This was not unusual.

Measurement of Halemaumau Rim Cracks

After the middle of the month, all along the ENE rim, the opening of cracks shown by the measurements was supplemented by breaks in the surface soil. At the NE flag the slumped slabs under the rim had moved down. By the end of the month the cracks ENE had widened and broken the soil extensively, with marked increase in rate of opening since the September equinox.

Weekly measurements of 32 marked places on rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of:

September 5, 7 opened, 6 closed, aggregate opening 10.5 mm. Crack No. 46 opened 9.0 mm.

September 19, 6 opened, 0 closed, aggregate opening 7.5 mm. Crack No. 46 opened 11.0 mm., and Crack No. 31 opened 3.5 mm. Crack No. 31 is east, No. 46 northeast.

September 26, 3 opened, 4 closed, aggregate opening 14.5 mm. No. 46 opened 13.0 mm., No. 31, 3.5 mm.

October 3, 12 opened, 1 closed, aggregate opening 28.0 mm. No. 46 opened 17.0 mm., No. 31, 6.0 mm.

—T. A. J.

EARTHQUAKES

Table

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant Earthquakes	Local* Seismicity
Sept. 6	20	4	0	0	0	7.00
Sept. 13	40	3	0	1	0	12.50
Sept. 20	91	4	0	0	0	24.75
Sept. 27	73	4	0	0	1	20.25
Oct. 4	87	10	1	0	1	27.75

* For local seismicity definition, see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, determinations of depth of focus have been made.

September 4, 6:06 am, very feeble, probable location under NE portion of Kilauea Crater.

September 4, 8:03 am, very feeble, probable location in Kilauea Crater about midway from the Pit to the Observatory.

September 4, 9:38 pm, very feeble, located 18 miles deep near the old Halfway House 13.0 miles SW of the Observatory. 19° 20′ 5N; 155° 26′ 0W.

September 6, 6:25 am, very feeble, probable location under NE rim of Kilauea Crater, 0.5 mile west of the Observatory.

September 7, 4:18 am, very feeble, located 0.8 mile deep, under NE edge of Kilauea Crater floor. 19° 25′ 4N; 155° 15′ 7W.

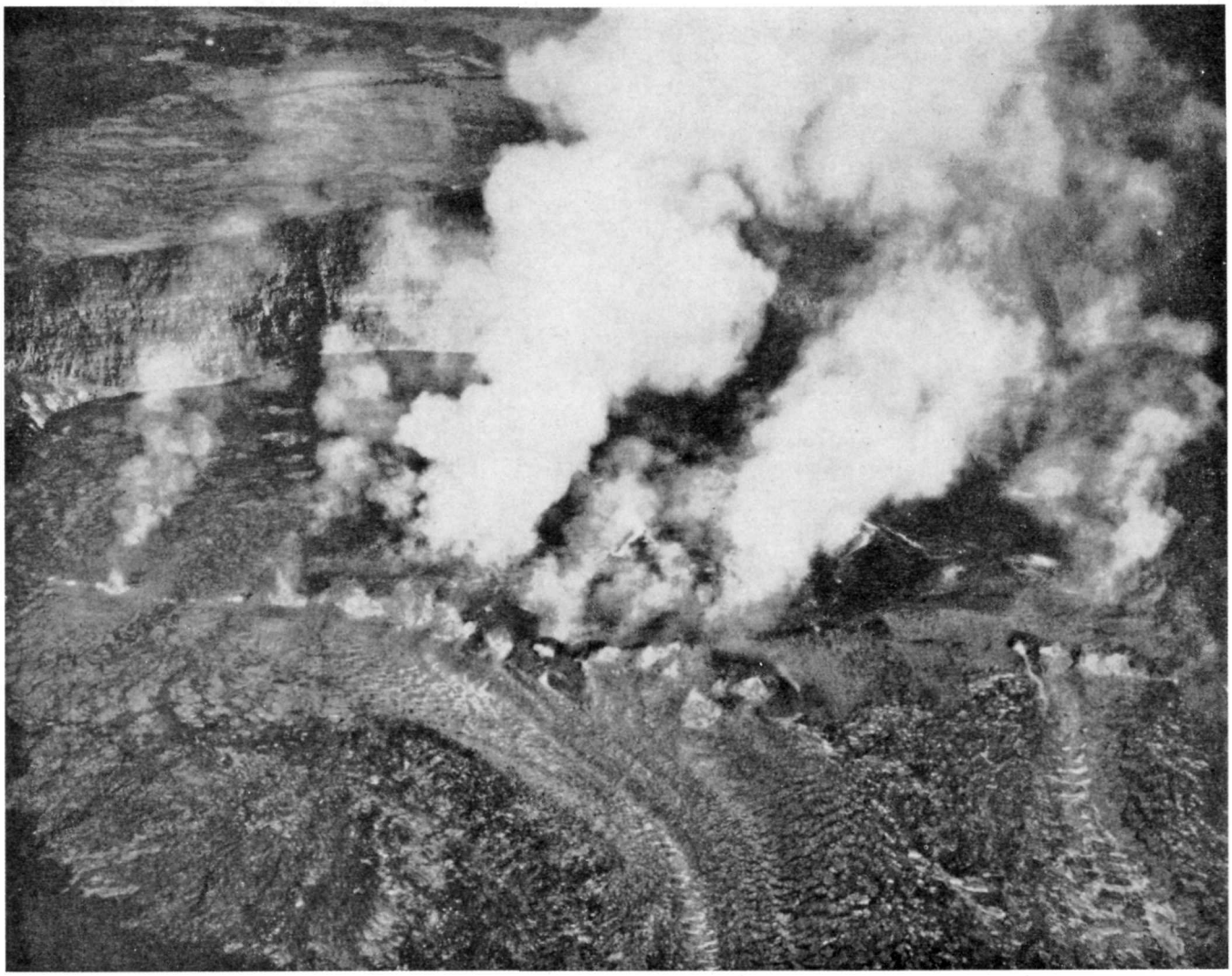


Figure 4. Line of main fountains inside Mokuaweoweo looking west, the second day December 3. The cone of 1914 is seen back of fume column. Lava-pattern, west cliff and outside Mauna Loa slope. From elevation 14,500 feet. By permission Fleet Air Base, U. S. Navy, Pearl Harbor.

September 8, 7:17 pm, very feeble, located 13.0 miles deep and 4.0 miles S of Makaopuhi Crater in the Hilina-Kapukapu Fault. 19° 18′ 8N; 155° 10′ 6W.

September 9, 5:46 pm, a slight shock felt by a few in Volcano district. Located 2.3 miles deep and 1.3 miles SE of the Pit Seismograph Station. 19° 23′ 4N; 155° 16′ 1W.

September 14, 3:39 pm, very feeble, located 4.0 miles deep and 2.0 miles NE of east entrance to Hawaii National Park. 19° 26′ 6N; 155° 12′ 9W.

September 15, 12:07 pm, very feeble, located 1.2 miles under NE portion of Halemaumau. 19° 24′ 7N; 155° 17′ 0W.

September 17, 1:37 am, very feeble, probably located under NE rim of Halemaumau.

September 20, 2:44 am, very feeble, located under SE rim of Kilauea Crater near Keanakakoi Crater. 19° 24′ 4N; 155° 16′ 2W.

September 21, 3:56 am, very feeble, located 5.5 miles deep under that portion of Kilauea Crater immediately to the east of Halemaumau and 0.4 miles N of Pit Seismograph. 19° 24′ 6N; 155° 16′ 9W.

September 23, 1:11 pm, very feeble, located 4.0 miles deep and 3.3 miles N of Uwekahuna. 19° 28′ 2N; 155° 17′ 4W.

September 24, 1:25 pm, very feeble, probably located in SE portion of Kilauea Crater.

September 28, 2:06 am, feeble, located 2.2 miles deep and 3.6 miles E of the Pit seismograph. 19° 24′ 1N; 155° 13′ 6W.

September 28, 3:08 am, very feeble, located 3.7 miles deep and 2.1 miles N by E of the Volcano Observatory. 19° 27′ 6N; 155° 15′ 1W.

September 29, 4.12 am, very feeble, probably located in NE rift of Mauna Loa near Puu Ulaula.

October 4, 12:02 pm, very feeble, probably located 1.0 mile NE of Kilauea Crater.

The surface (L) waves of a telesism began recording 2h 37m 41s, HST, September 25. Reported location was approximately 300 miles off W Coast of Southern Oregon, 2140 miles from Kilauea. 42° 5N; 131° 4W. Registration of the preliminary waves of another distant earthquake began at 11h 26m 25s, HST, October 4. It was 5340 miles SW by W of the Island of Hawaii and the reported location was the northern border of the Banda Sea east of Celebes Island. 3° N; 126° 4E.

Periods of continuous tremor registered as follows:

September 20, 3:49 am, 6 minutes and October 1, 12:33 pm, 4 minutes.

Microseismic motion of the ground at Kilauea was moderate September 16, 17 and 18, the remainder of the month it was light.

H. H. W.

CRATER ANGLES

Measurement of horizontal angles across Kilauea Crater from the Observatory on September 23, showed slight opening across Halemaumau and slight closing across the Crater as compared with similar measurements August 18. From Kilauea SE rim to Uwekahuna the angle closed 1″.92 August 18-September 1; September 1 to September 11 an opening of 2″.67; September 11 to September 23, an opening of 1″.25; total closing 0″.6. From the Pit seismograph to the NW Pit station there was a closing of 1″.00, August 18-September 1; September 1 to September 11, a closing of 1″.83 and September 11 to 23, an opening of 3″.33. Total opening 1″.50.

H. H. W.

SPIRIT LEVELLING

Spirit levelling across Halemaumau from the Spit SE edge of Kilauea Crater to the NW Pit BM showed a lowering of the NW Pit BM with reference to Spit of 5.5 centimeters between February 10 and September 3, 1936.

H. H. W.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 30, was 4.″23 N and 1″.1 E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit Resultant
September 6	0″.23 W	4″.71 N 58°W	4″.34 N 31°W	0″.65 toward
September 13	1″.00 N 72°E	4″.02 S 79°W	4″.28 N 19°W	0″.12 from
September 20	0″.00	1″.04 N 10°W	3″.30 S 31°W	1″.30 from
September 27	0″.50 N 71°E	5″.18 N 77°W	3″.82 N 31°W	1″.67 from
October 4	0″.95 N 65°E	2″.59 S 60°W	2″.92 N 6°W	0″.76 from

H. H. W.

THE VOLCANO LETTER

440

No. 440 monthly Department of the Interior National Park Service October 1936

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

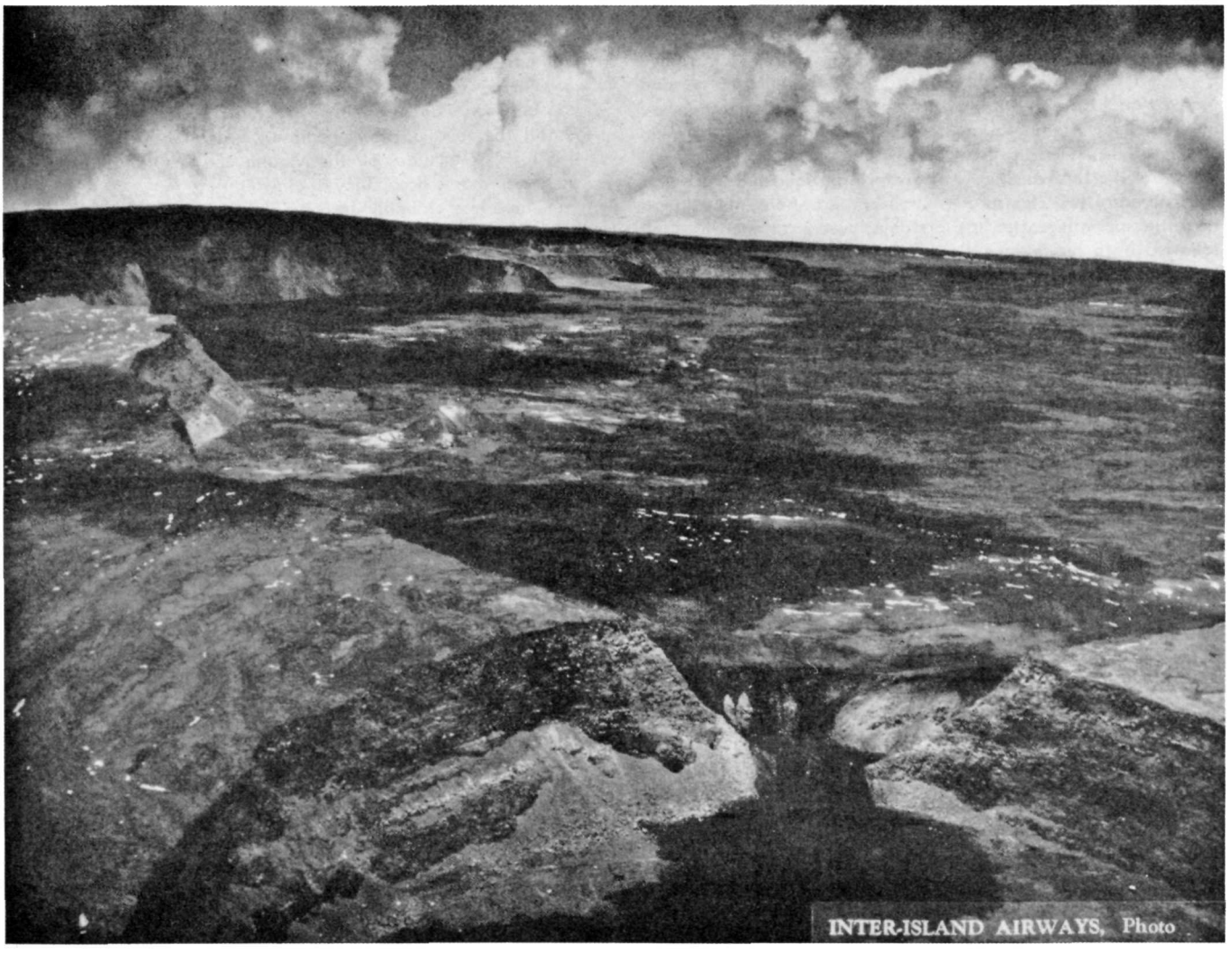


Figure 1. General view from plane of the Inter-Island Airways, Ltd., winter 1932-33 looking north. Mokuaweoweo, summit crater Mauna Loa, before December eruption of 1933. South Pit in foreground, 1914 cone on left, 1903 cones in center.

THE COMING LAVA FLOW

The Most Serious Responsibility in Our History

T. A. Jaggar

Annual Address, March 26, 1934, Hawaiian Volcano Research Association*

Mauna Loa at its summit crater has recently made a spectacular lava gushing December 2-18, 1933. This 17 days of summit activity should be followed by an outflow over somebody's land within a period of from 16 to 37 months.

This expectancy is the serious responsibility which rests on the shoulders of the Hawaiian Volcano Research Association. The words are not "the most serious lava flow in history." They are "serious responsibility." It is serious if we take our 22 years of volcano observing seriously, because we are called upon to make good, to make the forecast as careful as possible, and to advise the community soberly and preparedly.

* In sequence of dates to preceding and following Volcano Letters.

There is no call for fear. There is every appeal for an intellectual and practical victory over nature. Prediction and resulting preparation are what exhibit science at her best.

What are the Facts about the Past of Mauna Loa?

There are listed 23 summit crater eruptions of Mauna Loa, in 90 years, between 1843 and 1933. This is without counting some small summit effusions which may have gone unrecorded.

Between 1832 and 1899 there were nine NORTHERN and EASTERN flank outflows, with one source as low as 8500 feet elevation on this 14,000-foot mountain, namely 1852.

Between 1868 and 1926 there were eight SOUTHERN and WESTERN flows, with one source as low as 3500 feet elevation in 1868, and one below sea-level in 1877.

The districts invaded by Mauna Loa have been NORTH KONA, SOUTH KONA, KAU, SOUTH HILO, NORTH HILO INLAND, HAMAKUA INLAND, and even SOUTH KOHALA was touched by the prehistoric but recent Keamuku flow west of Humuula. The very voluminous 1843 flow at the same place might well have found its way to South Kohala. Puna and North Kohala are the only districts of the Island not visited by fiery lavas from Mauna Loa sources, and Puna has been abundantly invaded by flows from Kilauea volcano.

What are the Intervals between Crater Eruptions and Outflows?

There are two classes of Mauna Loa eruptions, those at or near the summit crater lasting days, weeks or months, and followed by a major lava flow, usually some years later; and secondly, those at or near the summit, but not necessarily in the crater, often making small preliminary flows on the upper rifts, always lasting only a few minutes, hours or days, and then followed immediately by an outflow from a vent farther down the mountain. This second class is the SOME YEARS LATER group of the first class.

In other words, all great lava flows are preceded immediately by high-level gushing, and some are preceded by a summit crater eruption a few years before which announces that a flow is coming; but this preliminary summit crater outbreak may announce that a GROUP OF SUCCESSIVE OUTFLOWS is coming.

In like manner, all eruptions exclusively in the summit crater, like our recent display of December, 1933, are followed eventually in a few years by one or more low-level outflows with their immediately accompanying summit gushings; but it is possible for such summit crater eruptions of the preliminary class to follow one another in a GROUP OF SUCCESSIVE SUMMIT CRATER ERUPTIONS, before the mountain breaks to emit an outflow lower down.

Applying these facts of history to December, 1933, for discovering what is to follow, we may expect either one or more additional summit crater extrusions, or one or more lava flow eruptions.

Eruptions wholly at the summit Crater

Year	Duration	Interval	Next Succeeding Outflow
1832	3 weeks	10½ years	1843
1849	3 weeks	2 years	1851
1865-66	4 months	2 years	1868
1870	2 weeks	7 years	1877
1872	2 months	5 years	1877
1873	10 months	4 years	1877
1874	10 months	3 years	1877
1875	2 months	2 years	1877
1876	1 week	1 year	1877
1880 (May)	6 days	6 months	1880 (Nov.)
1892	3 days	7 years	1899
1896	15 days	3 years	1899
1903	9 weeks	4 years	1907
1914	6 weeks	2 years	1916
1933	17 days		

Flank Outflow Eruptions with Near-Summit Beginnings

Year	Duration	Interval Between Near-Summit Start and Outflow	Elevation of Flow Source
1843	3 months	7 days	10,000 feet
1851	4 days	minutes?	13,000 feet
1852	4 months	3 days	8,500 feet
1855	16 months	hours?	11,000 feet
1859	10 months	minutes?	11,000 feet
1868	4 days	10 days	3,500 feet
1877	few days	10 days	30 fathoms submarine
1880 (Nov.)	9 months	5 days	10,500 feet
1887	10 days	2 days	6,250 feet
1899	26 days	5 days	10,800 feet
1907	14 days	4 hours	6,500 feet
1916	17 days	3 days	7,300 feet
1919	40 days	3 days	7,600 feet
1926	1 day	minutes?	13,000 feet
1926	19 days	3 days	8,000 feet

Summary of Frequency for Mauna Loa Eruptions

There were 30 summit or near-summit events on Mauna Loa between 1832 and 1933, within the period of 101 years. As all the lava outflows begin with a near-summit outburst, this number includes all the Mauna Loa eruptions recorded in the white man's occupancy of Hawaii.

There was probably an average of just as many Mauna Loa eruptions in the eighteenth century and the first quarter of the nineteenth, but the icy wastes of the high mountains were too remote to interest Hawaiians. Lava flows lower down were taken as a matter of course and were not recorded. White explorers like Captain Cook and Vancouver did not usually happen to arrive at eruptive dates. Captain Cook apparently never heard of Kilauea and records Mauna Loa as extinct.

What are the Average Intervals for Mauna Loa?

The average is one outbreak in three and a third years near the Mauna Loa summit. There are 14 flows between 1843 and 1926, in the period of 83 years, averaging one outflow from the flank of Mauna Loa, as perceived by man, either above sea-level or close to sea-level under water, every six years. It must be remembered that commonest interval is by no means identical with average interval. Reviewing:

Intervals, SUMMIT AVERAGE, 3⅓ YEARS.

Intervals, FLOW AVERAGE 6 YEARS.

There were probably several submarine outflows under deep water, not perceptible to man, but indicated by extraordinary crater collapses, like those at Kilauea in 1790, 1894 and 1924. The reason for thinking this is that observed outflows close above sea-level caused similar collapses, as in 1823, 1840 and 1868. The submarine outflow in Kealakekua Bay in 1877, made very slight impression on mankind, but as it drained Mauna Loa of lava after seven years of summit activity, it may have been one of the greatest lava flows of history, down that cold, dark, wet slope, tipping away steeply 12,000 feet off Kona. The crater collapses of Mauna Loa have gone unnoticed, as nobody lives there. There is plenty of room in this globe for it to do colossally big things without informing mankind, until such time as it occurs to man to distribute and live in numerous observatories of the earth.

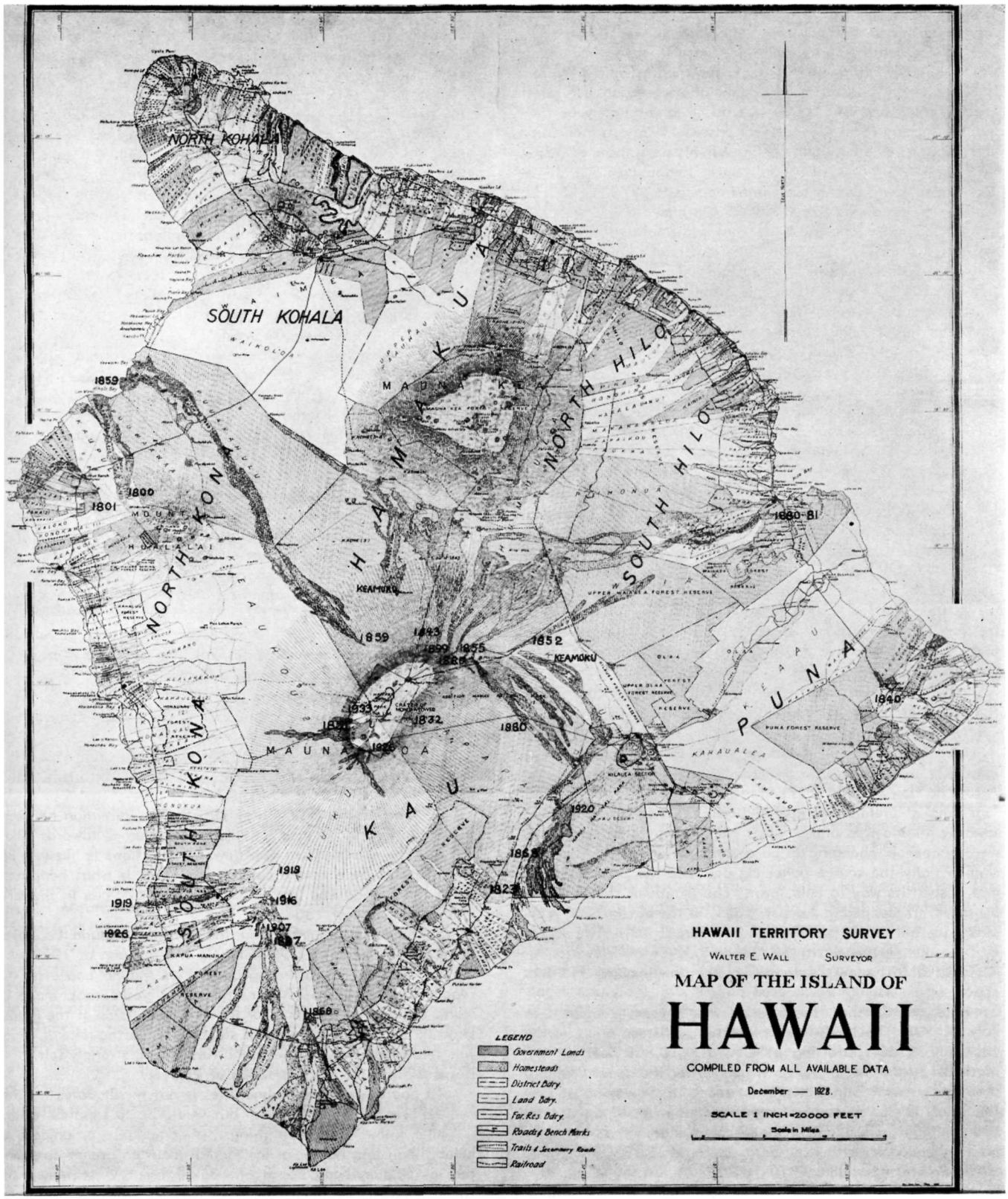
The frequency and continuity of lava activity at Kilauea have been even greater than on Mauna Loa, and there have been contributions within 200 years from Hualalai and Haleakala volcanoes, but this discussion is concerned only with Mauna Loa.

How the Lava Breaks the Dome

With summit eruptions of Mauna Loa every 3⅓ years, and outflows every 6 years, it appears to be nearly twice as easy for the lava and gas to squirt through the summit vents, as to break the flank of the great dome. We have to think of the expanding gas-charged paste swelling the mountain all the

time through hundreds of thousands of years, dammed back by its own accumulations which have built the mountain. An

sea-level, to elevations on Kilauea mountain 700 feet (1840), on Hualalai mountain 1500 feet (1801), and on Mauna Loa



eruption is determined by the yielding of the heap to a never-ending force.

The breaking of the flank ranges from 180 feet below

slopes approximately 3,000, 8,000, 10,000, 11,000, and 13,000 feet above sea-level for the statistics of only one century.

What Class was the Recent Eruption in?

The outbreak in Mokuaweoweo crater of Mauna Loa volcano in December, 1933, was not in the Class II of the second list, where the outflow follows the summit gushing by a few hours or days. No outflow has appeared. Therefore, the flow *is yet to come, and when it comes it will begin at the top.*

This concentrates interest in the first list where the summit eruptions lasted from three days to ten months, and were followed each by one or several flows of the second list, after repose intervals of from six months to ten and a half years.

By analogy the 1933 outbreak lasted 17 days; other eruptions of one to three weeks at the summit were those of 1832, 1849, 1870, 1876, 1880 and 1896. Imagining 1933 to be like one of these, let us see what happened:

Samples of Eruptions like the 1933 Outbreak

After 1832, June, at the summit, the interval was 10½ years to January, 1843. The 1843 flow poured for more than six weeks, largely pahoehoe as mapped today, filling the Mauna Loa-Mauna Kea saddle, flowing north and northwest 14 miles, starting at an elevation of 10,000 feet.

After 1849, May, at the summit, the interval was two years and two months to August, 1851. The 1851 flow poured only four days, pahoehoe lava above and aa lava below. It went towards Honaunau, very high up on Mauna Loa, moving due west eight and a half miles, starting from the southern pits of Mokuaweoweo at an elevation of 13,000 feet.

After 1870, January, at the summit, "steam and smoke," introducing seven years of summit activities, the interval was seven years to February, 1877. The other summit gushings lasted two months in 1872, 10 months in 1873, 10 months in 1874, two months in 1875, one week in 1876 and 10 days in 1877 just before the outflow. What was seen of the 1877 flow lasted only half a day. It was frothy lumps of hot pahoehoe under the sea in Kealakekua Bay in 30 fathoms of water a half mile off Keei. The pieces bubbled up and floated while hot and were collected. No one knows how far the flow went under the sea, nor how long it may have pushed onward under its water-chilled skin.

After 1876, February, the interval was one year to the Kona submarine flow February, 1877.

After 1880, May, the interval was six months to the flow of November 5, 1880. The 1880-1881 flow poured for nine months in several branches, aa at first, pahoehoe afterwards. A first aa flow went to Ohaikea in Kapapala, 11½ miles, after four days of preliminary upland flowing. Then aa flows went towards Mauna Kea and towards Hilo. Always the vent lavas were pahoehoe, changing to aa a short distance away by stirring. Finally the source pahoehoe overrode the previous flows and pushed its way to Hilo town. The length of the flow was 30 miles. It stopped in August, 1881, in the outskirts of Waiakea, one mile from the city center (August 10). The source was on the northeast rift of Mauna Loa at an elevation of 10,500 feet. The lower extremity of the flow is about 100 feet above sea-level.

After 1896, April, the interval was 3 years 2 months to July 1, 1899. The 1899 flow poured ten to fifteen miles northeast for 26 days, starting at elevation 10,800 feet on the northeast rifts of Mauna Loa. It headed for the upper Wailuku drainage back of Hilo, but did not reach it. It was aa at first over most of its course, but pahoehoe as mapped, in a final stream, eight miles long. One account states that an early branch headed towards Kau, as in the case of 1880.

Is the Present Time like 1870-1877?

The 1870-1872 time was critical for comparison with 1933, if it should happen that 1933 is the prelude to a new shift of flow sources, from the southern vents of the last thirty years, to northern vents in the near future.

Seismic happenings now in 1934, and the location of earthquakes under the mountain at the north in 1933, point to activity under the northeast rift of Mauna Loa. The progressive higher elevations of flow sources in 1868, 1887, 1907, 1916, 1919, 1926 and 1933, all on the southwest rift, point strongly to the probability that the cracking open of vents will cross the summit to the northern rifts. For the 1933 eruption, though mostly in Mokuaweoweo ,crater, began along southern cracks, just outside the crater and where the 1926 eruption left off.

If we make this expected shift a basis for comparison with the 1870's, there may come numerous summit crater eruptions for some years. Thereafter the northern flank will split open. Compound eruptions, involving numerous vents, for Mauna Loa, have occurred not only in the seventies, but also in the fifties, the eighties, the nineties and after 1914. Something similar is to be expected at present, as the combination 1926-1933 is already compound, and not yet finished. There is an eleven-year cycle following the profound crisis of 1924, which has been discussed elsewhere (Thrum's Annual 1932) for the Kilauea-Mauna Loa volcanic system.

How can we use Average Intervals?

The average interval, between summit eruption and outflow, for these six selected occasions that resembled 1933 in duration, was 4.1 years. The average interval for all the summit eruptions of the first list was 3.8 years. The range between longest and shortest intervals for all was from one-half year to ten and a half years. If we leave out the exceptionally long intervals of 1832, 1870 and 1892, we get an average interval of 2.6 years, and a range from one-half year to five years. The Mauna Loa average for all flows, and the probability of a cycle, ending in 1935, make two years after 1933 a probable limit of time within which the next event should come.

The National Park rangers right now report increasing fumes of sulphur at the summit crater vents of last December. Earthquakes have almost ceased under the southern half of Mauna Loa, where until recently they were most abundant. The suggestion of a coming flow on the Hilo side is inescapable. Let us summarize the probabilities:

Summary of the Expectations

1. A lava flow from Mauna Loa, or else another summit eruption, is expected within two years.

2. If it is a lava flow, the history of sixty-six years indicates sealing of the southwest rift, and coming outbreak at the north.

3. The resulting flow may push in any direction between North Kona and Kilauea. A likely direction is towards Hilo.

4. The change from Kau flows to Hilo flows is likely to be accompanied by a severe earthquake. This is what happened when the change was from Hilo flows to Kau flows in the terrific earthquake of 1868.

5. Severe earthquakes on the northern Mauna Loa rifts have already begun, at Hualalai, in the autumn of 1929.

6. Opening of the northeast rift of Mauna Loa after its repose and solidification for thirty-five years may make a world-shaking earthquake, for the whole east side of the island Hawaii, just before the outflow starts. The earthquake of 1868 was felt all the way to the island Kauai, and strongly felt.

Responsibility for the Protection of Property

To point out these probabilities is not to set dates for the events. To fail to point them out would be to suppress truth.

Hilo knows all these things, is completely organized to meet them, and has been instructed about the relief committees of Napier, Long Beach and Sakurajima. A statement of the Mauna Loa problem for the Hilo Chamber of Commerce appeared in Volcano Letter No. 338.

New Zealand, California and Japan have taught us lessons in earthquake insurance. With us the local government, the National Park administration, the National Guard, the Ameri-

can Legion, the Coast Guard, the Navy and the Army all know what they will be called upon to do. On December 11, 1933, the superintendent of Hawaii National Park called a meeting



Figure 2. Similar view to Figure 1, during eruption December 3, 1933, from altitude 14,500 feet, airplane photograph by permission Fleet Air Base, Pearl Harbor, T. H. Note offset in active rift cracks, new floor of South Pit, new and old cascades, and in upper left corner the trace of rim of ancient caldera.

of an emergency committee of these organizations in Hilo to discuss Mauna Loa, and it was done quietly and efficiently. Honolulu is also organized.

The Volcano Observatory at Kilauea was founded in 1911 under the Whitney Fund of the Massachusetts Institute of Technology, with these words: "To be conducted with a view to the protection of human life and property."

That charge was accepted by the Hawaiian Volcano Research Association. A fire department, which in dry weather with high winds did not take special precautions, would neglect its duty.

This address definitely announces that volcano dwellers in Hawaii should now take precautions, for **Mauna Loa has definitely mobilized and declared war.**

What Precautions Can Be Taken?

The answer is as follows:

1. The northeast slope of Mauna Loa must be made accessible. The roadway proposed should be built at once, no matter how roughly. It should extend from the top of the mountain to Kilauea.

2. The Hawaiian Volcano Research Association should increase from 180 to 1000 members and patrons. Government funds for the Observatory have been cut 83 per cent since 1932. Twenty thousand dollars are needed when the lava flow comes, which might be this summer, if 1880 is repeated.

3. The staff is now two scientists, and not even a typist. With a suitable staff, the Hawaiian Volcano Observatory can resume its scientific publication, which amounted to 3500 pages prior to 1932. It can keep the community properly informed. It can organize more volunteer observers to report small earth movements. It can patrol Mauna Loa with more expeditions. It can man an observatory on Mauna Loa when the rough road is built. It can organize preliminary plans for volunteer assistance by airplane services and other public relief, and prepare special maps. It can improve everything it is doing now in concentrating on Mauna Loa, if it has the requisite man-power. You cannot make war without money and men. The patrolling of an area as large as Mauna Loa is not a small job.

4. The actual details of how a northern Mauna Loa flow will lap up Hilo's water supply, as it has done it in the past, is set forth on page 3, Volcano Letter 338, under the title "Preparedness against Disaster."

5. Japan has had her Earthquake Investigation Committee, and does not hush up anything. The most important precaution to be taken we may copy from Japan. It is to face the situation, and not cry about bad advertising, and cry of wolf, and fear of scaring tourists. Tourists come from Los Angeles and Santa Barbara and San Francisco, and they know the game, and that Hawaii is not more dangerous than their own homeland.

6. A foreseen Mauna Loa flow can be made the best advertisement Hawaii has ever had. The headlines will read "Hawaii meets lava flow with complete preparation." "First time in history when mankind has been prepared." "Everybody in Hawaii rejoices and goes to the flow." "Everyone in Hawaii a member of Volcano Association." "Hawaiian lava flow scares nobody."

The introduction said: "There is every appeal for an intellectual and practical victory over Nature."

If every firm, engineer, officer, doctor, teacher and homemaker, if every business man will turn to and join the association now, if those who can't afford it will take an interest and get behind the Observatory at Kilauea, if every educated person will help and not kick, then this Territory can laugh at the fiery fountains and make them an asset. They may gush and bubble as inflammably as they choose, and we shall rub our hands with glee. Our engineers and aviators and bombers will rejoice at the opportunity to show their prowess. And finally, a program of generalship will be laid down, with advice from all experts, which can be carried out as an object lesson to the world. The Volcano Observatory cannot do it, but we can unite and do it, using the motto of volcanology, "Be always ready, and never hysterical."

Hawaiian Volcano Observatory Report for October 1936

VOLCANOLOGY

The month of October at Halemaumau Pit of Kilauea Volcano produced the culmination of the landsliding and crack opening which has been disturbing the NE edge of Halemaumau for two years. This took the form of a large avalanche on October 22. The records of crack opening and wall sliding increased to a maximum at this time, but the local seismicity, while greater because of the many tremors generated by the slides did not vary directly with the figures for sliding and crack opening. The following is the abridged table of these movements:

Week	Seismicity	Number of Slides	Aggregate Crack Openings
First	8.00	13	42.5
Second	17.50	12	93.0
Third	39.00	50+	Infinite
Fourth	20.25	16	26.0

For the first week slides increased to 13 from 4 the week before and crack opening to 42.5 from 28. For this same week seismicity decreased from 27.75 to 8.00. It should be remembered that the number of slides is merely the record for a short period of observation, not a quantitative expression of the measurable number, which is uncountable with any present apparatus. The word "infinite" for the third week in crack opening means that the big avalanche carried away the cracks.

Sequence of Events by Weeks

The first week produced many slides from the E and NE walls and along with this went excessive opening of ENE rim cracks.

The second week increased the cracking open of the rim and the sliding of the NE walls, while fresh cracks in the soil opened in many places. It is evident from the map of the pit outline, that the breaking down of this wall was eliminating one of the straight parts of the circular outline of the pit. This straight part was a nearly vertical cliff between the peaks of the E and NNE talus cones. The form of stability that will result for the pit will extend the circular curve in plan, and make the inner slope more a funnel and less a cliff.

The third week produced the large avalanche at 5:54 a.m. October 22, along with many other slides. This extended peeling of the wall for months has removed a length of 1500 feet along the rim ENE, to a maximum distance back near Crack No. 46 of more than 100 feet. Following the collapse of the former Crack No. 34 in March 1936, there were now obliterated Cracks Nos. 29, 30, 31, 32 and 46. This reduced our marked crack locations from 32 to 27.

The beginning of this yawning open of the cracks can be traced to measurements two years ago when Halemaumau erupted in September 1934. A marked increase of the gaping open, however, began in October 1935 just when the premonitory earthquakes were heralding the coming November outbreak of Mauna Loa.

The many slides kept a dust cloud over Halemaumau for most of the week. The result was a very large new talus cone halfway up the wall, over the middle of the white ledge known as the Canoe Sill. The new break is adjacent to the dykes of the Rift Belt on their eastern side. The whole of this part of the wall has fallen to form the heap, overlapping the 1934 floor about a third of the distance to the center of the pit, and covering the ENE floor cracks, the depression that lay along the wall, and part of the 1934 lake-basin. Crack No. 46 lay N 57° E from the pit center, and this direction is along the line of the former cracks across the bottom that were mapped after the eruption of 1931-32. (See mapping, Volcano Letter 394). The limit of destruction of the rim was slightly beyond No. 46, and movement on the deep rift possibly stimulated this landslide.

During the fourth week smaller slides ENE continued, the surface cracks in the ground had opened to the Volcano House Trail, so that on November 1 this area had to be roped off, and the trail was established farther back. The new breakage of the ground is southward from the great avalanche of October 22. The opening of measured cracks was now near the E corner of the pit.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows, but these are only a part of what actually occurred:

October 6, 9:40 a.m., moderate NE near Crack No. 29; fresh scar near No. 31.

October 6, 3:00 p.m., numerous avalanches.

October 7, 7:56 a.m., small rock sliding NE near Crack No. 31.

October 8, 9:11 a.m., rocks moving under Crack No. 29: scar 150 feet below it, new rocks and dust on floor.

October 9, 12:30 p.m., avalanche dust arose.

October 10, 10:15 a.m., moderate slide below Crack No. 34 NE.

October 10, 12:50 p.m., moderate avalanche and dust cloud NE.

October 11, forenoon, rocks sliding, east talus enlarged, more rocks and dust on floor, and fresh mark under Crack No. 31 perhaps due to earthquake of 4:05 a.m. Much cracking of soil ENE.

October 11, 1:30 to 1:45 p.m., numerous slides S of Crack No. 46.

October 11, 4:15 p.m., slide under Crack No. 31.

October 12, 2:00 p.m., dust from slide E.

October 12, 3:50 p.m., dust from slide E.

October 15, 9:05 a.m., dust from large slide E: changes in walls E and NE.

October 15, 10:00 a.m., small slide in motion.

October 16, 9:44 a.m., noisy NE slide: new scar 200 feet below edge there.

October 17, 10:25 a.m., big avalanche NE: heavy sliding during forenoon measurement with continuous dribbling of rocks down wall.

October 17, 11:55 a.m., big avalanche NE.

October 18, 9:20 a.m., moderate slide E, starting 300 feet below edge.

October 19, 9:20 to 9:49 a.m., thirteen slides NE; of these one at 9:20 was moderate, those at 9:30 and 9:40 were noisy and started 150 to 400 feet below edge under Cracks Nos. 29 and 31.

October 20, 4:19 a.m., loud roar of slide.

October 20, 2:00 to 3:40 p.m., continuous dribble of rocks NE half-way down.

October 20, 2:40 p.m., moderate slide.

October 22, 5:54 a.m., the great avalanche.

October 22, 8:30 a.m. to 2:45 p.m., 18 slides listed, the larger ones at 8:55, 11:20, 11:30 a.m., and 2:05 p.m.

October 22, 5:00 p.m., large cloud of dust lasting 20 minutes.

October 23, 8:30 a.m. to afternoon, continuous rock falls, with occasional moderate slides. Slides diminished between 5:00 and 6:00 p.m.

October 26, 9:20 a.m., moderate slide ENE.

October 26, 9:24, 9:47, 9:49, 9:57, 10:00, 10:04, 10:09 and so on, showing intervals for this period between small or moderate slides.

October 27, 9:23 a.m., slide making dust cloud, followed by dribbling of rocks.

October 27, 10:00 a.m., moderate slide: followed by smaller ones 10:03, 10:11, 10:15 a.m., etc.

October 28, 9:33 a.m., slide making thick dust cloud.

October 31, 10:20 a.m., large slide near dyke NE.

November 1, 12:50 p.m., dust over pit: this period showed some tendency to increase of slides just after the noon hour.

Halemaumau Solfataras

Fume from the sulphurous vents from the floor was conspicuous during forenoon crack measurements October 17, but nothing during this period of avalanching indicated anything unusual about the fuming of the solfataric vents.

Measurement of Halemaumau Rim Cracks

Weekly measurement of the 32 marked rim crack localities, reduced to 27 after October 22, around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of:

October 10, 9 opened, 4 closed, aggregate opening 42.5 mm. No. 46 opened 24.0 mm. No. 31 opened 14.0 mm.

October 17, 7 opened, 2 closed, aggregate opening 93.0 mm. No. 46 opened 47.0 mm., No. 25 2.0 mm., No. 31 43.0 mm.

October 24, five cracks had gone. Of the remainder many of them not on the avalanching sector; 8 opened, 3 closed, aggregate opening 12.0 mm.

October 31, 8 opened, 3 closed, aggregate opening 26.0 mm. Cracks at E corner of pit partly opened, while others closed as the rim blocks tilted: No. 24 close to the rim closed 1.0 mm., No. 25 a little farther back opened 11.5 mm.; No. 28 in the same region closed 1.0 mm.; No. 45 farther north opened 7.0 mm.

T. A. J.

TOPOGRAPHIC DATA

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory on October 20, showed slight opening across the Crater and closing across Halemaumau as compared with similar measurements September 23. From Kilauea SE rim to Uwekahuna there was an opening of 0".5, September 23 to October 6 and an opening of 0".41, October 6 to October 20. Total opening—0".91. From the Pit Seismograph to the NW Pit Station there was an opening of 0".33, September 23 to October 6 and closing of 1".17 October 6 to 20. Total closing —0".84.

Spirit Leveling

Spirit levelling across Halemaumau from the Spit SE edge of Kilauea Crater to the NW Pit BM showed a lowering of the NW Pit BM with reference to the Spit of 6.4 centimeters between September 3 and October 23. H.H.W.

SEISMOLOGICAL DATA

EARTHQUAKES

Table

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant Earthquakes	Local* Seismicity
Oct. 11	26	3	0	0	0	8.00
Oct. 18	50	15	1	0	0	17.50
Oct. 25	134	7	0	1	1	39.00
Nov. 1	67	7	0	0	1	20.25

* For local seismicity definition, see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, determinations of depth of focus have been made.

October 11, 4:05 am, very feeble, accompanying rock slide in Halemaumau.

October 11, 5:39 pm, very feeble, located 3.3 miles deep and 0.7 mile NW of Pit Seismograph Station. NW rim of Halemaumau. 19° 24′ 8N; 155° 17′ 3W.

October 12, 4:44 pm, very feeble, located 1.0 mile deep in Kilauea Crater, 0.6 mile SW of Volcano Observatory. 19° 25′ 6N; 155° 16′ 1W.

October 12, 4:59 pm, very feeble, of shallow focus SE portion of Kilauea Crater in immediate vicinity of Pit Seismograph.

October 14, 2:45 am, very feeble, 0.9 mile deep under fissures immediately W of Keanakakoi Crater. 19° 24′ 1N; 155° 16′ 3W.

October 15, 1:15 am, feeble, 2.3 miles deep under N rim of Kilauea Crater. 19° 26′ 1N; 155° 16′ 7W.

October 15, 8:15 am, very feeble, 3.5 miles deep and 1.0 mile SE of the Twin Craters. 19° 24′ 5N; 155° 13′ 7W.

October 15, 9:02 am, very feeble, 0.9 mile deep under fissures immediately W of Keanakakoi Crater. 19° 24′ 1N; 155° 16′ 3W.

October 15, 9:03 am, very feeble, probably located under Waldron Ledge E rim of Kilauea Crater.

October 15, 5:48 pm, very feeble, 1.1 miles deep under fissures 0.5 mile N of Puu Ohale. 19° 21′ 8N; 155° 17′ 3W. This quake was succeeded by one October 16, at 12:10 am and another at 6:41 am, both of latter very feeble and all three of same location.

October 16, 10:18 am, very feeble, 1.0 mile deep in E portion of Kilauea Crater adjacent to Kilauea Iki. 19° 24′ 9N; 155° 15′ 8W.

October 17, 5:17 pm, very feeble, 1.8 miles deep near Stone Corral, Kilauea Crater. 19° 24′ 8N; 155° 16′ 2W.

October 18, 7:15 pm, very feeble, 2.0 miles deep near center of Kilauea Crater, 1.2 miles SW of the Observatory. 19° 25′ 1N; 155° 16′ 4W.

October 19, 8:52 pm, very feeble, 1.4 miles deep under E rim of Kilauea Iki. 19° 25' 0N; 155° 14' 8W.

October 20, 4:19 am, very feeble, accompanying slide from NE rim and by roaring sound from Halemaumau heard on NE rim of Kilauea Crater.

October 21, 8:18 am, very feeble, 3.4 miles deep NW rim of Kilauea Crater 0.6 mile NE of Uwekahuna. 19° 25' 6N; 155° 17' 0W.

October 21, 5:53 am, very feeble, 5.0 miles deep near center of Kilauea Crater. 19° 25' 1N; 155° 16' 4W.

On October 22, at 5:54 am a slight earthquake occurred simultaneously with a large avalanche from the E and NE wall of Halemaumau. Lack of definite preliminary phases prevented exact location but a review of the seismograms from Halemaumau and Uwekahuna showed it to be of Kilauea origin and was possibly caused by the fall of the unusually large mass of material.

October 22, 8:55 am, very feeble, accompanying slide in Halemaumau.

October 29, 7:36 pm and 7:37 pm, very feeble, probably caused by slides in Halemaumau.

October 31, 6:11 am, very feeble, probably located in fissure zone immediately west of Keaankakoi Crater.

The preliminary waves of a distant earthquake began recording at 8h 02m 09s pm HST, October 22. It was located 2835 miles from Kilauea and was reported by radio to have occurred in Alaska. The preliminary waves of a teleseism began to register at 8h 18m 40.0s am HST, October 29. It occurred 3960 miles from Kilauea and reports indicated the location as the Marianas Trough south of the Island of Guam.

A period of harmonic tremor lasting twenty-two minutes began at 2:56 pm October 19.

Microseismic motion of the ground at Kilauea was strong October 25, moderate October 7, 11, 12, 13, 15, 16, 17, 21, 24, 26, 27, 29 and November 1, and was light the remainder of the month.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 1, was 4" 0N.

Table of Tilt

Week Ending	Observatory
October 11	0".00
October 18	0".35 S 15°E
October 25	0".89 N 78°E
November 1	0".38 S 77°E

	Halemaumau Clinoscope Stations		
	West	Southeast	Pit Resultant
Oct. 11	1".85 N 60°W	3".05 N 33°W	1".43 toward
Oct. 18	2".24 S 89°W	4".86 S 88°W	0".03 toward
Oct. 25	7".12 N 62°W	8".81 N 18°W	2".47 toward
Nov. 1	3".34 N 31°W	17".50 S 72°W	4".17 toward H.H.W.



THE VOLCANO LETTER

No. 441 monthly Department of the Interior National Park Service November 1936

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

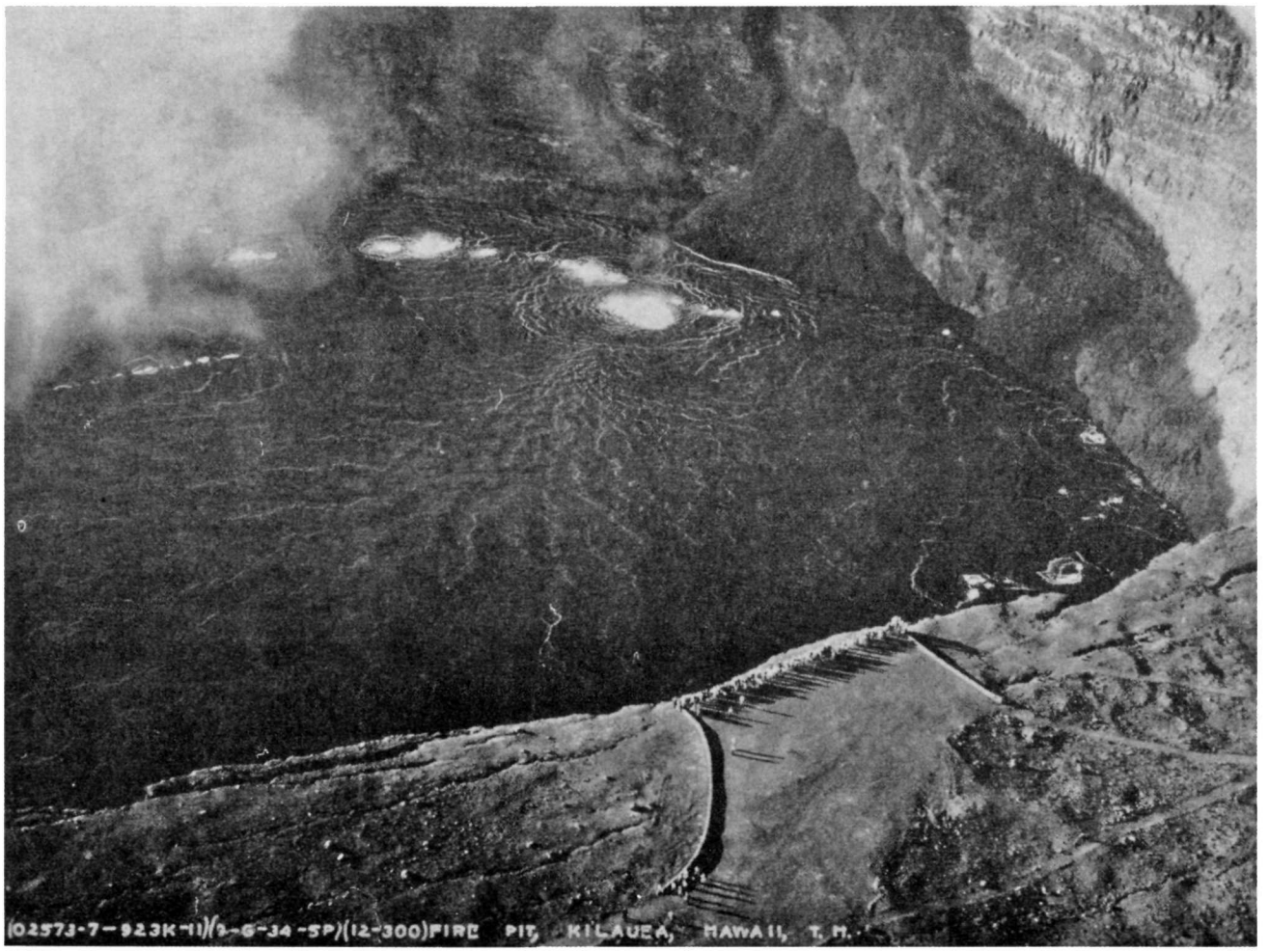


Figure 1. "The line of people is like a concourse of fire worshippers. At the bottom is a pool of blood-red molten slag." Halemaumau September 6, 1934, 5 p.m. Photo, 11th Photo Section, A.C., Wheeler Field, T. H.

ERUPTION OF KILAUEA VOLCANO SEPTEMBER 1934

T. A. Jaggar

This will show first the dramatic aspects of such an eruption and its effect on people living in Hawaii. Then there will be presented the scientific data describing the phases of the eruption. Here are two broadcasts by the Honolulu Advertiser, the first September 10, for the Hawaiian Islands, from Hawaii National Park: the second September 11, in a thunderstorm on the actual edge of Halemaumau pit, a national broadcast that was heard distinctly by listeners from Canada to Mexico, along with the detonations of the lava bursts on the floor of the pit 800 feet below. The eruption had started in the very early morning of September 6.

"September 10, Volcano House. Tonight in presence of the fire-pit, with the glowing lava again gushing and pounding and shaking the seismographs, I am asked to tell you something of the scientific meaning of it.

"We have established here a very small observatory. The University is helping and has made some experiments with the blasts at Moiliili quarry. The Bishop Museum is studying all

the Polynesian islands. The plantations are trying to find more water underground, and want to prevent their soils from washing into the sea. The engineers were baffled by the ocean at Mala, when they found that steamers cannot tie up to the wharf.

"These volcano changes, and shakings, and the building of coral islands, and the movements of the waters, are forces either useful or antagonistic to ourselves. We use gasoline from the earth which fifty years ago was hardly dreamed of for anything but cleaning gloves. The earth is full of secrets like this new force of petroleum. Six miles from Kilauea in the Kau Desert, we can light a stick at a crack. Here is a mysterious volcanic force from the ground, where continuously for fourteen years just past, we could have boiled water for making steam at those cracks.

We know a lava-flow is coming out of Mauna Loa. Where and when? The answer is written on that big, round, formidable mountain, with its cracks and caverns and sulphur and fume.

"We feel sure that a lava flow of 1924 lies under the sea east of Hawaii. Nobody has yet tried to discover it by sounding. A clever exploration there, with sonic sounding, wire sounding, bottom sampling, experiments, would make one of the great mappings of science, and would set a new standard.

"There is a job for fifty trained men for fifty years in unravelling the tangles of sea and land that beset us right here in Hawaii. This science of the earth will take men away from the cities. That is what the science of forestry is doing in the great public works program. That is what the Tennessee power plant is doing. That is what Boulder Dam is doing.

"It is astonishing that people with power, people who can employ labor, people with imagination, people who want to make a name or honor a name, cannot see the vision of the earth, and all the wonders it will yield. They see visions of the stars, but they do not see visions of the earth.

"Here in the light of the fiery lava which has risen thirty miles through the crust of the earth, which makes earthquakes for our seismographs twenty miles underground, which pours out under the sea or spouts up colossally on top of Mauna Loa, ought we not to be reminded of earth power?

"An Institute of Earth Research at Hilo could make a name for its donor that would live forever if it discovered the source of that rock heat at Mauna Iki, and the use of the powers of the living earth.

"September 11, crater's edge. Smooth miles in a noiseless car through hibiscus and stately tree ferns and summer habitations of men. No trace of volcanoes or brimstone in all that Hawaiian loveliness. And then in a flash you come upon a smoking fire-hole.

"A thousand people at the active crater Kilauea in Hawaii are standing here, on the edge of a vast circular pit three quarters of a mile across. The line of motionless white faces, all turned towards the setting sun, is like a concourse of fire worshippers. Sulphur of the volcano is in their nostrils. All are looking down, over a ring of precipice 800 feet high.

"At the bottom is a pool of blood-red molten slag. Through it come bursting fountains, making slow surges outward of fiery melt. Away from the fountains radiate zigzag bright lines. They are brilliant orange color, they are cracks eternally splitting the dark crust.

"Between them is a pattern of watered silk, in the black satiny robe that clothes Pele' the fire goddess. This magnificent garment lies over a bowl of the earth's glowing substance, molten, glassy, basaltic foam.

"Before the outbreak, a week ago, there was a hard lava floor, black or rusty, with a conelet at one side. The conelet is nearly drowned. The whole floor was the top of a taper cork, over converging slopes of debris. The live lava beneath lifted the cork and tipped it, escaping violently at one side of the neck of the bottle crater. Along with it, it lifted an upright slab of the wall four hundred feet high, and the glowing stuff squirted up the crack behind the slab.

"The eruption was the result. It was a quiet, instantaneous and unexpected gushing, in the dark before dawn, September 6. The evening before, nothing. The week before, nothing. The month before, nothing. People woke up, rubbed their eyes at three a.m., saw a brilliant glow and a vast cloud at the big inner pit two miles away. No one is frightened. Everybody cheers in Hawaii. Pele' has come back!

"It was all arranged as though the tourist stand, on the southeast side of the fire-pit, had been laid out by Pele' herself. In twenty minutes people were standing there, within a thousand feet of the near side of the lava lake, and just where the President's car stood a month and a half ago. There was no danger, the air was clear, the tremendous fire fountains and cataracts were all on the opposite side, and so were the whirlwinds. The best photographs were all made right there.

"The most spectacular and unusual feature of this lava rising was what happened at the wall slab, an immense cascade of incandescent liquid rock. Ribbon cataracts four hundred feet high, about twenty-five of them side by side, along a horizontal crack nine hundred feet long, fell from half-way up the wall of the pit. The liquid coalesced into a Niagara of fire at the side of talus. These cascades stopped flowing about three hours after the beginning of the eruption.

"A short distance to the north, at the edge of the glowing lake, were brilliant jets squirting up as though from hose nozzles, and criss-crossing against another slide-rock slope. These were more noisy, with deep rumble, than any of the other phenomena of the eruption. This rumble is due to gases rushing and shakng the whole volcano.

"Still farther around out in the lake was a tremendous fountain, shooting up three hundred feet in huge ropy flings, which slopped down onto the surface of the lake. The lake itself was indescribably beautiful, a vast labyrinth of glowing cobweb pattern ever changing radial and concentric to the central fountain group. The fire surf pounds on the shore, and the shore itself changes in the course of a few days of activity. A beach rampart forms. Then as the lake rises, slabs of crust pile up higher and higher on this rampart. It is like an ocean barrier beach of big flakes of stone, only the sea is made of fireworks.

"The deep shaking was such that all our seismographic instruments were vibrating violently, in unison with the trembling of the fire goddess.

"One of these machines is an annunciator, which rings a bell in the room above. When on the second day of the eruption, the big fountain started banging away like a big gun, this bell would ring in the Observatory building. Every detonation two miles away completely announced itself, as though Pele' were pressing the button.

"The whirlwinds were set going by the very hot rush of gas on the side of the pit away from the people. A strong trade wind threw this into cyclonic motion. Fragments of pumice, red hot, were falling on the west floor of Kilauea the first day. Some of them were a foot long. The whirls merged together and swept up the gravel on the ground as though with a giant's broom. I walked through this region on the first morning, in the light of the glowing pit, in order to read the tilt-meter in our cellar on the west side. My assistant picked up a pumice fragment with enough glow inside to light his cigarette. Now and then we had to crouch down to keep from being blown over. The gas and flying sand were trying, but the mighty yellow clouds shooting up above us, full of light fragments that floated down, made a marvellous spectacle. And the great billows of cloud rolled away to leeward for fifty miles in a straight

battalion of brownish volutes, tinged with pink by the rising sun. Pele' had declared war!

"What does it all mean to science? Do you say? Eight eruptions in ten years have laid new layers of lava on the bottom of Halemaumau pit in Kilauea crater. The layers average about sixty feet each. The pit is now about 800 feet deep.

"We have three active volcanoes in Hawaii, Kilauea, Mauna Loa and Hualalai. Mauna Loa had an outflow to the sea and destroyed a village in 1926. It erupted gloriously at its summit crater last December, and the travellers visited it in airplanes. We had a steam-blast eruption from Kilauea in 1924, and probably a mighty lava-flow poured out under the ocean to the east, where the water is 18,000 feet deep. We had a great trembling and shaking, thousands of earthquakes in a few weeks, from the volcano Hualalai on the west side of Hawaii in 1929. Add these things to Kilauea and you get eleven events in ten years. Who shall say that the Goddess is dead?

"A lava flow is soon coming from Mauna Loa. The scientific observatory of Hawaii National Park has been accumulating records for twenty-two years. Hawaii is the most perfect natural laboratory in the world. Here new land is being made, wind and weather act upon it, ocean and rivers sweep down the rubbish, and under all the crust of the globe is lifted. The Observatory will measure everything for a century to come. The measurement of the living earth and its breathing is just as important to your state as to Hawaii. Volcanoes in the past erupted in the Carolinas, Virginia, Pennsylvania, New Jersey, New York—your Palisades are a mass of Hawaiian lava—and in Connecticut, Massachusetts and Nova Scotia. But here in Hawaii you can take the pulse and breath and temperature of new rock when it is a-borning, and when it is making earthquakes. All over the globe there is need for more explorers for the study of the living earth.

"And now, listen to the Fire Goddess Pele' herself in the throes of her birth-pangs, listen to the pounding of liquid lava, to the bursts of earth puffing, to the surging of the waves of molten rock on the shore, all carried to you on the wings of radio, 180,000 miles a second—"

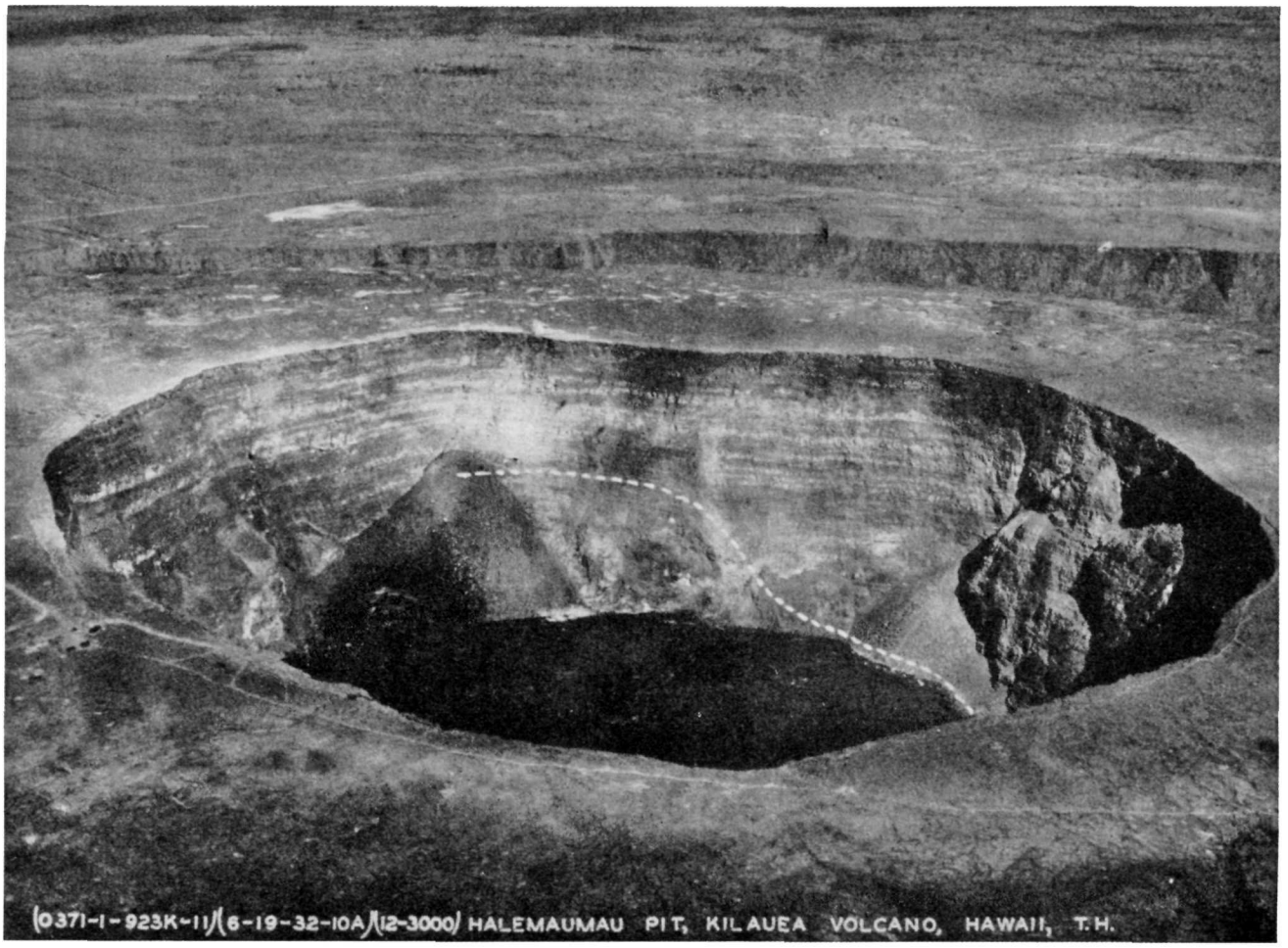


Figure 2. Halemaumau looking west from airplane June 19, 1932. Dotted line shows where the plug of 1931-32 lava lifted a wall slab to open the vent of 1934. Photo, 11th Photo Section, A.C., Luke Field, T. H.

ERUPTION OF KILAUEA VOLCANO, 1934

T. A. Jaggar

The seismic events in Hawaii that accompanied the outbreak of Mauna Loa in 1933 were reviewed by A. E. Jones in Journal Washington Academy Sciences for October 15, 1934, and those associated with the 1934 eruption of Kilauea in the number of October 15, 1935. In an earlier communication the writer has described and illustrated the 1933 eruption of Mauna Loa.

In Halemaumau pit there were slides before and after noon September 5, 1934, and the seimograph in a cellar near the southeast rim of the pit registered southwesterly tilt on the afternoon of this day. This was the first conspicuous premonitory symptom of the gushing up of lava in the bottom of the pit about 2:44 a.m. September 6.

Tremor spasms recorded seismometrically began at 1:07 a.m. and occured at intervals of a few minutes. Shocks close to the pit accompanied the outbreak, a feeble one at 2:44 a.m.

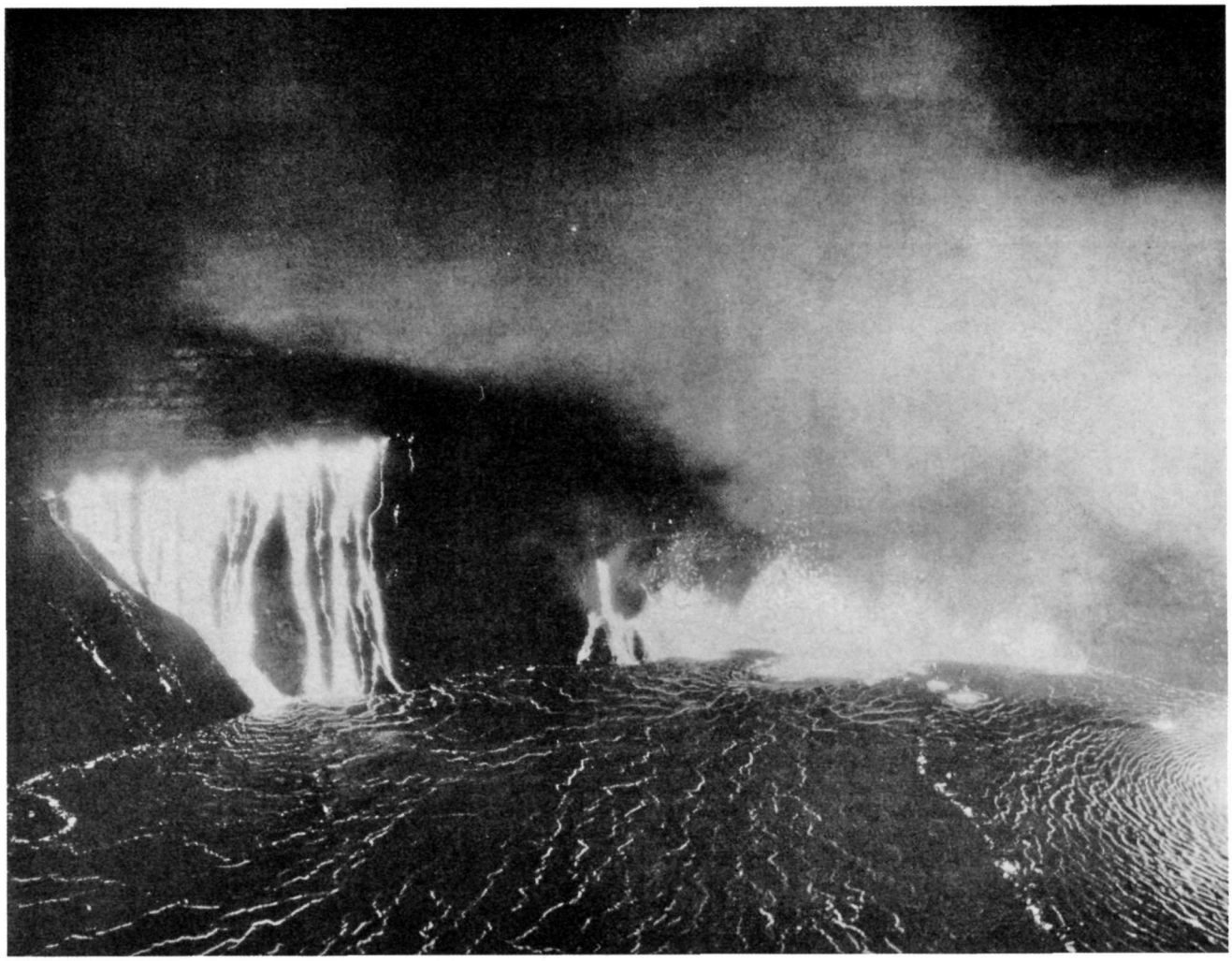


Figure 3. Halemaumau 4:30 a.m., September 6, 1934. Looking northwest, "twenty-five ribbon cataracts four hundred feet high, and brilliant jets squirting up below." Photo Maehara.

being followed by the continuous tremor which is characteristic of the rush of gas that accompanies fountaining. At the same time the bright glow of inpouring lava appeared, and clouds of fume arose. The fountaining places began at the edge of the lava floor at the bottom of Halemaumau on the north, northwest and west sides. The gush of gas bringing with it lava foam emerged through talus slopes at the first two places. The third was altogether different, and unique in the experience of the Observatory.

This was the gushing up of lava along an extensive fissure, forming a vertical crack back of a western buttress of the wall. The lava squirted up in 25 jets along a horizontal line half way up the wall of the pit. The frothy lava so ejected cascaded down the wall in ribbon cataracts. They poured over the large west talus between 3 a.m. and 6 a.m., and then went out of action. Ten main vents persisted until 6 a.m. along the cascade crack, the cascades being from 300 to 400 feet high, and there were two or three subordinate cascades, on an extension of the crack which opened on the northern side of the buttress. This buttress was in the nature of a fault slab, with the live dike fissure behind it. The wall of a pit of this kind is made up of several such imbricating fault blocks, produced by the caving away of the rim portions, and the leaving of a remnant buttress below. The vertical crack behind such a buttress is often not at all in evidence, and is frequently covered by talus.

The two photographs shown in Figures 3 and 4 are pubished by permission of K. Maehara for the night scene, and of the Eleventh Photo Section, Air Corps, Wheeler Field, U.S. Army, Territory of Hawaii, for the daylight view, which was made from an airplane. Both pictures were made from the southeastern side of the pit, the night scene about 4 a.m. September 6, while the cascades were in action, the daytime view at 9:30 a.m. September 7, the second day of the eruption, after the big western fountains had entirely ceased action. The two views show the contrast between the liquid flood of the first few hours of one of these pit eruptions, and the chilling around the borders which rapidly takes place afterward. The extraordinary feature of these photographs is the great western cascade. The upright fracture along the middle of the wall slope was 900 feet long and extended under the large west talus so that some of the fountains gushed through the talus along a horizontal belt, others poured over the rock buttress where there is an old intrusive body of irregular form, and still others cascaded out of the crack on the north side of the buttress, and it will be seen that the crack behind resisted the splitting effect for a quarter of its length. The most violent fountains were those at the northwest side of the pit shown at the right of the

night photograph. These were several hundred feet high, like jets from hose nozzles, covering the northwest wall and talus with pumiceous lava. The fragments of pumice were ejected several hundred feet above the rim of the pit the early morning of September 6, and fell in light spongy fragments as much as a foot long over the floor of Kilauea crater to the southwest. There was not much Pele's hair, but coarser needles of basaltic glass were common.

Phases of the Eruption

This eruption of Kilauea may be divided into four phases: (1) the large liquid pool of September 6; (2) the small lake heap and overflows which developed September 7 to 20; (3) border trickle flows from the wall-crack dike September 20 to 30 and (4) the period of subsidences, with detonations and intrusion from September 22 to October 8. These phases were more illuminating in revealing new explanations of some habits of Hawaiian lava, than anything which has happened here for many years.

Phase One: The Large Liquid Pool

This is the phase illustrated by the night photograph, and its decline is shown by the picture of September 7. Sulphurous fume of absinthe red color in transmitted light boiled up several thousand feet during the first 12 hours. The reflected fountain light was yellow-green to orange. The noise was a rumbling, and a rushing of gas, while hundreds of whirlwinds swept clouds of surface dust west and southwest of Halemaumau, and the odor was that of sulphur dioxide.

At 4 a.m. September 6 there were 30 jet fountains, and by 8 a.m. the new pool had covered the former floor 60 feet deep. Its area was 90 acres and its volume nine million cubic yards. Only the top of the 1933 border cone was still emergent. At noon the north fountains had dwindled, the northwestern ones were very violent, and the lava lake was covered with a bright-line pattern and black silky skins. A bench and rampart of crusts developed around the lake, wider at the talus slopes where the submerged slope was flatter. Between 3 and 4 p.m. the violent northwest fountaining stopped rather suddenly, and only thin blue fume was left rising from the north central fountains within the lake area itself.

Shrinkage of the lake now started in, so that by September 9 there was an inner lake 1100 feet in diameter surrounded by a floor which had shrunk and lowered beneath the border rampart 10 to 20 feet. The remnant lake was concentrating about the fountains at the NNE side of the floor. On all sides there was a slump scarp at the inner border of the rampart. The lake September 10 measured 1000 feet east-west by 400 feet north-south and became defined as an oval plateau on top of a terraced heap surrounded by a rim, over which went overflows. (See map). Within the lake spatter banks formed behind the two bigger fountains, showing that the lake was shallow, and that only the fountains were over source wells.

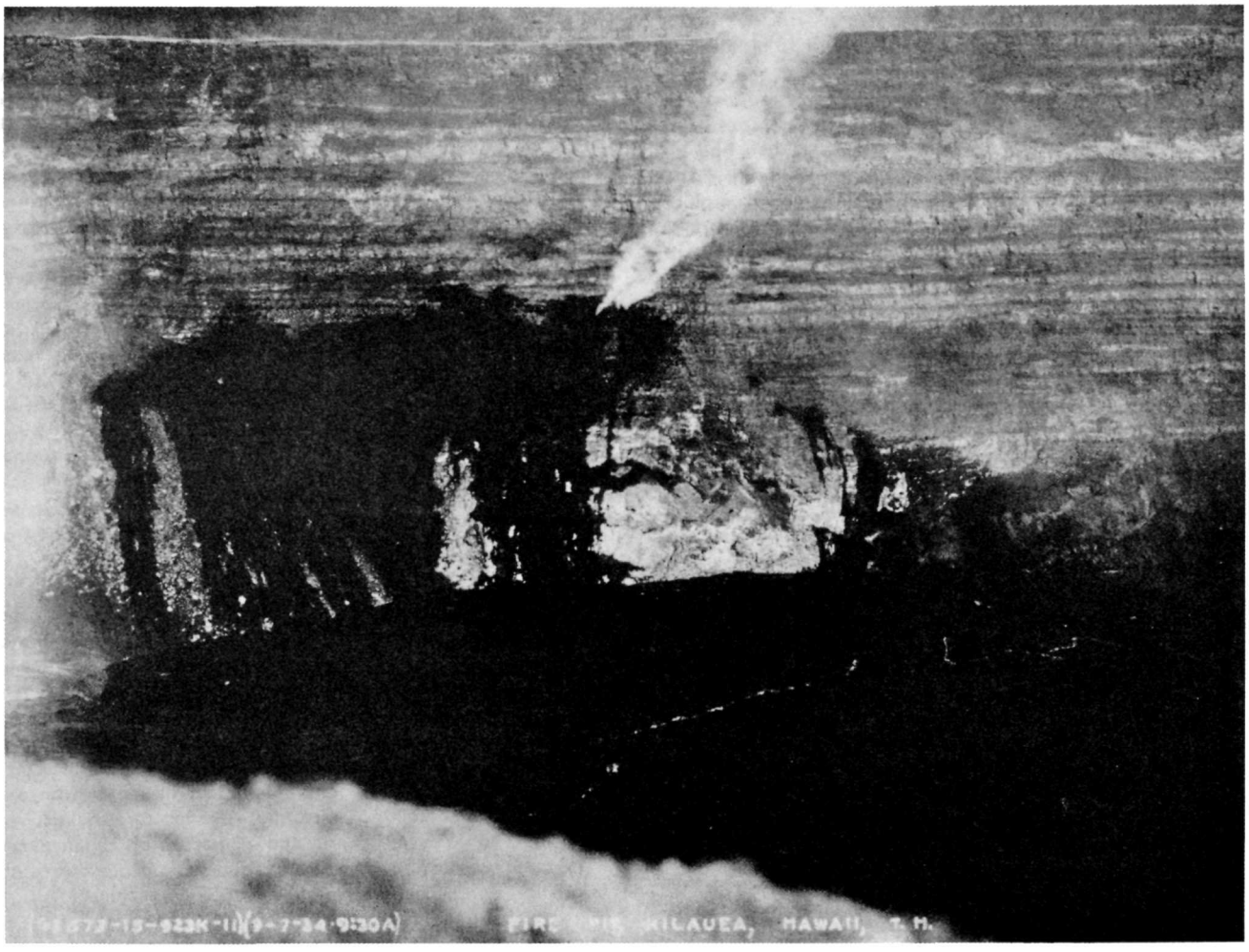


Figure 4. Halemaumau 9:30 a.m., September 7, 1934. Compare with Figures 2 and 3. Looking northwest. 11th Photo Section, A.C. Wheeler Field, T. H.

Phase Two: Small Lake Heap and Overflow

As early as September 7, temporary tremor increase rang the seismometric annunciator bell at the Observatory two miles

away. This meant that the larger fountain was making blast-like detonations, flinging up lava froth 300 feet, and emitting brown puffs. These detonations from the fountain wells increased as the vents clogged. September 15 there were five principal fountains, and a line of shoals across the lake. The reduced lake began to develop an interior topography, with a cone and crater around the large western fountain and nine other fountaining vents amid six islands and a peninsula.

By September 20 the floor measured 2700 by 2200 feet, and the lake oval was a detail within it at the north measuring 744 by 390 feet. The lake pool was on a heap 38 feet above the floor, and the highest grotto heap piled by the fountains stood 136 feet above the pre-eruption floor immediately under it. The average 1932 floor level was 2796 feet above sea-level, while the average 1934 new level was 2874 feet.

Overflows built up the new lake heap and 10 cracks developed in the outer floor radial to the lake, indicating that the lake heap was over a laccolithic swelling. Within the lake the streaming was from west fountains to east fountains, and sometimes the latter exhibited inward cascading downward. Evidently a convectional circulation was being established. Finally the sinkhole well tended to explode with detonations. Overflows were numerous from the lake so that it was being built up on a slag heap.

Phase Three: Lava Trickle up the Wall Crack

A new feature appeared September 20 around the extreme edges of the floor in the shape of a welling up of red lava, between the talus and the cake of 1934 fill, which constituted the floor. This was the first time any glowing lava had appeared from a source away from the fountaining wells. They began along the talus edges, but eventually extended to places where the floor made contact with the rock wall of the pit. In no case did they cascade over the slump scarp inward, but the lava rose as a dike between the floor cake and the containing funnel. The band of border extrusion was 20 feet wide in places, and it gradaully extended to all sides of the floor with the exception of the north edge that was closest to the lake. The marginal extrusion was always simultaneous with extra pressure at the lake, accompanied by overflow. It was evident that intrusive action was going on under the floor. Transit surveys in the course of the eruptive period showed that the outer floor rose, and the lake area gradually lost its relief.

Phase Four: Subsidence with Detonations

Detonation spells from both east and west wells, which had built cones within the lake, recurred from time to time during September 22. This usually happened when the east fountain had been transformed into a sinkhole grotto at the level of the lake, big bursts of gas and flame came up, and downpouring would last from 10 to 20 minutes. Then the pot would resume ordinary fountaining with outward flowing streams. During the detonation spells, tremor increased at the seismographs. By September 23 the west fountain had become a pool in a raised craterlet, from which a cascade poured into the lake. This craterlet also made noisy explosions, and four avalanches were noticed at the north wall of the pit close by.

About 2 p.m. September 23 the lake drained away through the eastern sinkhole leaving a saucer 20 feet deep, and then the liquid poured in again. These drainages increased in duration until October 1. Their violence also increased, they lasted from half an hour to two hours, and the intervals between them were notably about six hours. The detonations were finally heard three miles away.

It now appeared that the whole floor was swelling by intrusion, and a concentric ridge around the edge of the floor replaced the former slump scarp. Apparently the pulsations of lowering the lake basin were occasioned by inflow of the liquid under the shell of floor crust. The floor was lifted and the lake area went down. Gradually they were brought to a common level. The explosions were due to clogging of the gases in the increasingly viscous lava of the wells, and to the confinement of a small shaft. Failing to overflow the wells became gun-barrels. With each detonation an umbrella-shaped fling of stiff lava would shoot up, sometimes 400 feet, the roofs of the grottos would be blown to pieces, and fragments would clatter down all over the surrounding surfaces. Toward the end the explosive spells would be followed by complete quiet for a half hour. Then the liquid would quietly recover in the wells and restore the lake to a period of four or five hours of quiet streaming.

The detail of a sinking spell was as follows: At 9 a.m. the west fountain cone was cascading over its flank; at 11 a.m. the lake saucer was 25 feet deep, with shoals on its bottom, and both east and west wells were cannonading vertically, long squirts of viscous melt were sent up 200 feet or more, the intervals between detonations or hisses were from 5 to 10 seconds. The lava pooled in the wells and came back with quiet fountaining just after noon. The explosions gradually lessened, a fan-shaped flow on the lake bed from the west fountain encountered an expanding puddle from the east fountain in mid-lake, and the entire body of new liquid overrode the foundered crusts that formed the floor of the lake.

September 28 and 29, and again on October 1 occurred the last overflows of the lake margin. The extraordinary intrusion ridge at the edge of the floor at the foot of the east talus had become 25 feet high, crevassed along its crest, and the floor on the inner side of this ridge, which had been 15 feet below the slump scarp around the margins, was now 25 feet above it. The actual lift of the floor therefore, above its slumped position of three weeks before was of the order of 40 feet.

The lake area was gradually converted into several ponds. By October 3 three quarters of the lake basin had become a slag heap, with the northern pool a depression in its flank 300 feet long. There were evidently tunnels leading from the cone pots to the lakes. Several pots had developed and these became smoke holes. October 5 the lake area had collapsed, blowing noise was audible and some streaming was still visible. Thudding noise was heard in the western part of the swelling floor, and prolonged slides at the north wall of the pit showed that slumping of the lake area was in progress. The eruption ended October 8 and subsequent shrinkage caused numerous slides from the pit walls.

Level Changes

From time to time the Observatory runs levels from a bench mark on the gravel spit south of Kilauea crater as a base, so as to close a circuit around the rim of Halemaumau pit. After the eruption, October 17-25, A. E. Jones ran such a leveling circuit to discover changes since July 2, 1934. Treating "Spit" bench mark as stationary, results showed a stretch of the north rim of Halemaumau 1800 feet long to show positive elevation to a maximum of 1.28 feet; along 1000 feet of the rim on each side of the elevated tract, negative elevation to a maximum of 0.5 foot occurred northwest and northeast of Halemaumau. The remainder of the rim showed diminishing depression southward to a line of no change 400 feet SSE from the pit.

It should be observed that the north tilt cellar near the pit rim was much less disturbed by the eruption than the two other cellars southeast and west, as though the north were comparatively rigid ground. The rift belt of the mountain crosses the pit from southwest to northeast. The bench mark "Spit" lies within an old graben fault block on the side of downthrow relative to the north side of the rift belt. It seems likely that the evacuation of magma produced by the eruption undermined this fault block, that the northern country remained relatively stable, and that what is really represented by the level change

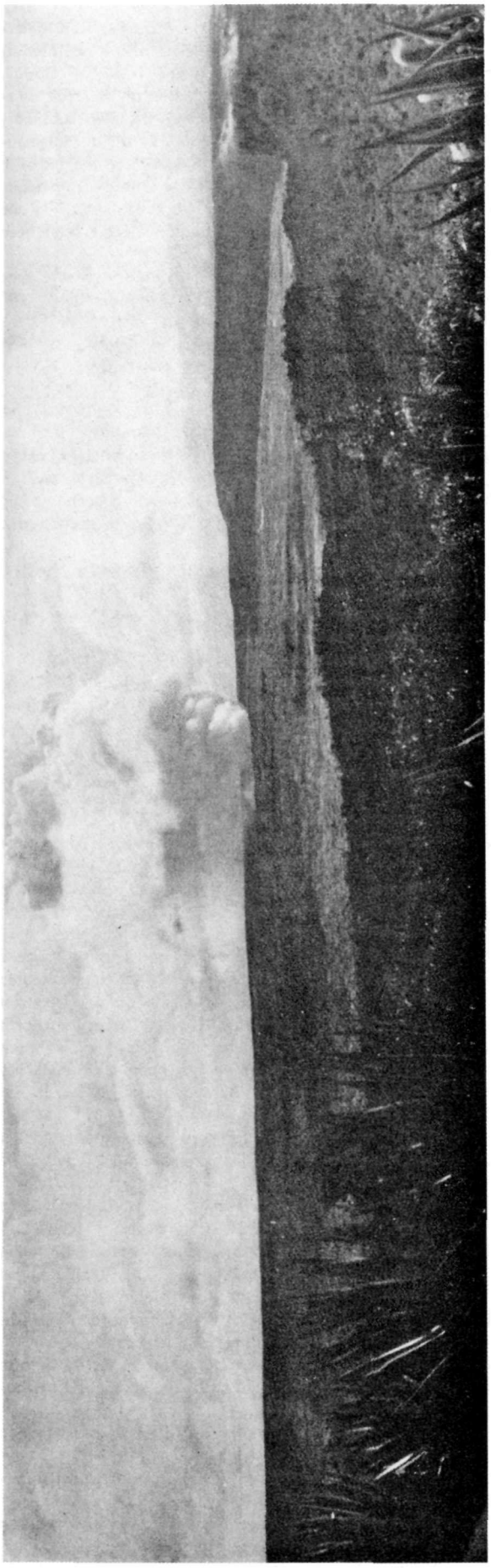


Figure 5. Halemaumau from Observatory September 6, 1934. Heavy fume column over lava fountains. Photo Jaggar.

is a lowering of the bench mark, rather than an elevation of the northern pit rim.

Hawaiian Volcano Observatory Report for November 1936

VOLCANOLOGY

The month of November at Halemaumau Pit of Kilauea Volcano continued the slides from the walls which have been so conspicuous of late.

The following is the abridged table of movements:

Week Ending	Seismicity	Number of Slides	Aggregate Crack Opening
November 8	15.50	20	518.5 mm.
November 15	19.75	14	20.0 mm.
November 22	11.75	14	5.5 mm.
November 29	7.50	16	0.5 mm.

Sequence of Events by Weeks

The first week slides and cracking of the NE rim continued with more debris added to the talus slopes, and much breaking of rim ground. Crack No. 34, a chasm close to the cliff edge, opened 501 mm.; this accounting for the excessive value above.

The second week kept up these processes, with a marked tendency to continuous dribbling of rocks down the E and NE walls about the noon hour.

The NE surveying station monument, the third week, was left unstable at the extreme edge of pit, undermined by slides.

The fourth week showed a change of habit, with much lower seismicity, much **closing** of cracks, so as to make the lowest record of weekly crack opening since September 20, 1935, and uplift instead of sinking for the levelling measurements of Kilauea floor at Halemaumau pit rim. The slides extended their operations to the north wall of the pit.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows, but these are only a part of what actually occurred:

November 2, 10:00 am., continuous sliding NE wall 12 to 1:30 p.m., dust from slides until 3:00 p.m., continuing slides N and NE.

November 3, 9:42 and 9:53 a.m., small slides.

November 5, 9:00, 9:40, 10:15 a.m., moderate slides. 9:55 a.m., small slide. 11:53 a.m., 12:55 p.m., slides. 2:20 p.m., 3:36 p.m., large slides NE station. 1:30, 5:00 p.m., continuous sliding. 3:18 p.m., earthquake rang No. 1 Annunciator Bell, dust cloud at pit NE. 3:46 p.m., No. 1 Bell again, dust continues. Below Crack No. 34, 200 feet, a dark spot in the wall was caving away.

November 6, 9:22, 9:30 a.m., moderate slides NE.

November 10, 9:02 a.m., a large slide had left a scar, and small rocks dribbled down the wall E, sending up light dust. 9:37 a.m., moderate slide NE, 100 feet below Crack No. 34. 9:51 a.m., large slide ENE.

November 11, 9:54 a.m., small slide sending up light dust E. The Volcano House trail near the pit ENE had now lost 100 feet of length by caving in, a new notch here indented the edge of the pit, and fresh cracks farther back had started to open.

November 12, 10 to 11 a.m., rocks falling continuously from E wall.

November 13, 8:50 a.m., rocks dribbling down wall. 11:55 a.m., 12:40 p.m., moderate slides send up dust.

November 14, 10:15 a.m., moderate slide E. 11:16 a.m., big noisy slide E.

November 15, 9:24 a.m., 9:55 a.m., moderate slides ENE with small slides in interim.

November 16, 9:45 a.m., moderate slide NE. 9:50 a.m., larger slide ENE, preceded for 15 minutes by dribbling stones. Slides during day undermining NNE wall and removing 100 feet of edge east of NE station.

November 17, 9:56 a.m., rocks dribbling at new scar NNE.

November 19, 10:12 a.m., rocks dribbling NNE.

November 21, 9:25 a.m., dust NE wall. 9:46 a.m., continuous small sliding ENE. 9:54 a.m., 10:17 a.m., moderate slides NE and ENE.

November 24, 9:00 a.m., NE dust cloud. 9:45, 9:47 a.m., small slides ENE. 9:50 a.m., large dust cloud. 10:15 a.m., moderate slide ENE and dust cloud under NE station. 10:22 a.m., large slide there leaving scar. 10:30 a.m., 10:45 a.m., large dust clouds N. 11:15 a.m., large dust cloud ENE. 2:50 p.m., dust cloud NE station. 4:00 p.m., moderate slide 400 feet west of NE station. 4:10 p.m., large slide same place. 3:00 to 4:00 p.m., continuous falling of rocks there, which ceased after the large slide.

November 25, 10:55 a.m., noise of moderate slide heard, followed by continuous dribble on wall 300 feet W of NE station.

November 27, 11:15 a.m., dust from slide NE.

Halemaumau Solfataras

Fume of bluish color continued to rise at the edge of floor of pit NW and SE. On November 13 it appeared dense at 8:50 a.m., and thinner at 9:40 a.m. It was reported "not conspicuous" the third week.

On November 19 a fresh slide was reported to have left a scar in the SE corner of Hiiaka Crater in the Chain of Craters east of Kilauea.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 27 marked rim-crack localities, reduced to 26 the third week, resulted as follows. Some time before November 21 possibly during the earthquake of November 16, sliding carried away the southern ledge of Crack No. 34.

Week ending forenoon of:

November 7, 11 opened, 1 closed, aggregate opening 518.5 mm.

November 14, 9 opened, 2 closed, aggregate opening 20.0 mm.

November 21, 9 opened, 1 closed, aggregate opening 5.5 mm.

November 28, 6 opened, 8 closed, aggregate opening 0.5 mm.

Crack No. 34 on November 7 was found yawning excessively and collapsed in the middle of the month. It is a chasm over the NE extension of the Kau Desert rift which crosses Halemaumau. Omitting it the general opening November 7 was 17.5 mm.; No. 17 opened 2.5, No. 25 8.0, and No. 45 2.0 mm. No. 17 is SSE, the others E (See map of pit, rim figures).

On November 14, the opening of cracks was in gradations to a maximum of 9.0 mm. at No. 28, where the edge had broken back the most. No. 34 NE opened only 2.0 mm., in contrast to November 17, when it opened 510 mm.

November 21, the destruction of No. 34 over the deep rift made the sixth marked crack on the rim destroyed within a month. The rift belt crosses the pit (see map) from SW Pit Station to NE Pit Station.

SEISMOLOGICAL DATA

EARTHQUAKES

Table

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Local* Seismicity
Nov. 8	22	15	1	0	2	15.50
Nov. 15	65	7	0	0	2	19.75
Nov. 22	21	8	0	1	0	11.75
Nov. 29	12	9	0	0	1	7.50

† Includes teleseisms or those shocks over 5000 kilometers distant.

* For local seismicity definition, see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, determinations of depth of focus have been made.

November 3, 5:28 pm, very feeble, located in fissure zone 0.5 mile NE of Ahua Kamokukolau and 2.4 miles deep. 19° 23' 1N; 155° 17' 2W.

November 5, 3:18 pm, very feeble, in Kilauea SW Rift Zone near the Kamakaia Hills and 16.0 miles deep. 19° 19' 5N; 155° 21' 0W.

November 5, 11:26 pm, very feeble, probable location, Mauna Loa NE rift about 18 miles SW of Hilo.

November 7, 1:43 pm, very feeble, 1.8 miles deep and 0.6 mile N of Kalanaokuaiki Pali. 19° 21' 7N; 155° 15' 3W.

November 7, 2:19 pm, very feeble, 3.3 miles deep, 2.0 miles S of Halemaumau and 1.4 miles W of Ahua Kamokukolau. 19° 22' 8N; 155° 17' 4W.

November 7, 3:47 pm, feeble, located 4.8 miles deep and 0.6 mile E of Keanakakoi Crater. 19° 24' 3N; 155° 15' 4W.

November 12, 4:25 am, very feeble, located near center of Kilauea and of shallow depth.

November 16, 1:44 am, very feeble, located 1.0 mile NW of Kilauea Military Camp and 4.0 miles deep. 19° 27' 1N; 155° 17' 0W.

November 16, 4:42 am, very feeble, located 4.2 miles deep in vicinity of Kilauea Military Camp. 19° 26' 3N; 155° 16' 2W.

November 16, 8:33 am, very feeble, 1.0 mile deep under NE edge of Kilauea Crater. 19° 26' 0N; 155° 16' 2W.

November 16, 8:36 am, very feeble, 0.9 mile deep under western portion of Kilauea Iki. 19° 25' 1N; 155° 15' 2W.

November 16, 10:14 am, very feeble, 5.0 miles deep in Kilauea Crater adjacent E edge of Halemaumau. 19° 24' 7N; 155° 16' 9W.

November 16, at 1:08 pm a slight to moderate earthquake registered on all the Observatory seismographs. It was located immediately to the SE of Kilauea Iki Crater, 1.4 miles E of Byron Ledge E rim of Kilauea Crater. Reports indicated that it was felt slightly by many people in Hilo. The shock was felt by a few in the Kilauea Area and very strongly in the vicinity of Puu Koae on the Kau Desert SW of Kilauea Crater. 19° 24' 8N; 155° 14' 4W.

November 16, 5:11 pm, very feeble, 4.8 miles deep near juncture of Pali Lele o Kalihipao and Kalanaokuaiki Pali. 19° 21' 1N; 155° 16' 0W.

November 16, 5:52 pm, very feeble, 0.4 mile N of N edge of Kilauea Iki, 3.5 miles deep. 19° 25' 5N; 155° 14' 9W.

November 16, 7:36 pm, very feeble, located 3.4 miles deep under E portion of Kilauea Iki. 19° 24' 9N; 155° 14' 7W.

November 18, 1:51 pm, very feeble, located 9.0 miles deep and 5.0 miles E of Mauna Loa Summit Crater.

November 23, 5:48 am, very feeble, probably located in the vicinity of Ahua Kamokukolau, 2.0 miles SE of Halemaumau.

November 25, 1:02 pm, very feeble, probable location under center portion of Kilauea Crater.

November 27, 9:39 am, very feeble, probably located under SE rim of Kilauea Crater.

November 28, 10:06 am, very feeble, probably located in fissure zone 1.3 miles SE of Ahua Kamokukolau.

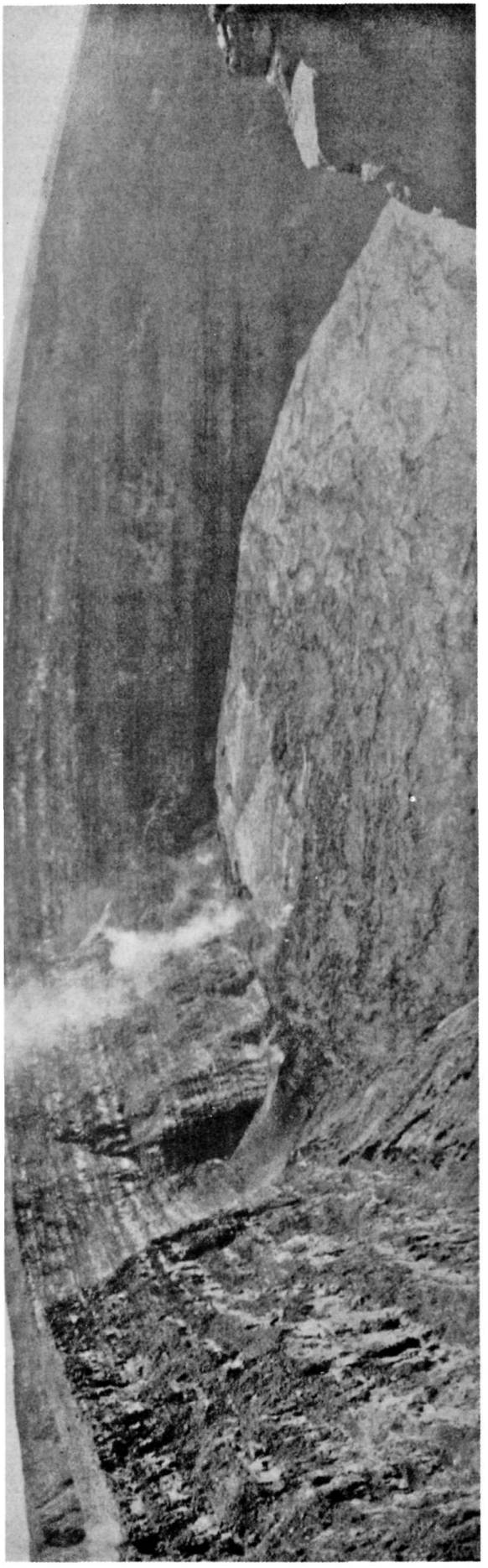


Figure 6. Halemaumau looking NE September 13, 1934, when the inner lake had formed at the top of a heap. Photo Jaggar.

The following very feeble earthquakes occurred simultaneously with, and are probably associated with rock slides from the E, NE or N walls of Halemaumau. November 5, at 2:03, 2:20, 2:28, 3:36, 4:40, 4:41 and 4:49 pm.

November 14, at 11:13 and 11:17 am.

November 24, at 2:13 and 4:08 pm.

Periods of continuous (harmonic) tremor registered during the month as follows: beginning at 5:41 am November 5, six (6) minutes; 6:54 pm, November 13, twenty-eight (28) minutes.

Microseismic motion of the ground at Kilauea was light November 4, 13 and 28; strong November 8, 9, 14 to 21 inclusive and 24; the remainder of the month it was moderate.

Teleseisms or Distant Earthquakes began registering on the Observatory seismograph as follows: November 2, the preliminary (P) waves at 4h 36m 39s H.S.T., thought to be located near Guam, 3485 miles from Kilauea. November 2, (P) waves at 10h 25m 48s H.S.T., 3850 miles from Kilauea, reported location off the coast of Honshu west edge of Japan Trough 38° N; 142° E (U.S.C.G.S.). November 12, (P) waves at 9h 43m 51s H.S.T., 3905 miles from Kilauea. November 13, (P) waves at 2h 10m 11s H.S.T., 3305 miles from Kilauea, reported location near Kamchatka Peninsula N of Japan Trough 57° N; 164° E (U.S.C.G.S.). November 25, (P) waves at 10h 10m 50s H.S.T., 2200 miles distant from the Volcano Observatory. November 28, Secondary waves (transverse) at 8h 21m 45s probably associated with news reports of disturbances in Alaska.

H. H. W.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 29, was 4" 85N and 3" 66W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
November 8	1"90 N 30°E	1".82 S 35°W
November 15	1".18 S 70°W	2".59 N 38°W
November 22	0".50 N 12°W	5".78 N 88°W
November 29	0".33 S 61°W	5".22 S 52°W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
November 8	4".92 N 17°W	3".'50 toward
November 15	1".20 S 69°E	1".86 from
November 22	6".67 N 16°W	0".35 toward
November 29	5".12 N 19°W	3".39 toward

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory November 23, showed closing across the Crater and slight opening across Halemaumau as compared with similar measurements October 20. From Kilauea SE rim to Uwekahuna there was closing 2".75, October 20 to November 2; closing of 0".66, November 2 to 13 and opening of 1".00, November 13 to 23. Total Closing 2".42. From the Pit Seismograph to the NW Pit B.M. there was opening 0".25, October 25 to November 2; closing of 0".58, November 2 to November 13 and opening of 0".67, November 13 to November 23. Total opening 0".34.

Spirit Levelling

Spirit levelling across Halemaumau from the Spit, SE edge of Kilauea Crater to the NW Pit B.M. showed elevation of the NW Pit B.M. with reference to the Spit of 6.4 centimeters. This is the first indication of elevation since before the 1934 eruption of Kilauea. H. H. W.

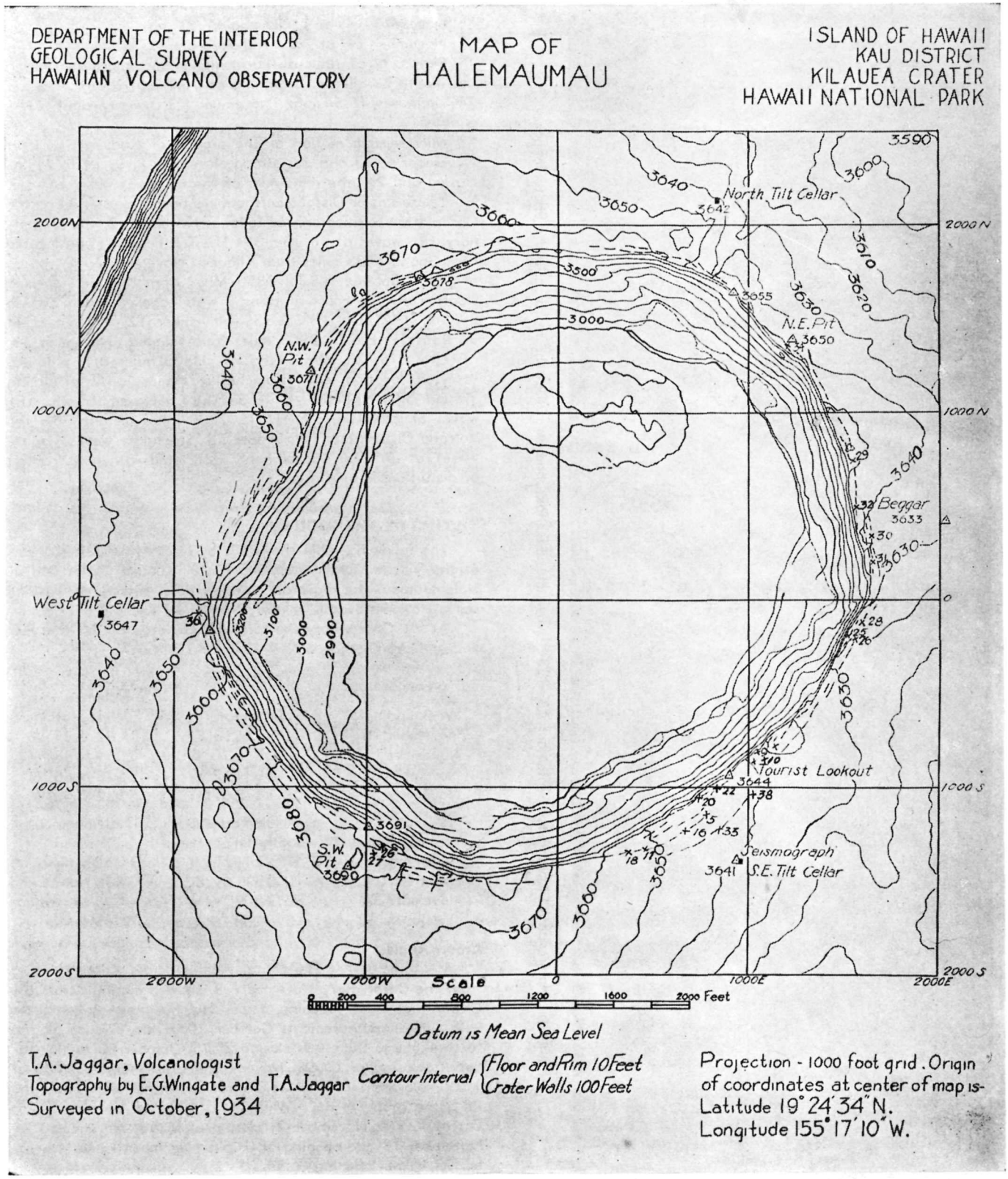
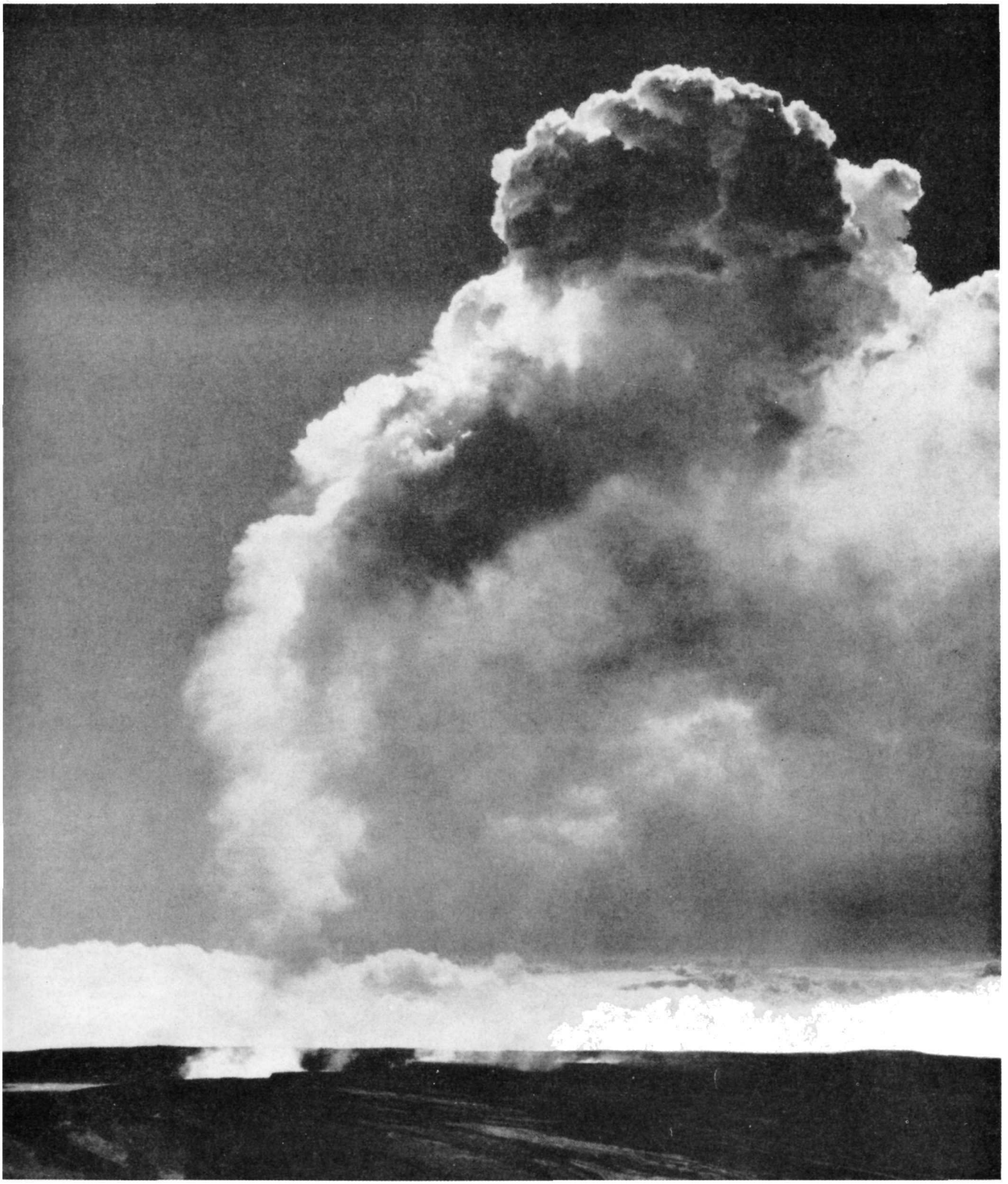


Figure 7. Map of Halemaumau October, 1934. Compare Volcano Letter No. 395 for map before 1934 eruption.



A remarkable photograph taken from an airplane above Makuaweoweo Crater, Mauna Loa, at an elevation of 14,500 feet. Thin fume rising from lava fountains playing within the crater, merges into dense white cumulus of atmospheric moisture above. By permission Fleet Air Base, Pearl Harbor, T. H.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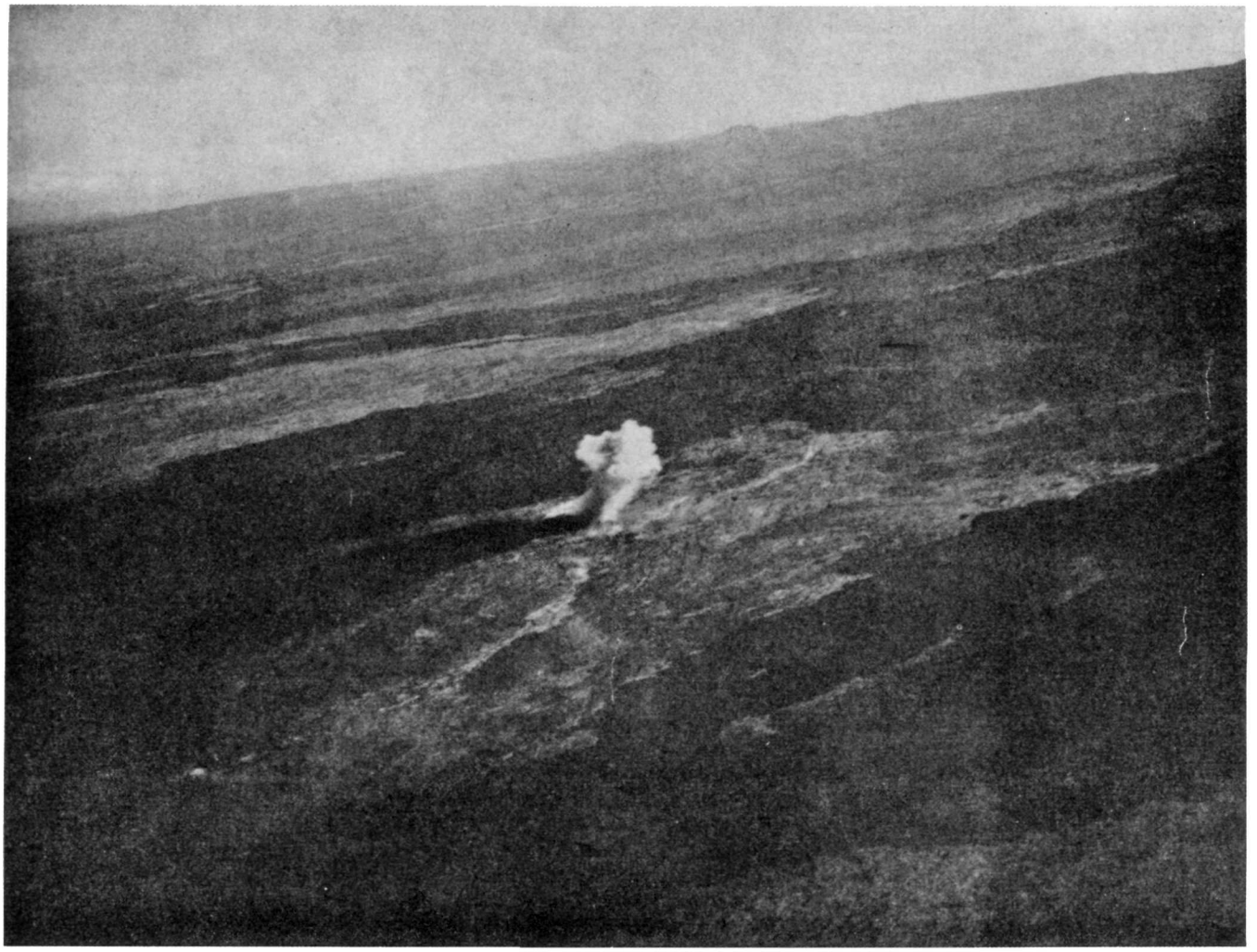
THE VOLCANO LETTER 442

No. 442 monthly Department of the Interior National Park Service December 1936

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



The mountainside and a channel hit. Photo, 11th Photo Section, U.S.A.

THE BOMBING OF MAUNA LOA, 1935*

T. A. Jaggar

Summit crater lava eruptions of Mauna Loa are always followed eventually by a breaking open of the mountain flank and emission of lava there. Mauna Loa crater filled with 100 feet of fresh lava December 2-18, 1933, and on March 26, 1934, the following statements were published: (1) A lava flow is expected within two years; (2) It should come at the north; (3) A likely direction is toward Hilo; (4) Several earthquakes, or one severe earthquake, may happen at Hilo.

Eight earthquakes came, one about every three months, close to equinox and solstice, some of them alarming shocks in Hilo. They occurred throughout the two years, and this relieved the city from any single cataclysm.

The lava flows came on the north side of the mountain, November 21, 1935. The near-summit gushing of fume, from the new rift which ejected the lava, continued into March. The

* Reprinted from the July-August 1936 issue of The Military Engineer, The Mills Building, Washington, D. C.

prolonged flow, which developed a vitreous cover, moved crookedly north, then, on December 22, bent east toward Hilo after pooling in the saddle between Mauna Loa and Mauna Kea. It was about 15 miles long including its meanders, and had 20 miles more to go to reach Hilo.

Expectancy and Policy for Emergencies

Apart from earthquake probability, above noted, the Hawaiian Volcano Observatory has experimented with preparation for emergencies for many years. The work is based on statistics and has been useful in many eruptions. Hilo is organized through its police and Red Cross systems, and these have the collaboration of the National Guard and the American Legion. A Conference of the Associated Engineers of Hawaii on January 16, 1918, was advised of the exact facts concerning Hawaiian volcanic blasts and lava flows, earthquakes and tidal waves. A Conference of the Chamber of Commerce, June 9, 1931, was advised of the Napier, New Zealand, unpreparedness. Organizations for discipline, communication, rescue, relief, funds, refugees, and rebuilding were considered.

Hilo understands that it is committed to future lava flows. The Volcanologist in the 1931 address stated: "A vitreous lava, flowing under crust in tunnels, but doing damage on lower mountain slopes, could be blown up at the source tunnel about the 9,000-foot level. This would open the tunnel, dam the lava stream with rocks, and force it to flow anew out of the blocked tunnel and channel over the surface of the upper country by a changed course. If the previous flow took 5 months to get near Hilo, the renewed flow 30 miles up the mountain would require as much, and the city would be given 5 months' respite."

The Crisis of December 22, 1935

The map shows the relation of the 1935 flow areas to earlier flows of definite years. The expectancy of a north flow was based on the succession of south flank outflows from 1868 to 1926, moving progressively up the mountain along the southwestern rift belt. The belt crosses the summit. Each flow on cooling seals the rift at its orifices. The next flow after 1933 was expected across the summit, and it so happened.

The expectation that 1935 would be the year was based on average intervals and past history. The expectation of northern earthquakes was based on a southward crossing of the summit in 1868 and southern earthquakes therewith. If there were a northward crossing of the summit now, northern earthquakes might be expected to accompany the rupture of the north rift. The likelihood of advance towards Hilo was based on the precedents of 1852, 1855, and 1881.

Without recounting all the detail of the 1935 eruption, it may be said that the first rapid flows, between November 21 and November 26, from a near-summit source, swept 8 miles northward and stopped. The loss of gas, heat, and energy of emission was very rapid the first day. The clinker slag cools from below upward, releases fixed gases that react exothermally to heat the top surface, and the stirring crystallizes the melt so that solidification is by crystalline frosting or sprouting. The Hawaiian name of this clinker lava is **aa** (pronounced ah-ah). The sprouts break up into boulders during viscous flow.

Beginning November 27, an entirely new flow vent appeared. This was 4,000 feet below the summit and 10 miles northeast from the top of Mauna Loa. An ancient tunnel or fissure was opened underground to drain the central well. From this orifice a new clinker-lava stream poured north toward Mauna Kea, between the 1899 and 1843 flows. The near-summit vent of the first outbreak clogged itself, and became noisy with gas bursts and viscous blobs. Then its lava subsided into the shaft, clouds of yellow smoke puffed up, and sulphur was deposited on the conelet. This upper vent was at about 12,000 feet elevation. The new lower vent was at 9,000 feet.

It was this lower flow that turned towards Hilo on December 22. Before that date there was doubt. The lava pooled in the saddle. It might have drained westward into waste lands, but the 1843 flow blocked it and it turned eastward a mile a day into valuable pastures, steeply sloping into the well-watered drainage of Wailuku River. This is part of the Hilo water supply. By December 26 it had flowed 5 miles of the 20 that would put it into Hilo.

During the month the lava had changed its character from clinker lava to vitreous, or glassy-skinned, lava. This the Hawaiians call **pahoehoe** (pah-hoy-hoy). It is exactly the same chemically as clinker lava, but is totally different physically. With less of stirred "sugaring," the glass may rise to the top of basaltic melt. It forms a gas-tight skin. The gas-making slag then pours onward under a heat-insulating crust of thickening membranes. This is the "ropy lava" of geology. It is silvery, smooth and vesicular, and unlike the clinker type, it cools and solidifies from the surface downward. The skins, ever reforming over bulbous toes which push down the hill, confine the heat and create a mechanism of tunnels. There is a single tunnel near the source, and there are distributary tunnels at the fronts. It is this vitreous-coated lava which may hold its heat and push forward for 40 miles. It is in sensitive equilibrium isothermally to its own evolution of self-heating gas bubbles, to the chill of the air, to the pressure on its pipe walls, and to the source pressure, which is both hydrostatic and effervescent—that is, the lava from inside the mountain is really a glassy foam.

The point of all this is that if the single source tunnel is broken open, a pressure-temperature adjustment of gas-in-slag is destroyed. Not only does this let the higher fluid escape and rob the lower distributary frontal tunnels, but also it lets loose the gas and heat, and solidifies the fluid **back into the source vent.** A lava filled shaft, after a month of violent release, is no longer a resistless mountain-breaker. The weight of the mountain and the cooling have reasserted themselves as dominant.

The Army Called In

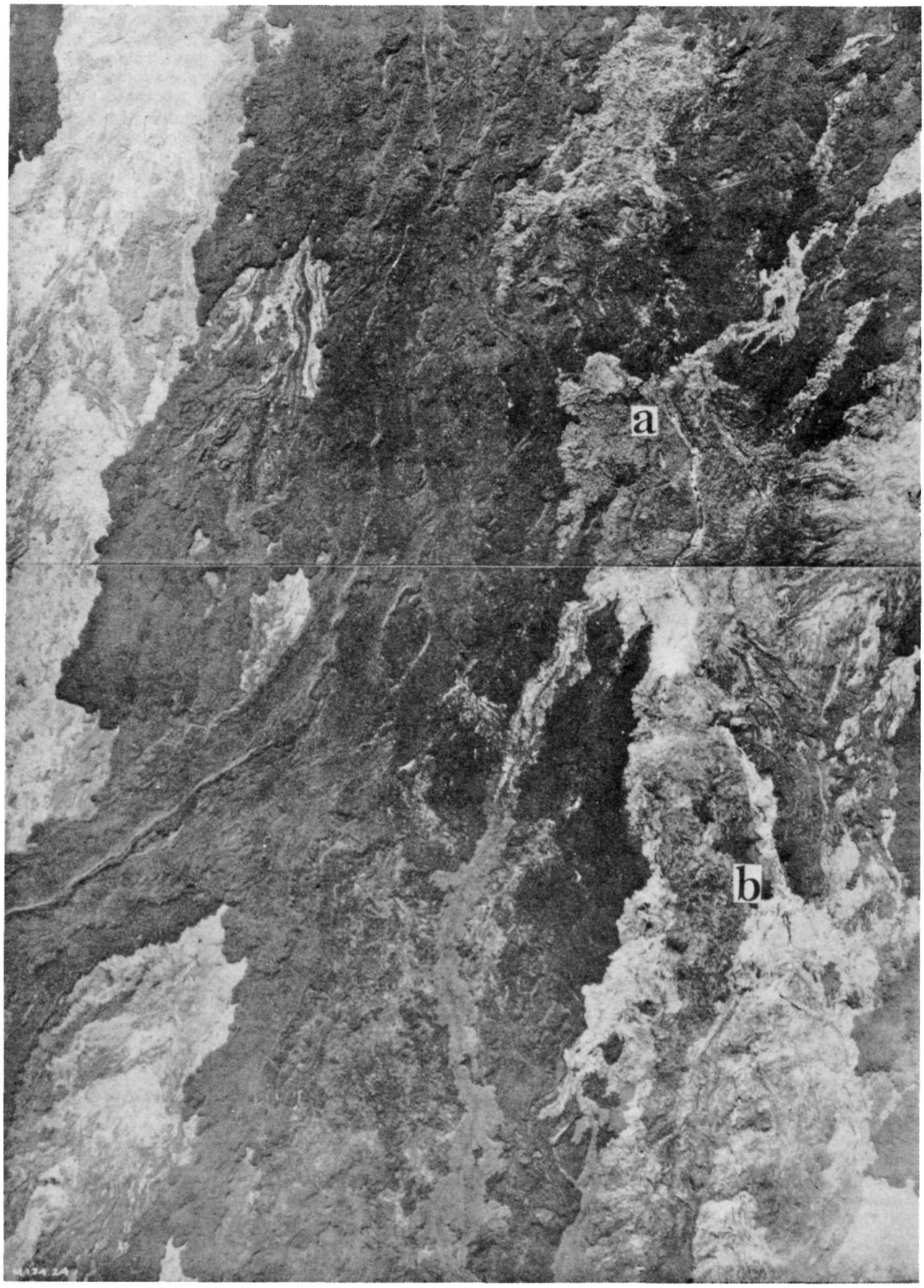
Monday morning, December 23, the Volcanologist, Dr. T. A. Jaggar, consulted Maj. Hugh C. Gilchrist, commanding Kilauea Military Camp. Before that time bombing would have been dangerous, for it might have diverted the flow **toward** Hilo, but now the flow was definitely headed thither. Major Gilchrist sent a radio at once to the Chief of Staff, Col. Daniel Van Voorhis. The Commanding General, Hawaiian Department, sent a plane from Honolulu with three officers of the bombing squadron that afternoon to inspect the lava flow area. At noon the next day a conference was held in Hilo with Col. Delos C. Emmons, Department Air Officer; Lieut. Col. V. L. Peterson, Department Engineer; Capt. J. J. Ladd, bombing officer; Lieut. J. W. Cox, Third Engineers; Lieut. B. J. Webster; Major Gilchrist; Mr. Stanley Elmore, President of Hilo Chamber of Commerce; Superintendent E. G. Wingate of Hawaii National Park; and the Volcanologist.

Col. Delos C. Emmons, Air Officer of the Hawaiian Department, reported that he and Lieut. Col. Virgil L. Peterson, Corps of Engineers, examined the lava flow from the air December 24 and held the conference above recorded with the Volcanologist, and with other officials. They jointly reported:

a. That lava flow actually threatened the headwaters of Wailuku River, which provides water to Hilo. There also seemed to be a possibility that this flow might endanger the city of Hilo with its valuable harbor.

b. That public opinion demanded that something be done to divert or stop this lava flow.

c. We recommend that twenty 600-pound bombs be dropped in an effort to divert the lava flow.



Vertical airplane photo of Target a, the uppermost channel, and Target b, a mile downstream.
Photo, 11th Photo Section, U.S.A.

Dr. Jaggar stated that there was a strong probability that properly directed bombs would help the situation materially; that there was always the possibility in the future of a more serious eruption which might destroy Hilo unless preventive steps were taken, and that it should be found out now whether or not aerial bombs would stop or divert a lava flow. The Secretary of War, during a recent visit, had expressed great interest in the aerial bombing of a lava flow, and Dr. Jaggar had been assured that, if an emergency arose, the Department Commander would assist in protecting life and property threatened by lava.



Aa and pahoehoe lavas of 1935. Jaggar photo.

The Conduct of Operations

It was decided, after the Volcanologist had outlined the problem, to conduct the operation December 27. The Army Transport **Royal T. Frank** brought twenty 600-pound TNT bombs; and as many 300-pound pointer bombs were brought by the planes and were charged in Hilo with black powder and sand.

On December 26, the Volcanologist accompanied a group of Bombing Squadron officers over the target in a Douglas amphibian plane in order to point out the area to be bombed. They, in turn, took up other officers later in the day, so that all should be acquainted with the terrain. The Volcanologist recommended that the uppermost channel of the actual flow be bombarded at elevation approximately 8,500 feet on the north flank of Mauna Loa. The channel about a mile down the lava stream was indicated as a second target. This was to be demolished in the event that the upper target had been successfully hit, so that if any liquid still trickled through the tunnel, it would encounter a second obstacle. Both parts of the channel were crusted over, but glimpses of the liquid lava appeared in open parts of the tube where the crust had caved in. By demolishing the tunnel roof, the operation would block the tube with debris, force the liquid within to overflow, cool it and release gas, and thereby rob the tube system farther down the mountain where the front of the flow was being fed with lava through this tunnel.

Special Orders Number 304, December 26, 1935, sent twenty officers and thirty-seven men, including sixteen sergeants and corporals, by air from Luke Field, Honolulu, to the island of Hawaii, in command of Lieut. Col. Asa N. Duncan, Air Corps. They represented the 23d and 72d Bombardment Squadrons, a Signal Corps operator of Headquarters Detachment, four men from Wheeler Field, including photographers of the 11th Photo Section, and one each from the 4th and 50th Observation Squadrons.

The departure for Hilo from Honolulu was at 8:30 a.m., December 26, in ten bombing planes, two observation planes, and two amphibians. Upon arrival at Hilo, work was begun immediately in locating the targets with the aid of the Volcanologist. The Ordnance Department sent two civilian employees to supervise fusing and loading of bombs.

Colonel Duncan's report shows that, in the operation of December 27, the first bombing plane took off at 8:45 a.m. from Hilo and was followed by four others at twenty-minute intervals. Each plane was loaded with two 600-pound demolition bombs, armed with 0.1 second delayed-action fuse, and two 300-pound practice bombs for sighting shots. The bombs were dropped from an altitude of 12,000 feet, approximately 3,500 feet above the target. Two photographic airplanes accompanied the bombers and carried cameras for still and moving pictures. The first mission showed that individual bombing produced good results, so that the salvo method, using five planes in formation, was not used.

Observation of the Bombing

Colonel Duncan and staff at Hilo Airport maintained short-wave radio communication with the airplanes; and telephone communication with Dr. Jaggar, the Volcanologist, who had established a station at Puu Oo ranch high up on Mauna Kea mountainside, to observe the bombing. Twenty demolition bombs were dropped between 9:30 a.m. and 3:00 p.m.

From the high post of the Volcanologist at Puu Oo ranch house, elevation 6,300 feet, the front of the flow was seen to be pushing through the valley 4 miles away in the foreground; Hilo airport was discernible with field glasses 23 miles away to the east; and the lava source targets were in full view up the mountain southwest, 12 miles in a bee line. The planes were moaning overhead all day long, and the bombers climbed high, poised, pitched forward, and a gray ball of smoke and dust boiled up from the upper lava channel.

The hits were noted at 9:43 a.m., there was a flash, 60 seconds interval, then a deep boom; at 9:49, a flash and a weak smoke column; at 10:15, a high column and noise after one minute; at 10:18, a soft column and the detonation; at 10:28, a high puff, interval, and booming; at 10:32, the same; and, at 10:59, a double puff, as though two bombs hit together. All the early shots were at the extreme upper tip of the gleaming silvery lava field, narrowing to a point at the source.

After 11 a.m. the lower target, the lava channel a mile below the source, was evidently the goal. One bomb exploded



The great bend of the flow towards Hilo, pahoehoe lava: a tunnel lies underneath. Jaggar photo.

with very deep penetration and heavy concussion in the depths of the incandescent stream, and great sheets of glowing melt shot hundreds of feet into the air, orange red, glistening, and spreading like a fan. When this was seen the Volcanologist knew that the single channel of the upper tunnel could not stand such punishment without damming itself, freezing, and spilling over. That tunnel lay at the bottom of a trench 10 feet wide and 40 feet deep in places; and a 600-pound bomb

crater might be blasted 20 feet wide and 5 feet deep in hard rock; hitting a trench of the size noted, it could hardly fail to wreck it. Hitting it in five places directly along the upper mile of its course (the 25 per cent of direct hits reported by Colonel Duncan) might be counted on to block the channels and leave the lower tube system to empty itself and collapse.

Other bombings were observed until 2:37 p.m. and notes were made of the soft black powder explosions, in contrast to the heavy puffs and thunder claps of the demolition shells.

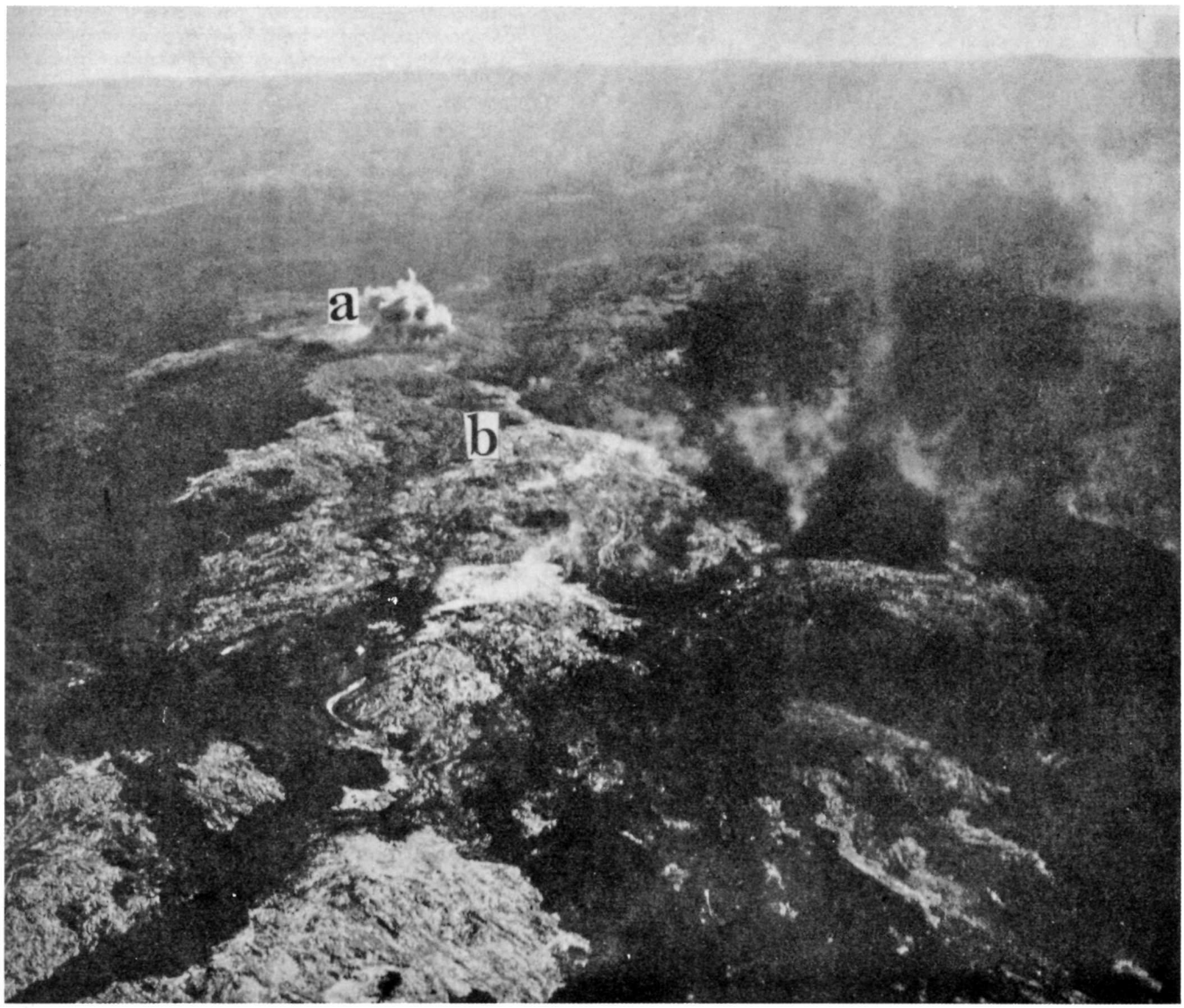
The Stoppage of the Flow

The evening of December 28 all motion at the front stopped temporarily. This was a totally new phenomenon, for the preceding week had shown the front making a mile a day; and the front lay on an increasingly steep slope, averaging 157 feet to the mile for the 7 miles of eastward flow from the lake of lava in the saddle.

The bombing thus smashed and dammed the source tunnel, released lava there, and beginning at the noon hour of the bombing date, the speed of frontal motion was:

12:00	noon	December 27	800 feet per hour
4:00	p.m.	December 27	150 feet per hour
10:30	a.m.	December 28	44 feet per hour
6:00	p.m.	December 28	0 feet per hour

The release of liquid lava at the source tunnel was confirmed as follows: December 26 the Volcanologist flew over and could see no liquid on the surface. During the bombing, December 27, the pilots could see liquid in short stretches of collapsed tunnel roof. Next day air inspection showed a rapid glowing stream at the source itself, on the surface of the lava

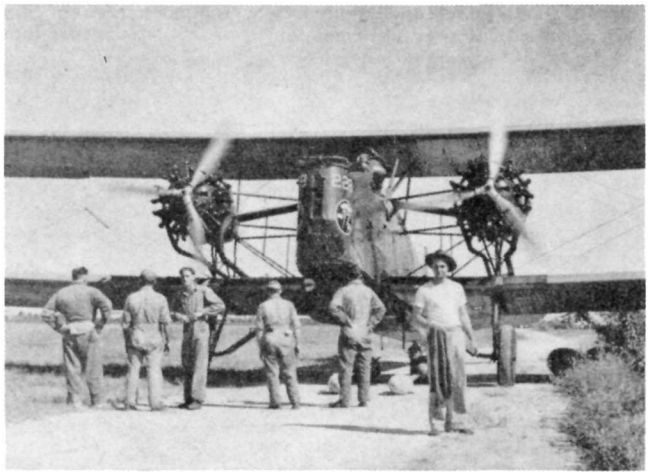


The lava heaps of the flow source; a direct hit near upper source channel target a: and a collapsed tunnel near foreground showing a glowing stream inside. Photo, 11th Photo Section, U.S.A.

Meanwhile the front of the flow pushed ahead, passing successive tree markers which had been photographed. All day photographs were taken to show the changing progress. At 11:15 a.m. the front of the flow piled itself 30 feet high, entered woods, and sent up clouds of black dust and flames, while explosions of carbon gas made noisy detonations in old caverns. That night, December 27, the flow was more brilliant than ever, for oxygen had been admitted to the tunnel system by its collapse. Up at the bombed area, ten or twelve glow spots were visible where liquid lava was welling up bomb holes. A side branch of smooth lava made out from the main flow below the saddle.

field. On December 31 all motion on the surface had ceased at the source.

This last fact was an unexpected development and was not the end of the eruption. But it was the end of the outflow. The inside eruption was manifest by clouds of sulphurous vapor from internal lava effervescing in the near-summit crater, showing that the well beneath was still charged with liquid;



A bombing plane with the bombs beneath. Maehara photo.

and this continued until March, 1936. An earthquake crisis in that month definitely ended the eruptive period.

That the bombing would end the source outflow was theoretically probable. The direct hits were sufficient in number to blast open the roofed channel and release to the air the vitreous froth called basaltic lava. The equilibrium of self-heating was destroyed and the slag, after spilling over for two days, stiffened, slowed down, and solidified into the source vent. Pilots who flew over on the second and third days after the shelling reported that the released liquid stream at the source had stopped.

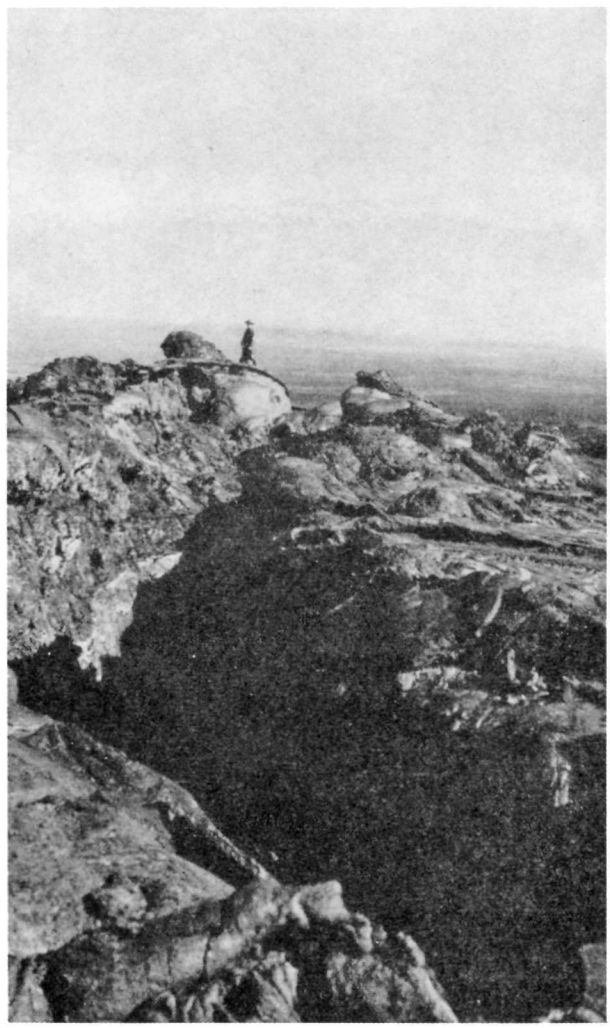
The remainder of the activity of frontal flowing towards Hilo was a spilling of remnant lava from the tunnels and streamways. This was partly over the sides of the lava fields, partly lengthening of the front. There was a notable sudden gushing out of clinker lava at the front on December 30 for 1,000 feet. The final tongues became narrower, and one of these slightly passed the Forest Reserve fence east of Puu Oo ranch January 1 at 11 a.m. The last motion of the tip of this finger, only 100 yards wide, was at 2 a.m., January 2. The position of this final front was in the drainage basin, 8 miles east of the saddle, and 12 miles short of the Kaumana Road in Hilo. The total movement forward after the bombing was 1 mile in 6 days. If the flow rate of the Christmas season had continued, the front would have been in Hilo on January 9.

The following is quoted from a report of the operation: "After the bombing was completed, a reconnaissance was made of the shelled area. It was found that five bombs hit the stream itself, three in the flowing lava of the first target (source stream), and two directly above the tube of molten lava of the second target (one mile downhill). One of these caved in the tunnel and the other failed to penetrate. Three other craters were within 5 feet of the stream, the explosion throwing debris into the red lava. Two others were within 20 feet of the target. From the sensing of the pilots, seven other bombs fell within 50 feet of the stream. Those who witnessed the bombing declare that the execution of the mission was superb; that the bombs had been placed exactly where they should have been; and that this aerial bombing of a lava flow made history for science in performing a great geological experiment which was a success. From a military viewpoint of the bombing, Colonel Emmons says: 'Very valuable tactical training was received as a result of this mission, well worth the cost. Excellent co-operation was received from the Quartermaster Depot, the Ordnance Depot, and the commanding officer, Kilauea Military Camp'."

Hilo Chamber of Commerce furnishes the following minimum approximation of values, apart from life, good-will and natural assets like the harbor:

Sewers	$ 1,200,000
Streets	2,125,000
Schools and churches	2,883,804
Water supply	1,000,000
Piers, breakwater, dredging	7,500,000
Taxable land	10,387,824
Taxable improvements	12,408,300
Territorial property	2,224,395
Federal property	350,000
Personal property, growing crops, etc.	11,000,000
	$51,079,323

Supposing that the flying, transportation, ammunition, and payroll cost $25,000, the operation of December 27 appears to have been more than justified. An experiment pouring



Detail of collapsed tunnel near Target B, Mauna Kea in distance. Jaggar photo.

liquid clay on a scale model of Hawaii showed that this flow would have extended itself down Wailuku Canyon so as completely to fill Hilo breakwater and wipe out the second harbor of the Territory. Just such a flow in 1859 extended the land at Kiholo. As there will be more flows on the Hilo side, the bombing experiment has furnished a new weapon to civilization.

The Volcano Observatory at Kilauea was founded in 1911 by the Whitney Fund of the Massachusetts Institute of Technology with the words: "To be conducted with a view to protection of human life and property." That responsibility was accepted by the Hawaiian Volcano Research Association and the National Park Service. The 1934 address announced that "Mauna Loa has definitely mobilized and declared war, there is every appeal for an intellectual and practical victory over Nature, and a program can be laid down whereby our engineers and aviators and bombers will rejoice at the opportunity to show their prowess." All honor to the Army for an excellent peace-time achievement.

Hawaiian Volcano Observatory Report for December 1936

VOLCANOLOGY

The coming of December, and the elapse of a year since the last outbreak of the Mauna Loa-Kilauea system, are both reasons for expecting return of lava to Halemaumau. The winter solstice has produced more eruptions here than any other season. And the average of intervals has been one year. But nothing happened in December 1936 except a sudden quietness the last week of the month. This may mean uplift under Kilauea crater, following the slumping that caused the October avalanches.

All the movements were fewer than in November, as shown (see Volcano Letter 441) by the following tabulation, that indicates by weeks the local seismicity, the counted number of slides in Halemaumau pit when it was under routine observation, the amount of aggregate opening of marked rim cracks at Halemaumau by weeks, and the seimograph count of local tremors and quakes:

Week Ending	Seismicity	Slides	Cracks	Quakes
December 6	5.00	1	6.0 mm.	12
December 13	8.75	0	6.0 mm.	13
December 20	7.75	2	5.0 mm.	25
December 27	12.75	1	2.5 mm.	33
January 3	0.50	0	0.0 mm.	2

Sequence of Events by Weeks

The first week the pit was generally quiet, and the second week showed no slides at all, and remarkable constancy.

The third week slightly increased seismic motion and dust from a few slides. The shocks were mostly from Kilauea.

The fourth week tremors increased, and fume from the NW floor solfatara was notable.

The new year opened with unparalleled quiet, no slides, very slight crack movements, and seismic activity confined to two tremors in seven days.

Slides at Halemaumau

Slides from the wall of the Pit have been noted as follows, mostly from a distance, or at type periods of visitation:

December 6, 4:10 p.m., small dust clouds east edge.

December 17, 11:00 a.m., dust at NE wall, and scar from a recent slide there.

December 27, 4:00 p.m., dribbling of small rocks down NE wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted as follows:

Week ending forenoon of:

December 5, 10 opened, 0 closed, aggregate opening 6.0 mm.

December 12, 7 opened, 4 closed, aggregate opening 6.0 mm.

December 19, 11 opened, 4 closed, aggregate opening 5.0 mm.

December 26, 7 opened, 2 closed, aggregate opening 2.5 mm.

January 3, 4 opened, 2 closed, aggregate change 0.0 mm.

It is of interest as showing consistency among the subjects selected for measurement after years of experience at the Observatory, that crack widening, numbers of quakes, intensity of quakes, and number of slides all dwindled simultaneously the last week. This shows Halemaumau to be an index vent for all Hawaii, as some of the usual earthquakes originate under other parts of the Island, and those regions also were quiet the last week of the year. It would seem also, with seismicity suddenly lowering along with crater values, that all the island seismicity is clearly volcanic. T. A. J.

SEISMOLOGICAL DATA

EARTHQUAKES

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Distant† Earthquakes	Local* Seismicity
December 6	14	3	0	5.00
December 13	31	2	1	8.75
December 20	19	6	0	7.75
December 27	47	2	1	12.75
January 3	2	0	1	0.50

† Includes teleseisms or those shocks over 5000 kilometers distant.

* For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, determinations of depths of focus have been made.

December 3, 11:17 pm, very feeble, located under SE rim of Kilauea Crater adjacent to Keanakakoi Crater and 1.5 miles deep. 19° 24' 4N; 155° 16' 2W.

December 4, 12:11 am, very feeble, located under N rim of Kilauea Crater 0.3 mile SW of Kilauea Military Camp and 2.0 miles deep. 19° 26' 1N; 155° 16' 7W.

December 11, 7:20 pm, very feeble, probably located under SE portion of Kilauea Crater.

December 16, 3:05 am, very feeble, located 0.7 mile NW of Ahua Kamukokulau S of Kilauea Crater and 0.8 mile deep. 19° 23' 4N; 155° 16' 6W.

December 16, 10:20 am, very feeble, located 1.1 miles SE of Pit Seismograph and 5.0 miles deep. 19° 23' 6N; 155° 16' 4W.

December 17, 5:52 pm, very feeble, located deep under SE slope of Mauna Loa. 19° 19' 0N; 155° 33' 2W. Reported felt at Hookena.

December 18, 3:22 pm, very feeble, probably located in SE portion of Kilauea Crater.

December 19, 5:56 am, very feeble, of Kilauea origin.

December 27, 12:06 am, very feeble, located deep under Kilauea SW Rift 5.0 miles SW of the Volcano Observatory. 19° 22' 0N; 155° 14' 5W.

Periods of continuous (harmonic) tremor registered on the Observatory seismograph as follows: beginning at 12:04 pm, December 1, six (6) minutes; 9:11 pm, December 13, twenty-one (21) minutes and 4:24 pm, December 26, seventeen (17) minutes.

Microseismic motion of the ground at Kilauea was light December 2, 3, and 5; moderate November 30 and December 1, 4, 6, 7 and strong the remainder of the month.

Registration of Distant Earthquakes at the Observatory was as follows: December 13, the preliminary waves at 11h 10m 37s am, HST, with 3020 miles as the distance of focus from Kilauea; probable location in the Kamchatka Peninsula as reported by newspapers. At 8h 50m 37s am, HST, December 21, the surface waves of a teleseism began recording. Its distance was undetermined. At 4h 27m 40s am, HST, December 29, the preliminary waves of a teleseism began recording. Its location was 3550 miles from Kilauea.

TILTING OF THE GROUND

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 3, 1937, was 3.60" N and 0.24" W.

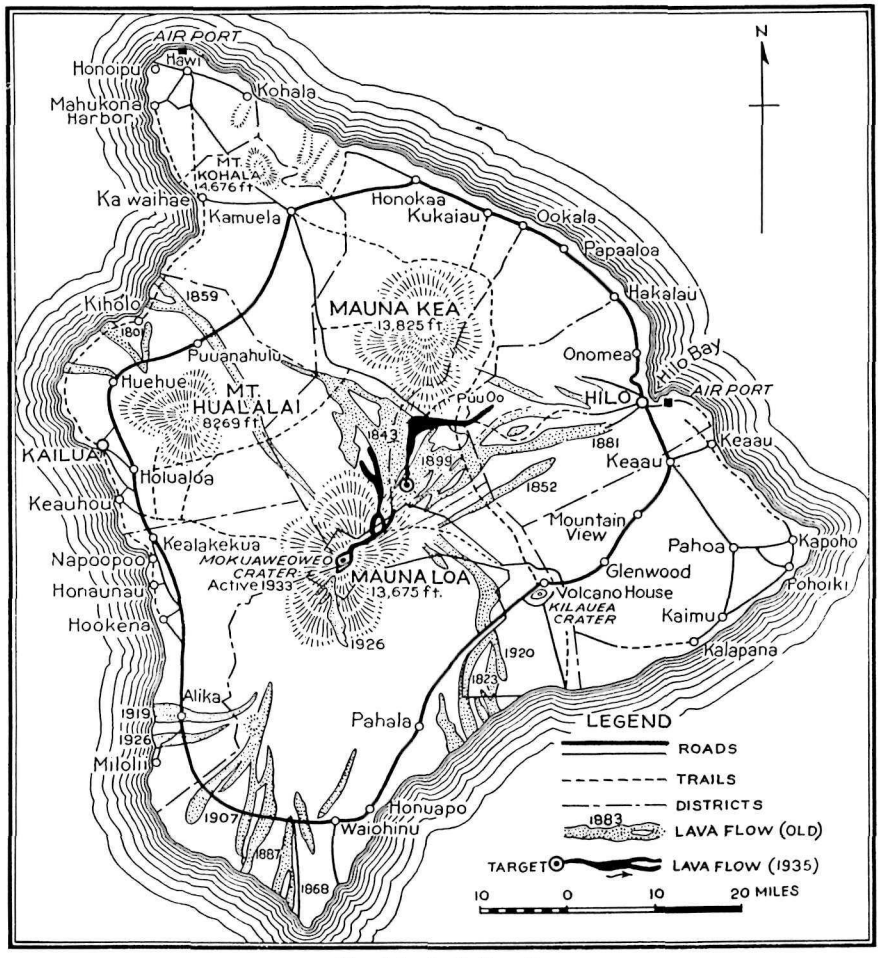
Table of Tilt

Week Ending	Observatory	Halemaumau West Station
December 6	0.62" S 78° E	3.19" N 57° W
December 13	1.10" N 43° E	2.15" S 65° W
December 20	0.74" N 38° W	9.86" W
December 27	1.05" S 33° W	3.75" S 61° W
January 3	1.18" S 02° E	5.13" N 64° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
December 6	3.79" N 11° E	0.26" from
December 13	1.46" N 34° W	0.63" from
December 20	2.20" N 61° W	7.75" from
December 27	3.11" S 21° W	5.05" from
January 3	5.61" S 81° W	2.04" from

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, December 26, showed a closing of the Halemaumau value and an opening of the crater value compared with similar measurements made November 23. From Kilauea SE rim to Uwekahuna there was opening 0.42" November 23 to December 11 and closing of 0.08" December 11 to December 26. Total opening 0.34". From the Pit Seismograph to the NW Pit B.M. there was a closing of 0.84" November 23 to December 11 and closing of 1.16" December 11 to 26. Total closing 2.00". H. H. W.



The Island of Hawaii

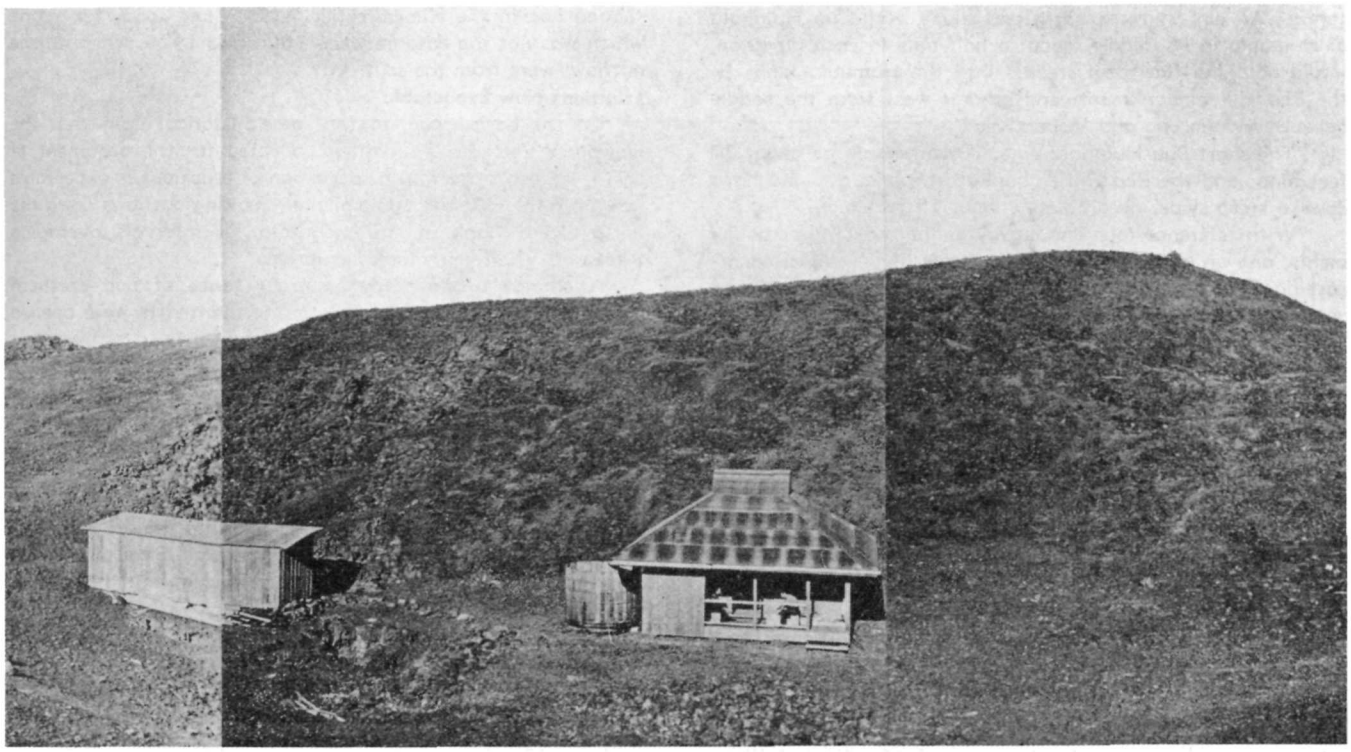
Map of Hawaii, from the Military Engineer.

THE VOLCANO LETTER 443

No. 443 monthly Department of the Interior National Park Service January 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Red Hill, at 10,000 Feet Northeast Rift of Mauna Loa, with Resthouse and Stable

PROTECTION OF HILO FROM COMING LAVA FLOWS*

By T. A. Jaggar

Observatory Plans 1936

The following paragraphs are from the special report of December, 1936, from the Volcanologist to the Superintendent of Hawaii National Park. They concern, not a new and sudden alarm, but a serious project for safeguarding the industries of Hawaii from the lava flows of Mauna Loa. It has long been the intention of the Hawaiian Volcano Research Association to make Mauna Loa its principal center of study, and the time has come to do this.

"It is just one year since the Mauna Loa Flow of 1935, which seriously threatened Hilo, and ceased flowing in sequence upon artificial bombing. The law of cycle recurrence on Mauna Loa for 101 years is one crater outbreak every three and a third years, and one lava flow every six years. The north rift is open and smoking, and the next outbreak may threaten Hilo again, by analogy with nineteenth century sequences.

"The National Park with CCC labor has finished nine and nine-tenths miles of truck roadway up Mauna Loa east slope, going WNW from Bird Park. The resources of volcano research should be brought to bear on the engineering problem of protecting Hilo with the planning aided by 1935 experience. In like manner the 1933 crater eruption of Mauna Loa furnished data for forecasting the 1935 outflow of lava.

"There are four issues involved, namely: more Park land on Mauna Loa, an embankment to deflect lava flows near the source, other embankments lower down, and a survey of the rift land. Discussion of the project has the approval of the park superintendent, and is on the initiative of the Hawaiian Volcano Research Association.

"The embankment proposed is entirely distinct from the

* Address delivered at Annual Meeting of Chamber of Commerce of Hilo, Hawaii, January 19, 1937.

bombing method. The latter is a last resort measure, intended for lava flows of the tunnel-flowing variety called 'pahoehoe,' which appear in late stages of an eruption. The embankment-deflection is for the early and most dangerous liquid stage of an eruption, lava called 'aa,' which we saw naturally deflected November 22, 1935, by old lava banks. There is abundant loose rock on Mauna Loa for construction. There is no question but that an artificial embankment aligned downhill oblique to flowing slag would deflect it. A lava flow fills as a liquid. It does not push as a solid.

"The source belt, a mile wide, is a series of definite cracks trending N 70 deg. E from the summit crater for eleven miles. The distance to Hilo in the same direction is 35 miles. The divide between Puu Kipu, and Puu Ulaula called 'Red Hill,' is the parting line between old Hilo flows and southward flows, and the line trends N 85 deg. E.

"An embankment from Red Hill N 20 deg. W, five miles long, would steer any flows such as 1855, 1880, and 1899 to safety. An embankment north and south, with Puu Huluhulu of Humuula in its middle, about a half mile in each direction, would hold the flow pool steered into the Humuula lands by the Red Hill embankment, and send it west from the saddle between Mauna Loa and Mauna Kea.

"The short Puu Huluhulu embankment would be about 20 feet high; and the Red Hill embankment, oblique to the flows down a steep slope, need be only about 15 feet high.

"With reference to a line survey of the proposed embankments, and an aerial photographic mosaic of the entire northeast flow belt from the rift to Hilo, General Drum has expressed approval of the project.

"There the matter stands at the end of 1936. The volcanologist recommends that the establishment of Observatory volcanologic work on Mauna Loa at Red Hill shall be the main purpose of 1937 plans of the Hawaiian Volcano Observatory. The founding of Mauna Loa seismological measurement, and rift patrol, appear essential to the safety of the community."

Motive of the Work Proposed

From a small village threatened by numerous lava flows, with upper land destroyed by two of them, and the main water source invaded by three of them, Hilo has grown to a city, a port, and an airport.

These things have been improved at great expense from time to time, and the population has grown from a few hundred to 20,000 people. The harbor dredging and breakwater, the airport, wharfs and real estate will all be improved much more, and the adjacent plantations in health, labor, insect control, transport, agronomy, water supply, and milling are models of scientific advance in aggressiveness and in defense against evils. Hilo is their harbor.

The shadow of the lava menace is just as removable as the shadow of malaria, tuberculosis or yellow fever, the noxious mosquitoes, the leaf hopper, or the plague fleas and rats. It merely never occurred to anyone to remove it.

There is just one way to do this, and that is to face the exact facts, and then act with decision and unanimity at this present time of Government employment of labor. Remove the lava shadow, and watch Hilo go ahead by leaps and bounds.

Expectable Intervals and Flow Sources

Using the data of the 1934 article (Volcano Letter, October, 1936) for the history of Mauna Loa flows, the average of Mauna Loa eruptions is one summit outbreak every three and a third years between 1832 and 1933, and one flank outflow every six years.

There were six Mauna Loa eruptions between 1914 and 1935, making present average three and a half years. There were four flank flows, making outflow average 5.5 years. Thus the twentieth century holds up the general average.

The succession of newly opened vents since 1868 was from elevation 3,500 feet that year at the southern end of the Mauna Loa rift, progressively up the rift to 13,000 feet in 1926, 13,150 feet inside the crater in 1933; and 12,000 feet in 1935, on the northern extension of the rift down the Hilo slope.

This was approximately five miles north of the 1933 eruption, and if the next flank outflow comes out five miles farther north, the place will be a half-mile above Red Hill, close to the source of the 1881 flow, which entered the city of Hilo.

It should not be understood that the next eruption of Mauna Loa will be a flank outflow. Furthermore it may not come in three and a half years; that figure is merely an average. It may come in the summit crater or on some other flank, as alternations between the two sides of the mountain are common.

We know, however, that fume and steam are rising, that the ground is hot, and that sulphur is depositing at the line of source cracks of 1935. That means that the north rift of Mauna Loa in the Hilo direction is open and ready for action which was not the case between 1900 and 1926, when all the outflows were from the south rift.

Eruptions Now Expectable

On the basis, then, of the same historical data that the Hawaiian Volcano Observatory collected for the argument of 1934, we can state that a succession of eruptions is expectable now from the Hilo rift, some of them making outflows down the northeastern flank of the mountain, at intervals averaging three and a half years for all eruptions.

A change began with the great series of bad northern earthquakes of 1929, whereby the northern rifts were opened and the southern ones were closed.

The historical flow sources of the northern rifts may be thought of as lying in a semicircle around the north side of Mauna Loa all the way from Huehue to Nanawale, making a set of radial fractures from the summit of Mauna Loa northwest, north, northeast and east, the northwestern one being the Hualalai rift, and the eastern one the Kilauea rift.

The Huehue Flow at the west poured into the sea from elevation 2,000 feet in 1801, and the Nanawale Flow at the east poured into the sea from elevation 650 feet in 1840. Note what low sources are possible.

It is fortunate for Hilo that the northeast rift bends eastward at elevation 8,000 feet; and we have no historic record of a flow source, of Hilo flows, lower than 8,424 feet, at the head of the 1852 flow. But there were many pre-historic ones that formed the entire south side of Hilo bay, when the ancient shore line extended from Waiakea Kai to Olaa Mill. The range of speeds of sudden aa flows has been 1 to 20 miles a day.

The Lava Cycles of the Nineteenth Century

There is good evidence in recent history for eleven year cycles, 1903-1913, 1914-1924, 1925-1935. These include both Mauna Loa and Kilauea, each with at least two eruptions Mauna Loa; Kilauea pit variously spouting, fluctuating, or rising, and the lava as a whole effervescing strongly and sinking at the end of the cycle.

The cycle is terminated by a very quiet year or years. The quiet years were 1913, 1925, and 1936; we are now approaching the end of the 1936 lull. The distinctive character of this 1936-1937 repose period, leading to an assumed 1936-1946 cycle, is that it is the first repose period following Kau flows and leading to Hilo flows, since 1840.

Leaving aside theories about cycles for 1840, as structural resistance to breaking is the real control, the significant feature of that year, with reference to the structure of the island, was that it made an outflow into the ocean from the eastern Kilauea rift, and it followed southern outflows from both Kilauea and Mauna Loa of 1823 and 1832. A characteristic of 1840 was that it was followed in the next cycle by two northern

outflows of Mauna Loa, 1843 and 1852, both beginning just where our 1935 eruption began.

Disregarding intervals, as structural sequence is more important and comparing 1924 with 1840, we had the eastern Kilauea rift erupting 1922 to 1924, following after southern outflows from both Mauna Loa and Kilauea, respectively, 1916, 1919, and 1920. This was very much like the sequence 1823 to 1840.

The parallel is made still more remarkable by the fact that the 1916-1924 sequence of southern and eastern outflows for the whole island has been followed in 1935 by an outbreak at the north in the same place as the eruption of 1843 from Mauna Loa, with the flow in very nearly the same volume and filling the saddle between Mauna Kea and Mauna Loa in just the same way.

This parallelism to the first half of the nineteenth century leads one to suspect that the unrecorded period of Mauna Loa activity preceding 1932 produced flows in Kau just as did the twentieth century period preceding 1935.

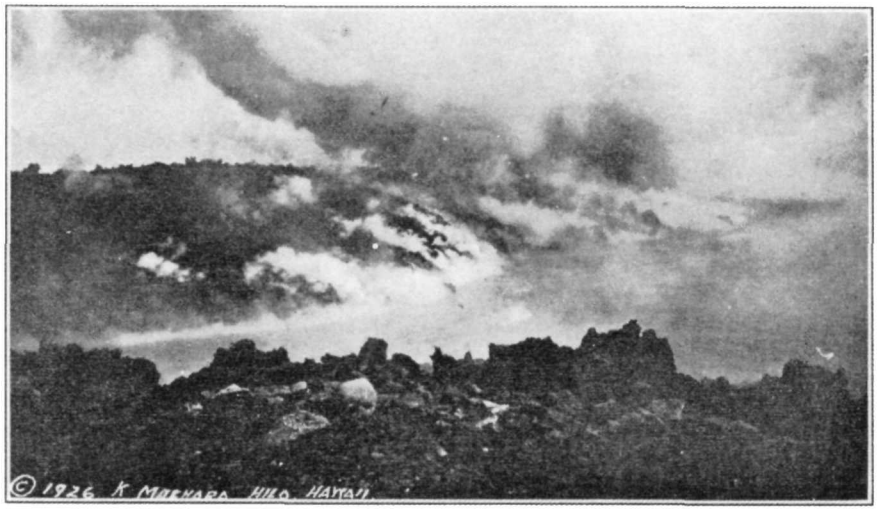
Loa summit, and travelled for seven months 38 miles into the sea at Kiholo Bay. There it filled the northeastern half of the bay making new land two miles along shore and a mile out to sea. Its first gushing of aa reached the sea in seven days at Wainanalii.

The next north flow was 1881 starting in the northeast rift and travelling 29 miles for nine months towards Hilo, with a side branch at first to Kapapala that flowed ten miles in a day. It stopped one mile from the city center.

The Fortification of a Harbor

The first flows are always very liquid aa. They travel far in a few days, and are the most dangerous to property if they get into industrial lands. For such flows bombing would be wasteful and useless.

It was this kind of flowing which destroyed Bosco tre Case on Vesuvius in 1906, and also Mascali, a large town of 7,000 inhabitants, on the railroad east of Etna in 1928. In either of these cases it would have been possible to fortify the town, if suitable earthworks oblique to the course of an expected lava



Rapid Lava Flow Pouring Into Ocean Destroying Hoopuloa Village in 1926

We know that the middle of the nineteenth century, beginning with 1843 and continuing to 1881, produced a tremendous volume of flows to the north from Mauna Loa, those of 1852, 1855, and 1881 ending progressively closer and closer to Hilo; 1855 and 1881 might have been successfully bombed.

Add to these 1935, straight down the Wailuku River valley, which if it had not been bombed might have filled Hilo harbor, and we find indication that the threat to Hilo is increasing. We now in 1937 find ourselves with the island structure broken wide open for a succession of lava flows historically similar to the series 1852-1881.

Early Series

That series was 1849 at the summit crater; 1851 west of the summit for 10 miles towards Kona; 1852 from the northeast end of the Hilo rift for 15 miles in 20 days straight toward the city, ending 11 miles from the Federal building.

1855 started at the northeast rift farther west than 1852, and travelled 25 miles for 15 months in a curved course to the Wailuku drainage, ending seven miles from the city.

1859 started at elevation 11,000 feet northwest of Mauna

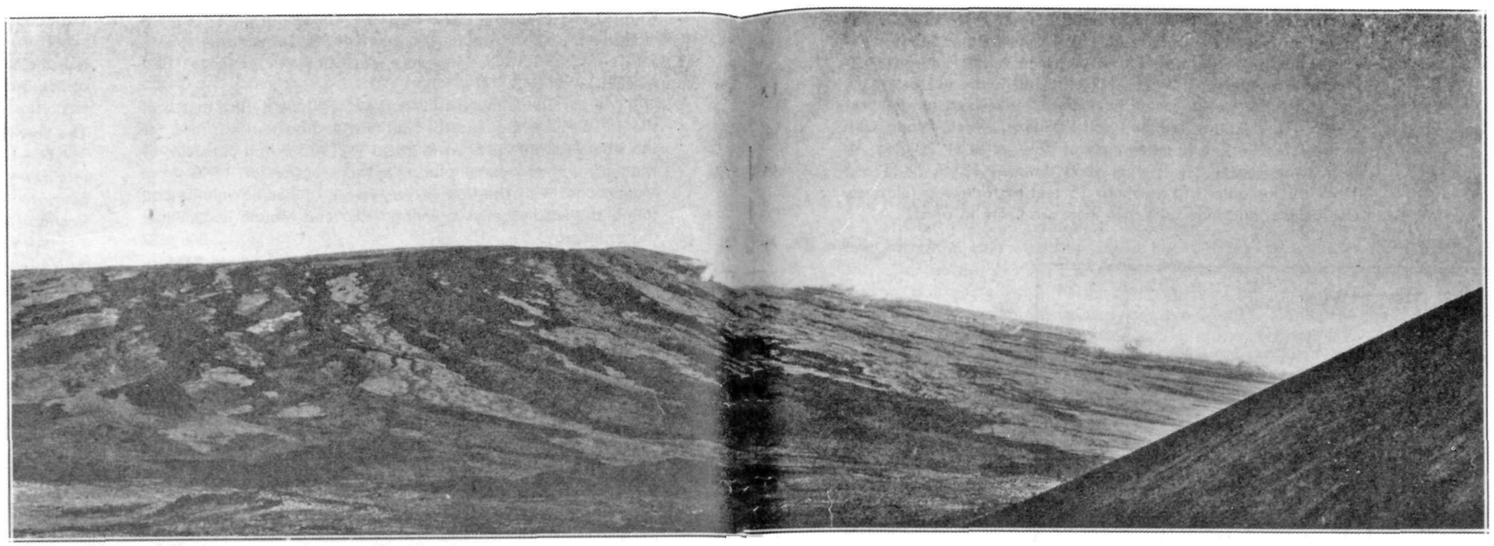
flow had been erected in advance, at a site selected to divert such a flow into a valley leading to agricultural or forest lands.

In neither of these cases was any harbor involved. A harbor is a national asset, it usually lies where a valley emerges on the ocean, and if a mass of new rock, a mile seaward and miles long, fills a developed port, the calamity cannot be reckoned in money. A harbor is vastly more valuable as a natural feature than all the millions spent on houses, roads, sewers, and public utilities.

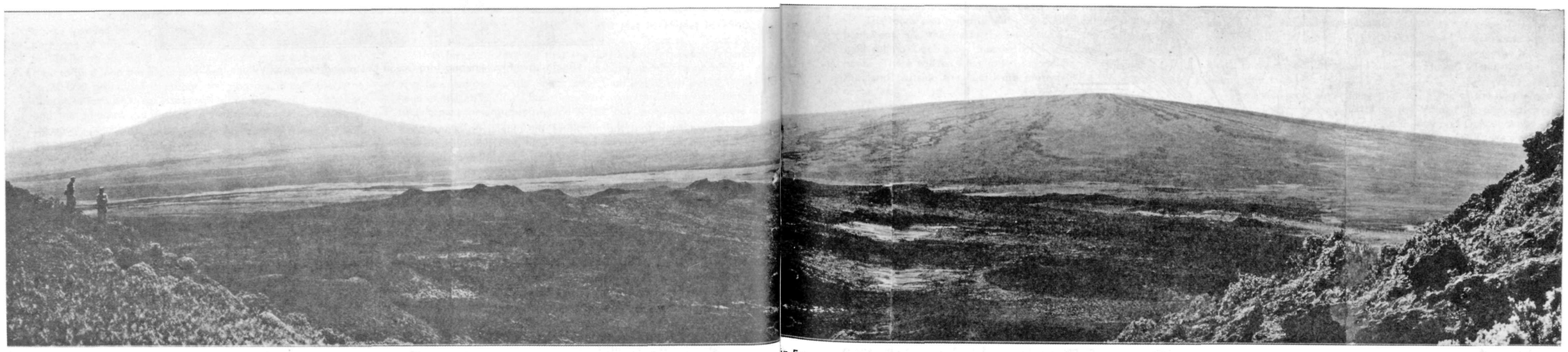
The Situation of Hilo

Hilo lies at the meeting place of three valleys all straight below the dangerous end of the Red Hill rift of Mauna Loa. These we may call the Wailuku Valley, the Kaumana Valley, and the Waiakea Valley. The first is the contact of lava flows against Mauna Kea drainage. The other two are seepage remnants of buried valleys on the east slope of Mauna Loa.

All three would lead a new rapid lava flow straight into the harbor. The distance is only 20 miles from the nearest possible lava source, Puu Kipu at Helipo Camp. Puu Kipu is right in the line of the east bend of the live rift. An existing heavy aa flow from it in the forest extends half way to Hilo.



North Face of Mauna Loa Volcano, Showing Net of Lava Flows Mutually Deflected; the Area of the Red Hill and Humuula Barriers



Mauna Loa (right) from Hualalai, Showing the Hualalai Rift Belt Line of Cones in Foreground: Behind Them aa Lava of 1859 (dark), and Pahoehoe Lava (light).

A new flow on its north side would sweep about 24 miles to Waiakea Fishpond, and at the rate of the 1859 flow would reach the sea in five days.

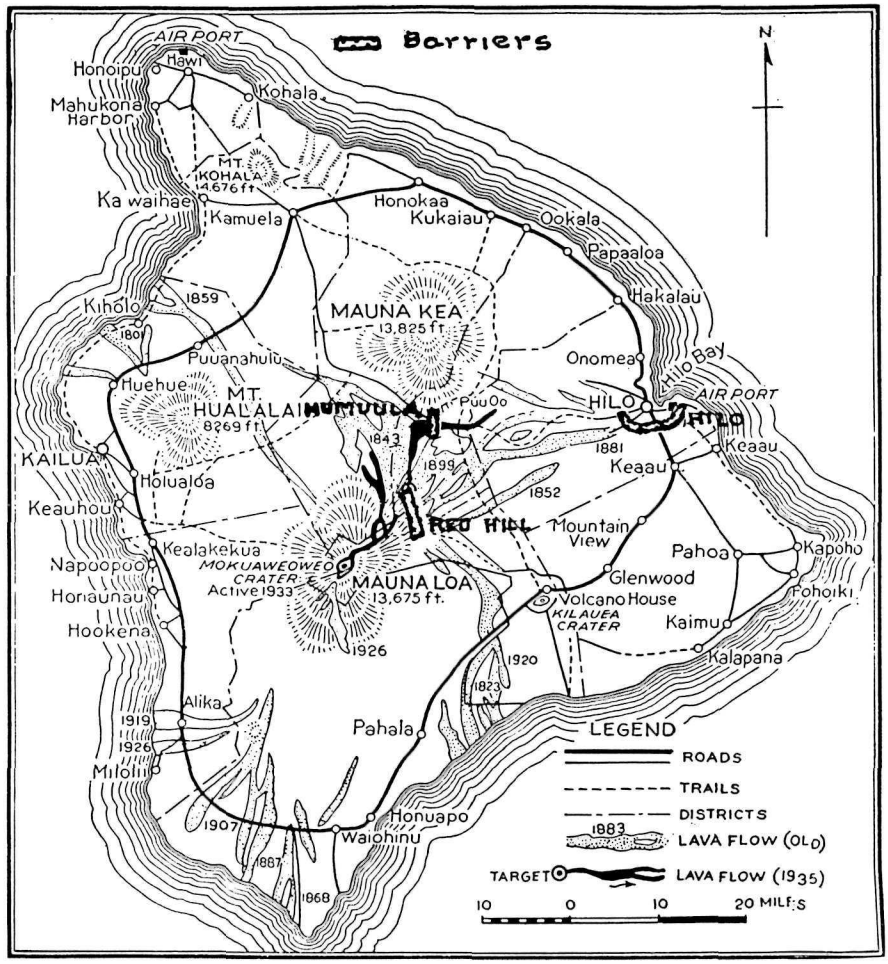
A flow from the 1852 source at the same rate would travel 26 miles, take six days, follow the southeast side of the 1881 flow and Alenaio stream, and enter the sea at Mooheau Park.

A flow from an old cone at elevation 8,750 feet 2¾ miles north of Red Hill, at the same rate, would flow 27 miles between the 1881 and 1855 flows, reach the Wailuku River by Kahoama stream and the gorge above Waiale Falls, pass Piihonua and reach the railway bridge over the Wailuku River in something like six days.

All these distances are shorter than the 1859 flow, which travelled 38 miles in seven days from a point 11,000 feet up.

There are three elements in the Hilo problem. One is to steer lava flows with obstacles, near their sources, into safe places like Humuula while they are liquid. The second is to build an obstacle at the Humuula pass that will protect Hilo's water supply. The third is to build a final protection for the harbor in Hilo itself in case of (1) an unexpected low vent or orifice in the mountain; (2) a vent too far east for the obstacles constructed; (3) the failure of all upper obstacles.

The first two obstacles have been mentioned in the preamble. One is the Red Hill embankment, which, along with natural features, will extend about five miles N 20 deg. W from near Red Hill, will steer such flows at 1855, 1881 and 1899 to Humuula, will be about 15 feet high down a relatively steep slope, and may take 300 men two years to finish.



Map of Hawaii 1937, Showing Proposed Barriers Exaggerated

If the 1859 flow had come out at Puu Kipu with the same energy, it probably would have done the 24 miles to Hilo Bay in four days and piled up the material of its remaining 14 miles of first gushing in Hilo breakwater. The breakwater would probably hold it and tongues of aa like the Laupahoehoe flat would spread out in a leaf delta to the north of Hilo harbor, after the harbor was transformed into the same kind of land as Keaukaha.

Defense of Hilo

The foregoing is a legitimate picture of what we have to fortify against. Fortification in war consists of two elements, protection and obstacle. Lava flows are the enemy. Protection will shield Hilo from a lava flow when it comes. Obstacle will prevent the lava flow from coming to close quarters if possible.

This is partially prepared for by the CCC camp at Hawaii National Park, which has built 9 9/10 miles of truck roadway up Mauna Loa, and has about eight miles more to go to reach Red Hill. The work of laying a 15-foot bank down natural grade, with double track for dump trucks on top, and using loose aa blocks, without much grading and almost no cutting, taking advantage of natural spurs, is simpler than building a road. It will be necessary to extend the present road as a rough track as fast as possible to Red Hill. A volcano observatory will be established there this year.

At Puu Huluhulu, the forested hill in front of Humuula sheep station, a bank 20 feet high will be built north against Mauna Kea about a half mile long. A similar one will be built south against Mauna Loa for the same distance until its top is

at grade. These, with the hill, will be at a height where a lava pool in the saddle will spill west over the top of the 1843 flow. The Red Hill bank will steer flows near the 1935 and 1843 flows. Such flows will pool in the saddle and spill west. The combined obstacles will protect the projected Kaumana-Kona road, the water supply of Wailuku River, and stave off 80% of expectable flows, including a low northern or Humuula vent. *This steers flows to Keamuku, not to Puuwaawaa.*

The Puu Huluhulu bank is prepared for by the improvement in the Humuula road made by the Pohakuloa CCC camp, and by the camp itself as a nucleus for labor, and as a shelter for laborers. The work will take a year, with perhaps 200 men.

The Hilo Causeway, or Lava Guard

At first it was thought that to construct a fortress against lava attack in Hilo would be impossible. So it would be if we threw up earthworks in a wide circle around the outer city limits. But a study of the topographic map has revealed a strategic line for a Hilo Causeway, or Lava Guard Embankment, which will not be excessively expensive, and may be used (1) as a parkway drive, (2) for possible impounding of water, (3) as a cross-connection for existing roads and (4) as a possible start for the Kaumana-Kona driveway.

As no lava flow on a slope is likely to be more than 12 feet high here, this embankment will average 18 feet in height, being higher where it has to cross low ground. It will start at *Wailuku valley above Piihonua over the head of Waiale Falls,* with a culvert or arch for the river. This is above the big Mauna Kea tributaries, so that it will not get maximum floods. The culvert construction will have to provide a steel gate capable of closing the arch to small dimensions in case of lava flow.

The line will start about South 70 deg. East for a mile from the river and then run east; the grade downhill to Lanikaula Street is 200 feet to the mile, and obliquely crosses all the valleys. The bank will cross only the Kaumana and Volcano *roads, and will make a smooth curve northeast before reaching* the railway near the quarries. It will then cross the railway fork, may be lowered to 15 feet, and carry far enough on the Keaukaha spur to guard the harbor as far as Keokea Point.

The roads and railways will pass under bridges in the embankment, and there also the uphill face of the causeway will hold rolling steel gates inclined at the natural slope of the bank. These will be kept rolled to one side. Remember that the lands outside the guard are protected by the upper two obstacles.

The total length of the Lava Guard will be seven miles to the top of the Keaukaha spur. The fundamental object of the guard is to protect Hilo and Hilo harbor, the second harbor of the Territory. If everything fails in the upper obstacles, if the water of one or the other valleys were buried, Hilo could still find water. But if a quick flow comes into Hilo itself and the harbor, there will be no motive left to find any water. There will be no Hilo. Remember what we watched as the 1926 flow swallowed Hoopuloa.

The Lava Guard will require heavy quarrying on the uphill side of the bank, the places being chosen to create a channel across obstacles.

I estimate roughly the Hilo job will occupy two years, and give work to 600 men.

The costs for the three jobs may be:

Red Hill	$300,000
Humuula	100,000
Hilo	400,000
Total	$800,000

If any of these embankments has a lava flow piled up against it, it will be more an obstacle than ever, strengthened for its work.

The Hilo Causeway will be the Hindenburg Line, the final protection. It should be begun first and it is most important. It is near labor and a base of supplies and subsistence. On that account it is much easier than the Red Hill job. The first thing to do is to run the line surveys. The second is for all organizations to pull together to get all three jobs done, for they completely interlock.

The Parallel With Kiholo Bay

In 1800 the Kaupulehu Flow poured from Hualalai into the south end of Kiholo Bay. It filled three miles of shoreline, and out to sea one mile. In 1859 the flow from Mauna Loa poured into the north end of Kiholo Bay. It filled the harbor a mile out, along two miles of shoreline.

The Puuwaawaa valley may well have been like the Hilo valleys centuries ago, ending in a deep indentation. Here were only 60 years of the nineteenth century, and the harbor that on the west side of the island corresponds exactly to Hilo, had five miles of length filled one mile wide.

From Mauna Loa Kiholo was protected by Puuwaawaa hill, Hualalai Mountain, and Puu Anahulu. The 1859 flow was not stopped at all by Puu Anahulu flats. The whole South Kohala shore as far as Puako is a filling of Mauna Loa flows. The early 18th century filled west. Seventy-five per cent of present-day flows are to the east.

Hilo has no hills whatever between it and the most dangerous present active rifts of Mauna Loa. It is on a valley which Mauna Loa is perfectly certain to fill up in time. It is 34 per cent nearer to the active vents than Kiholo is to the 1859 source. It has been attacked five times in 83 years, mostly when it was a small village. Last year it was attacked in its urban maturity, and it was saved by bombing pahoehoe. The next flow may be of different kind, when nothing will save Hilo but fortification.

The lava surface equal to the Kiholo fill would be five *square miles. This would fill Hilo harbor from a point a mile* north of Wainaku across to a place in the sea a half-mile north of Keaukaha. There would be no city, no Iron Works, no Canec, no Waiakea, no railway yards, no airport, no wharves, no electric works, no telephone center.

The city is worth $51,000,000; the harbor possibly $500,000,000 to the Territory, to commerce, and to the Nation. There are only two real harbors on Hawaii Island, Kealakekua and Hilo.

The river would find a new channel in one of the northern gulches. The people would sit on the Halai Hills and watch another layer added north from Reeds Bay and Onekahakaha, both of which are Mauna Loa lava flows. The Oil Tanks would blow up, the sugar in Kuhio wharf would be buried, and the lumber mills would burn, just as we watched the Hoopuloa wharf burn.

If a foreign Hobson were going to scuttle Merrimac hulks in the breakwater entrance, we would ask the Government to *line up a blockading fleet. That is exactly what we are called* upon to do against Mauna Loa. You have created an intelligence service, the Observatory. It is making its report soberly and conservatively. This is not alarmist sensationalism.

Conclusion

The thing I would suggest that the Hilo Chamber of Commerce do, is to have a meeting, for discussion of this question, with representative engineers, business men and the supervisors. At that meeting may be decided whether or how to approach the Governor.

I would suggest having representatives of the National Park, the Army, Navy, Parker Ranch, Shipman Ranch, and the Bishop Estate; with the Land Commissioner to represent the Governor. I have discussed the matter with Mr. Whitehouse, and with several of these administrators of Mauna Loa lands,

and also General Drum, and the presidents of the Hawaiian Volcano Research Association and the University. The protection of Hilo needs no argument, and these gentlemen have great respect for Mauna Loa.

The things to do are:

1. Extend the Mauna Loa road.
2. Equip a Red Hill Observatory and patrol.
3. Acquire the upper Mauna Loa waste lands.
4. Design and start the Hilo Lava-guard Causeway.
5. Design and start the Humuula Obstacle.
6. Design and start the Red Hill Embankment.

For all of these the appeal, started by myself as volcanologist of Hawaii National Park and the Hawaiian Volcano Research Association, for which I take full responsibility, should probably proceed through the Hilo Chamber to the Governor, who will take whatever action seems wise.

If we do these things you can sleep in Hilo and feel jubilant for your future and your business. Read the pathetic letters of Mrs. Severance to Miss Gordon-Cumming in 1881, when the flow was in Hilo, if you want to know the depression of it (book called "Fire Fountains," Gordon-Cumming). Or see the volcano film of Etna at the National Park museum. And after the embankments are built we still have bombing in reserve for the slow smooth flows.

More than all else, you will set an example to the world. Italy, Japan, the Philippines, Java and Central America will all watch Hilo. Hilo has not said "Manana" (tomorrow), nor "Shikata ga nai" (it can't be helped). The trails of the Hawaiians go straight to the goal with the motto "Eternal is the life of the land in righteousness." Righteousness means straightness. Let us perpetuate the life of the land in Hilo.

Hawaiian Volcano Observatory Report for January 1937

VOLCANOLOGY

The month of January indicated continuance of the quiet conditions which had begun rather suddenly the last week of December. The winter proved exceptionally rainy, with much stormy weather and high winds, occasioning deep ground swells that broke on the rocky cliffs of the island. As a result microseismic motion has been strong, and appears to vary with the impact of waves on the shore.

Observation of Mauna Loa

On January 2 a party from the Observatory, S. Sato and A. Okuda, accompanied soldiers from the Red Hill Resthouse up the Mauna Loa trail, encountering fresh snow from a point a mile and a half above the house. The old steam crack east of the trail was making vapor with snow close to its edge. The 1935 cones at about 12,000 feet elevation showed sulphur coatings that were too hot to hold the snow, and both vapor and blue fume were noted there. After exposure to snow glare from seven to ten hours, some of the party were snowblinded, and had to be led down the trail on the return. This experience of snowblindness has been repeated by other parties on Mauna Kea, where a new trail built by Civil Conservation Relief Workers has induced many to go skiing.

From the Observatory at Kilauea the 1935 cone on Mauna Loa, 18 miles away, was seen to make visible fume the hour before noon on January 6.

Observations of Kilauea

The following tabulation for January shows somewhat higher values for the Kilauea Volcano Observatory data than in the week ending January 3, but mostly lower values than December. There are indicated by weeks the local seismicity, the counted number of slides in Halemaumau pit when it happened to be observed, the amount at Halemaumau of aggregate opening of marked rim cracks by weeks and the Observatory count of local seismographic tremors and quakes:

Week Ending	Seismicity	Slides	Cracks	Quakes
January 10	7.25	3	2.5 mm.	11
" 17	2.75	4	3.0 mm.	9
" 24	3.00	3	6.0 mm.	8
" 31	7.00	0	3.0 mm.	14

Sequence of Events by Weeks

The first week produced two felt earthquakes and some sliding from the Halemaumau wall.

The second week had lower seismicity and small slides continued.

The third week produced occasional dust from slides and no change in the seismicity.

The fourth week of heavy rains filled the pit with large clouds of water vapor, surmounted by cauliflower clouds caused by convectional displacement, and the nucleation due to fume issuing from vents on the floor of the pit. There were some felt earthquakes, and southerly tilt was strong.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows, either from a distance or at typical times of visitation:

January 6, 12:45 p.m., dust rose from a small slide NE, while blue fume was seen at E and W Solfataras.

January 7, 9:30 a.m., small rocks dribbled down west wall, and at 1:30 p.m. dust arose NE.

January 8, at 2:18 p.m., a moderate slide fell from NNW wall.

January 15, 9:33 a.m., a small slide fell N.

January 17, 12:03, 12:27, and 12:35, dust clouds from slides arose NW; all were small.

January 22, 12:45 p.m., dust arose N rim.

January 23, A scar on the west wall indicated new sliding, and small rocks were in process of dribbling down there.

The last week was too stormy for observation of slides.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of

January 8, 5 opened, 2 closed, opening 2.5 mm.
" 15, 7 opened, 4 closed, opening 3.0 mm.
" 22, 6 opened, 1 closed, opening 6.0 mm.
" 29, 9 opened, 4 closed, opening 3.0 mm.

T. A. J.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, January 21, showed an opening of the Halemaumau value and an opening of the Crater value compared with similar measurements made December 26, 1936. From Kilauea SE rim to Uwekahuna there was closing of 0.17", December 26 to January 8 and opening of 0.84", January 8 to January 21. Total opening, 0.67". From the Pit Seismograph to the NW Pit B.M. there was an opening of 0.17", December 26 to January 8, and an opening of 0.83", January 8 to January 21. Total opening, 1.00".

H. H. W.

Spirit Levelling

A recheck of levels run in Kilauea Crater after February, 1936, indicates that values reported for elevation changes are erroneous. Improper corrections and poor instrumental adjustments have been responsible for the discrepancies. Proper corrections will be made and results reported in a later edition of the Volcano Letter.

H. H. W.

Note: Seismological Data for January, 1937, will appear in February issue.

THE VOLCANO LETTER 444

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Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

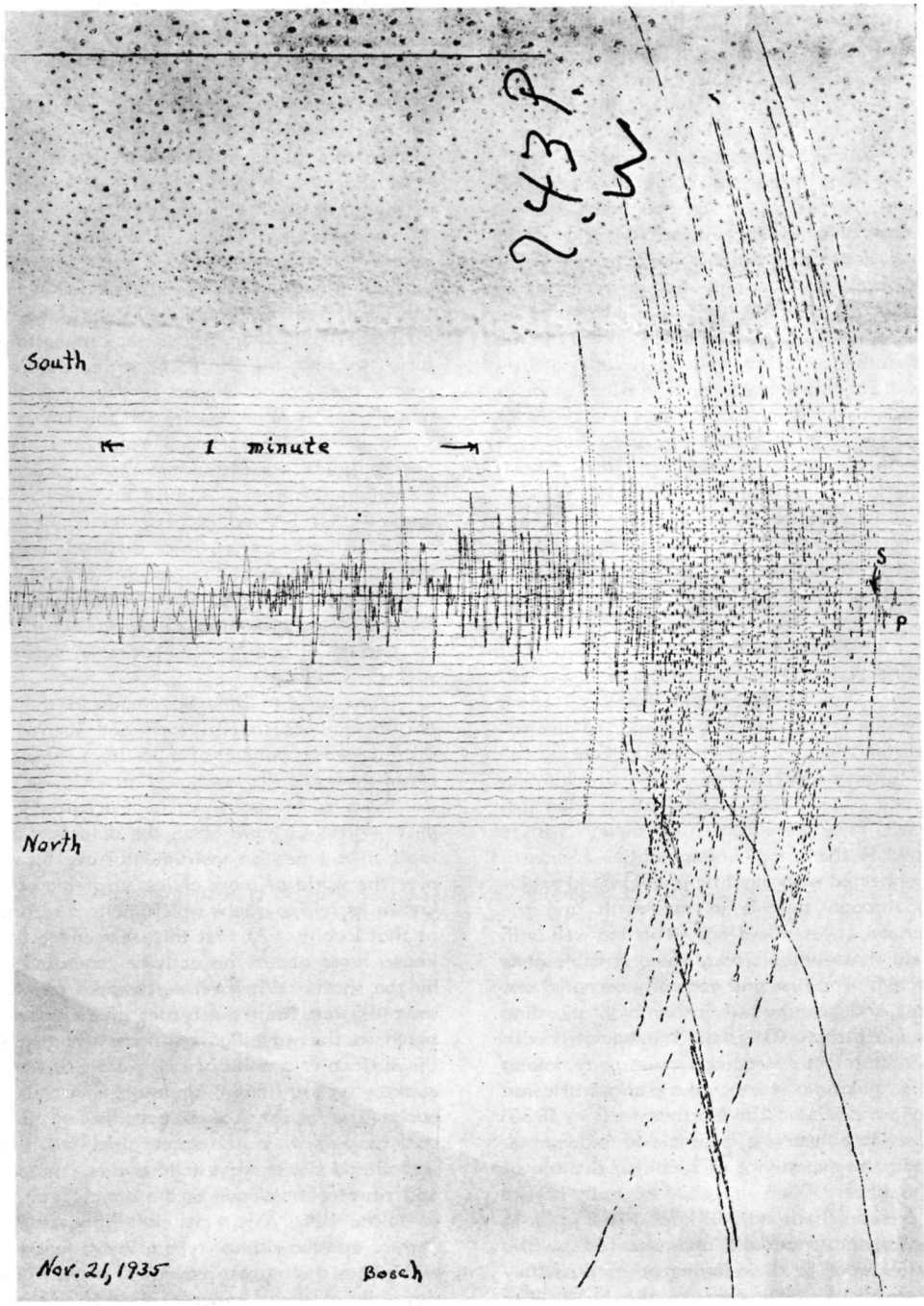

Figure 1.—N. S. component seismogram from Bosch-Omori instrument at the Hawaiian Volcano Observatory, November 21, 1935, 1:11 a.m. Preceded Mauna Loa eruption by seventeen hours.

EARTHQUAKES*

By Hugh H. Waesche, Asst. Geologist, H.N.P.,
Hawaiian Volcano Observatory

A very commonplace phrase or question in Hawaii is, "Did you feel the earthquake last night?" Sometimes there was one, more often imagination has played someone a trick and there was none. We are all earthquake conscious here on this island, and justifiably so, as fairly frequent earthquake shocks are as much a part of the region as are the volcanoes of Hawaii National Park, the City of Refuge at Honaunau or the Black Sands of Kalapana. Hawaii being volcanic, is at the same time an active earthquake center. This condition is true of other parts of the world. It has been discovered that earthquakes occur most commonly in two zones or belts on the earth's surface. One of these zones starts at the southern tip of South America and runs northward following the course of the Andes, passes through Central America, continues through Mexico and the U. S., following the Rocky Mountains, Sierra Nevada and Cascade Ranges to Alaska from where it follows the Aleutian Chain to Japan, passes on to Java and Sumatra of the Dutch East Indies and finally swings back eastward across the South Pacific. The other belt runs diagonally across this one and includes the Caribbean, the Mediterranean Sea, the Caucasus and Himalaya Mountains and the East Indies. It is interesting to note that these two zones also roughly indicate regions of volcanic activity. However, from that relation it must not be inferred that the one is the cause of the other. It would be better to think that both earthquakes and volcanoes are the resulting effects of disturbances or movements in zones of evident crustal weakness. Earthquakes can and do occur in these regions without volcanic activity. Volcanoes can and do erupt without being accompanied by major earthquakes although they usually occur simultaneously with local earthquake shocks, or are preceded by the latter. In Hawaii we often have earthquakes of various intensities without any sign of activity. They are usually located near features of structural importance such as under one of the five volcanic masses of the island or rifts associated with them. How these locations are determined will be described later.

The exact cause of earthquakes is still open to question but is always an interesting point. When a person feels the so-called ground under him shaking violently or possibly rocking like a ship at sea he wants to know what is causing the disturbance. This is a natural reaction and the early Greeks and Romans of the Mediterranean areas who were quite familiar with both volcanoes and earthquakes asked that question just as do their successors. They were contented though with a much more simple, and to them, logical explanation. Some of these explanations, connected with gigantic underground explosions, wind blowing through tunnels in the earth and the caving-in of subterranean caves would not fit in too well with modern concepts along those lines. Today three possible general causes are suspected. The first and generally accepted one is the most important and goes by the rather high sounding name of elastic rebound theory. This type is associated with the making of new fractures in the earth's crust or remaking of old ones such as the making of earthquake cracks in Hawaii in 1868 or a split along the Mauna Loa Northeast rift in 1935. In spite of the name of this theory, it is simple to understand. Most everyone has had the experience of breaking a piece of kindling wood over his knee. When the wood partially breaks with a snap there is a jar in the hand and knee. This jar is in reality a small hand-made earthquake and was felt by the rebound of the pieces of wood to their former position as they snapped back from the bent position across the knee. The bending is the elastic part of the theory name and the snapping back of the wood is the rebound. The same thing happens in most natural earthquakes, large or small, depending on the strength and snap of the material concerned. Stresses tend to build up on either side of a rift or crack in the earth's crust and so continue accumulating until like in the case of the stick of wood—it gives and the ends snap back into position and then everybody says "Oh! did you feel the earthquake?" and the telephone starts ringing at the Volcano Observatory. The second type of earthquake is spoken of as volcanic. Many of these occur around any active volcano and their originating cause is somewhat doubtful. They may be of the same origin as the first-mentioned group, caused by lava and gas pressure changes on the rocks composing the volcano. Explosive volcanic activity likewise results in earthquake movements. Another possibility would be the sudden stopping of a lava column with the same general effect as the jar in a hydraulic ram or the stopping of a weight in a pile driver. Rapidly flowing lava or gas produces earth vibration just as water flowing from the end of a hose nozzle will vibrate one's hand. In any event, although volcanic earthquakes as we all know here, can be quite strong locally, they are seldom felt at a great distance. This is characteristic of such disturbances. An exception was in the case of the great shock in Hawaii in 1868 which was classed as one of world-shaking variety. The elastic rebound type of earthquake first discussed is given the credit for causing practically all major disturbances. Typical examples of this great class are the Charleston earthquake of 1886, the Yakutat Bay earthquake of 1898 when a good-sized mountain range raised itself forty-two feet, the San Francisco earthquake of 1906 where in places the ground slipped as much as twenty feet sideways along the San Andreas rift, and the Tokyo earthquake of 1923 which practically destroyed Yokohama and Tokyo. Most any of the great world-shaking earthquakes one might mention belong to this class. A third and very minor cause of earthquakes is still listed in most textbooks. This theory is concerned with the caving-in of underground openings or caverns. The strong shocks of the New Madrid, Missouri region in 1812 were thought by some to have originated in this fashion. Subsidence of the ground certainly did occur but it would be hard to conceive of underground spaces of sufficient size to produce such disturbances.

From time to time one reads in the newspapers that an earthquake occurred at such and such a place and that its distance was a number of miles from some given locality. Sometimes these reports are based on someone reporting having felt the shock at the point where it occurred or on the basis of its destruction but more often the detection of the quake and its location is based on instrumental evidence. That is, scattered over the world at more or less strategic points are instruments known as seismographs which make a record of the earthquake at that locality. At first this all seems a little mystic until one knows more about the activity generated in the earth's crust by the shock. When an earthquake occurs, waves are set up radiating out from the center of disturbance in all directions much as the waves go out from where a stone or fly strikes the surface of a pond of still water. In the case of the earthquake, three different kinds of waves are started simultaneously. The fastest of these goes through the earth and vibrates back and forth in the same direction in which it moves. A second and slower wave follows the same path as the first type and vibrates crossways to the direction in which it moves just as do the waves on a tight clothesline which is struck sideways. A third and the slowest type of wave follows the earth's surface and makes the biggest movement of all. It, too, vibrates crossways. By means of experiments and mathematical calculations the respective speeds of these types of waves are known and it is this knowledge that makes distances from the earthquake to

* Radio talk, KHBC, Hilo, Hawaii, February 23, 1937.

seismograph stations determinable. Since the first group or longitudinal waves and the second group or transverse waves start together but travel at different speeds they must arrive at some other point at different times with the longitudinal waves arriving first. Tables have been made which show directly the distance a shock is from a station for any given time difference in time of arrivals of these waves. That means that it is only necessary to have some method of detecting and recording the wave movements and then for one experienced to identify the specified waves on the record which must have some time control. The first-mentioned wave travels moderate distances at about seven miles per second. However, as the distance increases the rate also increases. The waves that travel around the surface travel at a constant rate of about two and a half miles per second regardless of distance.

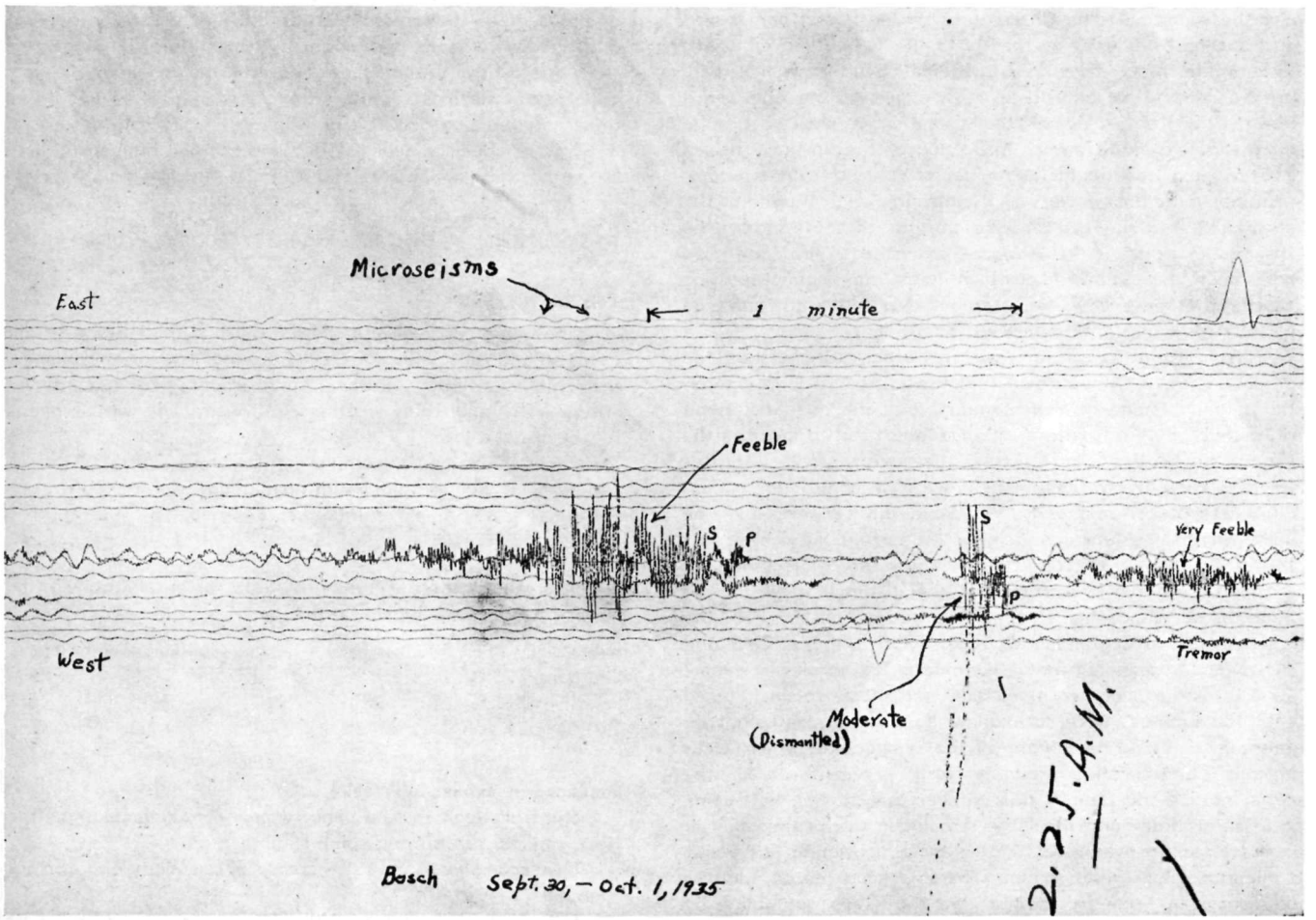

Figure 2.—East-West component of part of earthquake series of September 30-October 1, 1935. Observatory Bosch-Omori instrument, static magnification 115.

Now to return to the seismograph which is the instrument that records the earth's movements, we find a comparatively simple apparatus which nevertheless must be well constructed for proper results. It is a well-known fact that if a heavy object is at rest a lot of extra force is necessary to move it. When a fast-moving car stops suddenly the people are thrown forward, when the car starts the passengers are jerked backward. This is the same property and is known as inertia. No doubt you have all heard that word applied to some people with reason—and for the same reason. Anyhow, it is this property which makes the seismograph work. In these instruments a weight is suspended from a support which is attached solidly to the earth much as is the pendulum in a clock only in this case the earth swings in an earthquake and the weight stays still. Now, if the weight is connected properly to some device which will trace the record of the earthquake on a piece of paper then we have a seismograph. Since earth motions even of strong quakes seldom exceed, at most, a quarter of an inch the motion must be magnified so that the waves may be large enough on the record to study. This is accomplished by either of three methods, first, by mechanical levers, second, by electrical magnification and, third, by light beams as levers. Usually in the most sensitive instruments a combination of the last two is used for distant quakes. At the Volcano Observatory, mechanical levers are used, with magnification of the actual earth movement of about one hundred. Two common methods of registering are used. The first uses a sheet of paper which has been smoked with a kerosene flame, revolving on a drum at a known constant speed and in which a very light steel point attached to the pendulum through the levers draws a line. When nothing happens this mark is straight but zigzags when an earthquake occurs. The other type of recording uses a sheet of photographic paper and a beam of light takes the place of the steel pen of the first type. Magnification in the second type sometimes is as high as one thousand. The movement of the ground in Hawaiian earthquakes ranges between about one one-thousandth of an inch and a tenth of an inch. Remember the one of June 28, 1935, which knocked down a few chimneys and cracked several walls in Hilo? The ground movement at the Volcano Observatory was only slightly more than a tenth of an inch and the earthquake was centered as close to the Park as it was to Hilo. Yes, when mother earth moves even a little bit —and does it rapidly—you are going to know it. That earth-

quake was probably the first official herald of the Mauna Loa eruption in November.

A completely equipped seismograph station has three separate pendulums or instruments. They are usually so arranged that one records only earth movements north and south, another only east and west and the third, up and down. The advantage to this arrangement is that under favorable conditions an earthquake can be located from the one station. This is possible because the first longitudinal wave to arrive will move the pen east or west, another north or south and the third up or down on the record exactly proportional to the direction and intensity. The best recent example was the case of the earthquake of November 21, 1935 (Figure 1) which occurred at one-eleven a.m. and was pretty strongly felt all over the island. At the Observatory the east-west pen moved east one-half millimeter; the north-south pen moved south three millimeters. That meant the earthquake was a little south of east of us, or a little north of west. The time space between the first waves and the second waves showed it to be about nineteen miles away. Inspection of the up-down record showed that the ground had gone down at the Observatory, meaning that the wave was contracting and therefore the earthquake was nineteen miles, slightly north of west from the Observatory right on the Mauna Loa northeast rift about five miles below the summit. Seventeen hours later Mauna Loa was pouring streams of lava from around that spot. But don't be misled—they do not all come out that well.

The Volcano Observatory operates other stations than the one mentioned. It has one at Kealakekua, one at Hilo, one on the southeast edge of Halemaumau and one at Uwekahuna Museum at the Park Naturalist's headquarters. In locating the general run of shocks all of these stations are used. Distances are determined from each and laid off as circles on a map. Lines are drawn connecting the circle intersections and the point where these lines cross shows the earthquake center. But that is not all—by a little descriptive geometry the earthquake is ferreted up to the surface and the distance it was under ground is determined. Preceding the Mauna Loa eruption, the heavy shocks of September-October, 1935 (Figures 2, 3 and 4), ranged as deep as twenty-five miles. The shock of November 21 was not over five miles deep and those which occurred with the outbreak were so shallow that depths could not be determined. By no means are all the earthquakes which occur on this island located. Roughly, forty per cent are located within reason and half of this number are located with comparative accuracy and the large remainder are located only in a general sort of way as a Kilauea shock, a Mauna Loa shock a Hualalai shock, and so on. There is good reason for this deficiency. A large per cent of the shocks do not oblige by having nicely defined wave groups; many are close to only one station so cannot be checked on the others, because they are too weak to record that far away. Sometimes clockworks which rotate drums get stuck, time marks interfere and portions of the quake are lost and if the earthquake is strong and close by, dismantles the instrument before it can make a clear record—and some earthquakes just go by the name of "Maud" and both stubbornly and impudently defy you to locate them, but it makes a reasonably exciting chase at that.

At the Observatory some five different sizes of shocks are recognized as earthquakes. These are very feeble, feeble, slight, moderate and strong. By far the greatest per cent of them are very feeble with feeble a poor second. Both of these are only instrumental and are only felt where they are some distance from the instrument and near an observer. Slight earthquakes are usually felt by many people slightly near their origin. Moderate earthquakes are generally felt all over the island and produce visible effects such as moving objects, rattling doors and the like. A strong quake is anything resulting in some damage and many people frightened. The only really strong shock of the last two years was the one which was previously mentioned, June 28, 1935. Moderate shocks occurred frequently in 1935 averaging about one a month. Outstanding ones were January 2, June 25, a whole series of them, some of which bordered on strong the night of September 30, October 1 and November 21 (see Figures 2, 3 and 4). A still smaller vibration than the very feeble earthquake is one known as a tremor. Some of these last several minutes and always continuously accompany the play of fountains during eruptions. During 1935, 296 earthquakes of all sizes registered at the Volcano Observatory and besides these there were 6,227 tremors. In 1936 332 earthquakes of all sizes registered and only 2,078 tremors. That is an average of almost one earthquake a day—if we assume that the earth rests on Sundays and holidays it looks as though there may be a better average than one a day. I shall leave that for the individual to work out, meanwhile most of the strong earthquakes of 1935 were under Mauna Loa and it erupted; most of the strong ones of 1936 were under or near Kilauea and nothing happened. Let's all watch the earthquakes of 1937 and—what's next?

Hawaiian Volcano Observatory Report for February 1937

VOLCANOLOGY

The month of February showed marked increase of seismic activity, and of opening of cracks around the rim of Halemaumau pit in Kilauea Crater. Microseismic motion continued strong. The cold, rainy weather continued. The winter rainfall has been as follows:

December, 18.93 in., maximum day December 30, 5.12 in.
January, 22.01 in., maximum day January 14, 6.12 in.
February, 20.46 in., maximum day February 18, 4.87 in.

Total 61.40 inches.

The following are the monthly data for observations at the Observatory near Kilauea Crater:

Week Ending	Seismicity	Slides	Crack Openings mm.	Local Quakes
February 7	7.75	3	16.5	24
" 14	9.00	0	23.5	28
" 21	10.25	2	19.5	32
" 28	5.50	3	16.0	12

Sequence of Events by Weeks

The first week showed dense vapor from Halemaumau lava floor, due to rainfall and some sliding there.

The second week showed increase of seismicity and of crack opening.

The third week continued the increase in tremor and slides were small.

The fourth week showed less quaking and crack opening.

Slides at Halemaumau

Slides from the walls of the pit have been noted as follows:

February 2, 10:03 am, a small slide S; 10:08 am, rocks dribbling down NE wall.

February 3, 8:58 am, rocks falling NE wall.

February 19, 10:45 am, small slide NE wall; 5:23 pm, noisy slide N wall.

February 27, 10:08 am, slides NW and N walls.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of—

February 5, 14 opened, 1 closed, opening 16.5 mm.
" 12, 19 opened, 2 closed, opening 23.5 mm.
" 19, 13 opened, 1 closed, opening 19.5 mm.
" 26, 10 opened, 0 closed, opening 16.0 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Local* Seismicity
January 10.....	5	4	0	2	1	7.25
" 17.....	7	2	0	0	0	2.75
" 24.....	4	4	0	0	2	3.00
" 31.....	8	4	1	1	0	7.00

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible determinations of depths of focus have been made:

January 6, 9:13 am, very feeble, located 0.5 mile S of Bird Park area and 4.1 miles deep. 19° 26.2′ N; 155° 18.7′ W.

January 7, 11:35 pm, very feeble, probably located in vicinity of Ahua Kamokukolau.

January 8, 6:53 am, slight, probably located in Hilina Fault system S of Puu O hale.

January 8, 10:56 am, very feeble, probably located in vicinity of Kilauea Iki.

† Includes teleseisms or those shocks over 5,000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

January 10, 10:50 pm, slight, located in Kilauea SE rift zone 2.5 miles SE of Makaopuhi Crater and 7.0 miles deep. Reported felt in Hawaii National Park, in Hilo and at Honomu. 19° 20.5′ N; 155° 9.2′ W.

January 11, 9:06 pm, very feeble, located 1.8 miles NW of the Volcano Observatory and 4.1 miles deep. 19° 26.9′ N; 155° 18.7′ W.

January 13, 9:40 am, very feeble, located 4.1 miles deep under Bird Park area. 19° 26.5′ N; 155° 18.3′ W.

January 20, 9:56 am, very feeble, located 1.1 miles deep near center of Kilauea Crater. 19° 24.8′ N; 155° 16.3′ W.

January 24, 7:31 pm, very feeble, probable location in ocean 20 miles N of Upolu Point. Reported felt at Hilo, Hakalau and Puu Waawaa.

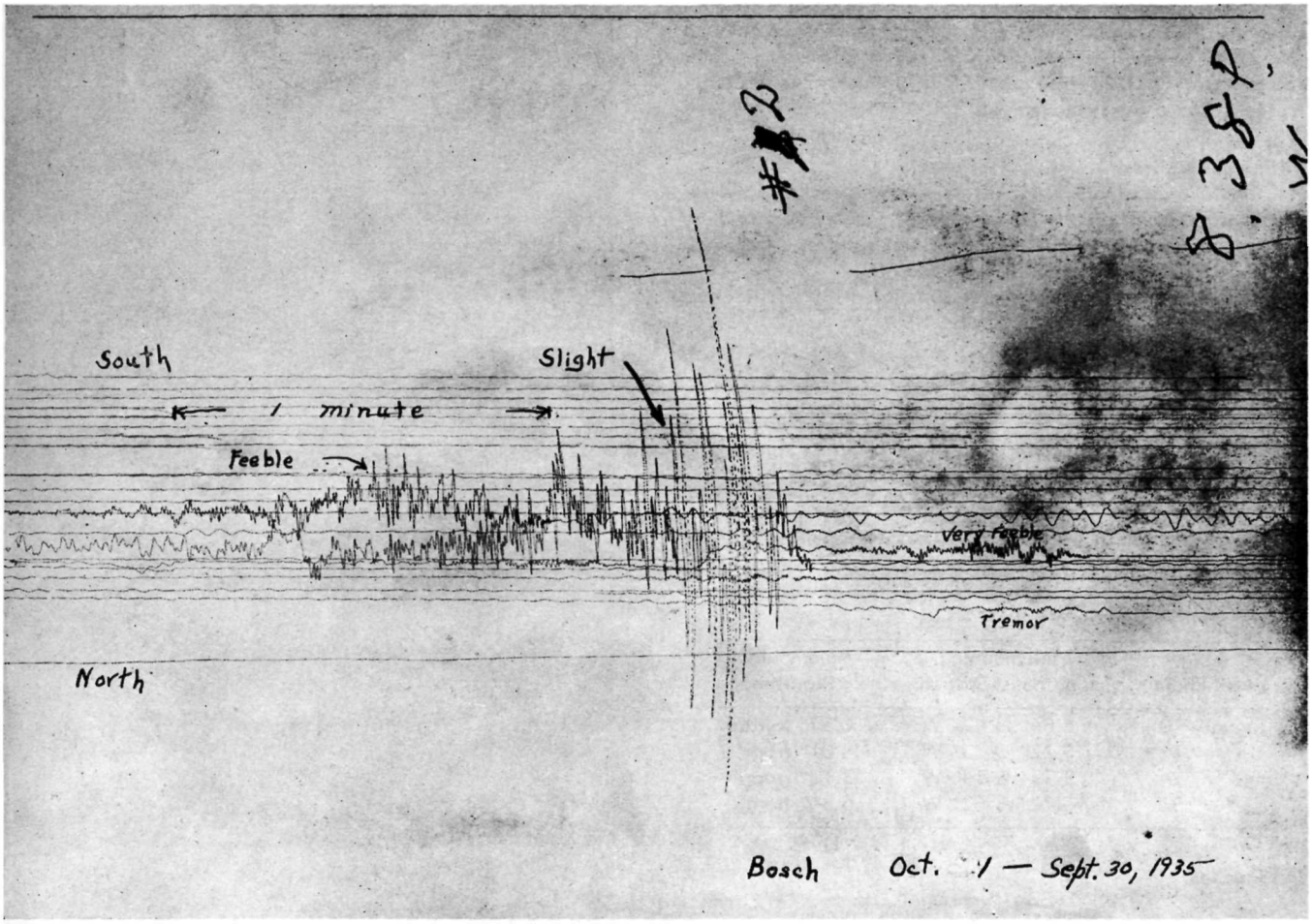

Figure 3.—North-South component of same series illustrated in Figure 2.

January 24, 9:38 pm, very feeble, located 2.8 miles deep, Kilauea SE rift near Hiiaki Crater. 19° 22.6′ N; 155° 14.0′ W.

At 3:39 am, January 25, a disturbance which recorded as a tremor at the Observatory was reported felt at Puu Waawaa.

January 25, 5:37 pm, very feeble, located 13.0 miles deep off coast near Keauhou Point, 4 miles S of Hilina Pali. 19° 15.1′ N; 155° 16.2′ W.

January 28, 6:05 pm, feeble, located 0.5 mile deep in E portion of Kilauea Crater near Byron Ledge. 19° 24.9′ N; 155° 16.0′ W.

January 29, 4:38 pm, very feeble, probably located in Kilauea Crater.

January 30, 4:00 am, very feeble, probably located in Kilauea Crater.

January 30, 11:26 am, very feeble, probable location 14 miles deep in marine extension of Kilauea SW Rift Zone, 5.0 miles E of Palima Point. 19° 9.3′ N; 155° 22.7′ W.

January 31, 7:33 am, slight, located 18 miles deep and 6.0 miles NW of summit of Mt. Hualalai. Reported felt at Hookena and at Kamuela. 19° 45.5′ N; 155° 55.3′ W.

Microseismic motion of the ground at Kilauea was strong throughout the month.

Registration of distant earthquakes at the Observatory was as follows:

January 7, the preliminary waves at 3h 04m 12s am, H.S.T., with a probable focal distance from Kilauea of about 6,100 miles. Radio reports indicated this disturbance as contemporaneous with a strong earthquake in Central Asia. The preliminary waves of a teleseism began recording at 12h 35m 38s am, H.S.T., January 23; estimated distance from Kilauea was 3,720 miles. The preliminary waves of a teleseism began recording at 8h 13m 23s, pm, H.S.T., January 24. Its estimated distance from Kilauea was 3,400 miles.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 31 was 2.05″ S. and 1.57″ W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
January 10	0.44″ S 58° E	5.81″ N 70° W
" 17	1.22″ S 14° E	6.29″ N 78° W
" 24	1.36″ S 8° W	5.96″ N 88° W
" 31	3.92″ S 23° W	6.85″ N 62° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
January 10	6.84″ N 47° W	1.57″ toward
" 17	5.22″ S 75° W	4.01″ from
" 24	3.73″ S 74° W	3.18″ from
" 31	10.72″ S 62° W	5.84″ from

H. H. W.

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Local* Seismicity
February 7	17	7	0	0	7.75
" 14	20	8	0	0	9.00
" 21	23	9	0	1	10.25
" 28	8	3	1	0	5.50

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, a determination of depth of focus has been made.

† Includes teleseisms or those shocks over 5,000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

At 12:23 am, February 1, a tremor was recorded at the Observatory corresponding in time with a recorded Feeble earthquake at Kealakekua. It was reported felt in the Kona district.

February 2, 2:05 pm, very feeble, located 0.5 mile deep, E portion of Kilauea Crater, near Byron Ledge. 19° 24.9′ N; 155° 16.0′ W.

February 2, 8:59 pm, very feeble, a shallow quake located immediately south of Keanakakoi Crater. 19° 23.9′ N; 155° 16.0′ W.

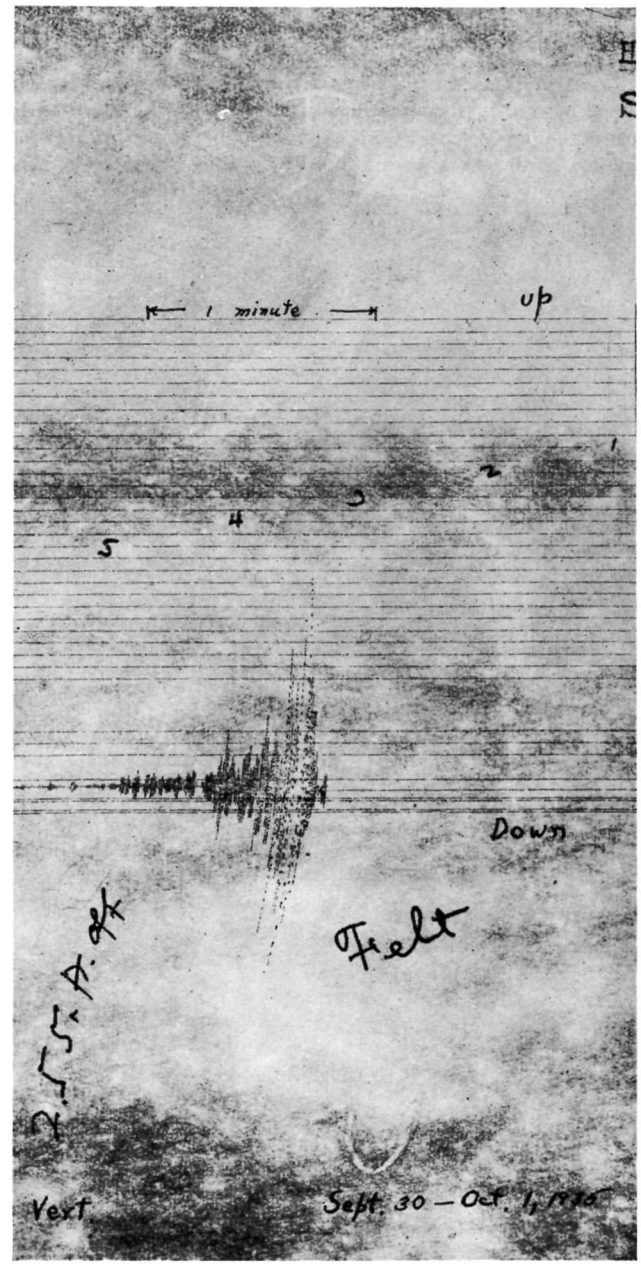

Figure 4.—Illustrates undamped vertical component of largest earthquake shown in Figures 2 and 3.

February 3, 7:13 am, very feeble, located 1 mile deep and 0.4 mile NE Pit Seismograph. 19° 24.7′ N; 155° 16.7′ W.

February 3, 6:06 pm, very feeble, located in Kilauea Rim Crack Zone immediately north of Keanakakoi Crater. 1.2 miles deep. 19° 24.5′ N; 155° 15.9′ W.

February 3, 6:10 pm, very feeble, located 1.5 miles deep in NW portion of Kilauea Crater. 19° 24.7′ N; 155° 16.7′ W.

February 7, 4:22 pm, very feeble, probably located 0.8 mile NW of Kilauea Crater.

February 8, 10:47 am, very feeble, located 1.4 miles deep under SE rim section of Kilauea Crater. 19° 24.4′ N; 155° 16.1′ W.

February 9, 5:45 am, very feeble, located 4.0 miles deep and 12 miles S of Volcano Observatory at Keauhou Point. 19° 15.8′ N; 155° 13.7′ W.

February 10, 12:49 am, very feeble, probably located in Kilauea Crater.

February 10, 6:50 am, very feeble, located 1.2 miles under NW rim of Kilauea Crater in vicinity of Uwekahuna. 19° 25.5′ N; 155° 17.2′ W.

February 10, 12:40 pm, very feeble, located 0.5 mile deep under E rim of Kilauea Crater. 19° 15.8′ N; 155° 24.7′ W.

February 15, 5:09 am, very feeble, located 6.0 miles SE of Puu Ulaula, SE slope of Mauna Loa and 18 miles deep. 19° 29.3′ N; 155° 24.6′ W.

February 16, 3:50 pm, very feeble, probably located at shallow depth near center of Kilauea Crater.

February 16, 4:06 pm, very feeble, located 1.6 miles deep and 3.0 miles E of Kilauea Crater. 19° 25.5′ N; 155° 11.9′ W.

February 18, 2:38 am, very feeble, probably of moderate depth under SW portion of Mokuaweoweo Crater, summit of Mauna Loa.

February 18, 5:20 am, very feeble, located 2.0 miles deep in Chain of Craters Rift Zone, near Devil's Throat. 19° 22.6′ N; 155° 14.0′ W.

February 23, 6:20 am, very feeble, probably located in SE portion of Kilauea Crater.

February 26, 8:04 pm, slight, located 8.0 miles SE of Halemaumau near Hilina Pali and 10.0 miles deep. 19° 20.0′ N; 155° 23.3′ W. This shock was reported felt by many in Hilo and in Hawaii National Park.

February 28, 7:34 am, very feeble, probable location in E portion of Kilauea Crater.

Microseismic motion of the ground at Kilauea was strong throughout the month.

The preliminary waves of a teleseism began recording at Kilauea at 8h 42m 01s pm, H.S.T., February 20. Estimated distance was 3,430 miles.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending February 28 was 5.56″ S and 0.60″ W.

Week Ending	Observatory	Halemaumau West Station
February 7	3.80″ S 32° W	3.81″ N 62° W
" 14	0.85″ S 69° E	5.10″ S 77° W
" 21	2.11″ S 27° W	3.10″ S 67° W
" 28	0.97″ S 4° E	6.88″ N 86° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
February 7	3.24″ S 56° W	3.27″ from
" 14	24.17″ N 32° W	19.06″ toward
" 21	4.11″ S 23° W	5.09″ from
" 28	8.26″ N 68° W	0.54″ from

H. H. W.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, February 25, showed closing of the Halemaumau value and an opening of the Crater value compared with similar measurements made January 21. From Kilauea SE rim to Uwekahuna there was closing of 0.84″, January 21 to February 3; opening of 4.59″, February 3 to February 12, and closing of 1.08″, February 12 to 25. Total opening 2.67″. From the Pit Seismograph to the NW Pit B.M. there was opening of 0.83″, January 21 to February 3; closing of 2.08″, February 3 to February 12, and closing of 2.25″, February 12 to February 25. Total closing 3.50″. H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.


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THE VOLCANO LETTER 445

No. 445 monthly Department of the Interior National Park Service March 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Figure 1. 1935 lava covering trail below summit crater.

MAUNA LOA*

We went up Mauna Loa from Kilauea on March 1st. The party included Mr. Coffman, chief forester of the Park Service, and Mr. Tillett, Superintendent of Territorial Emergency Conservation Work. The Red Hill resthouse was occupied as base.

We walked west two miles and studied the mountain slope towards Humuula. It is an even slope, interrupted by a few cones. In detail it is very rough where aa flows alternate with smooth ones of pahoehoe.

The proposed bank or wall to protect Hilo, across the Red Hill rift, where the flows emerge, will extend obliquely down the mountain north, when it is built. It will take advantage of existing depressions, where they are in the right direction. It will block them where they are not, diverting the stream.

This will create a channel towards Mauna Kea. The barrier would force any new flow obliquely down the slope towards the Hilo-Kona saddle.

There at the saddle the flow would make a lake. East of it on the Hilo side there would be a short high dam constructed. This would be between Puu Huluhulu and Mauna Kea, and it would extend south from Puu Huluhulu to Mauna Loa. It would block off the lava from Hilo.

It would be high enough to hold the lake until it spilled west towards Keamuku. This would protect the Ainahou and Puu Oo pasture land, and the Hilo drainage that supplies water to the city. Damming is practicable only where lava is a flat pool.

* Radio talk, KHBC, Hilo, Hawaii, March 9, 1937, and KGU, Honolulu, April 1, by T. A. Jaggar, Volcanologist, Hawaiian Volcano Observatory.

After the party had looked over this slope, and sized up the possibilities for a roadway from the Rest House down the rift northeast to some large cones, where the wall, five miles long, might start—there is smooth 1881 lava along this route —we spent the night in the Rest House, and the temperature was mild.

Next day against a bitter cold wind we rode up the rift five miles to the upper 1935 cone. This is yellow with sulphur, and steaming. It is one of many in a line. Here on November 21, 1935, the great eruption began.

At that time fountains of golden yellow slaggy foam shot up 500 feet. The whole crack for six miles from the summit crater was gushing. The torrents from it swept in many ribbons down the steep north slope away from the rift.

The liquid so bubbled and stirred itself as to crystallize in sugary lumps and sprouts. This is what is meant by aa lava. Near the actual vents the liquid that congeals is like candy or toffee. This is pahoehoe lava. It may be very stringy like coarse worsted. But its surface of ropes and folds is a natural glass, dark colored because of the iron in it.

The lava inside the mountain is mostly glassy slag with olivine crystals. The transition to aa in a quarter-mile of flowing is due to the boiling out of gases, the violent motion, and the rapid crystallization such as takes place in the centrifugals of a sugar mill.

Accompanying these changes there is great loss of heat. In the first 12 hours of an eruption there is enormous expenditure of energy. The gases are heat makers. Much more gas escapes than lava. The ebullition of gas comes from profound depths. The eruption pulls the cork. The opening of the mountain produces violent gas fizzing due to foaming up. The gas comes from whatever underground lava is relieved of pressure. Probably a big piece of mountain is lifted by the sudden frothing. The effervescence makes the inside lava swell. If you loosen the cork in a beer bottle, and start all the gas, and then try to put the cork back, you must make all that gas dissolve again, or else let it out. The volcano gases are heaters and liquefiers of the slag.

Probably some big force like the settling of the shell of the globe is always forcing the stiff inside lava up these volcano cracks. When the mountain gives way we get an eruption. Right now the lava is pressing up under Kilauea Volcano, the cork will lift, and the lava gas will spout up around the edges of the bottom of the pit.

What made the flow start out of the north flank in 1935? This came a week later than the big initial fountains. And the flow lava emerged from a crack 3,000 feet lower down the mountain slope. The answer appears to be that the internal swelling spreads down a rift belt, an old zone of vertical cracks that extend deep and are full of lava.

The top of the mountain is very heavy. The rift belt goes across the top. When splitting of the rift starts, the swelling lava inside acts as a wedge. The rapid foaming on top shrinks the lava inside as it loses heat and gas. Possibly the plug inside the top crater settles a little. The heavy summit squeezes together.

Down at the 9,000-foot level small cracks can still open in brittle old rock and let out the lowered liquid. It requires an enormous force to lift heavy slag to 12,000 feet elevation. The shrunken lava that has partly cooled glues together the top cracks. This hot paste is very tough like red-hot iron, and old places break more easily. The lower lava escaping at 9,000 feet still has gases heating and expanding it. It quietly welled forth and pushed down to lower places on the mountain. The smooth pahoehoe catches up with the aa, and finally passes the aa front. The movement is slow enough to let the glassy candy float to the top and make skin.

Then a strange and sudden change happens. Where the front that people visit had been a tumbling bed of coals, there quickly appears a gleaming glossy stream covered with beautiful membranes. These skins wrinkle, and festoon and tear and belch out glowing porridge. They puff into elephant toes. The top is silvery or opalescent, smooth and bulbous, flaming with the gas of burning sod below. Inside this crust the liquid has formed a tunnel for itself.

It was this tunnel that made the bombing effective. Let us imagine the water supply to a house under a cliff. The liquid enters the house from a hillside to the third floor. The inside pipe is broken and making a flood in the cellar. If you smash the source pipe and let out the water on the hillside, there will be no more flood in the cellar except for what liquid remains in the house plumbing.

The crusted flow on the mountain was the house. The top story inlet pipe was at 9,000 feet. The aviators of the Army bombed that place and smashed the upper tunnel. The liquid there came out. There was left below only the remnant lava of the plumbing.

With this explanation of the difference between the tremendous initial lava floods of the November, 1935, fountains the first week, and the smooth later flow, let us return to the proposed walls for protecting Hilo.

No bombing could have altered those first voluminous gushings of 1935. They travelled eight miles in a half day! If the lower vent had not opened they might have reached the sea in South Kohala in a week. Just this happened in 1859, a little farther west, for a very long and rapid aa flow.

Suppose such a flood were to burst out at the eastern or Hilo end of the northeast rift. This would be somewhere below Red Hill. It would enter Hilo Harbor in a week. It would burst forth with terrific fountains and might average five miles a day. The distance to Hilo is twenty-six miles. Mr. W. H. Shipman is among the people who can remember back to 1859.

Such lava would be intensely liquid and if it met barricades aligned down hill oblique to its natural course it would follow them. There is no question of damming across it. That is only for flat lakes. The plan is to create an artificial channel in the general direction of the natural slope. There are many natural channels. By taking advantage of them the cost of construction can be reduced.

The final Hilo Wall from Piihonua to Keaukaha is to be on such a natural slope. Its object is to give final protection to the harbor. It must be high enough to catch any flow in the Wailuku or Wailoa drainage valleys and deflect it eastward to the flat lauhala land of the cape south of Hilo Bay.

That land is all old Mauna Loa flows.

This Hilo project takes precedence of the Red Hill and Humuula projects for first construction. But it will not do to trust to the Hilo wall only. There are all the water supplies to protect, and the farms and suburbs and forest reserves. It is never good strategy to trust to one fortress for winning a battle.

The three projects interlock. They should all be started in the next three years. By average intervals, the next Mauna Loa eruption should be ready for outburst any year after 1939. Let us hope that it will be in the summit crater or at some other harmless location!

Mauna Loa in the textbooks is called the most active and bulkiest volcano on earth. Mauna Loa is the center of present-day activity in the Hawaiian Islands. Insurance against Mauna Loa eruptions and earthquakes, and consequent fires and floods, agitates the companies to know what rate to charge. If Hilo is safe the rate will be low. Marine insurance is equally important. Federal dredging to accommodate the biggest ships in Hilo harbor will be influenced by the harbor's safety. If they think it possible Hilo commerce will have to move to Kealake-

kua, the harbor will be less important. The army, the navy and shipping are all concerned. The Volcano Observatory has plans for a seismograph cellar on the Mauna Loa road soon to be constructed by C.C.C. labor. New instruments will be placed around Mauna Loa. Mauna Loa is just now the most interesting of world volcanoes. Hilo cannot afford to join the ranks of the world's disasters.

THE ILLUSTRATIONS

These photographs illustrate conditions at the north end of the summit region of Mauna Loa, as photographed by Ranger P. F. Murray June 15, 1936. At that time the upper cone at the 12,000-foot elevation was still emitting much hot sulphurous fume and yellow sulphur stained the cone. In Figure 1 this cone is beyond the large cone shown, this being a view close to the summit looking down the northeast rift. The trail here was covered for about a half mile with a new 1935 flow of thin shell pahoehoe shown in the foreground. A typical old crack of the rift belt is in the extreme foreground. The source of this flow was about three hundred yards northwest of the summit resthouse, from a crack that was probably the outlet for the 1935 lava lake that occupied the North Bay of Mokuaweoweo. Part of the flow poured down the open crack like the one in the foreground and the trail was covered within the area shown.

Figure 2 shows the 1935 fill of the North Bay, from the summit resthouse. The pahoehoe lava cascaded from a rim crack into the bay.

Figure 3 shows this rim crack in the foreground on the shelf where the resthouse is seated. A new small lava cone about ten feet high was built up only two hundred feet from the old stable of the resthouse. Some of this lava flowed toward the resthouse along the crater wall and disappeared through an upright crack in the wall; the remainder flowed to the right into the North Bay. The filling of the bay had been to a depth of some forty feet, and the pahoehoe surface stands within fifteen feet of the resthouse level. As shown by Figure 3, thin slabs of lava about four inches thick can be seen slumping down the wall crack completely around the north side of the bay from a level approximately fifteen feet below the house. This plainly marked rim crack extends around to the opening from the bay into the main bowl of Mokuaweoweo, according to Ranger Murray.

Figure 4 shows the summit resthouse of Mauna Loa, photographed in May, 1935, of iron and stone construction, and built with Hui o Pele funds.

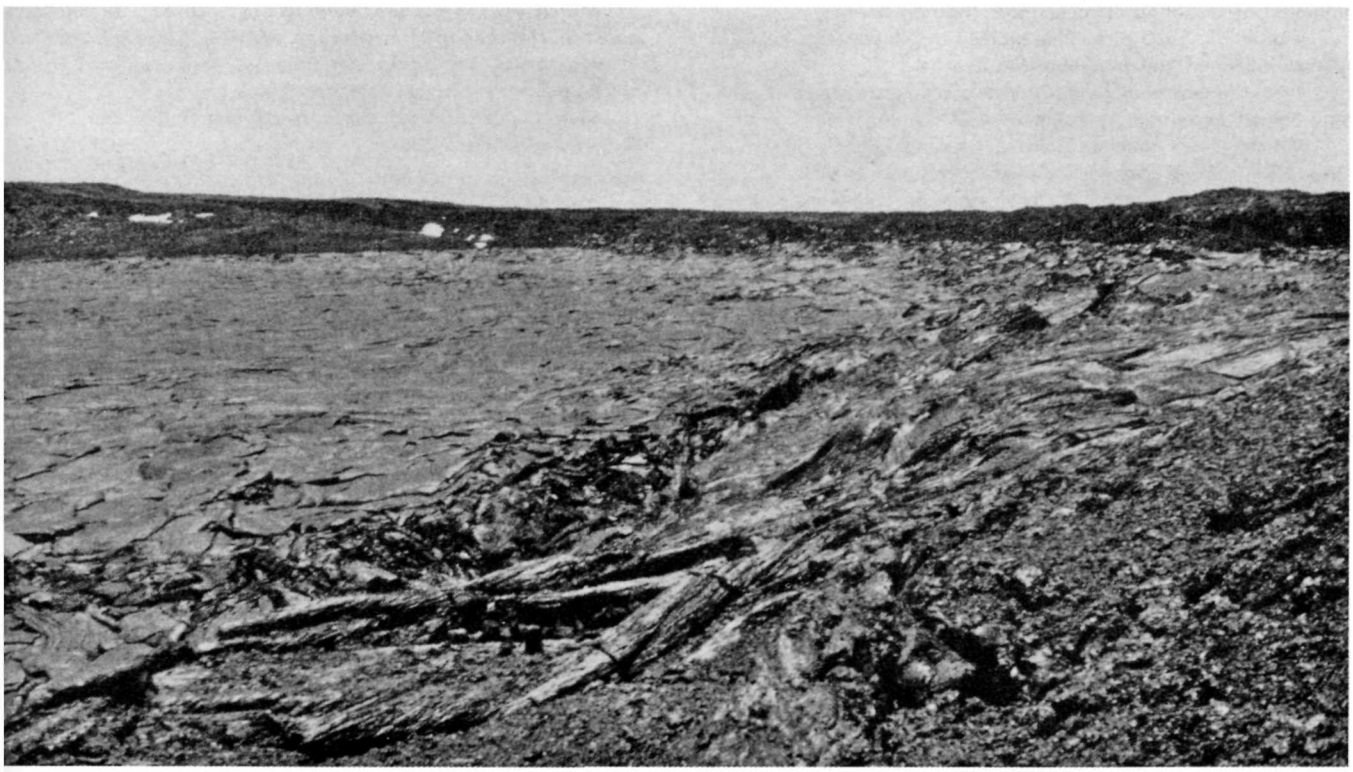

Figure 2. North Bay of Mokuaweoweo from resthouse region. New 1935 lava.

Hawaiian Volcano Observatory Report for March 1937

VOLCANOLOGY

The northeast rift of Mauna Loa was inspected March 2, the upper cones of 1935 were steaming mildly and one of them was stained with sulphur.

The following are the weekly data for observations of the Observatory near Kilauea Crater:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
March 7	11.25	0	23.0	37
" 14	9.50	0	23.5	30
" 21	26.25	5	16.5	69
" 28	13.00	0	14.5	39

There were light earthquakes during the month perceptible at Kilauea and of Kilauea origin. There were three at Mauna Loa distances, and one felt strongly at Kailua, believed to originate east of Hualalai.

Sequence of Events by Weeks

The first week showed quiet conditions at Halemaumau.

The second week no slides were noticed, and blue fumes from the sulphurous patches at the bottom of pit were only slightly in evidence.

The third week, which had the most earthquakes, produced several slides.

The fourth week produced no reports of slides and there was fuming from SE and NW bottom solfataras.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows:

March 16, a fresh scar appeared on NE wall 300 feet below edge.

March 17, slides fell from the end buttress, 10:30 a.m. and 3:40 p.m. The earthquake 12:30 p.m. set going a slide NE, followed by dribbling of rocks more than an hour.

March 21, 5:20 p.m. slide started at NE rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of—-

March 5, 15 opened, 2 closed, opening 23.0 mm.
" 12, 16 opened, 0 closed, opening 16.5 mm.
" 19, 12 opened, 0 closed, opening 16.5 mm.
" 26, 6 opened, 4 closed, opening 14.5 mm.

12 mm. of this was contributed by Crack No. 25, at the east end of the pit. This crack has opened continuously since the heavy sliding of October-November, 1936.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Weekly* Seismicity
March 7.....	29	6	0	0	0	11.25
" 14.....	24	5	1	0	0	9.50
" 21.....	49	16	2	2	0	26.25
" 28.....	36	2	3	0	1	13.00

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible a determination of depth of focus has been made.

March 1, 7:28 pm, very feeble, probably originated in NE portion of Kilauea Crater.

March 2, 1:26 am, very feeble, located 18.0 miles deep under Mauna Loa NE rift zone in vicinity of Puu Ulaula. 19° 32.5′ N; 155° 26.6′ W.

March 3, 8:42 am, very feeble, located deep under SE portion of Mauna Loa 13.0 miles W of the Observatory. 19° 26.0′ N; 155° 27.5′ W.

March 4, 1:24 pm, very feeble, probably originated in NE portion of Kilauea Crater.

March 8, 12:17 pm, very feeble, located 1.0 mile deep near center of Kilauea Crater, 1.4 miles from the Observatory. 19° 25.1′ N; 155° 16.6′ W.

March 9, 6:56 am, very feeble, probable origin under NE rim of Kilauea Crater.

March 10, 3:04 am, very feeble, located in N portion of Kilauea Crater, 0.9 mile deep. 19° 25.7′ N; 155° 16.7′ W.

March 10, 6:05 pm, very feeble, located in fissures at SE rim of Kilauea Crater immediately west of Keanakakoi. 19° 24.2′ N; 155° 16.1′ W.

March 10, 10:09 pm, very feeble, located 12 miles deep, 6.0 miles NE of Puu Ulaula, Mauna Loa NE rift. 19° 35.0′ N; 155° 23.0′ W.

March 11, 7:10 pm, feeble, located 5.0 miles deep under shoreline at Apua Point, 13.0 miles SSE of the Observatory. Reported felt in Hawaii National Park and at Mountain View. 19° 15.8′ N; 155° 11.0′ W.

March 15, 12:41 pm, very feeble, located 1.0 mile deep, SE rim of Kilauea Crater and 0.5 mile SE of Pit seismograph station. 19° 24.0′ N; 155° 16.6′ W.

March 15, 12:50 pm, feeble, located 0.6 mile NE of Pit seismograph station in Kilauea Crater. 0.4 mile deep. Reported felt strongly by many in Hawaii National Park with particular strength at Kilauea Military Camp, N rim of Kilauea Crater. 19° 24.8′ N; 155° 16.7′ W.

March 16, 11:00 am, very feeble, located 1.0 mile deep under SE rim area of Halemaumau. 19° 24.5′ N; 155° 16.9′ W.

March 16, 1:13 pm, very feeble, located under S portion of Halemaumau, 1.6 miles deep. 19° 24.5′ N; 155° 17.2′ W.

March 17, 3:05 am, very feeble, located under NE rim fault zone, Kilauea Crater, 1.0 mile deep. 19° 25.4′ N; 155° 15.8′ W.

March 17, 12:29 pm, slight, located 1.0 mile deep, 0.6 mile E of E rim of Halemaumau in Kilauea Crater. Felt by many persons in Volcano area and to a point 2.0 miles E of the crater. 19° 24.5′ N; 155° 16.6′ W.

March 18, 2:36 am, very feeble, same location as preceding shock.

March 18, 12:10 pm, very feeble, located 16.0 miles deep and 8.0 miles E of summit of Hualalai. Reported felt strongly at Puuwaawaa Ranch and at Kailua, Kona. Dismantled Kona seismograph. 19° 41.0′ N; 155° 44.5′ W.

March 19, 8:39 am, slight, located 1.4 miles deep in fissure zone SE rim of Kilauea Crater and 0.9 mile E of Halemaumau. Reported felt at CCC Camp. 19° 24.4′ N; 155° 16.2′ W.

March 20, 12:15 pm, feeble, located 1.8 miles deep near the Old Stone Corral in Kilauea Crater. 19° 24.8′ N; 155° 16.3′ W.

March 20, 7:13 pm, very feeble, located 1.6 miles deep and 1.2 miles SE of Pit seismograph station. 19° 23.6′ N; 155° 16.2′ W.

March 20, 7:14 pm, very feeble, probably originated in Kilauea Crater about 1.0 mile SE of the Observatory.

March 21, 6:10 am, very feeble, located 4.6 miles deep and 0.9 mile northwest of Cone Peak, Kilauea SW rift zone. 19° 24.0′ N; 155° 19.3′ W.

March 21, 3:37 pm, very feeble, probably located under Halemaumau.

March 22, 10:50 am, feeble, located 1.4 miles deep, 0.4 mile S of Kilauea Iki. 19° 24.5′ N; 155° 15.1′ W.

March 22, 11:12 am, feeble, located 0.4 mile N of Ahua Kamakokulau, 2.0 miles deep. 19° 23.3′ N; 155° 16.2′ W.

March 24, 7:11 pm, very feeble, located in Kilauea SW rift zone, 4.3 miles deep and 2.5 miles SW of Halemaumau. 19° 23.0′ N; 155° 19.0′ W.

March 24, 9:35 pm, very feeble, located 10.0 miles E of summit Crater of Mauna Loa, 7.0 miles deep. 19° 24.4′ N; 155° 32.0′ W.

March 26, 8:29 pm, feeble, located 8.0 miles deep and 7.0 miles S of Kilauea Crater in Hilina Pali Fault System. 19° 19.0′ N; 155° 16.0′ W.

Three minutes of continuous tremor registered March 26, beginning at 5:12 pm.

Microseismic motion of the ground at the Observatory was strong the entire month with the exception of March 25 when it was moderate.

The maximum wave of a teleseism recorded at 6h 37m 39s

† Includes teleseisms or those shocks over 5000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

am, H.S.T., March 25. It was probably associated with reported shocks in California of that time and date.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
REPORT OF THE SECRETARY
ANNUAL MEETING, HONOLULU, 31st MARCH, 1937

To the Members of the
Hawaiian Volcano Research Association*

I have the honor to report upon the work of your association for the year ending at this date.

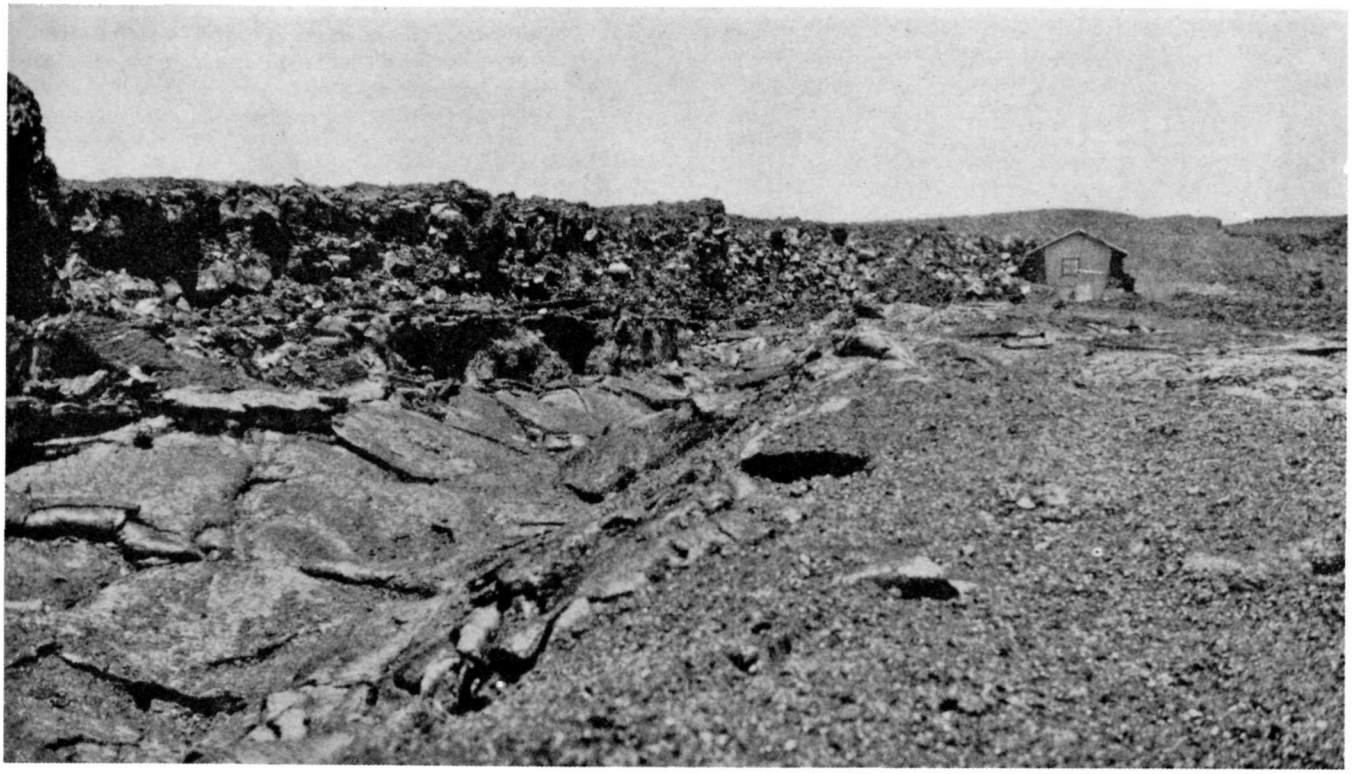

Figure 3. Mokuaweoweo Resthouse.

At the Observatory the total accumulated tilt for the year ending March 28 was 7.83" S and 2.6" W.

Week Ending	Observatory	Halemaumau West Station
March 7	1.23" S 71° E	4.77" N 77° W
" 14	0.94" N 35° E	6.29" N 73° W
" 21	3.33" S 49° W	6.88" N 4° W
" 28	1.42" S 45° W	4.29" S 78° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
March 7	4:15" N 60° W	0.58" from
" 14	7.06" N 51° W	0.99" toward
" 21	13.22" S 35° W	3.90" from
" 28	5.90" N 22° W	1.35" toward

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, March 24, compared with similar measurements of February 25, showed opening of 2.5" across Halemaumau and an opening of 0:41 across the Crater from the SE rim to Uwekahuna.

H. H. W.

A year ago it was announced that a plan was being initiated for cooperation with the University of Hawaii. This plan was carried out and has proved to be helpful and advantageous. The services of Dr. Ballard—an expert physicist—were made available to us through its operation and important work in gas collection and spectroscopic analyses was undertaken. We were also able to add a permanent member to the clerical staff at Kilauea with a resultant saving to the Director of much necessary but time-occupying detail work in the sorting and classifying of documents and correct indexing of the very large number of exchange publications.

This saving of time has made it possible to devote proper attention to our monthly publication, The Volcano Letter, which has now been brought up to date—while the transferring of the detail work of editing and publication to Honolulu office has enabled it to be issued and distributed at the proper intervals.

The Volcano Letter in its enlarged and illustrated format has aroused considerable interest in many parts of the world and it has been gratifying to receive very many most favorable comments upon it. The now historic period, ending with the bombing of Mauna Loa in 1935, has been exhaustively dealt

* At this meeting an address by Dr. Jaggar dealt with the "Protection of Hilo Harbor."

with in this medium—no less than four successive issues having been required thoroughly to cover the subject.

Other publication work has been undertaken, such as an illustrated article upon the "Bombing of Mauna Loa," in the American Military Engineer, and "The Life of Bundjiro Kato" in the Bulletin of the Geological Society of America—both by Dr. Jaggar. A request story of the Mauna Loa incident has been completed by your Secretary in French, for a French-Canadian Journal of international circulation.

ciation of Volcanology which next meets in Washington in 1939.

While at the moment it may be said that the publications and the Observatory plant have been restored to their pre-depression efficiency—it is increasingly evident from the now-existing situation with respect to Mauna Loa that greater responsibilities than ever before are devolving upon this Association. We cannot escape the fact that it is we—as an agency, distinctively Hawaiian but recognized by the world of science

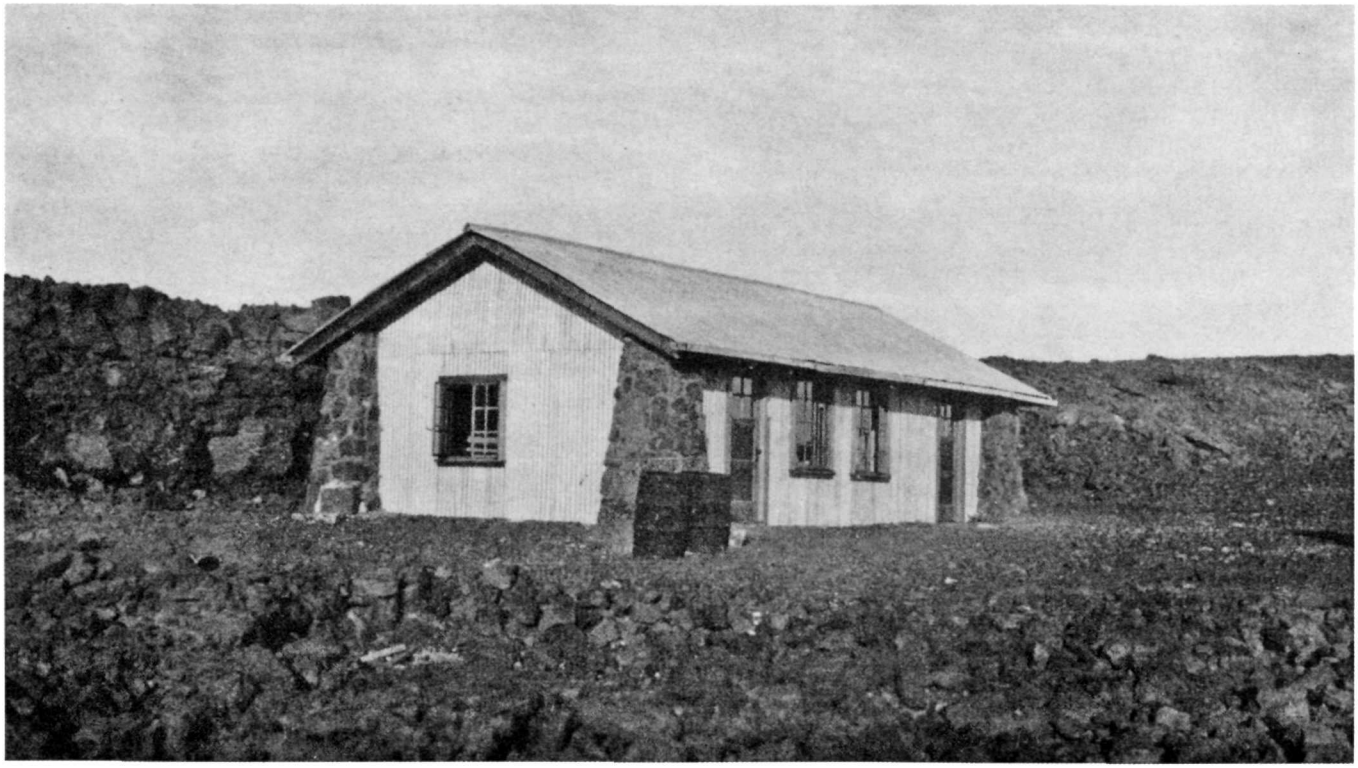

Figure 4. Resthouse, summit of Mauna Loa, constructed with Hui o Pele funds. May, 1935.

While on the subject of Mauna Loa, it may be mentioned that the great lava flow ended on January 2nd, 1936: summit emission of gas dwindled in March, but fuming and deposit of sulphur continued throughout the year. One of the most valuable lessons learned from this eruption by the people of Hawaii was that of the serious menace to Hilo and its nationally important harbor. It is upon this subject that Dr. Jaggar will address you tonight.*

In the spring of the year came an urgent request from the Royal Society of London for Dr. Jaggar to visit Montserrat in the British West Indies to help and advise in a serious seismic crisis that seemed to presage the possibility of a disaster comparable to that of St. Pierre in Martinique in 1902. Accordingly, Dr. Jaggar proceeded thither in April and, after thoroughly examining the situation, formulated a comprehensive program that—should disaster eventually occur—may be the means of saving very many valuable lives. It is of interest to recall that upon arrival in Montserrat, he found a number of Jaggar Shock Recorders were in use by the British authorities —having been made in the Kew Observatory near London. It should also be mentioned that the cost of this expedition was refunded to us by the Royal Society.

Your Association is honored by the election in Edinburgh of Dr. Jaggar as first vice-president of the International Asso-

as a pioneer—who are permanently called upon to direct and foster the progress of volcano research in Hawaii. It is not, as soom seem to think, a function of the Federal Government to educate our community here in Hawaii to an awareness of inimical forces close at hand. It is our function to do all that we can through our publications—and to take the initiative in matters of public safety. We have only to look back to as recent a time as December, 1935, to realize that, had we during the depression shirked this responsibility and been unprepared—a great disaster might have come upon the Territory; and the Federal Government might have been deprived of a harbor that may well prove vital in both war and commerce. It was this Association that saved the Volcano Observatory from extinction in 1934.

The whole question of safety for Hilo and its harbor, which looms large at this very moment, is one that—as we shall presently hear—is already receiving much serious thought in the Department of the Interior; in Hilo, and in Honolulu through the Territorial and other organizations whose interests are concerned.

It is our duty to undertake the initiative, to plan and to direct, and this is being done. Already, under the direction of the National Park Service—the Mauna Loa road—of supreme importance as a means of access to the mountain, is being extended towards Red Hill—a vital, strategic point for future operations—and has been completed by C.C.C. labor for nearly

* See Volcano Letter, January 1937.

ten miles at $5000 per mile. This is probably one of the most economical applications of labor on record in Hawaii.

A Mauna Loa Observatory is of paramount importance to the near future. It will entail staff additions to the Kilauea Station and we must promote the means to take care of it. We are extremely fortunate at the moment in the hearty cooperation extended to us by the National Park Service in Hawaii. Its work during the critical period at the end of 1935 was beyond all praise, and we are hopeful that this cooperation may long continue.

But the lesson of that time has taught us that there is very much to be done and we have but little money with which to do it. We depend entirely upon a continuance of the support which has been so loyally given to us in the past and for which we are profoundly grateful.

A year ago an appeal was made to our members to help us by interesting their friends. While our membership has increased steadily during the year it is noticeable that most of the increase has come from the mainland and from foreign countries. It takes a lot of members at $5.00 a year to produce an income sufficient to enable us to undertake important projects—and it is possible that the very nearness of the people of these islands to all that we are trying to do—blinds them to its real importance. That we have been able to carry on for a quarter of a century, however, is a tribute to the generosity of our community leaders who have done so much to make Hawaii one of America's chief assets.

It is appropriate here to state, for libraries and institutions at a distance, that their memberships in this Association are supporting unique scientific research and publication. They are not merely subscribing to a magazine. The Volcano Letter and technical papers—for numerous recent ones we are indebted to the University cooperation—are efforts to make this research known. The Government through the National Park Service is not financed to publish technical articles. The Association in Hawaii assumes this task. It has been difficult to combine interesting the general public as well as the scientific reader, along with prompt report upon volcanic activity. These three motives have been wrestled with for twenty-five years, with very feeble sinews of war.

This Volcano Research Association in the central Pacific stands for a world study of world processes of nature. Its publications and their indexing are limited by the money available for printing. May our generous leaders in Hawaii soon receive the support that will pay for the printing of numerous manuscripts now filed away, awaiting suitable publication, and the indexing of the serial ones.

Respectfully submitted,

L. W. de VIS-NORTON,
Secretary and Assistant Treasurer.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.


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THE VOLCANO LETTER 446

No. 446 monthly Department of the Interior National Park Service April 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

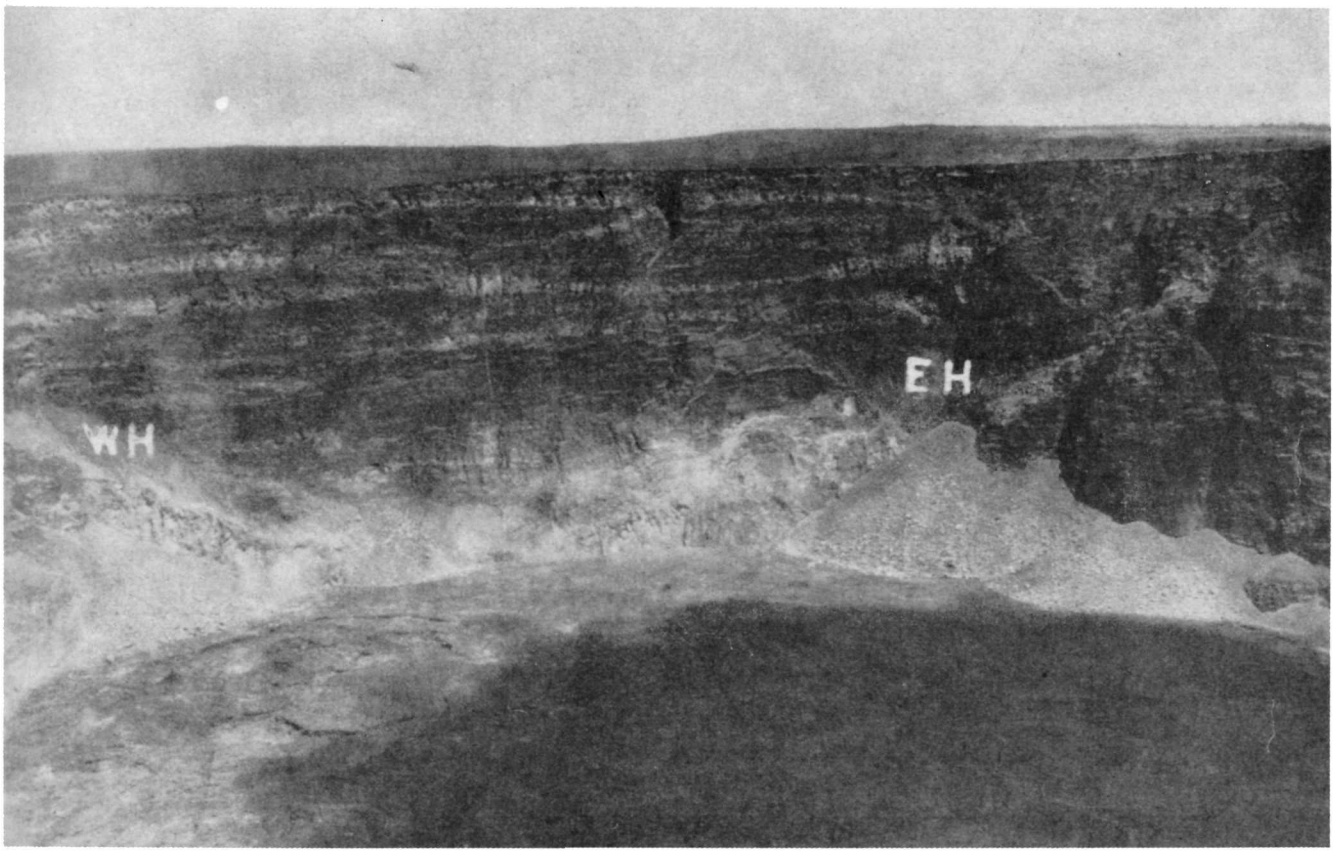

Figure 1. North wall Halemaumau before the landslip: WH the west horn, EH the east horn, of Canoe Sill.

CRACK MEASUREMENT AND TILT AT THE HAWAIIAN VOLCANO OBSERVATORY*

On February twenty-third of this year I had the pleasure of telling you something about the earthquakes on this island, their relation to the volcanoes, how they are detected and how located. It was a long subject to cover in fifteen minutes—in fact, I did not cover the subject in that time but went four minutes over the allotted amount. One might suspect from that state of affairs that earthquake studies took up about all of the time available to the personnel at the Observatory. It is true that the earthquake studies do consume a lot of time and energy, and they are a very important part of volcanologic research but they are by no means the only source of current information concerning the welfare of the volcano. There are other means of feeling out underground movements—not so spectacular but none-the-less important and probably even less ambiguous than earthshakings.

Each week there appears in the local newspapers a report of conditions for the preceding week, ending at twelve midnight Sunday. Among other things, the movement of cracks around Halemaumau and the tilt at the Observatory are reported. Not reported in the papers, but of great interest as significant observations are the results of triangulation and leveling determinations.

On the floor of Kilauea Crater and surrounding the rim of Halemaumau and roughly concentric to it, are a series of cracks. These cracks vary in width and depth from a few inches to several feet, and from some there issue considerable heat and steam. Every Friday morning two members of the

* Radio talk, KHBC, Hilo, Hawaii, April 6, 1937, by Hugh H. Waesche, Asst. Geologist, Hawaiian Volcano Observatory.

Observatory staff make a round of the pit and measure with a millimeter steel tape certain selected, marked localities along these cracks. The marks are copper studs on which are cut crosses for accurate reference. These studs are either cemented to or driven into the solid rock forming the respective sides of the crack toward or away from the pit. Thus, by regular measurement every appreciable movement may be and is detected. Gases and lava pressing up under the crater floor should open the cracks whereas a recession of lava and lowering of gas pressures should cause the cracks to close. It is possible also that tidal forces in the earth caused by moon and sun relationships may cause some changes in the cracks. Another factor, for individual cracks. The latter curves are comparatively smooth and show that as the time approaches for a section of the rim to give away and fall into the depths below, the rate of opening increases more and more rapidly, or is accelerated.

In March, 1936, thirty-two crack localities were being measured. In March of this year only twenty-six were being measured. One crack at the northeast triangulation station gave way during the latter part of March last year. A new one was established twenty feet further back. This one was doomed to a short life. It disappeared with five others along the northeast and east rim of the pit last October and November. One crack, the famous number forty-six, began to show movement

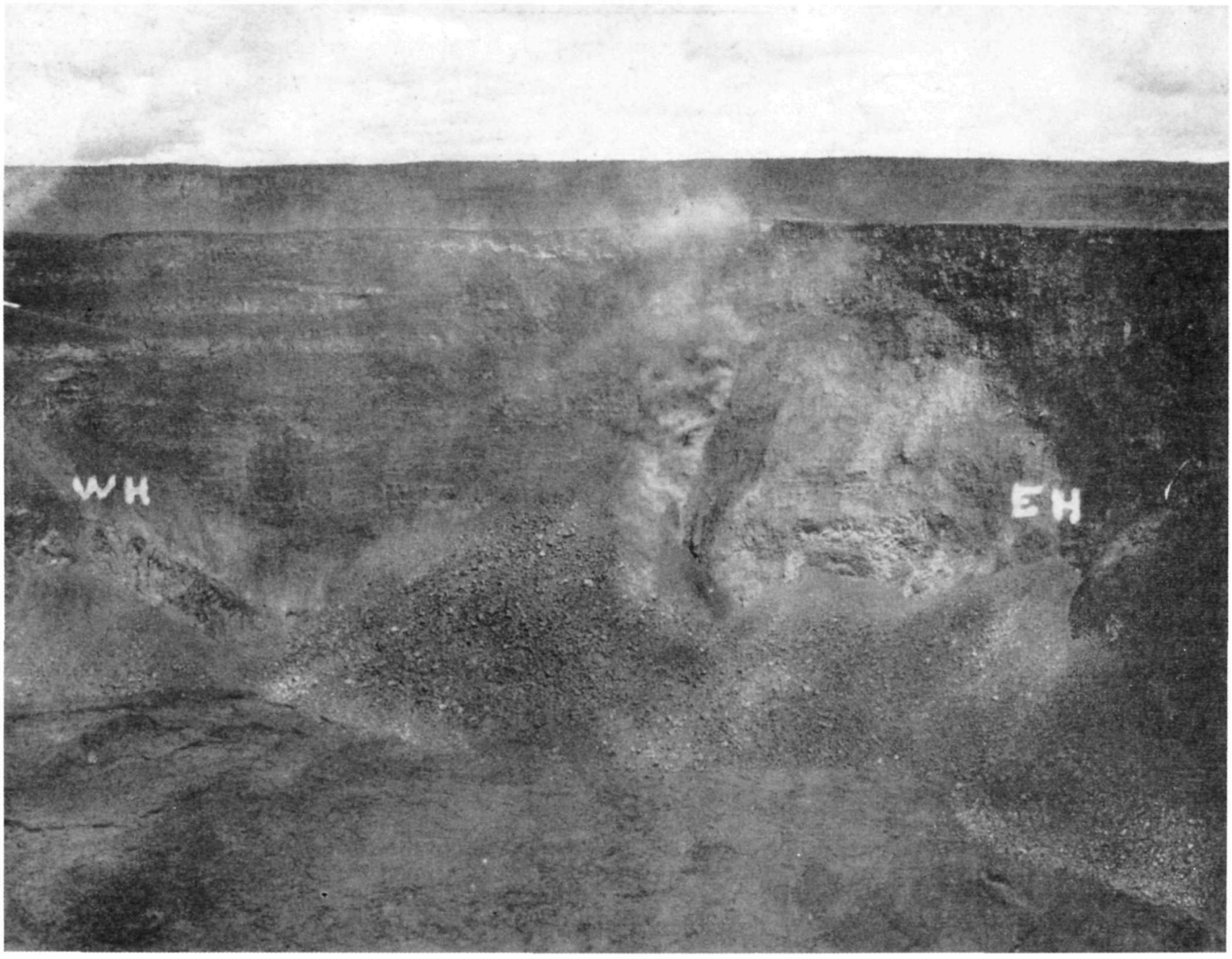

Figure 2. After collapse, October 22, 1936.

near the rim of Halemaumau, is undoubtedly the force of gravity ever tending to pull the large rim blocks bounded by these cracks, into the pit. Because of regular measurement of cracks indicating comparative movement the likelihood of material sliding in large amounts from certain localities around Halemaumau rim is known well in advance. The large slide of October twenty-second of last year was heralded by excessive crack opening, and a month before this occurred, the northeast area of the pit rim was wired off and warning signs were put up. The results of the crack measurements are plotted up on the basis of percentage opening for the total which makes an irregular curve and on the basis of actual amounts of opening of a definitely progressive nature over a year before it fell in with the other just referred to. It opened by ever-increasing amounts, a total of thirty-six centimeters or approximately a foot and a half in about twenty-two months. In the last month alone, it opened ten centimeters, or about four inches, and this crack was nearly two hundred feet back from the rim. On Tuesday afternoon Naturalist Lamb and myself were taking pictures of the region. Thursday morning, October twenty-second, the ground where we had been was at the bottom of Halemaumau and the north side of crack forty-six was the rim of the pit.

Generally speaking, all of the measured cracks have opened

by varying amounts continuously during the period following the Halemaumau eruption of 1934. One exception is number forty-one, about eight hundred feet southwest of the pit. It has shown no change in the same time period. At present, crack number twenty-five on the east rim is moving most rapidly and some large rock falls from that portion of the pit should be imminent and are anticipated.

One of the earliest established and probably one of the most significant branches of routine research at the Hawaiian Volcano Observatory is that related to what is referred to in reports as tilt or tilting of the ground. This action, although well identified, is by no means too easy to measure. At the Observatory and at Halemaumau tilt is measured by the wanderings of the seismograph pens, with relation to a fixed value recorded on the smoked seismograph drum. Also, tilt around Halemaumau is measured by a special apparatus known as a clinoscope. Two of these are now in operation, one on the southeast rim, and one to the west of Halemaumau. A third instrument was located northeast of the pit but was disrupted by an earthquake. It is the earthquake situation which makes tilt measuring difficult here. The problem is to have an instrument as sensitive as a seismograph, of high magnification, which would be inexpensive but accurate, and earthquake proof. In Japan a partial solution, at least, seems to be a sealed horizontal pipe, about half full of water with means of measuring changes of level of the water at the ends of the tube.

Tilt has been defined by Dr. Jaggar and R. H. Finch as "a change in angular relation between a portion of the earth's surface and the plumb line." A plumb bob suspended from an arm on a tall flagpole should illustrate this by the bob swinging to or from the pole, or sideways as the ground tilted, thus changing the angle of the pole with relation to the horizontal. If it were possible to attach a pen to the top of the flagpole and this pen wrote on a sheet of paper which was permanently fixed to the sky in its position, then the pen would trace a picture of the tilt graphically on the sheet of paper, the size of the drawing depending upon the height of the pole, the taller the pole the larger the drawing.



Figure 3. Crack No. 46 looking north before landslip.

Something of this nature is done at the Observatory. No flagpole is used but measured daily tilt on the Bosch-Omori seismograph is transcribed to a sheet of coordinate paper. Since the two pendulums of the seismograph are oriented north-south and east-west, these directions are used and all component directions resolved therefrom and a picture of what the top of the flagpole would have done is shown. It has been discovered that the ground on the northeast rim of Kilauea makes an

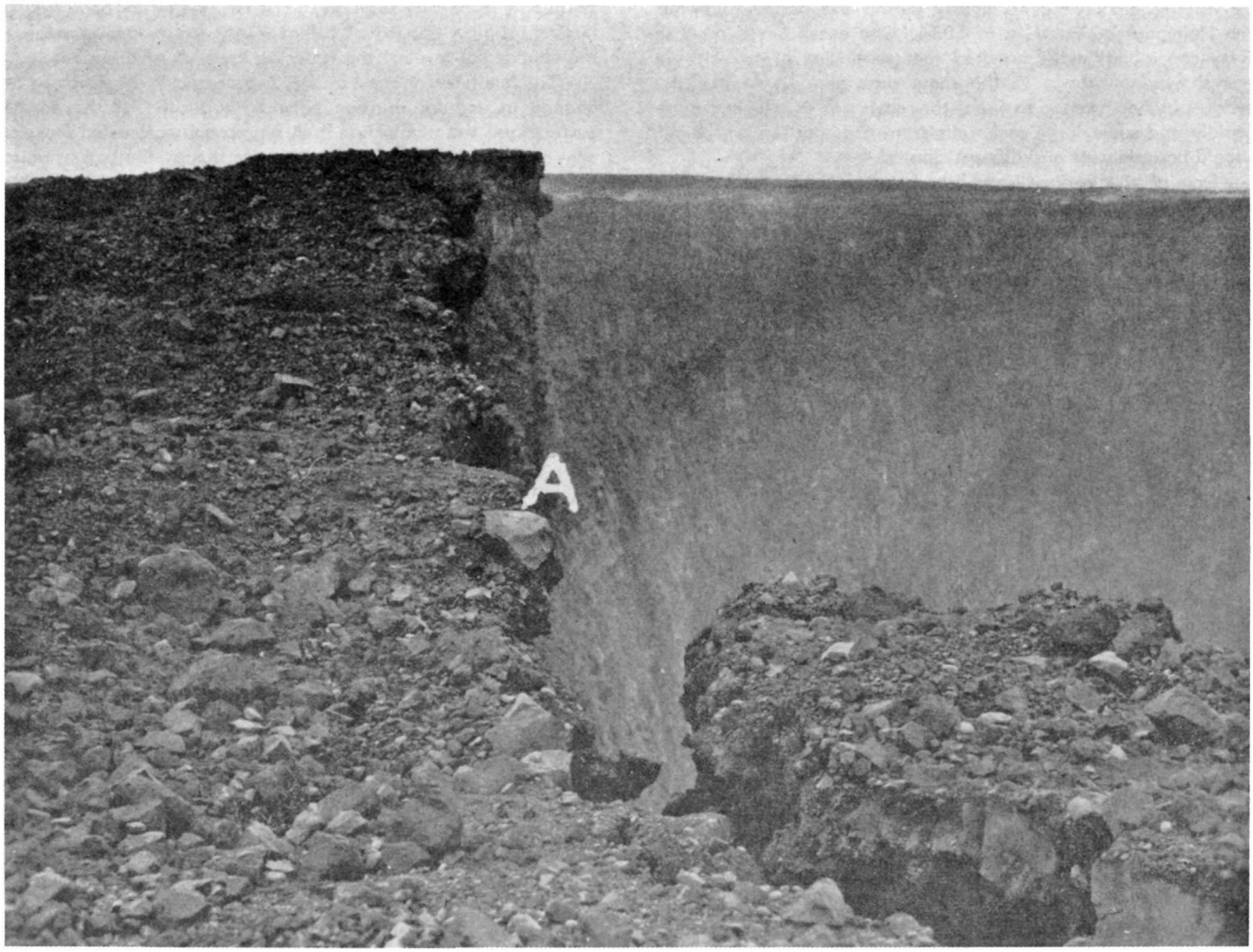

Figure 4. Crack No. 46 looking south after landslip (man in Figure 3 would be in air beyond A).

annual loop as much as twenty seconds of rotational arc for the greater diameter which runs northeast, southwest. Minor irregularities and loops occur in the major annual loop. Marked directional tilts have occurred preceding eruptions both of Kilauea and Mauna Loa. In the first week of October, 1935, tilt at the Observatory began to move, following the vigorous earthquakes of September thirty-October one, in a southeasterly direction and continued to do so until November seventeenth, when the tilt direction changed back to the northeast and on November twenty-one Mauna Loa erupted, thus relieving the pressure which had tilted the ground some two or three seconds at the Observatory. The tilt resumed its normal trend and made its usual annual loop in 1936. So far this year the tilt has moved slightly west of south very rapidly, necessitating adjustment of the seismograph to take care of the change quite frequently. However, this movement seems to have slacked up now and little tilt of any kind has occurred in the past week or ten days. What this may mean is a little uncertain but may mean considerable lowering of downward pressure under the crater.

The clinoscopes previously referred to as located around Halemaumau are quite different from seismographs. They consist of a circular heavy mass of iron suspended from a tripod frame supported by piano wires. The mass is damped by a tank of oil in which it moves. Thus, the arrangement is that of a plumb bob or pendulum attached to delicate levers and pivots which extend up in the tripodal frame. At the end of the light lever or boom is a point which approaches the face of a target-like indicator. This target indicator is graduated into concentric circles with a separation of two millimeters. From the center point are radiating lines corresponding to the cardinal points of the compass. The migration of the lever pointer indicates tilt by amount and direction. The magnification of the clinoscope has been previously calculated so that actual angular and directional daily tilts of the ground may be plotted graphically just as in the case of the seismograph at the Observatory. Since the clinoscopes are on widely separated portions of the pit rim, and the direction of the center of the pit is known with reference to the tilt stations, it becomes possible to resolve the components in such a way as to determine the radial tilt to or from the pit. Tilt toward the pit should indicate lowering in that direction accompanying decreased pressures with the reverse being true of tilting from the pit.

Dr. Jaggar and Mr. Finch in 1929 described tilt records and results for the thirteen years from 1913 to 1925 inclusive. Their very interesting conclusions will bear repeating and are as follows:

"1. Seasonal tilts of twenty seconds or more in a half-year

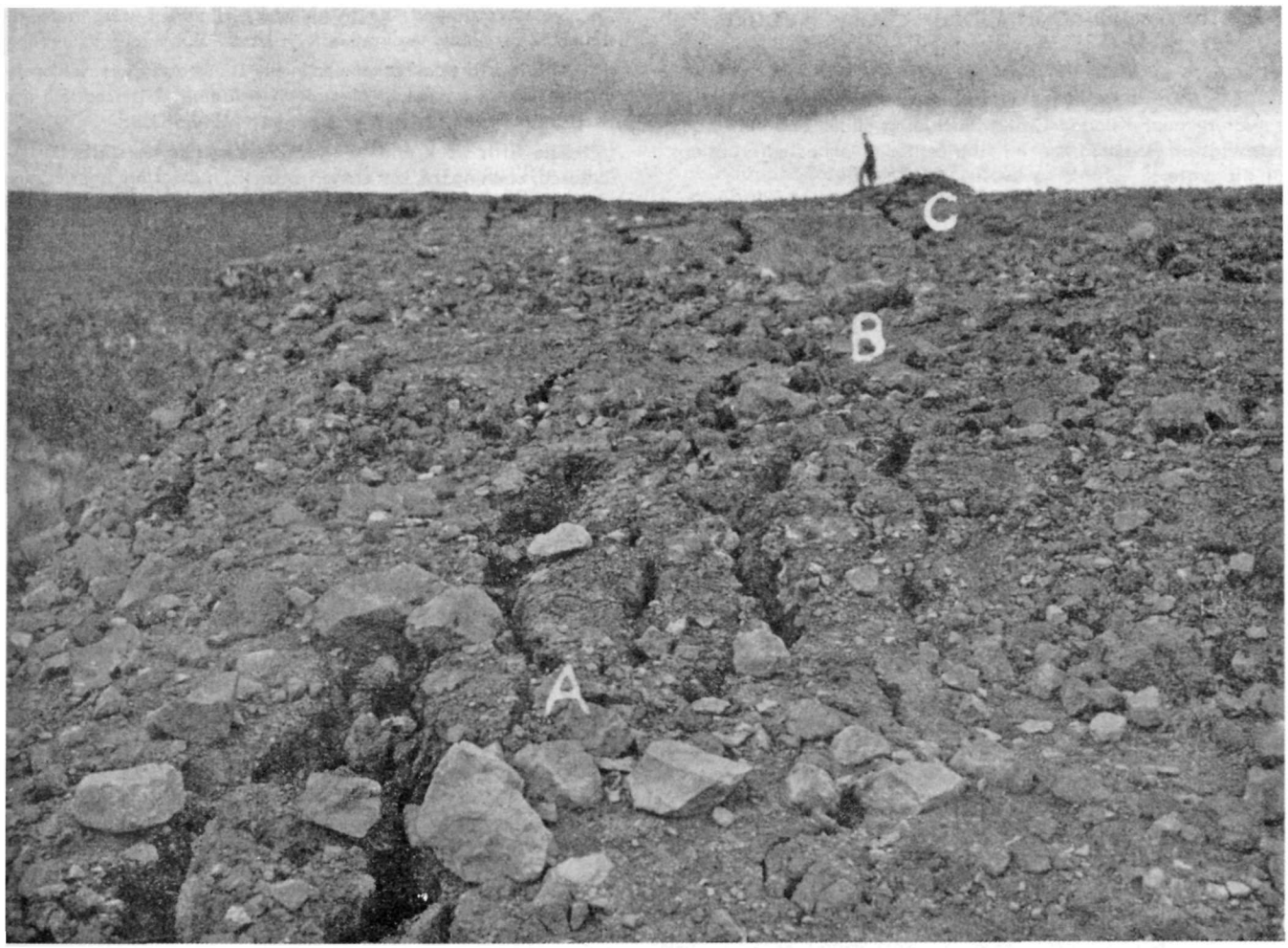

Figure 5. Before notch caved in 5:54 a.m. October 22 (taken October 20).

vary with air temperature, easterly tilts corresponding to cold months, westerly tilts to hot months.

"2. The range of angular tilting per half-year is greater when measured gushing up of lava is greater. The gushing up of lava and easterly tilting have been regularly greater in autumn and winter.

"3. There is practically no correlation between tilt and rainfall.

"4. Between 1913 and 1920 there was a northeasterly tilt of about eighty seconds accumulated at Kilauea, and an elevation of about 0.6 meters in the central part of the mountain, diminishing apparently to zero in a radius of ten kilometers. This was a partial eruptive cycle, characterized by rising lava.

"5. Between 1920 and 1926 there was a southwesterly tilt of about ninety-three seconds, accumulated at Kilauea and a depression at the central part of the mountain (distinct from collapse at the pit) of about four meters, diminishing in a radius of twenty-two kilometers to 0.09 meters. This was an extraordinary half-cycle of lava subsidence plus explosive eruption with engulfment.

"6. The total void computed from the engulfment and subsidence data is approximately 757 million cubic meters, of form suggesting the evacuation left by an intrusive sill of about thirty kilometers radius, swollen in the center.

"7. Local earthquake frequency and centripetal tilt accompany lava subsidence, otherwise there is little correlation between tilt and earthquakes.

"8. There is perfect correlation between Kilauea lava movement and Mauna Loa lava movement, whenever the Kilauea lava pit is not sealed. The east-west tilt curve exhibited accumulation of easterly tilt preceding every Mauna Loa eruption. The north-south tilt curve followed consistently the overflow and subsidence phases of Kilauea. These facts agree with the position of the instruments, north of Kilauea and east of Mauna Loa.

"9. Explanation of the correspondence between easterly tilt and lava gushing, on the one hand, and winter atmospheric mean lower temperature, on the other, is difficult. Two possible explanations are: (a) that solar heating in the summer checks volcanic radiation, whereas outward conduction is stimulated by the winter cold; (b) that a winter solstice tidal effect acts on the east-west fissure of the Hawaiian ridge, owing to a solar pull southward on the great mass of the ridge and on the equatorial protuberance. this might produce trigger stress for winter effervescence and tumescence, if the lava sponge below were in nice adjustment for gas-pressure release. Possibly both (a) and (b) work in concert."

If I may talk to you again at some future date, I should like to tell about level and triangulation values in the vicinity of the local volcanoes with corroboration of their action by volcanoes in other parts of the world.

Meanwhile, don't lose patience with Pele—Kilauea is going to erupt. However, I am glad this is a radio, so no one can ask me "when". Thank you.

Hawaiian Volcano Observatory Report for April, 1937

VOLCANOLOGY

The following are weekly data for observations of the Observatory near Kilauea Crater, including slides and rim-crack openings of Halemaumau Pit, the center of expected eruptions of the crater:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
April 4	25.00	1	25.0 mm.	75
" 11	30.75	6	34.0 mm.	89
" 25	15.50	5	44.5 mm.	42
" 28	13.25	10	28.0 mm.	42
May 2	12.50	2	47.0 mm.	46

Slides continued the third week, 7 quakes were from Kilauea, 2 probably Mauna Loa, 1 at Hualalai.

The fourth week continued noisy slides and increased opening of eastern cracks, 4 quakes including a perceptible one were at Kilauea, 2 were probably at Mauna Loa.

The fifth week ending May 2 showed fewer slides but increased opening of an eastern crack, indicating approaching collapse of that rim. A distant earthquake released a prolonged local tremor April 29. Eight quakes were from Kilauea, two probably Mauna Loa.

Slides at Halemaumau, and fumes

Slides from the wall of the pit have been noted as follows:

April 4, 2:50 pm, small slide made dust east.

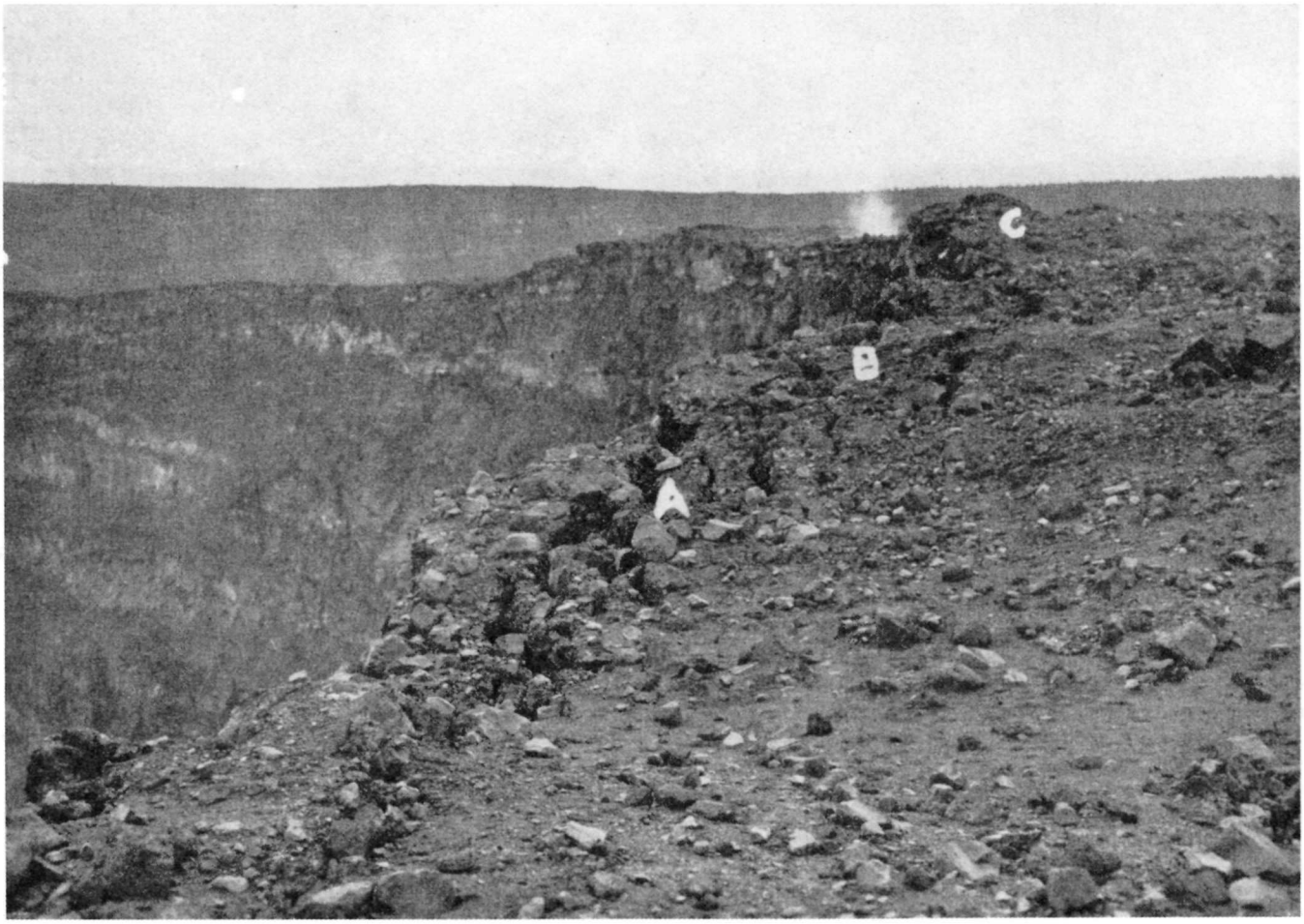

Figure 6. After the caving in, taken October 22.

Of felt earthquakes there were two in the feeble class, April 1 under Pahala (felt at Hookena), and Kau Desert, one under Hualalai felt strongly at Puuwaawaa ranch and otherwise generally felt April 18, and two April 30 at Kilauea.

Sequence of Events by Weeks

The first week ending April 4 had the Pahala shock and one reported slide at Halemaumau. There were 13 Kilauea quakes, four at northeast Mauna Loa rift, and one at southwest rift Mauna Loa.

The second week had numerous slides at east wall of Halemaumau, 15 quakes at Kilauea, 7 at Mauna Loa, including 2 stronger ones.

April 7, morning showed small slides had left scars on wall 400 feet under east cliff.

April 8, slides making dust NNE and E 12:38 pm, 1:05 pm, 1:10 pm, with rumbling heard at Uwekahuna, dust continuing to 1:20 pm. Intermittent dribbling of rocks 2:00 to 3:30 pm.

April 10, similar dribbling east 9:57 am. Fuming from solfataras at edges of floor was slight, becoming visible after April 9.

April 12, 3:20 pm, slide made dust cloud NE.

April 14, 3:25 pm, another at same place.

April 15, 11:47 am, slide made loud rumble, no dust.

April 16, all day 9 am to 5 pm, rock slides N and E, a noisy one sending up dust 11:30 am.

April 18, SE solfatara sent up conspicuous blue fume along with vapor of excessive humidity, noted 3 to 4 pm.

April 21, 9:57 am, small noisy slide NE.

April 25, 9:49 am, moderate slide NE after two small earlier ones, and followed by a large noisy slide 9:54 am, making dust cloud.

April 26, scars showed recent slides, and a small slide made the sound of falling rocks heard at Uwekahuna 11:30 am, and sent up dust.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of—

April 2, 12 opened, 2 closed, opening 25.0 mm.
" 9, 14 opened, 0 closed, opening 34.0 mm.
" 16, 10 opened, 3 closed, opening 28.0 mm.
" 23, 8 opened, 1 closed, opening 44.5 mm.
" 30 9 opened, 3 closed, opening 47.0 mm.

On April 23 two cracks close to the east edge contributed most of the opening: No. 24 5.5 mm., No. 25 36.0 mm., and these are behind rim blocks of rock extending southward the edge that collapsed in October, 1936; they are going to fall soon. On April 30, crack No. 25 contributed 42 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
April 4	56	16	3	0	0	0	25.00
" 11	67	20	1	0	1	0	30.75
" 18	31	9	1	0	0	1	13.25
" 25	36	5	1	0	0	0	12.50
May 2	35	8	1	1	0	1	15.75

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, a determination of depth of focus has been made.

March 29, 7:53 am, very feeble, probably located in Mauna Loa NE rift near Puu Ulaula.

March 29, 9:15 am, very feeble, located in Kilauea Crater.

March 29, 6:52 pm, very feeble, located in Kilauea Crater.

April 1, 5:31 pm, feeble, located in the vicinity of Pahala near the Kaapao Pali, and 20.0 miles deep. Reported felt in Hookena, where buildings creaked and hanging objects moved. 19° 13.3′ N; 155° 30.2′ W.

April 1, 6:49 pm, feeble, located 3.7 miles deep under Kalanaokuaiki Pali 1.3 miles SW of Puu Ohale. 19° 20.7′ N; 155° 17.8′ W.

April 3, 9:30 am, very feeble, located in vicinity of Kipuka Puaulu (Bird Park), 3.8 miles deep. 19° 26.5′ N; 155° 18.3′ W.

April 3, 10:55 am, very feeble, probably located under N rim of Kilauea Crater.

April 4, 1:52 am, feeble, located 0.5 mile west of Puhimau Crater 1.5 miles deep. 19° 23.7′ N; 155° 15.5′ W.

April 4, 8:10 am, very feeble, located 4.5 miles NW of the Observatory 1.4 miles deep. 19° 28.6′ N; 155° 18.9′ W.

April 4, 11:59 am, very feeble, thought to have been located in Chain of Craters area SE of Kilauea near Hiiaka Crater.

April 4, 5:11 pm, very feeble, probably located in SE portion of Kilauea Crater near Keanakakoi.

April 4, 11:41 pm, very feeble, of Mauna Loa origin.

April 5, 6:18 am, very feeble, probable location, Kilauea SW rift 0.7 miles NE of Cone Peak.

April 5, 9:47 am, very feeble, thought to have been located in Chain of Craters area, near Devil's Throat.

April 5, 10:57 pm, very feeble, located in Mauna Loa NE rift near Puu Ulaula and 18.0 miles deep. 19° 30.5′ N; 155° 29.0′ W.

April 6, 12:37 am, very feeble, located 1.5 miles W of Puhimau Crater and 0.5 mile SW of Kilauea Crater, 4.2 miles deep. 19° 23.7′ N; 155° 16.5′ W.

April 6, 11:15 am, very feeble, located 5.1 miles deep and 1.2 miles east of Kilauea Iki Crater. 19° 24.8′ N; 155° 13.5′ W.

April 6, 4:46 pm, very feeble, located 4.2 miles deep and 2.0 miles W by N of Uwekahuna. 19° 26.0′ N; 155° 19.8′ W.

April 7, 12:18 am, very feeble, located in vicinity of Lua Manu Crater 2.4 miles deep. 19° 24.1′ N; 155° 15.6′ W.

April 7, 9:51 am, very feeble. Probably located 2.3 miles SE of pit seismograph.

April 7, 11:02 pm, very feeble, located 4.2 miles deep in Kilauea SW rift zone near Cone Peak. 19° 21.9′ N; 155° 19.3′ W.

April 9, 12:18 am, very feeble, thought to have been located under Halemaumau.

April 9, 7:29 am, moderate, located near seacoast at Apua Point 3.0 miles S of Hilina Fault system and 7.0 miles deep. 19° 16.3′ N; 155° 12.2′ W.

April 9, 5:46 pm, very feeble, probably located in Kilauea SW rift, 3.8 miles from Halemaumau.

April 10, 9:24 am, very feeble, probably located 0.5 mile NE of Kilauea Crater.

April 10, 1:21 pm, very feeble, located 2.8 miles deep in Chain of Craters area near Hiiaka Crater. 19° 22.6′ N; 155° 14.0′ W.

April 11, 2:52 am, feeble, located near Mauna Loa NE rift 3.5 miles S of Puu Ulaula, 13.0 miles deep. 19° 29.4′ N; 155° 29.3′ W.

April 12, 7:38 pm, very feeble, located 2.4 miles deep near Lua Manu Crater. 19° 24.1′ N; 155° 15.6′ W.

April 13, 7:03 am, very feeble, located in rifts 0.4 mile N of Puu o Hale, 1.5 miles deep. 19° 21.5′ N; 155° 16.6′ W.

April 13, 8:33 am, very feeble, probably located 1.5 miles NE of Kilauea Crater.

April 15, 6:28 am, very feeble, located in cracks near NE rim of Keanakakoi Crater, SE portion of Kilauea Crater. 19° 24.2′ N; 155° 15.1′ W.

April 15, 6:21 am, very feeble, thought to have originated in Kaapo Pali near Pahala.

April 17, 12:14 am, very feeble, of Kilauea Crater origin.

April 17, 2:17 pm, very feeble, of Kilauea Crater origin.

April 18, 2:44 am, very feeble, located 1.2 miles deep under Byron Ledge, SE rim of Kilauea Crater and 1.0 mile east of Halemaumau. 19° 24.6′ N; 155° 15.9′ W.

April 18, 4:10 am, feeble, originated under Hualalai Volcano. Reported felt at 29.0 miles on Volcano Road, Hilo, Kamuela, and very strongly at Puu Waawaa Ranch House.

April 18, 8:50 pm, very feeble, probably located 1.5 miles E of Kilauea Crater and 1.0 mile S of Kilauea Iki.

April 19, 5:59 am, feeble, located under SE rim of Kilauea Crater, 1.2 miles deep. 19° 24.5′ N; 155° 15.5′ W.

April 20, 4:08 pm, very feeble, probably located in Hilina Fault zone N of Apua Point.

April 21, 11:59 pm, very feeble, probably located in Mauna Loa NE rift about 5.0 miles NE of Puu Ulaula.

† Includes teleseisms or those shocks over 5000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

April 23, 4:08 am, very feeble, probably located in Chain of Craters area near Devil's Throat.

April 30, 3:08 am, very feeble, located 0.7 mile deep near center of Kilauea Crater 19° 24.9′ N; 155° 16.3′ W.

April 30, 3:40 am, slight, located 0.8 mile deep near E edge of Keanakakoi Crater SE portion of Kilauea Crater. Reported strongly felt at the CCC Camp, felt at 29.0 miles on Volcano Hilo Road and dismantled pit seismograph. 19° 24.2′ N; 155° 15.9′ W.

April 30, 9:29 am, feeble, probably same location as preceding.

April 30, 12:35 pm, very feeble, thought to be of Kilauea origin.

May 2, 5:26 pm, very feeble, 5:27 pm, very feeble, and 5:29 pm, very feeble, all thought to be of Kilauea Crater origin.

Four minutes of continuous tremor began recording at the Observatory at 9:06 am, April 29.

Microseismic motion of the ground at the Observatory was strong throughout the month except from April 25 to 30 inclusive and April 18, when it was moderate.

The preliminary waves of a distant earthquake began to register at Kilauea at 4 hr. 39 min. 25 sec. pm, H.S.T., April 15. It was estimated to have occurred 2,700 miles distant, probably in Alaska. The preliminary waves of a teleseism began recording at Kilauea at 8 hr. 29 min. 41 sec. am, H.S.T., April 29. It was estimated to have been 3,560 miles distant.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 2, was 8.47″ S and 0.76″ W.

Week Ending	Observatory	Halemaumau West Station
April 4	1.64″ N 45° E	3.37″ N 60° W
" 11	0.73″ N 51° W	6.05″ S 76° W
" 18	1.11″ S 37° W	5.54″ N 67° W
" 25	0.17″ S 44° E	5.22″ S 73° W
May 2	1.17″ S 31° W	4.32″ N 71° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
April 4	7.23″ N 3° W	3.32″ Toward
" 11	4.47″ N 27° W	1.59″ From
" 18	4.99″ N 3° E	1.04″ From
" 25	6.48″ N 53° W	1.90″ From
May 2	3.95″ S 42° W	4.68″ From

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, April 21, showed slight closing of both Halemaumau and Crater values compared with similar measurements March 24. From Kilauea SE rim to Uwekahuna there was closing of 1.75″, March 24 to April 8, and opening of 1.67″, April 8 to April 21. Total closing 0.08″. From the Pit Seismograph to NW Pit B.M. there was closing of 2.00″, March 24 to April 8, and opening of 1.66″ April 8 to April 21. Total closing 0.33″.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

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Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Figure 1. Rim of Kilauea fire-pit falling in as lava below escaped to the submarine slope 1924. The collapse alternated with explosions of steam. An earth event limited to a single month.—Photo by Tai Sing Loo.

TRENDS IN THE PHILOSOPHY OF SCIENCE

T. A. Jaggar*

By the philosophy of science is meant the definition of its motives. What has a group of scientists in common? How has the motive of their labors changed in a hundred years since Darwin and Faraday worked? Whither are we bound, and what are the boundaries, in the professions called scientific?

Science is said to be any knowledge that appraises data with logic and care, and uses the method of classifying, generalizing, induction and deduction. But this would apply in some measure to literature, education, languages, history and economics.

The modern meaning of science is limited to the nature sciences, for which the earth is the chief subject, with its kinsfolk the stars, and its products and processes including man himself.

Language is the chief instrument of science, including mathematics, which Willard Gibbs defined as a language. Observation and experiment are the chief activities. Application to human service, and the reform of that service to man's benefit, are the chief goals of science.

Language, the chief promoter of science

It is curious there is no chapter on "language" in Karl Pearson's "Grammar of Science". We learn much of the unreality of matter, force, space and time, "intellectual concepts describing our perceptual routine". We learn about constructs, ejects, contingency and correlation. We are told that science lives upon inference and is a classification and analysis of the contents of the mind. But not a word appears to show that those contents, in the form of thinking, are what Watson calls "sub-vocal talking". An important eject is "other-consciousness", which must agree that two normal perceptive faculties construct practically the same universe. But do we always agree to this? Similarity of perceptive and reasoning faculties depends on a common thought-language.

This point appears frequently missed. Language, mathematics, and logic are not science. But they are the stuff without which science could neither be conceived nor conveyed. Clearly written and spoken language is at the root of accuracy. If you cannot say what you think, you cannot think what you think you cannot say.

Take the subject of forecast. Science is the study of nature; **natural** universe, earth, force, life; origin, progress and future of each of these. Do not omit the future. Science is the first human craft to treat prophecy without superstition. Prophecy based on measured accuracy is the supreme test of science. Astronomy can understand a Babylonian eclipse in the light of mathematical forecast, a new language. Truthful history by its cycles may illumine prophecy. Language by its structure is itself history. What is "prophecy" but the Greek for "speaking before"? It is important to know the history of mother-tongue, and to talk and think foreign tongues.

If we say "inevitable" we are using a French word. Our word "passenger" is not identical with "voyageur". We have no word to connote "geschwister", meaning either brother or sister. We have no word such as an imaginary "menwo", meaning either men or women; "persons" or "people" is not an identical sense. "Onto" is not good English, but is a needed word. We have "widen", but we have no "smallen". "Scientist" hardly includes the ladies, and "men of science" certainly leaves them out. Such are the limitations of thinking.

One can be scientific in speech without language being a science. One can be mathematical in business without business being mathematical. One can be either qualitative or quantitative in science, without science being mathematics. So in the scientific laboratory one can be humanistic, artistic, businesslike or religious. But language is supreme in reasoning, and needs history and all scholarship for scientific use.

"The American Language" by Mencken shows how Americans are remodeling the thinking of the British empire by their straight-shooting lingo. Such language remodels thought and science. Illustrations of vividness are the phrases "What is your reaction?" and "That is not in the picture". The pencil or blackboard chalk illustrates the incessant use of pictographic language in science: we cannot explain without a map, curve, section, formula or sketch as we talk or think.

It may seem strange to stress the importance of words. The diplomats have an expression, "finding a formula". If they had "found a formula" August 1, 1914, the difference might have been to avoid the Great War. Writing science that is understood by the people may get suggestions for progress from a hundred minds; illustrations are the camera, telescope, and radio hobbies. How different this is from the jealousy for priority in Europe. "The best test of the truth", wrote Mr. Justice Holmes, "is the power of the thought to get itself accepted in the competition of the market".

Does science spend as much effort over its phrases as it does over its differential equations? Does it consider the comparative value for progress, of writing a sound newspaper editorial rather than a technical paper? Does it compare the outreach, in selling the goods, of spoken thought compared with the printed word? Spoken speech is creating classes for adults all over the world, because of the realization of our slovenly voices and use of words that people get from listening to radio. Radio is itself a means for propagation of the gospel of science.

Our technical memoirs are long, boresome and addressed to specialists. Difficulties of reading and abstracting, and photographic methods of filing, mean that the short paper has come to stay. The scientist counts on these to sell his goods, but technical terms hide scientists even from each other. Even school teachers have a jargon of technicalities, ratings and curves along with I.Q., P.Q., Hi/Y and as many alphabets as a British army corps. The passion for abbreviation in America is only exceeded by invention of words; realtor, cosmetician, groceteria, mortician, and lubritorium. Non-mathematical scientific papers might sometimes, in the same space, be made intelligible. Remember that mathematics is a different language.

University teachers, in my own experience of Munich, Heidelberg, and Harvard, defeated their own sciences for me as a budding student. Rosenbusch set me to work on one felspar crystal all summer, when I wanted petrography of field rocks. Groth fascinated me with mounted crystals, but I ought to have had association of minerals in nature. Germanized, I returned to Harvard and wrote a doctor's thesis designed to test the abrasion hardness of a large number of crystalline minerals measured with a microscopical instrument that I invented. Result, my Harvard professors said "a mere instrument would not be enough for a doctor's degree", and dissipated my efforts on a double thesis adding a field subject in geology. Here everything turned on the wrong interpretation of three words, "a mere instrument". It all threw me out of mineral collections, and into volcanic craters.

Science is learning the power of speech on the public. Commerce, engineering and industry employ all our sciences in advertising: right there by clear and forceful speech science may educate commerce, engineering and industry.

Experiment, the chief activity of science

In my youth Audubon was my ideal as a scientist, motionless for hours watching wild turkeys in the forest, sketching and painting them, and combining system and art in large

* Address at Hawaiian Academy of Science, Honolulu, May 6, 1937.

volumes of colored plates. Darwin extended this idea to breeding experiments with domestic turkeys. Faraday, Darwin and Pasteur established experiment as the final arbiter of science.

Probably ninety per cent of my audience are laboratory people. Even when your constructive work is in the field, as in the innumerable branches of engineering that have grown up since Audubon's time, you make laboratory tests before you act. Engineering is the most important scientific application in the world today. Vital sciences have been taken in as the soul and body of commerce, including industrial psychology, physical chemistry, biology, preventive medicine and public health, meteorology and radio. Even experimental ethics and social service are commercial sciences. This is a far cry from the lonely impoverished French artist watching the bird in the wet jungles of Louisiana.

Science holds men and women because today it is interested in people and action. It produces results. Engineers are interested in designs, professors in research, merchants in growth of service, sea-captains in increased efficiency, doctors in visible cures.

The old geology, zoology, botany, chemistry, physics and astronomy are being replaced by geophysics, biometry, experimental physiology, electro-chemistry, atomic physics and astrophysics.

Medieval science mingled art, religion and science. We have learned to separate the compartments, the experimental field today is unlimited, and the method involves a quest of objective proof in America, started by Benjamin Franklin using common sense, and willing to tackle any subject from thunderstorms to volcanoes.

Just a word about the old physics of the nineteenth century, which considered solids, liquids and gases in motion, at controllable room temperature and pressure as the subjects of investigation. We human beings, and the soil we dwell upon, are solids, liquids and gases in motion. We are constantly told that the old physics thought it had nothing more to discover. We are practically told by the atomists that, as organic human subjects of bio-physics, unless we can be agitated at high voltage as a rarefied gas, we are not interesting.

This appears to me to be pure hokum. The nineteenth century never had such complacency. There was never a time of such immense foresight and development as from Faraday, through Clerk Maxwell, Elihu Thomson, Hertz, Kelvin, Helmholtz, Roentgen, the Curie Family, and J. J. Thomson. Look at the other sciences, Humboldt, Lyell, Darwin, Haeckel, Huxley, and Bergson the philosopher: Virchow, Koch, Pasteur, and Osler: and in America, Rumford, Gray, Newcomb, Dana, Rowland, Agassiz, father and son, and Welch. The twentieth cen-

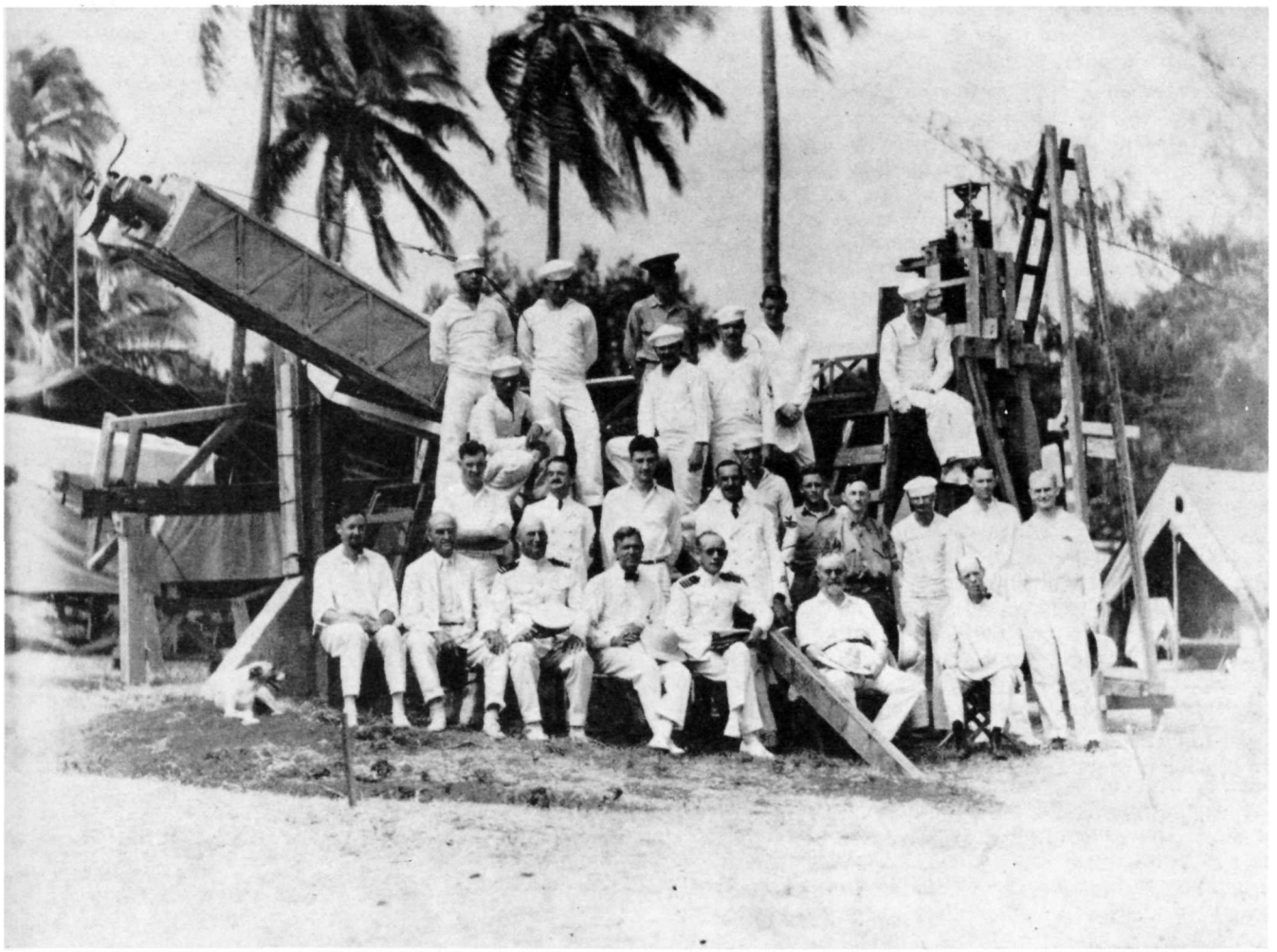


Figure 2. An expedition travels 12,000 miles for a single earth event—to photograph an eclipse of the sun—Navy Expedition, 1930, Niuafoou Island.

tury has barely scratched the surface with a few mathematical philosophers who are primarily linguists groping for ultimates. Otherwise we are working through corporate laboratories rather than individuals. This is good, but there is no sense in decrying the nineteenth century, nor in forgetting that our own seventy kilograms of flesh on solid rock has a problem apart from high voltage.

Reform, the chief goal of science

As science has become increasingly serviceable, so has it become less selfish. Stoddard has said "those peoples who first grasp and act upon the basic principles of the new knowledge will rightfully be the heirs of the future". Who will do it, the Germans, Italians, Russians or Americans? Reform has been disguised as research.

The twentieth century outlook on science has been jolted by the War and the Depression into seeing the need for more practical results, and the conquest of the world by extroversion. Here is a case of a new **word** for successful personality, the soul that opens outward instead of inward. We may have extrovert people, laboratories, cities, factories and nations. In this century the Wrights, the General Electric and Eastman Laboratories, the Peking Medical Center, Henry Ford, the Carnegie Institution, Rockefeller Medical Research, the Mayos, the Cancer Research Laboratories, and the Brookings Institute are all working on a theory of competitive donation. The Nobel and Cecil Rhodes Foundations and others are doing the same in Europe, Africa, Asia and South America.

Our government is extrovert, following upon the vague beginnings of the Monroe Doctrine, our missionary wars, the Open Door, and the Bryan and Kellogg Pacts. The South American pact and the Neutrality Law are a direct heritage of Woodrow Wilson. His League of Nations may seem eclipsed for the moment, but its scientific commissions are at work all over the world, and youth is arrayed against the armament trust. The present employment agencies and large engineering enterprises of the American government are extrovert science. Look over the list, and remember it is not confined to America. Public health, engineering, social security, public housing, slum clearance, agricultural relief, flood control, economic sciences, eugenics, home economics, home workshops, and adult education; add to this forestry, the great irrigation projects, the Tennessee Valley Authority, and the proposal to change the name of the Department of the Interior, which originally exploited our land in Audubon's time, to the Department of Conservation; and you have a world that would certainly astonish Andrew Jackson. Our extrovert government is opposed by the ancient acquisitive society of business. But science is responsible for our social consciousness of our kind. If psychology does what insurance has done, it may develop a cooperation of all science to higher accuracy, and higher truth than physics and mathematics.

The three fundamental concepts of all science are uniformity, evolution and value. Possibly evolution, uniformity, symmetry and rhythm are in Nature herself. Probably value and number are wholly human.

A tremendous gain over the nineteenth century is that physics, psychology and biology have all learned to distrust mechanism and to welcome positive liberalism. The intuitive of emotion, art, religion and philosophy, the elegance, symmetry, rhythm and universality of these cultures are more and more welcomed by science. Cosmopolitan demands will no longer allow science to dwell in a monastic cell.

Glenn Frank says that all laboratories have socially usable ideas that would lift the tone and temper of modern life. Our universities must dig up and put out the usable social ideas buried in each laboratory. Social science explores human nature for truth, searches for new ways, studies the "how", tests and "sees if", and finds out "whether". If your laboratory has an utterly new and usable idea, some island council should make you extrovert about it.

The Earth, the chief subject of science.

If you are studying the tonsils or teeth of school children or measuring binary stars, you may wonder what the earth has to do with it. This philosophy of science will be a success if it raises more questions than it answers. Science means the cooperation of all specialties. If they deal with human beings, they are concerned with civilization. The Polish Corridor, the Pyrenees, and Gibraltar are affecting the blood of future school children today. Civilization in America will be greatly affected by the eighty chemical plants in thirty different states of the DuPont de Nemours Company. They are placed in part for what the ground produces to make the earth yield up her increase.

Laboratory science likes to experiment with something like the fruit fly or white mice that will yield repetitions and controls. The earth, in explosive eruptions where lava flows drain out at the bottom of the sea (Figure 1), or in others capable of being bombed to save a city; the earth, in receiving the shadow of the moon (Figures 2 and 3) enduring seven minutes, does not admit of ten repetitions and ten experimental controls. But very important laws may be discovered from a single event.

The insurance man has the same problem; in life insurance he has hundreds of repetitions, and hundreds of controls. In disaster earthquake insurance, or in conflagrations, he has very few. Nevertheless, he learned something for his science in San Francisco, Tokyo and Napier. Henry Cabot Lodge, in spite of his opposition to Woodrow Wilson, said in a commencement address, "it is through the search for Utopias that the real advances have been made". Whatever your specialty in science, something about it may directly serve mankind out on the surface of the earth, and away from the congestion of cities. Science works either to discover the internal mind of nature, like Isaac Newton, or for a humanist love of nature like Audubon. The earth is a middle ground out of which we came ourselves; out of it comes all our food as well as the petroleum, iron and power that frame our civilization. The love of ultimates, describing something we cannot see in language which we do not understand, has tied science to cities.

But the age of infinite electric power is just across the threshold. Science is entering that door. The thing that created America was the frontier where man with axe and plow and rifle robbed nature and won freedom. The science of power is creating a new frontier that sees no limit to the materials and the arts that will build with the rock of the hill and the mud of the sea bottom. This is what is meant by the assertion that the earth is the chief subject of science.

It is the earth that affects our drinking water and our glands. It is the earth that produces a Utopia like the T.V.A. It is the earth that yields the atmosphere through which our airplanes fly. Seventy-two per cent of the earth's surface is a gigantic unexplored wilderness of fascinating possibilities possibly containing radium and all the rare earths and only just scratched for the first time by a recent invention that has taken a core six feet long from the mud covering this mysterious land. The core was obtained by shooting a tube straight down into the ground with a high-powered submarine gun (Figure 4). This wilderness is the bottom of the ocean.

The earth is necessarily the chief subject of science. It is conclusively so because science serves man. And man as the object of scientific effort is earthly, he is not celestial or electro-magnetic. It is in part science that is to blame, for

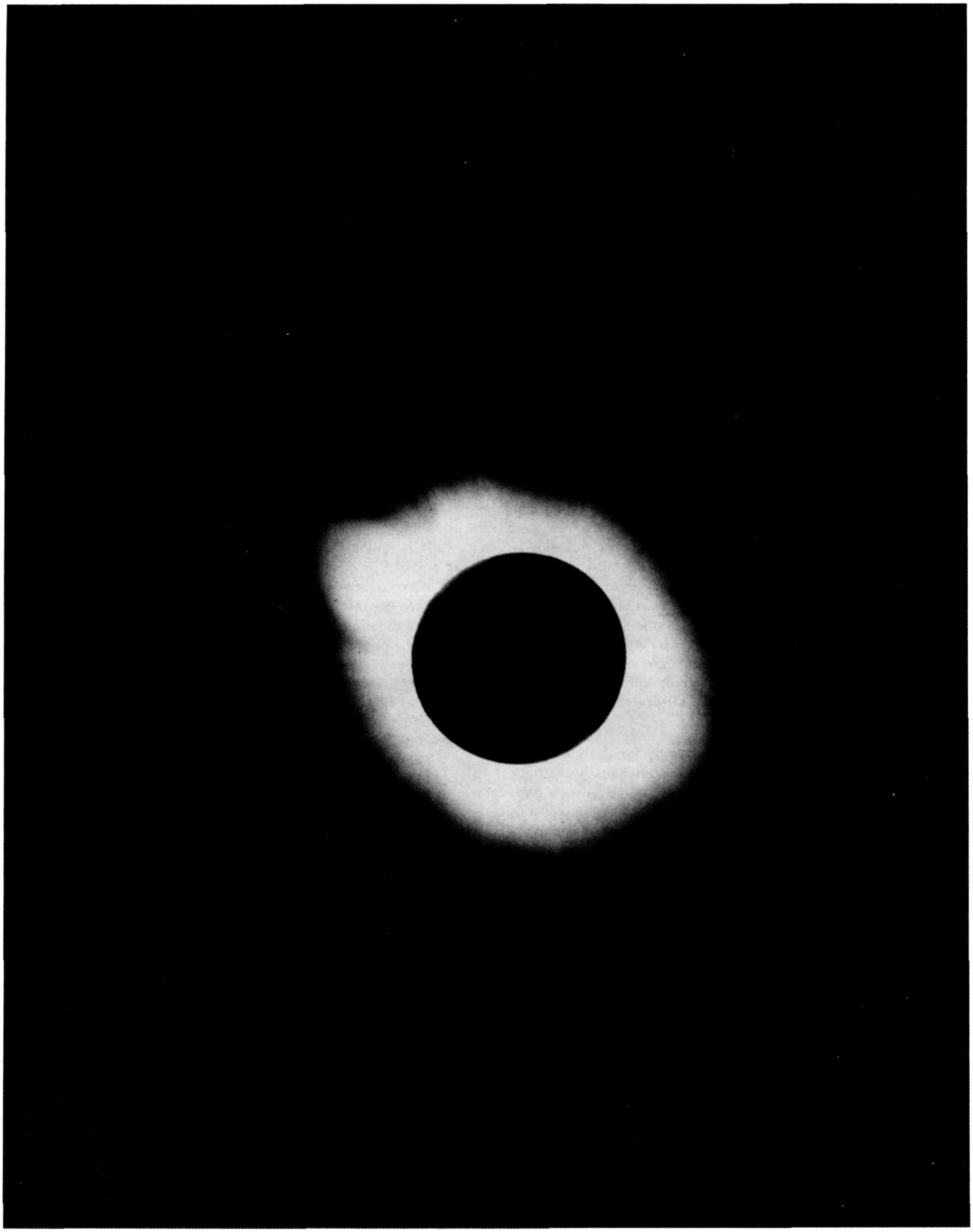


Figure 3. Photograph of the moon covering the sun's face. Niuafoou Island, October 21, 1930. Seventy men work three months for this photograph of an event lasting ninety-four seconds.

the misuse of science, that does not sufficiently consider man's happiness. Science agrees without protest to raising children in the sky-scraping gear wheels of a high stone-crusher like New York City, when there are thousands of square miles of country available with babbling brooks, grassy glades and sweet mountain air.

Science and education agree to an acquisitive society without protest, when every instinct of hygiene, sociality, uplift, public interest and experiment in the anthropometric laboratory suggests that human happiness lies in freedom, and in extroversion rather than acquisition. Science knows that an extrovert society will be more successful than an acquisitive one. Science has conquered distance and sluggishness, storm and savagery, famine and dearth.

But science shrugs its shoulder at the demand upon it to decentralize, to distribute and to invent a system of extrovert markets. Science knows it controls business, but it shrinks from reformation.

The terrestrial globe, the subject of the middle ground, producing the materials of physics and humanity intermediate between the electron and the germ cell, is pretty much left by the scientist to the rough and ready experiments of the prospector and pioneer, to the mountaineer and explorer, to the construction engineer and the navigator.

Laboratory science does not like to live in wild places. When we populate Howland, Jarvis and Wake Islands with a view to precise experiments in radio engineering and navigation of the air, we pick a group of Polynesian natives. If we were doing it in Antarctica we would pick a group of Eskimos or Icelanders. The suggestion is implied that no man or woman of European origin could reasonably be expected to live in a different climate. We are told that the Japanese have had similar difficulty in transporting their nationals to a colder belt. The earth is awaiting exploration by means of the new implements of modern science, but if modern laboratory science is afraid to dwell where the weather is hot, cold, dry or wet, the globe will remain undeveloped for the service of humanity.

Summary of trends in science

An attempt has been made in this essay for the speaker to review what fifty years of observation of natural history have impressed him as remaining unsaid and neglected in such general journals as "Nature" and "Science". The subject has been divided into four parts, in reviewing what seem to be the trends of scientific work in relation to human life for a century.

(1) First comes the overpowering importance of **Language,** both for thinking, and for arriving at agreement. Many scientists seem not to have realized with Willard Gibbs that logic, which comes from a Greek root meaning words, and mathematics, are languages and not sciences. It is not fair to say **mere** languages, because language itself, in the sense of the spoken tongue, is historically and constructively the most important implement in the whole range of all the sciences.

(2) Secondly, **Experiment** has been brought forward as the chief activity of science today. This is a great change from the time of Francis Bacon, who proposed categories, and extensions of science, which required observation rather than the invention of inductive tests.

A group of geologists, botanists, zoologists, and anatomists, meeting with natural philosophers and chemists at the Royal Society in 1845, was startled and delighted when Faraday sent in his nineteenth series of "experimental researches", to show that magnetic force produced an effect on polarized light. Medicine knew observational anatomy, and botany knew a systematic flora, but experimental physiology, phytometry, and phyto-chemistry had never been heard of.

There is of course nothing new nowadays in recognition of experimental work as a first essential of science. In my own science geology, however, the idea of experimental work in the field is decidedly new as a branch of pure science, and description of such work is notably lacking in the scientific journals.

(3) The third topic here considered, **Reformation** of the habits of mankind as the chief goal of science, is recognized by the gigantic efforts of special laboratories that the wealth of nations has produced, but is very little spoken of as an ethical ideal. The ethics of science emerges in the medical profession, and in some government activities actuated by political reform. In too many laboratories, however, science considers itself free, monastic, and privileged, or else it is frankly subservient to mercenary despotism.

The timidity of science in a bellicose world of overpowering industrialism and politics has had something to do with the two great catastrophies of the twentieth century.

(4) The last topic here considered, the **Earth** as the chief subject of science, involves a philosophical consideration, that few of you have ever thought of. Your own compartment was enough, and the earth could be left to the geologists.

What is the result? Thousands of men are at work building sensitive instruments, elaborating closed spaces for every possible temperature, pressure, and electrical condition, breeding insects, birds, animals, plants and bacteria for every possible service, and creating instruments of superlative grandeur, for evaluating the physical and chemical conditions of the universe of the stars. But all of this has preserved the habit of inertia in dwelling close to congestion centers, that existed in London in 1845.

It is only recently that the surface of the globe begins to be encased in a human net, demanding knowledge of the matter in outer atmosphere, mountain and plain, river and shoreline, sea-bottom and island; it is only recently that volcano and earthquake, simoon and flood, forest conflagration and drought, insect plague and blight, erosion and silt, have assumed proportions, where the interlocking of nations has made the misfortune of one a catastrophe for all.

Thus have sprung up geophysics, climatology, ecology, comparative anthropology, epidemiology, critical quarantine, and remedial construction in the service of insurance.

The people of London who looked upon Humboldt, Darwin and Livingstone as great explorers, have today barely begun to realize that travel is no longer a scientific virtue.

The discovery of the natural history of the earth by science can only be done by distributed laboratories that take pride in leading human enterprise to wealth that now is unsuspected. That wealth is partly materials, partly power, partly education. In metals China owns most of the tungsten, Canada the nickel, Peru the vanadium, South Africa the chromium, and America the molybdenum. The now precious xenon and krypton of the atmosphere are exercising the electric industry. The power of the sunshine and the tides is coming. **Science** it will be who shall educate the world to sheathe the sword, because happiness lies in experiments with mutual giving by men.

Hawaiian Volcano Observatory Report for May, 1937

VOLCANOLOGY

At Kilauea volcano the inner pit of the crater called "Halemaumau" went through another crisis of rim cracking on May 7, the east edge caving in, and carrying away a marked measurement-crack. This was an extension of the rim-breaking northeast that happened in October-November, 1936. Later in May the opening of eastern cracks diminished. There were two slight earthquakes, May 15 and May 30, the first of doubtful origin, the second about the Hilo end of the northeast rift of Mauna Loa. Thirteen very feeble shocks appeared to originate under Kilauea.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
May 9	6.75	1	65.0	22
" 16	10.75	2	46.0	31
" 23	4.25	3	19.0	13
" 30	10.50	1	16.5	29

Sequence of Events by weeks

The first week produced the crisis of rim breakage at Halemaumau on the east side, just south of the notch which caved in last October. The description and photographs of that collapse appeared in Volcano Letter 446. The cracks there for several weeks have exhibited excessive opening. The index fissure was Crack No. 25, which expanded its opening 36, 42 and 57 millimeters respectively April 23, April 30 and May 7. On the last date came the falling in.

The second week showed eastern cracks continuing to widen and break the soil, and to make hot vapor.

The third week produced less widening of cracks and a few slides. New measurement marks back of northeast rim were established by placing copper studs on opposite sides of cracks. Seismicity declined.

The fourth week continued the lessening of crack-opening. In the wall of Halemaumau below the edge east an upright chasm was uncovered by a slide.

Slides at Halemaumau

Slides, and their effects, from the wall of the pit have been noted as follows:

May 7, evening, a length of about 40 feet along the rim caved in, probably 15 feet wide at the place of maximum breakage. Within this piece Crack No. 28 was destroyed and removed; this crack had not been opening, but was rigid with the rock that fell.

May 15, 2:35 p.m., a slide east, dust cloud and noise of falling rocks.

May 16, 8:30 a.m., a moderate slide sent up a dust cloud north.

May 18, 4:30 p.m., dust cloud from a slide northeast.

May 20, 11:05 a.m., a slide east sent a cloud of dust floating away westward.

May 21, 3:50 p.m., an east-northeast slide occurred.

May 25-26, night, a slide from the east wall uncovered an upright chasm, in the area of recent active caving fenced off from the Volcano House trail.

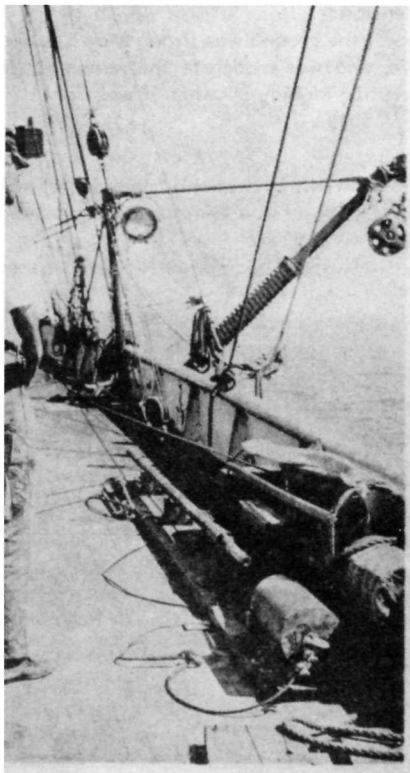


Figure 1. Apparatus in chocks on deck

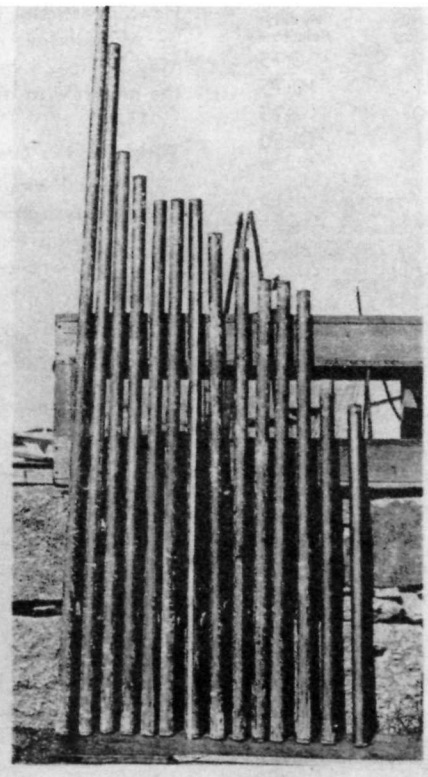


Figure 2. Cores taken August 1935 from depths of 200 to 1250 fathoms

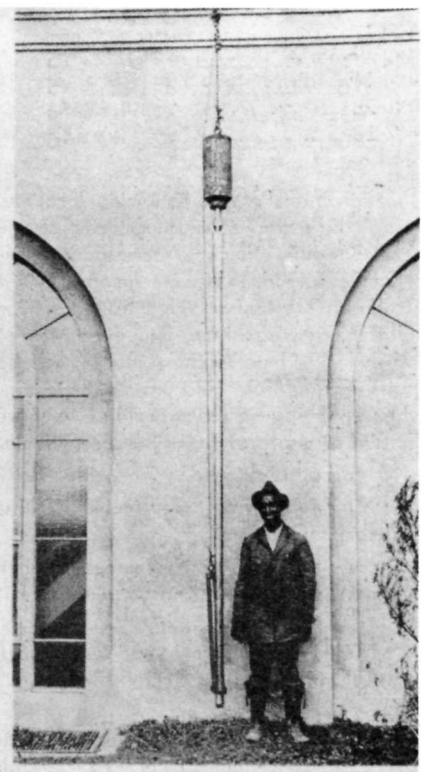


Figure 3. Core sounding apparatus ready for use

Figure 4. Core-drilling harpoon of Dr. Piggot. (Bull. Geol. Soc. Amer.—1936.) To sample the seventy-two per cent of unknown land—the sea-bottom. The gun takes cores 6 to 8 feet long in 200 to 1,250 fathoms of water.

Measurement of Halemaumau Rim Cracks

Weekly measurement of a varying number of rim crack locations destroyed and reconstructed during the month of May, resulted in aggregate movement as follows: week ending forenoon of—

May 7, 26 locations, 9 opened, 1 closed, opening 65.0 mm. collapse in evening destroyed No. 28.

May 14, 25 locations, 9 opened, 1 closed, opening 46.0 mm., to which Crack No. 25 contributed 40 mm. A new location, No. 37a, was established east of the road on an extension of Crack No. 37.

May 21, 26 locations, 7 opened, 1 closed, opening 19.0 mm., to which No. 25 contributed 14.0 mm. Four new measurement marks were established at northeast rim.

May 28, 30 locations, 13 opened, 1 closed, opening 16.5

mm., to which Crack No. 25 contributed 9.0 mm., showing marked decrease of rate. The ground extending the lost cracks of the east notch, after May 7, to the south of the notch, was broken and hot, with the soil ruptured and weeds browned with new vapor. Measurement with thermometer May 11 of the cracks south of Nos. 24 and 25, at 10:00 a.m., air 24°C., showed maximum crack temperature 64°C.

The break across the road southeast of Halemaumau, on the eastern extension of Crack No. 37, recently repaired, is moving again. Slowly this crack has opened: it is over the old sulphur beds on the Kilauea floor margin. The extension of the crack east of the road gave maximum temperature 50°C.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Slight Earthquakes	Weekly* Seismicity
May 9	17	5	0	6.75
" 16	25	5	1	10.75
" 23	9	4	0	4.25
" 30	22	6	1	10.50

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, a determination of depth of focus has been made.

May 6, 10:06 am, very feeble, of Kilauea origin.

May 7, 7:44 pm, very feeble, accompanied a slide at E rim of Halemaumau.

May 8, 12:22 am, very feeble, located 2.7 miles deep 0.4 mile NW of Kilauea Military Camp. 19° 26.4' N; 155° 16.7' W.

May 14, 3:13 pm, very feeble, located 0.6 mile deep in Kilauea Crater adjacent to Kilauea Iki. 19° 25.3' N; 155° 15.9' W.

May 14, 3:29 pm, very feeble, located 1.3 miles deep under E rim of Kilauea Crater. 19° 24.9' N; 155° 15.8' W.

May 14, 3:56 pm, very feeble, same epicenter as preceding except 0.9 mile deep.

May 14, 5:37 pm, very feeble, of shallow depth in cracks immediately east of Keanakakoi Crater. 19° 25.4' N; 155° 15.6' W.

May 15, 1:18 am, a slight earthquake was recorded at the Observatory, Uwekahuna and the Pit. It registered as very feeble in Hilo and as a tremor in Kealakekua. Because of lack of definite phases its location was not determined although it is thought to have been of Kilauea origin.

* For local seismicity definition see Volcano Letter 371.

May 16, 7:42 am, very feeble, probably located 0.7 mile NE of Kilauea Crater.

May 21, 1:20 pm, very feeble, tentative location in Kilauea SW Rift about 10 miles from Halemaumau.

May 28, 12:09 am, very feeble, located in cracks east of Keanakakoi, SE portion of Kilauea Crater, 0.9 mile deep. 19° 24.1' N; 155° 16.4' W.

May 28, 6:12 am, very feeble, located 1.3 miles deep under east rim of Kilauea Crater near Kilauea Iki. 19° 24.9' N; 155° 15.8' W.

May 28, 8:50 am, very feeble, located 0.8 mile deep and 0.5 mile S of Kilauea Iki. 19° 24.6' N; 155° 15.3' W.

May 30, 2:53 am, very feeble, probably located under N rim of Kilauea Crater and near Kilauea Military Camp.

May 30, 3:03 am, slight, tentative location Mauna Loa NE Rift about 10 miles from Hilo. Reported felt one mile east of Hawaii National Park entrance.

Microseismic motion of the ground was strong May 3 to 16, May 22 to 24 inclusive, and was moderate the remainder of the month with the exception of May 30 when it was light.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 30 was 8.98" S and 1.35" E.

Week Ending	Observatory	Halemaumau West Station
May 9	0.83" N 77° E	4.50" S
" 16	1.03" N 48° E	2.86" N 37° W
" 23	0.45" N 60° W	1.73" N 71° W
" 30	0.62" N 3.5° E	0.75" S 12° E

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
May 9	8.10" S 84° W	3.60" Toward
" 16	8.94" N 27° E	2.71" Toward
" 23	1.49" N 40° W	0.18" From
" 30	3.63" N 49° W	3.42" Toward

H. H. W.

Crater Angles

Measurement of Horizontal angles across Kilauea Crater from the Observatory, May 27, showed slight closing of both Halemaumau and Crater values compared with similar measurements April 21. From Kilauea NE rim to Uwekahuna there was closing of 2.50", April 21 to May 11, and opening of 0.84" May 11 to May 27. Total closing 1.66". From the Pit seismograph to NW Pit B.M. there was closing of 2.50", April 21 to May 11, and closing of 0.42" May 11 to May 27. Total closing 2.92".

H. H. W.

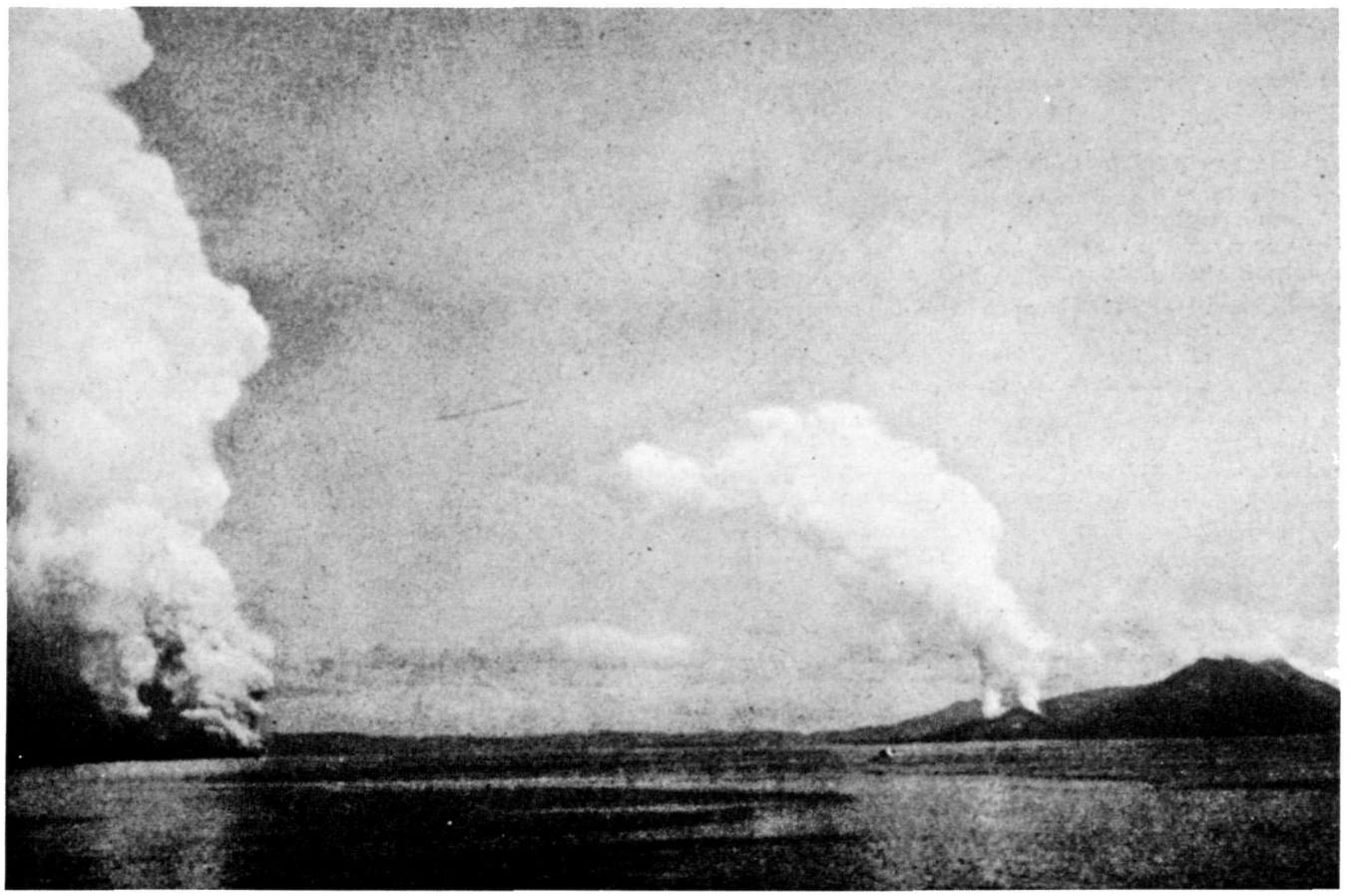


THE VOLCANO LETTER

No. 448 monthly **Department of the Interior** **National Park Service** **June 1937**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Volcanic eruptions that caused a temporary evacuation of Rabaul: Clouds of steam rising from the craters of Matupi (on the right) and Vulcan Island, the more violent of the two.

ERUPTIONS AT RABAUL, NEW GUINEA

Volcanoes of New Britain

At the northeast end of New Britain (formerly New Pommern), the middle larger island of the three that constitute the British mandated territory of New Guinea, the capital town in that tropical land of missions, mines and copra (Lat. 5° South, Long. 152° East) is called Rabaul.

It is on a protected harbor. An east-west arcuate belt of active volcanoes encloses the Bismark Archipelago to the north, and the middle of the bow, bellied southward, contains the volcano "Ritter Island". This island cone threw up flames and lava fountains in March, 1700, poured lava cascades in June, 1793, and made explosive eruption in March, 1888 (west of Mt. Nangila on map) that caused a tidal wave and ejected more than a third of a cubic mile of dust, gravel and rocks.

Ten years earlier two volcanoes erupted at the north end of the Gazelle peninsula where Rabaul now is; they were called "Ghaie" or Matupi, and "Raluan" or Vulcan. Matupi, 800 feet high, is a solfataric hill southeast of and close to Rabaul on the northeastern tip of the volcanic arc. The rift crosses Blanche Bay (Rabaul harbor) from southwest to northeast, and Vulcan island on the southwest side of the bay appeared above the waves in the 1878 eruption.

This eruption included both Vulcan and Matupi along a steam-blast rupture; it started February 4 and lasted four days for Vulcan and three weeks for Matupi. It made two tidal waves, and built at Vulcan a flat cone 70 feet high and 900 feet across; from a new crater on Matupi smoke, flames and pumice were ejected, piling dust and pumice on the country and blocking the channel.

Thus Matupi was the more violent in 1878, but it appears that Vulcan was the culprit in 1937. Vulcan had subsided to half its height by 1897; Matupi is a subsidiary crater to "Mount Mother", a mountain back of the town, and is visited for its steaming hot spring.

We are indebted to the Sydney "Mail" of June 9 for the following data about the town, the Papuan natives, and the eruptions:

With a northeast wind the fumes from Matupi start the natives talking about earthuakes, and about the memories of the terrifying eruption of sixty years ago; when the Beehive Islands at the entrance to the harbor lowered to their present height; and Vulcan Island was built up next to the southwestern shore of the bay, so that their banana plantations were weighted down with heavy ash; and fish and turtles were found cooked in the steaming waters.

About twenty years ago an "eruption" is reported whereby the Matupi Peninsula sank about eighteen inches, and rose to its former level within a few hours. One wonders whether this story might not refer to tidal wave effects of the "Father" eruption of 1912.

The natives of course attribute very feeble earthquakes, which are frequent in Rabaul, to "debbil-debbils", and just as the Hawaiian legend of Pele migrating from Kauai to Hawaii agrees with geology, so the shrewd Papuan observations tally with science.

Folklore has it that the active volcano "Father" (see Map) or "Ulawun" to the southwest, with two other hills known as "South Son" and "North Son", alternates in "smoking" with the Rabaul volcanoes known as "Mother", with her two offspring "North Daughter" and "South Daughter". It is of course the subsidiary crater of Matupi that does the smoking.

Geologists know that the "Father" group and the "Mother" group are on the northeast-southwest rift line of New Britain, and the alternation of activity is probable, just as between Mauna Loa and Kilauea.

Rabaul is built over volcanic ash and it is said to be extremely difficult sometimes to get an earth terminal for an electric circuit.

Vulcan Island after the nineteenth century was left about 100 acres in size, some 5 miles from Rabaul, a cone unconnected with the shore. It was 900 feet in diameter, 30 feet high, and fuming from solfataric vents.

The mission stations of Walour and Taviji were on the southwest shore of the bay close to this island, along the driveway leading from Rabaul around the bay. This leads to Kokopo, a village on the eastern point of New Britain, facing the strait that separates New Britain from New Ireland.

The 1937 Eruptions

During the past year earthquakes have been unusually numerous in Rabaul. Vulcan Island began to show signs of volcanic activity Friday morning, May 28, 1937, when the mission stations experienced severe earthquakes, and landslips were observed on the island. The earthquakes increased in violence during that day and the next.

On the afternoon of May 29 Vulcan Island broke forth into explosive eruption, throwing up clouds of fume, dust, ash, gravel and bowlders so thickly that day was turned into night.

An observer at one of the missions thought that the dusk was coming a few hours earlier than usual. Then he noticed that Vulcan Island was throwing bowlders many hundred feet into the air, and pumice was falling everywhere. He described seeing a ball of fire running along the top of the cone, this being followed by a terrific explosion.

Then Matupi Volcano broke out in sympathy, sending up sulphurous steam, cauliflower clouds, ash and pumice, but the main eruption that darkened the entire landscape was from Vulcan Island.

The water became violently agitated. The succession of explosive steam blasts came from the side of Vulcan Island apparently on a rift line extending in the direction of the Beehive Islands and Matupi Crater to the northeast. A dome-shaped jet of water was seen to shoot up about 50 feet, followed by another explosion hurling sea water up 100 feet. Then many explosions occurred at Vulcan Island itself, flinging up rocks and debris, the cauliflower clouds rising 4,000 to 5,000 feet.

Some of the longshore roads developed crater depressions and all were blocked with gravel and ashes. Plantations were damaged for many miles, crops of coffee and bananas were ruined and the coconut trees had their leaves broken down with heavy gray ash.

The dense black cloud appeared to descend from above on some of the mission villages, earthquakes were numerous, thunderstorms developed, trees were struck by lightning and were seen falling in earthquakes, heavy rains fell, and motor cars were choked with the dust and had to be abandoned in the mud.

Volcanologic evidence

We shall have to await scientific statements for an account of what happened in changes of the sea-bottom. The sea-bed is said to have changed in elevation so as to make a new survey necessary.

As usual with explosive eruptions great quantities of floating pumice appeared on the surface of Blanche Bay, and some of this was thought to be a new bank of sand and mud blocking the outer entrance to Rabaul Harbor. The ocean currents swept this out to sea within a week, and it was found that the outer channel was still navigable. Shipping could enter Blanche Bay and reach the wharves with safety.

What happened to Vulcan Island itself may well have been a rising of stiff magma along with the building up of a symmetrical cone and cup, as shown in the pictures. We learn from the accounts that the island has been raised from 30 feet to a large hill more than 700 feet high, and from an island 900 feet across, to a peninsula three-quarters of a mile in diameter connected with the mainland by the new accumulations.

There is no evidence nor probability that liquid lava flow occurred. The worst of the eruption was on Sunday, May 30. The eruption died away very rapidly. When Vulcan Island was enveloped in smoke, the first impression of the onlookers was that it had disappeared.

One observer described a sudden lift of the island when the water waves occurred which played havoc with many of the smaller vessels, some of them being beached high and dry on the foreshores. Soundings were taken by a survey ship on Saturday, June 5, showing plenty of depth in the main channel.

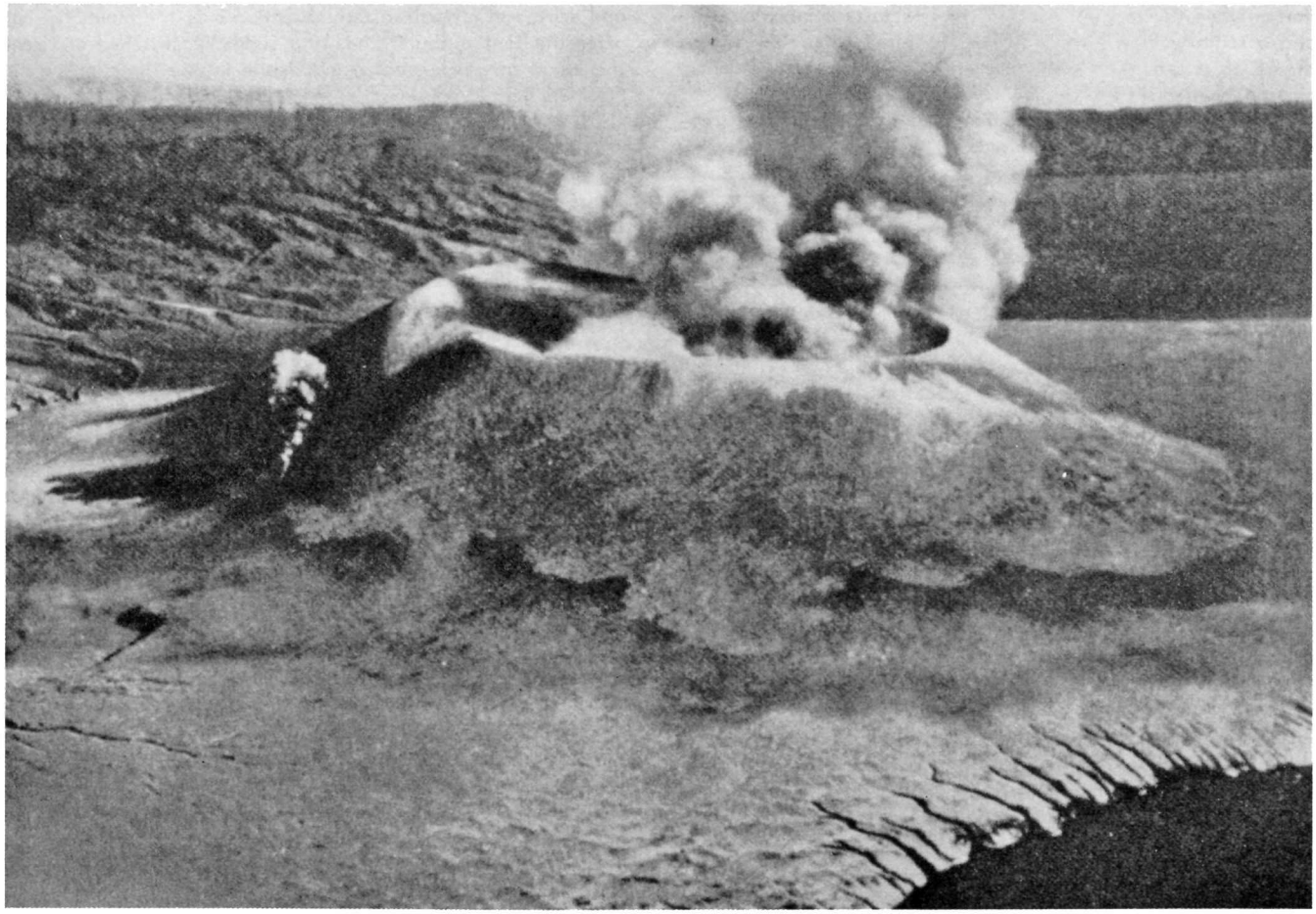
like "Anak Krakatoa", of a constructive effort of rising magma acting through the ages, and reacting with groundwater.

We may conclude that the nature of this eruption was not particularly different from other eruptions of this volcanic belt, and to judge from Sapper's report concerning Father Volcano in 1912, and Ritter Island in 1793, this belt of volcanoes is quite capable of pouring out lava occasionally.

Von Wolff reports the recorded specimens of lava from this bay to be pyroxene andesite, and of pumice from New Britain to be andesite pumice. The minerals are plagioclase, angite, hypersthene and magnetite. Silica varies from 57% to 62%, and iron oxides from 6% to 8%. Specific gravity is 2.36 to 2.51.

Effects on the People

The evacuation of Rabaul was ordered, and was carried out efficiently with the aid of ships that moved the people from Nodup (a village close to Rabaul), to Kokopo, twenty miles south. Some 4,500 people were moved, and about 20



The erupting crater of Vulcan Island (normally low-lying) seen from the air: a view showing molten pumice building the cone hundreds of feet high and flowing into the sea.

The observer in question reported that Vulcan Island rose rapidly at the time of the tidal crisis so that where there had been water and a few rocks, solid land appeared. The interpretation of the airplane photographs was that "flowing pumice" spread down the sides of the cone.

There was the usual reddish glow seen in the reflections from the crater on the clouds. This and the presence of pumice show that frothing magma took part in the groundwater explosions, and it is probable that this is just one more example,

stayed to guard the place. The rain of ashes and mud was the principal cause of damage in the town, the heavy weight breaking down structures and destroying vegetation. Food supplies were transported from Nodup to Kokopo by schooners, and a large camp was made at Kokopo with sanitation directed by the government. The refugees included 3,000 natives, 800 Chinese, and 700 whites.

Within a week the harbor was clear, and progress had been made in cleaning the town. The island superintendent of one

trading firm suggested moving his headquarters to Madang, on the coast of New Guinea. This company's wharves at Rabaul were valued at $150,000, and could not be shifted. Moreover, the harbor is better at Rabaul than at Madang.

However, the trading firms had grave doubts about building and expanding on a place between two active volcanoes.

Ship Reports

Two larger steamers were in harbor, the "Golden Bear" of the Matson Line, and the "Montoro" of the Burns Philp Line. These were not injured and were instrumental in evacuating the population. Two steamers and a schooner were swamped.

At 1:00 P.M., May 28, the "Montoro" passengers, with ship moored to the pier at Rabaul, suddenly felt violent earthquakes and saw buildings rocking and palm trees falling, so that the roadways were blocked with fallen timber. Quakes continued throughout the afternoon and at 5:00 P.M. the "Montoro" sailed.

The "Golden Bear" was loading copra at a pier in the harbor when the eruption started the next afternoon, May 29, and a radio was sent to ask the "Montoro", then 120 miles at sea, to return. The land radio station was put out of commission by the eruption. The "Montoro" was showered with dust 100 miles away and in approaching the harbor found the ocean surface covered with pumice.

The columns of steam above the volcano rose white and fluffy, with an inky black inner column that exhibited rocketing bowlders falling back into the crater. With every new jet lightning and thunder occurred.

The explosion of Matupi came at 12:45 A.M., May 30, and large pieces of rock were flung up from its crater.

Captain Olsen of the "Golden Bear" had been doing heroic work, taking on board at Nodup hysterical women and children, hospital patients, and the Chinese population.

"The "Golden Bear" had at first been tied up at the wharf in Rabaul right in the path of the dust from Vulcan Island, and the falling pumice, heat and gasses were such that the danger was great, while the tidal waves chafed the lines, and grounded the ship. The water was covered with pumice and the outward channel looked as though new sand-bars had risen.

There might not be any channel and the course out involved passing close to the spouting volcano. The captain did not hesitate, but let go his moorings, ordered his crew below decks, cleared the channel and reached the open sea in a magnificent performance of seamanship. Then he turned about and anchored off Nodup.

The natives were loaded ten deep on the decks of both ships along with their dogs, cats and parrots. There was no panic. The launches pulled three boats at a time. The mission at Kokopo did splendid work in housing and feeding refugees.

The "Montoro" left on June 9, Captain Mitchie of that ship clearing for Sydney with some 200 refugees.

Some details of the eruptions

Rabaul was covered in places with dust four feet deep, and boats had been washed up into the streets. The tropical trees and shrubs were all broken and not a green or living thing was in sight. The water, light, and telephone systems were broken down, hardly a roof was intact, the roads were a mass of ruts, and the health commissioner could not allow any one to live there until the place was cleaned up.

Captain Olsen himself described the detail of the eruption as follows:

The ship was tied up at a dock near Rabaul at the time. Before doors or portholes could be closed a foot of pumice dust had settled in every nook and cranny of the ship, destroying clothes and other property. Most of the crew were ashore at the time of the terrific outburst of Vulcan Island. All returned to the ship, however, except Radio Operator V. M. Costner, who in the darkness may have fallen into the sea from the wharf, when attempting to grope his way back through the blinding, choking gaseous smoke which enveloped the town.

Captain Olsen is quoted as follows (Honolulu Star-Bulletin, July 12):

"About 4:10 P.M., May 29, I was outside on the starboard side of the lower bridge deck. Looking toward Vulcan Island, I saw a small white speck on the water near the island which swelled and rolled over, with the appearance of a large, fluffy cotton ball.

"It was only when the ball began to ascend into the air *that I realized it was a volcanic eruption. After three or four* minutes the island suddenly burst wide open, and with a tremendous roar sent a column of white steam and black lava smoke thousands of feet into the air.

"The mixture of gas and lava enveloped Vulcan Island and drifted in a northwesterly direction over the mainland, but after the first outburst the wind suddenly switched and sent the cloud of black smoke and debris in the direction of the "Golden Bear".

"The ship was enveloped in a cloud of gaseous ashes. All visibility was completely obscured. We left the ship under conditions difficult to describe. We crawled along on the wharf on our hands and knees. We felt our way along the car-tracks. We nearly suffocated. Fortunately, the wharf office door was unlocked and we all took shelter there against the heavy downpour of ashes."

A check of the men revealed Mr. Costner missing. In the late afternoon the Captain and the crew returned to the "Golden Bear" and succeeded in keeping her from being materially damaged by a series of minor tidal waves.

After reaching the Kokopo anchorage, May 30, Captain Olsen had a view looking northwest of the two volcanoes in action. Two great columns of white and black smoke ascended for thousands of feet. Spreading out and coming together at the top, they formed a gigantic archway over the entrance to the harbor.

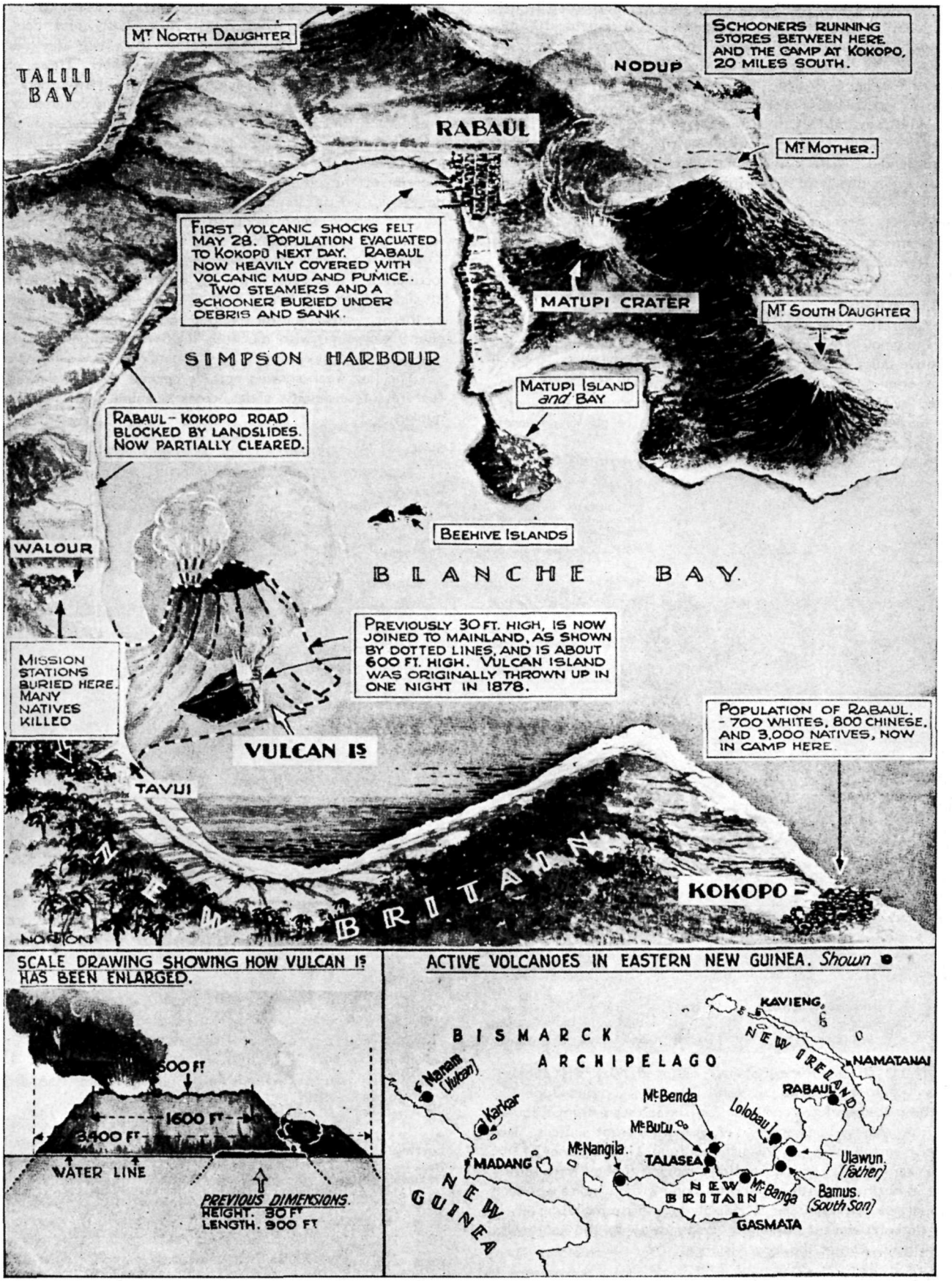
Vulcan Island, the largest and heaviest of the two eruptions, was a magnificent sight during the night. Great masses of fire would be thrown into the air for distances of 4,000 feet, measured by sextant. The barrage would curve over and outwards and, exploding, fall back to the earth in a rain of fire.

J. W. Faulkner took the place of the lost radio operator on the "Golden Bear" in Rabaul. His ship, the "Durour", was on a marine railway close to Vulcan Island when the outbreak occurred. He and his companion barely succeeded in escaping to Rabaul in a motor boat. His ship, with the natives on board, was completely engulfed and sank out of sight.

Faulkner described the rising of a reef some 10 feet above water near Vulcan Island. This happened during the earthquakes that occurred in the 24 hours before the eruption.

Conditions at first in Rabaul were terrible during the eruption. While refugees were being transferred to outside plantations, it was necessary to erect temporary dormitories for the sick and injured. Rescue parties went from house to house searching for any who might be trapped.

In Kokopo there was an acute shortage of food and water, bad sanitary conditions prevailed and anxiety was expressed over the possibility of dysentery and typhoid. The mosquitoes were bad and the people were destitute. The swimming pools were thrown open to the women and children, many of whom maintained a stoic calm throughout the ordeal. The casualty cases were attended by one doctor and numerous nurses.



The tragic course of events in stricken Rabaul.

Captain Olsen's estimate of the loss of life caused by the eruption was reported as approximately 250 natives, 10 Chinese children, and 1 European. In the Sydney account the losses of life were known to be two white men, and in the missions close to Vulcan Island not less than thirty native women and children, overwhelmed by mud and ash.

Whatever the fact, this small loss of life in a harbor populated by 5,000, with an active pair of volcanoes athwart it, is a splendid tribute to the efficiency of the sailormen, traders, missionaries and local authorities in facing a sudden crisis and moving 4,500 people. They were assisted by ships, airplanes and radio. It seems likely that a volcanologic observatory and a system of earthquake stations might learn the cycles of recurrence, and greatly assist the New Guinea government.

T. A. J.

VOLCANOLOGY

After the May crisis of caving in of the eastern rim of Halemaumau pit, Kilauea Crater entered upon a period of comparative quiet. The establishment of thirty marked crack locations around the rim of Halemaumau, which had been renovated in May, exhibited in June only a quarter of the aggregate crack opening of May. The numbers of quakes, tremors and slides remained about the same.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
June 6	15.00	0	11.0	20
" 13	11.25	1	10.0	35
" 20	12.75	4	10.5	36
" 27	5.50	2	9.5	16



A car covered with six inches of volcanic ash, which stopped the engine and compelled its owner, who was leaving for Kopoko, to abandon it: a typical scene of desolation in Rabaul.

Feeble shocks somewhat felt occurred May 31, June 3, June 13, June 16, two on June 20, June 21 and June 25. Of the measured local earthquakes, sixteen were from Kilauea, six from Mauna Loa, and two from more distant sources. Two distant earthquakes were registered June 21 and June 24.

A remarkable slow horizontally-moving fireball from southwest to northeast, with flaming tail, and without noise was seen throughout the Territory of Hawaii at 9:50 p.m., June 4. It was probably seventy or eighty miles away to the southward from the middle of the larger islands.

Sequence of Events by Weeks

The first week produced nothing important at Halemaumau. Crack widening, seismic frequency and sliding had all lessened. The yellow sulphur heap at the northwest margin of Halemaumau floor continued to fume hotly, and there was much cracking and sulphurous stain that had developed at the S.S.E. and N.N.W. edges of the floor. These places steamed occasionally, especially during wet weather. The northeast edge of the floor was now completely covered by new overlapping talus heaps from the north to the east sides of the pit. These have all been added to between October, 1936, and May, 1937. The wall above is raw and freshly scarred, and the rim of the pit is considerably changed by notches which have enlarged its circumference.

The second week produced a lessening of seismicity and widening of cracks, and one slide was noticed.

The third week there were more slides, characterized by location on three sides of the pit, a new feature in that nearly all slides during the previous years had been from the east and northeast walls. Seismicity and crack widening continued about the same, with much of the latter limited to a single crack at the east rim.

The last week showed notable decline in all the measured features of seismicity, slides, crack openings, and numbers of quakes.

Slides at Halemaumau

Slides from the wall of the pit Halemaumau have been noted as follows:

June 9, 8:57 a.m., a slide at the northeast wall.
June 14, 2:07 p.m., rocks fell from the east wall.
June 17, 9:57 a.m., a slide started from about half-way down the south wall.
4:35 p.m., a slide occurred at the east.
June 19, 10:45 a.m., a large slide occurred on the west side of the pit.
June 22, 11:25 a.m., a slide at the east wall made a small dust cloud.
June 23, 8:30 a.m., a slide at the northwest wall made a fairly large dust cloud. Slides south, west and northwest have been very unusual for the last year.

Measurement of Halemaumau Rim Cracks

Weekly measurement of a constant number of rim crack locations as reconstructed during the month of May, resulted during June in aggregate movements as follows:

Week ending forenoon of:

June 4, 30 locations, 8 opened, 3 closed, opening 11.0 mm.

June 11, 30 locations, 7 opened, 4 closed, opening 10.0 mm.

June 18, 30 locations, 10 opened, 5 closed, opening 10.5 mm., of which 6 mm. was accounted for by Crack No. 25 at east rim.

June 25, 30 locations, 10 opened, 2 closed, opening 9.5 mm., of which Crack No. 25 accounted for 5.0 mm. Crack No. 25 is one of the steaming extensions of the caved-in cracks of the east notch that collapsed May 7.

T. A. J.

SEISMOLOGICAL DATA

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly§ Seismicity
June 6	46	3	2	0	15.00
June 13	27	7	1	0	11.25
June 20	27	6	3	0	12.75
June 27	14	0	2	2	5.50

§ For local seismicity definition see Volcano Letter 371.
* Including teleseisms or those shocks over 5000 km. distant.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory, and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and, whenever possible, a determination of depth of focus has been made.

May 31, 6:18 am, very feeble, located 1.2 miles deep in Kilauea Crater near the old Stone Corral. 19° 24.8′ N; 155° 16.3′ W.

May 31, 6:29 am, feeble, located in N portion of Kilauea Crater 1.0 mile E of Uwekahuna. 19° 25.5′ N; 155° 16.5′ W.

May 31, 7:32 am, very feeble, probably located in SE portion of Kilauea Crater.

June 3, 3:07 am, feeble, located in Hilina Pali Fault system 9.0 miles S of Halemaumau 10 miles deep. 19° 17.2′ N; 155° 18.5′ W.

vicinity of the old Prison Camp 1.2 miles NW of Uwekahuna. 19° 25.8′ N; 155° 18.3′ W.

June 14, 7:01 am, very feeble, located 4.3 miles deep under N rim of Kilauea Crater 0.5 mile NW of Volcano House. 19° 26.2′ N; 155° 15.9′ W.

June 16, 4:52 am, feeble, located 0.5 mile E of center of Halemaumau in Kilauea Crater 1.0 mile deep. 19° 24.5′ N; 155° 16.7′ W. Reported felt rather strongly at CCC Camp on SE rim of Kilauea Crater and moderately felt near Park Headquarters.

June 16, 10:35 pm, very feeble, located in Kilauea Crater.

June 17, 11:27 am, very feble, thought to have been located in SE portion of Kilauea Crater near Keanakakoi.

June 21, 2:16 pm, feeble, probably located in Chain of Craters rift near Puhimau Crater.

June 25, 6:20 am, feeble, probably located 9.0 miles S of the Volcano Observatory in the Hilina Pali fault zone.

Seventeen minutes of continuous tremor began recording at the Observatory at 12:13 pm, June 5 and sixteen minutes of continuous tremor began recording at 9:22 am, June 6.



Trees stripped of foliage and their broken branches strewn on the ground: havoc caused by volcanic showers during the eruptions near Rabaul, the capital of New Britain.

June 4, 10:40 am, very feeble, probable location in Kilauea Crater.

June 7, 6:46 am, very feeble, located 25.0 miles deep in Kohala District 5.0 miles east of Mahukona. 20° 10.3′ N; 155° 49.0′ W. Reported strongly felt in Kohala and at Kamuela.

June 9, 9:12 am, very feeble, of Kilauea origin.

June 12, 11:29 pm, very feeble, located 0.8 mile deep in E portion of Kilauea Crater. 19° 24.9′ N; 155° 16.1′ W.

June 13, 9:21 pm, very feble, located 3.8 miles deep in

Microseismic motion of the ground at the Observatory was light May 31, strong June 5, 6, 8, 15, 16, 17 and 19 and moderate the remainder of the month.

The preliminary waves of a teleseism began to register at Kilauea at 4h 55m 8s, am H.S.T., June 21. It was estimated to have occurred 5450 miles away. There was a partial trace of a teleseism recording at the Observatory June 24, 3:18 am H.S.T.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending June 27 was 8.8" S. and 1.35" E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau West Station
June 6	0.60" N 4° E	1.49" N 79° W
June 13	0.60" S 4° W	2.24" N 87° W
June 20	0.60" N 4° E	1.49" N 80° W
June 27	0.50" N 4° E	1.40" S 70° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
June 6	1.75" N 55° E	1.16" from
June 13	4.01" N 72° W	1.16" toward
June 20	4.18" S 71° E	5.06" from
June 27	7.65" N 28° W	6.12" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory June 19, slight closing of the Halemaumau value and opening of the crater value as compared with similar measurements May 27. From Kilauea SE rim to Uwekahuna there was opening of 0.82" and from the Pit seismograph to NW Pit B.M. there was closing of 2.01".

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Ascsociation was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.



THE VOLCANO LETTER

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Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

WORK OF F. A. PERRET ON MONTSERRAT

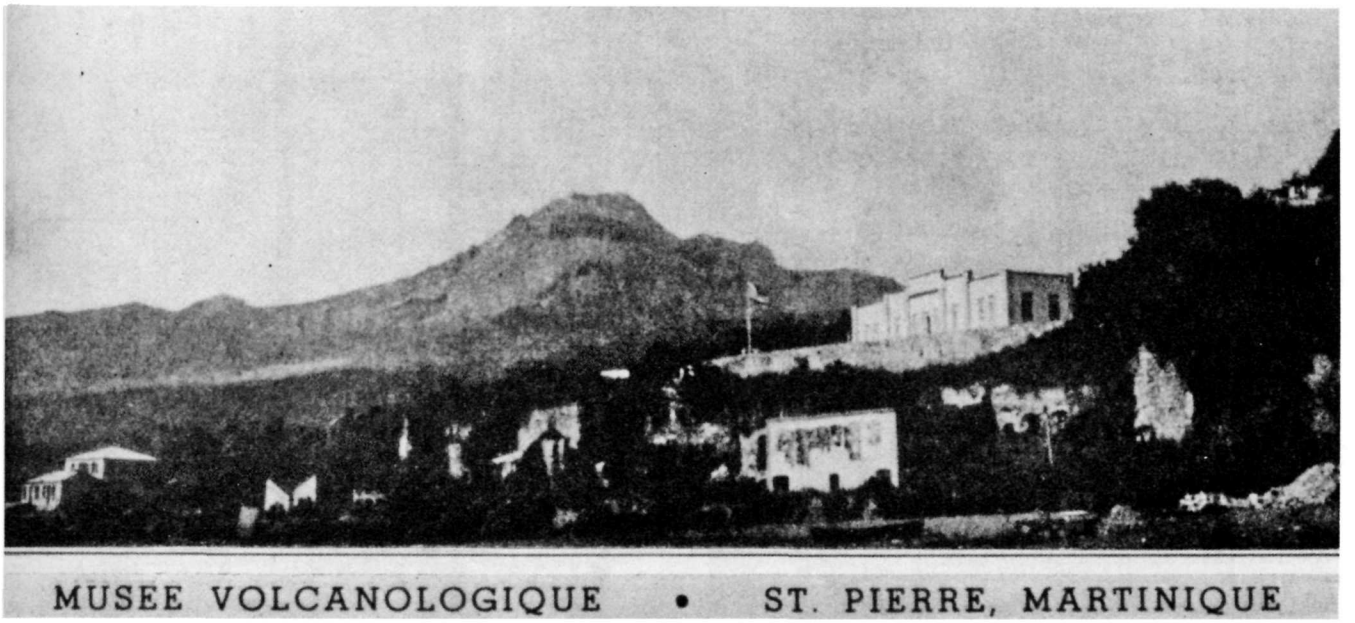


Figure 1. Museum at the ruins of St. Pierre, Martinique.

The Monserrat earthquake crisis of 1933-1936 was described in Volcano Letter No. 437, July 1936. Frank A. Perret, the volcanologist whose museum at St. Pierre, Martinique, is shown in Figure 1 (with the great new andesite dome of Mont Pele in the background) was called in to help by the governor of the Leeward Islands Presidency. Perret helped us in Hawaii in 1911, and his whole career has been devoted, as a volcanologist, to helping people in stricken volcanic lands. It may be of interest to show how such a man works. The Montserrat crisis was an apt illustration of such work, an island suddenly rushed into earthquake disaster in 1934, and its administration instinctively summoning the nearest expert for assistance.

The course of development of the Montserrat earthquake crisis, and its decline, are shown in the accompanying diagram, Figure 2. The columns are monthly seismicity. The four high ones May and December 1934, May and November 1935, were all times when churches and other masonry buildings fell, landslips occurred, and people were injured. These were earthquakes of grade VIII to IX Rossi-Forel. Frequency varied with intensity, and the sequence was from several and small shocks in 1933, itself a most unusual spell, to hundreds and severe earthquakes in summer and winter of the next two years. A terrifying feature of the crisis was the centering of these quakes at Gage's Soufriere, a crater gorge directly above the town Plymouth and only two miles away.

E. O. Hovey in revisiting the West Indies in 1903, after

careful work on Mont Pele in 1902, described these "principal craters of Montserrat as appearing to be in almost exactly the same condition as that of Pele, before the 1902 series of eruptions began."

Along with the coming of the quakes, the Montserrat solfatara gorge started vomiting up noxious odors of hydrogen sulphide, whose "rotten-egg" smell penetrated the town, and the gas actually darkened the white paint of steamers lying at anchor in Plymouth harbor. (Map, Figure 3.)

A striking feature of the map is the 100-fathom dotted line at the north. This contour under the sea is a half-circle. It outlines an ancient big volcano. The volcanic activity of recent ages has migrated to the south end at the Soufriere Hills. These hills have hot solfataras steaming and depositing sulphur on three sides. The ancient northern volcano is mostly eroded away by the ocean, leaving a platform 20 to 30 fathoms beneath the waves.

The new gas development was noted in April 1933 and earthquakes that year were most frequent at St. George's north of Soufriere Hills. They increased in force and number to April, 1934 and the government commissioner sent telegrams to inquire about volcanic conditions, which were found not to have changed in St. Vincent, Martinique, Guadeloupe and Dominica.

New sulphur vents were opening at the Montserrat solfataras. The hospital and private buildings were damaged by a sharp shock April 9, 1934. Revising the whole method of building was suggested.

Vague reports were at hand of a volcano scientist camped

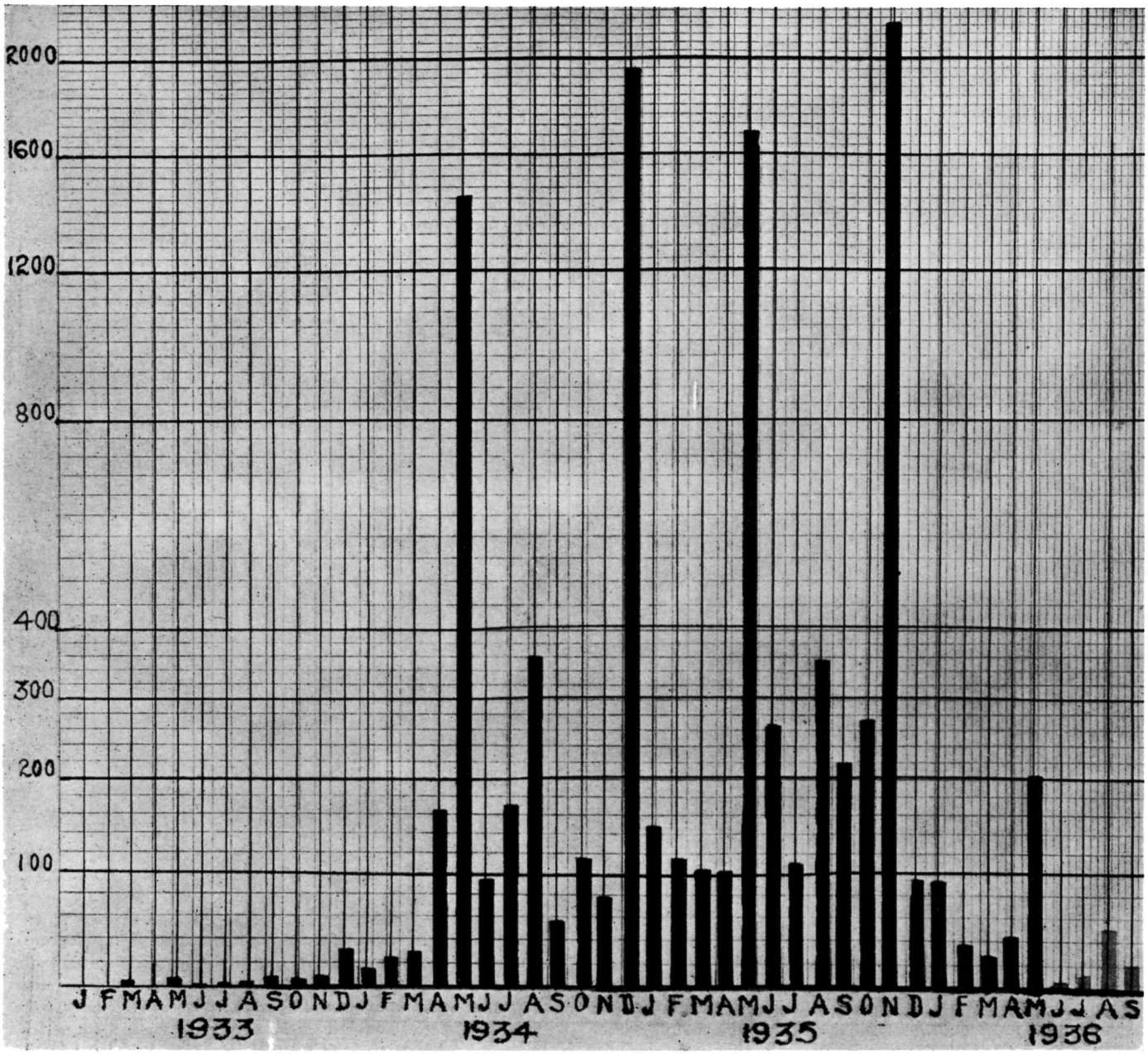


Figure 2. Chart of the rise and fall of earthquake activity in Montserrat.

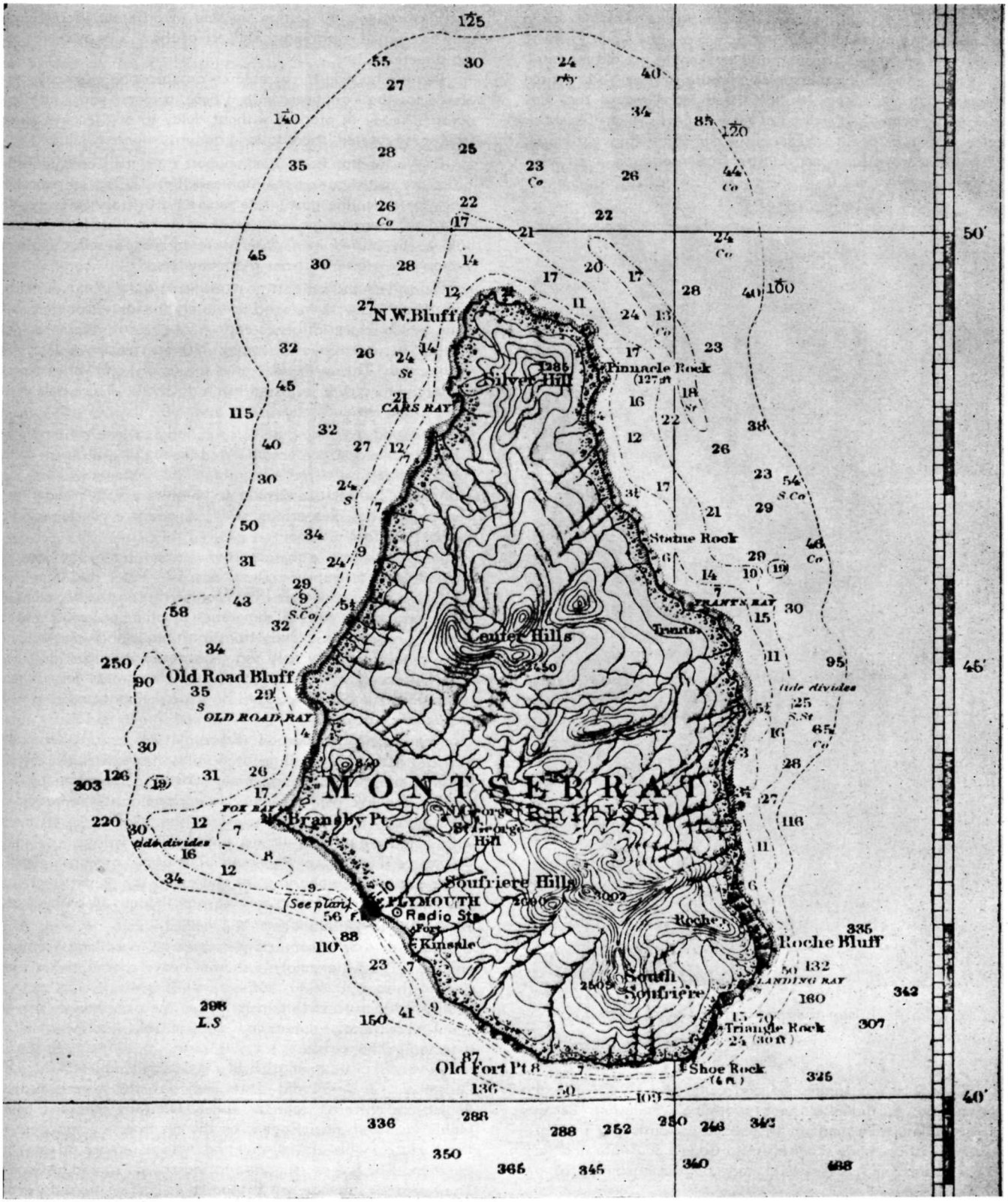


Figure 3. Chart of Montserrat, an island about ten miles long.

on Mont Pele with microphones in the soil. The British consul in Martinique phoned Perret, who was the reported scientist very much alive, and who reported Pele quiet.

May 13-14, 1934 produced sixty shocks, which cracked houses during an exceptional jolt at 2 a.m., the worst in thirty years. All of this was racking and weakening the old masonry.

Perret came by on a steamer en route to New York, visited Gage's Soufriere May 13th, predicted more shocks that day which duly came, and warned of more danger. A terrible shock came at 3 p.m. the 14th, seriously damaging the courthouse, all business was suspended, disorganization and disrupted sanitation were threatened.

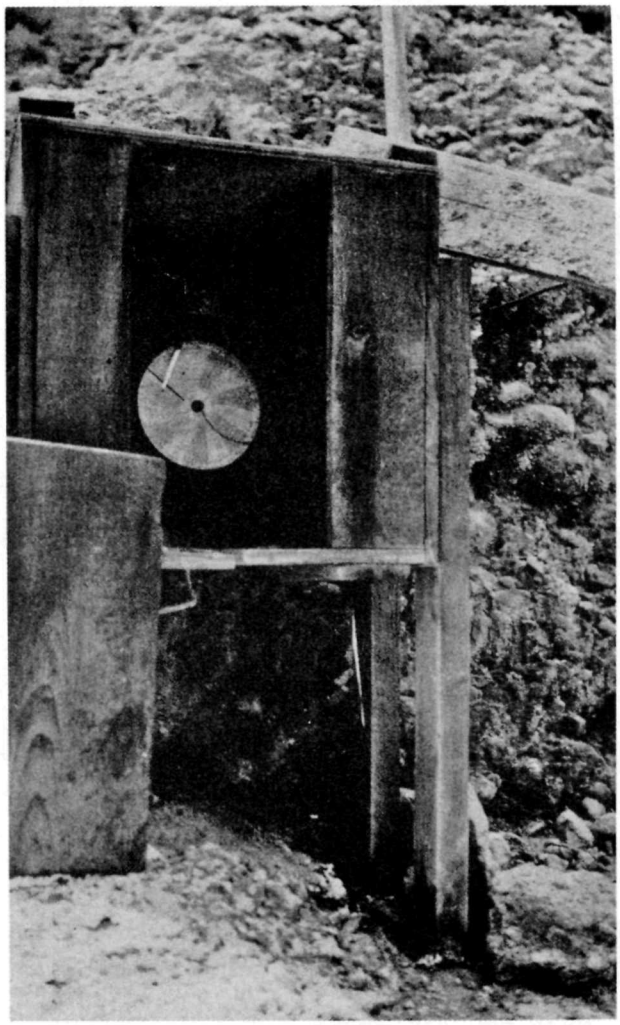


Figure 4. Bristol thermograph at Gage's Soufriere.

A warship was summoned and came May 21-31 to calm the people; earthquakes kept swarming. Following Perret's advice counts were made of the quakes, scientists of the agricultural station made daily visits to Gage's Soufriere and took temperatures, and notes were made on the chemistry of the waters and gases.

In July Mr. Perret was invited to return and install instruments; he had taken a water sample to Washington from the solfatara. No seismograph had yet been supplied.

Mr. Perret wrote Mr. Gomez, the director of agricultural station, suggesting a direction-finding seismoscope which was duly installed: "Suspend a series of weights of one pound each with fine wire as simple pendulums, of lengths varying 6, 12, 24, 48 and 96 inches. By watching these when shock occurs, some will swing, others not, showing period and direction of earth vibration. By setting up sets in different places much may be learned regarding the source of the shocks by coordinating directions."

Perret's hope is for a research organization eventually endowed for the Caribbees; with a base, a motor yacht with apparatus, ready to proceed without delay to any locality where trouble is reported, there to land and investigate conditions.

In Washington he secured support from the Carnegie Institution for investigating the Montserrat crisis, and sent vacuum tubes for collecting gases. He secured a Bristol gas-expansion recording thermograph with weekly charts, the lead-covered bulb to be buried in a gas fissure at Gage's solfatara; also microphone, and maximum thermometers.

He arrived and set up the instruments the end of November. Throughout his work he watched closely the luni-solar combinations, which might influence earth-tide stress in relation to gas tension in subterranean magma. The gas tension is localized in the crust. The earth tide varies seasonally, and varies exceptionally with certain sun and moon positions. The whole crust pumps with the earth tide.

The sudden frothing of volcanic magma in a subterranean fissure is a large force accumulated locally of a different kind, subject to release if the small tidal force relieves pressure exceptionally on certain dates. It is quite possible that deep plutonic earthquakes are so released, and are concerned with changes of state of magma.

Perret's reports to the governor were printed in the Leeward Islands Gazette between December 12, 1934 and May 19, 1936 in a series of letters from Montserrat, on the occasions of his several visits, coming sometimes by steamer, sometimes in haste by airplane and sloop from Martinique through Antigua. For a man of seventy they show extraordinary vigor; he made nine reports; and he built a hut within the crater gorge where he actually tried to sleep, until he injured throat and eyes with the deadly gases.

The Bristol thermograph (Figure 4) was set up in the bottom of the steaming gorge at Gage's. It registered 105° C. and the strong shocks also made of it a seismograph, by disturbing the ink pen. Mercury in saucers, for observation of small tremor, was placed in four localities. Gas tests were made with lead acetate and litmus paper. The hydrogen sulphide was tested thus even at Plymouth. The litmus at Gage's showed water sour with sulphuric acid, and air in the gorge which was alkaline. A gas irritating to eyes was thought to be hydrogen persulphide. Photographs were taken.

Vacuum tube collections were sent to Washington for gas analysis. The water analysis showed heavy charge of hydrogen sulphide, iron, alumina, sulphur, silica and organic matter; acidity 0.1 per cent, chlorine a trace; the gas analysis showed equal amounts of sulphur and chlorine. No fluorine could be detected in the waters.

A very sharp culmination of many earthquakes at 11 a.m. December 12, 1934 did more damage, was experienced by Perret, and differed from the widely felt May shocks in being highly localized, near Gage's, as though from magma close to the surface. This was disquieting with reference to possible eruption. The gas pressure had increased and spread at Gage's. The hydrogen sulphide was diagnosed as coming from dry vents lower than the wet solfatara. No tremors actuated the mercury surfaces between shocks, and the latter were sharp and brief. Absence of volcanic tremor indicated absence of moving magma, and the microphone confirmed this. The local observers were instructed to carry on with the instruments when Perret returned to Martinique.

Perret's second visit was in February-March 1935, and systematic observations had meanwhile been reported by the local men. He occupied his hut (Figure 5) in the crater gorge, observing the thermograph; the mercury bath with bell-glass cover mounted in a niche; a microphone buried in the ground; an air-microphone for the pressure-note of gas emission; a seismic pendulum for detecting direction of movement in earth shocks, with a mirror reflecting the beam from an electric torch at night.

A new hydrogen sulphide vent opened whistling the night of February 20, 1935. The other acrid alkaline gas that affected eye tissue made night stays impracticable. Tight-fitting goggles helped in daytime. Some subterranean sound was heard occasionally. The Bristol thermograph gave a deceptive indication of rising temperature on the record, which proved to be due to corrosion and weakening of the metal spiral. Check with thermometer proved error. "Bread-crust" bombs like Pele's were found in the gorge. Perret expressed intention of return in May, the critical month of 1933 and 1934.

The next visits of the American volcanologist were in April and May, 1935 and a severe, prolonged and deep shock did more damage on May 6, and exhibited much horizontal movement. The area shaken was farther north. The earthquake was preceded by early morning tremors, and very heavy rains came at 3:55 p.m. and were followed by aftershocks all night. The wide-spread effect relieved apprehension of volcanic eruption for Perret; the disturbance was not craterally localized.

Perret called attention to the sum total of the energy released and dissipated in the long series of earthquakes. If this energy had been concentrated in a single shock, like the Tokyo earthquake of 1923, the wreckage and loss of life might have been far worse. The comportment of the population, largely Negro, was good.

The deeper and more diffuse quality of the May 6 shock of 1935 satisfied the investigator that the volcano eruption danger had culminated at the December 1934 shocks, when high gas pressure and temperatures were dominant at the solfataras. Both had diminished in May 1935 when the deep earthquake came, and did tremendous seismic damage. Mr. Perret stated definitely to the authorities that possibility of more strong shocks remained, but that we might "now discard all likelihood of volcanic eruption."

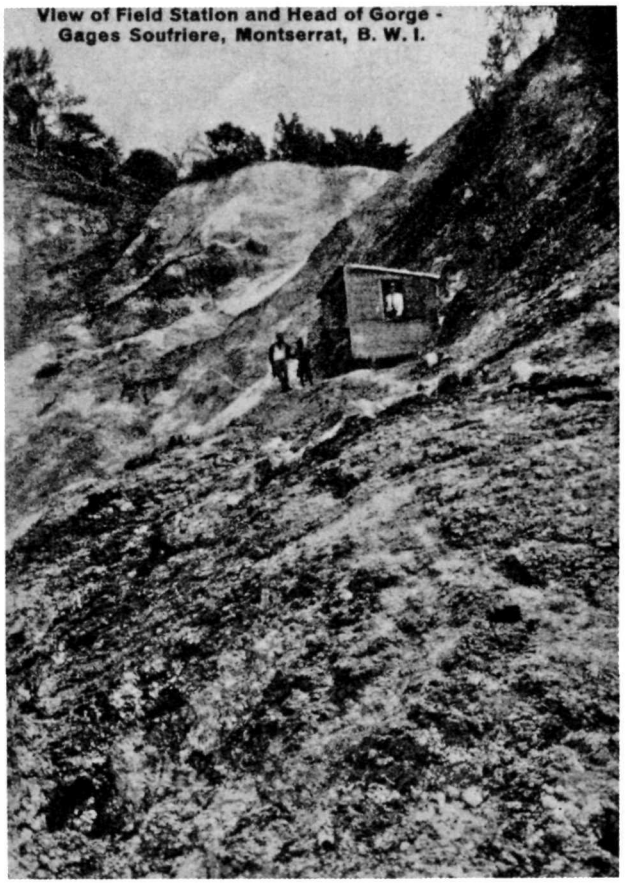
To make such a statement as this required courage. The event bore out its accuracy. In a paragraph of his final report when the Royal Society Committee was about to take his place he says, "It has been inspiring to work in such an atmosphere of discipline and good will, and I shall remember with pleasure **—in spite of such anxiety and responsibility as cannot be imagined by those who do not know**—the days of my investigations here."

The boldface are the reviewer's. Here is a man working devoted and alone. He is working that black men may live and their habitations be preserved, in a hot and humid climate amid poison gas. He is apt to receive for it the nosey snubbing of "superior" men of science who dwell in superior laboratories in the urban atmosphere of a superior climate, and who do not dirty their fingers with the poisonous solfataras of volcanoes.

Withal his inventive ingenuity never relaxed. He finally installed at Howes Estate near the solfatara a "Seismeter" of his own construction made out of three pedometers of the pace-counting watch pattern. This is shown in Figure 6. Two are laid horizontally with their pendulum interiors at right angles to each other, to beat and record on their dials the "paces" of the earth east-west and north-south respectively. The third is laid vertically, as it would be if attached to a man's belt in walking, and records the upright jolts of the earth. All shocks above a certain minimum of intensity will record. By reading the three dials after one of the savage shakings of the earth, the number of units above the intensity minimum, prescribed by the sensitivity of the pedometer, for each direction, describes what has happened at the instrument locality.

Thus the quake of November 10, 1935 gave 1v, 9n, 3e; that of November 11 was much more vertical, 7½v, 6n, 5e; while that of November 12 was intermediate, 4½v, 2n, 1e. In these v is vertical, n is north-south, and e is east-west.

The seismeter has the further quality that its dials may be read after any shock series, but not changed; and it goes on summing up, just as the pedometer does for a pedestrian, the totality of earthquakes for any period of time, regardless of whether there is present an observer to read it. Thus this extraordinary worker in the wilderness finds time to invent and add to the progress of science, even in the midst of quakes and ruins and fumes!



View of Field Station and Head of Gorge - Gages Soufriere, Montserrat, B. W. I.

T. A. J.

Hawaiian Volcano Observatory Report for July 1937

VOLCANOLOGY

The only events of importance at Kilauea Crater have been two spells of local earthquakes lasting about a day each July 22 and July 30. Each of these produced moderate earthquakes which were felt. Numerous distant earthquakes were recorded.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
July 4.....	8.00	2	6.0	22
" 11.....	9.25	0	7.0	37
" 18.....	6.50	0	9.5	18
" 25.....	26.00	0	11.5	84
Aug. 1.....	22.75	0	5.5	45

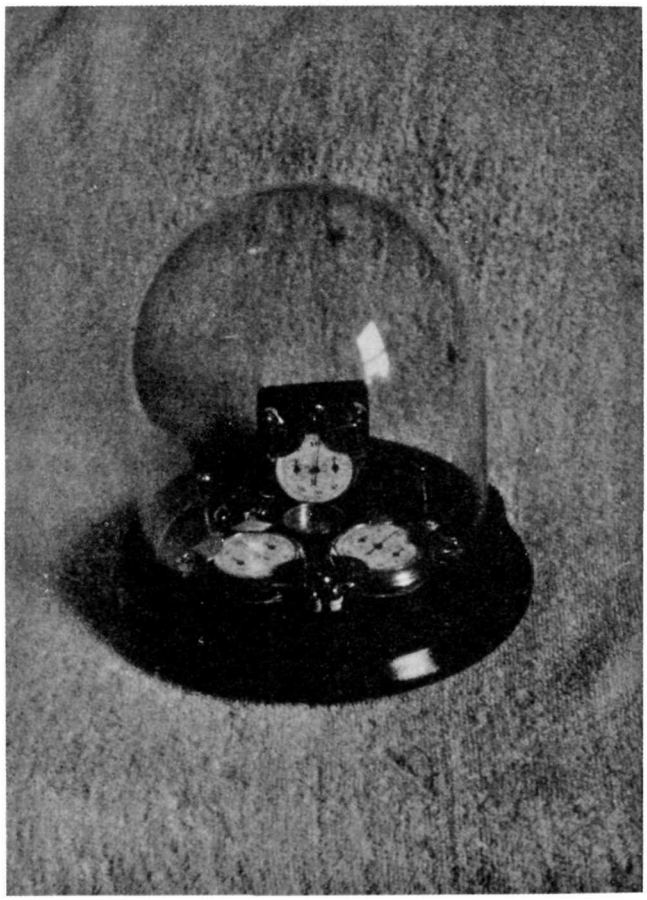


Figure 6. Experimental Seismeter installed at Gage's Oct. 25, 1935, records and integrates ground movement in vertical and horizontal components. (3) Totalizes on 9 dials (3 on each pedometer).

Frank A. Perret.

Sequence of Events by Weeks

The first week produced nothing more conspicuous at Halemaumau pit than two small slides.

The second week showed the pit still quieter.

The third week nothing was noted at Halemaumau but on July 14 Park officers on the upper Mauna Loa trail reported steam from a cone on the Northeast Rift at about elevation 11,000 feet, and bluish fume from cracks a quarter mile farther south.

The fourth week no slides were reported but the earthquakes of July 22 probably made avalanches. It was noticed July 25 that the northeast wall of Halemaumau has developed a buttress resulting from landslips on each side. The talus slopes NE, NW, SW, SSE, and E from the pit center all have buttresses of rock between them. The migration of landslip area from year to year since 1924 has kept the pit fairly symmetrical. The talus cones were made by such landslips and the buttresses are each backed by cracks concentric with the rim, and below the rim, that were formerly fissures in the upper country.

The last week produced excessive rainfall (more than 16 inches July 31-August 1), and a spell of earthquakes July 30.

Slides at Halemaumau

The only recorded slides from the wall of the pit were:

July 1, 1:22 p.m., made dust and noise.

July 2, 9:17 a.m., rocks fell from east wall 200 feet below rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim-crack locations resulted during July in aggregate movement as follows:

Week ending forenoon of:

July 2, 30 locations, 9 opened, 5 closed, opening 6.0 mm. At the east Crack No. 52 closed 4.5 mm.

July 9, 30 locations, 7 opened, 4 closed, opening 7 mm.

July 16, 30 locations, 8 opened, 1 closed, opening 9.5 mm.

July 23, 30 locations, 11 opened, 1 closed, opening 11.5 mm.

July 30, 30 locations, 3 opened, 4 closed, opening 5.5 mm. Most of this was at Crack No. 25, east rim.

SEISMOLOGICAL DATA

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
July 4.....	16	4	0	1	0	1	8.00
" 11.....	35	1	0	0	0	1	9.25
" 18.....	12	5	1	0	0	0	6.50
" 25.....	70	9	1	0	1	3	26.00
Aug. 1.....	29	9	4	2	1	0	22.75

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible a determination of depth of focus has been made.

June 30, 5:43 am, very feeble, located 3.5 miles deep under area 1.5 miles west of Kilauea Crater. 19° 25.0′ N; 155° 18.9′ W.

June 30, 8:46 am, very feeble, a deep quake with epicenter near Honokaa. 20° 4.0′ N; 155° 33.0′ W.

July 2, 9:16 am, very feeble, 2.6 miles deep and 2.0 miles west of Kilauea Crater. 19° 24.8′ N; 155° 19.4′ W.

July 3, 6:49 am, slight, 3.0 miles deep and 1.0 mile SW of Ahua Kamokukolau, 19° 22.0′ N; 155° 17.0′ W.

July 10, 9:43 pm, very feeble, thought to be of shallow origin near center of Kilauea Crater.

* For local seismicity definition see Volcano Letter 371.

† Includes teleseisms and distant earthquakes.

July 13, 5:40 pm, very feeble, originated near SE rim of Kilauea Crater.

July 16, 3:20 pm, very feeble, probably originated in rifts 1.5 miles S of Ahua Kamokukolau.

July 16, 6:51 pm, feeble, 3.5 miles deep in vicinity of Kipuka Ki, 2.0 miles NW of Uwekahuna. 19° 27.3′ N; 155° 19.2′ W.

July 18, 10:55 am, very feeble, 1.7 miles deep in W portion of Kilauea Crater near Uwekahuna Bluff. 19° 25.3′ N; 155° 17.0′ W.

July 18, 10:56 am, very feeble, 1.6 miles deep under Kilauea Crater rim near Uwekahuna Bluff. 19° 25.6′ N; 155° 17.1′ W.

July 18, 7:29 pm, very feeble, probably originated in NE rift of Mauna Loa near summit crater.

July 19, 8:36 am, very feeble, 1.7 miles deep in Kilauea Crater near the old Stone Corral. 19° 24.7′ N; 155° 16.3′ W.

July 22, 8:53 am, very feeble, probable origin, Kilauea SW rift near Cone Peak.

July 22, 10:38 am, feeble, probable origin in Chain of Craters near Puhimau.

July 22, 10:41 am, very feeble, 1.5 miles deep under SE rim of Kilauea Crater near Keanakakoi. 19° 24.5′ N; 155° 15.9′ W.

July 22, 10:53 am, very feeble, 2.2 miles deep, 6.0 miles N of Ahua Kamokukolau. 19° 23.3′ N; 155° 16.3′ W.

July 22, 11:14 am, very feeble, probably originated in Kilauea Crater near Halemaumau.

July 22, 11:18 am, very feeble, 1.6 miles deep, 1.8 miles NW of Puu Ohale. 19° 22.3′ N; 155° 17.9′ W.

July 22, 11:40 am, moderate, 1.8 miles deep and 1.7 miles SE of Pit seismograph. 19° 23.5′ N; 155° 15.8′ W. Reported felt in Park Headquarters Area; and at Kilauea Military Camp.

July 22, 11:45 pm, very feeble, 3.0 miles deep SE rim of Kilauea Crater near Keanakakoi. 19° 23.0′ N; 155° 15.6′ W.

July 23, 3:30 pm, very feeble, probably of shallow origin near center of Kilauea Crater.

July 24, 3:20 pm, very feeble, probably originated in Chain of Craters Area near Puhimau.

July 30, 2:40 pm, moderate, probable origin, Mauna Loa NE rift near Puu Ulaula.

July 30, 3:46 pm, feeble 2.8 miles deep in vicinity of old Koa Mill, 1.5 miles N of Kilauea Crater. 19° 27.1′ N; 155° 17.0′ W.

July 30, 3:50 pm, feeble, 2.8 miles deep in Chain of Craters rift near Lua Mau Crater. 19° 23.9′ N; 155° 15.4′ W.

July 30, 8:05 pm, very feeble, 5.5 miles deep in Chain of Craters rift near Kokoolau. 19° 23.1′ N; 155° 14.0′ W.

July 30, 8:17 pm, very feeble, 3.5 miles deep near Kipuka Puaulu, 2.5 miles NW of Kilauea Crater. 19° 27.0′ N; 155° 18.9′ W.

July 30, 8:46 pm, very feeble, 2.4 miles deep near Ainahou Ranch House. 19° 20.8′ N; 155° 14.0′ W.

July 30, 9:14 pm, very feeble, probably originated in Chain of Craters near Pauahi.

July 30, 9:29 pm, feeble, 2.7 miles deep and 0.7 mile E of Hiiaki Crater, Chain of Craters rift. 19° 22.8′ N; 155° 13.5′ W.

July 31, 10:11 pm, slight, 4.7 miles deep under Kilauea Crater rim 0.5 mile NE of Uwekahuna. 19° 25.7′ N; 155° 17.3′ W.

July 31, 10:13 pm, slight, location of focus same as preceding quake.

July 31, 10:27 pm, very feeble, 5.0 miles deep and 1.0 mile NE of Volcano Observatory. 19° 26.5′ N; 155° 15.3′ W.

August 1, 2:56 am, feeble, location of focus same as preceding quake.

August 1, 9:43 am, very feeble, 2.8 miles deep in rift area 0.8 mile N of Puu Ohale. 19° 21.9′ N; 155° 16.8′ W.

A period of continuous tremor lasting 26 minutes began at 9:24 am, July 6.

Microseismic motion of the ground at the Observatory was light July 5, 10 to 13, 17, 19 to 21, and July 26; moderate June 28 to 30, July 4, 7 to 9, 14 to 15, 18, 22 to 23, 27 to 30, and August 1; strong remainder of month.

Teleseisms or Distant Earthquakes registered at Kilauea as follows: July 1, 4h 28m pm, H.S.T., undetermined phase; July 3, 7h 46m 19s pm, H.S.T., undetermined phase; July 11, 7h 13m 55s am, undetermined phase, reported by Central Station of the Jesuit Seismological Association as located 20° 7′ N; 108° 3 W (west coast of Mexico); July 22, preliminary phase, 6h 47m 56s am, originated 3,010 miles from Kilauea and epicenter reported by Central Station of Jesuit Seismological Association as 64° 5′ N; 145° W (Central Alaska); July 25, preliminary phase, 5h 26m 44s pm, H.S.T., distance—3,780 miles and July 25, 10h 18m pm, undetermined phase.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 1 was 9.8″ S and 1.85″ E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau West Station
July 4	0.26″ N 20° W	1.55″ N 60° W
July 11	0.00	2.17″ N 68° W
July 18	1.13″ N 17° E	10.13″ N 82° W
July 25	0.36″ S 47° W	11.02″ N 71° W
Aug. 1	0.51″ S 60° E	6.35″ N 55° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
July 4	3.75″ N 60° W	2.22″ toward
July 11	3.40″ S 60° W	1.62″ from
July 18	10.85″ N 43° W	0.72″ toward
July 25	5.31″ N 86° E	12.89″ from
Aug. 1	10.37″ S 41° W	7.19″ from

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 450 monthly Department of the Interior National Park Service August 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Mount Rainier National Park. Washington.

VOLCANOES IN THE NATIONAL PARKS—

Radio Talk, KHBC, Sept. 28, 1937, Hugh H. Waesche

Because of their spectacular nature and their interference with man's activities, volcanoes have always been of intense interest to the human race. With primitive peoples they have been associated with the supernatural, but when attacked by modern scientific thought they serve as major stepping stones in the solution of many problems concerning the origin and history of the earth on which we live. Most advanced, and going beyond previous thought is the systematic study of volcanoes with protection of life and property in mind.

Many of our National Park areas contain volcanoes as major features. Other National Parks contain volcanic features of secondary importance. Of twenty-seven National Parks listed August first of this year, five have volcanic histories of major interest, and at least nine others contain some evidence of past volcanic history. So, more than half of our National Parks have a geologic story to tell of which some portion is volcanic.

In this series of Parks, volcanic conditions of practically every kind known are demonstrated, from the currently very active lava volcanoes in Hawaii, to ash deposits laid down in Shenandoah and Mammoth Cave National Parks many millions of years ago in that geologic period known as the Ordovician, when man's arrival on earth was in the very distant future and probably all life was still confined to the oceans. This variety of volcanic evidence applies equally to both kinds of activity, and amounts of activity.

Five National Parks illustrate stages of volcanic activity very clearly. Hawaii National Park heads the list as the most active, being the location of Kilauea and Mauna Loa. Lassen Volcano in Northern California illustrates a second stage of activity as well as holding the unique position of being rated the only active volcano within the boundaries of continental United States, excepting Alaska. Mount Rainier in Washington represents the dormant stage, Crater Lake a dormant or extinct volcano with a special history, and Yellowstone, an ancient volcanic region much eroded but with enough residual heat to produce a very special type of geyser activity found at only three localities in the world.

Not one of these volcanoes has been listed definitely as extinct, as that is a term which should not be applied too hastily. No doubt some of these volcanoes are extinct, but definite statement to that effect would certainly be open to question. Vesuvius in Italy was considered extinct until seventy-nine A. D. but that opinion was rudely changed with the destruction of Pompeii.

Aside from the volcanoes in the National Parks there are others in National Monuments such as Katmai in Alaska, Sunset Crater, Arizona, Capulin Mountain, New Mexico, and the Lava Beds of California. Various types of volcanic structures are also exhibited in Craters of the Moon in Idaho, Devil's Post Pile in California, Devil's Tower, Wyoming, Grand Canyon National Monument and Death Valley National Monument.

It is not surprising that the first and greatest area to be set aside as a national park was volcanic. Only a volcanic region could produce the superlative and dynamic landscape which holds this honor. Everyone has heard of and knows something of Yellowstone, the "Grand Old Man" of all the parks, both in the United States and elsewhere. It is located in the northwestern corner of Wyoming with a slight overlap into the states of Idaho and Montana. This region was rather inaccessible and practically unknown until the middle of the last century. A few men had visited the region, however, and brought back glowing tales of the wonders to be seen there. As far as these reports were concerned the public was very incredulous and the situation was such that few dared to tell of the things they had seen, as several lecturers were actually stoned in the streets as imposters. The first official and accredited exploration of the Yellowstone region was made by the Washburn-Langford expedition of 1869. Their glowing reports of the wonders of the region led to its establishment as our first National Park in 1872.

The feature of greatest interest in Yellowstone is that unusual form of volcanic activity, the geyser. It is justly celebrated in this respect as there are only two other places in the world where geysers are common, New Zealand and Iceland, and Yellowstone has more geysers than those two combined. There are more than three thousand geysers or hot springs within the Park and every conceivable type or form of either is represented.

A geyser may be thought of as a water volcano. They can occur only in places where the internal heat of the earth is near the surface. Water from the surface plus some added from depth flows into an opening in the form of a more or less tubular vent, or maybe even a crack, and eventually reaches regions of highly heated rocks below. When this happens steam is formed but does not escape because of the heavy column of water above. After a time, however, the steam pressure becomes equal to or slightly greater than that exerted by the water column and as soon as this condition is reached the water is forced out and appears at the surface as a fountain.

The height of the fountain, frequency of play, and force of the water depend on conditions which vary widely with the different geysers. Such conditions are size of orifice at the surface, temperature below the surface, length and size of the tube leading to the hot rocks, ground water level, and probably other conditions which are not known.

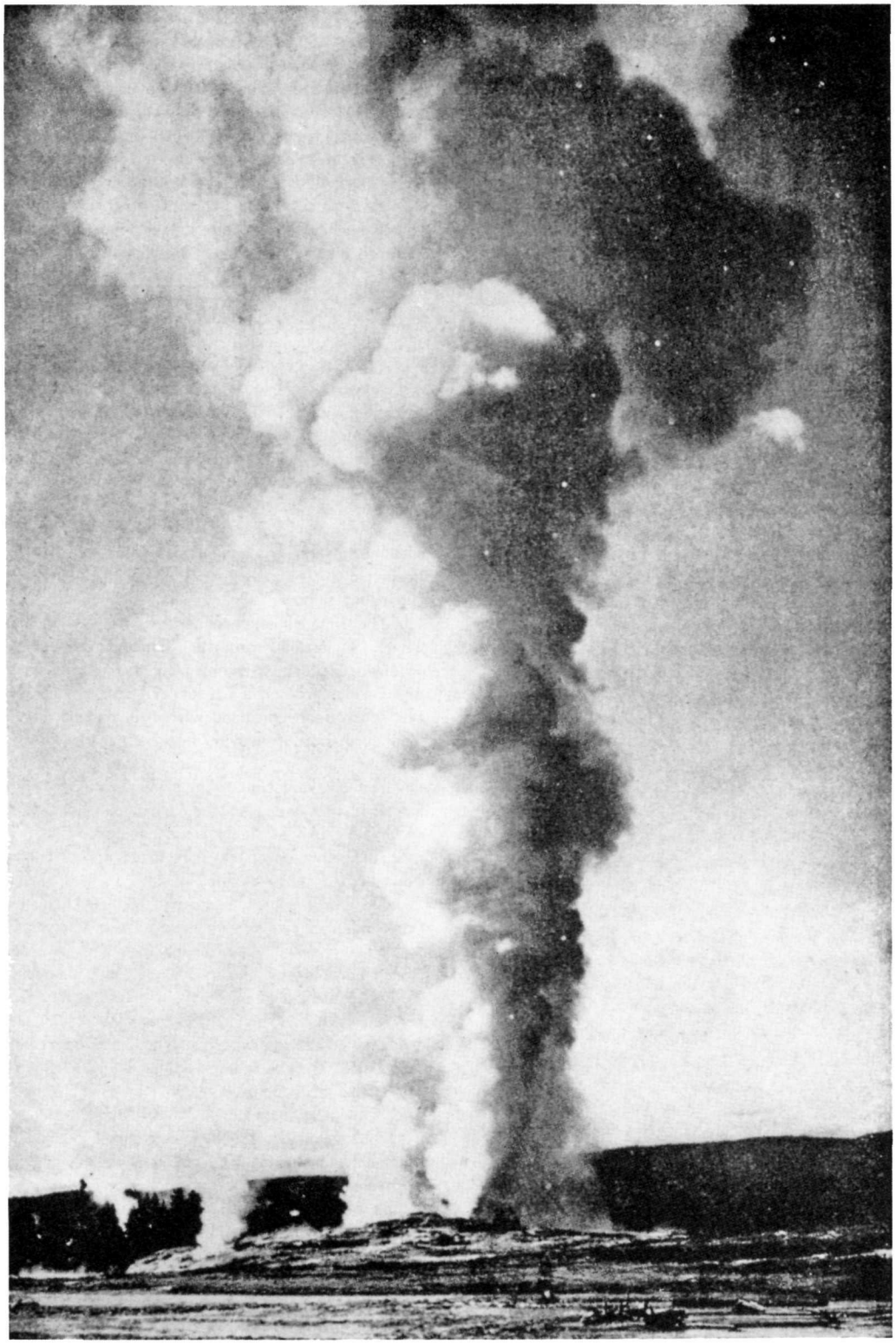
There are six principal geyser basins in the Yellowstone, all lying in the west and south-central sections of the Park. Some geysers erupt quite regularly. The most famous of these are Old Faithful, Daisy and Riverside. Old Faithful erupts about once an hour year in and year out and shoots a shaft of water over one hundred and fifty feet in the air for four minutes. The water temperature is about two hundred degrees Fahrenheit. Besides the geysers, the entire region contains many hot springs which are in most cases clear water with a beautifully colored background of orange, yellow, green or blue created by algae which live on the rocks forming the container. Other springs are filled with mud in constant agitation which, in one case, is named the Paint Pot. At Mammoth Hot Springs the water has brought to the surface large amounts of lime in solution which is precipitated on reaching the air. These mineral deposits build high terraces of beautifully encrusted basins over which the water flows.

Practically the entre region incorporated in Yellowstone is volcanic. Not only the surrounding mountains but the great interior plain is made of material once ejected as ash and lava from depths far below the surface. In some places entire forests have been buried by ashes blown from these ancient volcanoes, in another place lava which poured out on the surface cooled so rapidly that volcanic glass was formed, now represented by the famed Obsidian Cliffs. Yellowstone's volcanoes were probably active in that geologic age known as the Tertiary, millions of years ago. Since that time the region has quieted down, and has even been through a period of glaciation. The stage of erosion there, plus the lack of recent activity, marks the area as one in which a great volcanic exhibition had been through its youth, maturity and is now in advanced old age with only enough heat left over to keep the geysers busy.

Several hundred miles west of Yellowstone lies an area of a quarter million square miles which is the greatest field of volcanic activity in the United States and one of the greatest in the world. Large portions of the States of Washington and Oregon, and lesser portions of California, Nevada, Idaho, Montana and Wyoming are within this area. It includes the Cascade Range of Mountains extending from northern California across Oregon into Washington.

Within this range are three of our National Parks, all volcanoes, and they are, in order, south to north, Lassen Peak, Crater Lake and Mt. Rainier. Of this group, only Lassen is considered active. Crater Lake was probably active as recently as eight hundred years ago. Mt. Rainier near Tacoma, Washington, is considered "king" of all the towering volcanoes of this region. It is a huge volcanic cone over 14,000 feet in height and covering more than 100 square miles. A few steaming vents and hot springs are all that remain of activity which was evidently on a very grand scale in its past history. Now this huge mass of lava, cinders and ashes is covered by snow and ice resulting in a glacier system. Mt. Rainier is now an imperect cone, but once it was complete like the famous Fujiyama of Japan. Then it was probably 16,000 feet high. Sometime in its late history an explosion or engulfment occurred which took 2,000 feet off the top and left Mt. Rainier beheaded. Indian legends tell of a great eruption, but no man really knows when this great mountain was last active.

The southern limit of the Cascade Range is marked by Lassen Peak. This volcanic pile is the only aggressive member of the group to which it belongs. It had been quiet for over two hundred years although one or more doubtful eruptions are reported, and "mud" flows have occurred within the last five hundred years as estimated from buried logs.



Yellowstone National Park. Wyoming.

On May 30, 1914, a series of eruptions began from Lassen which lasted through June of 1917. The first eruption was short and mild, opening a new vent in the summit crater. The materials thrown out the first year were not excessively hot. By March of 1915 over one hundred and fifty explosions had occurred, probably aided by water from an unusually heavy winter snowfall. On May 19, 1915, there appeared the first glowing lava which spilled over the western edge of the crater to flow down the slope one thousand feet. That night several destructive mud flows poured into valleys down the slope.

Three days later a mushroom-shaped cloud of smoke and dust arose four miles in the air accompanied by a hot blast of gas which rushed down the northeast slope destroying every living thing for ten miles. So violent was this blast that trees on Raker Peak three miles away were all felled uniformly in the direction of the outburst. The heat turned snow in its path to water. After this convulsion the energy of the Volcano was mostly spent although occasional outbursts of steam and ash continued for two years when it finally subsided.

At the present time Lassen is quiet, although from time to time there are earthquake shocks. There are many hot springs, boiling mud pots and sulfurous deposits in and around Lassen Peak. A seismograph station is maintained at Lassen for recording earthquakes as is done here in Hawaii. Lassen was formerly a part of the study program of the Hawaiian Volcano Observatory. Lassen Peak is 10,453 feet above sea level and is surround by lava fields, and other volcanic cones illustrating many phases of volcanic activity. Lassen's activity will probably be resumed in the future.

Although Grand Canyon National Park is set aside as a great example of stream erosion, it has some evidences of volcanic activity of a minor nature which occurred millions of years ago. However, within sixty miles of Grand Canyon is one of the largest extinct volcanoes in the United States. This is the San Francisco Mountain area of Arizona. Included in this region is Sunset Crater, a 700-foot cinder cone and associated lava fields. The latter locality has been recently active—that is within a thousand years. Some of the lava associated with Sunset Crater is very similar to our Hawaiian aa. Sunset Crater is a National Monument.

The Devil's Tower in Wyoming is an interesting volcanic exhibit. It is a 600-foot pile of vertical jointed lava similar to that to be seen in Makaopuhi Crater here in Hawaii National Park. It tops a 600-foot mound of sedimentary rock and can be seen for a hundred miles in any direction. Some people think it is an intrusive plug, but there are others who think it is a remnant of an old intrusive sheet, and there is a lot of evidence to back this latter theory.

In the country north of Lassen National Park there is an area in California near the Oregon line known as the Lava Beds National Monument. This large region is typical of its name and contains many lava tubes similar to our Thurston Lava Tube. Some of the tubes contain ice the year around and are known as ice caves.

Alaska is one of the most active volcanic regions of the world. A belt of volcanoes extends for 1,500 miles through the Alaskan Peninsula to the west part of the Aleutian Islands. Katmai is one of this series of volcanoes. It is 6,970 feet high, located on treacherous Shelikof Strait, opposite Kodiak Island.

Very little attention was paid to Katmai until June, 1912, when it announced itself to the world with an explosion that was heard in Juneau, 750 miles away. Earthquakes followed this blast and then came a spell of smoke and dust causing sixty hours of darkness in Kodiak, a hundred miles away. Dust fell in Ketchikan, 900 miles away and fume was carried by the wind to Vancouver, fifteen hundred miles away. Hazy atmosphere was noted over the United States the succeeding weeks and even peculiar atmospheric effects were noticed in Europe the following summer.

The scene of this explosion was made a National Monument in 1918. One of the most interesting phases of development at Katmai was the formation of the valley of 10,000 smokes near by. This has been described at length in the National Geographic Society's publications.

This review of volcanic National Parks and Monuments is by no means conclusive. However, it does give an idea of the great variety of volcanic activity to be found within the United States and its territories, with unlimited possibilities for study and research, or entertainment for those who prefer a spicier type of geologic story, connected with their Parks. Volcanoes can be depended upon to put on a good show when they are so minded in spite of their temperamental natures. To people of Hawaii, visits to the other areas should be interesting.

Kilauea Lava Flow of 1823

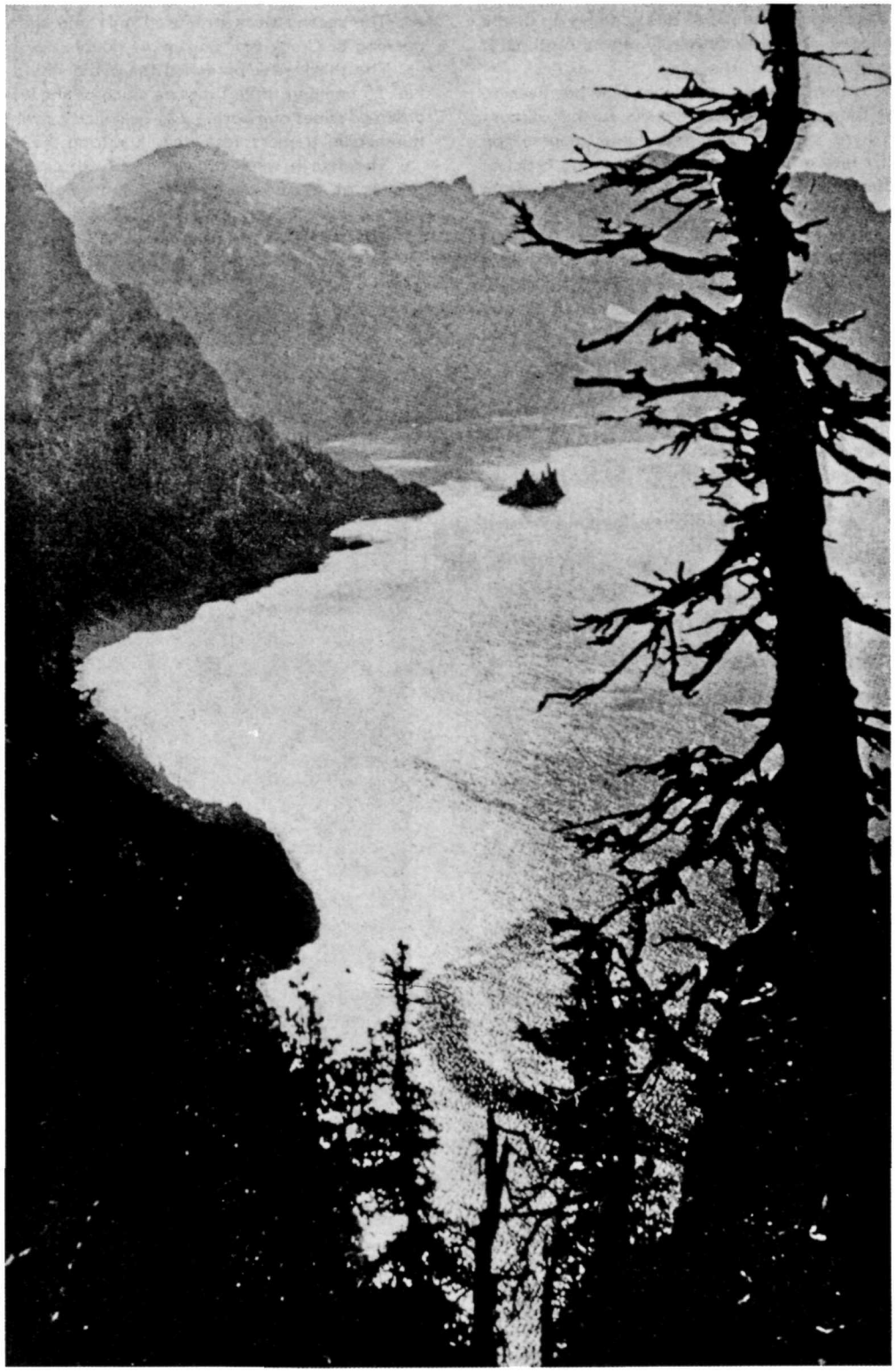
A major structural feature of Kilauea is the fracture zone extending twenty miles SW of the Crater, in the general direction of Pahala. This rift disappears out into the sea. It is commonly spoken of as the Kilauea SW Rift and is the feature indicated by that term frequently used in the Volcano Letter.

Although most of the Kilauea eruptions have occurred in the summit crater within historic times, some major activity has taken place in the regions associated with the SW Rift. The numerous prominent cinder cones and flows of the Kau desert in this vicinity testify to abundant activity before historic recording began.

The first nineteenth century flow from Kilauea occurred in 1823. It issued from the "Great Crack" twelve miles SW of Kilauea Crater. A minor flow took place in the SW rift zone eight miles from the Crater in 1868. The identity of this flow has often been confused with the more extensive flow of 1823. The confusion, however, has been straightened out with reasonable certainty by Stone, Stearns, and Jaggar, who have covered the question in published articles. The third and last SW Rift flow was that of 1920, resulting in the formation of Maunaiki. All of these flows are correctly shown on the latest maps. In the last 110 years there have been only three known periods of activity in the SW Rift.

The morning of February 26, 1937, a party of National Park officials visited the area of the Keaiwa Flow (local name for 1823 flow). This group included Mr. John D. Coffman, Chief Forester of the National Park Service, and Mr. E. E. Tillett, Field Supervisor of the Emergency Conservation work for the Islands.

The 1823 flow was found to be of considerable interest and unusual in that it seemed to have issued from the Great Crack which probably opened up immediately preceding the eruption and, no doubt, was accompanied by rather strong earthquakes. By Ellis' dates the outflow was about February, 1823, and the most serious earthquake about May. The lava formed a comparatively thin skin over older flows, leaving many small kipukas or islands of the older material and thus indicating a very fluid condition. Lining the Great Crack, there are rounded lava balls similar in appearance to bombs but of a much different origin and in two localities there are indications of phreatic explosions. The lava balls are accretion-spheres formed of hardened liquid lava around fragments in the chasm, swept out by later gushes which embedded them. The absence of cinder or driblet cones would indicate that the lava issued from the earth in a somewhat different fashion from the usual Hawaiian flow which has both at its source. A very striking and prominent feature is the presence of many tree molds. These are of a wide variety as to form. Some are several feet in thickness and



Crater Lake National Park. Oregon.

as much as six feet in height. The forms of the trees responsible are well preserved and the relative position of trunk and branches is often indicated. None of the molds observed was apparently formed by trees with a trunk of more than three or four inches in diameter. The direction of flow is clearly indicated by the flow lines around the molds and a piling up of the lava on their north sides. The flow definitely moved south as it should across the contours, toward the sea.

The history and general description of the flow has been so thoroughly covered by several writers that no further discussion will be given here. Those wishing to know more of an unusual Kilauea Rift flow are referred to the following articles:

1. Harold T. Stearns, "The Keaiwa or 1823 Lava Flow from Kilauea Volcano, Hawaii, Journal of Geology, Vol. XXXIV, No. 4, May-June, 1926.

2. Harold T. Stearns and W. O. Clark, "Geology and Water Resources of the Kau District, Hawaii," Water Supply Paper 616, U. S. Geological Survey, 1930.

3. T. A. Jaggar and Oliver Emerson, "Bulletin of the Hawaiian Volcano Observatory," May, 1924, pp. 34-35, and Nov., 1924, pp. 110-111; U. S. Geol. Surv. Figures 13-16, Vol. XIII, No. 6, June, 1925.

4. "The Keaiwa Flow of 1823, Hawaii," by John B. Stone, Amer. Jour. Sci., May, 1926.

5. "The 1823 Lava Flow from Kilauea," by R. H. Finch, Volcano Letter No. 18, 1925.

6. "Ball Lava," by J. A. Thomson, New Zealand Journal of Science and Technology, about 1925.

H. H. W.

Hawaiian Volcano Observatory Report for August 1937

VOLCANOLOGY

The most important event at Kilauea Crater was a fall of the rim rock of Halemaumau pit at the east, at 8:41 am August 22, carrying away the measurement marks of Crack No. 25 and also No. 24; at Crack No. 25 excessive opening had been revealed by measurement for weeks. The crash of the avalanche produced earthquake disturbance marked on the seismographs. The disturbance of the rim occasioned by this avalanche caused many subsequent slides, enlarging the talus, and gradually adjusting the cliff. There was increase of tremors for the last fortnight of the month, but no good method has yet been developed to prove cause and effect in the relation between slides and tremors. It is of interest to note, however, that the succession of cliff adjustments following a big avalanche is not unlike the succession of aftershocks following an earthquake.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
August 8.....	9.50	1	25.0	26
" 15.....	10.75	1	40.5	34
" 22.....	11.75	22	95.5	35
" 29.....	17.50	3	15.0	47

There were felt shocks of Kilauea origin August 3, 7, 10, 23, and 27; and two others of Mauna Loa and Hualalai origin August 16 and 18, felt on the west side of the island. Of all the measured shocks 27 indicated Kilauea distances of origin and three were from Mauna Loa or beyond. Distant earthquakes August 10 and August 20 indicated origins about 5,500 miles away, the second reported of destructive intensity on Luzon in the Philippines.

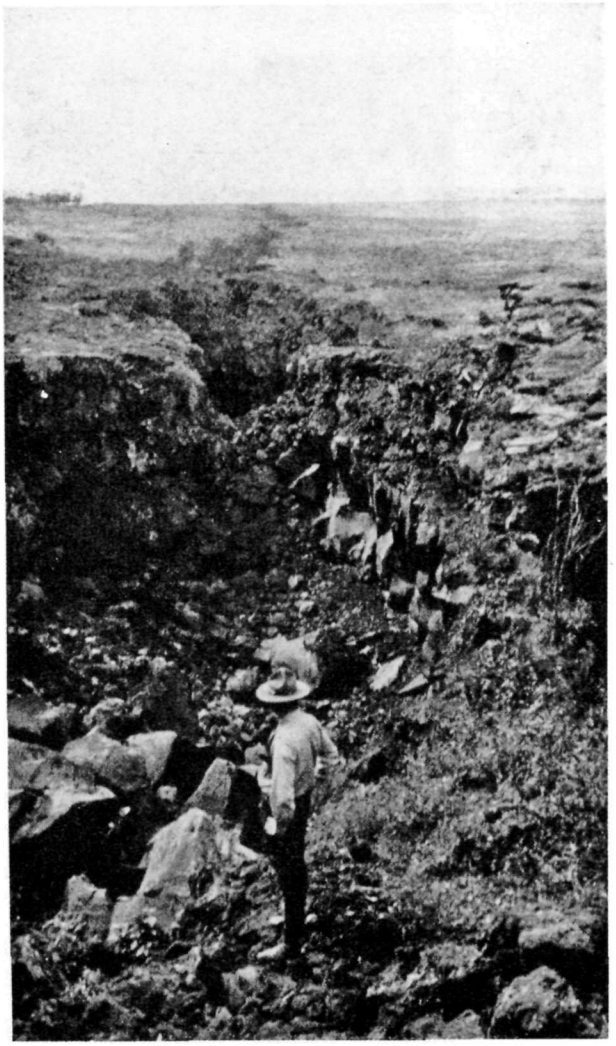
Sequence of Events by Weeks

The first week produced low seismicity and nothing more at Halemaumau pit than the excessive opening of Crack No. 25 at the east, which was one of the steaming extensions of the caved-in cracks of the east notch that had collapsed destroying Crack No. 28 on May 7. This opening of Crack No. 25 had been noticed repeatedly since May.

The second week produced only one slide, but the rate of opening of Crack No. 25 almost doubled.

The third week produced the avalanching crisis with Crack No. 25 opening three times as much as the week before and the observed slides numbering 22. Seismicity, owing to the increased numbers of tremors, rose steadily during the month.

The fourth week produced only three observed slides, the taluses at the base of Halemaumau wall had been enlarged, aggregate crack opening dwindled, but seismicity continued to increase.



Looking south along the great crack from which issued 1823 flow as viewed at Puna Trail crossing. Waesche.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

August 2, 2:20 a.m., a noise like sliding during excessive rain, possibly a cataract at Uwekahuna.

August 12, 1:00 p.m., dust from west side of pit.

August 17, 2:30 p.m., eastern slide.

August 20, 11:20 a.m., western slide.

August 21, 11:40 a.m., noisy east slide, leaving scar 30 feet down.

August 22, 8:40 a.m., very large slide east making very feeble earthquake on seismograms.

August 22, 9:45 a.m., large dust cloud east.
August 22, 9:57 a.m., dust floated westward.
August 22, 10:28 a.m., eastern slide.
August 22, 10:35 a.m., eastern slide.
August 22, 10:50 a.m., slides continued.
August 22, 11:00 a.m., more slides.
August 22, 11:05 a.m., more of east rim fell.
August 22, 11:19 a.m., slide west-northwest.
August 22, 11:20 a.m., very large eastern slide.
August 22, 11:30 a.m., more slides.
August 22, 11:33 a.m., " "
August 22, 11:45 a.m., " "
August 22, 11:50 a.m., " "
August 22, 11:55 a.m., " "



Looking north along the great crack from same locality. Waesche.

August 22, 12:10 p.m., " "
August 22, 12:19 p.m., " "
August 22, 12:20 p.m., rim rock fell and slides continued.
August 22, 3:00 p.m., rim rock fell in a large slide east; talus below now showed great enlargement.
August 24, 3:45 p.m., eastern slide.
August 25, 12:50 p.m., large dust cloud northwest rim.
August 26, 9:38 a.m., slight northwest slide.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted August in aggregate movement as follows:

Week ending forenoon of:

August 6, 30 locations, 12 opened, 1 closed, opening 25.0 mm. Crack No. 25 east opened 18.0 mm.

August 13, 30 locations, 13 opened, 1 closed, opening 40.5 mm. Crack No. 25 opened 31 mm.

August 20, 30 locations, 7 opened, 6 closed, opening 95.5 mm. Total opening was 99 mm., six cracks exhibiting a closing of 3.5 mm. Crack No. 25 by weeks had exhibited the following:

July 30, 6.0 mm. opened.

August 6, 18.0 mm. opened.

August 13, 31.0 mm. opened.

August 20, 96.0 mm. opened.

August 22, the cracked block collapsed, showing that the rate of opening had made forecast of the rim breakage.

August 27, 27 locations, 17 opened, 00 closed, opening 15.0 mm.

Cracks 24 and 25 had been destroyed August 22 and No. 51 on northeast rim was mutilated by unknown causes.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Weekly* Seismicity
Aug. 8.....	18	6	2	0	0	9.50
Aug. 15.....	27	6	1	0	1	10.75
Aug. 22.....	27	6	2	0	1	11.75
Aug. 29.....	36	9	0	2	0	17.50

*For local seismicity definition see Volcano Letter 371.
†Including teleseisms or those shocks over 5,000 km. distant.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, a determination of depth of focus has been made.

August 2, 3:45 am, very feeble, 1.3 miles deep E rim of Kilauea Crater near junction of Byron and Waldron Ledges. 19° 25.3′ N; 155° 15.6′ W.

August 3, 1:39 am, very feeble, probably originated in NE portion of Kilauea Crater.

August 3, 8:52 am, feeble, probably originated in Chain of Craters near Hiiaka.

August 6, 10:41 pm, very feeble, 2.4 miles deep, S rim of Kilauea Iki. 19° 24.8′ N; 155° 14.8′ W.

August 7, 7:09 am, feeble, 5.7 miles deep, SE rim of Kilauea Crater. 19° 24.2′ N; 155° 16.2′ W.

August 8, 4:40 pm, very feeble, of Kilauea origin.

August 8, 5:06 pm, very feeble, of Kilauea origin.

August 9, 5:39 pm, very feeble, 0.9 mile deep in rifts 0.4 mile W of Keanakakoi Crater. 19° 24.2′ N; 155° 16.4′ W.

August 9, 8:57 pm, very feeble, 3.6 miles deep in area 1.5 miles W of Kilauea Crater. 19° 25.0′ N; 155° 18.9′ W.

August 10, 5:13 am, very feeble, 0.7 mile deep SE rim of Kilauea Crater near Keanakakoi. 19° 24.4′ N; 155° 16.2′ W.

August 10, 5:00 pm, feeble, 2.3 miles deep, E portion of Kilauea Crater near Kilauea Iki. 19° 25.2′ N; 155° 15.9′ W.

August 11, 4:57 am, very feeble, 5.0 miles deep, 3.8 miles SE of Observatory. 19° 23.7′ N; 155° 13.1′ W.

August 12, 11:56 am, very feeble, of Kilauea origin.

August 12, 2:21 pm, very feeble, thought to have originated in Kilauea Crater immediately NE of Halemaumau.

August 16, 4:39 am, feeble, 18 miles deep, SW slope of Mauna Loa, 13 miles from Summit Crater. 19° 16.0′ N; 155° 38.0′ W.



Tree mold in 1823 Lava Flow. Waesche.

August 18, 5:27 pm, feeble, probably of deep origin under Hualalai. Felt in Kona and dismantled seismograph at Kealakekua.

August 18, 9:31 pm, very feeble, of MaunaLoa origin.

August 19, 3:22 am, very feeble, 1.0 mile deep, N portion of Kilauea Crater near Kilauea Military Camp. 19° 25.8′ N; 155° 16.6′ W.

August 21, 10:49 pm, very feeble, 0.8 mile deep, Kilauea Crater near E rim of Halemaumau, 0.4 mile N of Pit seismograph. 19° 24.7′ N; 155° 16.9′ W.

August 22, 4:21 am, very feeble, 3.8 miles deep, 3.2 miles N of Uwekahuna. 19° 28.2′ N; 155° 17.3′ W.

August 22, 8:41 am, very feeble, caused by slide from E rim of Halemaumau.

August 22, 11:49 pm, very feeble, E portion of Kilauea Crater 0.5 mile deep. 19° 25.0′ N; 155 ° 15.9′ W.

August 23, 12:45 am, very feeble, of shallow depth, Kilauea Crater 0.7 mile SSW of the Observatory. 19° 25.3′ N; 155° 15.9′ W.

August 23, 3:02 am, slight, 0.5 mile deep E portion of Kilauea Crater. Dismantled Pit seismograph. 19° 25.0′ N; 155° 15.9′ W.

August 23, 2:20 pm, very feeble, 1.0 mile deep, W edge of Keanakakoi Crater (SE rim of Kilauea Crater). 19° 24.1′ N; 155° 16.1′ W.

August 23, 7:41 pm, very feeble, 4.3 miles deep, 0.7 mile NW of Uwekahuna. 19° 25.6′ N; 155° 18.0′ W.

August 25, 12:04 am, very feeble, 0.7 mile deep under SE rim of Halemaumau. 19° 24.4′ N; 155° 16.9′ W.

August 27, 12:12 am, slight, 1.5 miles deep SE rim of Kilauea Crater, 0.3 mile NE of Keanakakoi. Reported felt by few near Hawaii National Park Headquarters and at CCC Camp. 19° 24.4′ N; 155° 15.8′ W.

August 27, 12:15 am, very feeble, 0.9 mile deep, Kilauea Crater, 0.3 mile N of Keanakakoi. 19° 24.6′ N; 155° 16.0′ W.

August 29, 7:36 am, very feeble, thought to have originated near Pit seismograph and shallow depth.

The preliminary waves of a teleseism began to register at Kilauea at 2h 38m 1s, pm, H.S.T. August 10. Distance was 5,520 miles. The preliminary waves of another teleseism began registering at 1h 41m 29s, am, H.S.T. August 20. Distance from Kilauea was 5.465 miles and reported location was in the Philippine Islands, where it was of destructive intensity, especially on the Island of Luzon.

Microseismic activity of the ground at the Observatory was light August 5 to 9, 18, 21, 27 to 29, strong August 3, 4, 24, 25 and moderate the remainder of the month.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 29 was 10.80″ S and 0.46″ E.

Week Ending	Observatory	Halemaumau West Station
August 8	1.12″ N 53° E	5.78″ S 82° W
August 15	1.17″ S 69° W	5.04″ N 40° W
August 22	0.31″ S 8° E	6.73″ S 73° W
August 29	0.58″ N 45° W	2.62″ S 44° W

Week Ending	Halemaumau Southeast Station	Pit Resultant
August 8	7.29″ N 63° W	0.67″ toward
August 15	0.23″ S 66° W	2.67″ from
August 22	5.18″ N 45° W	1.53″ from
August 29	7.78″ N 17° W	5.35″ toward

H. H. W.

THE VOLCANO LETTER 451

No. 451 monthly Department of the Interior National Park Service September 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

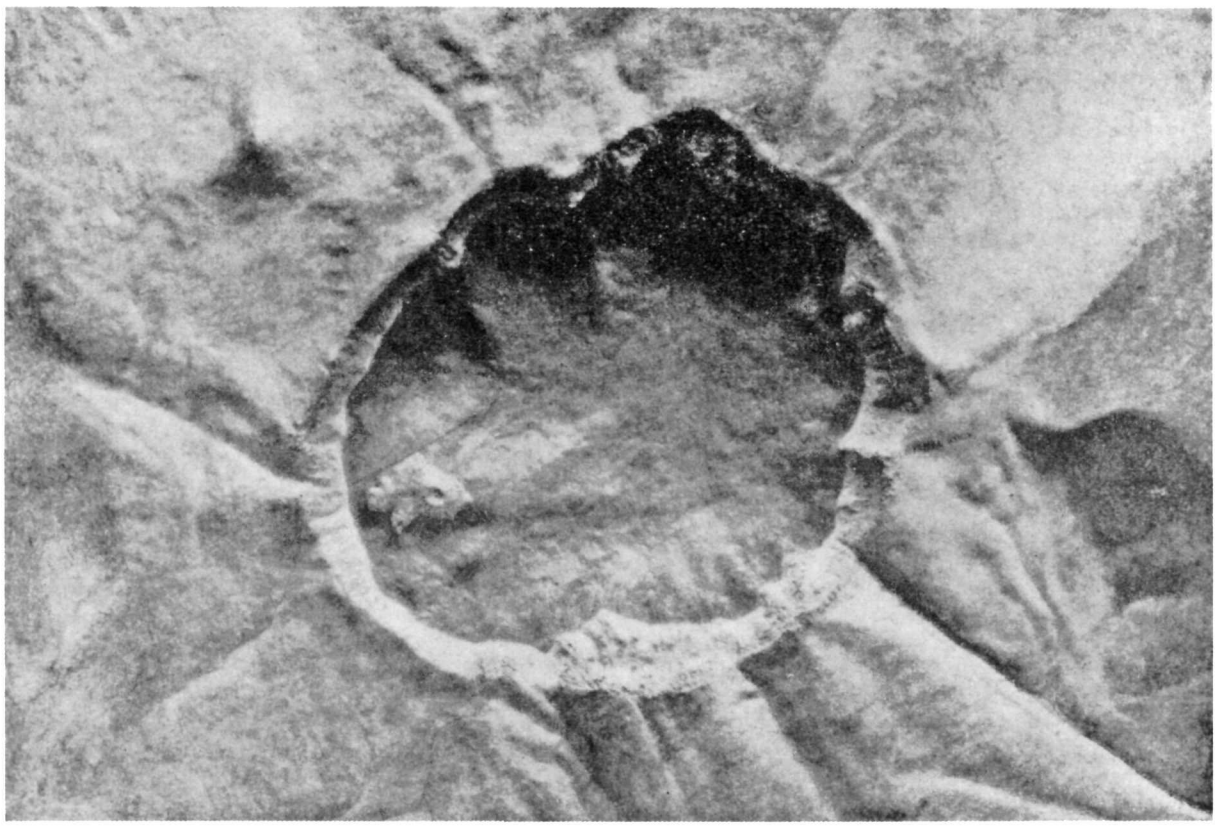


Fig. 1. Model of Crater Lake (after Diller).

CRATER LAKE NATIONAL PARK—

By H. H. Waesche

Certain areas in the United States and its territories have been set aside by the Federal Government as National Parks. Included in these are such well known places as Yellowstone, Grand Canyon and Yosemite Valley. National Parks are of importance because they contain within their boundaries some feature of both exceptional beauty and scientific interest which should be protected for the pleasure and benefit of the nation. Crater Lake National Park is one in this great system of recreational areas. It is probably not so well known as those mentioned but it is a region of unusual beauty and of great geologic interest.

The Park is located in south central Oregon, about seventy-five miles north of the California line. The central feature of the Park is Crater Lake which is a body of pure, sapphire blue water. The water is so blue that the officials often jokingly are accused by visitors of having put bluing in it. The Lake is relatively large, being from four to six miles across and two thousand feet deep. It is surrounded by cliff-like walls rising from five hundred to two thousand feet above the surface of the water. The walls are of many colors with reds, grays, purples, yellows and browns predominating. It is no wonder that such a spot is spoken of as the gem of our National Parks. Its moods are many, with color in unbelievable variations, ever changing with light alterations from sunrise to sunset. As a background and giving additional color there are many trees forming numerous patterns and designs of green. A gasp of admiration is

the first expression offered by most visitors, followed by a moment of silence as though they were trying to believe that such a place could be real. As is true of most scenes of nature that are so striking, Crater Lake cannot be described, so we shall deal in this discussion with its history and geologic story.

Although pioneers entered what is now the state of Oregon at a comparatively early date, it was around eighteen fifty before they began to filter into the southern part of the state. The region was none too accessible and the sparse population was in constant dread of Indian wars. Gold had been discovered in California and many people were moving westward. Many of these, disappointed in California, migrated to Oregon. It was not long before gold was discovered there too and exploration and prospecting in southern Oregon advanced accordingly. A band of California prospectors came to the mining town of Jacksonville to prepare for a trip into the mountains, keeping their purpose a secret. They were betrayed by one of their members to a group of Oregon miners who learned that they were searching for a "Lost Cabin Mine," supposed to be near the head of the Rogue River. The Oregon group immediately started after the California party which tried unsuccessfully to evade them. Both parties eventually ran out of food and through the efforts of John Wesley Hillman, leader of the Oregon group, the parties combined in order to hunt for game. On June 12, eighteen fifty-three, Hillman went ahead of the hunting group, and rode up a deep canyon, which, judging from its size, he thought would lead to a higher slope. He let the mule pick its own way while he peered through the woods for game. Imagine his astonishment when the mule stopped on the rim of a deep blue lake lying many hundreds of feet below. Here he beheld a scene of unsurpassed beauty. Other members of the party soon joined the leader and they agreed to call the body of water "Deep Blue Lake."

Gold and Indian wars caused men soon to forget Crater Lake so that in eighteen sixty-two another group of miners "rediscovered" the lake only to learn afterwards of the Hillman party's previous visit. A third "discovery" was made in eighteen sixty-five by soldiers from Fort Klamath who called it Lake Majesty. The name was changed to Crater Lake in eighteen sixty-nine by some visitors from Jacksonville and it has been known by that name ever since.

In eighteen eighty-five William Gladstone Steel first visited Crater Lake. He had heard of this natural wonder as a school boy and had resolved to visit the locality. He came to Oregon in eighteen seventy-two but it was nine years later before he could find anyone who had heard of the lake and several more years passed before he found anyone who had seen it. He was so impressed when he finally reached his destination that he immediately started agitation to make the area a National Park. Seventeen years later his efforts were rewarded. Congress established Crater Lake National Park in May, nineteen hundred and two. Judge Steel devoted the rest of his life to the development of the park and was for years Park Commissioner. He died in October of 1934.

The U. S. Geological Survey made a survey of the area in eighteen hundred eighty-six and at the same time sounded the Lake.

Paved roads are now to be found in the Park and it is visited by over one hundred and sixty thousand persons annually.

The story of the origin of Crater Lake is coupled with the geology of the Cascade range of mountains. These mountains are formed on the surface of volcanic rocks which have been poured out through a series of vents along a weak zone of the earth's crust. The vents are represented by a long line of volcanoes extending from Lassen Peak in northern California to Mt. Baker in Washington. Others of this series are Mt. Shasta in California, Mt. Theilson, the Three Sisters and Mt. Hood in Oregon, and Mt. Rainier in Washington. All of them are now extinct or dormant, although hot springs and steam vents are found on Mt. Shasta, Mt. Rainier and Mt. Hood. Within historic times only one of the entire group has been conspicuously active. This one is Mt. Lassen in California which erupted in nineteen fourteen and again in nineteen twenty-three. Previously it had been inactive like the others but early explorers and Indians reported some eruptions. All of these volcanic peaks are comparatively high, ranging from ten thousand to nearly fifteen thousand feet abave sea level. All are snow-capped the year around and abound in glaciers. They are some of the most picturesque and rugged mountains of the United States.

Crater Lake now occupies a yawning pit which marks the site of an old volcanic peak of this group which probably rivaled in grandeur the towering Mt. Rainier or Mt. Shasta. It is supposed to have been at least fourteen thousand feet high and may have reached the fifteen thousand foot mark. This former mountain has been given the name Mt. Mazama. Crater Lake is now six thousand feet and the rim is between seven and eight thousand feet above sea level. How do we know a mountain formerly existed here? What has become of that ten thousand foot mass of rock that once extended to the summit? That is the mystery of Crater Lake! Scientists are still trying to solve this great geologic mystery drama. A number of possible solutions have been offered but none seems satisfactorily to fit the facts of the case. Apparently where now all is peaceful and quiet, formerly gigantic forces of nature waged a fierce, spectacular struggle with each other.

The walls of Crater Lake are built up of alternate layers of rock. Some of these are dense and others are fragmental. This shows that Mt. Mazama was built by a series of explosions alternating with periods when molten lavas poured out of its vent and down its slopes. The explosions blew material high into the air which settled back around the old vent. The accumulation of explosive materials plus the outpourings of molten lava resulted in the building of the cone of Mt. Mazama. There must have been times when Mt. Mazama was quiet over periods of many years. This is shown by the irregular form of the rim and of materials deposited by running water and glaciers. At several points the Lake rim is indented by large U-shaped depressions which have the typical outlines of glacial valleys. These valleys have been cut off, as their cross sections show that they must have extended much farther up mountain slopes since destroyed. At other localities loose gravels and assorted materials show the effect of glacial deposition. In a few cases running water has cut "V" shaped valleys. One of the most interesting valleys of all is one which is filled by a great lava flow. Here one can see evidence of a regular succession of events which helps to prove the existence of Mt. Mazama, of glacial action, stream action and intermittent volcanic activity. First a "U"-shaped valley was formed in the alternate lava flows of Mt. Mazama, by a glacier, which represents a long period of snow accumulation and volcanic inactivity. Then the glacier receded and streams cut a "V"-shaped valley in the old glacial valley. This was followed by explosive activity which filled the floor of the valley with pumice, a light frothy volcanic rock. Soon after the explosion the valley was completely filled by a massive lava flow which even overflowed on the broader mountain slopes. Another explosion covered the lava flow with a layer of pumice similar to that over which it had flowed. At times forests grew on the slopes of Mt. Mazama as they do on Mt. Rainier today. The trees were even similar to those of the present. Charred logs, buried in volcanic ash, give mute evidence of the fate which overtook these trees. All of the rock layers do not run parallel to the mountain slopes. In a number of places peculiar layers cut across the other more horizontal layers at right angles. These forms are known as dikes. They show that the column of molten material in the old vent was under pressure and that there were weak places in the wall of the cone. The

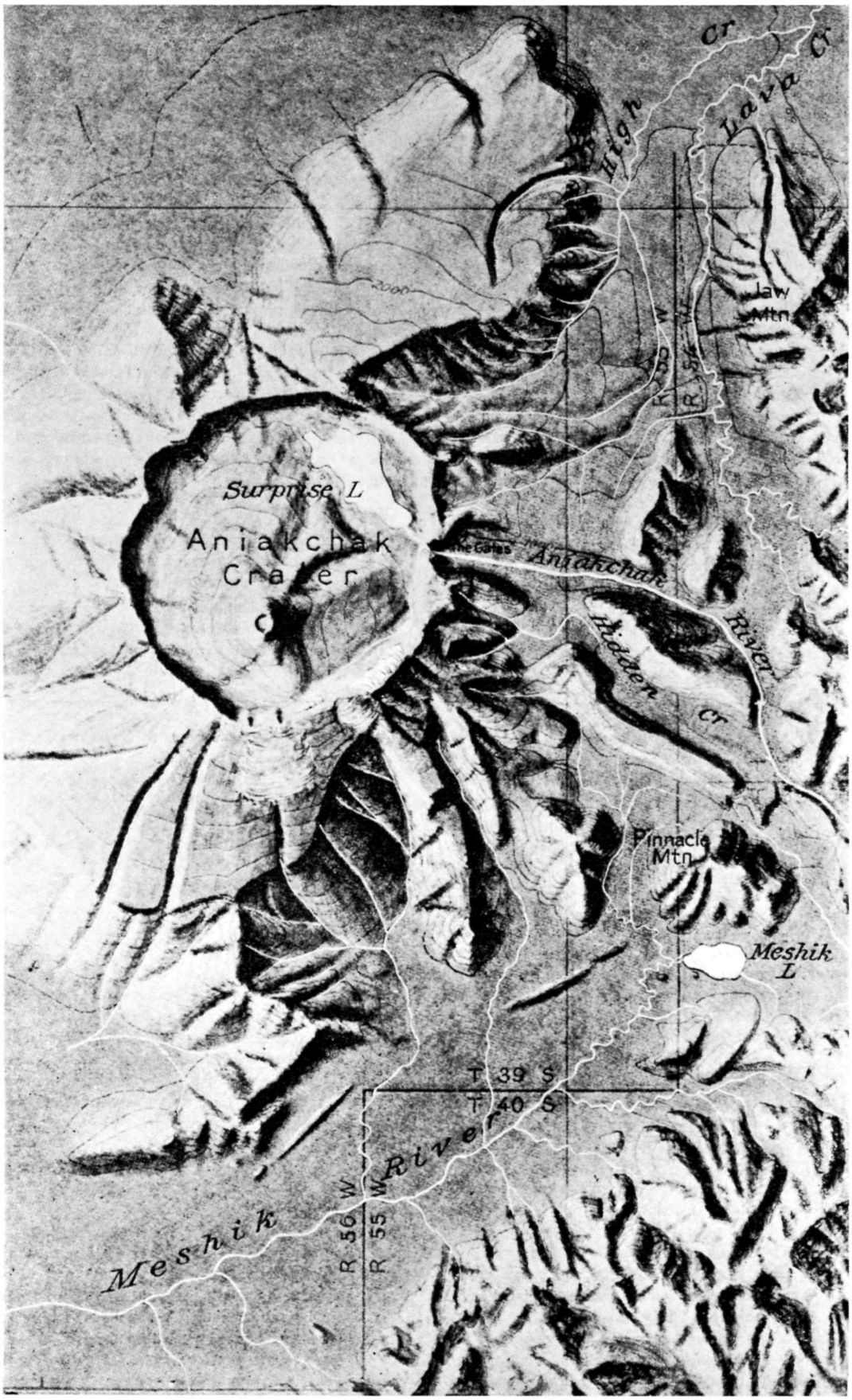


Fig. 2. Relief Map of Aniakchak Crater and Vicinity, Alaska Peninsula (after W. R. Smith).

pressure caused molten rock to flow into these weak zones, producing a number of radiating rib-like rocks which project from the flows because of their greater resistance to weathering. Such forms, likewise, indicate a former volcano.

The building of Mt. Mazama is no mystery—it is the destruction of the mountain which leads to extensive speculation. There are three explanations which have been offered to account for this great catastrophe. The first and oldest one has been the most popular. According to this theory the lava in Mt. Mazama's vent gradually receded into the earth because of the eruptions of a neighboring volcano. This removed the support of the upper part of the cone which caved in and was engulfed, leaving the large crater which the Lake now occupies. The second supposition was that gigantic explosions blew the mountain top off, and distributed it over the landscape for possibly hundreds of miles in every direction. The third possibility was a process similar to that going on today in Hawaiian volcanoes. There the molten lava rises and falls periodically in a large pit and in so doing causes sections of the rim of the pit to fracture and perhaps to fuse in the lava column.

The lack of large fragmental materials in the vicinity of Crater Lake which should be present if explosion had occurred, caused the earlier thinkers to accept the subsidence theory. More detailed examination of the surrounding areas by later investigators shows that explosive materials several hundred feet in thickness extend for many miles in every direction. Furthermore, some of the lava layers near the lake turn abruptly upward as though some force had bent them in that position; then, too, there is no known case of a whole volcano subsiding and it seems to be contrary to laws of earth structure for seventeen cubic miles of rock to go back into the earth where pressures should be high. On the other hand, numerous mountains of the same type as Mt. Mazama have been known to destroy themselves by explosion. Examples of the latter are the great explosion of Katmai in Alaska in 1912 and Krakatoa in Java in 1883. The best explanation at present seems to be a modification of the first two ideas. That is, the crater was probably produced from old Mt. Mazama by one or more explosions followed by slumping of the walls which sank into the pit, leaving the original upturned edges caused by the explosion in several places. Be that as it may—Mt. Mazama did exist and was destroyed, leaving a crater around four thousand feet in depth and averaging about five miles in diameter. And we still have our mystery!

Following the great mountain destruction, volcanic activity started again and built several small cones inside the crater. Two of these are now submerged below the lake but the third is over seven hundred feet in height and is quite a good sized volcano in its own right as it rises twenty-seven hundred feet above the crater floor. It possibly represents the last gasp of a dying volcano.

Meanwhile water was beginning to accumulate in the crater. The precipitation at Crater Lake National Park averages about seventy inches per year. At that rate any depression would soon tend to fill up, providing seepage and evaporation were not too great. This is what has happened. Figures show that evaporation at Crater Lake amounts to about fifty-five inches per year and that leaves fifteen inches to account for seepage through the lower slopes away from the Lake. There are no known major streams flowing into the Lake and none flowing out on the surface. The water is not salty but is quite fresh. Since rain water is practically distilled water and only slight solution of the rock walls takes place, this condition is easily explained.

Geologically speaking, Crater Lake is a young feature on the earth's surface. The extensive glaciation of the slope of Mt. Mazama indicates that it probably existed during the glacial age so that its destruction must have come about since that time. The last glacial period was between twenty-five and fifty thousand years ago. The age of the trees on Wizard Island, the largest of the cones in the crater, ranges up to eight hundred years. It is thought that Wizard Island was last active not more than two hundred years before the date of the oldest tree. That means that it was probably active within the last thousand years. To look at this young volcano one would think it had been active only yesterday, so fresh are its lavas and so little has it been affected by the erosive forces of the weather. The steepness of the crater walls and the rapid rate of erosion now going on show that the Crater is fairly new as the walls seem to be little changed by erosion.

The region around the Lake is heavily forested with hemlocks, pines and firs. Where these grow within the rim they both aid and retard erosion. They split the rocks with their growing roots and hold the soil in place on steep slopes by these same roots. Trees play an important part in the geology of this region.

Crater Lake, as is true of all lakes, is at best a temporary earth feature. Erosion of the walls with a consequent filling of the lake, aided by stream valleys cutting back the outer slopes, will eventually cause this mysteriously beautiful lake to be destroyed. However, it will take generations to accomplish this end so that man will enjoy this superb spot for many years to come.

ORIGIN OF CRATER LAKE CUP—

Mr. Waesche's moderate statement of the controversy about the origin of Crater Lake cup should be supplemented by the following reading for anyone interested:

1. Crater Lake National Park. Natinal Park Service pamphlet, Washington, 1936, page 9, "Destruction of the Mountain."
2. Mount Mazama: explosion versus collapse, by W. D. Smith and C. R. Swarzlow. Bull. Geol. Soc. Amer., Vol. 47, p. 1809. 1936.
3. The Glacial History of an extinct volcano, Crater Lake National Park, W. W. Atwood Jr. Journ. Geol., Vol. XLIII, No. 2, February-March, 1935.
4. Geological History of Crater Lake, by J. S. Diller, Department of the Interior, 1912 (Gov't Printing Office, Washington, 10 cents).
5. Engulfment at Krakatoa 1883. Review of Stehn, Volcano Letter No. 234, June 20, 1929.
6. Geology and Geography of Niuafoou Volcano, map and sections, Volcano Letter No. 318, January 29, 1931.
7. Volume relations of Explosive Eruption 1924 (Kilauea) Monthly Bulletin Haw'n Volc. Obs'y., Vol. XII, No. 12, December, 1924.
8. Geology and Mineral Resources of the Aniakchak District, Alaska, by R. S. Knappen, Bulletin U. S. G. S. 797-F, 1929.

There is no reason for such an immoderate controversial position favoring only the explosive process as is taken by No. 2 above. Nature works gradually even at active volcanoes. The great steam blast eruptions of the world have been accompanied by what Mercalli called "sprofondamenti", deepenings by collapse.

Atwood and Stehn, Nos. 3 and 5, cited for support of explosion by No. 2, both endorsed engulfment. The National Park pamphlet No. 1 states a moderate position. Diller was moderate in all his writings, and a judicial observer (No. 4).

Niuafoou (No. 6) is clearly an **engulfment plus steam-blast** kind of sink crater, the dome was quite like Kilauea, and the crater lake was formed millions of years ago (cited in No. 2 (p. 1828) as formed in 1886; when in fact a mere minor steam-blast occurred).

Kilauea steam-blast eruptions are no different from those of basaltic volcanoes anywhere, and the combined engulfment and explosion of 1924 removed volumes one part by explosion and 250 parts by engulfment. (No. 7).

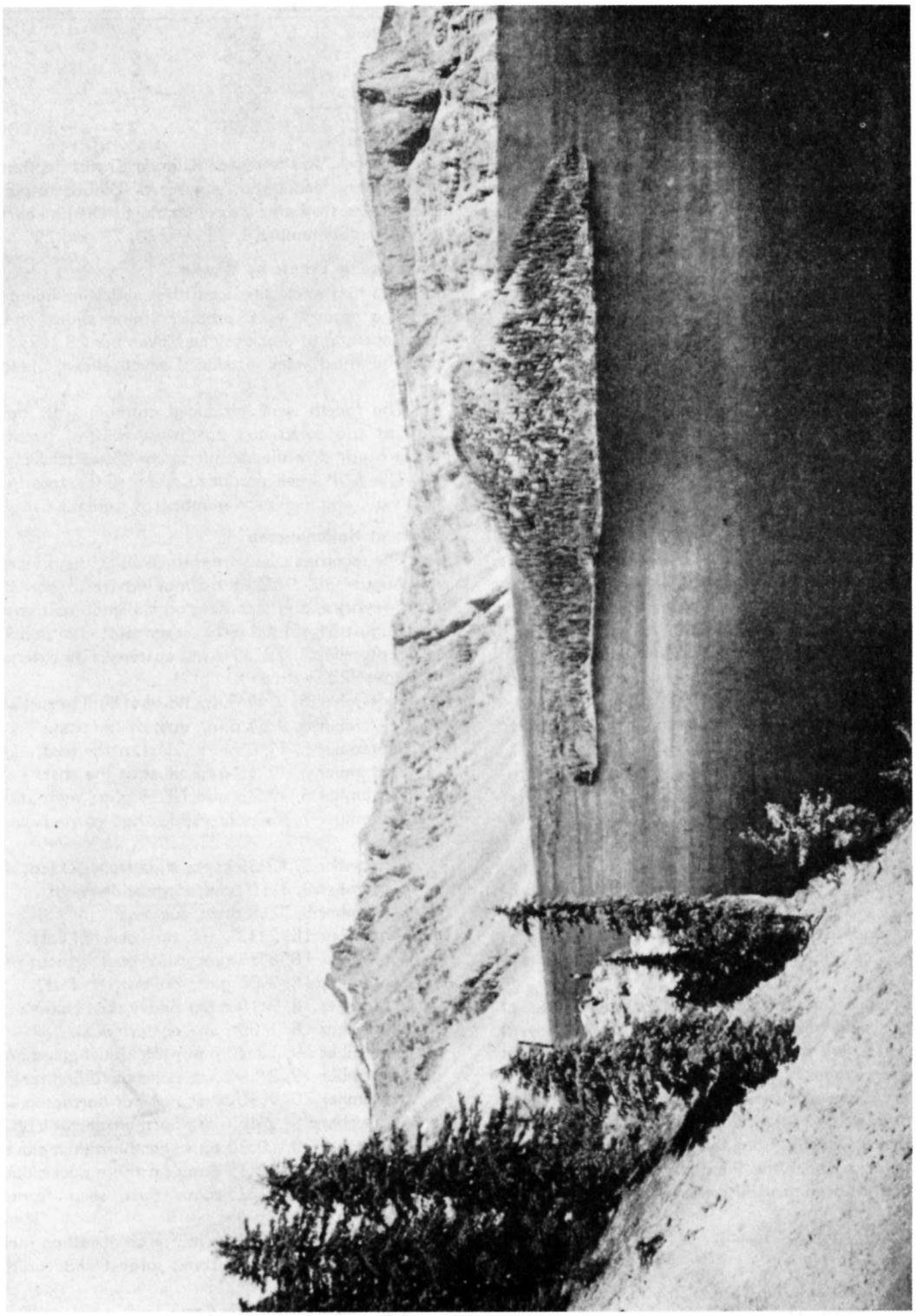


Fig. 3. Western Border of Crater Lake, from Victor Rock to Llao Rock (after Diller).

The basis for reconstruction of mountains over such saucer craters as Crater Lake, Niuafoou, Aniakchak, Batoer in Bali, or Aso in Kyushu, was stated admirably by Diller (No. 4, p. 24): "The glaciation and structure of the rim clearly establish the former existence of Mount Mazama but there may well be doubt as to its **exact form and size".**

Veniaminof Crater west of Aniakchak, (No. 8) but 5000 feet higher, is a triplicate of Aniakchak and Crater Lake, but full of ice spilling over in valley glaciers. It is the same height and size as Crater Lake, 6 miles across, and 8000 feet above sea-level; but it is a mountain, because it rises from sea-level.

Restore glaciation to the Cascade Range and you don't need a mighty peak of five cubic miles to scratch ledges, deposit till, and make U-shape valleys. The great Veniaminoff cup is itself at the **top** of a peak.

Finally, the geologist objection to voids underground is answered by underground intrusive bodies with straight-sided fracture boundaries that would fit together if the igneous matter (lava) were removed. If a void can form to let **up** the lava, it can form to let down the lava into crevices when whole mountain ranges are faulting and rifting.

At the Hawaiian volcanoes when lava lakes are rising and falling, this is happening all the time. The craters are on down-slipping fault rifts.

The tremendous event of the Vesuvian crisis, when a steam-blast eruption happens, is a "sprofondamento", a deepening. The amount of surface lava, dust and rocks is trivial compared to the crateral evacuation.

But the notion that such a volume as the contents of Monte Somma was left by the single evacuation of the Pompeiian eruption, is as fantastic as that Niuafoou crater was completely made in 1886.

The total volume of everything poured out and blown out of Vesuvius from 79 A. D. to the present would scarcely change the profile of the volcano. We know the history (Sapper). And we know that such eruptions as 1631 and 1906 engulfed the peak, which was subsequently restored from within.

A process of caving in and filling up again is normal extrusive volcanism and normal intrusive volcanism. The normal result is a gas loss to the atmosphere, a magma loss into crevices of the crust; and a compensating igneous bulk in the crust, for the substratum loss of igneous volume.

When the magma loss is a few cubic miles from a big cauldron, it means there has been a cycle of inflation; followed by a cycle of deflation, made up of hundreds of events such as submarine lava flows, or interstitial intrusive dikes along rifts tectonically opened.

The Hawaiian vents systematically robbed each other at progressively lower levels from 1855 to 1924. The 1924 vent was under the ocean where there is a slope to levels 18000 feet below sea-level in forty miles horizontally.

There was every opportunity for graben and cross-fault lava drainage in California and Oregon, from Miocene to Pleistocene time, for 20000 feet of depth, from the rim of Crater Lake to the broken shore blocks under the Pacific. And extrusive volcanism decayed from Miocene to the Present.—T.A.J.

Hawaiian Volcano Observatory Report for September 1937

VOLCANOLOGY

The month was notable at Kilauea Volcano for a decline of seismic phenomena and pit movements, except for a group of large distant earthquakes about the equinox, and at the same time a revival of many slides at Halemaumau in a new place, namely at the north.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
September 5.....	6.00	3	3.00	20
" 12.....	5.25	9	0.50	18
" 19.....	3.50	7	6.00	9
" 26.....	2.25	27	6.50	9
October 3.....	5.25	7	4.00	18

A shock was felt near Kilauea Crater September 15. Most of the very feeble shocks were of Kilauea origin, and most of the local disturbances were tremors. Distant earthquakes were registered September 3, 15, 19, 20, 23 and 29.

Sequence of Events by Weeks

The first week produced three slides in Halemaumau.

The second week produced nine slides and the smallest total opening of cracks since November 28, 1936.

The third week produced seven slides and declining seismicity.

The fourth week produced crumbling of the Halemaumau wall at the north and northwest taluses, twenty-seven slides being counted, while seismicity continued to decline.

The fifth week produced seven slides, mostly at the northeast wall, and increased numbers of tremors.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

August 30, 9:25 a.m., making fresh scar 300 feet below northwest rim, and recording on Halemaumau seismograph.

August 31, 11:00 a. m., large slide NW, sending up dust.

September 3, 12:30 p.m., eastern slide extending the notch of August 22 southward.

September 6, 9:47 a.m., noise of falling rocks east.

September 6, 9:57 a.m., dust at the east.

September 6, 11:05 a.m., dust at the east.

September 6, 12:10 p.m., dust at the east.

September 6, 12:33 and 12.38 p.m., more dust.

September 7, forenoon, slides had carried away part of the east edge.

September 8, 12:39 p.m., slide from 50 feet below rim east.

September 8, 1:10 p.m., large slide north.

September 8, 2:18 p.m., dust east.

September 15, 2:33 p.m., rim rock fell east.

September 18, 8:53 a.m., slide east without noise.

September 18, 9:00 a.m., dust at the east.

September 18, 9:10 a.m., heavy dust cloud east.

September 18, 1:00 p.m., eastern dust.

September 19, 12:20 p.m., thick dust cloud north.

September 19, 2:55 p.m., noise of falling rocks east side.

September 20, 9:30 a.m., noise of northern slide.

September 20, 9:45 a.m., northern dust cloud.

September 20, 10:30 a.m., northern dust cloud.

September 20, 10:35 a.m., northern dust cloud.

September 20, 11:25 a.m., dust seen from Observatory, north.

September 20, 12:40 p.m., noise of falling rocks north.

September 20, 12:45 p.m., largest slide of this day, noise and dust north.

September 20, 12:55 p.m., 2:40 p.m., 3:25 p.m., northern slides making dust.

September 21, 9:20 a.m., northwest dust clouds.

September 21, 9:25 a.m., northern slide.

September 21, 9:30, 9:52, 10:00, 10:05, 10:13, 10:17, 10:20, 10:24, 10:49, 11:05 a.m., and 12:05 p.m., northwestern slides making dust.

September 25, 10:25 a.m., dust and noise from the west.

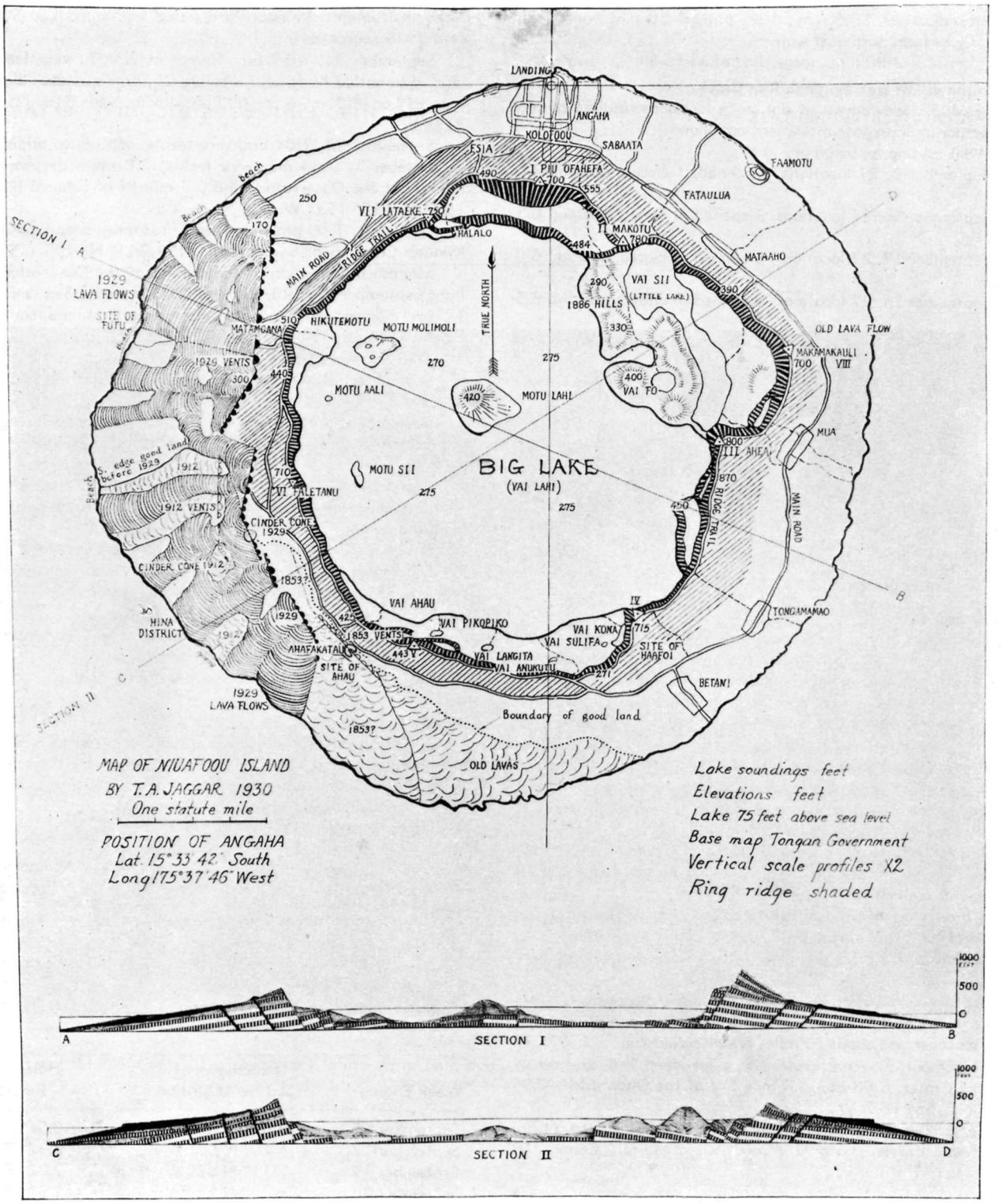


Fig. 4. Map of Niuafoou.

September 26, 10:02 a.m., 1:15 p.m., and 2:15 p.m., slides at the north side.

September 29, 10:25 a.m., slide at northwestern wall.

September 29, 1:10 p.m., sliding under both NE and N walls.

September 29, 1:15 p.m., 1:45 p.m., 1:50 p.m., and 3:25 p.m., slides from northeast wall.

October 1, 2:00 p.m., large slide at east wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during September in aggregate movement as follows:

Week ending forenoon of:

September 3, 27 locations, 4 opened, 1 closed, opening 3.0 mm.

September 10, 27 locations, 3 opened, 4 closed, opening 0.5 mm.

September 17, 27 locations, 8 opened, 1 closed, opening 6.0 mm.

September 24, 27 locations, 6 opened, 0 closed, opening 6.5 mm.

October 1, 27 locations, 7 opened, 1 closed, opening 4.0 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant† Earthquakes	Weekly* Seismicity
Sept. 5.....	16	4	0	1	6.00
" 12.....	15	3	0	0	5.25
" 19.....	6	2	1	3	3.50
" 26.....	9	0	0	2	2.25
Oct. 3.....	15	3	0	1	5.25

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

August 31, 10:51 am, very feeble, 12 miles deep, Hilina Kapukapu Fault, 2.0 miles N of Keauhou Point. 19° 17:5' N; 155° 14.1' W.

September 1, 8:34 pm, very feeble, 1.4 miles deep and 0.6 miles NW of Uwekahuna. 19° 25.8' N; 155° 17.7' W.

September 1, 8:55 pm, very feeble, location same as preceding.

September 5, 6:44, pm, a tremor at the Observatory, very feeble in Kona. Probably originated under W slope of Hualalai near seacoast and about 10 miles N of Kealakekua.

September 9, very feeble 1.3 miles deep, NE portion of Kilauea Crater, 8:08 am, 0.8 mile SW of the Observatory. 19° 25.5' N; 155° 16.2' W.

September 12, 4:30 am, very feeble, 2.6 miles deep, N rim of Kilauea Crater, 0.6 mile W of Kilauea Military Camp. 19° 26.1' N; 155° 17.1' W.

September 12, 4:32 am, very feeble, 1.0 mile deep, 0.4 mile SE of Keanakakoi, 19° 24.1' N; 155° 15.7' W.

September 13, 3:56 am, very feeble, probably originated in area 1.0 mile E of Kilauea Iki.

September 15, 8:04 pm, feeble, 0.8 mile deep, Kilauea Crater 0:5 mile W of Byron Ledge, 19° 24.6' N; 155° 16.2' W. Reported felt by many in "CCC" Camp and near Park Headquarters.

September 19, 6:07 am, very feeble, 3.0 miles deep, 1.6 miles N of N rim of Kilauea Crater. 19° 27.6' N; 155° 16.6' W.

September 19, a tremor at the Observatory, very feeble on Kona instrument. Probably originated in Mauna Loa SW rift near 1919 source cone.

September 21, 8:59 pm, tremor at H.V.O., very feeble in Hilo, dismantled Kona seismograph, 25.0 miles deep, NE rift of Mauna Loa 4.0 miles W of Puu Ulaula, 19° 31.6' N; 155° 31.0' W.

September 27, 7:01 am, very feeble, of Kilauea origin.

October 1, 9:34 am, very feeble, 2.8 miles deep and 0.8 mile SE of the Observatory and 0.5 mile N of Kilauea Iki. 19° 25.6' N; 155° 15.0' W.

October 1, 7:05 pm, very feeble, 1.2 miles deep E portion of Kilauea Crater near Byron Ledge, 19° 24.9' N; 155° 15.7' W.

Microseismic motion of the ground at the Observatory was light September 2-7, 20, 22, and 28-30; strong September 10, 12, and 25; and was moderate the remainder of the month. All dates inclusive.

Teleseisms registered as follows:

September 3, "P" waves at 8h 25m 17s am, distance from Kilauea 2415 miles.

September 15, "P" waves at 2h 06m 45s am, distance from Kilauea 3485. Reported location Solomon Islands. 9° S; 164° E.

September 15, undetermined portion at 9h 26m am.

September 19, "P" waves, 8h 54m 15s, pm, no determination of distance.

September 20, undetermined portion at 11h 21m 50s pm.

September 23, "P" waves at 2h 45m 47s am, distance from Kilauea 3390 miles. Reported location, Solomon Islands 6° S; 154° E.

September 29, undetermined portion, 1h 16 m 6s am. Reported felt and to have been located in Japan.

Hawaiian Standard Time used for above reports.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the pit.

At the Observatory the total accumulated tilt for the year ending October 3 was 10.85" S and 0.12" E.

Week Ending	Observatory	Halemaumau West Station
September 5	0.20" S 50° W	7.75" S 83° W
September 12	0.33" N 4° E	1.55" S 59° E
September 19	0.75" N 57° E	4.32" N 74° W
September 26	0.63" N 38° E	1.49" S 60° W
October 3	0.88" S 85° E	2.68" S 87° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
September 5	8.46" N 45° W	0.51" Toward
September 12	1.20" N 60° W	2.32" Toward
September 19	2.11" N 86° W	2.72" From
September 26	4.70" N 2° E	2.39" Toward
October 3	1.75" S 73° W	2.05" From

Crater Angles

Crater angles measured September 5, showed closing of 2.65" across Halemaumau and opening of 0.58" as compared with similar measurements of June 29, 1937.

H. H. W.

* For local seismicity definition see Volcano Letter 371.

† Including teleseisms or earthquakes over 5000 km from Kilauea.

THE VOLCANO LETTER

No. 452 monthly Department of the Interior National Park Service October 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

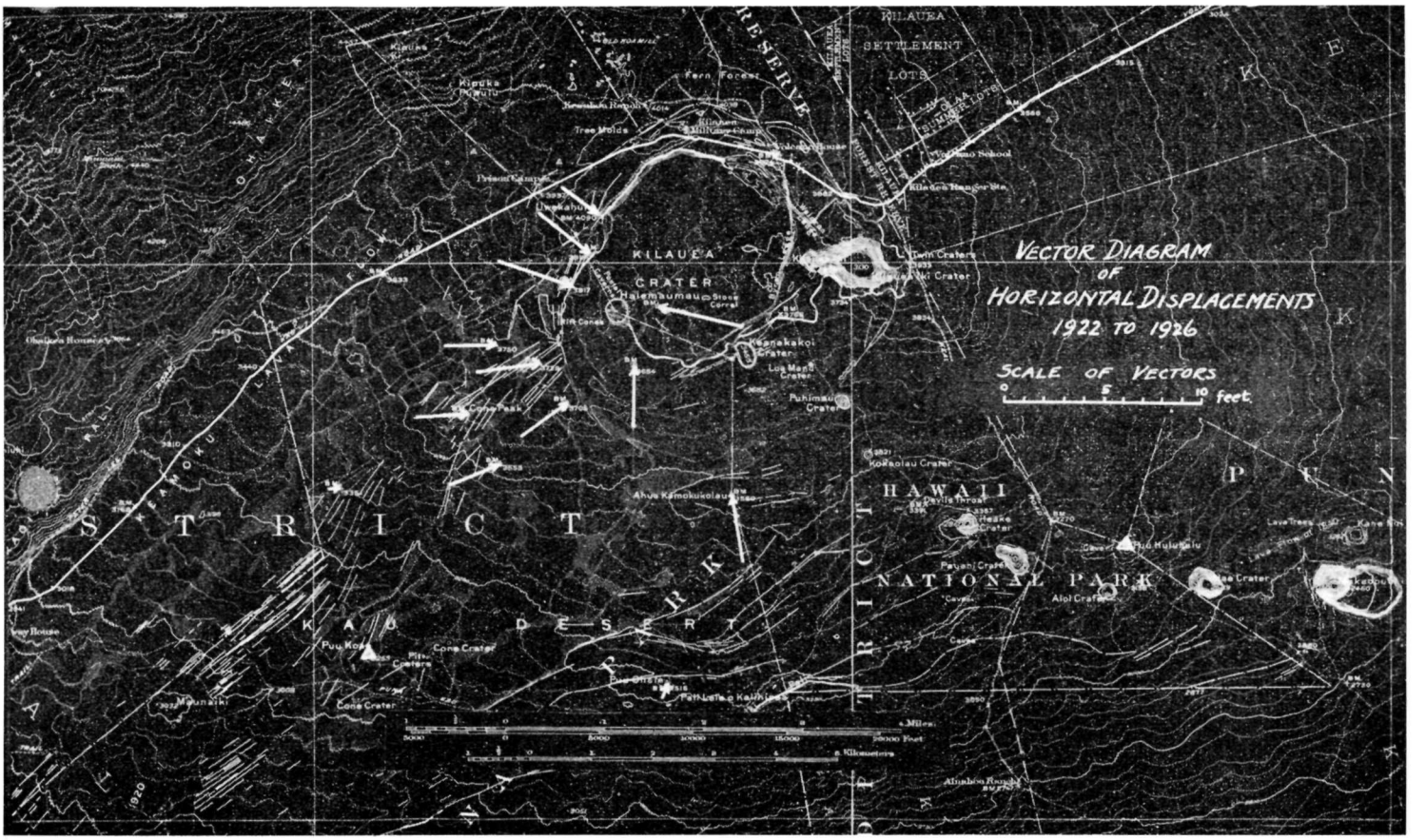


Figure 1. Map of Kilauea Crater; the tip of each white arrow on a monument; proved to move toward the center about 1924; by as many feet as the arrow is long by the scale.

TRIANGULATION AND LEVEL CHANGES AT KILAUEA—

Radio Talk June 22, 1937

By Hugh Waesche, Assistant Geologist, Hawaii National Park

On previous occasions (Volcano Letter February and April, 1937) I discussed earthquakes, crack measurements and tilting of the ground at Kilauea. Most of you probably are somewhat familiar with these phases of our work. Today I shall attempt to tell you about two other studies which have proved most interesting from the scientific standpoint but which are probably not so well known by the general public. (See also May and July 1936, Volcano Letter.)

Movements of the large volumes of lava below the earth's crust should create changes on the earth's surface. These movements in all probability would not be visible to the human eye, although in many cases they actually are. Two, well established, and reliable means of detecting such disturbances are by using instruments which would show by actual measurements, amounts of change of elevation and amount of horizontal dis-

placement in and around volcanic areas. For changes of a vertical nature the precise level and for horizontal displacements on engineer's transit are used, to establish measurements of a refined type just as is done by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey in their land survey and location work. A great amount of triangulation and leveling has been done in volcanic regions in Japan, particularly at Asama, with very definite and positive results. Similar work has been done in California along earthquake-making faults, with a great deal of success.

Measurements of this nature have been a part of the working program at Kilauea since the establishment of the Observatory in 1912. In 1920 at the First Pan-Pacific Scientific Congress in Hawaii, there was published among its recommendations the following: "Great earthquakes and volcanic eruptions are often preceded and followed by elevations, depressions and horizontal displacements in the regions concerned; therefore this Conference **recommends** that precise leveling and triangulation be carried on at definite intervals in selected seismic and volcanic districts in order to ascertain precursory and other changes in underground stress accompanying great seismic and volcanic disturbances."

Horizontal ground displacements may be thought of as expanding or contracting areas of the earth's surface. Their measurement with a transit is called triangulation. At Kilauea there have been four epochs or periods of such surveys. The first was as a part of the original Hawaiian Government Survey of 1871, reaching Kilauea in 1897; the second was by R. M. Wilson of the U.S. Geological Survey in 1922; the third was by J. C. Beam in 1926 and the fourth by Wilson in 1926. Inasmuch as the second and fourth were run by the same engineer under as near identical circumstances as possible, they are considered of greatest value. These two epochs are also of special interest in that respectively they precede and follow the explosive activity of Kilauea in 1924. Kilauea crater and the outer slope of the volcano, as far south as Puu O Hale, were a part of the surveyed area.

In triangulation procedure various points in a given area are selected as the key or control locations. From these stations angles are turned off repeatedly to other stations in the system or net, and from the average angle values, azimuth determinations and intervening distance calculations and relative positions are determined. It of course is not so simple as this may have sounded, as there are many sources of error, such as refraction because of heat and moving air and poor visibility. Corrections are made for all of these.

Careful comparison of results showed quite definitely that the older surveys did not agree with the newer ones, nor did the survey of 1922 agree with that of 1926. Of the sixteen stations used probably the most familiar to you are, the monument in front of the Volcano House, the Little Beggar on Kilauea crater floor, Uwekahuna and the Spit. Another quite familiar location point is on the summit of Puu Hulu Hulu which may be seen on a trip down the Chain of Craters road. In a general sort of way it was found that there was little or no change between certain specifically selected points well outside of Kilauea crater such as the Observatory, Ohale, Koae, and Puu Hulu Hulu. On the other hand, relative to these fixed stations other locations showed considerable movement toward Halemaumau accompanying the collapse after the explosive eruption. A map was plotted using vectors to show this movement. More or less radial movement toward the pit from all directions was thus definitely shown. (Figure 1.)

Triangulation on a minor scale is still carried on from the Observatory. The same "Berger" transit used by Wilson in his earlier surveys is set up on the Observatory bench mark about every ten days, and the angles across Kilauea crater, from its southeast rim to Uwekahuna on the northwest rim, and across Halemaumau in the same direction, are determined. Each angle is measured six times in a forward or clockwise direction and then repeated in a reverse direction in the same manner. The results are then averaged and calculations made, and this in turn plotted for comparison on coordinate paper; so that a continuous relative picture of opening or closing of the crater, and of the pit, is available. Over longer periods changes are readily observed, but for short periods, due to errors which are unavoidable, changes are not so marked. The probable error calculated by Wilson was plus or minus two and one half seconds of arc, which is more than the usual variations which are now encountered from one reading to the next. Recent readings since the Mauna Loa eruption of 1935 seem to indicate, to date, a gradual closing of both crater and pit angles, as though the lava underneath Kilauea may have receded following that eruption. It would be safer, however, to say that no apparent change of appreciable magnitude has occurred within the past two years.

As was the case with the triangulation surveys, the level surveys may be divided into epochs. There were three of them. The first run was made in 1912 by the Birdseye party of the U.S. Geological Survey; the second by R. M. Wilson in 1921 and 1922, and the third in 1926 and 1927, also by R. M. Wilson. The instrument used is shown in Figure 2, sighting on a rod not shown. Just as with the triangulation, the last two of these runs were made before and after the explosive eruption in 1924. There were two classes of level determinations. One class consisted of lines run from tidal bench marks at sea level to the summits of Kilauea and Mauna Loa. The second class was of a local nature run only in the vicinity of Kilauea. The first two were what is known as "third order" leveling and the third run was "first order" leveling. In "first order" leveling invar metal rods are used and the level is shaded; in earlier runs wooden rods were used. Accuracy is of a very high degree in "first order" levels.

Probably the greatest problem encountered in running the levels from Hilo to the Volcano was changes of rod length. The wooden rods of the early surveys were found to vary from their original Bureau of Standards length. This variation was usually an increase in length with increase of moisture absorption. After very careful analyses Wilson applied corrections to take care of this. His conclusions are published in Research Publication number 10 of the University of Hawaii (Ground Surface movements at Kilauea Volcano) and are most interesting. The level results seem to check the triangulation and tilt values and, at the same time, seem to be more tangible in their demonstration of a factor in volcanic change, which had been suspected here and demonstrated elsewhere.

It would be hard for a visitor who has been to Kilauea frequently to realize how great the level changes were after that 1924 eruption. The Volcano House seems quite substantially located on the northeast rim of Kilauea crater, yet between 1921 and 1926, the Volcano House went down nearly four feet (3.56). Uwekahuna too looks firmly planted—a sort of Gibraltar, yet it sank nearly five feet (4.56) in the same period. As far south as Puu Hulu Hulu and Puu Koae the ground sank between three and four feet. In a general way and as would be expected, amounts of depression increased toward Halemaumau, reaching a maximum sinking of thirteen feet near the old spatter cone, "Little Beggar," about two-tenths of a mile east of Halemaumau. In fact, it seems pretty certain from tilt and levelling data, that between 1912 and 1921 the entire slope of Kilauea to sea level rose; and then sank between 1921 and 1927 in gradually increased amounts as the crater of Kilauea

was approached, and with a very rapid rate of change at Halemaumau. Hilo was thought possibly to have risen slightly, and then to have gone down about six-tenths of an inch after 1924.

Local levels in Kilauea crater were run regularly in 1934 and 1935 and until February 1936. This line started at the Spit bench mark, southeast rim of the crater and made a loop around Halemaumau. Occasionally the run was made just to the northwest bench mark on that rim of Halemaumau. This particular line is used in order to obtain relative displacements between the actual crater floor and its rim. Plotted results of this level line have proven very significant. Among other things it has been discovered that a relative change in Kilauea crater of several millimeters within twenty-four hours is not unusual. Following the 1934 eruption of Kilauea the northwest rim of Halemaumau apparently settled about six inches with reference to the southeast crater rim. In August 1935 the lowering ceased, and the value remained unchanged until Mauna Loa erupted in November. Immediately the Kilauea crater floor began to settle again, and by February 1936 it had settled another two inches. Apparently settling has continued and as soon as possible new determinations will be made.

From this brief review it will be seen that surveys of this sort are very important and informative parts of the Hawaiian Volcano Observatory program. This work will be continued and the results noted with interest relative to future eruptions and thus more knowledge of our volcanoes will be accumulated, and activity predictions made more accurate.

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
October 10.....	7.00	4	7.00 mm.	12
" 17.....	6.25	0	0.00 mm.	12
" 24.....	4.75	4	2.50 mm.	14
" 31.....	6.00	2	4.75 mm.	16

A feeble shock October 18 and a stronger one classed as "slight" October 25 were felt in National Park and Hilo, and were Kilauea movements. Of nine measured shocks for the month seven were from Kilauea, one from Mauna Loa, and one from Mauna Kea.

Sequence of Events by Weeks

The first week produced four observed slides, the second week was very quiet, the third week with its four slides may have had them started by the earthquake of October 18. The fourth week showed only two slides that were observed, and an increase in number of spasmodic tremors.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

October 4, 9:33 a.m., large slide NE.

October 4, 11:13 a.m., dust NE.

October 4, 11:18 a.m., dust from slide NW.

October 4, 1:39 p.m., another slide NW.

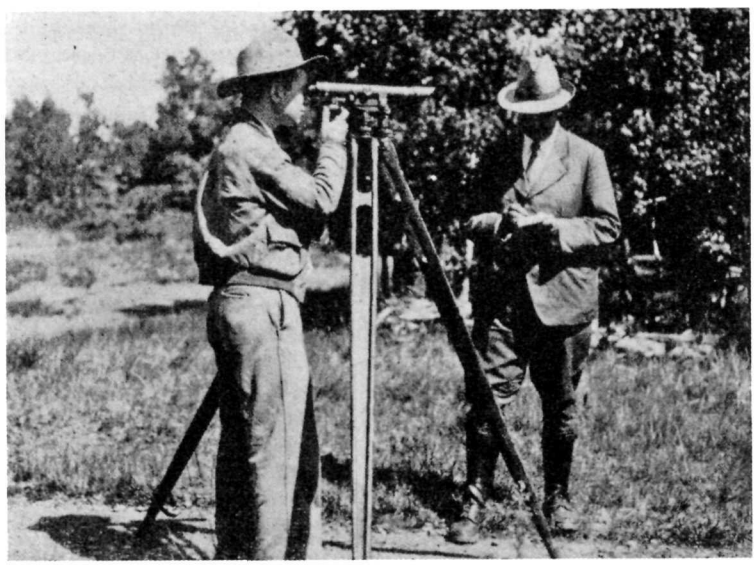


Figure 2. Precise level sighted on a rod marked in decimals of a foot, held upright by a rodman (not shown). Waesche sighting, Jaggar entering notes.

Hawaiian Volcano Observatory Report for October 1937

VOLCANOLOGY

The month at Kilauea Volcano showed little change in local tremors and movements about Halemaumau pit. As in September, there was a revival of slides from the walls toward the end of the month.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

October 18, 11:15 a.m., dust observed over north rim.

October 18, 12:15 p.m., another slide at the same place.

October 19, 9:31 a.m., slide from NW wall heard at Uwekahuna Museum.

October 19, 10:08 a.m., slide at east rim observed from Tourists' Stand.

October 31, 11:20 a.m., dust rising at north wall.

October 31, 2:10 p.m., slide at the west wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during October in aggregate movement as follows:

Week ending forenoon of:

October 8, 28 locations, 11 opened, 3 closed, opening 7.0 mm.

October 15, 28 locations, 2 opened, 3 closed, opening 0.0 mm.

October 22, 28 locations, 6 opened, 2 closed, opening 2.5 mm.

October 29, 28 locations, 10 opened, 2 closed, opening 4.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquake	Distant† Earthquakes	Weekly* Seismicity
Oct. 10.....	26	1	0	0	2	7.00
" 17.....	15	5	0	0	0	6.25
" 24.....	11	2	1	0	0	4.75
" 31.....	14	1	0	1	0	6.00

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible a determination of depth of focus has been made.

October 7, 1:49 am, very feeble, 15 miles deep under Mauna Kea. 19° 48.7' N; 155° 30.4' W.

October 14, 10:32 am, very feeble, 1.8 miles deep in Kilauea Crater 0.5 mile W of Byron Ledge, 19° 24.6' N; 155° 16.2' W.

October 15, 3:24 pm, very feeble, of shallow origin in cracks SW of Keanakakoi. 19° 24.1' N; 155° 16.2' W.

October 17, 12:58 am, very feeble, 0.5 mile deep in cracks near SE rim of Kilauea Crater 0.5 mile SE of Pit seismograph. 19° 24.1' N; 155° 16.6' W.

October 18, 12:44 am, feeble, 28.0 miles deep, SE slope of Mauna Loa 10 miles west of Kilauea Crater. 19° 26.3' N; 155° 25.0' W. Reported felt at Hawaii National Park Headquarters and in Hilo.

October 19, 5:56 am, very feeble, 1.1 mile deep in Kilauea Crater 0.4 mile E of Pit seismograph. 19° 24.4' N; 155° 16.7' W.

October 22, 11:36 pm, very feeble, of shallow origin, SE rim of Kilauea Crater. 19° 24.0' N; 155° 16.4' W.

October 25, 5:43 am, slight, 9.0 miles deep in Hilina Fault system 8.0 miles S of the Volcano Observatory. 19° 19.8' N; 155° 15.0' W. Felt by many at Hawaii National Park Headquarters and in Hilo.

October 30, 11:44 am, very feeble, 4.1 miles deep and 0.4 mile W of Ahua Kamokukolau. 19° 22.9' N; 155° 16.4' W.

Microseismic motion of the ground at the Observatory was moderate October 4 and 5 and strong the remainder of the month.

A portion of a teleseism was recorded at Kilauea beginning at approximately 8h 11m pm, HST., October 4. Reported location was 3200 miles ESE of Hawaii; 22° N; 108° W. An unidentified portion of another teleseism began recording at approximately 7h 00m am, HST, October 6.

Periods of continuous tremor which registered on the Observatory seismograph were: 16 minutes beginning at 10:30 pm, October 6, and 9 minutes beginning at 1:43 pm October 16.

H.H.W.

* For local seismicity definition see Volcano Letter 371.
† Including teleseisms or earthquakes over 5000 km from Kilauea.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending October 31, was 9.83" S and 0.38" W.

Week Ending	Observatory	Halemaumau West Station
October 10	1.25" N 9° E	1.55" West
October 17	1.41" S 35° W	3.37" N 78° W
October 24	0.58" S 11° E	1.43" N 29° E
October 31	1.62" N 40" E	4.17" S 53° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
October 10	3.47" N 54° W	1.75" Toward
October 17	3.99" N 43° W	0.92" Toward
October 24	3.18" S 70° E	2.01" From
October 31	8.29" N 29° W	4.68" Toward

H.H.W.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory October 16, showed slight opening of the Halemaumau value, and closing of the Kilauea Crater value, compared with similar measurements September 15. From Kilauea Crater SE rim to Uwekahuna there was closing 1.16", September 15 to October 6 and closing 2.68", October 6 to October 16. Total closing 3.84". From the SE Pit B. M. to NW Pit B. M. there was opening 1.57", September 15 to October 6 and closing 1.48", October 6 to 16. Total opening 0.09".

Levelling at Kilauea

October 12 and 13, a series of levels was run from the Spit B.M. on the SE rim of Kilauea Crater, to the NW Pit B. M. on the NW rim of Halemaumau. A Stanley level was used, and the results obtained were the first check on this determination since February 10, 1936 when a U. S. Geological Survey model precise level was used. Between September 3, 1936 and January 26, 1937, five sets of levels over the same line were run, using a new U. S. Coast and Geodetic Survey type precise level. These in no case gave satisfactory checks on closure of the circuit. The run made with the Stanley level giving a satisfactory check, October 12, 1937 showed that results obtained with the Geodetic Survey level were of value in spite of inaccuracies, in that they were of qualitative value indicating continuous relative lowering of the floor of Kilauea Crater with reference to the SE rim since October 1934 at the close of the Halemaumau inflow at that time. Level determinations of October 12, 1937 showed that the NE rim of Halemaumau (floor of Kilauea) had relatively lowered 19.7 centimeters since February 10, 1936 (closing stages of Mauna Loa Eruption) and 37.8 centimeters since October 17, 1934, with reference to Spit B. M. SE rim of Kilauea. Between August 13, 1935 and November 26, 1935, relative change of elevation between the same stations was 4.0 millimeters, or essentially no change in the period leading up to the Mauna Loa eruption. The termination of the Mauna Loa eruption marked the beginning of another period of relative lowering of Kilauea Crater floor which has continued up to the present time. The period of unchecked levels run between September 3, 1936 and January 26, 1937 in general confirmed this apparent downward movement. It must be remembered that Spit B. M. on SE rim of the greater crater might have been relatively elevated, hence the word "apparent".

H.H.W.

THE VOLCANO LETTER 453

No. 453 monthly Department of the Interior National Park Service November 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

KILAUEA VOLCANO LABORATORY
OF THE UNIVERSITY OF HAWAII 1937—

By T. A. Jaggar

Research at the Kilauea Volcano Laboratory with workers from the University began on July 13 with the arrival of Dr. Stanley S. Ballard, accompanied by Mr. Paul Gow, chemist of the Hawaiian Sugar Planters' Association. They made preliminary chemical tests for three days, setting in operation oxy-flamo blow-pipe apparatus for melting glass. This and numerous items of equipment and supplies for making vacuum tubes, and collecting volcanic gases were put in working condition.

Spectrograms made with the large quartz spectrograph of the H.S.P.A. in Honolulu show domination of carbon monoxide. An analysis carried out at the University by Assistant Professor J. H. Payne shows carbon dioxide, sulphur dioxide, nitrogen and oxygen, but no carbon monoxide nor hydrogen. The results show chemical reactions in progress even at the relatively low temperature of Sulphur Bank. The analysis residue is used for spectroscopic work. On August 17 Dr. Ballard and Dr. Eller set up new apparatus, and during the ensuing fortnight Dr. Ballard collected samples of specially dried gas with filter tubes for removing excess of carbon and sulphur.

Dr. Ballard reports as follows:

I left Honolulu bound for Hilo via Inter-Island steamer on Friday, August 13, arriving there the following day. We left the Big Island to return to Honolulu on Sunday, August 29. The two weeks spent at the volcano observatory were most worth while from the research point of view. The major accomplishment was the collection of four tubes of solfataric gas from the Sulphur Banks wells. One of these tubes was filled, using a method similar to that used for some of the collections of last year, in order to determine whether any major changes in the constitution of the gas had occurred since then. The other three were collected through an ice pack in order to condense out the large steam content and through two traps containing concentrated potassium hydroxide. The gases were passed through the potassium hydroxide solution in order to absorb the large content of carbon dioxide and sulphur dioxide which had been detected spectrographically and chemically in the 1936 collections. Spectrographic examinations had shown that so much carbon monoxide, carbon dioxide, or organic matter was present that other constituents could not be detected by this method. The chemical analyses conducted by Dr. J. H. Payne, Assistant Professor of Chemistry, had revealed a large sulphur dioxide content, so large in fact that the determination of nitrogen, oxygen, and combustible gases was difficult and uncertain.

Figure 1 shows 250 cc. tube connected with 70-foot well drilled at Sulphur Bank, Kilauea. This is set up for sucking the well gas through an ice pack. The inner box is packed with ice and covered. A hand suction pump is used.

Figure 2 shows the gas being drawn through two bulbs packed with ice and salt and a Milligan gas tower absorption bulb containing a 50% solution of caustic potash. A three-way stop-cock below is used to flush the line before collection. The bulbs are for the purpose of absorbing steam, carbon dioxide and sulphur dioxide.

Instructor Iwao Miyake did the following important work in checking over the Observatory shop tools and the seismographs of Halemaumau, Hilo, Uwekahuna and Kona:

1. Made a list of necessary shop supplies.
2. Turned out flange and mounted the new chuck for the Observatory shop lathe.
3. Overhauled the Uwekahuna seismograph. The vertical component was not working.
4. Overhauled the Pit seismograph and adjusted the clock contacts.
5. Built seismograph constant measuring device.
6. Overhauled the Kona seismograph and took complete data necessary for constant determination:
   a. Established known points on seismograph boom for future constant checking measurements.
   b. Worked out a routine for constant checking measurement and taught same to Mr. Yasunaka.
7. Overhauled Uwekahuna seismograph drive clock.
8. Installed and adjusted new electric contact points on Uwekahuna time marking clock.
9. Overhauled the Hilo seismograph and took complete data necessary for constant determination:
   a. Established known points on seismograph boom for future constant checking.
   b. Rebuilt timing clock and put in new electric contact points for time marking.

Mr. Miyake arrived July 14 and Dr. Eller July 31. Special studies were made of all the seismological instruments on the island of Hawaii, and the constants of the instruments were determined.

Mr. Miyake finished his shop work and seismographic tests August 4. Professor Eller continued work here until August 18.

Dr. Eller reports as follows on his new tilt-meter:

"As my main interest in the work at the H. V. O. is the study of tilt measurement, most of my time there was spent in that connection. Several trips to the pit and to the country around Kilauea served to make the general lay of the land

familiar to me. This was followed by a study of maps of the region, for the purpose of planning possible points for future placing of tiltmeters for an extended program of tilt measurement.

"Also a recording tiltmeter, constructed in Honolulu, was adjusted and put in proper working order, and installed in the seismograph room at the Hawaiian Volcano Observatory. This is of a design which I hope will be found useful for future work. This meter is still in operation and I am receiving records from it each week. So far these records show little change from the original setting, due to slight activity in the Kilauea region during the past few months.

"A considerable study was made of the tilt records available at the Observatory, and notes taken from them for future study."

Dr. Jaggar was greatly assisted by the physicists in his work of designing and building a set of ten earthquake recorders to

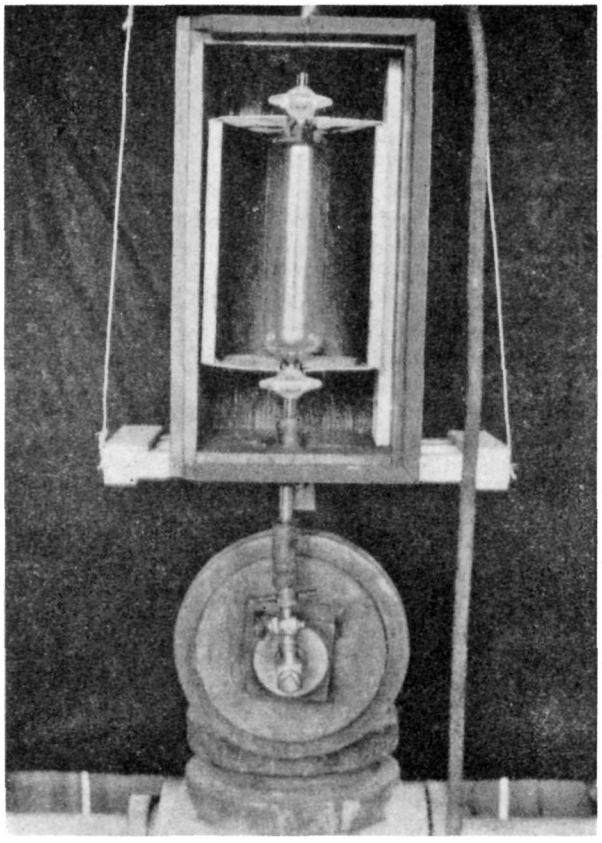


Figure 1. A tube for gas collection over Sulphur Bank well by suction and packing in ice.

be located at the telephone exchanges of the island. Several of these instruments have been tested out, at the Kilauea laboratories with a view to progressive improvement of detail.

The investigations of the summer of 1937 on volcanologic physics, by Professors Jaggar, Eller and Ballard, Instructor Miyake, and geophysical assistant Sato, aided by the mechanical staff of the Hawaiian Volcano Research Association, namely H. Yasunaka and A. Okuda, have started new work that will be carried out both here and in the University laboratories throughout the coming year. Aided by the Department of Chemistry and by the large spectroscope of the Sugar Planters' Association, a new effort is under way to understand the gas action and rock crystallization that constitute volcanic activity, and eventually makes the soil, air, and water of Hawaii.

The following address was delivered at Radio Station KHBC, Hilo, August 17, 1937, by Professor Eller:

"TILTING OF THE GROUND"

Two years ago plans began to develop at the University of Hawaii for cooperation in the work of the Hawaiian Volcano Observatory. So far active participation has been restricted to a few weeks during the summer when members of the teaching staff were free to work at Kilauea.

The Department of Physics of the University has entered into this program from several angles, as there are many problems connected with the work of the Hawaiian Volcano Observatory that are more physical than purely geological. In the main these are: the study of the gases from the volcano, and the volcanic rock, which are being examined spectroscopically to determine their constituents, both as to the elements present and their quantity; and the study of movement of the earth, both temporary and permanent.

Earth movements and displacements of seismic origin are of interest because of their possibilities in forecasting earthquakes or eruptions. The earth movements at Kilauea are observed primarily for the purpose of studying volcanic activity which might result in eruption. They are in the nature of quakes of varying degrees of magnitude, and tilting of the earth's surface. Observations and measurements of these movements were begun early in the history of the Hawaiian Volcano Observatory.

The earthquakes are recorded by several seismographs, three of which are at Kilauea, one in Kona and one at Hilo. From the records of these instruments it is possible to determine the magnitude, character and location of quakes originating in various parts of the island of Hawaii, say in Halemaumau, or Mauna Loa, both of which are sources of many of the disturbances noted. These quakes result from movement of the underlying lava, and by their nature assist in the forecasting of eruptions.

Tilting of the ground, sometimes sudden, but more often gradual, accompanies the movement of the underlying lava. A tilt is a change in the angular relation between a portion of the earth's surface and the horizontal. Tilting is usually very slight, and is measured in seconds of arc. A tilt of one second, which is fairly large as tilts go, represents the angle through which a line about three and one-half miles long is rotated about one end when the other end is raised one inch. Such ground movements can be measured by precise leveling, but this method is expensive and slow, and not suitable except over a fairly extended area.

It is apparent, then, that an instrument for measuring a localized tilt must be very sensitive to change of angle of its supports. The seismographs, such as are in use for earthquake measurement, are utilized for tilt measurement, and are sufficiently sensitive, but a seismograph installation is much too expensive to use for the large number of tilt stations that are needed.

A type of tiltmeter has been developed at the Hawaiian Volcano Observatory which is very satisfactory for indicating the tilt, both in magnitude and direction, but has the disadvantage that it is not a recording instrument. It must be visited and read to determine the tilt. Two of these instruments are in use on the floor of Kilauea crater, near Halemaumau, and are read at twenty-four hour intervals, but there is no record of any variations that might occur between readings, nor of the time when any particular amount of tilt takes place. Furthermore, these instruments are not of a type to be made self-recording, except photographically, and that has its disadvantages.

There is need for a tilt-measuring device that is sensitive, economical in construction and operation, which will record the tilt hourly, at least, and that need be visited not oftener than once a week, at which time the record can be removed and

replaced by a new, blank record sheet. Many such instruments could be placed around Kilauea crater and the rifts about this region and a very complete record of the tilting of the ground obtained which would be of great value in the study of the lava movements below the ground, as well as in the prediction of future eruptions.

It is in connection with the development of such an instrument that I am spending a few weeks at the Hawaiian Volcano Observatory this summer. I have a model in operation from which daily records are now being obtained. This model appears to have possibilities for development into the type of device required for the more widespread study of tilts which I have mentioned.

At the present time tilting is being measured at Halemaumau, as before stated, and also at some of the seismograph stations, by measurements taken from the seismographs. Such measurements have been carried on continuously at the Obser-

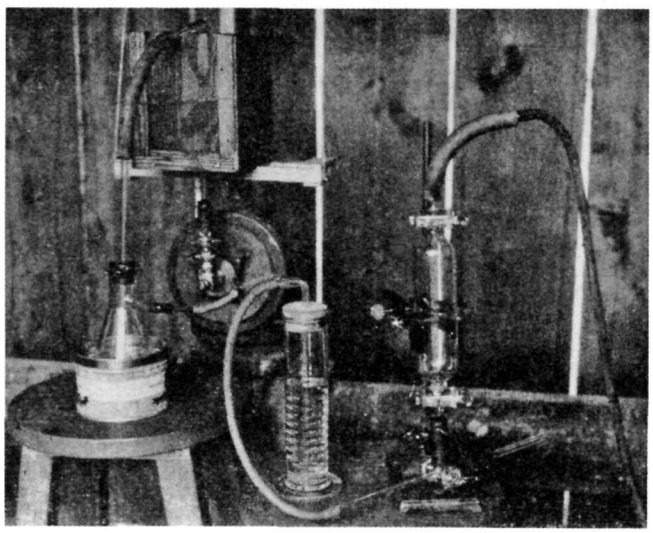


Figure 2. Gas drawn through salt-and-ice mixtures and KOH before reaching collecting tube.

vatory for many years, and have shown that volcano tilts coordinate with lava movement, and that seasonal tilts also occur over large areas. The annual variation of tilt at the main Hawaiian Volcano Observatory station takes place along a line about NNE and SSW. The tilt is greatest to the NNE about the end of December and the greatest SSW value is in May or June, and varies through a range of from twelve to eighteen seconds of arc in the different years. At the same time there is now a slight residual tilt toward the west which is at the rate of less than one second per year.

The tilt stations on the crater floor, near Halemaumau, indicate in general, tilts to or from the pit as being predominant. This shows a swelling and subsidence with the rising and recession of the underlying lava, or one might say, a sort of diaphragm action of the crater floor. These movements at the pit are very localized, and do not show ground movements over a larger area as would stations around the crater rim, or at points on Mauna Loa.

In most cases the tilts as measured at the various stations have been gradual, with small daily change. Likewise a tilt of one day might be in an entirely different direction from that of the day before, but in general, over a period of several days, or in many cases several months, the tendency of the tilt is in one definite direction. Then there may be a reversal of the tilt over an extended period, so that at no point does the tilt continue indefinitely in one direction.

At times, especially of considerable seismic disturbance, a tilt of several seconds may occur between readings of the instruments. This large change probably takes place in a few seconds of time, at the time of the quake. But whether the tilt be large or small, gradual or sudden, it gives definite information of movement of underlying lava, and an extended tilt study should assist greatly in following the course of this movement.

Hawaiian Volcano Observatory Report for November 1937

VOLCANOLOGY

The Hawaiian volcanoes were quiet during the month, and there was little motion in the walls of Halemaumau pit at Kilauea.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
November 7.....	6.75	2	3.00 mm.	19
" 14.....	3.75	0	5.05 mm.	11
" 21.....	4.00	2	0.00 mm.	11
" 28.....	9.75	0	0.00 mm.	24

The slight earthquake November 27 damaged the Halemaumau seismograph and was felt in National Park. Of the measurable local seismic disturbances, sixteen were from Kilauea, one from Mauna Loa and one from northwest of Mauna Kea.

Sequence of Events by Weeks

The first week produced two slides from Halemaumau walls, two more were noted during the third week and on November 28 scars of a slide appeared in Puu Huluhulu crater after the sharp jerk of the earthquake of November 27.

Slides at Halemaumau

The recorded slides from the wall of the pit were:
November 1, 11:05 a.m., dust arose at NW wall.
November 2, 9:00 a.m., another slide in the same place.
November 21, 1:45 p.m., two slides north wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during November in aggregate movement as follows:

Week ending forenoon of:

November 5, 28 locations, 6 opened, 4 closed, opening 3.00 mm.

November 12, 28 locations, 12 opened, 3 closed, opening 5.5 mm.

November 19, 28 locations, 6 opened, 4 closed, opening 0.0 mm.

November 26, 28 locations, 6 opened, 5 closed, opening 0.0 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Seismicity Weekly*
Nov. 7.....	13	5	1	0	0	6.75
" 14.....	7	4	0	0	1	3.75
" 21.....	12	2	0	0	0	4.00
" 28.....	15	8	0	1	0	9.75

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seis-

* For local seismicity definition see Volcano Letter 371.
† Including teleseisms or earthquakes over 5000 km from Kilauea.

mograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of the depth of focus has been made.

November 1, 2:49 a.m., very feeble, probably originated in area immediately NE of the Observatory, NE rim of Kilauea Crater.

November 1, 5:50 p.m., very feeble, 38.0 miles deep in vicinity of Waimea Table Land about 18.0 miles NNW of Summit of Mauna Kea. 19° 59.0′ N; 155° 30.8′ W.

November 3, 1:59 p.m., feeble, probably originated in Kilauea Crater near SE portion of Halemaumau.

November 6, 4:18 p.m., very feeble, probably originated in NE portion of Kilauea Crater.

November 8, 8:58 a.m., very feeble, 1.1 miles under Byron Ledge. 19° 25.0′ N; 155° 15.6′ W.

November 8, 10:13 a.m., very feeble, location same as preceding quakes but of slightly deeper focus.

November 8, 10:25 p.m., very feeble, probably orginated in SE rim area of Kilauea Crater near Keanakakoi.

November 11, 12:02 a.m., very feeble, probably originated in Western portion of Kilauea Crater near Uwekahuna.

November 17, 12:24 p.m., very feeble, 3.9 miles deep, 3.4 miles NW of the Observatory. 19° 27.8′ N; 155° 18.0′ W.

November 23, 4:37 p.m., very feeble, probably originated in NE rift of Mauna Loa about 15.0 miles from Hilo.

November 25, 10:10 p.m., very feeble, 2.2 miles deep NE rim Halemaumau, Kilauea Crater. 19° 24.9′ N; 155° 17.0′ W.

November 25, 10:11 p.m., very feeble, 1.4 miles deep NW portion of Kilauea Crater. 19° 25.6′ N; 155° 17.0′ W.

November 25, 10:23 p.m., very feeble, 1.5 miles deep in SE rim cracks, Kilauea Crater immediately NE of Keanakakoi. 19° 24.4′ N; 155° 16.2′ W.

November 25, 10:26 p.m. very feeble, location same as preceding quake.

November 26, 12:44 a.m., very feeble, of shallow origin SE rim cracks Kilauea Crater. 19° 24.2′ N; 155° 16.3′ W.

November 26, 11:50 p.m., very feeble, probably originated in E portion of Kilauea Crater.

November 27, 11:26 a.m., very feeble, 5.0 miles deep, SW rift zone at junction with Kilauea Crater. 19° 24.5′ N; 155° 17.7′ W.

November 27, 6:35 p.m., slight, 1.1 miles deep, 0.3 mile E of E rim Halemaumau and 0.4 mile from Pit seismograph. Reported felt at CCC Camp, SE rim of Kilauea Crater and around the National Park residential area. Pit seismograph was dismantled and the supports of N-S component broken. 19° 24.4′ N; 155° 16.7′ W.

Microseismic motion of the ground at the Observatory was strong throughout the month.

Four (4) minutes of continuous tremor began recording at the Observatory 3:53 a.m., November 21.

An unidentified portion of a teleseism began registering at Kilauea at 9h 03m 28s, p.m., H.S.T., November 9.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 28, was 10.05″ S and 1.55″ E.

Week Ending	Observatory	Halemaumau West Station
November 7	1.38″ N 48° E	2.62″ N 31° W
November 14	0.65″ N 61° W	2.80″ N 80° W
November 21	0.00″ 0	5.16″ N 82° W
November 28	1.00″ N 79° E	4.14″ N 71° W

Week Ending	Southeast Station Halemaumau	Halemaumau Resultant
November 7	1.62″ S 34° W	1.69″ From
November 14	3.43″ N 46° W	0.89″ Toward
November 21	6.42″ N 28° W	2.79″ From
November 28	8.59″ S 16° E	4.37″ From

H. H. W.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory November 27, showed slight closing of the Kilauea Crater value and slight opening of the Halemaumau value as compared to similar measurements October 16. From Kilauea Crater SE rim to Uwekahuna there was opening 0.09″, October 16 to November 10, and closing of 0.25″, November 16 to 20. Total closing 0.16″. From the SE Pit B. M. to NW Pit B. M. there was opening 1.40″, October 16 to November 10, and closing of 0.84″, November 10 to November 27. Total opening 0.56″.

H.H.W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 454 monthly Department of the Interior National Park Service December 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

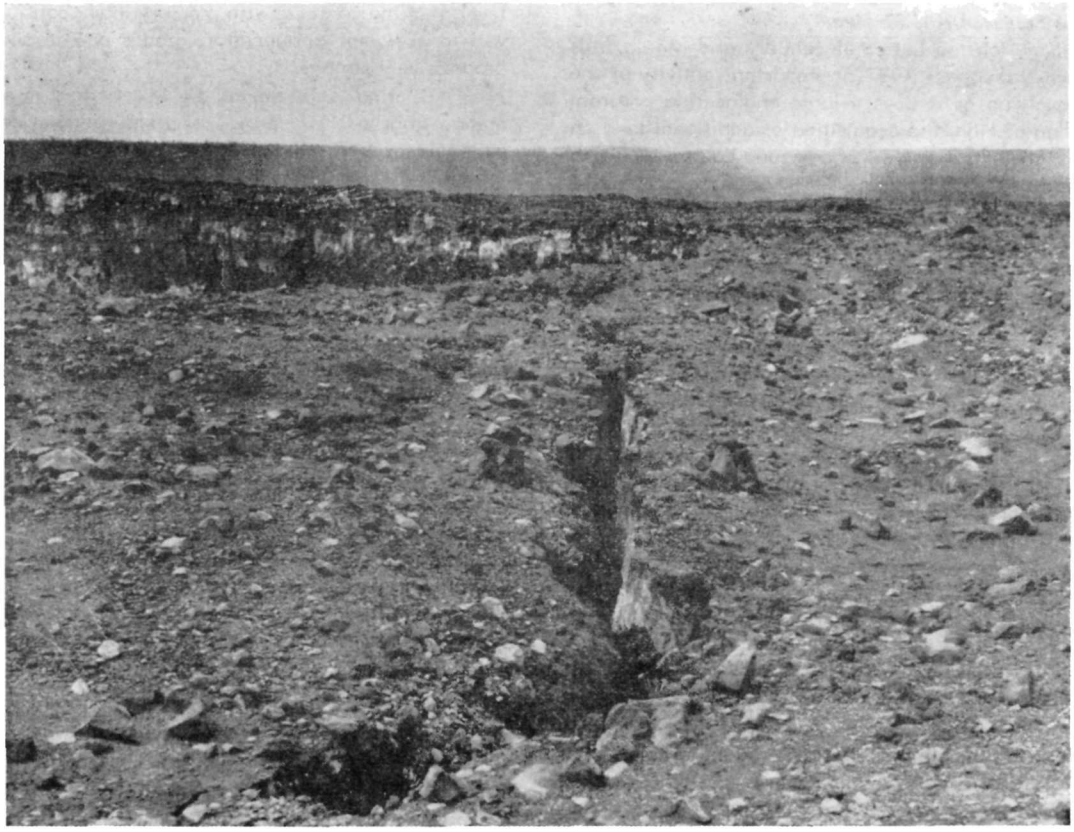


Figure 1. Crack on east margin of Halemaumau No. 25. Note two stone piles right side of crack, May 10, 1937.

WORK OF THE OBSERVATORY 1937—

The Hawaiian Volcano Observatory is administered under the Branch of Research and Education of the National Park Service. In collaboration is the Hawaiian Volcano Research Association, an educational corporation of the Territory of Hawaii which supplements the work of the Government. The staff in 1937 was:

T. A. Jaggar, Volcanologist
H. H. Waesche, Assistant Geologist in charge of seismology
S. Sato, Librarian
H. Yasunaga, General Assistant
A. Okuda, Mechanic

Associates of the Observatory in Honolulu are:

Willard H. Eller, Associate Professor of Physics
Stanley S. Ballard, Assistant Professor of Physics
Iwao Miyake, Instructor in Physics
L. W. de Vis-Norton, Secretary and Assistant Treasurer, Hawaiian Volcano Research Association
Mrs. B. Y. Ching, Clerk

The Directors of the Hawaiian Volcano Research Association are:

F. C. Atherton, Castle & Cooke, Ltd.
R. A. Cooke, C. Brewer and Co., Ltd.
D. L. Crawford, University of Hawaii
A. L. Dean, Alexander and Baldwin, President

W. F. Dillingham, Oahu Railway & Land Co.
J. R. Farrington, Honolulu Star-Bulletin
W. F. Frear, Bishop Trust Building
L. T. Peck, Stangenwald Building
W. W. Thayer, Stangenwald Building
L. P. Thurston, Honolulu Advertiser

Volunteer operators of seismographs for the Research Association on the island of Hawaii are:

R. V. Woods, Kealakekua
St. Mary's School, Hilo

The routine of the Observatory, besides the accumulation of data exhibited in the Volcano Letter, which involves attention to five seismographs, two clinographs, weather records, levelling and triangulation, and measurements at Halemaumau pit, includes also circulation of a weekly press report for Island newspapers, transmittal of a monthly report to the National Park Service, transmittal weekly and monthly of weather data to U.S. Weather Bureau and preparation of scientific papers.

Mauna Loa and Proposed Hilo Barriers

As outlined in Volcano Letter of January and March, this subject has been throughout 1937 an important activity of the Observatory, involving as it does a large engineering program for the protection of Hilo, the acquisition of additional land on Mauna Loa, and the establishment of a Mauna Loa seismograph at the terminus of the Park Road.

The Barrier Project for defending Hilo from lava flows was announced at a lecture by T. A. Jaggar to Hilo Chamber of Commerce January 19, followed by the proposal of the Hawaiian Volcano Research Association to acquire all lands on Mauna Loa above 7,000 feet that might be needed for patrol by the National Park Service. This action was authorized in February by the Board of Directors of the Research Association and an expedition over the ground on Mauna Loa was made in March by Chief Forester Coffman of the Park Service, and Mr. Tillett, Superintendent of Hawaiian Emergency Conservation Work, along with Superintendent Wingate, the Volcanologist and others. March 23 a resolution by Hilo Chamber of Commerce requested the Rivers and Harbors Committee of Congress to provide for a survey of the barriers for the protection of Hilo harbor. This was incorporated in the Rivers and Harbors Bill in May, and the bill was passed in August. The several owners of the upper lands on Mauna Loa, including the Territorial Government, expressed tentative approval of the enlargement of the Park, as might be later demanded by Act of Congress. In July and August Colonels Thomas and Browne of the U.S. Engineers went over the lands on Mauna Loa, Mauna Kea and at Hilo where the barriers would be constructed. General Markham, Chief of Engineers, inspected the field in November, and the U.S. Engineer in charge of Hawaii, Major P. E. Bermel, held a hearing in Hilo December 17 where the harbor protection was discussed.

On September 9 a site was selected on the upper side of the present terminus of the Mauna Loa road for a cellar of concrete with double walls to house a seismograph of Hawaiian type, and this cellar was nearly completed at the end of the year, built by Emergency Conservation labor.

Seismology and Engineering

Mr. Waesche was engaged in January in applying a relay to the radio apparatus receiving time signals, so that these signals were written directly on seismograph drums. He prepared earthquake maps of Kilauea crater and the island of Hawaii. He assisted in arrangements for a new kiosk at Halemaumau to exhibit to travelers history of eruptions. A levelling instrument gave much trouble during the year, but a substitute instrument was obtained, and it was discovered that the northwest Halemaumau benchmark had lowered relative to the Sand Spit south of Kilauea about fifteen inches since October 1934. In December a rotary wind-measuring instrument was set up on the Observatory roof, so as to record directly on the chronographs of the seismograph cellar. A similar instrument was obtained for the Rest House on Mauna Loa.

Investigation of simplified seismological instruments for volunteers has occupied the staff. Four new model shock recorders were built during the first half of the year having in view the recording of three components of motion by means of weights suspended by flat springs.

In May a second series of experiments was begun with normal pendulums designed to actuate a mercury contact, ring a bell, and exhibit intensity by length of swing.

The object of this work was to install annunciators at telephone exchanges which would give a numerical value to intensity of an earthquake. The operators would enter the number on a postal card sent the Observatory. It was finally decided to use a rectangular heavy mass capable of swinging in one direction only, with a very light horizontal high-magnification lever, making contacts with mercury in six cups. These connect with a six-point annunciator, grades one to six being shocks progressively stronger.

The normal activities of the Observatory in seismology and engineering will be found described in the articles by Mr. Waesche in Volcano Letters of February, April and October. The instrument that will be placed in the Mauna Loa cellar consists of a pair of pendulums built in our shop, magnifying earth motion one hundred times, and writing on smoked paper wrapped round a drum driven by clockwork. This instrument will be visited once a day by a member of the staff who will change the drum. The location is eleven miles from the Observatory WNW, on the Mauna Loa slope ten miles below the rest-house. This will give the Observatory a definite check on shocks occurring under the rift belt of Mauna Loa.

The shock recorders and annunciators are simple instruments in wooden cases designed to screw on a wall anywhere, announce an unfelt earthquake by ringing a bell, and proclaim its size by the distance to which the pendulum swings. When an electric annunciator dial is used the length of the swing is indicated by a number. The operator after noting the hour and the number, sets the annunciator back to zero. Plans for making one of the models self-recording are not yet perfected, but tests have been made with ink, smoked paper, and photographic film.

Kilauea Laboratory, University of Hawaii

The work of the University physicists was outlined in November Volcano Letter. S. Sato, a University assistant, is resident at the Observatory as librarian and has introduced order into the library by classifying, filing and card cataloging the earthquake and eruption notices clipped from the press, also the books, pamphlets, notes, and photographic negatives that are parts of the invaluable Kilauea records.

Among things filed are the long smoked paper seismograms, fixed with shellac varnish and stored by thousands. The work of classifying finds these congested by overflow from the metal case originally made for them. All the records are in a room eighteen feet square from which books had to be ejected with transfer to the University building five hundred yards away. In the attempt at economy of space, there have been packaging and storing surplus publications, correspondence, and the less used books, in the hot, dry, wooden Observatory attic; transferring seismological pamphlets to the Assistant Geologist's wooden office, and lastly filing, selecting reserves, and setting apart sets for binding, of the Observatory Bulletin and of the Volcano Letter, the entire file of the latter being kept in the old wooden Observatory building. This building also houses as fire hazards chemical and photographic work, electric soldering irons, and kerosene smoking apparatus for the daily seismograph routine

in the basement. Here also are main switchboxes and fuses; and battery equipment for radio time signals.

This situation is a continuous fire menace for the storage of the valuable records and publication files of the twenty-six years of work of the Hawaiian Volcano Research Association. The record material cannot even be studied properly, for there is no room for large tables nor for modern filing cases and everything has to be distributed to five rooms in three different buildings.

There is no solution for this problem of congestion other than the creation of a new large fireproof Hawaiian Volcano Observatory building.

Dr. H. Nagaoka of the Institute of Physical and Chemical Research in Tokyo has discovered at Asama Volcano that a magnetometer needle moves suddenly during underground volcanic disturbance. Theoretically this should be true, for liquid lava on solidifying or liquefying changes its magnetic attractiveness. At Asama various intermittent disturbances of the magnetic needle are observed several weeks before an explosion

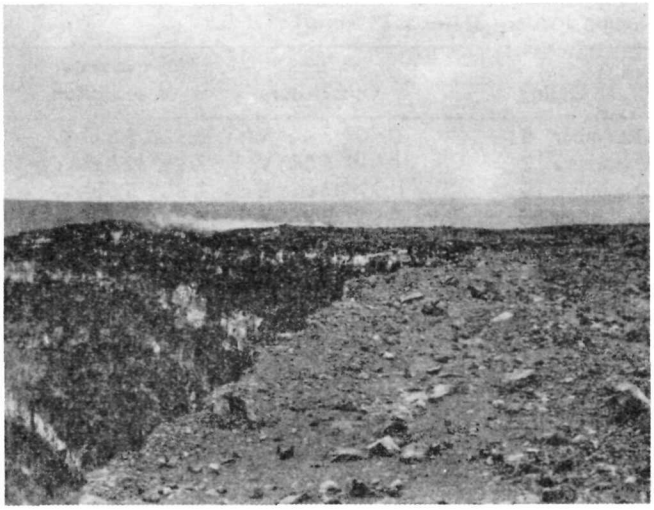


Figure 2. Crack locality No. 25 after caving into pit August 22, 1937. Photographs by Waesche.

of the volcano, and the rumbling is always accompanied by great magnetic changes. A specialized magnetograph was constructed giving the value of the time-rate of variation, serving as an indicator of rapid magnetic disturbances and registering the vertical component. It is relatively insensitive to magnetic storms. Professor Eller is greatly interested in the possibilities which this apparatus has for exhibiting the melting or the congealing of Hawaiian eruptive lava underground. Experiments are in progress for melting the lava and studying its change of magnetic properties.

As candidate for the degree of Master of Science Mr. A. E. Jones presented a thesis at the University of Hawaii on "Empirical Studies of the Seismic Phenomena of Hawaii" and on September 23, came up for examination which he passed satisfactorily. This thesis presents a statistical investigation of many seismograms of the Hawaiian Volcano Observatory.

In these days of Kodachrome photography an appeal may be made to amateur photographers interested in the Hawaiian volcanoes to explore the great rift belts and to photograph them. Either still or motion pictures in color, for purposes of projection and exhibition, should be made of the hundreds of subjects, such as cracks and pits and cones, that lie along the southwest rift of Mauna Loa in Kahuku, the northeast rift near the Rest House, the vicinity of Kulani; and the great extent of the Kilauea rift in the forest to the east of the Chain-of-Craters; and along the many pits and cones of the Kau Desert. There is here a magnificent opportunity for photographic exploration in the wilderness, something that few people seem to care to do.

Hawaiian Volcano Observatory Report for December 1937

VOLCANOLOGY

Until the solstice season of December 20, the month at Halemaumau pit of Kilauea volcano was extraordinarily quiet. After solstice local seismicity became three times as great, and five large distant earthquakes were recorded, in part from the Mexico-Central America region. Sixteen of the local shocks were from Kilauea, one from Mauna Loa and one from Hualalai.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending		Seismicity	Slides	Openings Crack	Local Tremors and Quakes
December	5.....	3.75	0	3.5 mm.	10
"	12.....	2.25	0	1.0 mm.	7
"	19.....	2.00	0	6.0 mm.	7
"	26.....	6.50	1	0.0 mm.	20
January	2.....	7.50	0	2.5 mm.	19

Perceptible earthquakes occurred in Hilo December 28, Kona December 30, and at National Park January 1.

Sequence of Events by Weeks

The first week was quiet, with noticeable blue fume showing over Halemaumau during humid Kona weather.

The second week was even quieter, and the seismic index for the third week was astonishingly small just as it was a year ago at this period. This was interrupted by a landslip in Halemaumau the fourth week, and the fifth week showed increased numbers of earthquakes near and far.

Slide at Halemaumau

A recorded slide from the wall of the pit was:

December 21, 4:08 p.m., a considerable slide from the north rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during December in aggregate movement as follows:

Week ending forenoon of:

December 3, 28 locations, 11 opened, 6 closed, opening 3.5 mm.

December 10, 28 locations, 8 opened, 6 closed, opening 1.0 mm.

December 17, 28 locations, 10 opened, 2 closed, opening 6.0 mm.

December 24, 28 locations, 6 opened, 4 closed, opening 0.0 mm.

December 31, 28 locations, 8 opened, 3 closed, opening 2.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending		Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly† Seismicity
Dec.	5.....	7	3	0	0	3.75
Dec.	12.....	5	2	0	0	2.25
Dec.	19.....	6	1	0	0	2.00
Dec.	26.....	14	6	0	3	6.50
Jan.	2.....	10	8	1	2	7.50

* Including teleseisms of earthquakes over 5000 km. from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of the depth of focus has been made.

December 1, 9:15 am, very feeble, probably originated in Kilauea S W rift, 19 miles from the Observatory and 4.0 miles N of Palina Point.

December 2, 8:00 pm, very feeble, 3.1 miles deep, W rim of Kilauea Crater 0.6 mile SW of Uwekahuna, 19° 25.2' N; 155° 17.9' W.

December 3, 6:58 am, very feeble, 1.4 miles deep and 0.8 mile W of Puhimau Crater. 19° 23.6' N; 155° 15.8' W.

December 7, 12:47 pm, very feeble, 11.0 miles deep, 7.0 miles W of Volcano House. 19° 26.9' N; 155° 21.8' W.

December 12, 5:30 pm, very feeble, 21.0 miles deep under Hualalai. 19° 41.5' N; 155° 50.7' W. Felt in Kohala and at Paauilo.

December 25, 2:18 pm, very feeble, 2.5 miles deep and 0.4 mile SW Kokoolau Crater. 19° 23.1' N; 155° 15.2' W.

December 25, 5:26 pm, very feeble, 6.0 miles deep Kilauea SW rift 7.5 miles from Halemaumau. 19° 20.2' N; 155° 22.2' W.

December 26, 1:58 am, very feeble, probably originated in SW portion Kilauea Crater in vicinity of Halemaumau.

December 26, 6:42 am, very feeble, location of epicenter same as preceding but probably of slightly greater depth.

December 27, 2:19 pm, very feeble, 06. mile deep under W portion of Kilauea Iki, 0.2 mile E of Kilauea Crater rim. 19° 25.1' N; 155° 15.4' W.

December 28, 11:27 am, very feeble, 1.5 miles deep in Kilauea Crater immediately W of Kilauea Iki. 19° 25.3' N; 155° 15.8' W.

December 28, 7:15 pm, very feeble, 11.0 miles deep and 4.0 miles off coast S of Hilina Pali. 19° 12.6' N; 155° 14.2' W. Reported felt in Hilo.

December 29, 6:18 pm, very feeble, probably originated in Kilauea SW Rift.

December 31, 4:34 pm, very feeble, probably originated near center of Kilauea Crater.

January 1, 2:39 am, very feeble, 17.0 miles deep in Hilina Fault 3.5 miles S of Kamakaia Hills. 19° 16.0' N; 155° 20.3' W.

January 1, 9:16 am, feeble, 4.8 miles deep near Heake Crater, 19° 22.6' N; 155° 14.1' W.

January 1, 10:44 pm, very feeble, 13.0 miles deep under SW slope of Mauna Loa 5.0 miles NE of Kauna Point. 19° 05.6' N; 155° 49.5' W.

January 2, 6:01 pm, very feeble, probably originated in area approximately 12.0 miles NE of the Observatory.

Microseismic motion of the ground at the Observatory was moderate, December 16 to 21 and on December 24; the remainder of the month, the motion was strong.

Teleseisms registered as follows:

December 21, "P" waves at 5h 19m 20s pm, distance from Kilauea was about 3,200 miles and epicenter was apparently off W Coast of Mexico. 17° N; 106° W, by preliminary determination U. S. Coast and Geodetic Survey.

December 21, 9h 08m pm, no information obtained on location.

December 23, 2h 57m 25s pm, "P" waves, distance from Kilauea was approximately 3,700 miles. Epicential location 16° N; 98° W, by preliminary determination, U. S. Coast and Geodetic Survey.

January 1, 1h 07m 41s pm, "P" waves. No determination of distance.

January 2, 12h 06m 50s pm, "P" waves, probable distance from Kilauea, 3,600 miles.

Hawaiian standard time used for all preceding reports.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 2, was 9.7" S and 0.47" E.

Week Ending	Observatory	Halemaumau West Station
December 5	0.46" S 41° W	2.92" S 81° W
December 12	1.01" S 50° W	2.98" N 33° W
December 19	0.97" N 65° E	2.38" S 66° W
December 26	0.82" S 26° E	4.23" N 58° W
January 2	0.25" N 27° W	0.00 Unchanged

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
December 5	9.17" S 67" W	0.56" From
December 12	10.40" S 73° W	1.91"Toward
December 19	10.08" N 12° E	4.24" Toward
December 26	1.62" S	4.72" From
January 2	6.29" N 15°W	5.83" Toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, December 22, indicated opening of both the Halemaumau and Kilauea Crater values compared with similar measurements made November 27. At that time the Halemaumau value from the SE Pit B.M. to the NW Pit B.M. increased 2.51" and the Kilauea Crater value from the SE rim to Uwekahuna increased 0.44".

Leveling at Kilauea

On December 9, a series of levels similar to that of October 12 was run in Kilauea Crater from the Spit B. M., SE rim of Kilauea Crater to NW Pit B. M. on the NW rim of Halemaumau. Results of this run indicated relatively no change or not more than 4 millimeter lowering of the NW Pit B. M. relative to Spit B. M. The Lietz, Coast and Geodetic Survey type precise level was used for the December levelling. It checked favorably with the Stanley "Wye" level used for the October determination. H. H. W.

THE VOLCANO LETTER 455

No. 455 monthly Department of the Interior National Park Service January 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



View of the Sulphur Bank, Kilauea. Notice the cliff in the background which is doubtless the wall of a Kilauea crater much older than the present one. Most of the gas collections were made at the wells which are beneath the temporary laboratory building in the left foreground.—National Park Service Photo.

THE VOLCANIC GAS PROBLEM

By Stanley S. Ballard

Research Associate in Geophysics, Hawaii National Park, and Assistant Professor of Physics in the University of Hawaii.

More and more attention is being focused upon the problem of the analysis of volcanic gases. Overlooked almost entirely until recent years, the evolution of gas is now considered to be one of the major phenomena accompanying a volcanic eruption. In fact some volcanologists feel that a satisfactory solution of the volcanic gas problem will shed much light on the fundamental problems of volcanology. In particular, it is thought that here may be found the source of some of the enormous quantity of heat that is given off at the time of eruption. The volcanic gases appear to have their origin underground in the fluid magma. As the magma rises during an eruption the hydrostatic pressure upon it is greatly decreased and at the earth's surface is so small that the gases here come out of solution and are given off into the atmosphere, usually in flames. Fortunately they can be analysed by chemists and physicists, the results of analysis being of course turned over to the volcanologist or the geochemist for interpretation.

There are at least four distinct approaches to the volcanic gas problem. First there is the possibility of photographing the spectra of the burning gases at the time of eruption. This would involve setting up a light portable spectrograph in the field near the fluid lava and focusing upon the slit of this instrument by suitable lenses the light from the flames of the burning gases emanating from cracks in the advancing lava flow. The photographs thus obtained would not be pictures of the flames themselves, but would be spectra of the substances burning in the flames. A trained spectroscopist could readily interpret these spectrograms to tell what elements or molecules in the burning gas gave rise to each of the spectrum lines. In the past vol-

canic flames have sometimes been examined through small hand spectroscopes, but the writer doubts whether results obtained in this way are particularly significant. Even a person experienced in spectroscopy can easily mistake the colored line of one element for some neighboring line of another element and thereby make an incorrect visual analysis. For this reason it is felt that the photographic method, giving a permanent record which can be compared later with standard spectrograms of the various suspected elements, is much preferable. It is hoped that a small field spectrograph can be obtained for use in this connection at the next eruption of Kilauea or Mauna Loa.

The second approach to the problem is through the collection of gases emanating from the fluid lava at the time of eruption, and their subsequent analysis in the laboratory by chemical and spectroscopic means. It is important to collect the gases **before** they burn, if possible, and to make the collections so as to exclude air from the surrounding atmosphere as completely as possible. Collections of volcanic gases were made at Kilauea in 1912 by Drs. Day and Shepherd of the Geophysical Laboratory of the Carnegie Institution of Washington, and further collections were made in 1917, 1918 and 1919 by Dr. Shepherd and Dr. Jaggar at Kilauea and at Mauna Loa. These samples were analysed in the Washington laboratory by Dr. Shepherd, the results being reported in papers appearing in the monthly bulletins of the Hawaiian Volcano Observatory and in national geological journals. No opportunity to collect volcanic gases has presented itself since the writer has been in the Territory, but a new type of collecting tube which it is hoped is somewhat of an improvement upon the vacuum tubes used previously has been devised. This new type of tube is described below.

The third approach consists of extracting dissolved gases from samples of cold lava after the eruption is over, and then analysing these gases. The extraction is performed by heating a ground portion of the rock in a vacuum furnace. When the rock comes up to the softening temperature large volumes of occluded gas, many times the volume of the rock in some cases, are driven off. The chief difficulty here appears to be in developing analytical methods for handling accurately the rather small samples of gas obtained. Suitable methods have been worked out by Dr. Shepherd and some analyses of gases driven off in the vacuum furnace from lava samples are given in his 1925 paper in the Journal of Geology. An attractive feature of this approach to the volcanic gas problem is that collections need not be made at the time of eruption when field conditions are seldom ideal, but may be made some weeks later after the excitement is over. In fact one should be able to go around the island of Hawaii, stop at the various dated lava flows and obtain suitable samples of rock, take them back to the laboratory, drive off their occluded gases, analyse these gas samples, and have a time-history of the composition of Hawaiian volcanic gas.

The last approach to the volcanic gas problem is by far the least direct of the four. It involves the collection and analysis of the sulphurous fumes emanating from vents in the immediate neighborhood of the crater. Of course there is often a general steam crack activity in a volcanic region, but the emanations here seem to consist largely of steam. This is doubtless ground water that has seeped down into the warmer regions of the ground, been vaporized and returned to the atmosphere as steam. There are often, however, small areas at which free sulphur is brought up from the depths and deposited at the surface, building up the so-called sulphur banks. The emanations in these cases consist of steam, sulphur vapor and additional gases. The important question here is as to how intimately volcanic these solfataras can be considered to be. Do some of the gases rise directly from the bed of molten magma that is thought to underlie the volcanic region? If so, the analysis of the readily accessible and continuously fuming solfataric gases should afford an index to the activities of the magma below. In the case of Kilauea, sulphurous fuming regions can be seen around the bottom edge of Halemaumau pit, around the edge of Kilauea crater beneath the present CCC camp, and at the edge of a still older, prehistoric Kilauea crater. This last area is located near the Hawaiian Volcano Observatory and the Kilauea Volcano House and is the Sulphur Bank that is visited by practically all tourists to the Park, being but 100 yards off the main highway. At this location collections of solfataric gases were made some 16 years ago by Dr. E. T. Allen of the Geophysical Laboratory. His results as published in the Bulletin of the Hawaiian Volcano Observatory for August 1922 are as follows:

Steam	96.2%
Fixed Gases	3.7
Sulphur Dioxide	.096
Sulphur Vapor	.004
Hydrogen Chloride	Trace

These are volume percentages for a temperature of 95.5° C and a pressure of 646 mm.

There are discussed below the collections and analyses of Kilauea Sulphur Bank gases which have been carried out by the writer during the last two years. The chief purpose of this investigation was to study the less obvious solfataric gases, that is, those other than steam and sulphur vapor. The actual collections were made at various times during an interval of over a year, and it was hoped that some variation in the constitution of the gases might be found. No significant variation has appeared, but the writer feels that collections and analyses should continue to be made at perhaps monthly intervals, the program lasting long enough to include a period of activity of Halemaumau. If variations in constitution are found to occur during the period of activity, the results will surely justify the work involved. In fact there is the possibility and hope that such variations might exist and might be correlated with volcanic activity sufficiently to enable predictions of eruptions to be made through gas anlaysis as well as through a study of seismic records. Whether such prediction will ever be possible or whether this is only a fond dream, only time can tell.

Collection of Volcanic Gases

The collection of the gases billowing forth from fluid lava at the time of eruption is ordinarily effected by the use of vacuum-type collecting tubes. A typical tube consists of a large bulb of several hundred cubic centimeters capacity to which is joined a long, narrow glass tube which may be several feet in length. The whole assembly is originally evacuated to a high degree. Then when the end of the long glass tube is thrust into the volcanic flame and the tip of the tube is broken off or melted through, gas will rush into the evacuated volume. If it can be successfully trapped there, the collection is complete. A desirable feature is that outside air may be eliminated from the collection as completely as possible.

Vacuum-type tubes of the sort used in the collections of Drs. Day, Shepherd and Jaggar are pictured on page 7 of Volcano Letter Number 437 for July 1936. The largest tube in this figure is the smallest tube shown in Figure 1. Above this tube is the largest vacuum-type tube used by them. Note the long drawn-out tip which could easily be broken off by striking the end of the tube against the lava when the time to make the collection arrived. Note also the narrowed portion of the slender tube near the large bulb which is designed for ready sealing off with a gasoline torch after the collection is completed. The tip of the lower tube has in its end a plug of glass of low melting point which should soften quickly in the intense heat of the volcanic flame, allowing the gas to rush in. The chief difficulties encountered with these tubes were in causing the tip to

break or melt at the appropriate time, and in sealing the tube quickly before contaminating air entered.

The top tube in Figure 1 is the first vacuum-type collecting tube designed by the writer in collaboration with Mr. Paul Gow, Assistant Chemist at the Experiment Station of the Hawaiian Sugar Planters' Association. Features of this tube are a type of tip which is certain in its action, and a method of sealing the collected sample quickly so that no outside air can enter to contaminate it. The breakable tip is simply a crook-necked tip which is scored with a file to insure breaking at the bend, the breaking being effected by a quick jerk on a wire attached at one end to the crook and at the other to the collector's right hand, the tube being held in his left hand. After the gas has

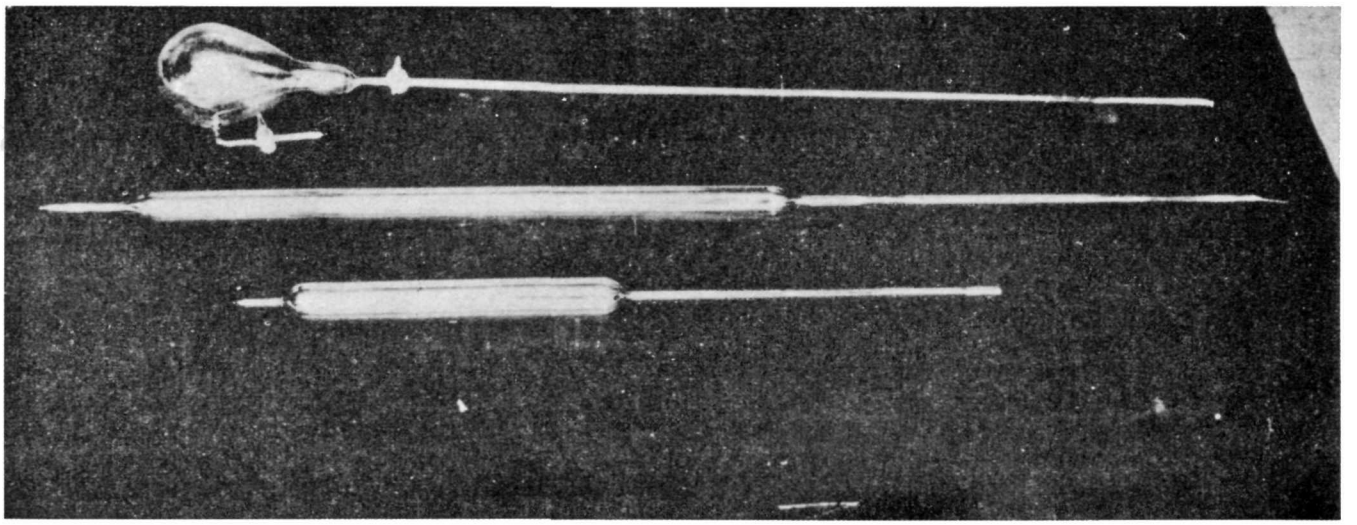


Figure 1. Old and new vacuum-type volcanic gas collecting tubes. Capacities are approximately as follows: Upper (new style) tube, 800 cc.; center tube, 450 cc.; lower tube, 350 cc.—National Park Service Photo.

rushed into the evacuated volume it is trapped there simply by turning through ninety degrees (i.e. from open to closed position) the large vacuum-ground stopcock between the three-foot long slender glass tube and the large bulb. In Figure 2 is pictured the original tube along with two later "stream-lined" models. These differ from the original tube in two important respects. First, the side arm with small stopcock which was attached to the large reservoir bulb has been eliminated. This attachment was used in evacuating the bulb. Evacuation is now effected through a small side tube which is sealed off with an oxy-gas flame when the tube is evacuated to as high a degree as possible. The second improvement is in the greater mechanical strength obtained by making the weld between the large bulb and the stopcock very short and hence very sturdy. These latest tubes are made to order by a New York glass-blowing firm. The long slender tube is added locally in order to save freight charges. Then the breakable tip is drawn out and the tube is evacuated. The price complete per tube is under five dollars. The tubes may also be clamped to a sturdy pole, the stopcock being rotated by a "remote-control" device not shown in the figure. This recourse would be necessary in cases where the collector could not approach to within three or four feet of suitable gas sources.

No opportunity to test these tubes under actual field eruption-time conditions has presented itself as yet. The original tube pictured in the figures was tested at the Sulphur Bank in the summer of 1936, however, and appeared to work most satisfactorily. The difficulties which might be encountered with the tubes would be the result of the fragile nature of any piece of glass apparatus or of the failure of the vacuum-ground stopcock to hold a vacuum in the tubes while they are in storage awaiting eruptions. In general these stopcocks have been found to be quite satisfactory, two tubes now at the Hawaiian Volcano Observatory having held a vacuum perfectly for six or eight months to date. It should be remarked that at the Observatory there is now a complete outfit for evacuating these tubes and for doing any glass blowing and repairing that might be necessary.

Collection and Analysis of Solfataric Gases

The analyses about to be reported upon should be thought of still as preliminary studies which supplement the first analyses made by Dr. Allen in 1922. The purposes were to establish the identity of the 3.7 per cent of "fixed gases" reported by Allen, to see if there were any gases being given off which were unusual in nature, and to establish what definitely volcanic gases were emanating from the solfataras. Interest was centered particularly upon the combustible gases hydrogen and carbon monoxide which are known to burn in volcanic flames; sulphur vapor, another known volcanic gas, is very evidently a constituent of the solfataric gases. The analyses therefore do not concern themselves with either the amount of the sulphur vapor or the steam that was being given off at the vents.

The first collections were made in August and September of 1936. A temporary shack suitable to house collecting equipment was erected by the Park Service over the wells that had been sunk at the Sulphur Bank area some fifteen years ago. The best collections were made from the manifold connecting these three wells, the side wells being 15 feet deep and the center well some 70 feet deep. The figure on page 2 of Volcano Letter Number 453 for November 1937 illustrates the "vertical wet" method of collection from the wells. In this case the sulphurous fumes are drawn by a hand-vacuum pump through a collecting tube until it is thoroughly flushed with the gas, whereupon the collection is effected simply by shutting off the collecting tube stopcocks, thereby trapping some of the gas inside. By surrounding the tube with an ice pack much of the steam is made to condense and run back into the walls, thus giving a sample which is considerably enriched in the fixed gases. This type of collecting has proved the most satisfactory and dependable of the several methods tried, and a sample has been collected using this method each time the region has been visited by the writer. There were also made field collections at sulphurous fuming spots in the vicinity of the Sulphur Bank. As a "control" we collected a sample using the field collection technic at the steaming bluffs a mile or two from the Sulphur Bank along the

government road, in a region where no sulphur fumes could be detected. It is interesting to note that even in this non-sulphurous area sulphur dioxide to the extent of 1.3 per cent of the dry gas (i.e. air and carbon dioxide) was detected.

Upon returning to Honolulu one of the samples was tested spectrographically using the excellent spectroscopic facilities of the Experiment Station of the Hawaiian Sugar Planters' Association. The only lines or bands detected on the spectrum plates were those of carbon monoxide and hydrogen. The hydrogen lines were undoubtedly due to water vapor (steam) present in the sample, whose molecules are broken down by the high voltages applied to the spectrum tube to hydrogen and oxygen atoms, the hydrogen lines showing clearly. The predominance of carbon monoxide bands cannot be taken as a guarantee of the presence of carbon monoxide in the sample, as indeed later chemical analysis showed. It is well known to spectroscopists that carbon dioxide gas as well as almost any organic material will break down under the extreme electrical conditions existing in a spectrum tube into carbon monoxide, which has a very strong and easily excited spectrum. These spectroscopic analyses therefore served only to show that it would be necessary to subject the samples to chemical analysis. It was at this point in the investigation that the writer called upon Assistant Professor John H. Payne of the University of Hawaii Department of Chemistry for assistance. And the Ballard-Payne collaboration has continued harmoniously since that time.

Chemical analyses were made by Dr. Payne in his university laboratory using the standard Burrell gas analysis equipment and methods. His results showed that sulphur dioxide was the chief constituent (other than steam, of course) of the solfataric gases collected. Other constituents were carbon dioxide and air, the latter being principally nitrogen and oxygen. In none of the dozen-odd samples analysed was any significant trace of combustible gases such as carbon monoxide, hydrogen, hydrocarbons, etc., found. The occurrence of definite amounts of these gases would have established beyond question of doubt the intimately volcanic origin of the Sulphur Bank gases. The amount of air present in the samples varied greatly from sample to sample, depending upon the method of collection as well as the place of collection. A sample analysis of a vertical wet collection is as follows:

Sulphur Dioxide	58.6%
Carbon Dioxide	4.6%
Oxygen	7.0%
Residue	29.8%
Combustibles	None

These are volume percentages at room temperature and pressure in Honolulu; that is, approximately 20° C and 760 mm. All analyses were conducted with saturated water vapor present, so that the percentages are those of the **dry** gases. The residue was tested spectroscopically and found to be nitrogen, as expected. The ratio of nitrogen to oxygen is seen to be approximately 4:1, the normal atmospheric ratio. The air in the samples is hence thought to be of atmospheric origin, having leaked into the porous ground and come up again with the solfataric gases. The analysis of the 1936 gases showed that so much sulphur dioxide was present, as high as 90 per cent in some cases, that any relatively rare constituents might indeed escape detection. Therefore, we decided to make the 1937 collections in such a fashion as to eliminate this large SO_2 content.

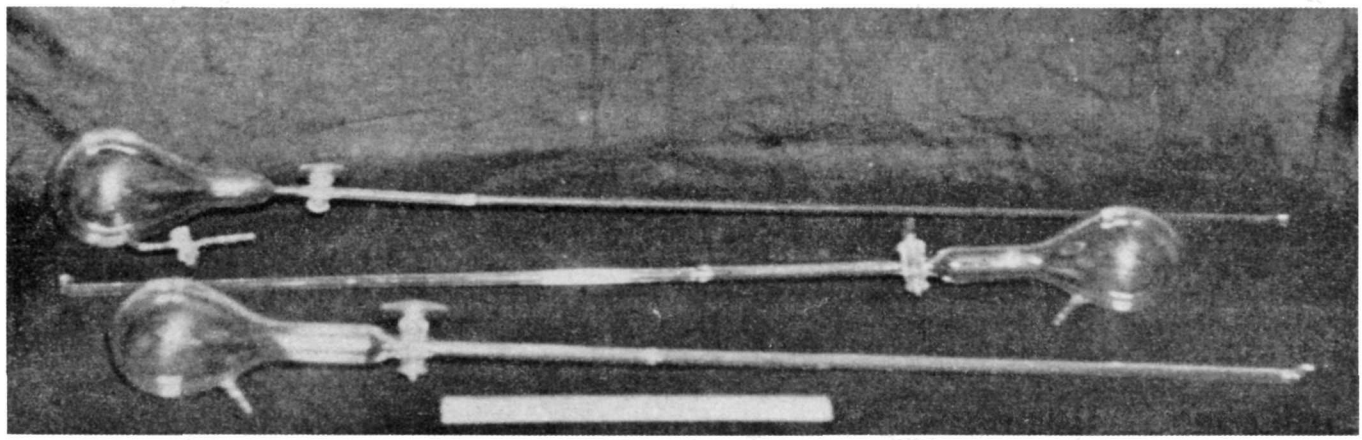


Figure 2. Improved vacuum-type volcanic gas collecting tubes. The upper tube has a capacity of 800 cc. (see Fig. 1). The two lower tubes are of the newer, sturdier construction and have capacities of 500 cc. each. Note the foot ruler which gives the scale of the figure.—University of Hawaii Photo.

Several samples of gas were collected in September 1937. As illustrated in the picture printed on page 3 of Volcano Letter Number 453 for November 1937, the gas was drawn first through a condenser which was packed with ice and salt and hence removed a large portion of the steam, then through two absorption tubes which contained a 50 per cent caustic potash solution. The function of the potassium hydroxide was to absorb the major percentage of the sulphur dioxide and carbon dioxide, allowing the minor constituents of the gas, if any, to be concentrated in the sample. Analysis of these collections showed that the absorption of the sulphur and carbon dioxides was not complete. However, the last traces of these gases were removed in the laboratory and the residue was treated with hot lime and magnesium in order to absorb the nitrogen content known to be present. The gas remaining after this operation was examined spectroscopically as shown in Figure 3 and found to consist chiefly of argon, which is known to be present to the extent of about 1 per cent in the atmosphere. No traces of the other rare gases, helium, neon, krypton and xenon, could be detected. In Figure 3 is shown the complete analytical equipment which consists of the chemical train of seven pipettes which hold the solutions to absorb the various gases, the gases being forced through the solutions by the mercury-filled leveling tube held in Dr. Payne's right hand. The gas is then forced into the long horizontal tube in the center of the picture, where upon heating the calcium-magnesium mixture its nitrogen content is absorbed. Then the gas is forced over to the right into the spectrum tube, whereupon its spectrum can be observed and measured using the wavelength spectrometer shown.

It was decided that collections should be made in which there was definitely no sulphur dioxide present, and in Decem-

ber 1937 Dr. Payne and the writer made a flying trip to Hawaii for this purpose. This time the gas was pumped through **four** absorption tubes containing caustic potash, and this time no sulphur dioxide got through! Analysis of these samples showed nothing present but air.

In conclusion, one can state the results of these preliminary analyses as follows: The Kilauea solfataric gases tested consisted of steam, sulphur vapor, sulphur dioxide, carbon dioxide, and air (that is, nitrogen, oxygen and argon). No new combustible gases and no rare gases other than argon were detected. It is hoped, however, that when larger samples can be collected, larger residues of argon can be obtained which can be studied by more searching **spectrographic** methods which may possibly reveal traces of helium and other rare gases which could not be detected by the visual spectroscopic methods here employed. Referring again to Dr. Allen's analyses, we would judge that his 3.7 per cent of fixed gases was air and carbon dioxide. If the sulphur dioxide content of the gases has not changed since 1922, then Allen's collections must have been very badly contaminated with air. It is interesting to note that A. Brun of Geneva made partial analyses of these gases in 1910 and detected **no** sulphur dioxide. Twelve years later Allen detected a very definite amount of sulphur dioxide, and fifteen years still later sulphur dioxide was found to be by far the predominating gas, save water vapor. We are preparing for publication elsewhere a paper which will describe more fully the technical details of this program of analysis.

As regards future plans for solfataric gas analysis, we hope to establish a fixed technic of sampling—probably the vertical wet collection method, and continue to test the sulphur dioxide vs. carbon dioxide ratio, which ratio has been in the range 10:1 to 15:1 for comparable collections. If collections could be made monthly and continued long enough to include a period of volcanic activity it could readily be established whether this ratio in solfataric gases affords an index of volcanicity. It should also be of interest to make a **complete** analysis comparable to Dr. Allen's, particularly to see whether there has really been a marked increase in the amount of sulphur dioxide present in relation to the steam content, as suggested above.

This program is being supported jointly by the University of Hawaii, the Hawaiian Volcano Research Association, and the Hawaii National Park. Acknowledgment is made of the kind cooperation on the part of the Experiment Station of the Hawaiian Sugar Planters' Association in making available the glass-blowing skill of Mr. Gow and the facilities of the spectroscopic laboratory. Obviously the successful completion of the solfataric gas analyses was made possible only through the active cooperation of Dr. Payne and of his student assistant, Mr. Luther Foster, to whom thanks are due.

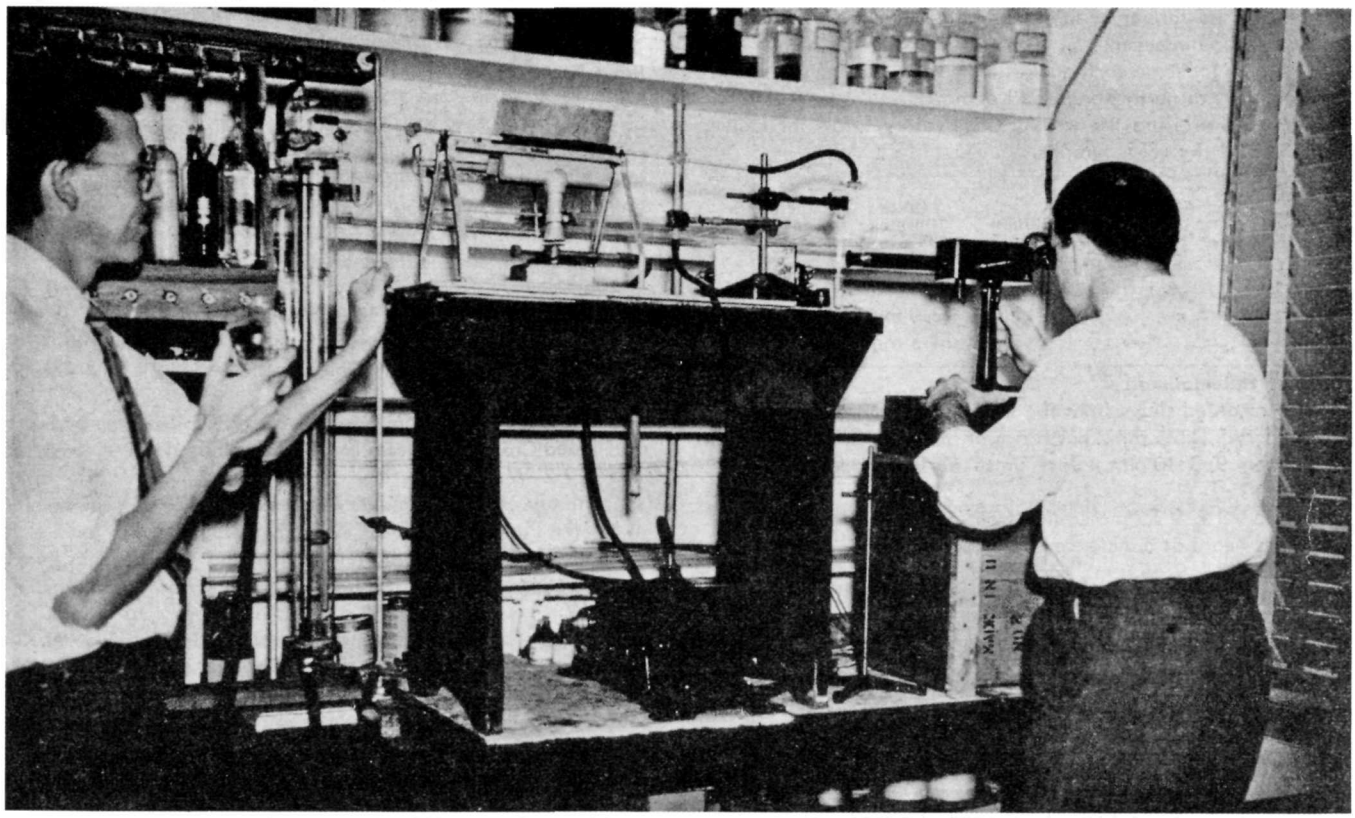


Figure 3. Apparatus set up in the University of Hawaii chemistry laboratory for the chemical and spectroscopic analysis of solfataric gases. Dr. Payne is forcing gas into the nitrogen absorption tube (center of the picture) and Dr. Ballard is measuring the spectrum of the residual gas with a wavelength spectrometer.—University of Hawaii Photo.

Hawaiian Volcano Observatory Report for January 1938

VOLCANOLOGY

The volcanoes of Hawaii have remained quiet. The seismicity which had increased about the solstice, again trebled in value the first three weeks of January. The most notable event of the month was a very strong earthquake January 22 that centered on Maui, doing much damage there. It was very strong on Molokai, Lanai and Kahoolawe, and alarming at Honolulu and in Kohala. It was generally felt in the Hawaiian Islands.

Apparently the middle belt of this earthquake extended from central Maui westward towards Kahoolawe. The serious character of the shock raised questions of earthquake-proof construction in Honolulu. It is of interest that the strong 1868

earthquakes affected the east-west faults of south end of Hawaii island; the 1929 disastrous shocks of north Kona extended to Mauna Kea and affected a northeast-southwest belt there; the 1938 cataclysm affects an east-west belt through Maui; and this series suggests a migration of fault movements on the transverse fractures across the west-northwest line of the Hawaiian Islands. The next important transverse fracture is the one crossing the north side of Molokai, which extended westward would pass Honolulu close to Diamond Head. If this fracture should move, it might be disastrous for Honolulu.

Of the measured earthquakes 22 were from Kilauea, 5 were from Mauna Loa, and 8 were beyond Mauna Loa. Feeble shocks somewhat felt occurred January 3, 14 and 17. A slight shock was felt in Hilo January 9. After the big Maui shock there was marked decline in seismicity. The first week of the month had been notable for some earthquakes indicating distances of origin corresponding to north Kona and Kohala.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Opening	Local Tremors and Quakes
January 9	16.75	2	6.5 mm.	40
" 16	16.00	1	0.5 mm.	49
" 23	17.50	2	3.0 mm.	21
" 30	6.75	0	11.3 mm.	21

Slides at Halemaumau

The recorded slides from the wall of the pit were:

January 5, 1:25 p.m., north rim of pit.

January 9, 3:46 p.m., dust arose during moderate earthquake.

January 14, 9:25 a.m., slide from north wall, noise of falling stones heard at a distance and cloud of dust.

January 21, 9:45 a.m., north rim.

January 22, 10:03 p.m., noise of slides heard accompanying earthquake.

A fresh scar from a slide on the wall was found at Alealea pit of the Chain-of-Craters.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during January in aggregate movement as follows:

Week ending forenoon of:

January 7, 28 locations, 11 opened, 3 closed, opening 6.5 mm.

January 14, 28 locations, 5 opened, 4 closed, opening 0.5 mm.

January 21, 28 locations, 10 opened, 4 closed, opening 3.0 mm.

January 30 (nine days), 28 locations, 13 opened, 2 closed, opening 11.3 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
Jan. 9	29	8	1	1	1	0	16.75
Jan. 16	36	12	1	0	0	0	16.00
Jan. 23	40	5	1	0	1	0	17.50
Jan. 30	15	6	0	0	0	1	6.75

* For local seismicity definition see Volcano Letter 371.
† Including teleseisms or earthquakes over 5000 km from Kilauea.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

January 3, 11:36 am, very feeble, 40 miles deep under Hualalai. 20° 42.8′ N; 155° 48.0′ W.

January 3, 12:33 pm, feeble, located 47 miles deep under Mauna Loa NE rift zone. 19° 30.7′ N; 155° 25.7′ W.

January 3, 6:02 pm, very feeble, 40 miles deep under summit crater area of Mauna Loa. 19° 26.2′ N; 155° 35.8′ W.

January 3, 8:51 pm, very feeble, 1.0 mile deep, 0.5 mile SE of Pit seismograph. 19° 24.0′ N; 155° 16.7′ W.

January 5, 2:31 am, slight, 5.0 miles deep in Hilina Kapukano Fault system, 3.0 miles N of Apua Point. 19° 18.1′ N; 155° 11.6′ W.

January 9, 2:49 am, very feeble, of Kilauea origin.

January 9, 3:47 pm, moderate, 3.8 miles deep near SW rim of Kilauea Iki. 19° 24.8′ N; 155° 15.2′ W. Dismantled Pit and Observatory seismographs. Reported felt by many at CCC Camp, SE rim of Kilauea Crater and by several around the National Park Headquarters area.

January 9, 4:40 pm, very feeble, 3.4 miles deep and 3.5 miles NW of H.V.O. 19° 27.9′ N; 155° 18.0′ W.

January 10, 4:55 pm, very feeble, 1.8 miles deep and 2.8 miles SE of the Volcano Observatory. 19° 24.5′ N; 155° 13.5′ W.

January 10, 6:04 pm, very feeble, 1.3 miles deep NW rim of Kilauea Crater, 0.8 miles N NE of Uwekahuna. 19° 26.0′ N; 155° 17.2′ W.

January 10, 6:11 pm, very feeble, 4.2 miles deep in vicinity of Kipuka Puaulu. 19° 27.0′ N; 155° 18.3′ W.

January 10, 10:24 pm, very feeble, 0.8 mile deep in Byron Ledge Area, E rim of Kilauea Crater. 19° 24.6′ N; 155° 15.3′ W.

January 11, 11:37 pm, very feeble, 1.8 miles deep in Kilauea Crater, 1.0 mile SW of the Observatory. 19° 24.6′ N; 155° 16.7′ W.

January 12, 12:21 am, very feeble, 1.6 miles deep under Byron Ledge, E rim of Kilauea Crater. 19° 24.8′ N; 155° 15.6′ W.

January 13, 2:36 pm, very feeble, of shallow origin, SE rim of Kilauea Crater. 19° 23.9′ N; 155° 16.2′ W.

January 13, 3:39 pm, very feeble, of shallow origin in area immediately SE of Keanakakoi. 19° 24.0′ N; 155° 15.6′ W.

January 13, 3:29 pm, very feeble, of shallow origin, SE rim of Kilauea Crater. 19° 24.4′ N; 155° 15.6′ W.

January 13, 5:45 pm, very feeble, 0.4 mile E of Pit seismograph, 0.7 mile deep. 19° 24.3′ N; 155° 16.6′ W. Dismantled Pit seismograph.

January 14, 6:19 am, very feeble, 1.5 miles deep near SW rim of Kilauea Iki. 19° 24.8′ N; 155° 15.2′ W.

January 14, 5:40 pm, feeble, 8.0 miles deep, along seacoast 3.5 miles S of Hilina Pali. 19° 15.0′ N; 155° 17.0′ W. Reported felt in city of Hilo.

January 15, 5:33 pm, very feeble, probably originated in Mauna Loa NE rift 4.0 miles NE of Puu Ulaula.

January 17, 11:39 am, feeble, 0.8 mile deep E portion of Crater, 1.0 mile E of Halemaumau. 19° 24.6′ N; 155° 15.9′ W. Reported felt on NE rim of Kilauea Crater.

January 17, 4:27 pm, very feeble, 1.0 mile deep, in Kilauea Crater near W end of Kilauea Iki. 19° 24.9′ N; 155° 15.5′ W.

January 22, 4:36 am, very feeble, located in Mauna Loa NE rift in vicinity of Puu Ulaula. 19° 32.0′ N; 155° 26.6′ W.

January 22, 10:03 pm, moderate to strong near shock, probably centered about 60 miles below the ocean surface near a point 25 miles N of Pauwala Point, Maui. 21° 12′ N; 156°

06′ W. This shock was felt throughout the Hawaiian Islands and recorded on seismographs throughout the world. It was felt most strongly on the Island of Maui and by nearly everyone. Damage to property was estimated to have been about $150,000, and included disruption of water tanks and dams, interruption of telephone service, cracked walls and roads, slides along roads and upsetting of objects in buildings. The road to Hana, Maui, was closed by slides from steep adjoining slopes. Greatest damage was in vicinity of Wailuku and Kahului. On Oahu the intensity of the shock was considerably less than on Maui but is thought to have been greater than on Hawaii. In Honolulu many people were alarmed and theatre patrons rushed hurriedly out of the buildings. Light flashes visible for 20 miles were reported from Hilo; radio transmission interference was reported on the shorter wave lengths. In the Volcano district, Hawaii, long swinging motions were described causing loose objects to move and tall slender objects such as floor lamps to sway. Pheasants squawked, dogs barked and most sleepers were awakened. Buildings creaked and doors swung on their hinges. A report from Hilo indicated that ceiling lights swung in an E NE-W SW direction. All seismographs in operation in the Hawaiian Islands were dismantled with the exception of the strong motion instrument at the Hawaiian Volcano Observatory. This instrument made a complete record. Felt portion of quake was thought to have lasted, one and one-half to two minutes.

January 26, 9:01 pm, very feeble, located 1.1 miles deep, in Kilauea Crater, 1.0 mile NE of Pit seismograph. 19° 24.9′ N; 155° 16.2′ W.

January 27, 5:22 am, very feeble, 2.0 miles deep, 1.3 miles SW of the Observatory in Kilauea Crater. 19° 25.2′ N; 155° 16.4′ W.

January 28, 2:23 am, very feeble, 2.5 miles deep and 0.7 mile N of Uwekahuna NW rim of Kilauea Crater. 19° 26.0′ N; 155° 17.5′ W.

January 29, 6:02 am, very feeble, probably of shallow origin near center of Kilauea Crater.

Microseismic motion of the ground at the Observatory was strong throughout the month.

27 minutes of continuous tremor began to register at the Observatory at 3:35 am, January 19.

An unidentified portion of a teleseism began recording at Kilauea at 12h 58m 25s, H.S.T., January 24.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilt toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 30, was 6.3″ S and 0.48″ W.

Week Ending	Observatory	Halemaumau West Station
January 9	0.75″ N 53° W	5.07″ N 48° W
January 16	0.86″ S 5° E	6.26″ S 65° W
January 23	0.51″ S 4° W	8.70″ S 44° W
January 30	1.58″ S 30° W	4.38″ N 19° E

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
January 9	2.59″ N 87° W	1.84″ From
January 16	6.41″ N 80° W	1.28″ From
January 23	3.73″ N 57° W	3.29″ From
January 30	16.20″ S 18° W	7.45″ From

H. H. W.

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, January 11, indicated closing of the Halemaumau value and slight opening of the Kilauea Crater value compared with similar measurements made December 22. The Halemaumau measurement from the SE Pit B. M. to NW Pit B. M. showed a decrease of 1.51″ and the Kilauea Crater value from the SE rim to Uwekahuna showed an increase of 0.67″.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.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THE VOLCANO LETTER

No. 456 monthly Department of the Interior National Park Service February 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

PUBLICATIONS RELATING TO HAWAIIAN VOLCANOES

T. A. Jaggar

As supplement to an address delivered by the writer at the Annual Meeting March 31, 1932, of the Hawaiian Volcano Research Association in Honolulu, there was published in Volcano Letter No. 384, May 5, 1932, a list of publications.

Since 1932 numerous articles, popular and scientific, have accumulated as the output of workers at the Hawaiian Volcano Observatory. Many of these are on hand as reprints, one of which will be sent while they last to anyone interested who addresses The Hawaiian Volcano Observatory, Hawaii National Park.

Publications of the Observatory

The suspension of the Volcano Letter. Jaggar, Volcano Letter No. 385, May 12, 1932.

Eruption in Lake Rotorua, New Zealand. Jaggar, Volcano Letter 386, May 19, 1932.

Ash Eruptions in the Andes. Jaggar, Volcano Letter 386, May 19, 1932.

Eruption of Merapi in Java. Jaggar, Volcano Letter 387, May 26, 1932.

A Note on Kamtchatkan Volcanoes. Jones, Volcano Letter 390, August 1932.

Results of One Year's Crack Measurements. Wingate, Volcano Letter 393, November 1932.

Lassen Report No. 32. Finch, Volcano Letter 395, January 1933.

Earthquake-Tidal Wave March 2, 1933. Jaggar, Volcano Letter 397, March 1933.

Puna Triangulation. Wingate, Volcano Letter 400, June 1933.

Lassen Report No. 33. Finch Volcano Letter 401, July, 1933.

What May be Learned From Tilt. Wingate, Volcano Letter 432, February 1936.

How to Make a Simple Seismograph. Finch, Volcano Letter 433, March 1936.

A Trip Up the 1935 Mauna Loa Flow. Waesche, Volcano Letter 433, March 1936.

Lassen Volcano, California. Farmer, Volcano Letter 433, March 1936.

Earthquakes in the U. S. de Vis-Norton, Volcano Letter 434, April 1936.

Volcanic Area of Bufumbira, Uganda. Palmer, Volcano Letter 434, April 1936.

The Influence of Volcanic Research in Hawaii. Jaggar, Volcano Letter 434, April 1936.

University of Hawaii Summer Session. Jaggar, Volcano Letter 434, April 1936.

Earthquakes at Lassen, May 1936. Swartzlow, Volcano Letter 435, May 1936.

Methods of the Hawaiian Volcano Observatory. Jaggar, Volcano Letter 435, May 1936.

Japanese Volcanology and Seismological Research. Waesche, Volcano Letter 436, June 1936.

Adventures and Methods in Studying West Indian Volcanoes. Jaggar, Volcano Letter 437, July 1936.

Des Moines Seismological Station. de Vis-Norton, Volcano Letter 437, July 1936.

More About Volcano Observatory Methods. Jaggar, Volcano Letter 437, July 1936.

Science in the National Parks. Jaggar, Volcano Letter 438, August 1936.

Summit Outbreak of Mauna Loa, December 1933. Volcano Letter 439, September 1936.

The Coming Lava Flow, the Most Serious Responsibility in Our History. Jaggar, Volcano Letter 440, October 1936.

Eruption of Kilauea Volcano September 1934. Jaggar, Volcano Letter 441, November 1936.

The Bombing of Mauna Loa 1935. Jaggar, Volcano Letter 442, December 1936.

Protection of Hilo From Coming Lava Flows. Jaggar, Volcano Letter 443, January 1937.

Earthquakes. Waesche, Volcano Letter 444, February 1937.

Annual Report of Secretary, Hawaiian Volcano Research Association. de Vis-Norton, Volcano Letter 445, March 1937.

Mauna Loa. Jaggar, Volcano Letter 445, March 1937.

Crack Measurement and Tilt at the Hawaiian Volcano Observatory. Waesche, Volcano Letter 446, April 1937.

Trends in the Philosophy of Science. Jaggar, Volcano Letter 447, May 1937.

Eruptions at Rabaul, New Guinea. Jaggar, Volcano Letter 448, June 1937.

Work of F. A. Perret on Montserrat. Jaggar, Volcano Letter 449, July 1937.

Kilauea Lava Flow of 1823. Waesche, Volcano Letter 450, August 1937.

Volcanoes in the National Parks. Waesche, Volcano Letter 450, August 1937.

Crater Lake National Park. Waesche and Jaggar, Volcano Letter 451, September 1937.

Triangulation and Level Changes at Kilauea. Waesche, Volcano Letter 452, October 1937.

Kilauea Volcano Laboratory of the University of Hawaii 1937. Jaggar, Volcano Letter 453, November 1937.

Work of the Observatory 1937. Jaggar, Volcano Letter 454, December 1937.

The Volcanic Gas Problem. Ballard, Volcano Letter 455, January 1938.

Publications of the Observatory. Jaggar, Volcano Letter 456, February 1938.

Publications Outside the Observatory

Ballard, S. S., and Gow, P. L.

An Improved Vacuum-Type Tube for Collecting Volcanic Gas. Proc. Haw'n Acad. Sci., Spec. Pub. No. 31, B. P. Bishop Mus. 1937. 1 page.

Finch, R. H.

Slump Scarps. Jour. Geol. XLI, No. 6, Aug.-Sept. 1933, pp. 647-649.

Burnt Lava-flow in Northern California. Zeitschrift fur Vulkanologie 1933, XV, pp. 180-183, 2 plates.

Block Lava. Jour. Geol., XLI, No. 7, Oct.-Nov. 1933, pp. 769-770.

Shishaldin Volcano. Proc. Fifth Pac. Sci. Cong., Vancouver 1933, Univ. Toronto Press 1934, A7. 21, pp. 2369-2376.

On the Mechanics of Nuees Ardentes. Jour. Geol. XLIII, No. 5, July-Aug. 1935, pp. 545-550.

Akutan Volcano. Zeitschrift fur Vulkanologie, 1935, XVI, pp. 155-160, 4 plates.

A Tree-ring Calendar for Dating Volcanic Events at Cinder Cone, Lassen National Park, California. Amer. Jour. Sci. XXXIII, Feb. 1937, pp. 140-146.

Jaggar, T. A.

History of Mauna Loa. Paradise of the Pacific, Honolulu, Vol. 46, No. 2, Feb. 1934, p. 5.

Hot Places at Kilauea. Paradise of the Pacific, Vol. 46, No. 7, 3 pages.

Fossil Human Footprints in the Kau Desert. Paradise of the Pacific, May 1932, Vol. 46, No. 5, 5 pages.

Shipboard Plane-table and Azimuth Camera: An Experiment in Navigation. Proc. Haw'n Acad. Sci., B. P. Bishop Mus. Spec. Pub. 26, 1935, pp. 13-14.

Living on a Volcano (Tin Can Island). Nat. Geog. Mag. July 1935, pp. 91-106.

Kilauea's Lost Lava Flow. Paradise of the Pacific, Vol. 46, No. 6.

Pele's Secret. Paradise of the Pacific, Vol. 46, No. 8.

The Breathing of Pele. Paradise of the Pacific, Vol. 46, No. 9, Sept. 1934.

Eruption of Halemaumau 1934 (broadcast from crater). Paradise of the Pacific, Vol. 46, No. 10, Oct. 1934.

Elevation Changes, Horizontal Shift and Tilt at Kilauea Volcano. Proc. Geol. Soc. Wash. 494th meeting, Journ. Wash. Acad. Sci., Vol. 23, No. 2, Feb. 15, 1933, pp. 113-114.

The Coming Lava Flow. Reprinted from Honolulu Advertiser, March 27, 1934.

Protection of Hilo from Coming Lava Flows. Reprinted from Hilo Tribune-Herald Jan. 20, 1937, 8 pp. (Also Volcano Letter No. 443, January 1937).

The Bombing of Mauna Loa 1935. The Military Engineer, July-Aug. 1936, 8 pp. (also Volcano Letter No. 442, December 1936).

Trends in the Philosophy of Science. Proc. Haw'n Acad. Sci. 1937, B. P. Bishop Mus. Spec. Pub. 31, 1 page. (Also in full Volcano Letter 447, May 1937.)

New Seismographs for Mauna Loa. Proc. Haw'n Acad. Sci. 1937, B. P. Bishop Mus. Spec. Pub. 31.

Memorial of Bundjiro Koto. Proc. Geol. Soc. Amer. 1935, pp. 263-272.

Methods of the Hawaiian Volcano Observatory. Proc. Haw'n Acad. Sci. 1936, B. P. Bishop Mus. Spec. Pub. No. 30, 1937, p. 9. (See also Volcano Letter Nos. 435 and 437, May and July, 1936.)

Jones, A. E.

Earthquakes Associated with the 1934 Eruption of Kilauea, Hawaii. Jour. Wash. Acad. Sci. Vol. 25, No. 10. Oct. 15, 1935, pp. 429-435.

Earthquakes Associated with the 1933 Eruption of Mauna Loa, Hawaii. Jour. Wash. Acad. Sci., Vol. 24, No. 10, Oct. 15, 1934, pp. 413-418.

Hawaiian Travel Times. Bull. Seis. Soc. Amer., Vol. 25, No. 1, January 1935, pp. 33-61.

A Seismologic Study of the Kilauea Eruption 1931-1932. Univ. Hawaii Research Pub. No. 9, 1935, 60 pages.

Ground Surface Displacements and Earthquakes at Kilauea, Hawaii, first half-year 1935. Bull. Seis. Soc. Amer., Vol. 27, No. 2, 1937, pp. 112-138. (Also B. P. Bishop Mus. Spec. Pub. No. 30, pp. 9-10, 1937.)

The Formation of Basaltic Lava Flows. Jour. Geol. XLV, No. 8, Nov.-Dec. 1937, pp. 872-880.

de Vis-Norton, L. W.

Una Nueva Aplicacion Cientifica. (Bombing Mauna Loa Lava Flow 1935.) Revista Geografica Americana August 1936, Ano. III, Vol. VI, Num. 35, Buenos Aires, Argentina.

La Science sauve une Ville. La Revue Colombienne, Quebec, Beauceville, May 1937, p. 6.

Palmer, H. S., and Powers, H. A.

Pits in Coastal Pahoehoe Lavas Controlled by Gas Bubbles. Jour. Geol. XLIII, No. 6, Aug.-Sept. 1935, pp. 639-643.

Powers, Howard A.

The Lavas of the Modoc Lava-bed Quadrangle, California. California American Mineralogist, Vol. 17, July 1932, pp. 253-294.

Stone, J. B., and Earl Ingerson

Some Volcanoes of Southern Chile (with petrography). Amer. Jour. Sci. XXVIII, Oct. 1934, pp. 269-287.

Stone, J. B.

The Volcanoes of Southern Chile. Zeitschr. fur Vulk. 1935, XVI, pp. 81-97, 8 plates.

Wentworth, C. K., and Howel Williams

Classification and Terminology of the Pyroclastic Rocks. Bull. Nat. Research Council U. S., No. 89, 1932.

Williams, H.

Geology of the Lassen Volcanic National Park, California. Geol. Bull. Univ. Cal., Vol. 21, No. 8, 1932, pp. 195-385.

Wilson, R. M.

Ground Surface Movements at Kilauea Volcano, Hawaii. Univ. Hawaii Research Pub. No. 10, 1935. 56 pages.

Hawaiian Volcano Observatory Report for February 1938

VOLCANOLOGY

Much study was given the question of the meaning of the strong earthquake that affected Honolulu January 22. Parallels exist in the history of the Observatory, and several earthquakes in the past quarter century centered under Maui.

Measurements about Halemaumau pit showed increase of motion throughout February. Alternation between motions on the Hualalai-Mauna Loa rifts and much higher frequency on the Kilauea fractures continued. This alternation may imply lowering of lava under Hualalai-Mauna Loa after the 1929 and 1935 crises, and return of lava under Kilauea especially along the eastern rift belt, for an eruption that is near at hand.

The following are the weekly Observatory totals for Halemaumau pit of Kilauea Crater and the seismographs:

Week Ending	Seismicity	Slides	Crack Opening	Local Tremors and Quakes
February 6.....	11.75	0	2.5 mm.	37
" 13.....	10.00	1	6.0 mm.	36
" 20.....	23.25	5	10.0 mm.	55
" 27.....	12.50	9	9.5 mm.	38

Notable shocks were a moderate one on northeast rift of Mauna Loa February 17, and one the next day at Kilauea. There were two feeble Kilauea shocks February 20 and 21. A slight shock of Mauna Loa origin dismantled the Kona seismograph February 25. These illustrate the alternation referred to. Of all measured shocks, twenty-three were from Kilauea, two from Mauna Loa, two from Hualalai, and one from Mauna Kea.

Sequence of Events by Weeks

The first week produced nothing of importance except two distant earthquakes. The second week Kilauea remained quiet. The third week showed notable increase of tremors, number and strength of earthquakes, and some slides, with decrease of tilt at the Kilauea rim and increase at Halemaumau. Seismicity was cut in half the fourth week, though slides continued: tilt at Halemaumau changed from inward to outward by 18 seconds, and at the Observatory tripled in amount westerly. The opening of cracks at Halemaumau rim increased during the month.

Slides at Halemaumau

The recorded slides from the wall of Halemaumau were:

February 8, 9:30 a.m., fresh scars and dribbling rocks SE.
February 8, 4:22 p.m., slide north wall.
February 9, 9:11 a.m., slides at north cliff.
February 14, 9:42 a.m., dribbling rocks north.
February 20, 11:35 a.m., dust from slide N.
February 20, 12:07 p.m., slide NE.
February 21, 11:10 a.m., slide NE.
February 21, 11:30 a.m., dust rising NE.
February 21, 12:05 p.m., dust rising NE.
February 25, 9:53 a.m., slide north.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations around Halemaumau resulted during February in aggregate movement as follows:

Week ending forenoon of:

February 4 (5 days only), 28 locations, 7 opened, 2 closed, opening 2.5 mm.

February 11, 28 locations, 9 opened, 1 closed, opening 6.0 mm.

February 18, 28 locations, 11 opened, none closed, opening 10.0 mm.

February 25, 28 locations, 14 opened, 1 closed, opening 9.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
February 6..	27	10	0	0	2	11.75
" 13..	32	4	0	0	0	10.0
" 20..	39	13	1	2	0	23.25
" 27..	28	9	1	0	0	12.50

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

† Including teleseisms or earthquakes over 5000 km from Kilauea.
* For local seismicity definition see Volcano Letter 371.

January 31, 3:57 pm, very feeble, located approximately 5.0 miles ENE summit of Hualalai at a depth of 29.0 miles. 19° 43.3′ N; 155° 47.5′ W.

February 1, 8:43 am, very feeble, probably located in Kilauea SW rift zone.

February 1, 5:44 pm, very feeble, probably originated in Chain of Craters to SE of Kilauea Crater.

February 3, 12:23 am, very feeble, 0.6 mile deep in Kilauea Crater 0.6 mile NE of Halemaumau. 19° 24.7′ N; 155° 16.4′ W.

February 3, 7:09 am, very feeble, probably originated in N portion of Kilauea Crater.

February 6, 8:05 pm, very feeble, 25.0 miles deep, 7.0 miles NW of Humuula. 19° 45.5′ N; 155° 32.8′ W.

February 6, 10:14 pm, very feeble, 11.0 miles deep, 2.0 miles SE of Kilauea Crater. 19° 23.5′ N; 155° 15.5′ W.

February 7, 11:10 pm, very feeble, 1.1 miles deep near center of Kilauea Crater. 19° 25.1′ N; 155° 16.6′ W.

February 8, 2:07 am, very feeble, 35.0 miles deep and 3.5 miles NW of summit of Hualalai. 19° 44.2′ N; 155° 53.3′ W.

February 8, 8:20 pm, very feeble, 1.2 miles deep, SE rim of Kilauea Crater, 1.2 miles E of Halemaumau. 19° 24.5′ N; 155° 15.9′ W. Report felt at CCC Camp (old).

February 9, 1:07 pm, very feeble, 1.5 miles deep SE portion Kilauea Crater. 19° 24.2′ N; 155° 16.2′ W.

February 14, 10:15 pm, very feeble, 3.3 miles deep 0.3 mile N of Puhimau Crater. 19° 24.1′ N; 155° 15.0′ W.

February 15, 10:13 am, very feeble, probably originated in Kilauea Crater near NE rim.

February 16, 3:54 pm, very feeble, 2.0 mile deep in SW portion of Kilauea Crater near SW edge of Halemaumau. 19° 24.6′ N; 155° 17.3′ W.

February 17, 2:18 am, moderate, 8.0 miles deep in NE rift zone, Mauna Loa near Puu Ulaula. 19° 33.0′ N; 155° 27.0′ W. Dismantled seismographs at Observatory and Pit, reported felt strongly in Kona and in Hawaii National Park. Felt slightly by many in Hilo.

February 17, 2:38 am, very feeble, 7.0 miles deep, Mauna Loa NE rift. 19° 32.0′ N; 155° 26.6′ W.

February 17, 4:05 am, very feeble, 1.3 miles deep in Kilauea Crater, near N rim of Halemaumau. 19° 24.9′ N; 155° 17.1′ W.

February 17, 8:41 am, very feeble, 2.0 miles deep near Keauhou Ranch House, 1.3 miles N by E of Uwekahuna. 19° 26.5′ N; 155° 17.1′ W.

February 18, 11:22 am, very feeble, of shallow origin in area between Keanakakoi and Lua Manu Crater. 19° 24.2′ N; 155° 15.7′ W.

February 18, 1:18 pm, very feeble, 2.0 miles deep near center Kilauea Crater. 19° 25.1′ N; 155° 16.4′ W.

February 18, 10:53 pm, moderate, 0.5 mile deep in E portion of Kilauea Crater. 19° 24.9′ N; 155° 15.9′ W. Felt only locally in Hawaii National Park near Kilauea Crater.

February 19, 3:15 am, very feeble, probably originated in NE portion of Kilauea Crater.

February 20, 1:37 am, feeble, 3.5 miles deep under SE portion of Kilauea Crater. 19° 24.4′ N; 155° 16.1′ W.

February 21, 3:45 am, feeble, 2.0 miles deep SE portion of Kilauea Crater. 19° 24.1′ N; 155° 16.0′ W.

February 23, 1:23 pm, very feeble, probably originated NE portion of Kilauea Crater.

February 24, 2:19 pm, very feeble, probably originated near center of Kilauea Crater.

February 25, 6:00 am, very feeble, "P" lost in hour mark on Observatory record. No definite location but apparently of Hualalai origin. Reported felt in Kona.

February 26, 9:16 am, very feeble, of Kilauea origin.

February 26, 4:35 pm, very feeble, of Kilauea origin.

At 8h 46m 07s am, HST February 1, the "P" waves of a teleseism began to record at the Observatory. Distance from Kilauea 5,150 miles. Reported location was west of Aru Island in Banda Sea region of the Malay Archipelago, 4.0° S; 132.50 E. Another teleseism began to register at 4h 5m 27s pm HST, February 4. Distance undetermined.

Microseismic motion of the ground at the Observatory was moderate February 2, 3, 12, 13, 14, and February 21; strong the remainder of the month.

Tilting of the ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, and at Halemaumau the algebraic sum of radial tilt toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending February 27, was 3.76" S and 3.91" W.

Week Ending	Observatory	Halemaumau West Station
February 6	2.06" S 54° W	1.82" N 2° W
February 13	1.83" S 44° W	4.38" N 10° E
February 20	0.85" S 49° W	5.00" S 65° W
February 27	2.68" S 53° W	14.75" N 61° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
February 6	5.90" N 54° W	4.02" Toward
February 13	3.95" S 70° W	2.17" Toward
February 20	6.42" N 51° W	8.19" Toward
February 27	2.14" N 72° W	10.28" From

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory February 21, indicated no change in the Halemaumau value and slight closing of the Crater value compared with similar measurements of January 11. The Halemaumau measurement from the SE Pit B. M. to NW Pit B. M., showed opening of 1.42", January 11 to February 3 but closed 1.42" between February 3 and February 21 for a total no change. The Crater measurement from the SE rim to Uwekahuna showed a closing of 0.17" January 11 to February 3 and closing of 0.67" February 3 to February 21. Total closing 0.84".

H.H.W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 457 monthly Department of the Interior National Park Service March 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Slides at Waikane bridge, Hana belt road.

THE MAUI EARTHQUAKE OF JANUARY 22, 1938

On the evening of January 22, 1938 at about 10:03 a moderate to strong earthquake registered on all the seismographs operated by the Hawaiian Volcano Observatory. The Hilo and Kona seismographs apparently dismantled at the arrival of the first impulse of the secondary waves. The instrument at the SE rim of Halemaumau as well as that at Uwekahuna NW rim of Kilauea Crater were dismantled shortly after the preliminary waves had started to register. At the Observatory the Bosch-Omori seismograph was dismantled within a few seconds after the beginning of the preliminary wave registration as was the vertical motion instrument. The only instrument to receive a complete record of the quake was the low magnification instrument at the Volcano Observatory, NE rim of Kilauea Crater. The latter was specifically designed and built in the Observatory shops to register local shocks of strong intensities. It magnifies ground movement about eleven times.

The earthquake was classified as a near shock which includes those from 100 to 750 miles distant. It was felt throughout the Hawaiian archipelago and registered on seismographs as far away as Fordham University in New York City. In this respect it differed from the usual quakes so common in the Territory, and particularly on the Island of Hawaii, which sel-

dom are felt more than a few miles from their point of origin and practically never register off the island on which they occur. Inasmuch as there are at least three volcanoes on the Island of Hawaii which are considered active, earthquakes there of varying intensities and of almost daily occurrence, are expected and do occur. On the other islands, earthquakes though comparatively rare, are not uncommon.

The January 22 earthquake was an exception: it definitely was not located on the Island of Hawaii. It was felt about equally on Oahu and Hawaii. The Island of Kauai was apparently least disturbed, although it was reported as being the strongest ever felt there by older residents. All indications, both instrumental and by reports, were that the center of the disturbance was in the vicinity of the Island of Maui. The exact center was difficult to locate because of the disruption of seismographs and somewhat misleading observations received from persons near the epicenter. The final location, as determined by the Observatory, by the Coast and Geodetic Survey and by the Jesuit Seismological Association is in very close agreement. Taking an average of these determinations, the epicenter would be located in the ocean about eighteen miles north of Pauwala Point on the Island of Maui.

First reactions of some of the Oahu residents were interesting. Felt quakes in Honolulu are comparatively rare and the people of that city are inclined to overlook the fact that they most certainly live in a region where earthquakes are assured, and that strong ones may occur at any time. Consequently when this shock was felt no one suspected that such a thing as an earthquake could possibly be centered nearer Honolulu than to Kilauea Volcano on the Island of Hawaii. Consequently, the radio stations and telephone communications between the Islands were busy with calls from Honolulu trying to find out whether the "Big Island" had been completely blown off the map or had sunk into the sea. Their first thought was that if the shock was that strong in Honolulu, it must be terrific on Hawaii. The Observatory was swamped with calls from all directions. It is suspected that there was a tinge of disappointment from those elsewhere who discovered that on this island the earthquake not only had been of relatively moderate intensity but that most of the people seemed actually to have enjoyed it.

REPORTS FROM THE SEVERAL ISLANDS

Kauai:

Reported as severest quake in memory of older residents. Felt as two separate shocks resulting in some minor damage to some household articles.

Oahu:

Because of the early hour at which it occurred most of the people apparently felt the earthquake. A great deal of excitement resulted. Hotels and theaters were filled with people; at the Alexander Young Hotel elevators stuck, dancers on the roof were forced to scurry down the stairs, orchestras continued to play while entertainers went on with their performances. There was a rush from all the downtown theaters. The Waikiki Theater was completely emptied in a few minutes. The excitement of persons downtown was shared by those in private homes who rushed from their houses to see what had occurred. Residents of Manoa Valley reported three separate shocks, at 10:03, five minutes later, and a third shock at 10:23. A check by the County police division showed that no bridges nor roads had been damaged, no highways blocked, though apparently 40 rocks rolled on the Kamehameha highway at Kipapa Gulch. The largest was about two feet in diameter. One automobile was damaged when it struck a rock in the road, but there were no injuries. At the Oahu Prison a four pound strip of ceiling fell in one cell. Preparations were made for the removal of prisoners if the tremor continued. However, no damage apparently was done to either telephone or power lines. Damage on Oahu seemingly was limited to breakage of crockery and glassware. Hanging objects swung from the ceilings and some small articles were knocked from shelves.

Molokai:

The quake here opened cracks between two and three inches in width and twenty five to one hundred feet in length on the east Molokai road at Mapulehu. From Ohia to Mapulehu stone walls collapsed, otherwise damage was confined to crockery and other household possessions.

Lanai:

A radiogram received at the Observatory from the manager of the Pineapple Company on Lanai, stated that "the quake did no damage to the reservoir or water development project. There was a two inch crack in the breakwater twenty feet leeward of the light, accompanied by slight settling. The pipe lines of the Maunalei Gulch above and below the pumphouse were broken in several places by falling rocks. There was no damage to pipes running over palis to the reservoir. Slight damage occurred to plumbing in houses. In stores some supplies were thrown on the floor. A crack 10 feet wide and 15 feet deep was reported in the Maunalei region."

Maui:

The north coast of East Maui was probably the hardest hit of any portion of the Territory. There the earthquake took no toll of life, and resulted in few injuries, but inflicted considerable property damage throughout Maui's most isolated communities. Two large oil tanks owned by the Standard Oil Company were lost. Both tanks, containing diesel oil and kerosene respectively, were shattered. Thirty thousand gallons of the oil flowed into the nearby sea from the damaged tanks. The little town of Hana, Maui, was completely blocked by road slides between Paliku and Hana. The worst landslide was at Waikane. The Kaupo-Kieahu trail was blocked by bad landslides. The Keanae stone crusher was completely covered by a landslide. The powerhouse of the Kaeleku Sugar Company was thrown out of commission. Immediately following the quake Hana was without lights for fifteen minutes. Ranches in southern Maui suffered heavy damage as water tanks and stone walls were razed by the quake. Mr. H. A. Baldwin of the Maui Agricultural Company, Ltd. reports as follows:

"Your letter of the 4th inst. to hand some time ago and I apologize for not replying sooner; however, I have not yet been able to learn definitely just what happened on Kahoolawe during the earthquake. I hope to get this information within a few days and will write you again. I know there was considerable of a shake up as a watertank on the northern coast of the Island, which was set on a comparatively solid foundation, was turned over. I think part of the foundation was built of loose rocks.

"You say you wish to know if Pauwela or Kahoolawe got the severest shock. I think the idea that Pauwela experienced more of a shock than other portions of Maui is erroneous. Certainly the greatest damage in the way of slides on gulch sides and road cuts was east of Pauwela. The country from Kailua on to Nahiku received what was apparently a very much heavier shock than at any time during my life, which goes back 67 years. The road has not yet been fully opened up and there were numerous slides blocking up our ditches for considerable distances up the gulches."

Concrete buildings in Lahaina were cracked. A landslide broke the intake pipe near the Lahaina River and flumes were used Sunday to carry water from the stream to the old intake. Storage tanks between Wailuku and Kahului were damaged. Kahului was without water for a brief period. At Wailuku the Hollister drugstore, the Kress store, and the Courthouse showed

some damage to the interiors of the three buildings. Walls of the Kahului Theater were cracked by the quake, while the fire station tower was moved one-half inch. According to Mr. Edgecomb of the US Lighthouse Service mercury was thrown from the floats of the revolving mechanism of some of the big lighthouses on Maui. District Ranger Peck of the Hawaii National Park stationed at Haleakala on Maui reported as follows:

"The earthquake that occurred on the evening of the 22nd jarred many tons of rocks into the road, several of them very large, and a number of small cracks appeared in the pavement. Fortunately the road was not completely blocked and by noon today we had it cleared enough to make it safely passable.

"I think we can clear the road in a reasonable length of time with the one man I have for help, provided mother earth does not soon decide to go into another dance.

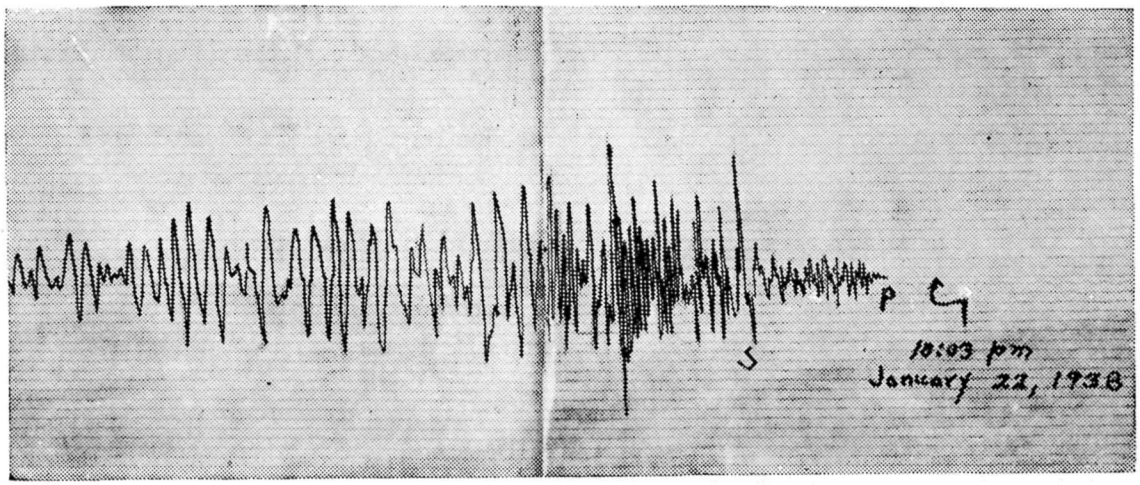
"I have not yet had time to inspect the Halemauu trail, which I fear may be in bad shape. I will inspect it very soon and report.

"No apparent damage was done to any of the buildings. Numerous cracks appeared in the road below the park area, some of them one and one half inches wide."

Communication with the town of Hana was completely severed, for several days. The only communication was by way of observation from an airplane which was chartered in Honolulu.

Hawaii:

Compared with the residents of the other islands, those on the Island of Hawaii were quite calm. The shock was felt by most people but was no greater in intensity in most parts of the island than shocks which commonly occur here. At first Mauna Loa or Kilauea were thought to be responsible for this earthquake. Examination of the records at the Observatory, however, changed that opinion and by the next morning the evidence indicated a near shock 100 miles or more from Kilauea. Throughout this island the earthquake motion was apparently of a slow, swaying type. Concensus of opinion expressed by residents throughout the Big Island was that the quake, while one of the longest ever experienced, was not as severe as some of the big shocks of 1929, which climaxed the series of earthquakes, apparently centered under the Hualalai district. Certainly the intensity of this quake was not as great as that recorded June 28, 1935, when stone walls in Hilo were cracked, nor was this quake as great in intensity on the records of the Volcano Observatory as that of 11:58 p.m. the night of September 30, 1935. Reports indicate that the shock was strongly felt in the Kohala district and gradually became less intense toward the southern tip of the Island of Hawaii. In Kohala, dishes were broken in many homes throughout the district. Pictures were knocked from walls, chandeliers crashed to the floor and furniture was generally disarranged. Small landslides occurred along the Kohala Mountain road. The shock was likewise strongly felt along the Hamakua Coast district. At the home of George Becker in Honomu many dishes were broken when china cabinets swayed and their contents crashed to the floor. At the home of John M. Ramsay, Manager of the Honomu Plantation, a large crack appeared in the ceiling going straight through the house from front to back. Despite the severity of the shock, there was no panic in any section of the island. In Hilo, people were awakened and ran from their homes but the excitement soon subsided. It appears to have been most strongly felt in the Pueo district, which usually reports earthquakes as stronger than in other sections of town. In that area some homes reported that stoves and iceboxes were moved as much as two or three inches from their original positions.



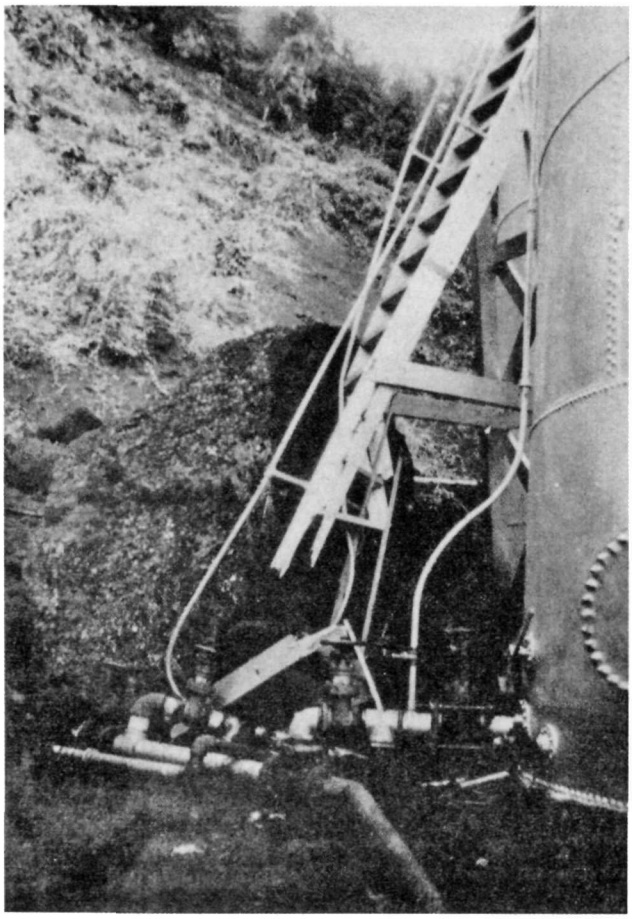
This seismograph record shows plainly the vibrations set up by the earthquake of January 22nd, 1938. Reading from right to left—note the normal line at the right, the intensification of the record and then the still disturbed line which shows that tremors were running through the earth long after they could be felt by human beings.

Location of the Epicenter by Seismograms

Only one complete record of the earthquake was available for study. That record was the one from the low magnification instrument located at the Hawaiian Volcano Observatory, NE rim of Kilauea Crater. Partial records were available from the US Coast and Geodetic Survey seismograph located at the University of Hawaii in Honolulu, and instruments operated by the Volcano Observatory in Hilo, Kealakekua, Uwekahuna Bluff (Kilauea Crater), SE rim of Halemaumau, the Bosch-Omori at the Observatory and a vertical component instrument also at the Observatory. All of these were dismantled at either the beginning of the preliminary phases or a few seconds afterward. The Hilo and Kona instruments apparently dismantled with the first impulse of the secondary phase.

The location was made from azimuths determined by the first impulses of the preliminary waves on the several seismograms and from Hawaiian travel times compiled by Mr. A. E. Jones, formerly of this organization. Also available was the preliminary arrival time at the Honolulu station, which is in charge of Commander J. H. Peters, who is making an intensive study of all phases of the earthquake. Assembly of all the

information available resulted in a comparatively reliable location although considerable checking and rechecking of the data was necessary to attain this end. First reports from the Volcano Observatory placed the disturbed area 154 miles N, 55° W of Kilauea. The distance was determined by the S-P interval of 22.8 seconds from the low magnification record and the azimuth indicated by the Bosch-Omori instrument to the same location. From these data the epicenter was tentatively placed at a point in the sea 20 miles S of Palaoa Point, Lanai. Comdr. Peters in Honolulu, using the first impulse time value at the University of Hawaii in conjunction with that at the Observatory, made his preliminary location at a point off the South Point of Maui, Cape Hanamanioa. The preliminary waves began to register at Kilauea at 10h 03m 20s p.m. HST; at the University of Hawaii at 1h 03m 15s p.m. HST. Using these two time values the location was definitely on a line running roughly



Boulder which hit S. O. Co. tanks at Hana in slide from north slope of Kauiki hill.

NE-SW through the western portion of Kahoolawe and Pauwela Point, Maui. On the basis of direction determined from the Bosch-Omori instrument the quake was thought to be about sixty or seventy miles deep and in the vicinity of the channel between Maui and Kahoolawe.

When seismograms from Kona, Hilo and other stations around Kilauea were examined directions did not agree with those of the Bosch-Omori. Macroseismic reports likewise did not agree completely with the preliminary location. Directions from all the stations except the Observatory converged on a general locality to the north of Pauwala Point north of Maui. The directions were:

Volcano Observatory	N 55° W
Pit Seismograph	N 24° W
Uwekahuna	N 23° W
Hilo	N 28° W
Kealakekua	N 3° W

Meanwhile, it appeared that the Hilo and Kealakekua instruments had not dismantled until the beginning of the secondary phase. On this assumption the graphical method of Isikawa was applied to the three stations, Hilo, Kealakekua and Volcano Observatory, using the Jones travel times for the S-P values determined. More careful study placed the Bosch-Omori S-P value at 22.3 seconds. The resulting location agreed roughly with directions indicated above, omitting the Observatory. A depth of 65 miles was indicated. This was the final location as determined from the Observatory (See Volcano Letter 455, January 1938). The epicenter thus determined was a point 25 miles N of Pauwala Point, Maui, 21° 12' N; 156° 06' W. By other methods Commander Peters had arrived at approximately the same location. The final computations from completely assembled data of local as well as distant stations places the epicenter at the above value. Time of origin was 10h 03m 08s p.m. HST.

Rossi-Forel Intensity values for a few localities on the Island of Hawaii were

Kilauea	IV
Kealakekua	IV-V
Puu Waawaa	VI
Hookena	IV

Kohala—probably same as Puu Waawaa

Excerpts from the Volcano Observatory Record Book:

Bosch-Omori

Period	Trace Amplitude	Phase	*Time (HST)	
0.2	— 0.3 mm	i P ENZ	10:03: 20.0 p.m.	
	+ 0.2			
0.7	— 4.0	i E	10:22: 07.0	}
	+ 2.0			} Dismantled
	+ 90.0	i N	11:23: 07.0	}

* Ten and one half hours behind Greenwich Time.

Low Magnification Instrument

		i PEN	10:03: 20.0 pm
		i SEN	10:03: 42.3
		f N	03: 53.3
0.9	—20.0 m		
	+ 11.0	i ME	04: 05.0
	— 9.0		
	—19.0	i MN	04: 15.4
		F E	10 42±

Some of the local residents thought this was probably the heaviest earthquake in 20 years. Dr. Jaggar has gone over the records since 1912 and has compiled the following list of near shocks showing that their occurrence has been relatively frequent.

Quakes—Hawaiian Volcano Observatory—150 to 500 Km

1912—Oct. 13, record imperfect
Dec. 5, 279 miles
1913—July 31, 136 miles
1914—Mar. 30, 93 miles
Aug. 8, 140 miles

1916—June 6, 93 miles
June 7, 125 miles
July 23, 140 miles
1918—June 14 ..? Felt Maui?
Nov. 2 ? Felt Maui
1919—Jan. 29, 177 miles, felt in Honolulu.
Sept. 14 ? Maui?
Sept. 18 ? Felt Maui?
1920—Mar. 30, 33 miles, felt Maui?
May 15, 60 miles, felt Maui? and Honolulu.
1923—Dec. 25 ? Felt Lanai, Maui, Honolulu and Molokai.
1926—Mar. 19, 124 miles, felt Maui and Honolulu. Mauna Loa eruption came April 10.
1927—Mar. 20, 110 miles from HVO. 4:52 a.m. Seismogram illustrated Fig. 14. Bulletin March, 1927. Felt in all Hawaiian Islands.
Aug. 3, felt in Honolulu? 9:42 a.m., moderate.

Hawaiian Volcano Observatory Report for March 1938

VOLCANOLOGY

The month at Kilauea Volcano showed decline in seismicity and opening of cracks, but some increase of slides during the last two weeks. The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending		Seismicity	Slides	Crack Openings	Local Tremors and Quakes
March	6	27.50	0	6.5 mm.	62
"	13	11.50	1	15.0 mm.	40
"	20	4.75	0	7.0 mm.	11
"	27	11.50	10	7.0 mm.	39
April	3	5.50	4	3.0 mm.	20



Crack in Wailua pali road above Keanae flats.

The writer has examined the records of the ones of March 1926 and 1927. They are in many respects similar to that of January 22, 1938. Their distances of 124 and 110 miles respectively would be correct for East Maui with Haleakala in mind.

It is very definitely a mistake to think that earthquakes are unlikely in other parts of Hawaii. The imposing list shown here is proof that they can and may occur at frequent intervals. Their intensity is unpredictable and consequently it would be well to take that into consideration in discussing constructional developments in the Hawaiian Islands.

Twenty-seven of the measured shocks were of Kilauea origin, four were of Mauna Loa, and four were from beyond Mauna Loa. A moderate felt shock of Kilauea origin occurred February 28, slight felt shocks occurred March 2 and 7, the first under Kilauea Crater, and the second a deep source under Kilauea.

Distant earthquakes were registered March 22 and 25, this occurrence just after equinox being usual.

Sequence of Events by Weeks

The first week produced nothing of importance except that

the tilt at Halemaumau continued to be away from the pit. This tendency lasted until March 20, and with it the Observatory cellar began to show northeasterly tilts. The second week there were some sliding and increased opening of cracks. The third week was quiet. The fourth week showed notable increase of slides, and just after the equinox the tilt at the Halemaumau cellars turned inward. The fifth week was quiet.

Slides at Halemaumau

The recorded slides from the wall of the pit were:
March 8, 4:34 p.m., small slide NE wall.
March 22, 10:19 a.m., slide heard from W cellar.
March 22, 10:30 a.m., slide from N wall.
March 25, 10:23 a.m., small slide N wall, from near bottom.
March 25, 10:55 a.m., dust cloud from W wall.
March 25, 11:03 a.m., dribble of rock, N wall.
March 25, 11:06 a.m., dust above W wall.
March 25, 11:11 a.m., dust over W wall.
March 25, 11:20 a.m., dribbling of rock N and W wall.
March 25, 3:15 and 4:15 p.m., dust above N wall.
March 26, 10:20 p.m., noise of slide in pit.
March 29, 1:25 p.m., noise below W rim.
March 29, 2:20 p.m., noise from N wall.
March 30, 9:25 a.m., noise of slide NE and NW walls.
March 30, 5:43 p.m., dust cloud over NE rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during March in aggregate movement as follows:

Week ending forenoon of:

March 4, 28 locations, 10 opened, 2 closed, opening 6.5 mm.

March 11, 28 locations, 15 opened, 0 closed, opening 15.0 mm.

March 18, 28 locations, 10 opened, 1 closed, opening 7.0 mm.

March 25, 28 locations, 11 opened, 0 closed, opening 7.0 mm.

April 1, 28 locations, 6 opened, 1 closed, opening 3.0 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
March 6	52	13	3	1	1	0	27.50
" 13	16	5	2	0	1	1	11.50
" 20	11	4	0	0	0	0	4.75
" 27	32	7	0	0	0	2	11.50
April 3	18	2	0	0	0	0	5.50

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

February 28, 5:44 pm, very feeble, 2.1 miles deep in Kilauea Crater 0.6 mile E of Halemaumau. 19° 24.6′ N; 155° 16.2′ W.

February 28, 9:40 pm, moderate, dismantled both components of Observatory seismograph and felt at Hawaii National Park Headquarters area; 2.8 miles deep in Kilauea Crater near N rim of Halemaumau. 19° 24.8′ N; 155° 17.1′ W.

March 1, 7:58 am, very feeble, 2.4 miles deep in Kilauea Crater 0.4 mile NE of Halemaumau. 19° 25.0′ N; 155° 16.7′ W.

March 1, 1:20 pm, very feeble 1.0 mile deep near center of Kilauea Crater. 19° 24.9′ N; 155° 16.5′ W.

March 1, 1:48 pm, feeble, 1.6 mile deep under Byron Ledge, E rim of Kilauea Crater. 19° 24.8′ N; 155° 15.7′ W.

March 1, 2:40 pm, very feeble, 1.0 mile deep in NE portion of Kilauea Crater. 19° 25.4′ N; 155° 15.8′ W.

March 1, 6:24 pm, very feeble, 1.3 mile deep SE rim area of Kilauea Crater. 19° 24.4′ N; 155° 15.4′ W.

March 1, 7:29 pm, feeble, 2.1 miles deep in Kilauea Crater 0.6 mile E of Halemaumau.

March 1, 9:52 pm, very feeble; of Kilauea Crater origin.

March 1, 10:50 pm, very feeble, of Kilauea Crater origin.

March 2, 3:16 am, slight, 2.7 miles deep, Chain of Craters rift near Kokoolau Crater. 19° 21.9′ N; 155° 15.1′ W.

March 2, 4:22 am, very feeble, 1.3 mile deep SE rim area of Kilauea Crater. 19° 24.4′ N; 155° 15.4′ W.

March 3, 3:47 am, of shallow origin probably near center of Kilauea Crater.

March 3, 5:13 am, feeble, probably originated near SE rim of Kilauea Crater in vicinity of Keanakakoi.

March 3, 6:00 am, very feeble, probably originated in NE portion of Kilauea Crater.

March 4, 5:53 am, probably of Kilauea origin.

March 7, 12:04 am, very feeble, 30.0 miles deep in saddle between Mauna Loa and Mauna Kea. 19° 43.0′ N; 155° 27.0′ W.

March 7, 5:56 am, moderate, 28.0 miles deep, Mauna Loa NE rift about 8.0 miles SW of Hilo. 19° 42.0′ N; 155° 32.0′ W. Reported felt by many in Hilo, Kona and Hawaii National Park.

March 8, 4:05 am, feeble, probably of Kilauea origin.

March 8, 4:06 a.m., very feeble, of shallow origin in Kilauea Crater.

March 10, 4:15 am, very feeble, probably originated in NE portion of Kilauea Crater.

March 10, 6:42 am, feeble, probably originated near Halemaumau in Kilauea Crater.

March 15, 1:30 am, very feeble, originated in NE portion of Kilauea Crater.

March 15, 11:12 am, very feeble, 1.5 miles deep, Kilauea Crater 0.8 mile E of Halemaumau. 19° 24.7′ N; 155° 16.3′ W.

March 20, 11:00 am, very feeble, 20.0 miles deep under Mauna Loa summit Crater. 19° 27.0′ N; 155° 37.0′ W.

March 21, 10:02 am, very feeble, probably originated near Halemaumau in Kilauea Crater.

March 25, 6:14 pm, very feeble, probably originated in Mauna Loa SW rift.

March 26, 9:12 pm, very feeble, of Hualalai origin. Windows reported to have rattled in building in Hookena.

March 31, 9:05 am, very feeble, probably originated in Mauna Loa NE rift.

April 3, 2:56 pm, very feeble, 4.0 miles deep, 1.7 miles NW of Kilauea Crater in vicinity of Kipuka Puaulu. 19° 26.1′ N; 155° 18.7′ W.

Teleseisms were:

March 7, 7h 30m 06s pm HST, beginning of unidentified portion.

March 22, 5h 5m 34s am, HST, beginning of secondary wave recording. Location by reports from U. S. Coast and Geodetic Survey, 53° N; 131°8 W, in vicinity of Queen Charlotte Island, Southern Alaska.

March 25, 5h 36m 35s am, HST, beginning of unidentified portion.

Microseismic motion of the ground at the Observatory was:

Light, March 20, 22 and 23.

Moderate, March 4, 5, 6, 7, 12, 13, 14, 15, 16, 21, 31. April 1 and 2.

Strong, the remainder of the month.

Tilting of the ground:

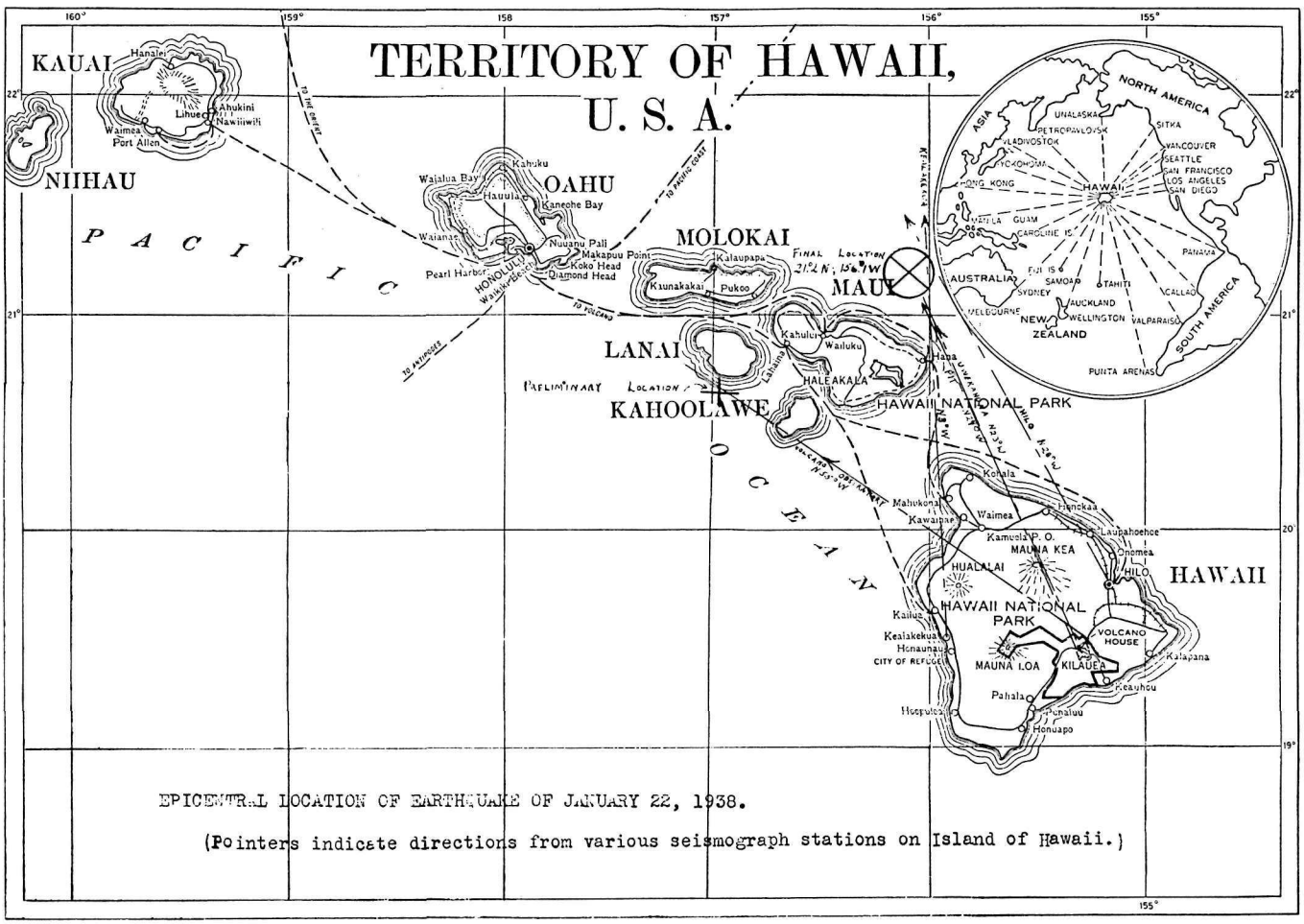
The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum of radial tilt toward or away from the Pit:

At the Observatory the total accumulated tilt for the year ending April 3, was 3.64"S and 4.42"W.

Week Ending	Observatory	Halemaumau West Station
March 6	1.81" S 27° W	9.54" N 85° W
March 13	1.40" N 66° E	5.90" S 74° W
March 20	0.66° S 75° W	5.90" N 80° W
March 27	1.52" S 55° W	3.07" N 12° W
April 3	0.20" N 40° E	4.17" N 80° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
March 6	2.59" S 79° W	8.94" from
March 13	6.48" N 29° W	0.51" toward
March 20	2.33" S 22° W	6.79" from
March 27	5.18" N 24° W	4.72" toward
April 3	7.52" N 13° W	2.78" toward

H.H.W.



EPICENTRAL LOCATION OF EARTHQUAKE OF JANUARY 22, 1938.

(Pointers indicate directions from various seismograph stations on Island of Hawaii.)

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

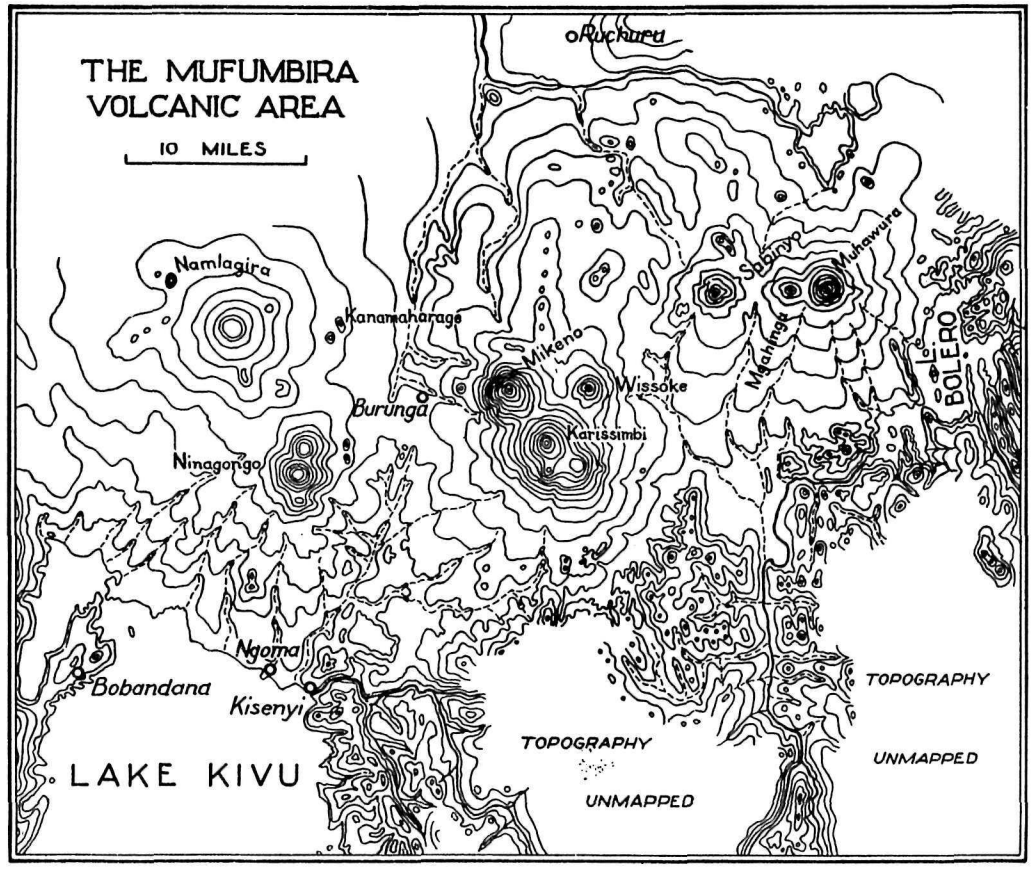


THE VOLCANO LETTER

No. 458 monthly Department of the Interior National Park Service April 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Map of Virunga or Mufumbiro Volcanoes (after Bowen).

EXCURSION TO NYAMLAGIRA VOLCANO, VIRUNGA OR MUFUMBIRO RANGE, PARC NATIONAL ALBERT

By P. PHILIPPSON
(Translated by Jaggar)
(Bulletin de Club Alpine Belge Sept.-Dec. 1934, p. 137)

In order to reach Lake Kivu in coming from the north by the mail route of Rutshuru the automobile road crosses the Virunga volcanic belt, passing between imposing profiles of the extinct volcanoes Mikeno (4,437 meters) and Karisimbi (4,506 meters) on the East; and the active volcanoes Nyamlagira (3,058 meters) and Niragongo (3,470 meters). The most active unit and doubtless the most recent of the whole group is Nyamlagira, situated about 15 kilometers from the route that we leave, when an hour's march south from the Mission of Tongres-Ste-Marie, in order to enter upon a pilgrimage across a plain of lava of more or less ancient origin. The most recent fields of lava were crossed first showing a vegetation of ferns and shrubs growing in the crevices of the rock, whereas on the flank of the mountain proper the very old age of the lava flows shows decomposition with the formation of soil and development of forest.

Nyamlagira is a dome, shaped like a turtle back, and is thereby distinguished from the other volcanoes of the chain, some of which are pointed (Karisimbi) or truncated cones (Niragongo) and others have peaks of jagged rock (Mikeno and Sebinyo). There are fresh tracks of herds of elephants; pigeons flap their wings on all sides, brilliantly colored butterflies flit about the undergrowth or are abundant on the orchids that are both terrestrial and aerial. One of the most remarkable kinds is an orchid possessing a white flower with a scarlet heart seen in large numbers during June and July on tree trunks covered with moss; another species is much smaller with fleshy flowers that are blood red.

Along the trail there are frequent leopard tracks, and occasionally the mark of lions. At places where the lava is covered with earth and moss, the footprints of the wild animals show with remarkable distinctness.

The track had been recently cleared and we travelled without difficulty, but this appears to be not invariable; the guide told us that shortly the trail would be blocked again by trees overthrown by elephants, or by windfalls that result from storms of extraordinary violence. Some months before our visit, four native porters had been frozen to death by a storm of hail that took them by surprise on the flank of the mountain.

After a march of about two hours and a half we passed a pond in the bottom of old craters. It is the watering place of elephants, for everywhere one sees their tracks. The water, which is the product of rain, is foul. This is the only water found between here and Kannusi, which is about four hours' march beyond this place.

On emerging from the crater we reach immediately the camp called Mushumangabo that commands a superb view of the whole country. Off to the east the magnificent cones of Mikeno and Karisimbi stand out in sharp relief; to the south is Niragongo and to the west Nyamlagira. Toward the south and southwest, between the two last named volcanoes, numerous subsidiary volcanoes produce an impression of much volcanic outpouring.

We continue our march toward the camp Mumurima, on the north side of the volcano close to 2,400 meters of altitude. The trail traverses a lava plain apparently older than the first part crossed before arriving at Mushumangabo. The jungle becomes denser and in places we passed through lovely old forests where the lava with bare surfaces is not so often seen.

A few hundred meters before arriving at the camp, we crossed the bed of a lava torrent and after a short climb found ourselves in a clearing where there are huts for the porters. Here we pitched our tent and soon the night enveloped us. In the big trees around the camp a goodly number of wood pigeons roosted and out of the bush came the calls of the wood partridge, more properly called francolins. We could also distinguish the whistle of the rock rabbit (hyrax) and from the valley came the bleat of a "harness" antelope calling to its mate. The landscape by moonlight was splendid; the ocean of jungle on the Rutshuru plain extended away to infinity, framed both east and west by a border of mountains.

Early the next morning we set out for the mountain top. Vegetation gradually disappeared. First through a cold lava channel, in the midst of equatorial plants and giant shrubs, then over a desert region, we arrived at the rim of the crater. It was truly fantastic. In a depression 2.3 km. in diameter bluish water vapor and greenish sulphur fume surrounded a rocky islet: truly a vision of the magic castle of the fairy stories. From the bottom of this enormous pit 150 meters deep the dull rumble of molten lava gave the impression of fiery power, and of the role of heat as creator and destroyer within our globe.

We set up our two tents close to the edge of the crater, on a solidified platform, where the wind incessantly brought to us sulphur smells. The night is cold and the porters have disappeared. They are entombed in a long subterranean gallery. By moonshine we reach the margin of the inner crater by way of plains covered with sulphur in ebullition. The spectacle is Dante-esque: here are glowing lavas in fusion bursting through the midst of black surfaces, and active eruption cones growling and emitting jets of flame and whirls of vapor.

Early in the morning we extracted our blacks from under the lava plain (the underground gallery where they lived had only a small opening) and we climbed down into the inferno for a depth of 100 meters. Surrounded by steam and sulphur we found the walking troublesome on this lava, that may break in underfoot at any moment. We approached within a few meters one of the active cones where fused lava was boiling; strong gushes of sulphur gas prevented any long stay.

The edges of the vents, yellow with crystals of sulphur, made contrast with the red of the boiling lava; on the interior crust of these little craters from two to twenty meters in diameter, and ten in number, there are clinging long tresses of hair (filamentous lava) which are agitated by the currents of hot air. After visiting several of these cones, and dodging the lava spatter and the dense clouds of sulphur vapor that they disgorged, we finally reached the base of the central island by walking across hot lava surfaces. The island is of massive rock 80 meters high.

After studying the map, I undertook the first ascent of the craggy height and in 20 minutes reached the summit. The only difficulty was a climb through a chimney for a height of four meters. The summit is covered with volcanic gravel surrounding a shallow funnel. The panoramic view was extensive.

Toward the north on the middle platform, could be seen the active region with its cracks, chimneys and cones spouting lava, lava which poured incessantly through subterranean tunnels into the big pit in the southwestern part of the crater. The bottom of this pit forms a lower platform. The level of the bottom of this large pit, 750 meters across, was in January 1932 at elevation 2,767 meters, in January 1933, 2,810 meters, and in June 1933, 2,828 meters. This regular elevation gives a measure of the amount of lava that has poured into this lower pit from the active area amounting to about twenty million cubic meters per year. At this rate the lower pit will be filled with lava about September 1934, and the level of the middle platform will be built up in from 3 to 4 years to elevation 2,904 meters, corresponding to the height of the active sources; unless a flank eruption of Nyamlagira drains the crater and again lowers the level of the bottommost flow.

The last eruption of Nyamlagira in 1912 was by way of the new subsidiary volcano Rumoka, situated 20 kilometers south-southwest from the main dome. Another eruption in about the same direction came from the Singiro vent erroneously called Nahimbi, 6.5 kilometers from Rumoka and about 15 kilometers from Nyamlagira. Between these two outbreaks there was another in 1905 from the volcano Kanamaharagi, 11 kilometers east of Nyamlagira, and about 13.5 kilometers N.N.E. from Niragongo.

From 1901 to 1912 there were four eruptions. From 1912 to 1933 external outbreaks have not occurred, but the level of the crateral lava within Nyamlagira has always risen. It is possible to calculate almost exactly the time when the lava level will reach the elevation (2,952 meters) of the upper platform, which is also the level of the overflow of this great volcano; but usually a breach occurs elsewhere.

The study of the two active volcanoes of Albert National Park is part of the programme of the Belgian Scientific Institution. Such study will be of great interest to the geologists.

Hawaiian Volcano Observatory Report for April 1938

VOLCANOLOGY

Slides at Halemaumau pit were erratic with the greatest concentration in numbers during the first and third weeks. The slides undoubtedly were responsible for many of the tremors reported during those periods. Seismic activity showed a slight increase toward the latter half of the month. Occurrence of earthquakes indicating distance of origin Mauna Loa as well as Kilauea shows that movement is taking place at both volcanoes. At Kilauea tilt and angle measurements would suggest that lowering of the crater floor is continuing. A summary of data for the Kilauea station for April 1938 follows:

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
April 10	13.50	21	9.0 mm.	50
" 17	8.50	1	6.0 mm.	28
" 24	11.75	23	—0.5 mm.	35
May 1	12.25	11	4.5 mm.	43



Photograph of model of summit of Nyamlagira as viewed from southwest. (W, main outer crater-wall; T, inner terrace; P, lava pit; F, fountain-basin; I, island; S, sink-hole.)

Four of the quakes were of proper distance for Mauna Loa northeast rift, five may have originated deep under Mauna Loa elsewhere, a shock April 15 was felt strongly at Kapapala and a feeble earthquake April 12 was located twenty miles from Kilauea. The sixteen earthquakes remaining originated under or near Kilauea crater.

Frequency of Events by Weeks

The first week produced slides at Uwekahuna, very slight tilt at the Observatory, more pronounced tilt at Halemaumau. The second week had less sliding and crack opening, and increased tilt at the Observatory. The third week showed increase of earthquakes and slides, unusual closing of the Halemaumau rim cracks and notable change of direction of tilting at the Observatory and at Halemaumau west. The fourth week produced additional slides and less tilting.

Slides at Halemaumau

The recorded slides from the wall of Halemaumau were:

April 4, 9:25 a.m., W wall.
April 4, 11:25 a.m., NW wall.
April 4, 11:44 a.m., NW wall.
April 4, 12:27 p.m., NW wall.
April 4, 1:27 p.m., NW wall.
April 4, 1:30 p.m., N wall.
April 4, 5:00 p.m., large dust cloud from NNE rim.
April 7, 7:45 a.m., W wall.
April 7, 8:05 a.m., W wall.
April 7, 8:10 a.m., NW wall.
April 7, 8:15 a.m., W wall.
April 7, 8:24 a.m., W wall.
April 7, 8:40 a.m., W wall.
April 7, 10:16 a.m., W wall.
April 7, 10:25 a.m., W wall.
April 7, 11:00 a.m., W wall.
April 7, 11:40 a.m., W wall.
April 17, 12:17 p.m., small slide NW wall, noise heard at Uwekahuna.
April 21, 12:45 p.m., dust over W rim.
April 23, 9:15 a.m., dust clouds NW.
April 23, 11:10 a.m., dust clouds NW.
April 23, 11:12 a.m., dust clouds NW.
April 23, 11:15 a.m., dust clouds NW.
April 24, 9:00 a.m., dust from W rim.
April 24, 9:10 a.m., dust from W rim.
April 24, 9:18 a.m., dust from W rim.
April 24, 9:31 a.m., dust from W rim.
April 24, 10:05 a.m., dust from W rim.
April 24, 10:12 a.m., dust from W rim.
April 24, 10:16 a.m., dust from W rim.
April 24, 10:31 a.m. dust from W rim.
April 24, 11:02 a.m., dust from W rim.
April 24, 11:08 a.m., dust from W rim.
April 24, 11:23 a.m., dust from W rim.
April 24, 12:09 p.m., dust from W rim.
April 24, 12:15 p.m., dust from W rim.
April 24, 12:23 p.m., dust from W rim.
April 24, 12:25 p.m., slides from N rim.
April 24, 2:00 p.m., slides from N rim.
April 24, 3:06 p.m., slides from N rim.
April 24, 3:12 p.m., slides from N rim.
April 25, 11:02 a.m., slide from N or NW walls.
April 25, 11:05 a.m., slide from N or NW walls.
April 25, 12:25 p.m., slide from N or NW walls.
April 25, 1:16 p.m., slide from N or NW walls.
April 25, 1:25 p.m., slide from N or NW walls.
April 25, 2:28 p.m., slide from N or NW walls.
April 28, 1:45 p.m., slide from W rim.
April 29, 10:50 a.m., moderate slide from N rim near hot crack.
April 29, 2:30 p.m., slide from W rim.
May 1, 12:25 p.m., slide from N rim.

Measurement of Halemaumau Rim Cracks

Weekly measurements of rim crack locations around Halemaumau resulted during April in aggregate movement as follows:

Week ending forenoon of:

April 9, 28 locations, 13 opened, 1 closed, opening 9.0 mm.
April 15, 28 locations, 11 opened, 3 closed, opening 6.0 mm.
April 22, 28 locations, 7 opened, 5 closed, closing 0.5 mm.
April 29, 28 locations, 8 opened, 1 closed, opening 4.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly† Seismicity
April 10	46	4	0	0	13.50
April 17	24	3	1	0	8.50
April 24	25	8	1	1	11.75
May 1	37	6	0	0	12.25

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

April 7, 8:28 pm, very feeble, 2.2 miles deep, Kilauea Crater, near NE rim of Halemaumau. 19° 24.9′ N; 155° 17.0′ W.

April 9, 3:00 am, very feeble, probably originated in area about 1.0 mile NE of Kilauea NE crater rim.

April 10, 7:04 pm, very feeble, of shallow origin near Byron Ledge. 19° 24.6′ N; 155° 15.4′ W.

April 10, 7:05 pm, very feeble, of shallow origin near W portion of Kilauea Iki. 19° 24.9′ N; 155° 15.3′ W.

April 12, 8:48 am, a feeble earthquake registered. It was probably of Mauna Loa origin although there was no record of it either at Hilo or Kealakekua. Distance from the Observatory was 20.0 miles.

April 15, 2:36 pm, very feeble, no location but reported felt at Kapapala Ranch. Distance from the Observatory 18.0 miles.

April 16, 12:57 am, very feeble, 22.0 miles deep in vicinity of Kapapala Ranch. 19° 18.5′ N; 155° 29.5′ W.

April 19, 2:12 am, very feeble, 1.9 miles deep in NW portion of Kilauea Crater. 19° 25.4′ N; 155° 16.8′ W.

April 19, 2:56 am, very feeble, 2.6 miles deep, in vicinity of Lua Manu Crater. 19° 24.0′ N; 155° 15.5′ W.

April 19, 8:48 am, very feeble, probably originated under NW rim of Kilauea Crater.

April 19, 8:46 pm, very feeble, of Kilauea Crater origin.

April 22, 1:04 am, very feeble, of shallow origin, SE rim area of Kilauea Crater. 19° 24.1′ N; 155° 16.2′ W.

April 23, 5:51 am, feeble, of Kilauea origin.

April 23, 8:21 pm, very feeble, located at junction of SW rift with Kilauea Crater. Reported felt at CCC camp, SE rim of Kilauea Crater and at the Kilauea Military Camp, N rim of Kilauea Crater.

April 23, 8:22 pm, very feeble, location probably same as preceding shock.

April 24, 4:54 am, very feeble, probably located in Kilauea SW rift about 20.0 miles SW of the Observatory.

April 27, 3:42 pm, very feeble, probably originated in NE portion of Kilauea Crater.

A period of continuous tremor, lasting 20 minutes, began recording at 12:59 pm, April 5.

An unidentified portion of a distant earthquake began to register at 6h 02m 24s pm, H.S.T., April 21.

Microseismic motion of the ground at the Observatory was light April 14, 15, 16, and 21; moderate April 4, 5, 10, 11, 12, 13, 22, 23, 24, 25, 26, 30; strong the remainder of the month.

Tilting of the ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum of radial tilt toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 1, was 1.62″ S and 1.30″ W.

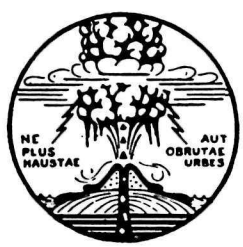
Week Ending	Observatory	Halemaumau West Station
April 10	0.37″ S 45° E	4.32″ N 76° W
April 17	1.22″ S 69° W	2.83″ N 80° E
April 24	1.29″ N 45° E	8.05″ S 84° W
May 1	0.68″ N 30° W	2.29″ S 66° E

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
April 10	1.59″ S 49° W	1.35″ from
April 17	4.96″ N 64° W	1.55″ toward
April 24	5.96″ N 44° W	0.61″ toward
May 1	3.08″ N 62° W	1.11″ toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory April 20, indicated closing of the Halemaumau value and slight opening of the crater value compared with similar measurements of February 21. The Halmaumau measurement from SE Pit BM to NW Pit BM showed closing of 2.58″ and the crater measurement from the SE Crater rim to Uwekahuna showed an opening of 0.90″.

H.H.W.



THE VOLCANO LETTER 459

No. 459 monthly Department of the Interior National Park Service May 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

ERUPTION OF NYAMLAGIRA VOLCANO 1938

(A letter from Dr. Jean Verhoogen)

Nyamlagira Volcano north of Lake Kivu in the Belgian National Park of the Congo District is a volcano of first magnitude containing lava pits in its crater similar to those of the Hawaiian volcanoes. It is characterized by dominant outflows of lava, and is distinguished as an intensely active lava producer in the midst of the interior of the great continent of Africa. It ranks with Mauna Loa and Etna, and yet is as remote from the ocean as they are near it. Its height is 3,058 meters, its position 1° 35′ S latitude, 29° 11′ E longitude. It had a voluminous eruption of lava estimated three cubic kilometers in 1894, an ash eruption from a side crater to the southwest in 1899, a lava flow in 1902 from a southern parasitic crater and it formed new mixed cones in 1904 and 1905. Other eruptions were in 1907 and 1912, the latter a flank lava flow that put out very liquid streams that reached Lake Kivu. Other activity in 1920 and 1926 shows how continuous is the release of pressure at this volcano and in 1904 there was an eruption from the bottom of the northwest corner of Lake Kivu with boiling of great surfaces of the lake accompanied by rumbling. There were possibly sixty-six eruptions in all between 1801 and 1914. (Sapper.)

From April 27 to May 26, 1935, Mr. Jean Verhoogen worked at the Hawaiian Volcano Observatory as a student sent from Belgium to prepare himself for volcanological work in the Belgian Congo. He acted as a temporary assistant at the Kilauea laboratory in order to learn the routine, and afterwards worked in graduate geological studies on California volcanoes. He published "Mount St. Helens" (Bull. Dept. Geol. Sci. Univ. Cal. 24-9-263, 1937), and took courses at both California universities; afterwards he became a teacher at Brussels.

Under date of June 12, 1938, Dr. Verhoogen writes to the Volcanologist at Hawaii National Park that he is at work on Nyamlagira volcano. When word came that a major eruption had begun the National Park Institute sent Verhoogen by airplane to Africa arriving February 1938. Dr. Verhoogen writes:

"What happened is this: you remember from Bowen's description that in September-October 1929 (N. L. Bowen, Trans. Amer. Geophys. Union 1929-30, pp. 301-307, 10 figures) the crater of this volcano consisted of a sink-hole SW, a middle platform, and an upper one, all enclosed within the walls of a caldera. The lava was issuing from tunnels in the edge of the middle platform, down the cliff margin of the sink and filling the latter.

"In 1934 the sink-hole got filled up. The lava began to pile up on the middle platform until it reached the level of the upper platform in December 1937. A few flows spread out through a gap in the caldera wall into the local 'Kau Desert' (by analogy with Kilauea, Hawaii.)

"On January 28, 1938, four fissures opened simultaneously on the SE and SW sides of the volcano, and a deluge of exceedingly fluid lava poured out. Gigantic sinking took place in the crater, and the middle platform and the sink hole appeared again. The flows from the fissures stopped quite soon.

"A new volcano was born lower down half an hour after the stoppage of the flows, on the SW side, and about a mile from Nyamlagira crater. It has been active up to June 1938 and the history is following, from up-hill down the slope.

"(a) An ever increasing number of spatter cones, all on two main lines, spitting vesicular lava in the early days of their existence, and only flames later.

"(b) A lava lake, 100 meters long, 60 meters wide, in which the lava entered from the south and disappeared all around the northern banks.

"(c) The source of a lava flow which flows down the mountain at 12 miles an hour in the open part of the channel. Total discharge has been one hundred million cubic meters from this stream (June 1938). This flow is almost entirely buried in a self-made tunnel. The construction of this tunnel was most interesting to watch.

"The intermediate lava lake on the mountain flank over the rift has had a most surprising behavior. The level sank steadily, until one day it divided up into two smaller lakes. In the southern pool, lava was fed from below the southern bank (the feeder was visible), but in the northern pool lava entered from the north. The level of the northern pool continued to lower, and as the pool got smaller and smaller, the lava which kept on entering from the same vent had to run down a bank quite a distance to the pool. Then this stream of lava solidified.

"Now there is still a circulation in the pool, lava entering apparently from below the banks. Activity on these pools consists of rising gases, folding crust, engulfment of the crust, and wild fountains which last a few minutes, so that there results a rapid sinking of the level. The level starts rising again, a crust is formed, folds appear, engulfment begins, a fountain sprouts up, and the level sinks. At the present time the whole cycle takes about 10 minutes in the southern pool, and is very irregular in the northern pool. It suggests more a geyser action than anything else.

"I have with me an optical pyrometer which works wonders, as it allows measurement in inaccessible spots. A number of measurements has shown that the lava is just as hot in the stream half a mile below its source as it is in the hottest fountain.

"I have taken still pictures, movie films and color films. The attempt to collect gases with vacuum tubes was only partially successful, as the tubes broke in transport, and the fusible tips failed to fuse. I think I have one air-free sample.

"I am expecting a spectograph. The spatter cones keep on day and night heaving huge yellow flames, almost sufficient to read by: I have not seen blue flames."

This is a perfect description of the Halemaumau activities of 1917-19, the masking and heat-holding effects of lava tunnels, the rift eruption of Kau Desert 1919-20, and the concealing of vent cracks as soon as lava covers them and forms concentric banks.

A translation showing what preceded the 1928 eruption was printed in the April Volcano Letter.

T. A. JAGGAR.

Hawaiian Volcano Observatory Report for May 1938

VOLCANOLOGY

The measurements at Halemaumau pit showed nothing exceptional until the forenoon of May 28. On that day, beginning about 6:00 a.m., almost continuous quaking developed with several moderate shocks that were generally felt. On that same day it was discovered that one large crack and numerous small ones were developing in an East-West direction, athwart the Chain-of-Craters road between Pauahi and Aloi pits, east rift of Kilauea Volcano.

The nature of the development appeared to be block faulting with downthrow to the south and there is possibly some graben faulting. This motion along the eastern rift belt of Kilauea mountain implies extension westward of the active cracks of 1924 at Kapoho, 1922 at Makaopuhi and 1923 in the upland west of Makaopuhi. A hot spot on the cracks which is killing the verdure indicates the presence of active lava below.

Diminishing seismic activity continued to the end of the month and a seismoscope was placed near the Chain-of-Craters road. Halemaumau showed no sign of breaking out.

Location of the earthquakes indicates that their epicenters were partly some five to six miles from the Observatory and a few of them were as close as two miles distant. These distances correspond to the southeast rim of Kilauea, and to Pauahi pit or slightly beyond.

The following are the local weekly data for the month at the Observatory and Halemaumau:

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
May 8	10.50	3	2.5 mm.	36
May 15	11.75	5	5.5 mm.	40
May 22	8.75	0	3.0 mm.	27
May 29	247.75	8	4.0 mm.	726

Shocks capable of being felt occurred on May 5, of Kilauea origin, and also of May 28 to 30 as indicated above. Shocks of Mauna Loa origin occurred May 17, felt at Kapapala and Pahala. The last three weeks of the month were notable for strong distant earthquakes six in number located near Mexico, Papua, Borneo, Japan, the Philippines, and Oregon. This world-wide sympathy in time, with a similar seismic activity of down-breaking fault blocks of Kilauea, occurring a month before the summer solstice season of 1938, is worthy of close attention.

It should be noted that the accumulated tilt for the year always tending southward at the Observatory, and the tendency of levelling surveys to show the south bench marks of the Kilauea rim low with reference to the Halemaumau rim, and much evidence of crater angles closing, all tend to agree with downsinking of fault blocks. It should be noted that whenever the levelling (see October and December Volcano letters 1937) reports relative elevation of Spit bench mark (a southern rim bench of Kilauea crater) and the northwest Pit bench mark at Halemaumau, the statement that the crater floor has lowered may mean that the southern rim bench has been raised. And the statement that the Halemaumau rim is higher, may mean that the Spit bench mark is relatively lower. The northwest station on the Halemaumau rim is on the Mauna Loa side of the rift belt; Spit bench mark is on the side of Hilina Pali fault blocks. If one of the fault blocks adjoins Kilauea crater, its movement downwards might produce a relative tilt to the northwest between Spit bench mark and the western rim of Halemaumau. There has been a notable amount of northwest tilting lately in the Halemaumau southeast station. The spell of downfaulting with road cracks and earthquakes at the Chain-of-Craters rift belt is confirmatory of a trend noticed for years past, suggesting southwesterly tilt at the Observatory, and general lowering of the southern side of Kilauea crater and its floor.

Sequence of Events by Weeks

The first week produced westerly tilt at all stations and otherwise nothing exceptional. Second week showed increase of slides, quakes and opening of cracks and the Halemaumau tilt increased to the northwest. The third week was quiet, but the Observatory tilt increased to the southwest. The fourth week was the time of excessive earthquakes and numerous slides. Crack openings were moderate, Observatory tilt was away from the crater, Halemaumau west station tilted east, and Halemaumau southeast station tilted north; the resultant for these two was exceptional tilt toward the pit.

Slides at Halemaumau

The recorded slides from the wall of the Pit were:

May 2, 3:00 p.m., slide from W rim sent up dust cloud.
May 7, 9:35 a.m., dust rose at N wall.
May 8, 3:43 p.m., slide from N rim.
May 9, 10:25 a.m., N rim.
May 11, 5:40 p.m., large dust cloud N rim.
May 12, 9:52 a.m., rocks dribbled continuously from N wall.
May 12, 11:30 a.m., dust from N wall.
May 15, 12:30 p.m., N rim.
May 25, 9:45 a.m., N rim.
May 25, 9:55 a.m., N rim.
May 27, 10:36 a.m., N rim.
May 27, 10:46 a.m., W wall.
May 27, 1:15 p.m., N rim.
May 28, 1:33 p.m., N rim.
May 28, 1:40 p.m., N rim.
May 29, 4:55 p.m., N wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations around Halemaumau pit resulted during May in aggregate movement as follows:

Week ending forenoon of:
May 6, 28 locations, 6 opened, 2 closed, opening 2.5 mm.
May 13, 28 locations, 9 opened, 1 closed, opening 5.5 mm.
May 20, 28 locations, 7 opened, 2 closed, opening 3.0 mm.
May 27, 28 locations, 5 opened, 0 closed, opening 4.0 mm.

Chain-of-Craters Crisis

The continuous tremor that began at 6:05 a.m. May 28 and continued until 1:00 p.m. the same day marked an outbreak of seismic motion that included numerous felt earthquakes. This unusually heavy swarm of tremors and earthquakes at the Hawaiian Volcano Observatory was accompanied by visible evidence of breaking and shearing of the ground along the Chain-of-Craters road near Pauahi crater. It was remarkable that this entire seismic spasm continuing into June was localized and shallow, and even the moderate felt earthquakes of Kilauea were not felt at all in Hilo and Pahala. While some of the shocks had epicenters near Devil's Throat, slides at that overhanging pit were not reported until June. The appearance of the tremor on the seismograph record was similar to that which appears during lava movement. Recent discovery of a new hot area in the forest near Kokoolau crater makes the

Pahoehoe lava on middle platform, central crag, and southern sinkhole of Nyamlagira Crater in 1933. (Philippson).

Puna rift belt a possible location for rising lava that has been recovering its pressure since 1924. Kokoolau is a mile toward Kilauea from Devil's Throat, and the new vapors have killed the vegetation within the last year or two. The combination of events probably represents both crustal adjustments and underground lava rising.

On the evening of May 28 a large crack across the Chain-of-Craters road was reported. At least eleven sets of new cracks had developed across the road between Pauahi and Aloi pits with general direction East-West. Seventeen individual cracks were counted on the evening of May 29.

The largest break in the asphalt paving of the road near Pauahi crater had caused the pavement to cave in in a chasm widest toward the west and narrowing half-way across the road to a three-inch crack extending on in the country rock beyond. There is evidence in the bushes away from the road of an old chasm in the rock. The cracks cross the road obliquely in plan. The widest part of the big hole in the road was five to six feet across. A hump in the paving near the Devil's Throat was higher than before as tangential compression had there been at work. This hump has been growing since the road was built some years ago, and its increase, as well as the development of the Kokoolau hot area indicates that the movements of the present crisis are accelerations of a process long continued.

The evidence for shallow depth of these earthquakes, and the correspondence of the distance of epicenters with the crack area of the Chain-of-Craters, and the location of some of the shocks much closer to Kilauea, as well as the strength of the vertical record, make it certain that we have good correspondence here between deformation of the land and epicentral distance. If an outbreak of Halemaumau follows, the expectancy will agree with the outcome. T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
May 8	32	3	1	0	0	0	10.50
May 15	33	7	0	0	0	2	11.75
May 22	21	5	1	0	0	3	8.75
May 29	593	107	9	14	3	1	247.75

* Including teleseisms or earthquakes over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

May 5, 11:38 am, very feeble, 18 miles deep under area 15 miles east of Summit Crater of Mauna Loa and seven miles NW of Kilauea Crater. Reported felt at Kapapala Ranch. 19° 27.0′ N; 155° 21.5′ W.

May 5, 3:17 pm, feeble, 1.5 miles deep in SE rim area of Kilauea Crater. 19° 24.5′ N; 155° 15.6′ W.

May 6, 8:15 am, very feeble, 1.3 miles deep and 0.4 mile SE of Keanakakoi. 19° 23.9′ N; 155° 14.4′ W.

May 6, 8:18 am, very feeble, 1.7 miles deep in Kilauea Crater 1.5 miles SW of the observatory. 19° 24.7′ N; 155° 16.3′ W.

May 9, 2:30 am, very feeble, 0.9 miles deep near Puhimau Crater. 19° 23.6′ N; 155° 14.9′ W.

May 10, 3:50 pm, very feeble, 22.0 miles deep and 10.0 miles N of summit of Mauna Kea. 19° 57.5′ N; 155° 27.0′ W.

May 10, 10:05 pm, very feeble, 1.8 miles deep in Kilauea Crater 1.0 mile SW of the observatory. 19° 25.2′ N; 155° 16.1′ W. Reported felt at CCC camp NE rim of Kilauea Crater.

May 14, 3:47 am, very feeble, probably originated in Kilauea SW rift about 13.0 miles SW of the Crater.

May 15, 9:16 am, very feeble, probably of Kilauea Crater origin.

May 15, 12:44 pm, very feeble, 0.6 mile deep in SE rim area of Kilauea Crater near Keanakakoi. 19° 24.3′ N; 155° 16.1′ W.

May 16, 3:35 am, feeble, 11.0 miles deep in Hilina-Kapukapu Fault system. 4.0 miles south of Makaopuhi Crater. Reported felt rather strongly in Pahala and at Kapapala.

May 16, 4:36 am, very feeble, of Kilauea Crater origin.

May 17, 2:13 am, very feeble, 27.0 miles deep under Mauna Loa summit Crater. Reported felt at Kapapala Ranch and at Pahala. 19° 27.5′ N; 155° 33.5′ W.

May 20, 8:18 pm, very feeble, probably originated near Kokoolau Crater.

May 23, 11:33 am, very feeble, 3.2 miles under Kilauea Crater. 19° 25.1′ N; 155° 16.4′ W.

May 23, 11:46 am, feeble, of shallow origin near SE rim of Kilauea Crater in vicinity of Keanakakoi. 19″ 24.3′ N; 155° 15.9′ W.

May 23, 11:50 am, very feeble, of Kilauea Crater origin.

May 23, 1:25 pm, very feeble, 1.8 miles deep in Kilauea Crater 1.0 mile SW of the observatory. 19° 25.2′ N; 155° 16.1′ W.

May 24, 3:15 am, very feeble, probably originated in Chain-of-Craters rift near Devil's Throat.

May 28-29: beginning at 6:05 am, May 28, a period of continuous tremor lasting 414 minutes began to record at the Volcano Observatory and ended at about 1:00 pm the same day. Within that period of 7 hours there occurred 3 moderate, 12 slight, 7 feeble and 66 very feeble earthquakes for a total of 88 disturbances excluding the tremor. The greatest concentration of these was between 6:00 and 9:00 am, during which period the tremor reached its greatest intensity and there were 3 moderate, 7 slight, 4 feeble and 52 very feeble shocks. Seismic activity continued abnormally high the remainder of the week. For the entire day, May 28, there were 3 moderate, 12 slight, 7 feeble, 85 very feeble earthquakes and 499 minutes of tremor. There was considerable decrease in activity on May 29 although seismic activity was high. On that day there occurred 2 slight, 1 feeble, 16 very feeble earthquakes and 84 tremors.

Moderate earthquakes:

May 28, 6:32 am, distance from observatory 4.0 miles.
May 28, 6:52 am, distance from observatory 4.0 miles.
May 28, 6:57 am, distance from observatory 5.0 miles.

Slight earthquakes:

May 28, 6:22 am, distance from observatory 4.3 miles.
May 28, 6:33 am, distance from observatory ? miles.
May 28, 6:34 am, distance from observatory 5.0 miles.
May 28, 6:47 am, distance from observatory ? miles.
May 28, 7:26 am, distance from observatory 2.4 miles.
May 28, 8:13 am, distance from observatory 3.8 miles.
May 28, 8:21 am, distance from observatory 5.0 miles.
May 28, 9:32 am, distance from observatory 4.6 miles.
May 28, 9:38 am, distance from observatory 3.5 miles.
May 28, 10:21 am, distance from observatory 2.7 miles.
May 28, 11:07 am, distance from observatory 3.8 miles.

May 28, 11:46 am, distance from observatory, 3.2 miles.
May 29, 9:48 am, distance from observatory 4.0 miles.
May 29, 6:32 pm, distance from observatory ? miles.
Feeble earthquakes:
May 28, 6:07, 6:19, 6:32, 6:52, 8:05, 11:42 am, 12:46 pm; May 29, 10:01 pm with distances averaging about same values as slight and moderate shocks.

The 101 very feeble earthquakes were of similar origin with the exception of one that registered May 28, 7:32 pm, which apparently originated under summit crater of Mauna Loa and May 29, 12:55 pm which indicated a distance of 18.3 miles.

Residents of the Hawaii National Park and at Kilauea Military Camp were generally awakened by the first moderate shock of 6:32 am, May 28. Houses creaked, doors and windows rattled, dogs barked, pheasants squawked and hanging objects swayed. A few articles on shelves were overturned. The Bosch-Omori and vertical seismographs at the observatory and the Hawaiian type seismograph at the SE rim of Halemaumau were dismantled. Slight earthquakes and the tremor perceptably shook the ground until after the moderate shocks of 6:52 and 6:58 respectively. Although these disturbances were registered on the Hilo and Kona seismographs, the recordings were of a minor nature and the shocks were felt only a few miles from Kilauea crater.

The evening of May 28, new cracks in the Chain-of-Craters road SE of Kilauea crater were discovered. Eleven groups of them crossed the road between Pauahi and Aloi craters. Near Pauahi crater and where the most northerly of the cracks crossed the road, a section of the road caved in. The cracks ran roughly in an E-W direction.

General locations of this series of earthquakes fell within an area extending from Kilauea Crater to Alealea Crater along the Chain-of-Craters rift. Development of the road cracks was undoubtedly associated with these earth disturbances and the relationship was very close.

The moderate earthquakes of May 28 indicated greater successive distances from the observatory. The location of that of 6:32 am was 1.9 miles deep in the Chain-of-Craters area near Kokoolau Crater. 19° 23.3' N; 155° 14.6' W. The moderate shock of 6:52 am, probably originated near Devil's Throat and the one of 6:58 am, near Pauahi Crater. The earlier quakes seemed to be closer to Kilauea Crater than the later ones as though some sub-surface disturbance was from the Kilauea Crater, southeastward.

A hump in the road near Devil's Throat was noticeably increased in relative height.

Depths of the earthquakes of this series ranged from shallow ones near the surface to two and one half miles.

A portion of the preliminary waves of a teleseism began to register at Kilauea at 4h 37m 38s am, May 11; from news reports, it was located off W coast of Mexico 16° 8 N; 100° 7 W. The preliminary waves of a second teleseism began recording at 5h 19m 24s am, location in vicinity of East Papua, adjoining New Britain, 4,350 miles from Kilauea; 5° S; 147° E. At 6h 51m 05s am, May 19, the preliminary waves of a teleseism began to register, distance 5,750 miles, located 0.5° N, 119° E, near Borneo. May 22, 8h 58m 32s pm, the preliminary waves of an earthquake strongly felt in Japan began registering at the observatory. It was 3,815 miles from this station. At 10h 04m 01.0s pm, the same day the preliminary waves of a quake felt in Manila reached Kilauea; it was 5,500 miles distant. A portion of a teleseism whose reported location was in Oregon, U.S.A., began registering at Kilauea 12h 57m 51s pm, May 27. All time is Hawaiian standard.

Microseismic motion of the ground at the Observatory was moderate May 3, 13, 14, 18, 19, 20, 22, 23, 24, 27, 28 and strong the remainder of the month. H.H.W.

Tilting of the ground

The following tables show tilt by weeks as recorded by the observatory seismograph and at Halemaumau, the algebraic sum of radial tilt toward or away from the pit.

At the observatory the total accumulated tilt for the year ending May 29 was 3.5" S and 5.7" West.

Week Ending	Observatory	Halemaumau West Station
May 8	0.90" S 72° W	3.19" S 43° W
May 15	0.52" S 73° W	4.38" W
May 22	1.10" S 62° W	2.44" S 67° W
May 29	0.74" N 43° E	4.98" N 73° E

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
May 8	6.22" S 85° W	0.98" toward
May 15	7.11" N 59° W	2.16" toward
May 22	6.25" N 30° W	4.38" toward
May 29	6.09" N 3° W	9.01" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the observatory May 18, indicated slight opening of the Halemaumau value and closing of the crater value compared with similar measurements of April 20. The Halemaumau measurements from the SE Pit BM to NW Pit BM showed opening of 0.08" and the crater measurement from the SE Crater Rim to Uwekahuna showed closing of 1.74". H.H.W.

Errata:

"The Maui Earthquake of January 22, 1938," by H. H. Waesche, Asst. Geologist at the Hawaiian Volcano Observatory; Volcano Letter No. 457, March 1938, page 4, column 2, under Bosch-Omori should be iE, 10:03:22.7 pm and iN 10:03:23.7 pm (Dismantled). H.H.W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 460 monthly Department of the Interior National Park Service June 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

PLANNED PROGRAM FOR THE HAWAIIAN VOLCANO RESEARCH ASSOCIATION

By T. A. JAGGAR

The following statement on the subject of financing technical publication of the records of the Hawaiian Volcano Observatory was presented April 1, 1938, to a group of business leaders of Hawaiian industry in Honolulu at the call of the Board of Directors of the Hawaiian Volcano Research Association. The meeting was held in the Board of Directors' room of the Hawaiian Sugar Planters' Association.

The Hawaiian Volcano Observatory under the Whitney fund of Massachusetts Institute of Technology was proposed in 1909 with a view to continuous record of Kilauea and Mauna Loa volcanoes. It aimed at an engineering science of volcanic phenomena of all kinds, in order to increase safety of life and property.

The Research Association was founded to safeguard the precious records for Hawaiian use. The financing was by $5 members and voluntary contribution of donors from year to year. It was supplemented by government.

In 1933 the government cut its appropriation. This was the fourth severe crisis that had to be met. As before the Research Association and the University saved the Volcano Observatory. This was followed by an extraordinary scientific success in 1935, namely, the printed prediction of all details of a disastrous eruption of Mauna Loa. A blasting enterprise with army aid led to the eruption stopping. This had been a plan fostered by the late honored L. A. Thurston many years ago.

In 1937 another public service was inaugurated by the association, extending the national park to the whole of Mauna Loa, and surveying for barriers to defend Hilo harbor against lava flow with United States engineers as designers.

The reason for disheartening financial crises depended on the essential instability of annual congressional appropriation 5,000 miles away. The cure is to create a sponsor for technical volcanology which is permanently Hawaiian, to assist the Government.

What is technical volcanology? It is like clinical surgery. Our population is the patient. Volcanic fever or shaking is the disease. Selecting an earthquake-resistant or lava-resistant human intelligence, will make Hawaiians different from peoples of other volcanic lands. Our publications have taught foreign scientists. A Matson ship rescued the people being overwhelmed by a volcano in Papua. The British government sent to us when volcano and earthquakes were wrecking Montserrat. When Napier was demolished, New Zealand sent to Hawaii for instruments.

Volcanology has started making a volcano science publishing the results of observation. It assists soil and water geology, safety by patrols at eruptions, prediction based on history, preparedness based on organization. Hilo and Honolulu are organized.

Hawaiian volcanology has sent forth trained men: Wood at Pasadena, Finch in California and Alaska, Stearns, Powers and Wentworth in Hawaii, Perret in Martinique, Wingate, superintendent of Hawaii National Park, Wilson in Washington, Jones in oil geophysics.

Among its by products are the park itself, Uwekahuna museum and the Kilauea military camp, volcanology in California and Alaska, the Mauna Loa and Haleakala roads. In education your association has collaborated with the University of Hawaii since the college was founded. The University now helps the Association immeasurably. The Government has assisted Hawaiian volcanology liberally since 1919, under respectively weather bureau, geological survey and national parks.

Throughout all the 26 years, however, the anchor to windward that has never dragged has been the Hawaiian Volcano Research Association. Publishing an outline of observations in monthly bulletins has informed scholars what we are doing. Critical eruptions with thousands of earthquakes, and other measurements, have left voluminous records that are still not worked up. Your present director is growing old. He knows these records, notes taken by 15 former workers. They need publication as scientific memoirs during the next 10 years.

Important discovery emerges from codifying and platting the figures of old series of measurements. In 1929 we recorded times, sizes and places of 6,000 earthquakes in three weeks, North Kona was being shaken to bits. We had no time then to do more than place instruments, cheer up the ranchers, keep the recording going, and cover as much ground as possible. It is for such a crisis that we want a simple shock-recorder at every telephone exchange. I wish we had had them in Maui and Oahu on January 22, this year, 1938.

The record of 1929 contains eruptions of Kilauea in February and July, a simultaneous eruption at Tin Can island in Tonga, and the Kona earthquakes as a sign the lava of Mauna Loa was shifting northwest to a new place. The completed story is greatly needed by the British and Tongan scientists studying Samoa and New Zealand. To publish the facts of 1929 is one of many tasks lying in filing cabinets: Notes, maps, curves, photographs and seismograms.

The next eruption of Mauna Loa in December, 1933, was farther north than 1926 and wholly in the summit crater. The northern 1929 earthquake spasm informed us Pahala and Waiohinu at the south were less in danger, the Hilo direction

in greater danger. The lava outlets had migrated along the crack up the south slope to the summit ever since 1868. We studied the intervals, arrived at a probable two years after 1933 for an outbreak still farther north threatening Hilo, and published the facts. The flow came exactly two years after 1933 with outlet five miles farther north, it threatened Hilo, and the bombing deflected it.

This episode, of our Association's 26 years, is only one of many critical studies made, which are of use to this territory.

Let us look at large earthquakes: A fracture that broke open Hualalai volcano in 1800; a quake that ripped open a huge crack at Pahala in 1823; a jolt and lava flow in Puna in 1840 a terrific one with two lava flows including Mauna Loa in 1868. It suggests migration in the direction of Kohala and Maui.

Next a bad earthquake in Hilo in 1887; the 1929 series of shocks at Puuwaawaa; the January, 1938, a crash at Maui affecting Honolulu. What about the great fracture still farther northwest across the north side of Molokai? Projected westward it hits Diamond Head on the map, and Diamond Head is Honolulu city.

In all, we find a series of big earthquake spasms, extending through a century, from the Kilauea-Mauna Loa axis to the Haleakala-Kahoolawe axis. Will the Molokai-Diamond Head axis move? It is worth study.

We have many unstudied records. We need to learn everything possible about cycles and intervals, and about building codes and fire safety. Mr. Stearns is perfectly sound in recalling the Haleakala eruption of the Kaupo gap about 1750. It is merely asking, are our records, that cost us $260,000, worth preserving in permanent form before they are mere scrap paper?

The superintendent of schools, after the recent earthquake in Honolulu, wrote me asking what to do in case of severe earthquakes for reconstruction or discipline, in second class school buildings. I told him of California, New Zealand and Japan experiences, and referred him to the authorities.

The national guard officer asked me to criticize a written out problem of discipline and organization for Hilo. The terrific destruction of hospitals, roads, cliffs, drug stores, banks, water supply and docks in Napier, New Zealand, was the model. I sketched and put in print the plan of organization.

The Chamber of Commerce, during the fright of 1935 when lava was pouring down Wailuku valley above Hilo, asked what Hilo should do in case of a quicker flow from a nearer vent straight toward the harbor. We consulted engineers, studied the contour maps, examined precedents and costs, and the barrier plan was the answer. Incidentally, it turned out that such a flow is very probable.

The Association has no sufficient money in the next 10 years to print the records the society has filed. The immediate need is to publish technical results under our own imprint before the present director is incapacitated.

The national park does not publish technical volcanology. It is not economy to spend $260,000 through a quarter century for precious records, and leave them to fire and cockroaches.

The volcanologist is no more a prophet of evil than an army officer. They both have expensive jobs over large areas making war against evils.

The one has popular government money, the other is unknown. Hawaii has taken the lead to make seismic strategy known.

A famous scientist was asked by a lady, "What use is it?" He replied, "What use is a baby?" In the 19th century we had leaf hoppers, now we have parasites; then smallpox and plagues, now vaccination and quarantine; then floods and storms, now control and resistant construction; then slums and overgrown roads, now welfare and cantoneering. It took a century to persuade people to use common sense sciences.

Volcanology is a common sense science. There was earthquake, lava and tidal wave destruction, now there is earthquake proof construction, air bombing and seismic foretelling of waves. Then there was city congestion and panic, now city planning and education. Then there was resistless lava filling, now constructed barriers as planned. Then there was disaster and death, now preparedness organiaztion.

The Government offers us the plan of a $125,000 reinforced concrete building for the new volcano observatory at Kilauea, with large laboratories, library, exhibit rooms, auditorium, map room and safe storage.

A group of generous local donors has given a sum of money for beginning the publication of monographs.

Summarizing this question of publishing valuable scientific archives of the Territory of Hawaii, there is needed:

1. Fifteen thousand dollars a year for the next 10 years.
2. To get the $125,000 government laboratory proposed.
3. To complete publications in technical form.
4. To appoint a scientific board to oversee publication.
5. To shift current work and routine publication gradually to Hawaii National Park, with the consent of the park service.
6. To allow the volcanologist to edit finished reports as his chief remaining work.
7. To present this program to the Secretary of the Interior, from the Hawaiian Volcano Research Association, as representing the contributors who have accumulated these records.

Hawaiian Volcano Observatory Report for June 1938

VOLCANOLOGY

The crisis of downfaulting of benches south of Chain-of-Craters that began at the end of May continued into the first week of June, but died away completely to a quiet spell at the end of the third week, or just at the time of solstice. New cracks were discovered on the trails extending north and south from Chain-of-Craters road and about June 5 caving in of the Devil's Throat was discovered and rock falls into that pit continued for a week. It was evident that the breakage crossing the line of the Chain-of-Craters on cracks trending ENE about Pauahi Crater were now being supplemented by the breakage northeastward along the mapped cracks that lie to the southwest of the Devil's Throat. The month of June developed no sign of Halemaumau activity.

The following are the local weekly data for the month at the Observatory at Halemaumau:

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
June 5	65.00	3	3.5 mm.	195
" 12	24.50	12	2.0 mm.	80
" 19	8.00	1	3.0 mm.	24
" 25	15.00	0	0.5 mm. closed	48

Sequence of Events by Weeks

The first week produced notable reduction in the value of seismicity, the second week further reduction and increase of slides, the third week notable diminution of both, and the fourth week the ordinary increased frequency of local tremors and the registration of one distant earthquake, that would be expected after solstice.

Slides at Halemaumau

The recorded slides from the wall of the Pit were:
May 31, 10:00 a.m., 12:20 p.m., 12:29 p.m., dust cloud NE.
June 6, 11:20 a.m., 5:30 p.m., N rim.

June 8, 9:20 a.m., N rim.
June 9, 8:45 a.m., 8:50 a.m., 3:15 p.m., N rim.
June 10, 9:55 a.m., 10:45 a.m., 10:58 a.m., N rim.
June 12, 12:35 p.m., 1:25 p.m., 1:40 p.m., N rim.
June 17, 5:20 p.m., N rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim cracks located around Halemaumau pit resulted during June in aggregate movement as follows:

Week ending forenoon of:
June 3, 28 locations, 7 opened, 6 closed, opening 3.5 mm.
June 10, 28 locations, 8 opened, 5 closed, opening 2.0 mm.
June 17, 28 locations, 5 opened, 2 closed, opening 3.0 mm.
June 24, 28 locations, 2 opened, 3 closed, closing .05 mm.

Chain-of-Craters Crisis

During the week ending June 5 new cracks were discovered on the road to Ainahou Ranch leading south from Pauahi Crater; these were extensions of the cracks which had fractured the Chain-of-Craters road. Eight distinct groups of cracks were counted on the Ainahou road and one on the road leading toward Puu Huluhulu about two hundred yards from the main road leading east. All the older cracks showed some evidence of opening and in some cases down-faulting to the south was pronounced.

On June 6 cracking of the ground around Devil's Throat was discovered and there was evidence of slides from the rim of this pit within the past twenty-four hours. Most of the slides had occurred at the east and south rim, at 2:30 p.m. June 6 rocks were heard falling in Devil's Throat, and cracks were noticed in the masonry wall on its southwest side. Some new cracks were seen on the opposite side and it was evident that the circle of the pit was under stress on all sides. Rock falls continued in this pit during the remainder of the week, and the area was closed to visitors. T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly† Seismicity
June 5.....	158	31	3	2	1	1	65.00
June 12.....	68	9	3	0	0	2	24.50
June 19.....	18	5	1	0	0	1	8.00
June 26.....	40	6	2	0	0	2	15.00
July 3.....	43	10	1	1	0	0	18.75

* Including teleseisms of earthquakes over 5000 km. from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

May 30, 1:43 am, slight, 1.3 miles deep in SE portion of Kilauea Crater, 0.6 mile E of Pit Seismograph. 19° 24.4′ N; 155° 16.5′ W.

May 30, 11:52 am, very feeble, of shallow origin in rifts 1.2 miles SW of Pauahi Crater. 19° 21.6′ N; 155° 14.5′ W.

May 30, 8:54 pm, very feeble, probably originated in Kilauea SW rift about 15 miles from the crater.

May 31, 1:13 am, very feeble, probably of shallow origin, vicinity of Hiiaka crater.

May 31, 1:19 am, very feeble, of shallow origin in rifts 0.5 mile SW of Pauahi crater. 19° 22.0′ N; 155° 14.0′ W.

May 31, 4:53 am, very feeble, 1.3 miles deep under SE rim of Kilauea crater. 19° 24.5′ N; 155° 15.8′ W.

May 31, 5:58 am, feeble, originated at junction of Lele o Kalihipaa and Kalanaokuaiki Palis, 1.7 miles SW of Pauahi crater. 19° 21.4′ N; 155° 14.8′ W.

May 31, 2:16 pm, very feeble, of shallow origin, vicinity of Hilina Pali. 19° 18.8′ N; 155° 16.3′ W.

June 1, 10:27 am, feeble, 3.0 miles deep in area immediately S of Kilauea Iki. 19° 24.8′ N; 155° 15.2′ W.

June 1, 10:38 am, moderate, 7.0 miles deep in Hilina Pali area about 3.0 miles N of Apua Point. 19° 18.2′ N; 155° 11.5′ W. Dismantled seismographs at observatory and SE rim of Halemaumau.

June 1, 8:03 pm, very feeble, probably originated in vicinity of Pauahi crater.

June 2, 3:25 am, very feeble, 1.0 mile deep in Kilauea crater, SE rim cracks 0.4 mile W of Keanakakoi. 19° 24.2′ N; 155° 16.4′ W.

June 2, 4:42 am, very feeble, 12.0 miles deep, Mauna Loa NE rift 4.5 miles NE of Puu Ulaula. 19° 34.5′ N; 155° 24.5′ W.

June 2, 8:24 am, very feeble, 4.3 miles deep, N rim area of Kilauea crater. 19° 26.1′ N; 155° 16.7′ W.

June 2, 3:33 pm, slight, 15.0 miles deep, Kilauea SW rift near Koae, 3.5 miles SW of Kilauea crater. 19° 21.7′ N; 155° 19.5′ W.

June 2, 8:55 pm, very feeble, of shallow origin under Byron Ledge, E rim of Kilauea crater. 19° 24.6′ N; 155° 15.7′ W.

June 2, 10:10 pm, very feeble, 1.8 miles deep under NE portion of Kilauea crater. 19° 25.2′ N; 155° 16.2′ W.

June 4, 2:48 am, very feeble, 0.7 mile deep, SE rim of Kilauea crater. 19° 24.3′ N; 155° 15.9′ W.

June 4, 7:57 pm, very feeble, probably originated in Kilauea crater, near N rim of Halemaumau.

June 4, 9:46 pm, very feeble, 0.8 mile deep, NE portion of Kilauea crater, 0.9 mile S by E of Volcano observatory. 19° 25.2′ N; 155° 14.8′ W.

June 5, 1:18 am, very feeble, of shallow origin, near center of Kilauea crater.

June 5, 1:47 am, feeble, 1.0 mile deep near center of Kilauea crater, 0.6 mile NE of Pit seismograph. 19° 24.7′ N; 155° 16.7′ W. Reported felt by many in Hawaii National Park.

June 6, 1:14 am, feeble, probably originated in cracks about 1.0 mile W of Hiiaka crater. Reported felt by many in Hawaii National Park.

June 6, 7:46 am, very feeble, probably originated in Chain-of-Craters area, vicinity of Hiiaka and Devil's Throat.

June 6, 11:53 am, very feeble, probably originated in rifts, 1.0 mile W of Pauahi crater.

June 7, 11:59 pm, very feeble, 1.7 miles deep under Byron Ledge, E rim of Kilauea crater. 19° 24.9′ N; 155° 15.6′ W.

June 8, 12:07 am, very feeble, 1.8 miles deep in E portion of Kilauea crater. 19° 24.8′ N; 155° 15.9′ W.

June 8, 5:39 am, feeble, of shallow origin in fault blocks along NE rim of Kilauea crater. 19° 25.7′ N; 155° 15.8′ W. Felt by several around National Park Headquarters area.

June 8, 8:32 pm, very feeble, thought to have originated in NE portion of Kilauea crater.

June 9, 7:17 am, very feeble, of shallow origin, SE rim area of Kilauea crater. 19° 24.3′ N; 155° 15.8′ W. Reported felt by few in the National Park.

June 10, 12:27 am, very feeble, 1.1 miles deep in E central

portion of Kilauea crater. 19° 24.8′ N; 155° 16.2′ W.

June 10, 12:51 am, feeble, 1.4 miles deep, E portion of Kilauea crater near Byron Ledge. 19° 25.0′ N; 155° 15.8′ W. Reported felt at new CCC Camp and by residents along NE rim of Kilauea crater.

June 12, 3:39 pm, very feeble, of shallow origin in Kilauea crater about 1.2 miles NE of Pit seismograph. 19° 25.0′ N; 155° 16.7′ W.

June 14, 12:13 am, 1.5 miles deep in NE portion of Kilauea crater. 19° 25.4′ N; 155° 15.9′ W.

June 17, 5:18 am, very feeble, 0.5 mile deep, E portion of Kilauea crater. 19° 24.8′ N; 155° 15.8′ W.

June 17, 7:34 pm, very feeble, probably of shallow origin in NE portion of Kilauea crater.

June 18, 6:26 am, feeble, 1.1 miles deep, in N portion of Kilauea crater. 19° 25.5′ N; 155° 15.4′ W.

June 19, 12:55 pm, very feeble, 1.3 miles deep near center of Kilauea crater (NE rim area of Halemaumau) 19° 25.0′ N; 155° 16.8′ W.

June 19, 6:59 pm, very feeble, probably originated in NE portion of Kilauea crater.

June 20, 10:01 am, very feeble, 1.0 mile deep in N portion of Kilauea crater about 1.0 mile NE of Uwekahuna. 19° 25.9′ N; 155° 16.6′ W.

June 20, 5:22 pm, very feeble, 2.2 miles deep, Chain-of-Craters, near Pauahi crater. 19° 22.4′ N; 155° 13.7′ W.

June 23, 5:46 am, feeble, 1.2 miles deep E portion of Kilauea crater. 19° 24.8′ N; 155° 16.0′ W. Reported felt at new CCC camp and at the observatory.

June 23, 5:53 am, very feeble, of shallow origin near center of Kilauea crater, 1.0 mile NE of Pit seismograph. 19° 24.9′ N; 155° 16.4′ W.

June 26, 1:45 am, feeble, 1.8 miles deep in E portion of Kilauea crater. 19° 24.8′ N; 155° 16.0′ W.

June 27, 1:58 pm, very feeble, 0.8 mile deep, E rim area of Kilauea crater. 19° 24.8′ N; 155° 15.9′ W.

June 27, 3:23 pm, very feeble, of Kilauea crater origin.

June 28, 12:30 pm, very feeble, probably of shallow origin in Kilauea crater near E rim of Halemaumau.

June 30, 11:42 pm, very feeble, 19.0 miles deep under Mauna Loa, 3.0 miles NE by N of Summit crater. 19° 32.2′ N; 155° 33.8′ W.

July 2, 1:29 pm, very feeble, 21.0 miles deep, Mauna Loa NE rift, 9.0 miles NE of Puu Ulaula. 19° 35.5′ N; 155° 20.2′ W. Reported felt strongly at Kapapala Ranch.

July 2, 2:20 pm, slight, 8.0 miles deep in Chain-of-Craters rift 6.0 miles SE of the Volcano observatory. 19° 23.0′ N; 155° 11.5′ W. Reported felt at Kapapala and in National Park area.

July 2, 3:16 pm, feeble, 10.0 miles deep, in Kilauea SW rift 6.0 miles SW of the crater. 19° 22.0′ N; 155° 22.2′ W.

Distant Earthquakes

May 30, "P" waves at 4h 09m o3s am, located 3660 miles from Kilauea. 20° 4′ S; 169° 4′ E in the Solomon Island area.

June 8, "S" waves at 9h 7m 25s am, origin in the Molluca Sea, Dutch East Indies, 5550 miles from Kilauea. 3° 1′ S; 125° 7′ E.

June 9, "P" waves, 11 h 35 m 22s pm, originated off NE coast of Formosa, 5000 miles from Kilauea. 25° 2′ N; 124° 6′ E.

June 15, "P" waves, 3h 56m 22s pm, off the SW tip of Kyushu Japan along E border of China Sea. 29° 2′ N; 127° 7′ E. Distance 4750 miles.

June 20, unidentified portion began to register at 3h 50m 04s am.

June 23, "P" waves at 2h 34m 43s am, located in the vicinity of New Hebrides, 3615 miles from this station. 19° 1′ S; 168° 9′ E.

Hawaiian standard time used in above reports.

Microseismic motion of the ground at the observatory light June 10, 12, 14 to 25 and June 30 to July 3; moderate May 30, June 2 to 6, June 9, 11, 13 and 26 to 29, dates inclusive. It was strong May 31, June 1, 7 and 8. H.H.W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the observatory seismograph and at Halemaumau, the algebraic sum of radial tilt toward or away from the Pit.

At the observatory the total accumulated tilt for the year ending July 3 was 3.76" S and 6.42" W.

Week Ending	Observatory	Halemaumau West Station
June 5	0.75" S 42° W	6.20" S 16° W
June 12	0.16" S 46° E	8.02" N 68° W
June 19	0.67" N 27° E	4.44" W
June 26	0.54" N 12° W	4.32" S 78° W
July 3	0.62" N 10° W	2.18" S 81° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
June 5	7.91" S 27° E	9.56" from
June 12	1.65" N 69° W	5.85" from
June 19	6.54" N 35° W	1.85" toward
June 26	10.11" N 85° W	2.33" toward
July 3	4.28" N 55° W	1.80" toward

Crater Angles

Measurement of horizontal angles across Kilauea crater from the observatory June 17, indicated closing of both the Halemaumau value and the total crater value. The Halemaumau measurement from the SE Pit BM to NW Pit BM showed closing of 0.84" and the crater measurement from the SE crater Rim to Uwekahuna showed closing of 1.66".

H.H.W.

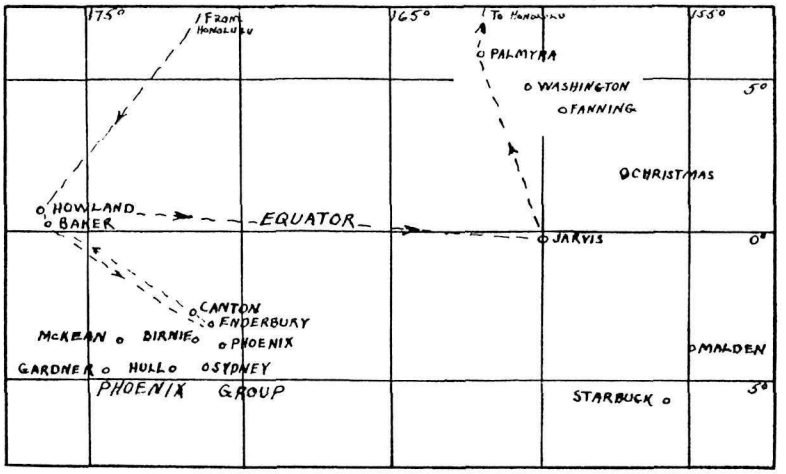
THE VOLCANO LETTER

461

No. 461 monthly Department of the Interior National Park Service July 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Map of Pacific Equatorial Islands showing route of the 1938 Spring expedition of the Roger B. Taney.

AN EQUATORIAL CRUISE

By Hugh H. Waesche, Assistant Geologist

For some years the Department of the Interior of the United States government has sponsored and maintained colonists on the tiny Pacific Equatorial Islands, Howland, Baker and Jarvis. Reference to the accompanying map will show their location to other islands. These pin-points of coral sand are not suitable for sustaining human life as they are practically of desert climate. This has necessitated regular trips to the Islands to deliver supplies to, and replacements in, the colonizing personnel. The colonists who are young Hawaiian men are transferred from island to island and are not allowed to remain away from their homes in Hawaii for more than nine consecutive months at a time. Transportation to and from the islands is part of the regular duties of the U. S. Coast Guard. The Cutter, "Roger B. Taney," makes about three trips per year to these Islands, usually late autumn, early spring and mid-summer.

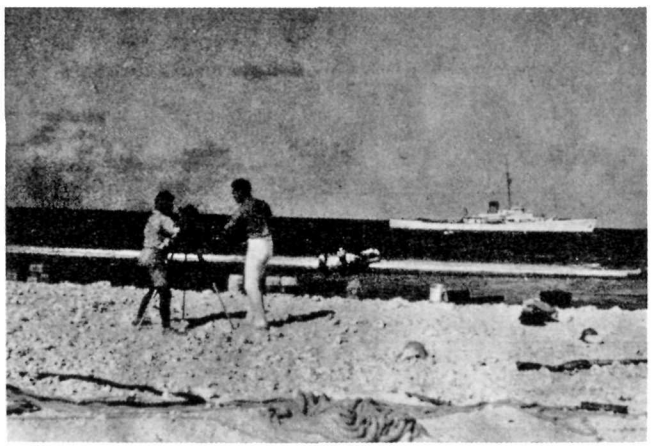
Mr. E. G. Wingate, superintendent of Hawaii National Park, conceived the idea of some member of the Observatory staff making one of these trips to make general observations, the main issue being the practicability of establishing seismograph stations as an aid in seismological studies of the mid-Pacific areas. Selected for this reconnaissance were Messrs. S. H. Lamb, Park Naturalist, and Hugh H. Waesche, Assistant Geologist of the Hawaiian Volcano Observatory. Mr. Lamb was to make natural history studies of fauna and flora, and Mr. Waesche was to set up instruments for seismometric studies.

There was no opportunity to construct a conventional seismograph. The alternative was to take shock recorders of the mercury cup, annunciator type, developed during the past year by Dr. T. A. Jaggar for use on the Island of Hawaii. These instruments are of little value for recording distant earthquakes but have been of value in studies of local shocks. They are relatively sensitive and will readily indicate the very feeble earthquakes which are not generally felt here in Hawaii. These shock recorders register only maximum intensity for any particular shock giving no indication of phase. They are designed for use by people who have no technical training whatever. Registration of any earthquake is accomplished by annunciators which show a number from one to six, depending on the intensity of the earthquake. Once an earthquake has recorded, the value remains until reset to zero manually, by the observer. If a number of such seismoscopes were well distributed over an area, they should show relative increases of intensity toward the epicenter from all directions with diminishing values in the opposite directions. As no seismologists or otherwise scientifically trained men were among the colonists of the Equatorial Islands the shock recorders were apparently the most desirable; also they were easily portable and could be set up in any given locality with only a screw driver and a pair of pliers in a few minutes. No record paper was necessary, with the other complications which go with recording devices either on smoked paper or by photographic means. All that was necessary was a solid base and daily observation. These were assured.

Two of the shock recorders were available so were crated and prepared for shipment to Honolulu. No definite locality was predetermined for their placement. They were to be placed on the most desirable islands with regard to location and per-

sonnel. Tentatively chosen were Howland and Jarvis if landing were easy; they are widely separated giving a desirable variation of location. On arrival in Honolulu the instruments were put aboard the Cutter and preparations made for the expedition.

The "Taney" sailed from Honolulu at 5:00 p.m. Sunday, February 16, 1938. After four rather uneventful days the party arrived off Howland Island. At 7:00 a.m., March 4, a change in the colony personnel was made but no supplies were taken ashore. That afternoon a landing was made through heavy surf at nearby Baker. Originally Howland Island had been considered as the probable location of one of the shock recorders. However, the day before arrival there, Mr. Black announced that a colony was to be established on Canton Island in the Phoenix Group and suggested that one of the shock recorders be placed on it as the greatest number of more technically skilled colonists were to be there, and that both a shelter and concrete base for the instrument would be found, left by the eclipse expedition the preceding year.



Landing supplies at Enderbury.

Howland Island is located about forty miles north of the Equator and about one hundred miles west of the 175th meridian. Baker Island is about thirty-five miles S. by E. of Howland and the two might well be considered together. They are similar in appearance, geology, and climate. Both are of coral, shells, and lithothamnia and might well have been atolls or parts of atolls formerly although there is no water in their interiors at present. In the vast Pacific Ocean, both are mere specks of land. Howland Island is elongated in shape in a more or less N-S direction with a length of about three and one half miles and a maximum width of about 1.1 miles. Maximum elevation about mean sea level is about ten feet. Baker Island is smaller than Howland, not so elongated, and has a maximum elevation of about fifteen feet. They are saucer-shaped with high ridges of coral sand and debris along the shore line and the low points near, or only slightly above sea level toward their interiors. No evidence of rocks other than of coral or marine organic life were noticed on this trip nor have been reported by any previous visitors. Along the beach are coral sands of varying texture and rather massive reef rock and coral conglomerate near the water's edge. Inland, the sand was of fine texture with accumulations of bird guano in all low or basin areas. As in some other Pacific Islands this guano had been previously worked for commercial use.

The climate of the two islands is quite uniform. This is true of the temperature in particular which probably does not vary greatly from a minimum of about 78° to a maximum of 94° F. daily. Precipitation is light, mostly falling at night or in the early morning before daybreak. Sun pouring on the brilliant white coral sand is reflected as heat. The rising hot air causes rain-producing clouds approaching the islands either to break up or dissipate. Many observers report that clouds moving from the east with the prevailing winds will separate on reaching the edge of the island and pass to the north and south. As would be expected, vegetation is scant. Christophersen reports Boerhaavia and Portulaca as abundant in open spaces. A few clumps of Cordia were reported also on Howland. Attempts are being made to develop a growth of coconut palms brought with soil from Palmyra, but the results so far have not been promising.

Gas-operated lighthouses have been constructed by the colonists on both Howland and Baker. They are automatic and will operate for six months or more without attention. They are about twenty-five feet in height. The lighthouse at Howland has a diorite or similar dark igneous block above the doorway inscribed "Amelia Earhart, 1937" and is a memorial to that flyer who was lost while enroute to tiny Howland Island from New Zealand.

After brief stops at Baker and Howland Islands the "Taney" headed in a southeasterly direction, crossing the Equator about 6:30 p.m. Friday, March 4. On Saturday morning ceremonies were held on deck for benefit of those who had never crossed the "Line" before. King Neptune and Court saw to it that all "pollywogs" became "shellbacks."

Enderbury Island was sighted early the morning of Sunday the 6th. Like Howland and Baker, bright coral sand which reflected the sun's rays with great intensity was the first thing to impress the visitor. It was in strong contrast to the surrounding blue sea. Work of unloading supplies for the new colony to be established was started immediately. Food and water, the latter in old oil drums, were taken ashore. The food was taken through the surf in ship's boats. The water was floated ashore in the drums. This was accomplished by removing one gallon of water from each drug, lashing four to six of them together and then towing them from ship to island. The fresh water in the drums also added to their buoyancy.

Except for thousands of booby (gannet) and frigate (man-o'-war) birds, Enderbury was uninhabited. There were also in evidence the red-tailed tropic bird and several varieties of terns including the very beautiful "love-bird". The latter are snow-white and hover in pairs over the heads of intruders. They seem as though carved from exceptionally white porcelain. The "Taney" remained throughout the day, but sailed for Canton after sundown, leaving a camp, complete supplies and four Hawaiian colonists behind.

Enderbury Island is similar to Howland. It is a coral island about three miles long and one mile wide. It, too, is saucer-shaped with a decided depression toward its center. The low areas are partially filled with soft muddy materials which are principally bird guano. Around one of the muddy areas were several small coconut palms. At the southeastern end of the island were many large angular blocks of rock. From the ship these seemed dark and even looked as though they might be igneous rocks. Close observation showed them to be coral conglomerates evidently tossed upon the beach by wave action.

Enderbury is located about three degrees below the Equator and about one hundred and seventy-one degrees west. Canton Island, the most northerly of the Phoenix group, is about forty-three miles to the northwest.

A party from the "Taney" landed on Canton about 9:00 a.m. Monday, March 7. The American colonists began immediately to put up a temporary camp and to land supplies. As had been anticipated by Mr. Black, an old building with a concrete floor had been left by the Eclipse Expedition of 1937 (see National Geographic Magazine, June 1938). That afternoon a shock recorder was brought ashore and placed in oper-

ation. It was oriented to record earth waves only in a N-S direction. At the Hawaiian Volcano Observatory these shock recorders vibrate with slight motion of the pen continuously. This is probably caused by the microseismic motion of the ground. Vibration of the same nature was observed at Canton. In Hawaii wave motion of the sea on the NE shore of the Island is a suspected cause. This view might be even more readily acceptable on Canton where the motion of the sea acts only on a very narrow strip of land.

Canton is a typical coral atoll. A strip of coral sand and coral conglomerate, 150 feet to a third of a mile in width, almost completely enclosing a shallow coral-bottomed lagoon about nine miles long and three miles wide. The distance along the atoll around the lagoon is reputed to be about twenty-seven miles. To the southwest of the lagoon is a channel connecting it with the open sea. The channel is deep enough for small boats and if deepened could be utilized by larger craft. At



View at Canton Island. Shock recorder located in long low building at right.

various times of the day strong currents move in the channel so that it is used only at times when these are not dangerous. The channel may be as much as a quarter of a mile wide. It is well filled with large sharks which seem to prefer that locality to any other.

The atoll has two beaches, one to the open sea and one to the lagoon. Exploration of the area around the western lip of the channel revealed only coral sand, fragments and conglomerate. What appeared to be a peculiar rounded earthen mound about a mile and a half from camp turned out to be only a kou tree about twenty feet high which afforded a nesting place for a multitude of birds. The beach to the open sea along the southeast portion is broken by the presence of large quantities of angular slabs of coral conglomerate similar to the ones observed on Enderbury. On the lagoon side the beach is smooth, made up of coral sand and small shell fragments. Tide and waves in the lagoon have had a sorting effect, as various shells and sizes of sand show definite zones of stratification. Low areas lie inland between the beaches, and they as on the other islands contain deposits of guano. Also, one part of Canton rises some twenty feet above sea level.

The climate is mild, has steady easterly winds and a temperature maximum in the daytime of between 85° and 90° F. Rainfall is scant, but enough for several groves of coconut palms to have obtained a good start.

Monday night, March 7, 1938, the "Taney" returned to Enderbury. It remained there until noon Tuesday, completing final arrangements for the party left behind, and then returned to Canton, arriving there at 4:00 p.m. On Tuesday the shock recorder was again checked and it was moved to a more desirable location in the same building, and oriented for E-W movement instead of N-S as previously set up. Final instructions were given to an army sergeant who was to observe the instrument periodically. No registration occurred the two days the writer was at Canton. Apparently none has occurred since. It is not like a volcanic region where local shocks would be expected. A seismograph for recording of distant earthquakes located on Canton should produce some interesting results.

Wednesday evening, March 9, the "Taney" sailed for Howland and Baker Islands, arriving at the former at 8:30 a.m. Friday. By 1:00 p.m. landing of supplies and replacement of colonists had been completed and the ship left for Baker, which was reached at 4:30 p.m. Supplies were landed there and then at 8:20 p.m. the "Taney" again sailed for Howland to transfer a colonist to that island from Baker. Early Saturday morning, March 12, the "Taney" headed east for Jarvis Island nearly one thousand miles away. It was reached early the morning of March 15.

Jarvis is another isolated, saucer-shaped coral island. It is small, having a land area of 1.7 miles. It is about one mile wide and two miles long. The location is 160° W. longitude, 00° 23' S latitude. Jarvis is probably higher above sea level than any of the other islands visited. The beach slopes steeply up from the sea to a rim twenty feet or more above. This rim encircles the entire island. Toward the interior there is a gentle slope which produces the saucer effect. The lowest portion of the depression is in places slightly below sea level, and over most of the area is probably between this low and an elevation of ten feet. As was true of the other islands, the interior depressions are collecting spots for bird guano. The beach is made up of coral sand, and shell fragments of other marine organisms. Along most of the north and east shores there is a bench along the lower portion of the seaward slope. The bench is made up of stratified calcareous conglomerates which have been formed by cementation and consolidation of beach deposits. They are made up of corals and corallines and remains of other marine organisms. Above the conglomerate along the northeast shore are flat, roughly circular coral rocks tossed up by the waves and lying at low angles. Wentworth calls these "coral shingles." They were undoubtedly formed by wave action which was responsible both for their shape and location.

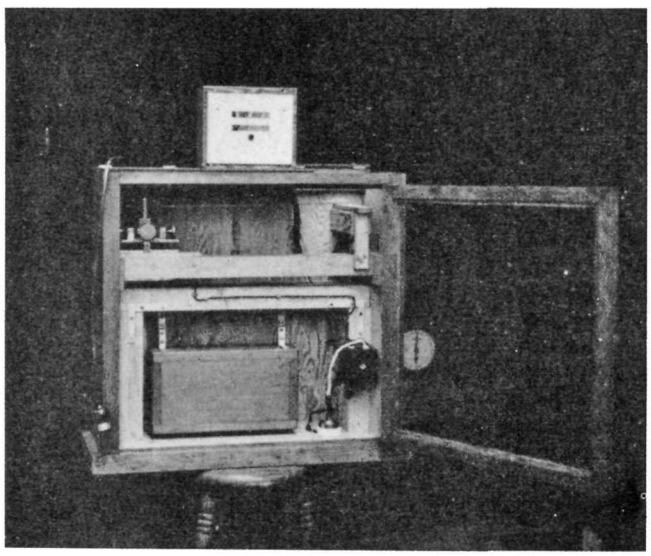
The second shock recorder was taken ashore at Jarvis and set up for operation. The only concrete base available was the floor of the lighthouse. This was considered desirable at first, but Mr. Edgecombe thought that it would be dangerous to place an electrical recording device which produced open sparks so near the gas supply. As an alternate the recorder was set up temporarily in the living quarters of the colonists. This proved very unsatisfactory as the moving of the people around the house caused a great deal of disturbance to the instrument. It was finally decided that the instrument be left in the house as set up but with the current shut off until the colonists stationed at Jarvis could build a concrete base and small shelter nearby. This has been done with the shock recorder oriented to record motion in a N-S direction, at right angles to the one left on Canton.

Explorations of the west and northwest beaches of Jarvis were made and the interesting remains of the barkentine "Amaranth" wrecked in 1913 were examined. It was apparently loaded with coal as pebbles of the black material are well distributed along the adjoining beach. These pebbles are well rounded and water worn.

The "Taney" left Jarvis the same day and sailed for its last stop of the trip, Palmyra Island, where it arrived in the early morning of Thursday, March 17. The day was very stormy with heavy rainfall. The small tree-covered islets composing Pal-

myra were visible only rarely during the day. Crew members fishing off the stern caught several black-finned sharks and a few red snappers. The sky cleared after sundown. Many "booby" birds and terns hovered about the ship throughout the day and several "boobies" flew aboard after dark attracted by the lights.

It had been agreed that there would be a landing party the next day regardless of weather conditions. Conditions were much more favorable on the morning of March 18, so that two of the ship's boats were sent as near the island as feasible. Two small boats with outboard motors were also towed in and with the party were landed on Home Island. From Home Island the party went across the large western lagoon to Cooper Island on the north side. After exploration there the boats returned across the lagoon to the south side, landing in the vicinity of



Type of shock recorder left on Canton and Jarvis Islands.

Paradise Islet. Lunch was eaten on the south side of that island. Soon after noon rain squalls began and occurred at intervals the remainder of the afternoon. A number of pictures were obtained in the morning but weather conditions prevented photographic work later in the day. Most of the afternoon was utilized in making underwater observations of marine life in the channels around Home and Paradise Islets and on the coral shelf to the west of the group.

Palmyra Island, otherwise known as Samarang or Palmoore, is located in the north Pacific Ocean 960 miles S. by W. of the city of Honolulu, Hawaii. Latitude 5° 53' North, longitude 162° 05' W. The island is a regular atoll, well covered with vegetation wherein it differs from other equatorial islands such as Jarvis and Howland. Altogether, Palmyra consists of a group of some fifty-two islets all of which are projections above the ocean surface from one underlying mass of coral growth and debris occupying a space of five and two-thirds miles in an east-west direction and one and one-half miles in the north-south direction. Including the entire extension of reef under water the length is nearly eight miles, east-west. The atoll encloses three large lagoons and one small one. All the larger lagoons have depths of at least twenty fathoms and the large western lagoon has a depth of 28 fathoms. In one of the lagoons are several small islets which are exposed at low tide. The greatest elevation is located on Eastern Islet and is about six feet above sea level. The U. S. Hydrographic Chart gives a maximum elevation of the trees as 91 feet above sea level and these may be observed from a ship 15-20 miles at sea. The largest islet is 46 acres in area and the smallest is reputed to be 0.47 acres.

An extensive coral flat extends to the westward of the islet for about three miles from the shore line where the depth is 6-7 fathoms at high tide. More or less cylindrical coral heads rise from the shelf nearly to the water's surface and are often five feet or more in diameter. Their number increases toward the island proper where the water becomes very shallow and a person can readily walk on the coral bottom. Boat landings can only be made in this vicinity at high tide, and it is the only portion of the island group where one may go ashore safely. At low tide no boats can pass over the coral shelf nearer than one mile from the shore.

Heavy surf af white-foamed breakers continuously roars against the reef from the open sea, to the north, east and south. They are never more than a few hundred feet from shore. This condition is to be expected as Palmyra is in the trade wind area of prevailing northeast and southeast winds the year around. This also accounts for the western side or lee side being the only safe landing point.

On the lagoon side the islets are bordered by strips of white coral sand which may extend inward in the form of spits. At high tide this sand is covered by about ten inches of water; at low tide it is often exposed and dry with never over an inch or two of water. The islets are separated by narrow channels through which flows considerable current at high tide. At low tide the channels are often blocked or the current obstructed by sand bars on the lagoon side. They deepen seaward. It is possible to walk between most of the islands as the water in the channels is seldom more than waist deep. The bottom is sandy toward the lagoon and becomes more rugged with new coral growth toward the sea. This is a natural gradation typical of atolls in general.

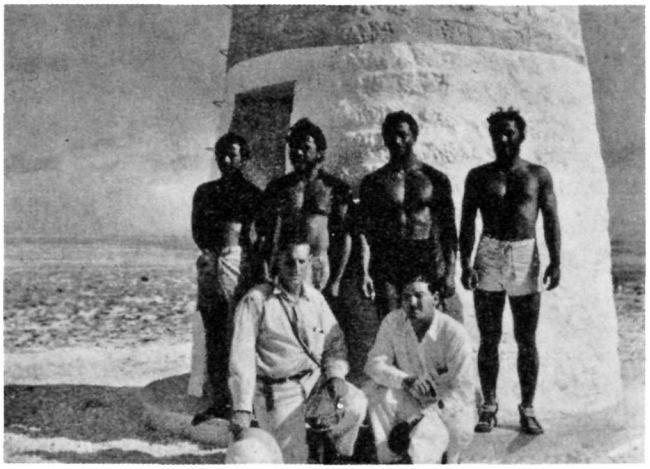
The weather at Palmyra is probably rather uniform. No visits to the island have apparently been of length sufficient to make accurate observations. The dense vegetative cover of the island indicates ample rainfall. Determinations for short periods indicate a rainfall of at least one hundred inches per year and probably as much as one hundred and fifty inches per year. All visitors report rain at Palmyra and heavy rainfall occurred the two days of this visit. Daily and yearly temperature range is probably not great. Rock reports a high of 90° during the day and a low of 78° during the night. Tropic islands completely surrounded by ocean and far from other land masses are likely to have a mild and equitable climate.

Palmyra is near no existing commercial ocean traffic lane. It is reached only by privately owned vessels capable of making long ocean voyages or by government vessels of the Coast Guard or Navy. Some people of the Hawaiian Islands visit the island annually in privately owned ships.

The map of Palmyra shows that the group is open at the western end and closed with a point at the eastern end. Prevailing winds and ocean currents from a general easterly direction are probably responsible for this condition as this fits in with the general rule. According to such a rule the coral growth should be most favored on the current side and along the northern and southern tip extremities of the western end of the island where the seaward current carrying the greatest quantities of coral food is likely to flow by and eddy backward, greatly retarded in speed. Corals and calcareous algae are sensitive marine organisms demanding close adjustment of temperature, depth, aeration, condition of water and amount of sandy material present. As a result coral growth would be accelerated on the windward, and less on the more protected, portions of the island. This is borne out by the facts illustrated by the reef extension to the westward and the diminishing of coral growth inward from the sea in the inter-island channels. Coral growth is greatly retarded in the lagoons and over the

entire area surrounded by the islets, where sand and debris brought in from the sea is deposited, destroying the living coral.

During the approach of high tide and for considerable time afterward there is much scouring action in the channels which keeps their seaward end very clean. The slowing of the current in passing through the channels causes deposition of the sand to build fans and shoals into the lagoon. Presumably this process continued over a long period would cause the filling up and elimination of the lagoon, which would go through a brackish marsh stage before attaining that end. After the lagoon had been filled by debris in this manner it seems likely that eventually wave action building up the resulting shore line would produce the elongated saucer type of coral island so common in the South Pacific. Probably because of the open west end on the lee side offering less resistance to the flow of water, the current return to the ocean at low tide seemed to be



Typical colonists on Jarvis Island.

less through channels than at high tide inflow. This also would tend to increase the chance of eventual elimination of the channels by building up from the sea. The heavy surf on the seaward side of the island prevents accumulation of sand or small debris in spits or bars. The outer beaches are of sand and some of coarse gravel and Tridacna shells.

Some coral grows in the inner lagoons contributing to the building processes but is much less vigorous than that on the outer portions of the island, as debris accumulation in the interior is more plentiful and food less available. The inner beaches are formed of fine coral and shell-fragment sand which at some localities become a fine mud quite soft, and often ankle deep. Heavy rains wash great quantities of bird guano into these mud flats. Beach water-lines fluctuate widely between high and low tide over these areas because of their very low angle of deposition. No evidence points to former sea levels above the present ocean level. The inner portions of the various islets are made up of coarse detrital materials with a few composed of calcareous sandstones and conglomerates. The islands to the east are apparently the youngest, and no doubt other islands may develop even farther eastward superseding the existing line of growth.

In order to make proper tide connections the return to the ship was made at 4:00 p.m. Stormy weather was again in evidence on the morning of March 19th. One squall about 8:00 a.m. with a wind velocity of over 60 miles per hour tore away a large portion of the "Taney's" awning. It was thought that weather conditions would not improve so the ship weighed anchor and set a course for Honolulu. The ship arrived at that port at 6:00 p.m., March 21, ending a most interesting cruise of 23 days.

References

1. Christophersen, E.; Vegetation of Pacific Equatorial Islands, Bernice P. Bishop Museum Bulletin 44, Whippoorwill Expedition Publication Number 2, 1927.
2. Emory, Kenneth P.; Archaeology of the Pacific Equatorial Islands, Bernice P. Bishop Museum Bulletin 123, Whippoorwill Expedition, Publication Number 4, 1937.
3. Rock, Joseph F.; Palmyra Island, Honolulu Star-Bulletin, 1916.
4. Wentworth, Chester K.; Bernice P. Bishop Museum, B., Occasional Papers, Volume IX, Number 15, Whippoorwill Expedition, Publication Number 15, Whippoorwill Expedition, Publication Number 3, 1931.
5. Gardner, Irvine C.; Crusoes of Canton Island, The National Geographic Magazine, Vol. LXXIII, Number 6, pp. 749-766, June 1938.

Hawaiian Volcano Observatory Report for July 1938

VOLCANOLOGY

With the exception of the last two weeks of July rock slides from the north and east rim walls of Halemaumau were numerous during the month. The excessive sliding of the first fortnight along with several earthquakes indicating origins of about Halemaumau distance (2 miles) and the occurrence of higher seismicity after the sliding stopped, justifies the inquiry whether the recent fault movements southeast are extending themselves to the Kilauea block. Fuming from the southeast solfatara on the floor has continued. Seismic activity has been ordinary with most of the disturbances indicating Kilauea origins. Three felt earthquakes July 2 were of Mauna Loa origin. The Kona seismograph recorded only five small disturbances, indicating that there is only minor activity taking place under Mauna Loa and Hualalai. Kilauea seems to be currently the most active volcanic center on Hawaii. Two rather feebly recorded distant earthquakes were registered during the week ending July 24.

Observations from time to time of the cracks in the vicinity of Pauahi crater have been made and slight earth movements there are continuing, with a tendency shown both on the ground and by seismic distances for the fault movements to extend themselves northwestward. The hump in the road near Devil's Throat has increased in height. The large crack near Pauahi pit increased in width with increased downthrow to the southeast. The large crack near Aloi pit has widened. Systematic measuring of these cracks is provided for.

Temperature measurements at the hot area near Kokoolau pit have been made with highest readings about 85° C. The area does not appear to have increased its dimensions.

The Chief Ranger reported the discovery Friday, July 15, on an inspection trip to patrol the telephone line, along the trail up Mauna Loa northeast of the summit, that new cracks about four inches wide broke the surface of the trail at three places. The first one encountered was about 1.5 miles above Puu Ulaula resthouse at elevation 10,800 feet approximately; the other two were in the vicinity of 12,000 feet elevation, or about opposite and to the east of the main cone source of the 1935 flow. This is important as suggesting a breakage on the rift belt of Mauna Loa farther east than the fracture of 1935. It is worthy of note that earthquakes near Puu Ulaula shook Mauna Loa after the middle of January 1938, when the startling earthquake of Maui and Honolulu occurred: and that ten days before the earthquake crisis at Chain-of-Craters began, a deep earthquake occurred under Mauna Loa summit crater. These two Mauna Loa seismic events may be correlated with the new cracks.

The following are the local weekly data for the month of July at the Observatory and Halemaumau.

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
July 3	18.75	30	7.0 mm.	55
" 10	10.25	15	0.5 mm.	17
" 17	18.25	28	0.0 mm.	50
" 24	23.25	3	3.5 mm.	67
" 31	20.00	3	0.5 mm. closed	60

One slight and two very feeble earthquakes were felt at Kapapala Ranch July 2. One very feeble earthquake July 13 was felt in Kilauea National Park.

Sequence of Events by Weeks

The first week was notable for many Halemaumau slides and Mauna Loa earthquakes. Slides continued the second week but tremors were less frequent. During the third week slips of rock from the wall of Halemaumau were numerous around the northern and eastern rims and seismic activity increased both at Kilauea and Mauna Loa. For the fourth week numbers of slides decreased to a low figure but earthquakes and tremors increased in number. The fifth week showed Halemaumau very quiet with reference to both slides and crack movements but seismicity remained high; many shocks were of Kilauea origin, a few showed Mauna Loa distance and one seismogram indicated Hualalai.

Slides at Halemaumau

The recorded slides from the wall of the Pit were:

July 1, 8:58 a.m. to 12:58 p.m., 13 slides N and NE.

July 2, 9:32 a.m. to 2:47 p.m., 14 slides N and NE.

July 3, 10:08 a.m., 1:03 p.m., 1:40 p.m., slides from northern walls.

July 4, 1:05 p.m., small slide from new crack high up N wall; rocks dribbled down SW and N walls for a half hour.

July 5, 12:57 p.m., slide N rim.

July 6, 9:33 a.m., 3:29 p.m., 3:37 p.m., 3:41 p.m., N rim.

July 7, 10:49 a.m., 11:19 a.m., N rim.

July 9, 9:45 a.m., 10:00 a.m., 10:45 a.m., 1:07 p.m., 1:30 p.m., 2:50 p.m., northern walls.

July 11, 9:00 a.m., 9:28 a.m., 9:35 a.m., 10:10 a.m., 10:11 a.m., 11:03 a.m., 11:11 a.m., slides from N, NE or E walls.

July 11, 6:47 p.m., dust clouds N rim, indicated large slide.

July 13, 8:50 a.m. to 12:05 p.m., 18 slides from N, NE and E walls.

July 15, 10:00 a.m., N rim.

July 17, 10:40 a.m., 1:13 p.m., northern wall slide.

July 18, 3:43 p.m., NE rim.

July 20, 9:45 a.m., N rim.

July 28, 9:10 a.m., NE rim.

July 28, 9:50 a.m., 10:05 a.m., N rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations around Halemaumau pit resulted during July in aggregate movement as follows:

Week ending forenoon of:

July 1, 28 locations, 11 opened, 1 closed, opening 7.0 mm.
July 8, 28 locations, 2 opened, 3 closed, opening 0.5 mm.
July 15, 28 locations, 5 opened, 5 closed, opening 0.0 mm.
July 22, 28 locations, 4 opened, 1 closed, opening 3.5 mm.
July 29, 28 locations, 3 opened, 4 closed, closing 0.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly† Seismicity
July 10	35	3	0	0	10.25
July 17	33	14	3	0	18.25
July 24	45	20	2	2	23.25
July 31	42	17	1	0	20.50

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.



Frigate birds, found on all islands except Palmyra.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

July 4, 2:13 pm, very feeble, probably originated near Pauahi crater.

July 7, 1:56 pm, very feeble, 0.4 mile deep in E portion of Kilauea crater. 19° 24.7' N; 155° 16.0' W.

July 12, 9:58 am, very feeble, of shallow origin, Kilauea SE crater rim. 19° 24.2' N; 155° 16.3'W.

July 13, 10:45 am, feeble, 0.9 mile deep, Kilauea crater, 1.2 miles E of Halemaumau. 19° 24.6' N; 155° 15.7' W.

July 15, 4:12 am, feeble, location same as preceding.

July 15, 4:58 am, very feeble, 0.6 mile deep in Kilauea crater rim area near Kilauea Iki. 19° 25.1' N; 155° 15.4' W.

July 15, 5:34 am, very feeble, probably originated in Chain of Craters rift near Lua Manu.

July 15, 5:56 am, feeble, 1.6 miles deep in NW portion of Kilauea crater. 19° 25.7' N; 155° 16.7' W.

July 15, 11:04 pm, very feeble, probably originated in Chain of Craters rift near Lua Manu.

July 16, 6:52 am, very feeble, 1.4 miles deep, E rim of Kilauea crater, 19° 24.9' N; 155° 15.7' W.

July 17, 8:49 pm, very feeble, of shallow origin, NW rim area of Kilauea crater, 1.1 miles SW of the Observatory. 19° 25.2' N; 155° 16.2' W.

July 17, 10:51 pm, very feeble, 0.7 mile deep in Kilauea crater, 1.1 miles SW of the Observatory. 19° 25.2' N; 155° 16.2' W.

July 18, 4:37 am, very feeble, 1.0 mile deep, Waldron Ledge, NE rim of Kilauea crater. 19° 25.4′ N; 155° 15.5′ W.

July 19, 12:36 am, feeble, of shallow origin (0.3 mile), Kilauea crater, 0.4 mile E by N of pit seismograph. 19° 24.4′ N; 155° 16.3′ W.

July 19, 3:58 am, very feeble, of shallow origin 0.5 mile SE of pit seismograph. 19° 24.1′ N; 155° 16.6′ W.

July 21, 2:36 pm, very feeble, 0.6 mile deep SE rim, Kilauea crater, 1.6 miles E of pit seismograph. 19° 24.2′ N; 155° 15.5′ W.

July 22, 4:29 am, very feeble, 1.7 miles deep, Kilauea crater, 1.2 miles NE of pit seismograph. 19° 25.1′ N; 155° 16.4′ W.

July 22, 4:42 am, very feeble, 0.7 mile deep near Puhimau crater. 19° 24.0′ N; 155° 15.3′ W.

July 22, 5:02 am, very feeble, 0.8 mile deep, NE rim Kilauea crater (Byron Ledge), near Kilauea Iki. 19° 25.2′ N; 155° 15.6′ W.

July 22, 5:49 pm, very feeble, of shallow origin E rim of Kilauea crater. 19° 24.6′ N; 155° 15.7′ W. Felt in National Park residential area.

July 22, 7:32 pm, very feeble, 1.0 mile deep under N portion of Halemaumau. 19° 24.8′ N; 155° 17.2′ W.

July 23, 9:38 am, very feeble, probably originated in vicinity of Kilauea Iki.

July 23, 4:06 pm, very feeble, of Kilauea crater origin.

July 23, 10:09 pm, very feeble, probably originated in N central portion of Kilauea crater.

July 24, 12:54 am, very feeble, probably of Kilauea crater origin.

July 24, 5:20 am, very feeble, probably originated in Chain of Craters near Puhimau.

July 24, 7:51 pm, feeble, of shallow origin (0.6 mile) in SE rim area of Kilauea crater. 19° 24.5′ N; 155° 16.1′ W.

July 25, 7:16 am, very feeble, of Kilauea crater origin.

July 25, 9:31 am, very feeble, 1.5 miles deep, NW rim of Kilauea crater 0.5 mile NE of Uwekahuna. 19° 25.7′ N; 155° 17.1′ W.

July 28, 7:50 am, very feeble, probably originated in Mauna Loa NE rift in vicinity of Puu Ulaula.

July 30, 11:36 am, very feeble, 1.4 miles deep in NE portion of Kilauea crater, 1.4 miles NE of pit seismograph. 19° 25.2′ N; 155° 16.1′ W.

July 30, 9:43 pm, very feeble, 1.7 miles deep, 1.6 miles SE of pit seismograph in vicinity of Puhimau. 19° 23.6′ N; 155° 15.8′ W.

July 30, 9:50 pm, feeble, 0.7 mile deep Kilauea crater, 1.0 mile NE of pit seismograph. 19° 24.9′ N; 155° 16.3′ W.

July 31, 2:54 am, very feeble, 1.5 miles deep, E portion of Kilauea crater. 19° 24.8′ N; 155° 15.9′ W.

July 31, 8:27 am, very feeble, of Kilauea crater origin.

July 31, 8:45 am, very feeble, 2.0 miles deep N central portion of Kilauea crater. 19° 15.1′ N; 155° 16.4′ W.

At 11:49 am, July 9, 22 minutes of continuous tremor began to register.

Distant Earthquakes:

July 21, unidentified portion began recording at the Observatory at 9h 37m 24s pm, H.S.T.

July 24, unidentified portion, 3h 00m 30s am, H. S. T.

Microseismic motion of the ground at the Observatory was light July 4-8, 13, 14, 19-25; moderate July 9, 11, 12, 15-18, 26-31 and strong July 10.

Tilting of the Ground:

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the pit.

At the Observatory the total accumulated tilt for the year ending July 31 was 1.85″ S and 6.30″ W.

Week Ending	Observatory	Halemaumau West Station
July 10	0.61″ N 26° E	5.00″ N 75° W
July 17	0.56″ N 35° W	4.71″ S 75° W
July 24	0.87″ N 14° W	4.47″ S 85° W
July 31	0.85″ N 50° E	4.83″ S 65° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
July 10	4.73″ S 55° E	9.14″ from
July 17	12.70″ N 22° W	7.38″ toward
July 24	5.60″ N 37° W	1.03″ toward
July 31	3.24″ S 47° E	7.71 from

Crater Angles:

Measurement of horizontal angles across Kilauea crater from the Observatory July 21 indicated closing of both the Halemaumau value and the total crater value. The Halemaumau measurement from the SE pit BM to NW pit BM showed closing of 0.83″ and the crater measurement from the SE crater rim to Uwekahuna showed closing of 0.84″.

H.H.W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 462 Department of the Interior National Park Service August-December, 1938

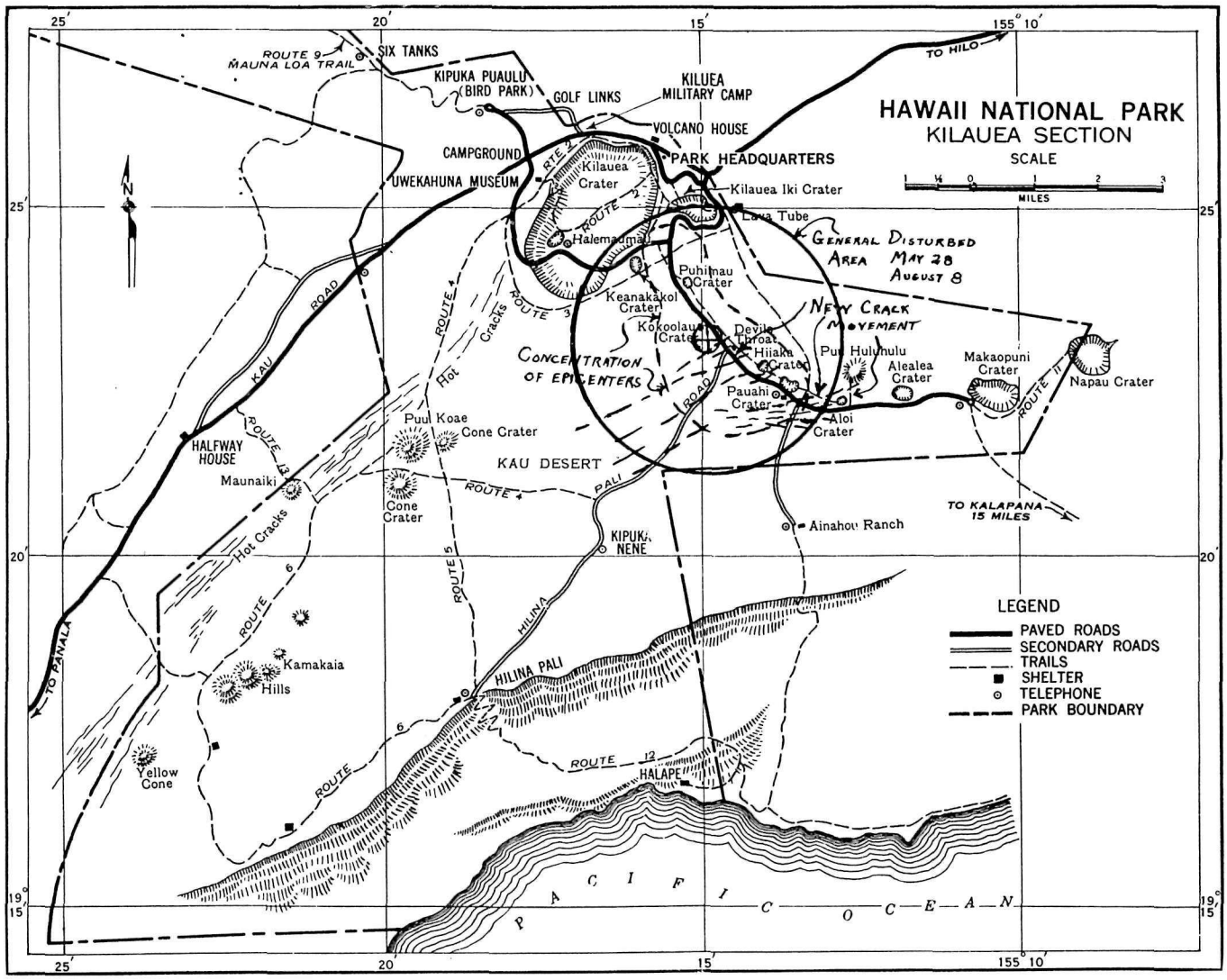
Edward G. Wingate Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

NOTICE CONCERNING PUBLICATIONS

This number of the Volcano Letter completes the 1938 series, and is published by the University of Hawaii. Hereafter the Letter will be published as a quarterly and will be sent out from the publication office of the University of Hawaii. Members of the Hawaii Volcano Research Association will receive it without cost.

The Third Special Report of the Hawaiian Volcano Observatory has been published by the Hawaiian Volcano Research Association: Ash Formations of the Island of Hawaii, Chester K. Wentworth, 1938, pp. 183; and is ready for distribution upon application to the Secretary, 320 Jas. Campbell Bldg., Honolulu, T. H. $3.00 per copy, postage free.



Map of disturbed area, Chain-of-Craters. Hot vapor killing vegetation is between Kokoolau and Keanakakoi.

Hawaiian Volcano Observatory Report for August-December 1938

VOLCANOLOGY

AUGUST 1938

During this month there was another disturbance of the fault blocks making new crack movement along Chain-of-Craters road similar to the one of May 28, 1938. There were felt earthquakes the forenoon of August 8, the road hump near Devil's Throat increased in elevation, eight new cracks were found between Devil's Throat and Hiiaka pit, and a large number of local shocks were registered instrumentally during the second week of the month. They were not felt in Hilo, but eleven shocks August 8-10 were from Mauna Loa. There were slides in Devil's Throat and Pauahi pit.

Opening of cracks in the road near Devil's Throat amounted to 2.5 and 4.00 mm. between August 10 and 12. The third week two Devil's Throat cracks opened 7.5 mm., and of three cracks between Pauahi and Aloi pits two opened 8.5 mm. The fourth week, of seven cracks marked along the Chain-of-Craters road, one at Devil's Throat opened 1.0 mm., another a half mile east of Pauahi opened 16.0 mm., and one near Aloi closed 14.5 mm. A heavy slide from the west rim of Pauahi crater occurred August 26. Kilauea quakes had decreased in number after August 14 and all but two of the measured shocks showed Mauna Loa distances.

The following are the local data for August:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
August 7	0	0.0 mm.	26
" 14	5	7.0 mm.	454
" 21	0	1.0 mm.	24
" 28	0	5.0 mm.	11

SEPTEMBER, 1938

Slides September 3 at the north wall of Kilauea crater made a new talus there. The week ending September 5 showed some recurrence of movement along Chain-of-Craters rift with settlement of the rim of Pauahi pit, and a new crack at Devil's Throat. On September 26 the large road crack near Pauahi crater caved in farther under the impact of a car.

Inspection of northeast rift of Mauna Loa September 15 showed recent disturbance of the new cracks at 11,000 feet elevation, and the 1935 cone was fuming and depositing sulphur.

The following are the local data for September:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
September 4	3	1.5 mm.	11
" 11	5	2.5 mm.	11
" 18	2	0.5 mm. closing	9
" 25	1	7.5 mm.	11
October 2	0	5.5 mm. closing	12

OCTOBER 1938

The first week of the month produced no earthquakes and few tremors although there was increase of slides at Halemaumau. During the second week there were no slides and only two small earthquakes. The third week was seismically the quietest of the year to date. The last week produced an earthquake at 6:12 p.m. October 27 on the southwest rift of Mauna Loa that cracked a concrete floor in the village of Naalehu.

The following are the local data for October:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
October 9	24	2.5 mm.	12
" 16	0	5.5 mm.	13
" 23	1	0.5 mm.	6
" 30	0	2.5 mm.	12

NOVEMBER 1938

The month was notable in the Pacific area in producing eleven distant earthquakes, and the local field here was extraordinary in developing large numbers of small slides from the Halemaumau wall, and also some avalanches from the northern corner of Kilauea crater. It is remarkable that the measured local earthquakes of the fortnight ending November 27 were dominantly from sources in the island not within Kilauea Volcano, although there were great numbers of Halemaumau slides.

The following are the local data for November:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
November 6	3 (Kilauea)	0.0 mm.	33
" 13	1 (Halemaumau)	4.5 mm.	10
" 20	23 "	4.0 mm.	24
" 27	93 "	3.5 mm.	30

DECEMBER 1938

The first week showed slides in some of the pits of Chain-of-Craters, and also on the Puna cliffs towards the sea. There was one day of slides in Halemaumau. During the third week some motion occurred along the Chain-of-Craters.

Inspection of Mauna Loa northeast rift December 9-10 showed the upper cone of 1935 steaming and smelling of sulphur dioxide and hydrogen sulphide; parts of the bright yellow sulphur coatings had the orange tinge of either iron or selenium.

The following are the local data for December:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
December 4	7	4.5 mm.	38
" 11	0	1.0 mm.	8
" 18	3	3.5 mm.	17
" 25	0	2.0 mm.	14

T.A.J.

SEISMOLOGY AND GROUND MEASUREMENTS

Earthquakes

AUGUST 1938

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
Aug. 7	17	9	0	0	0	0	8.75
Aug. 14	1,014	184	56	36	3	0	482.50
Aug. 21	17	6	1	0	0	0	8.25
Aug. 28	10	1	0	0	0	0	3.00

† Including teleseisms or earthquakes of over 5000 km from Kilauea.

* For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

August 2, 8:51 am, very feeble, probably originated near center of Kilauea Crater.

August 2, 9:17 am, very feeble, probably originated in NE portion of Kilauea Crater.

August 3, 9:53 am, very feeble, probably originated near center of Kilauea Crater.

August 4, 9:50 pm, very feeble, same as preceding.

August 5, 8:59 pm, very feeble, 0.9 mile deep under Byron Ledge. 19° 25.5′ N; 155° 15.5′ W.

August 6, 2:59 am, very feeble, 12.0 miles deep under Mauna Kea about 5.0 miles S of Summit. 19° 45.5′ N; 155° 27.0′ W.

During the week, August 7-14 inclusive, 454 local seismic disturbances were recorded on the seismographs of the Hawaiian Volcano Observatory. Between midnight August 7 and 2:10 am August 8, there were three tremors and one very feeble earthquake. At 2:14 am, 840 minutes of continuous tremor began to register, ending at 4:38 pm August 8. During the remainder of the day there were 74 tremors, 184 very feeble, 56 feeble, 36 slight and 3 moderate earthquakes.

The moderate earthquakes were:

5:12 am, 1.3 miles deep, 0.4 miles SW of Hiiaka Crater.

9:44 am, thought to have originated in the vicinity of Devil's Throat.

11:41 am, probably originated in cracks about 0.6 mile W of Kokoolau Crater.

It may be noted that the three were successively closer to Kilauea Crater, indicating distances from the Observatory of 4.7, 3.5 and 3.2 miles respectively.

These and associated shocks were felt by most residents of Hawaii National Park. Those asleep were awakened by the early disturbances. The swarm of earthquakes began after the continuous tremor. The shocks were not felt at any great distance from Kilauea Crater.

For the week there are the following data:

Date	Disturbances	Minutes of Tremor*	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes
Aug. 8	323	917	166	45	31	3
Aug. 9	83	60	11	8	4	....
Aug. 10	22	16	4	1	1	....
Aug. 11	10	8	2	....	....	....
Aug. 12	6	6	....	....	....	....
Aug. 13	8	5	1	2	....	....
Aug. 14	2	2	....	....	....	....
Totals	454	1,014	184	56	36	3

* —840 continuous and 77 spasmodic.

Focal distances of the shocks were between 0.5 and 6.0 miles from the Observatory. The circle on the accompanying map shows the general area of disturbance. The majority of the shocks were located by determinations derived from a study of seismograms from the Observatory, Pit and Uwekahuna seismographs. The epicenters thus determined fell within the irregular area inside the circle on the map. The center of the circle (+) was apparently the center of greatest disturbance and was determined by averaging all the S-P values from the three stations mentioned above. The earthquakes were most strongly felt within the areas indicated. The fact that they were not felt at any great distance (probably not over 7.0 miles) from their source indicates they were local to the Kilauea Crater area, particularly in the Chain-of-Craters to the SE and were of shallow origin. By graphic methods of determination depth of focus was in no case more than two miles. Most were less than 1.0 mile and in many cases appeared to have been less than 0.5 mile. A substantial number indicated depths of 1.5 to 1.8 miles.

Accompanying the earthquakes there was apparently considerable movement of probably preexisting cracks between Kokoolau and Hiiaka Craters. The cracks which had shown movement during May disturbances apparently changed slightly. The latter were located between Pauahi and Aloi Craters. Concentric cracks around Devil's Throat increased and more rockfalls from the rim occurred. Slides also occurred in Pauahi. The hump in the Chain-of-Craters road near Devil's Throat increased in height and the road surface was considerably fractured. Other cracks opened 10 feet north. Three sets of cracks in the road developed to the S of Devil's Throat, i.e., between Devil's Throat and Hiiaka and on the S rim of Hiiaka. Many shocks originated in Kilauea Crater.

One slight shock felt at Kapapala Ranch at 9:45 am, August 8, was apparently located 15.0 miles deep in the Hilina Fault system 7.5 miles SW of the Observatory. 19° 19.0′ N; 155° 15.0′ W.

Another (very feeble) from same general locality registered at 5:53 pm. A third (very feeble) located in Hilina Fault System near the junction with the SW rift 8.0 miles deep occurred at 1:24 am, August 10. 19° 16.0′ N; 155° 19.5′ W.

Other August earthquakes were:

August 15, 6:46 am, very feeble, originated 8.0 miles deep in Kilauea SW rift, 13.0 miles from Halemaumau. 19° 14.5′ N; 155° 24.0′ W.

August 15, 6:14 pm, very feeble, 2.0 miles deep, SE portion of Kilauea Crater. 19° 24.7′ N; 155° 26.1′ W.

August 16, 7:43 pm, feeble, 25.0 miles deep under Mauna Loa, about 20.0 miles W of Kilauea Crater. 19° 25.0′ N; 155° 34.0′ W. Strongly felt in Pahala and at Kapapala Ranch.

August 20, 3:12 pm, very feeble, 2.0 miles deep, Kalanaokoai Pali, 2.0 miles WSW of Pauahi Crater.

August 20, 5:06 pm, very feeble, 14.0 miles deep, Mauna Loa NE rift about 3.0 miles E of Puu Ulaula. 19° 32.5′ N; 155° 26.0′ W.

August 22, 1:19 am, very feeble, 15.0 miles deep, Mauna Loa SW rift, 14.0 miles SW of summit. 19° 18.5′ N; 155° 43.5′ W.

Microseismic motion of the ground at the Observatory was light August 1-8; moderate August 9-13, 18, 24-28 and strong August 14-17, 19-23 inclusive.

Tilting of the Ground.

The following tables show tilt by weeks as recorded by the observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 28 was 1.49″ S and 6.6″ W.

Week Ending	Observatory	Halemaumau West Station
August 7	0.40″ N 15° W	3.19″ N 75° W
August 14	1.20″ N 42° E	8.08″ N 60° W
August 21	0.32″ S 59° W	4.17″ N 69° W
August 28	0.12″ N 68° E	1.61″ S 50° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
August 7	8.42″ N 54° W	5.15″ toward
August 14	10.69″ N 39° W	4.13″ toward
August 21	7.06″ N 72° W	4.01″ from
August 28	2.79″ N 72° W	1.09″ toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory August 10 and 22, indicated slight opening of the Halemaumau value and closing of the total Crater value compared with similar measurements July 21. Between July 21 and August 10, the Halemaumau measurement from SE Pit BM to NW Pit BM showed closing of 0.26″ and between August 10 and 22, opening of 0.59″. Total opening 0.33″. Between July 21 and August 10 the Crater measurement from SE rim station to Uwekahuna showed opening of 0.67″ and between August 10 and 22, closing of 1.01″. Total closing 0.34″.

H.H.W.

Earthquakes

SEPTEMBER 1938

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly† Seismicity
September 4	7	3	1	1	4.25
September 11	10	1	0	0	3.00
September 18	6	3	0	0	3.00
September 25	8	3	0	0	3.50
October 2	9	3	0	0	3.75

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.



New hump in road near Devil's Throat, May and August 1938.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

August 29, 2:30 pm, very feeble, 10.0 miles deep. Mauna Loa NE rift 4.0 miles NE of center of summit crater. 19° 30.5′ N; 155° 32.2′ W.

September 2, 2:53 am, feeble, 13.0 miles deep, Kilauea SW rift, 8.0 miles SW of Halemaumau. 19° 20.0′ N; 155° 23.0′ W. Reported felt at Kapalapala and Pahala.

September 2, 4:09 am, very feeble, 17.0 miles deep, Mauna Loa NE rift, 7.0 miles NE of summit crater. 19° 31.5′ N; 155° 29.0′ W. Reported felt at Kapalapala Ranch.

September 3, 7:13 am, very feeble, probably originated about 4.6 miles S of Pit seismograph station in Kalanaokuaiki.

September 9, 6:58 am, very feeble, probably located in Kilauea SW rift near Pahala.

September 14, 5:38 pm, very feeble, 1.6 miles deep in vicinity of Puu Huluhulu, Chain-of-Craters rift. 19° 22.7′ N; 155° 12.6′ W.

September 16, 2:42 pm, very feeble, 1.8 miles deep in Kalanaokuaiki fault, 1.8 miles E of Puu Ohale. 19° 21.2′ N; 155° 15.2′ W.

September 21, 6:17 pm, very feeble, probably originated in Kilauea SW rift about 11.0 miles SW of Halemaumau.

September 24, 1;49 pm, very feeble, 11.0 miles deep, 3.0 miles N of Halfway House between Kilauea and Mauna Loa. 19° 21.4′ N; 155° 25.2′ W.

October 1, 9:04 pm, very feeble, 2.8 miles deep, near center of Kilauea Crater. 19° 25.1′ N; 155° 16.4′ W.

Distant Earthquakes

"P" waves began recording at Kilauea at 1h 30m 33s am, H.S.T., August 30. Distance from the Observatory estimated at 4,400 miles.

Microseismic motion of the ground at the Observatory was light September 3, moderate August 29, 31, September 1, 2, 4, 5, 10-15 and strong August 30, September 6-9, 16-30 and October 1 and 2.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending October 2, was 0.73" S and 5.36" W.

Week Ending	Observatory	Halemaumau West Station
September 4	0.72" N 65° E	2.38" N 41° W
September 11	0.70" N 24° E	3.73" N 45° W
September 18	0.84" N 39° E	6.05" N 80° W
September 25	0.70" N 24° E	2.00" N 20° W
October 2	0.75" S 4° W	1.85" S 61° W

Week ending	Halemaumau Southeast Station	Halemaumau Resultant
September 4	4.57" S 16° E	5.41" from
September 11	10.40" N 39° W	7.99" toward
September 18	5.64" N 4° E	1.43" from
September 25	14.42" N 31° W	13.49" toward
October 2	8.88" N 63° W	6.30" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, September 7 and 22, indicated closing of the Halemaumau value and closing of the total Crater value compared with similar measurements August 22. Between August 22 and September 7, the Halemaumau measurement from SE Pit BM to NW Pit BM showed closing of 2.66" and between September 7 and September 22, closing of 0.58". Total closing 3.24". Between August 22 and September 7 the Crater measurement from SE rim station to Uwekehuna showed closing of 0.66" and between September 7 and 22 closing of 0.67". Total closing 1.33".

Levelling at Kilauea

Since December 9, 1937 three sets of levels have been run in Kilauea Crater from the S pit BM, SE rim area of Kilauea Crater and the NW pit BM on the NW rim of Halemaumau. The first run, February 8, 1938 showed a relative lowering of NW pit BM with reference to S pit BM of 6.7 centimeters within the preceding two-month period. Similar measurements July 24, indicated a raising of the NW pit BM of 4.6 centimeters since February 8 and from July 24 to September 15, a raising of 0.5 centimeter. As in the February run, the last two are with reference to the S pit BM. It is possible that the movement indicated February 8, may have been a raising of S pit with reference to NW pit and in the last two cases S pit may have lowered. The latter movement seems quite plausible in view of recent visible earth movements along Chain-of-Craters road where cracks indicate apparent downward movements to the south. These measurements give only relative changes between two stations with no reference in either case to changes relative to sea-level.

H.H.W.

OCTOBER 1938

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Slight	Distant*	Weekly† Seismicity
October 9.....	12	0	0	0	3.00
October 16.....	11	2	0	0	3.75
October 23.....	5	1	0	2	1.75
October 30.....	7	3	2	0	7.25

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

October 10, 11:52 am, very feeble, 4.7 miles deep, NW rim area of Kilauea Crater about 0.5 mile N of Uwekahuna, 19° 25.7′ N; 155° 17.4′ W.

October 13, 5:09 am, very feeble, 33.0 miles deep, Hualalai-Puu Waawaa area. 19° 47.0′ N; 155° 52.7′ W.

October 19, 7:25 am, very feeble, 15.0 miles deep in Chain-of-Craters area 4.0 miles SE of the Observatory, 19° 23.4′ N; 155° 13.6′ W.

October 25, 12:18 pm, slight, 16.0 miles deep, near Glenwood, 18.5 miles SSW of Hilo. 19° 27.8′ N; 155° 09.5′ W. Reported felt by many in Hilo and by a few in Hawaii National Park.

October 26, 9:38 am, very feeble, 2.6 miles deep in Chain-of-Craters, vicinity of Aloi and Puu Huluhulu. 19° 22.1′ N; 155° 12.6′ W.

October 27, 6:11 pm, slight, 15.0 miles deep under Hualalai. 19° 42.0′ N; 155° 50.2′ W. Reported felt by many in Kona and at Naalehu.

October 29, 7:07 am, very feeble, of Mauna Loa origin.

October 30, 2:46 am, very feeble, probably originated south of Kilauea Crater in cracks near Puu Ohale.

Distant Earthquakes

"P" waves began recording at Kilauea at 4h 01m 58s pm, H.S.T., October 19. Probably originated about 5500 miles from the Observatory.

Unidentified portion began registering at 1h 10m 56s am, H.S.T., October 20.

Microseismic motion of the ground at the Observatory was light October 13, 14, 15; moderate October 12, 16, 17, and strong the remainder of the month.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending October 30, was 0.52" N and 4.74" W.

Week Ending	Observatory	Halemaumau West Station
October 9	1.22" N 40° E	5.00" S 43° W
October 16	0.12" W	2.68" N 18° W
October 23	0.15" S	4.53" S 83° W
October 30	1.24" N 19° E	5.96" N 73° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
October 9	4.96" N 63° W	0.64" toward
October 16	2.92 S 20° W	2.22" from
October 23	10.27" S 40° W	6.90" from
October 30	4.44" N 47° W	1.13" from

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, October 11 and 25, indicated little change in the Halemaumau value but closing of the Crater value compared with similar measurements September 22. Between September 22 and October 11, the Halemaumau measurement from SE pit BM to NW pit BM showed closing of 0.43" and between October 11 and 25, opening of 0.50". Total opening 0.07". Between September 22 and October 11, the Crater measurement from SE rim station to Uwekahuna showed closing of 1.66" and between October 11 and October 25, closing of 0.50". Total closing 2.17".

H.H.W.

NOVEMBER 1938

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Distant*	Weekly† Seismicity
November 6.....	26	6	1	4	10.50
November 13.....	31	2	1	4	9.75
November 20.....	18	7	1	2	9.00
November 27.....	24	6	0	1	9.00

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

October 31, 1:05 pm, very feeble, 20.0 miles deep, Hualalai, 5.0 miles SE of summit. 19° 39.2′ N; 155° 47.7′ W. Reported felt at Puu Waawaa ranch house.

November 2, 12:14 am, very feeble, probable origin, E portion of Kilauea Crater.

November 3, 12:53 pm, very feeble, probable origin, Hilina Fault system about 4.0 miles SE of Makaopuhi.

November 4, 7:40 am, very feeble, 2.8 miles deep in N portion of Kilauea Crater. 19° 25.6′ N; 155° 16.6′ W.

November 5, 10:37 am, very feeble, 1.7 miles deep, 0.5 mile NE of Hiiaka Crater. 19° 23.0′ N; 155° 13.6′ W.

November 5, 10:27 pm, feeble, 2.0 miles deep, 0.4 mile W of Kokoolau. 19° 23.2′ N; 155° 15.2′ W.

November 7, 6:15 am, feeble, 25.0 miles deep, 4.0 miles W of summit of Hualalai. 19° 42.8′ N; 155° 56.0′ W. Reported felt in Kona district.

November 9, 12:01 am, very feeble, probably originated in NE rim area of Kilauea Crater.

November 12, 9:37 pm, very feeble, probably originated in NE rim area of Kilauea Crater.

November 14, 12:17 am, very feeble, probably originated under Halemaumau, Kilauea Crater.

November 18, 2:29 am, very feeble, 28.0 miles deep, 10

miles W by S of summit of Mauna Kea, 14 miles E by N of Puu Waawaa. 19° 47.8′ N; 155° 38.0′ W.

November 18, 3:48 am, very feeble, 3.8 miles deep, 0.8 mile S of Pauahi Crater. 19° 21.7′ N; 155° 13.4′ W.

November 20, 5:31 pm, feeble, 13.0 miles deep in Hilina-Kapukapu fault system, 4.0 miles S by W of Makaopuhi. 19° 19.0′ N; 155° 12.0′ W. Reported felt by several persons in Hawaii National Park Headquarters area.

November 20, 6:08 pm, very feeble, probably originated in Hilina fault system about 3.0 miles SE of Kamakaia Hills.

November 21, 11:13 pm, very feeble, probably originated near Kokoolau, Chain-of-Craters.

November 22, 10:48 am, very feeble, of Mauna Loa origin, NE rift.

November 27, 9:21 am, very feeble, of Kilauea Crater origin, vicinity of Halemaumau.

Four minutes of continuous tremor registered November 10, beginning at 10:33 am. The tremor was superimposed on a portion of a teleseism. At Halemaumau it was equivalent in size to a feeble shock so probably originated in Kilauea Crater near Halemaumau.

Three minutes of tremor registered November 16 beginning at 4:09 pm.

Teleseisms

November 4, 10h 23m 20s pm, "P" waves, distance from Kilauea 3775 miles.

November 5, 12h 30m 05s am, "P" waves, distance 4025 miles. Located in Northern Japan where some damage resulted. Also reported felt in Tokyo.

November 5, 10h, 33m 41s pm, "P" waves, distance 3880 miles.

November 6, 11h 18m 37s am, "P" waves, distance 3550 miles.

November 8, 11h 13m 18s pm, unidentified portion.

November 10, 9h 55m 42s am, "P" waves, distance 2485 miles. Apparent location was near Shumagin Islands off S coast of Alaska. U.S.C. & G.S. location of origin was 55° N; 159° S. Seismographic registration of this shock was unusually strong throughout the world. Maximum waves dismantled Bosch-Omori seismograph at the Hawaiian Volcano Observatory at 10:07 am. Small tidal wave was observed in Hawaiian Islands between 3:00 and 3:30 pm. Reported felt over large portion of Alaska but no damage reported.

November 10, 2h 34m 49s pm, "P" waves, distance 3370 miles.

November 13, 12h 49m 42s pm, unidentified portion.

November 14, 1h 46m 09s am, unidentified portion.

November 16, 5h 31m 37s pm, "P" waves, distance 2420 miles. According to news dispatches, originated Aleutian Islands, Alaska, at approximately same locality as earthquake of November 10.

November 21, 2h 54m 02s pm, "P" waves, distance 3725 miles.

Time used above is Hawaiian Standard, 10h 30m behind G.C.T.

Microseismic motion of the ground at the observatory was moderate December 17, 18, 19 and 26 and was strong the remainder of the month.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 27 was 1.1" S and 4.43" M.

Week Ending	Observatory	Halemaumau West Station
November 6	0.92" S 20° E	2.68" S 75° W
November 13	1.13" N 80° E	4.17" N 40° W
November 20	0.40" S 47° W	6.05" S 77° W
November 27	0.93" N 35° E	3.33" S 55° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
November 6	3.30" S 80° W	1.08" from
November 13	3.24" N 5° W	0.97" from
November 20	2.91" N 71° W	3.68" from
November 27	3.89" N 55° W	0.73" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, November 23, indicated closing of the Halemaumau value and opening of the Crater value compared with similar measurements made October 25. During that period the angle between SE pit BM and NW pit BM closed 1.58" and the angle between SE rim Station and Uwekahuna opened 1.48". H.H.W.

DECEMBER 1938

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Distant*	Weekly† Seismicity
December 4	23	11	4	1	15.25
December 11	6	2	0	0	2.50
December 18	20	6	0	0	8.00
December 25	21	2	0	0	6.25
January 1	9	5	0	0	4.75

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

November 28, 2.03 pm, very feeble, 1.8 miles deep, 1.0 mile west of Puhimau and 0.6 mile south of Keanakakoi in Chain-of-Craters, 19° 23.7′ N; 155° 15.9′ west.

November 29, 5:43 am, feeble, 4.0 miles deep in SW portion of Kilauea Crater immediately W of Halemaumau. 19° 24.7′ N; 155° 17.6′ W. Reported felt in Hawaii National Park.

November 29, 9:59 am, very feeble, probably originated in Chain-of-Craters area near Kokoolau.

November 29, 10:18 am, very feeble, of Kilauea Crater origin.

November 29, 10:19 am, feeble, of Kilauea origin. Reported felt in national park residential area.

November 30, 4:17 am, very feeble, probably originated in Kilauea SW rift about 2.0 miles from Halemaumau.

November 30, 2:05 p.m., very feeble, of shallow origin in Chain-of-Craters near Puhimau and Kokoolau. 19° 23.4′ N; 155° 15.2′ W.

November 30, 3:08 pm, feeble, 3.2 miles deep, Chain-of-Craters, 1.0 mile N of Hiiaka. 19° 23.5′ N; 155° 14.1′ W. Reported felt in national park residential area.

November 30, 3:13 pm, very feeble, 1.2 miles deep, 0.8 mile E of Keanakakoi, 19° 24.2′ N; 155° 15.2′ W.

November 30, 8:57 pm, feeble, 4.0 miles deep, 1.4 miles W of Pauahi Crater. 19° 22.3′ N; 155° 14.8′ W. Reported felt in Hawaii National Park residential area and at CCC camp.

December 1, 4:32 pm, very feeble, location approximately same as preceding shock.

December 2, 6:53 pm, very feeble, 8.0 miles deep, Mauna Loa NE rift 3.5 miles SW of Puu Ulaula. 19° 30.7′ N; 155° 31.0′ W.

December 2, 9:27 pm, very feeble, same general locality as preceding shock. 19° 31.5′ N; 155° 31.0′ W.

December 4, 4:32 am, very feeble, originated in Mauna Loa NE rift near Puu Kulua.

December 4, 7:34 am, very feeble, 2.2 miles deep in Chain-of-Craters near Hiiaka and Pauahi craters. 19° 22.7′ N; 155° 13.3′ W.

December 8, 11:09 pm, very feeble, of comparatively shallow origin, Mauna Loa NE rift, vicinity of Pohaka Hanalei. 19° 30.0′ N; 155° 33.6′ W.

December 10, 7:59 pm, very feeble, 12.0 miles deep under N slope of Mauna Loa about 5.0 miles N of Puu Ulaula. 19° 36.5′ N; 155° 26.8′ W.

December 13, 7:26 am, very feeble, E slope of Mauna Loa, 5.0 miles E of summit crater. 19° 28.3′ N; 155° 31.0′ W.

December 13, 10:11 am, very feeble, 8.0 miles deep under coast line S of Hilina Pali and 4.0 miles W of Keahou Point. 19° 16.5′ N; 155° 18.0′ W. Reported felt in Hilo.

December 14, 12:13 am, very feeble, in Hilina Fault system, 4.5 miles SE of Makaopuhi.

December 16, 1:18 pm, very feeble, of shallow origin near Devil's Throat. 19° 22.9′ N; 155° 14.5′ W.

December 16, 1:27 pm, very feeble, possibly 35.0 miles deep, under E slope of Mauna Loa. 19° 26.5′ N; 155° 32.0′ W.

December 17, 1:31 pm, very feeble, originated in Kilauea Crater, probably under Halemaumau.

December 19, 5:24 pm, very feeble, probably originated in Kilauea SW rift near Junction with Hilina Fault system.

December 20, 12:51 pm, very feeble, originated in Kilauea Crater near E rim of Halemaumau.

December 23, 7:18 am, a tremor which registered as feeble on Mauna Loa seismograph and originated in Mauna Loa NE rift.

December 26, 6:23 pm, very feeble, probably originated in area 3.2 miles E of Kilauea Iki.

December 27, 6:33 am, originated in Kilauea crater under Halemaumau.

December 28, 3:12 am, very feeble, 1.2 miles deep, Chain-of-Craters, 0.9 mile east of Keanakakoi. 19° 24.7′ N; 155° 15.2′ W.

Continuous tremor:

10 minutes, beginning at 3:45 pm, December 15.

10 minutes, beginning at 7:22 pm, December 19.

Teleseisms

Unidentified portion began to register at the Observatory 4h 17m 28s pm, HST, November 29. Located in Japan, E coast of Honshu. 37° 5′ N; 141° 3′ W.

Microseismic motion of the ground at the Observatory was moderate December 9 and 10 and strong the remainder of the period between November 28 and January 1 inclusive. Stormy weather prevailed at sea contemporaneously.

Tilting of the Ground

The following tables show tilt by weeks, as recorded by the Observatory seismograph and at Halamaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 1, 1939, was 0.86″ S and 6.82″ W.

Week Ending	Observatory	Halemaumau West Station
December 4	1.12″ S 68° W	7.36″ N 71° W
December 11	0.80″ E	6.00″ S 76° W
December 18	1.10″ N 12° W	0.42″ N
December 25	2.17″ S 30° W	3.22″ S 57° W
January 1	0.80″ N 66° W	3.43″ S 60° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
December 4	2.08″ N 34° W	4.76″ from
December 11	7.08″ N 12° W	0.92″ toward
December 18	3.97″ N 41° E	0.81″ toward
December 25	8.10″ S 49° W	3.32″ from
January 1	10.05″ N 49° E	2.32″ from

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, December 29, indicated opening of both the Halamaumau and the crater values compared with similar measurements of November 23. Between November 23 and December 13 the Halemaumau measurement from SE pit BM to NW pit BM showed opening of 0.35″ and between December 13 and 29, opening of 0.57″. Total opening of 0.92″. Between November 23 and December 13, the crater measurement from SE rim station to Uwekahuna showed closing of 1.07″ and between December 13 and 29, opening of 1.51″. Total opening 0.44″. H.H.W.

THE VOLCANO LETTER

463

No. 463 Department of the Interior National Park Service January-March, 1939

Edward G. Wingate Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
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HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, is leased and operated by the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigations.

The **Volcano Letter,** a quarterly record of the Hawaiian volcano laboratories, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

Hawaiian Volcano Observatory Report for January-March 1939

VOLCANOLOGY

January 1939

Until the last week, the month of January was locally quiet at the Hawaiian volcanoes. A feeble earthquake was sharply felt January 15, and there was a notable increase of spasmodic tremors during the last fortnight of the month. These originated under Mauna Loa and Hualalai. Distant destructive earthquakes of large size from Chile and the Solomon Islands were registered January 24 and January 29.

A moderate slide December 30, 1938 from about 300 feet below the north rim of Halemaumau occurred 10:07 a.m. On January 14 rock slides from the east and northwest walls occurred about 1:40 p.m. Slides became more numerous from the western walls of Halemaumau on January 25, ten being counted between 9:55 a.m. and 11:53 a.m.

On the morning of January 17 with nearly calm air much fume hung over Halemaumau originating mostly at the southeast solfatara at the edge of the floor.

Opening of the measured cracks around Halemaumau rim increased somewhat during the month along with the seismicity and the slides. For the week ending January 1, cracks across Chain-of-Craters road near Devil's Throat closed 2.0 mm. The next change noted there was opening of these cracks 1.5 mm. as measured January 20, and again by a like amount January 27. (See map Volcano Letter 462.)

The following are the local data for January:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
January 1	1	0.5 mm.	14
" 8	0	1.5 mm.	32
" 15	1	3.0 mm.	16
" 22	0	3.0 mm.	60
" 29	10	3.0 mm.	45

February 1939

The general conditions in Halemaumau pit as observed February 22 showed a small hole on the southeastern floor of the pit to be steaming near a long white stained crack. Fume above this eastern wall crack had lately been conspicuous. Stain was evident on the 1932 cone southwest, and along the canoe sill at the base of the northeast wall. Margin of the floor was sulphurous in several places. Slides had made a new scar on the south wall February 6 and February 16, and that wall kept scaling off during the last half of the month. The break made a wide white scrape up the entire height of the wall, on the east side of the upright southwestern rift cavern.

Kilauea was quiet the first week of February in contrast to volcanic disturbances in Central America and South America and a reported eruption of Asama in Japan February 3. The second week produced heavy rainfall February 9-10 resulting in clouds of vapor over Halemaumau.

A noisy rock slide fell from the southeast wall of Halemaumau 11:55 a.m. February 6. Rock slides increased during the third week and were noted February 16 at northeast rim 9:25 a.m.; February 17 north wall 7:55 a.m. and west wall 8:53 a.m.; February 18 northeast and north rims 11:00 a.m.; February 19 west wall 10:01 a.m. and northeast rim 10:08 a.m. This was the period when fresh scars and dust streaks were produced on the southeast wall. Two rock slides at the north wall occurred February 21, 9:18 a.m. and 12:10 p.m.

Measurements February 11 showed the new road cracks in the vicinity of Devil's Throat to have opened 2.0 mm., one near Hiiaka pit closed 0.5 mm., and the cracks beyond Pauahi pit were stationary. On February 17 the cracks near Devil's Throat had closed 1.0 mm.; one near Hiiaka closed 0.5 mm.; and one beyond Pauahi closed 0.5 mm. The excessive opening of Halemaumau rim cracks during the week ending February

26 was accompanied by openings of cracks near Devil's Throat 0.5 mm.; Hiiaka 0.5 mm.; and a large crack at Pauahi 1.0 mm.

The following are the local data for February:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
February 5	0	0.0 mm.	17
" 12	1	1.0 mm.	32
" 19	6	5.0 mm.	27
" 26	2	8.5 mm.	15

March 1939

The most distinctive event of March 1939 was excessive rainfall at the beginning of the month. This produced clouds of vapor from the floor of Halemaumau. Precipitation exceeded 19 inches in Hilo in one day, March 2, at Kilauea Crater the rain gauge registered 11.02 inches, and for the week ending March 5, 17.54 inches. The flood was disastrous in Hilo, and the level of water in Olaa Mill well rose three feet above the flood level of 1938 so as to require removal of machinery.

Sharp tilting of the Observatory ground westward March 2 may have been caused by the loading of floor of Kilauea Crater with rain. This was followed by remarkable increase of rim crack openings at Halemaumau for the week ending March 12. Fifteen of twenty-eight crack locations showed opening, one closed, resulting in aggregate opening 17.5 mm. The greater part of this value was contributed by cracks east and southeast. Increased rate of opening of the rim cracks about spring equinox has been noted each year since 1933, generally with accompaniment of rock slides. The strong opening of cracks continued for the remainder of the month.

Observations at Makaopuhi pit March 21, in the Chain-of-Craters, showed that sulphur deposition and fuming are in progress at a hot spot halfway up the crater wall, and a small rock slide was observed at the north rim. On March 29 vapor was observed rising from the talus on the east side of Alealea Crater probably stimulated by deeper penetration of the recent rain.

The cracks near Devil's Throat had opened 2.0 mm. March 3 and 1.5 mm. March 10. The cracks near Hiiaka pit and Pauahi pit had opened 0.5 mm. March 10. Inspection March 21 indicated that new cracks across the road are developing near Devil's Throat, a small portion of the southwest rim of this pit has recently fallen, cracks to the northwest have increased and humps in the road pavement are growing higher near Pauahi and near the Ainahou road. Temperature measurement at the hot area in ohia forest near Kokoolau Crater showed no change and there is no encroachment of solfataric action on the surrounding forest.

Rock slides in Halemaumau were observed at northeast wall March 3, 10:15 a.m. and 10:28 a.m. Two small slides from the north wall occurred at 10:20 and 10:30 a.m. March 6. Slides increased March 27 and were observed 11:51 a.m., northwest wall; March 30, 7:36 a.m., northeast wall and 11:07 a.m. northwest wall; March 31, 8:58 a.m. northeast wall; April 1, northeast rim 11:50 a.m. and 1:30 p.m.

The following are the local data for March:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
March 5	2	4.5 mm.	13
" 12	2	17.5 mm.	17
" 19	0	13.5 mm.	32
" 26	0	10.0 mm	24
April 2	6	13.5 mm.	28

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

	Minutes of Tremor	Very Feeble	Feeble	Slight	Distant*	Weekly† Seismicity
Jan. 8	28	4	0	0	0	9.00
" 15	12	3	1	0	0	5.50
" 22	55	4	0	1	1	17.75
" 29	80	1	0	0	2	20.50
Feb. 5	15	2	0	0	1	4.75
" 12	28	4	0	0	1	9.00
" 19	32	4	1	0	0	11.00
" 26	11	4	0	0	0	4.75
Mar. 5	11	2	0	0	0	3.75
" 12	16	1	0	0	0	4.50
" 19	24	5	2	1	0	12.50
" 26	18	4	2	0	1	8.50
Apr. 2	23	5	0	0	0	8.25

* Including teleseisms or earthquakes over 5000 km. from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

January 2, 8:45 am, very feeble, 8.0 miles deep off seacoast 5.0 miles south of Ahua Point. 19° 11.0′ N; 155° 12.7′ W.

January 4, 8:40 am, very feeble, 2.5 miles deep, Kanaokuaiki Pali about 1.5 miles east of Puu Ohale. 19° 21.2′ N; 155° 15.4′ W.

January 7, 5:15 am, very feeble, 7.0 miles deep NE rift of Mauna Loa. 19° 31.5′ N; 155° 33.0′ W.

January 10, 9:41 pm, very feeble, 2.6 miles deep near Hiiaka and Pauahi Craters. 19° 21.3′ N; 155° 13.9′ W.

January 13, 12:01 am, very feeble, 18.0 miles deep in vicinity of Puu Kulua, Mauna Loa NE rift. 19° 34.0′ N; 155° 26.3′ W.

January 14, 10:46 am, very feeble, 1.2 miles deep, 0.7 mile SW of Ahua Kamokukolau. 19° 22.7′ N; 155° 16.7′ W.

January 15, 3:30 pm, feeble, of shallow origin in Kilauea Crater near Halemaumau. 19° 24.5′ N; 155° 16.3′ W. Reported felt by many persons in Hawaii National Park residential area and by a few in Hilo.

January 16, 1:10 am, very feeble, about 13.0 miles deep in Mauna Loa NE rift, in the vicinity of Puu Ulaula. 19° 33.0′ N; 155° 27.0′ W.

January 17, 4:35 pm, very feeble, about 6.0 miles deep under area about 3.0 miles SE of Puu Ulaula, Mauna Loa NE rift. 19° 31.7′ N; 155° 25.8′ W.

January 17, 8:19 pm, very feeble, 13.0 miles deep in Kilauea SW rift about 9.0 miles from Halemaumau. 19° 20.6′ N; 155° 24.5′ W.

January 19, 2:58 pm, slight, 16.0 miles deep under Hualalai. 19° 41.6′ N; 155° 52.0′ W. Reported strongly felt by many persons in Kona and Kohala districts and slightly by some in Hilo and Kau districts.

January 25, 11:42 am, very feeble, probably originated in Chain-of-Craters SE of Kilauea Crater.

February 2, 9:56 pm, very feeble, originated in Mauna Loa NE rift near Summit Crater. 19° 30.0′ N; 155° 32.0′ W.

February 5, 1:57 pm, very feeble, probably originated about 5.0 miles W by N of Pahala. (3.0 miles NW of Kula mountain.)

February 9, 7:45 am, very feeble, 0.9 mile deep at Chain-of-Craters near Pauahi and Hiiaka Craters.

February 10, 9:56 am, very feeble, 3.3 miles deep in same general area as preceding quake. 19° 21.3′ N; 155° 13.9′ W.

February 10, 3:46 pm, very feeble, 10.0 miles deep in Mauna Loa NE rift near Puu Ulaula. 19° 33.0′ N; 155° 27.0′ W.

February 13, 7:17 pm, very feeble, probably originated in area between Devil's Throat and Ahua Kamokukolau.

February 16, 9:26 am, very feeble, probably originated under NE edge of Kilauea Crater floor.

February 17, 6:05 am, very feeble, 25.0 miles deep, 8.0 miles E of Kulani cone. 19° 34.3′ N; 155° 13.3′ W. Reported felt in Hilo.

February 17, 6:36 pm, feeble, 4.0 miles deep under N rim of Kilauea Iki. 19° 25.8′ N; 155° 14.7′ W.

February 18, 4:36 pm, very feeble, probably located in Chain-of-Craters near Kokoolau.

February 21, 2:26 pm, very feeble, 2.7 miles deep in area N of Kilauea Iki. 19° 25.8′ N; 155° 14.5′ W.

February 23, 12:52 pm, very feeble, 5.0 miles deep in Hilina fault system 3.0 miles S of Makaopuhi. 19° 19.2′ N; 155° 11.0′ W.

February 26, 7:53 am, very feeble, originated under N portion of Halemaumau.

February 26, 6:11 pm, very feeble, probably originated in Kohala area about 4.0 miles N of Kawaihae. 20° 5′ N; 155° 50.0′ W.

March 4, 3:18 am, very feeble, originated in NE portion of Kilauea Crater.

March 5, 1:11 am, very feeble, 15.0 miles deep in Mauna Loa NE rift, 7.0 miles NW of Kulani Cone. 19° 35.4′ N; 155° 21.6′ W.

March 8, 10:33 am, very feeble, 22.0 miles deep in Mauna Loa NE rift near Pukauahi Cone. 19° 33.0′ N; 155° 31.2′ W.

March 13, 9:28 pm, very feeble, 10.0 miles deep under E slope of Mauna Loa, 2.5 miles SE of Mauna Loa seismograph. 19° 27.5′ N; 155° 21.2′ W.

March 14, 6:08 am, very feeble, 2.0 miles deep near Kipuka Puaulu. 19° 26.8′ N; 155° 18.7′ W.

March 14, 9:54 am, slight, 2.3 miles under Halemaumau, Kilauea Crater. 19° 24.6′ N; 155° 17.2′ W.

March 14, 10:56 am, feeble, probably originated in area between Makaopuhi Crater and Hilina Pali.

March 14, 12:10 pm, feeble, of shallow origin in area about 0.8 mile W of Devil's Throat. 19° 22.7′ N; 155° 14.9′ W.

March 20, 12:13 am, very feeble, probably originated in Hilina Pali area about 6.00 miles SE of Makaopuhi.

March 21, 8:47 am, very feeble, of shallow origin in area immediately E of Kilauea Iki. 19° 24.7′ N; 155° 13.6′ W.

March 22, 5:46 am, 40.0 miles deep Mauna Loa NE rift, 8 miles from Summit Crater. 19° 33.0′ N; 155° 30.0′ W.

March 22, 10:57 pm, feeble, 10.0 miles deep Mauna Loa NE rift, 13.0 miles from Hilo. 19° 38.0′ N; 155° 16.0′ W. Reported generally felt in Hilo.

March 24, 8:59 pm, very feeble, 9.0 miles deep in Kau desert area about 2.0 miles S of Puu Ohale. 19° 20.7′ N; 155° 15.0′ W.

March 25, 11:02 pm, very feeble, probably originated in Chain-of-Craters between Devil's Throat and Puhimau Crater.

March 28, 5:36 am, very feeble, 20.0 miles deep, Mauna Loa NE rift near Puu Kulua. 19° 35.2′ N; 155° 26.0′ W.

March 29, 9:47 am, very feeble, of Kilauea Crater origin.

March 30, 9:35 pm, very feeble, originated in NE portion of Kilauea Crater.

Continuous Tremor

Thirty-seven minutes beginning at 8:30 am, January 27. Eleven minutes beginning at 2:02 am, February 18.

Teleseisms

January 18, 11:53 pm, H.S.T., beginning of unidentified portion.

January 24, 5h 15m 41s pm, H.S.T., "P" waves began to register. Shock originated in Chile and was of very destructive nature resulting in estimated loss of over 20,000 human lives, distance from Kilauea 6,435 miles.

January 29, 3h 57m 57s pm, H.S.T., "P" waves began to register. Shock originated in Solomon Islands. Distance from Kilauea 3,800 miles.

February 2, 7h 05m 37s pm, H.S.T., "P" waves began to register. Distance from Kilauea, 3,795 miles.

February 7, 8:26 pm, unidentified portion began recording. No reports have been received concerning this quake either by press or from other stations.

February 24, 4:01 am, unidentified portion.

Microseismic Motion

Microseismic motion of the ground at the Observatory was moderate January 15-21 inclusive and January 29, 30, and 31. It was strong the remainder of the month.

For February it was light on the 20th, 21st, and 25th; moderate on the 12th, 22nd-24th, 26th-28th, and strong the remainder of the month.

During March it was strong 3-5, 17-19, and moderate the remaining dates. All dates inclusive.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the observatory seismograph and the one at Halemaumau; the algebraic sum toward or away from the pit.

At the Observatory the total accumulated tilt for the year ending January 29, 1939 was 1.15" S and 5.93" W.

For the year ending February 26, it was 1.00" S. and 1.73" W.

For the year ending April 2, it was 3.08" S and 4.85" W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
Jan. 8	0.43" S 54° E	3.22" S 64° E
" 15	0.55" S 11° E	3.52" S 42° W
" 22	0.91" S 19° W	4.77" N 15° W
" 29	0.97" S 35° W	2.62" N 30° E
Feb. 5	2.00" S 28° W	2.92" N 85° W
" 12	0.77" S 12° W	1.49" S 60° W
" 19	0.25" N 16° W	1.49" N
" 26	0.00" 0	1.64" N 25° W
Mar. 5	1.81" N 26° W	2.89" N 20° E
" 12	0.62" S 29° W	2.59" S 60° W
" 19	3.20" S 43° W	3.61" S 34° W
" 26	1.30" S 51° W	1.49" N 39° W
Apr. 2	1.03" S 30° W	1.49" N 61° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
Jan. 8	2.53" N 85° W	4.30" toward
" 15	1.65" N 70° W	1.23" from
" 22	2.95" S 35° W	1.56" from
" 29	4.54" S 34° E	1.98" toward
Feb. 5	1.13" N 44° E	2.67" from
" 12	4.28" N 59° W	2.55" toward
" 19	2.56" N 87° W	1.62" toward
" 26	2.49" N 25° W	1.81" toward
Mar. 5	4.05" N 37° W	5.08" toward
" 12	3.30" N 15° W	0.70" toward
" 19	1.07" N 31° W	2.17" toward
" 26	4.21" N 81° W	2.03" toward
Apr. 2	1.20" S 9° W	2.00" from

H. H. W.

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory January 21, indicated closing of both the Halemaumau and the crater values compared with similar measurements of December 29. The Halemaumau angle between the pit seismograph and the NW pit BM closed 0.50". The crater angle between the SE crater rim station and Uwekahuna closed 1.58".

Angle values determined on February 15, indicated opening across Halemaumau and closing across the crater. Between January 21 and February 15, the Halemaumau value increased 0.83", and the crater value decreased 1.15".

During March two determinations were made of the angles. These were March 13 and 30. On the first of these two runs, the Halemaumau angle closed 2.25" and the crater angle closed 0.25". Between March 13 and March 30 the Halemaumau angle again decreased (0.59") and the crater angle opened by an amount of 2.24". Total change for the month, Halemaumau angle closed 2.84" and the crater angle opened 2.00".

During the first three months of 1939 the Halemaumau angle has decreased 2.51" and crater angle has decreased 0.84".

These changes agree favorably with current tilt toward Halemaumau.

H. H. W.

Levelling at Kilauea

Since January 1, 1939 two sets of levels have been run over the usual circuit on the floor of Kilauea Crater between the Spit BM on the SE crater rim and the NW Pit BM. The line of levels follows the S-SW-W, rims of Halemaumau.

These determinations were made January 30 and March 21. In both cases the NW Pit showed relative lowering with reference to Spit BM. On the first run, this value amounted to 14.0 millimeters and on the second run, a similar value of 15.0 millimeters. These determinations are in accord with both tilt and horizontal angle determinations.

Since the lava inflow at Halemaumau in September, 1934 the NW Pit BM has showed a total relative lowering with respect to the Spit BM of 0.429 meters or 1.41 feet.

H. H. W.

Chain of Craters, Crack Openings*

At 6:00 am, May 28, 1938 a series of earthquakes of various intensities began to register on the seismographs of the Hawaiian Volcano Observatory. Many were strongly felt in the National Park Headquarters area. Within the ensuing 24-hour period well over 100 earthquakes were recorded as well as several hours of continuous tremor in the early stages of the disturbance. Accompanying this seismic activity were visible ground movements along pre-existing cracks in the Chain-of-Craters between Pauahi and Aloi, roughly four miles SE of Kilauea Crater. Definite evidence of these movements was produced by shattering of the hard surface of the Chain-of-Craters road at approximately 11 different localities. Slides occurred in Pauahi. The largest crack developed near Pauahi where a large section of the roadway was destroyed by caving. A few days later seismic conditions had returned to normal.

On the morning of August 8 at 2:14 o'clock, a similar crisis began. More earthquakes were recorded in the following 24 hours than had occurred in the corresponding period in May. Over 200 earthquakes occurred on August 8 alone. This time there were a number of shocks from Kilauea Crater, several from Hilina Pali and others at various points along the Chain-of-Craters but mostly concentrated near Kokoolau and Devil's Throat. Again visible evidence of the general area of disturbance was indicated by cracks across the Chain-of-Craters road; three groups near Devil's Throat and one near Hiiaka (SW rim). The cracks between Pauahi and Hiiaka showed no appreciable changes.

On August 10 seven representative cracks were chosen for measurement and numbered successively from the large crack (hump) near Devil's Throat to the last large crack near Aloi.

The list is as follows:

No. 101—At the "hump" about 1000 feet W of Devil's Throat.

No. 102—At W side of junction of Chain-of-Craters road with the Hilina Pali road.

No. 103—Near S rim of Hiiaka.

No. 104—Large crack near S rim of Pauahi.

No. 105—About 1000 feet SE of the Chain-of-Craters road and Ainahou Ranch road junction.

No. 106—About 50 feet SE of No. 105.

No. 107—About 750 feet W of W rim of Aloi Crater.

Table of crack measurements on Chain-of-Craters road. (Values in centimeters except No. 104 which is in feet, inches and sixteenths.)

Date	101	102	103	104	105	106	107
August 10	402.05	62.85	101.60	17'8- 8/16"	87.00	88.45	41.00
September 2	402.65	63.90	101.45	17'8-12/16"	87.10	88.60	40.90
October 7	402.80	64.00	101.40	17'8-14/16"	87.15	88.65	40.75
November 4	402.95	64.10	101.40	17'8-15/16"	87.20	88.65	40.65
December 2	403.00	64.10	101.45	17'9.0"	87.15	88.65	40.60
January 6	403.30	64.20	101.45	17'9.0"	87.05	88.65	40.50
February 3	403.45	64.25	101.45	17'9.0"	87.05	88.65	40.45
March 3	403.65	64.30	101.40	17'9- 1/16"	87.10	88.65	40.40
March 31	403.70	64.40	101.35	17'9- 1/16"	87.15	88.65	40.40
Total change in mm.	+16.5	+15.5	—2.5	+10.0	+1.5	+2.0	—6.0
	plus (+)=open			minus (—)=close			

The indications from the above figures are that the greatest amount of movement has been and continues near Devil's Throat with next highest rates of change at Pauahi and Aloi respectively.

These measurements are to be continued and will be reported regularly.

H. H. W.

* See Volcano Letter 462, August-December 1938 for map and description.

THE VOLCANO LETTER

No. 464 Department of the Interior National Park Service April-June, 1939

Edward G. Wingate Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, is leased and operated by the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigations.

The **Volcano Letter,** a quarterly record of the Hawaiian volcano laboratories, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

TIME CONTROL FOR SEISMOGRAPHS OPERATED BY THE HAWAIIAN VOLCANO OBSERVATORY

HUGH H. WAESCHE, Asst. Geologist

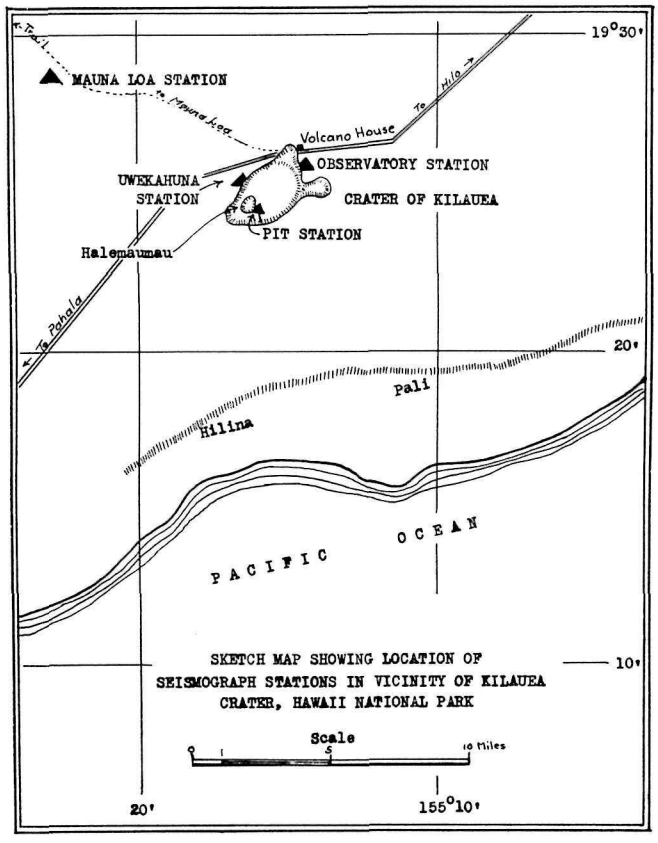
A major problem concerning the operation of any group of seismograph stations is the time control. This is important for widely separated stations but becomes of increasing value for studying travel times between stations separated by distances from one mile to several hundred miles where time errors of tenths of seconds may produce relatively large error in determining earthquake focii.

At Kilauea, seismographs are located at the Observatory, NE rim, Uwekahuna, NW rim and at the SE rim of Halemaumau (see map). At the Observatory there are three instruments, the Bosch-Omori, a vertical component and a low magnification instrument of special design. The entire group has always had a common time control, originating from a pendulum clock (Howard) equipped with electrical contacts for closing the circuit on the fifty-ninth second and breaking on the sixtieth second of every minute and closing for ten seconds during the first minute of each hour. Proper correction of clock is maintained by comparison with radio time signals from NPM and NPG daily at 4:30 pm, H.S.T.

The writing pens are lifted off the smoked drums by a solenoid supported in front of and slightly above each needle. This system has been the most satisfactory method found for indicating the time on the smoked paper. It is true that occasionally important phases are missed in an earthquake but this occurs far more rarely than might be suspected and indicates the time in a reliable manner. The Bosch-Omori low magnification and Uwekahuna recording drums have minutes 50 millimeters in length; all the other records have minute lengths of 30 millimeters.

Individual time clocks were installed at Halemaumau and Uwekahuna as well as in the outlying stations at Hilo and Kealakekua. A station using the same system was installed on Mauna Loa in October, 1938. The latter is located about 10.0 miles NW of the Observatory. None of these stations had radio sets for time corrections and were unattended except for daily visits to change the recording drums.

In 1931 Mr. A. E. Jones began studies of travel times in

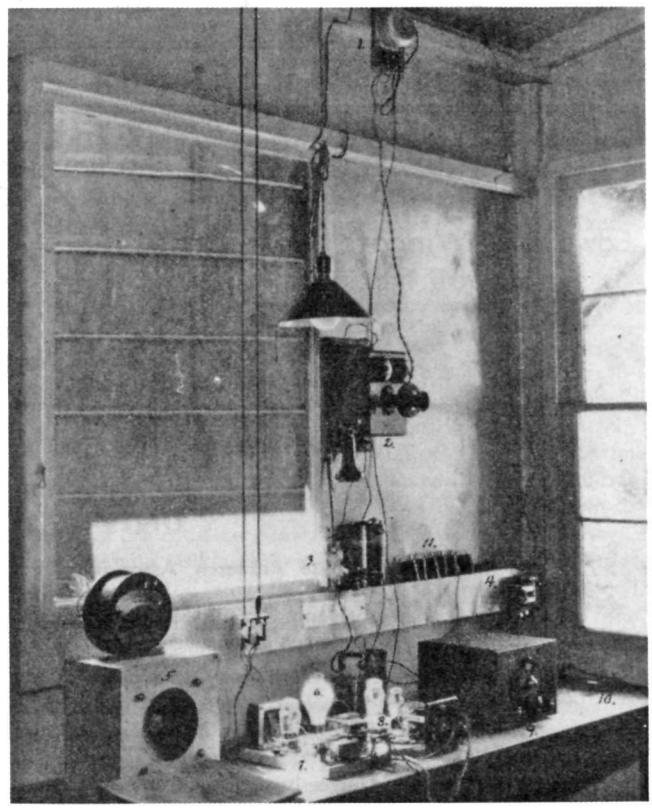


the Hawaiian Islands. Before this, travel times developed by Omori for local shocks in Japan had been used. Mr. Jones found that the Omori travel times did not agree with the seismic facts in Hawaii so immediately set to work developing a set of travel times for the Island. He succeeded in doing this very ingeniously as described in his paper "Hawaiian Travel Times", published in the Bulletin of the Seismological Society of America in January, 1935. During these studies, time comparisons between the Pit and Uwekahuna clocks were made with the clock at the Observatory using a stop watch carried between stations daily. Time corrections at Hilo and Kona were made by listening to the time tone and then as nearly as possible synchronizing this by manual operation of a key which transmitted a signal over the mutual telephone lines to those stations. Lags and other errors of the personal equation as well as unreliability of time clocks in the outlying stations made the system only partially successful and by 1937 all attempts at time control have been given up other than for S-P determinations based on the known speed and dimensions of the recording drum and at the Observatory where close watch could be kept on clocks and radio.

As more earthquakes were recorded, however, there came the conviction that good, reliable time control with all the stations exactly correlated with the clock at the Observatory was a necessity. There was still considerable doubt as to the speed of the compressional and transverse waves from various parts of the Island and earthquakes with good preliminaries at all stations still did not give satisfactory solutions when locations were attempted. Consequently, various plans were considered, varying from radio control from the central station to direct wire connections. Little was done because of the expense of the necessary equipment.

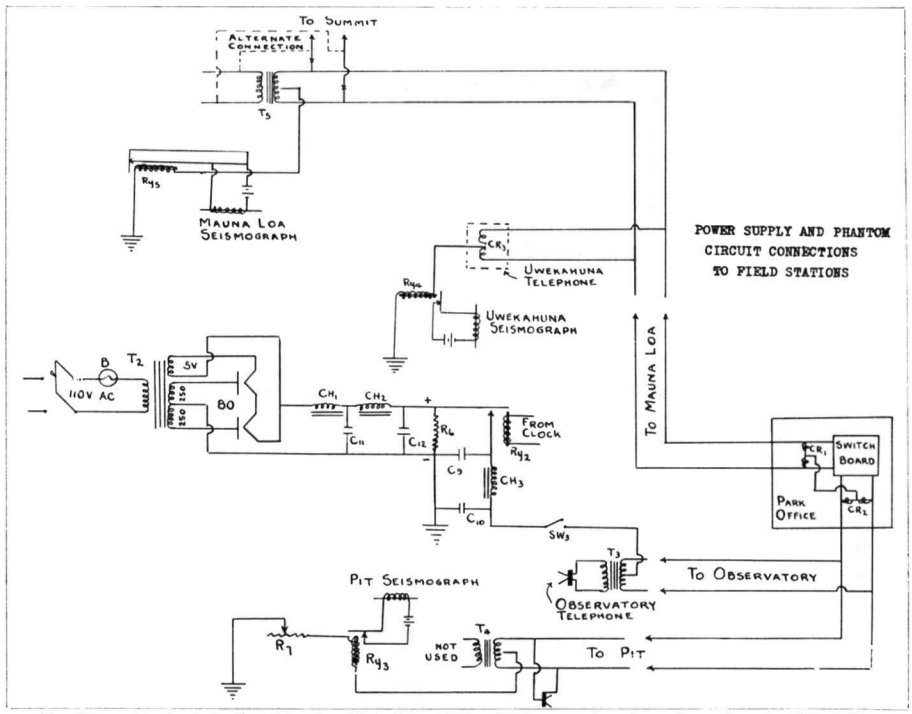
The first step was made in December, 1936, when a sensitive relay and vacuum tube amplifier to operate it were added to the regular short wave receiver then in service. About the same time a rectifier was added to the set, thus utilizing the Hilo power, 110 volts A.C. Previously batteries had been used but had proved expensive. The radio-operated sensitive relay closed the same circuit operated by the time clock and thus indicated the position of true time with reference to the nearest minute. Every day time was checked at 4:30 pm, by an operator tuning the set to the 12,885 kc frequency of NPG or NPM. This was highly successful and probably gave a time correction at the Observatory well under 0.5 sec. for all the instruments operated in that building.

About one year after the relay was installed, the 10,000-ohm coil winding burned out. A new 5,000-ohm coil was wound and operation resumed with little change in the sensitivity of the relay. In attempting to make some mechanical changes in the relay during April of this year, the coil was injured beyond repair. Rather than rewind the relay and take chances on its burning out again, a new relay was constructed, using two 1,250-ohm telephone ringer coils in series. This relay proved sensitive enough (closes on about 0.5 milliamps) and has the added

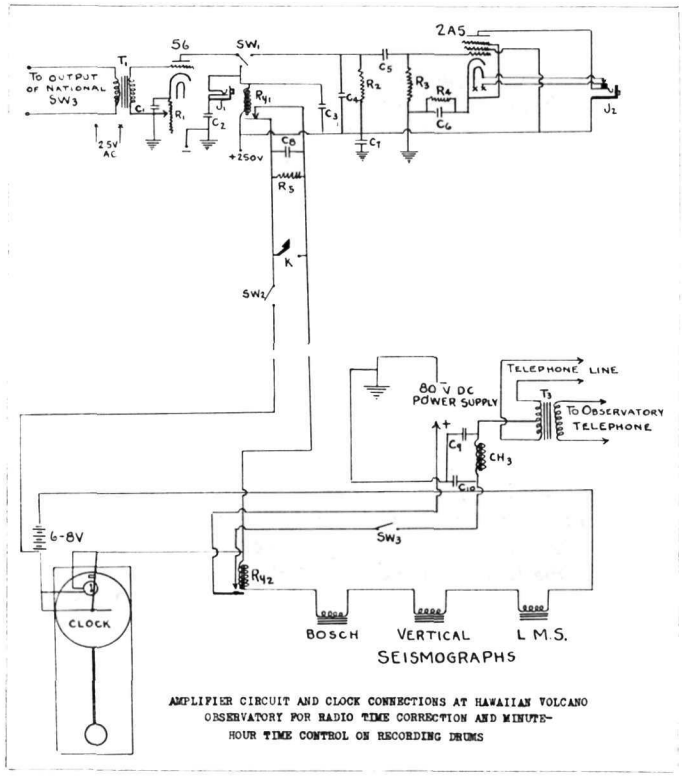


TIME CONTROL STATION AT THE HAWAIIAN VOLCANO OBSERVATORY

1. Observatory repeating coil; 2. Test telephone set; 3. Anne-mometer switch; 4. Sensitive time relay connected to radio receiver; 5. Loud speaker; 6. 50-watt ballast bulb in series with power transformer; 7. Power unit and rectifier for operation of time control system; 8. Power and amplifier unit for radio receiver; 9. National SW3 radio receiver; 10. Key for manual control of circuits; 11. Wave band coils for radio receiver.



B—50-watt electric light bulb; CH_1, CH_2, CH_3—Filter chokes (receiver type); CR_1, CR_2—Double sets of 800-Ohm telephone ringer coil; CR_3—Ringer coil on Uwekahuna telephone; T_2—Power transformer 250-250 secondary and 5 V for rectifier; T_3, T_4, T_5—Repeating coils; Ry_2—Relay of low resistance in Observatory circuit; Ry_3, Ry_4, Ry_5—1250-Ohm relays at seismograph stations; SW_3—Single pole, single throw switch for cutting off phantom circuit; $C_9, C_{10}, C_{11}, C_{12}$—8 mfd filter condensers; R_6—50,000-Ohm bleeder resistor; R_7—5000-Ohm wire wound variable impedence (not found) necessary).



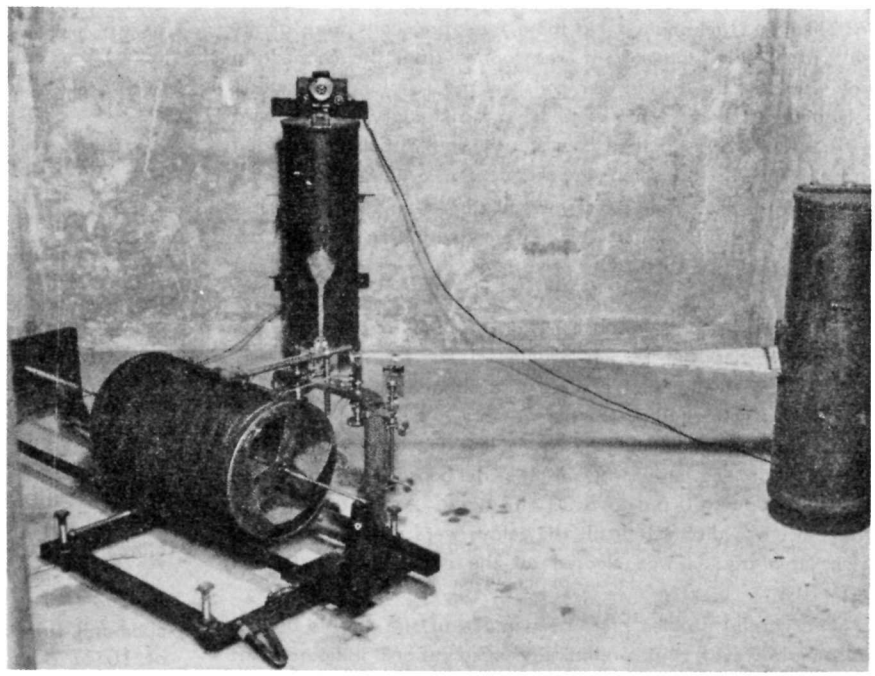
AMPLIFIER CIRCUIT AND CLOCK CONNECTIONS AT HAWAIIAN VOLCANO OBSERVATORY FOR RADIO TIME CORRECTION AND MINUTE-HOUR TIME CONTROL ON RECORDING DRUMS

T—Audio-amplifier, coupling transformer; SW_1—Single pole double throw toggle switch; J_1, J_2—Jacks for connecting speaker; C_1—4 mfd; C_2—0.2 mfd; C_3—0.1 mfd; C_4—0.002 mfd; C_5—0.1 mfd; C_6—10 mfd; C_7—0.25 mfd, relay sparking filter; C_8—0.5 mfd; R_1—50,000-Ohm potentiometer DC component control; R_2—30,000-Ohm 1 watt carbon; R_3—75,000-Ohm 1 watt carbon; R_4—300-Ohm 2 watt carbon; R_5—500-Ohm 1 watt carbon relay sparking filter; Ry_1—Home-made relay 2500-Ohm; K—Key for manual operation; SW_2—Single pole single throw switch to disconnect amplifier from clock; SW_3—Single pole single throw switch to disconnect power from telephone line; C_9, C_{10}—8 mfd electrolytic filter condenser; Ry_2—Relay operated by clock circuit, closes time circuit to other stations; T_3—Repeating coil.

advantage of having readily replaceable coils of which there always are some in stock as the Hawaii National Park keeps a supply for replacement purposes in their telephones.

The U. S. National Park Service, for purposes of protection and convenience, operates its own telephones and necessary lines in the Park. There is a small exchange at Park Headquarters through which are connected three trunk lines, all of which are metallic, that is, two wire and ungrounded. One line is connected to the Observatory and also serves the southern part of the Park, including Halemaumau. A second line serves the Park employee, residential area and the third line serves Uwekahuna Museum, the Hotel, Military Camp and the Mauna Loa line extending to the summit. For some time these lines had been thought of as potential connecting links between the seismograph stations with direct time control from the Observatory clock. A plan was evolved using center tapped resistors across the line, one at the Observatory and one at the Pit seismograph station. This would produce a phantom circuit on the metallic line with a ground return. A relay was to be activated by the clock simultaneously with the Observatory seismographs. The contact circuit of the relay would then be made to send a direct current of sufficient voltage over the phantom circuit to operate a relay at the Pit station. Theoretically this circuit would not interfere with the telephone circuits as the current on the metallic line would be balanced and moving in the same direction over the lines. Before trying this arrangement Mr. L. W. Branch, local manager of the Mutual Telephone Company, was consulted. His opinion was that such a circuit would be effective but recommended the use of standard telephone repeating coils instead.

In December two of the repeating coils were purchased from the telephone company. One of these was placed in the Observatory and the other was placed at the Pit and connected as indicated in the accompanying diagram. Ninety volts of "B" battery were the source of power. The trial was successful in that the time was transmitted and synchronized with the Observatory. However, it was discovered that each time the circuit was closed or opened, an unbearably strong popping noise was heard on all phones on that line or others connected through the switch-board. A filter circuit consisting of the conventional 8 mfd condenser—filter choke and 8 mfd of condenser inserted in the phantom alleviated the situation so that the phones were usable; but this did not completely clear up the situation. The lines were undoubtedly either unbalanced or one wire was grounded. Furthermore, the batteries soon became exhausted. As batteries were short-lived and therefore impractical a power pact similar to those used regularly on radios was constructed. This was connected to the regular 110-volt A.C. power. The transformer was that from an old radio receiver and an 80 rectifier tube was used. A 50-watt electric light bulb was hooked in series with the primary of the transformer as an indicating device and safety precaution in case any of the circuits should become shorted. The flash of this bulb every minute showed that the circuit was operating and continuous bright glow of the bulb showed that something was wrong with the circuit. When the high voltage power was idling and only the filament current for the rectifier



MAUNA LOA SEISMOGRAPH STATION SHOWING LARGE DRUM FOR 48-HOUR CONTINUOUS OPERATION. N-S COMPONENT TO RIGHT; E-W TO LEFT.

tube was being drawn, only a dull red glow showed from the bulb in the darkness.

For about three months the test circuit operated consistently but the disturbance to the phones, though not bad, continued. Finally the relay at the Pit stopped. Current tests showed that the line drew 150 milliamperes. It was evident that at least one line was shorted. A careful check showed that the short was at a place near the Pit station, where insulation had been worn from a wire running through a portion of the line which had been put in a pipe below ground. Correction of this fault cleared the telephones of all noise and the relay responded vigorously. The trial circuit was then a complete success and the Pit station was considered permanently time-coupled to the Observatory.

The problem was now to add the Mauna Loa and Uwekahuna stations to the circuit. This could be done by putting repeating coils at the switch-board terminals of the Observatory-Pit line and the Mauna Loa line. A repeating coil with one side of the transformer burned out was available in the Park. Cost of more transformers made them impractical. The burned out transformer was placed at the Pit and the good side used. The transformer from there was transferred to the Mauna Loa station. To offset the lack of repeating coils at the switchboard two sets of two 800-ohm ringer coils were used. One set was connected across the Mauna Loa line and the other set across the Observatory line. The two coils in each set were connected in series. This connecting wire was equivalent to a center tap so a jumper was connected from the link on one pair of coils to the link on the other. This made a phantom circuit path for the time signal whether the two lines were directly connected through the switchboard or not. Effective resistance across the metallic line was that of two telephones at 1,600 ohms each, but offered only a total of 800 ohms in the timing circuit. The relays at the Pit and on Mauna Loa had 150-ohm coils. They were replaced by 1,250-ohm telephone ringer coils. This made them much more sensitive and reduced current consumption materially and even allowed for considerable current loss through line leakage in wet weather or from other causes.

A third relay patterned after the one at the Pit was installed at Uwekahuna. No more repeating coils were available so the phantom circuit was tapped from the connecting link between the two ringer coils on the regular Uwekahuna telephone. This was found to be a satisfactory arrangement with the relays responding consistently and without interfering in any way with the telephone service.

With the telephone lines clear all three relays in the circuit operating and a 50-watt bulb in series with the power transformer primary, the current drawn is 60 milliamperes at about 80 volts.

The results have been very gratifying. The only interruption was caused by an accidental short on the line to Mauna Loa by linemen placing a grounded cable against a guy wire which in turn was bent across a service line. When this short was in existence, the Mauna Loa and Uwekahuna relays responded only when the switchboard was connected through from 4:00 pm to 8:00 am, daily. A few days before the short was discovered, all the relays were out of operation. Since this trouble was cleared up the circuit has performed perfectly.

No careful studies have been made of the results on the seismograms yet, but preliminary observations indicate that the arrangement is extremely worthwhile and gives direct time correlation for the entire circuit. Extra work involved in making time corrections has been eliminated and the uncertainty of S-P values has been corrected.

The remaining problem now is to obtain accurate time correlation for the Hilo and Kona stations. Specially designed semi-automatic radios have been requested and it is hoped they will be available in the near future. There will be much value and satisfaction to a completely coordinated set of seismograph stations. When this is accomplished accurate travel times for the area may be determined and possibly more knowledge obtained of the underground structure in Hawaii.

Hawaiian Volcano Observatory Report for April-June 1939

VOLCANOLOGY

April 1939

The Volcanic Observatory recorded a cold and rainy April, with low seismicity and some Halemaumau slides. A rock slide from the northwest wall of Halemaumau occurred at 9:50 a.m. April 5 and several unusually large newly fallen boulders were seen at the foot of the northeast talus at 10:00 a.m. April 7. On April 16 a slide from the southwest rim at 9:32 a.m. continued for about five minutes. It left a mark on the Pit wall and produced tremor at the Halemaumau seismograph. Marks on the Pit walls indicated other slides.

Crack measurements at the twenty-eight marked localities around Halemaumau showed decline from the measurements of March during the first week of April, there was increase of opening the second week, and thereafter the crack movement notably declined and for the whole month there was strong decrease of crack-opening.

Mauna Loa was visited by the northeast trail April 20, and no visible changes in the conditions of that volcano were observed.

Of the sixty-six shocks and tremors registered on the seismographs for April, fifteen were located by seismometric method, and of these eleven were under Kilauea mountain, three were Mauna Loa and one was Hualalai.

The following are the local data for April:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
April 9	2	6.0 mm.	19
" 16	1	10.5 mm.	16
" 23	0	3.0 mm.	18
" 30	0	2.5 mm.	13

May 1939

The month of May appears to have been strongly seismic and volcanic all over the world with press reports of a destructive earthquake in Japan and of increase of volcanic activity in Alaska, Costa Rica, Italy and Java. Hawaii showed steady increase of numbers of earthquakes reaching a peak of seismic activity May 31 with three strongish shocks near Hilina Pali and Kilauea. Exceptionally strong tides with high waves altered the black sand beach at Kaimu May 19 and 20, measured cracks near Chain-of-Craters road both opened and closed, relative height of the road humps on this road increased, and slides occurred at Makaopuhi, Devil's Throat and Hilina Pali.

Rock slides occurred in Halemaumau at northwest rim 8:47 a.m. and 9:02 a.m. May 3. At 12:47 p.m. May 11 a slide fell from the northwest wall. The strongish earthquake of 10:27 a.m. May 15 was accompanied by slides from the northern and western walls 10:28 a.m. and 10:29 a.m. Sliding at northwest wall occurred 11:23 a.m. May 15. Along

with earthquakes approximately fifteen slides occurred in Halemaumau as follows:

May 23, southwest wall, 2:14 and 2.31 p.m. ;
24, northeast and northwest rims 1:11 p.m. and north rim 2:30 and 5:50 p.m.;
26, north wall, 8:17, 8:20, 8:40 a.m. and 4:29 p.m.;
27, northwest rim, 2:20 and 2:40 p.m.;
28, northern rim, 8:38, 8:59, 10:15 and 11:05 a.m.

At Makaopuhi Crater a scar indicating fresh slide from the north rim was seen on May 5, and the Devil's Throat continues to fracture and break away along the west and north rims. Several slides from the cliffs in the Hilina Pali region occurred about 2:05 p.m. May 18.

Of one hundred eighty-four seismic disturbances twenty-three indicated place of origin. Of these, six were from Kilauea, six from Hilina Pali and six from Mauna Loa. One each was from Hualalai and Chain-of-Craters. One was near Honolulu, one west of Maui and one from Mountain View.

The following are the local data for May:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
May 7	2	7.5 mm.	12
" 14	1	3.5 mm.	38
" 21	3	13.0 mm.	39
" 28	15	8.5 mm.	95

June 1939

After the second week of June the seismic activity dwindled. The maximum of the different types of activity, including seismic frequency, was the second week of June, but the greatest intensity of quaking had been at the end of May. A strongish shock occurred June 12 and another June 19, both fairly deep under Kilauea; a peculiar shock June 24 was like a blast, of shallow origin under the northeast rim of Kilauea crater. Of late, Veniaminof has been active on the Alaskan peninsula, Poas and Irazu volcanoes in Costa Rica, Vesuvius excited some press report, and so did Krakatoa. Eleven distant earthquakes have been registered from New Caledonia, northeastern Asia, Solomon Islands, Lower California, Aleutian Islands, Tonga Islands, and a near shock about ninety miles from us.

Rock slides at Halemaumau were reported June 7, north wall, 12:53 p.m.; June 8, northern walls, 12:53 p.m.; and from northwest wall on June 9; June 14 a slide wth large boulders from high up west wall 3:25 p.m. Dust clouds indicated slides at northwest wall June 12, 1:36 p.m.; June 16, 2:12 and 2:13 p.m. A slide from northwest wall was reported June 26 11:15 a.m.

That the working of the fault benches southeast of Kilauea is a distributed movement was shown by discovery June 12 of a fresh landslip on Pali Lele O Kalihipaa four miles south of the center of Kilauea.

Of a total of three hundred thirty-seven local seismic disturbances in June, thirty-one had their centers located, of which twenty-two were under Kilauea, five along Chain-of-Craters, three at Hilina Pali and one between Kilauea and Hilo. It is remarkable that Mauna Loa and Hualalai were not heard from. There was some seismic activity near Maui.

The following are the local data for June.

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
June 4	0	8.5 mm.	36
" 11	3	10.5 mm.	124
" 18	8	4.5 mm.	88
" 25	0	4.0 mm.	58
July 2	1	5.5 mm.	31

T. A. J.

SEISMOLOGICAL AND GEODETIC DATA

Earthquakes

Date	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
April 9	16	3	0	0	0	1	5.50
" 16	11	3	0	2	0	0	8.25
" 23	15	3	0	0	0	3	5.25
" 30	10	3	0	0	0	1	4.00
May 7	11	1	0	0	0	1	3.25
" 14	35	2	0	1	0	1	11.75
" 21	34	4	0	0	1	0	14.50
" 28	85	7	0	1	2	0	33.75
June 4	28	5	0	1	2	1	17.50
" 11	102	21	1	0	0	2	37.00
" 18	72	12	1	2	1	0	33.00
" 25	49	6	0	2	1	0	23.25
July 2	30	0	0	0	1	0	11.50

* Including teleseisms or earthquakes over 5000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

April 4, 9:03 pm, very feeble, probably originated near center of Kilauea Crater.

April 5, 3:04 am, very feeble, 3.0 miles deep, Kilauea near W rim of Halemaumau (SW rift). 19° 24.6'N; 155° 17.8' W.

April 6, 9:09 pm, very feeble, Mauna Loa NE rift near Puu Ulaula.

April 12, 4:18 am, slight, 18.0 miles deep NE slope of Kilauea about midway between the crater and Glenwood. 19° 27.0' N; 155° 14.0' W. Reported felt in Hilo, Olaa and Hawaii National Park.

April 13, 2:53 pm, very feeble, probably originated in Twin Craters area E rim of Kilauea Crater.

April 15, 9:48 pm, slight, felt by many persons in Hawaii National Park. Located 1.3 miles deep in Kilauea Crater, NE rim of Halemaumau. 19° 25.0' N; 155° 16.9' W.

April 16, 6:14 pm, very feeble, probably originated in Hilina fault system S of Makaopuhi Crater.

April 16, 10.57 pm, very feeble, probably of shallow origin near center of Kilauea Crater.

April 17, 1:08 pm, very feeble, of Kilauea Crater origin, near center.

A shock was reported felt in Hilo at 10:24 pm, April 17. This corresponded with the registration time of a tremor at the Observatory. It apparently originated 13.0 miles from Hilo in the NE rift of Mauna Loa.

April 20, 6:42 am, very feeble, Kilauea Crater near NE rim of Halemaumau.

April 20, 8:49 am, very feeble, NE portion of Kilauea Crater.

April 24, 2.51 pm, very feeble, Kilauea SW rift about 18.0 miles from Kilauea near sea.

April 25, 2:21 am, very feeble, 22.0 miles deep under Hualalai area. 19° 41.5' N; 155° 46.0' W.

April 29, 9:57 pm, very feeble, Mauna Loa NE rift, 5.0 miles deep and 5.0 miles NE of the summit crater. 19° 31.6' N; 155° 26.0' W.

May 1, 5:15 pm, very feeble, originated under Halemaumau.

May 8, 7:03 am., slight, probably originated in Hilina fault system about 20.0 miles deep and 4.0 miles S of Makaopuhi Crater.

May 11, 7:51 am, very feeble, probably originated 7.0 miles under Kilauea Crater.

May 13, a tremor at the Observatory recording at 3.32 pm corresponded with time of an earthquake reported felt in Honolulu.

May 14, 5:37 am, very feeble, of Kilauea Crater or Chain-of-Craters origin.

May 15, 10:28 am, moderate to strong, strongly felt over entire Island of Hawaii with exception of Kohala district. Probably most strongly felt in Hilo where there was slight damage to some masonry structures and plaster work. Also quite strongly felt in Hawaii National Park. Located 10.0 miles deep, 2.5 miles E of Makaopuhi Crater. 19° 22.0′ N; 155° 08.0′ W.

May 18, 8:48 pm, very feeble, 10.0 miles deep in Hilina Pali area, 4.0 miles S of Makaopuhi. 19° 19.0′ N; 155° 9.0′ W.

May 20, 2:05 am, very feeble, Kilauea Crater near NE rim of Halemaumau.

May 20, 10:18 am, very feeble, probable origin, Hilina fault system about 4.0 miles S of Puu Huluhulu.

May 23, 2:14 pm, moderate to strong, felt over entire Island of Hawaii and registered on University of Hawaii seismograph at 2h 16m 03s pm. All instruments at the Observatory except the strong motion seismograph were dismantled. Subsidiary stations at Hilo, Kona on Mauna Loa and around Kilauea Crater likewise were dismantled. Source of origin was apparently 7.5 miles NW of Kilauea Crater from a depth of 12.0 miles. 19° 28.5′ N; 155° 22.0′ W.

May 24, 12:59 pm, moderate to strong. Similar to quake of preceding day in that it was felt throughout Island of Hawaii and dismantled all seismographs except strong motion instrument at the Observatory. Registered at Unversity of Hawaii, Honolulu, "S" wave at 01h 00m 29s pm. Location 15.0 miles deep, 2.5 miles SE of Observatory, E rim of Kilauea Crater. 19° 25.0′ N; 155° 14.0′ W.

May 24, 1:09 pm, slight, probably same epicenter as preceding but possibly 5.0 miles deeper.

May 25, 3:39 am, very feeble, probably originated in Hilina fault system.

May 25, 8:54 am, very feeble, probable epicenter same as moderate shock of May 23, 2:14 pm.

May 26, 10:40 pm, very feeble, probable origin, Hualalai.

May 27, 4:29 pm, very feeble, probable origin, about 5.0 miles from Summit Crater, Mauna Loa, NE rift, about 8.0 miles deep.

May 28, 3:48 am, very feeble, probable origin, about 15.0 miles under Mauna Loa Summit Crater.

May 28, 6:34 am, very feeble, probable origin, Mauna Loa SW rift, 15.0 miles under area near 1907 source cones.

May 29, 7:15 pm, very feeble, registered on Honolulu seismograph "P" wave at 07h 15m 09s pm. Reported widely felt on Oahu and on Maui. Located 20-30 miles deep, 90.0 miles S of Lanai, 19° 30′ N; 156° 50′ W.

May 29, 11:45 pm, very feeble, probable origin, Chain-of-Craters near Devil's Throat.

May 31, 3:10 pm, moderate to strong, 11.0 miles deep in Hilina fault system, 8.0 miles S of Kilauea iki. Dismantled seismographs at Observatory and Pit but no others. 19° 18.5′ N; 155° 14.5′ W. This shock was peculiar in that there were no reports of it being felt. Members of the Observatory staff were conscious that earthquake was taking place through a special electric signal system, yet experienced no sensation of earth motion.

May 31, 8:38 pm, slight, felt in Hilo and Hawaii National Park, 12.0 miles deep, Mauna Loa NE rift, 13.0 miles SW of Hilo. 19° 37.5′ N; 155° 15.5′ W.

May 31, 8:51 pm, moderate to strong, reported felt throughout Kau and Hilo districts as well as other parts of Island of Hawaii but was particularly strong in Hawaii National Park and moderately so in Hilo. Location of source of origin, 11.0 miles deep, area 4.0 miles W of Mountain View. 19° 34.0′ N; 155° 10.5′ W.

June 2, 11:38 am, very feeble; Hilina fault system near SW rift was probable origin.

June 5, 2:06 am, very feeble, probable origin, under Kapoho area about 7.0 miles E of Pahoa, E extremity of Island.

June 5, 7:01 pm, very feeble, probably originated under sea floor off SE coast of Hawaii near Kalapana.

June 6, 4:07 pm, very feeble, 4.0 miles deep in Kilauea SW rift at Crater Junction. 19° 24.1′ N; 155° 18.0′ W.

June 7, 1:34 pm, very feeble, origin similar to that of moderate quake of 3:10 pm, May 31.

June 7, 10:47 pm, very feeble, NE portion of Kilauea Crater.

June 8, 10:45 pm, very feeble, 1.1 miles deep, 1.0 mile W of Puhimau Crater. 19° 23.6′ N; 155° 15.9′ W.

June 9, 2:25 am, very feeble, 3.0 miles deep, 0.5 mile NW of Pit seismograph station, Kilauea Crater. 19° 24.8′ N; 155° 17.1′ W.

June 9, 9:29 am, very feeble, probably of relatively deep origin, Hilina Fault system, 10.0 miles SE of Observatory.

June 9, 2:06 pm, very feeble, of shallow origin, cracks 0.7 mile N of Puu Ohale. 19° 21.9′ N; 155° 16.7′ W.

June 10, 5.41 am, very feeble, 1.1 miles deep, E rim of Kilauea Crater in vicinity of Kilauea iki. 19° 25.0′ N; 155° 15.6′ W. Felt slightly by a few persons in Hawaii National Park.

June 10, 10:10 am, very feeble, about 3.0 miles deep, 1.0 mile SW of Kamokukolau. 19° 22.5′ N; 155° 16.9′ W.

June 10, 8:51 am, feeble, 3.0 miles deep, about 0.5 mile W of Ahua Kamokukolau. 19° 23.0′ N; 155° 16.6′ W.

June 11, 11:18 am, very feeble, probable origin deep under Hilina fault system about 8.0 miles S of Observatory.

June 11, 10:45 pm, very feeble, 2.5 miles deep, about 2.1 miles W of center of Halemaumau. 19° 24.6′ N; 155° 19.0′ W.

June 12, 1:11 am, moderate to strong, 13.0 miles deep in Kau Desert area near Koae and Puu Ohale. Felt generally on the Island of Hawaii but apparently with greatest intensity in Hilo and Hawaii National Park areas. Dismantled Observatory, Pit and Mauna Loa seismographs.

June 12, 5.47 pm, feeble, 3.7 miles deep, 2.0 miles W of Pit seismograph under SW rim, Kilauea Crater. 19° 24.4′ N; 155° 18.5′ W.

June 12, 6:26 pm, very feeble, of shallow origin (0.5 mile ±), approximately 0.5 mile N of Uwekahuna. 19° 26.0′ N; 155° 17.4′ W.

June 13, 10:47 pm, very feeble, probably originated near SE rim of Kilauea Crater.

June 14, 1:04 am, slight, approximately 2.0 miles deep, Kilauea Crater between SE rim of Halemaumau and SE rim of Crater. 19° 24.5′ N; 155° 17.8′ W.

June 14, 2:06 am, very feeble, probably originated near SE rim of Kilauea Crater.

June 14, 6:27 am, very feeble, 2.3 miles deep, Kilauea SW rift near Cone Peak. 19° 23.7′ N; 155° 18.5′ W.

June 14, 10:02 am, slight, 2.1 miles deep, S rim of Kilauea Crater, 1.3 miles SE of Center of Halemaumau. 19° 23.6′ N; 155° 16.5′ W.

June 15, 3:18 pm, very feeble, 15.0 miles deep, S rim area of Kilauea Crater. 19° 23.5′ N; 155° 15.5′ W.

June 15, 5:46 pm, very feeble, probably originated near Kilauea iki.

June 16, 11:35 am, very feeble, Kilauea Crater origin near Halemaumau.

June 18, 5:12 pm, very feeble, of shallow origin near NE portion of Halemaumau.

June 19, 4:49 am, moderate, 15.0 miles deep in area E of Kilauea Crater approximately 2.0 miles SE of Observatory. 19° 25.3′ N; 155° 15.0′ W. Felt in Hilo and Hawaii National Park, where many persons were awakened. Dismantled E-W component of Bosch seismograph at Observatory and both components at Pit.

June 20, 4:10 am, very feeble, of shallow origin, Kilauea Crater near SE portion of Halemaumau.

June 20, 3:01 pm, slight, 13.0 miles deep, Puna rift near Makaopuhi. 19° 22.0′ N; 155° 10.0′ W.

June 24, 2:04 pm, slight, Bosch seismogram at Observatory indicated no S-P phase interval but began abruptly with "M" phase. In immediate vicinity of this station (Hawaii National Park headquarters) the shock was reported felt as a sudden vibration similar to that produced by nearby blasting. Many persons thought it actually was a heavy blast. On this evidence it was assumed the quake originated in the faulted area NE rim of Kilauea Crater. Examination of the Pit and Uwekahuna seismograms confirmed this assumption and the point of origin was so placed and considered of shallow origin. 19° 25.8′ N; 155° 16.6′ W.

July 1, 12:20 am, moderate, 11.0 miles deep, Chain-of-Craters near Puu Huluhulu and Alealea Crater. 19° 23.0′ N; 155° 11.5′ W. Reported felt by many persons in Hilo, where a large number were awakened. In Hawaii National Park the shock was reported felt as a prolonged and persistent swaying motion lasting 15 ± seconds. Here, too, a number of persons were awakened. E-W component of Bosch seismograph was dismantled as was the same component at Halemaumau.

Teleseisms

April 5, "P" waves began recording at 6h 21m 58s am, 3,755 miles from Kilauea. Reports from the Jesuit Seismological Association place the origin in the vicinity of New Caledonia. 27° S; 167° E.

April 17, unidentified portion at 8h 16m 33s pm.

April 20, "eP" at 6h 08m 17s pm, distance 3,630 miles. Jesuit Seismological Association reports 500 km deep, NE Asia. 48.6° N; 138° E.

April 21, "eP?" at 9h 42m 35s am, no distance determined and no reports from other localities received.

April 29, "eP" at 4h 34m 49s pm, distance 3,730 miles. Reports from U. S. C. and G. S. give origin as 11° S; 158° E. Solomon Islands.

May 2, "eS?", 3h 01m 26s am, U. S. C. and G. S. report—off coast of Lower California as place of origin. 29.5° N; 113.8° W.

May 9, "ePr?" at 9h 21m 27.0s pm, U. S. C. and G. S. location given as Aleutian Islands. 41° N; 179° W.

June 1, "iP" at 5h 15m 10s pm, no distance, no reports.

June 8, "eP" at 10h 24m 31s am, U. S. C. and G. S. reported location between Samoa and Tongas. 15° S; 173° W.

June 11, "eP?" at 5h 01m 13s ± am, no distance, no location reported.

On June 16, at 4:20 am, a tremor registered on the Observatory seismograph having the appearance of a near shock. Kona seismograms indicated a distance of 66 miles; the Mauna Loa seismograph indicated a distance of 93.0 miles.

Microseismic Motion

April

Light—10, 11, 13, 14, and 25.
Moderate—9, 12, 15, 16, 19, 21-24, 26-28.
Strong—3-8, 17, 18, 20, 29, 30.

May

Light—2, 6, 7, 19, 20.
Moderate—3-5, 8-13, 16-18, 21-31.
Strong—1, 14, 15.

June

Light—2-9, 13-16, 18, 21-30 inclusive.
Moderate—1, 10, 11, 12, 17, 19, 20.
Strong—None.

Time used throughout is Hawaiian Standard, 10h 30m slower than G. C. T.

Tilting of the Ground

The following tables show tilt by weeks recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum toward or away from the Pit as indicated by tilt stations on the W and SE rims respectively.

At the Observatory the total accumulated tilt for the year ending April 30, was 4.0" S and 5.35" W.

For the year ending May 28, it was 3.92" S and 4.75" W.

For the year ending July 2, it was 3.75" S and 2.6" W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
April 9	1.61" S 83° W	1.85" N 5° E
" 16	0.93" N 72° E	3.73" N 87° W
" 23	0.25" N 83° E	1.49" S
" 30	0.47" S 60° W	2.53" W
May 7	0.45" N 22° E	6.11" N 69° W
" 14	2.19" S 61° W	7.09" S 79° W
" 21	0.92" N 73° E	11.62" S 64° W
" 28	0.31" N 25° E	15.44" N 41° W
June 4	0.43" N 19° E	3.37" S 85° W
" 11	0.48" N 36° E	3.99" W
" 18	0.17" N 45° E	11.18" N 72° W
" 25	0.88" N 11° E	4.41" S 50° E
July 2	0.42" N 21° E	11.62" N 48° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
April 9	6.48" N 63° W	5.97" toward
" 16	15.91" W	5.82" toward
" 23	15.31" W	9.09" toward
" 30	6.12" N 41° W	3.63" toward
May 9	4.99" N	1.62" from
" 14	5.67" N 21° E	3.93" from
" 21	12.15" N 40° E	7.96" from
" 28	16.20" N 86° W	1.59" toward
June 4	16.85" S 74° E	17.04" from
" 11	8.42" N 37° W	4.41" toward
" 18	1.72" S 41° W	10.46" from
" 25	2.75" N 11° W	4.75" toward
July 2	6.45" S 89° W	8.38" from

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, April 15, indicated closing of both the Halemaumau and the Crater values compared with similar measurements of March 30. The Halemaumau angles between the Pit seismograph and the NW Pit BM closed 0.91". The crater angle between the SE crater rim station and Uwekahuna closed 1.16".

During May two determinations were made of the same angles. These were May 6 and 26. On May 6 the Halemaumau angle had opened 1.59" and the Crater angle had closed 1.17". Between May 6 and 26 the Halemaumau angle closed 0.34" and the Crater angle opened 0.75". Total change for the month, Halemaumau angle opened 1.25" and the Crater angle closed 0.42".

Angle values determined June 17 indicated closing of the Halemaumau and closing of the Crater angle. Halemaumau value decreased 3.33". Crater value decreased 0.38".

Total change at Halemaumau, March 30 to June 17, 2.99", closing; across Crater 1.16" closing.

Chain-of-Craters Road Cracks

Date	101	102	103	104	105	106	107
April 28	403.70	64.40	101.35	17'19/8	87.15	88.60	40.35
June 2	404.00	64.40	101.45	X	87.20	88.60	39.75
June 30	404.35	64.50	101.45	X	87.25	88.75	39.70
Total change in mm.	+ 6.5	+ 1.0	+ 1.0	——	+ 1.0	+ 1.5	—6.5

Plus (+) = open. Minus (—) = close.

In 104, near Pauahi was temporarily discontinued. Large size makes it difficult to measure but determinations will be resumed in near future.

There was no change between March 30 of last report and April 28 of this report.

It is obvious that these cracks were greatly accelerated in their openings during the month of May, when seismic activity likewise increased. Cracks around Halemaumau showed relatively large increase in same period. This demonstrates the probability that the cracks around Halemaumau, although greatly activated by gravity, are also moved by volcanic changes, i.e., seismic changes.

H. H. W.



THE VOLCANO LETTER

465

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EXPEDITION TO LAVA-BOMBING SITE

T. A. JAGGAR

This expedition to the north slope of Mauna Loa was conducted by the volcanologist of Hawaii National Park in cooperation with the Territorial Department of Forestry and Agriculture. The scientific members of the party were T. A. Jaggar, L. W. Bryan and H. H. Waesche. Cordial assistance came from Parker Ranch through Joseph Ignacio, who prepared trail and camp ground at 7,000 feet elevation on the north slope of Mauna Loa. The objects were to photograph the exact spots where bombs fell to deflect the 1935 lava flow, to delimit the flow area, to note the bomb effects, to map some older flows and to start a campaign to study more closely Mauna Loa on its danger slope above Hilo.



Fig. 1—Bomb crater with upstanding edges and pahoehoe ring and torrent of released lava; Target 2, elevation 8,200 feet. Arrow shows crater. Photo by Jaggar.

Camp was made August 30, 1939; the Bryan party studied the middle of the flow September 1 and the source region at 8,900 feet September 2. The Jaggar party joined them, and mapped and photographed the bomb craters September 3 and 6, taking color and monochromatic pictures. On September 5 a study was made of the 1899 flow about 8,000 feet, and on September 7-8 a heavy black aa flow in contact with the 1935 flow on its east side was found to be very fresh and to check perfectly in age and position with the western 1880 flow, **never hitherto mapped,** but described succinctly by Coan, Baker and Hitchcock as sweeping from Puka Uahi twelve miles towards Mauna Kea the first week of November 1880. This becomes of very great importance in studying the source of the 1935 Humuula flow that was bombed, for the 1935 outburst was between this relatively recent flow and the 1843 flow and was guided by the depression between them. The contact between the aa lavas of this 1880 branch and 1935 was found, 1935 red and free from vegetation, 1880 black with some lichens and with large concretionary "snow-ball" boulders on its surface (Figure 8).

The exploration of the bomb craters was started by Forester Bryan and carried forward by Dr. Jaggar, Mr. Waesche and Ranger Jess, so that most of the twenty demolition bombs dropped by the army squadrons were accounted for in the mile of lava-source cracks and tunnels between Target A and Target B. (See Volcano Letter 442.) Fragments of shrapnel, rusty red, were found in profusion; several of the "pointer" bombs of black powder and sand were discovered; one large "dud" bomb was found with end torn off and several hundred pounds of TNT exposed (Figure 3); and pieces of casing, vanes, covers and detonator tubes were picked up (Figure 6). The pointer bomb casings contained Hilo beach sand. The TNT was lighted and burned, first piecemeal, then as a whole with a newspaper fuse, while the party retreated down the mountain. After *twenty-five minutes of flame and black smoke, the remains of* the explosive were detonated by the fire perhaps reaching the war-head mechanism, and a quarry blast ended the perform-

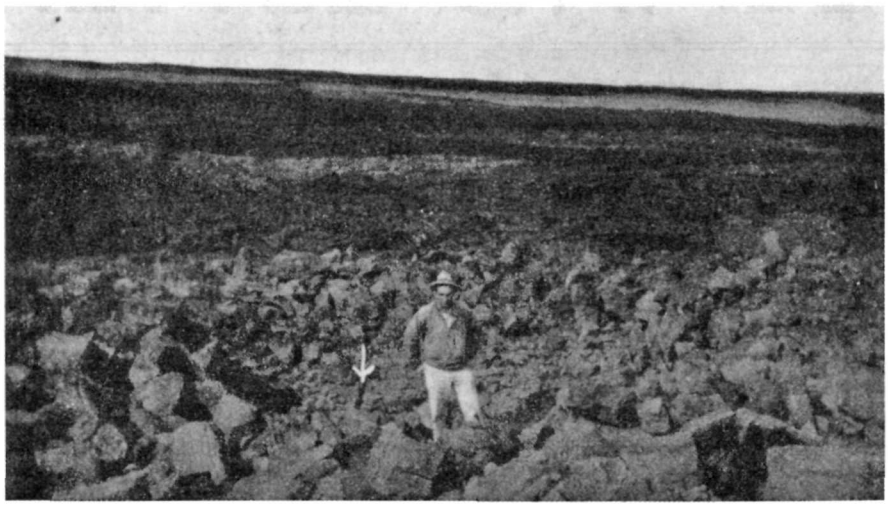

Fig. 2—Bomb crater in old lava; near Target 1, elevation 8,800 feet. Photo by Stearns.

ance. The place was revisited and photographed by Mr. Jess, who found a 3-foot depression, and fragments 100 feet away.

About sixteen of the bomb-holes were identified, one a perfect oval one hundred feet long by forty feet wide, crowned by a ring of upturned fragments of the rim, the interior a pit forty feet deep to a lava tunnel below. Liquid lava had splashed up and out in great sheets and gushes of molten glass. Seventy-five per cent of the holes found had exposed liquid lava. Four holes were off the stream line and in pairs, making bomb craters of broken rock (Figure 2), circular saucers twenty feet across and six feet deep.

In one case melted glass clung to shell fragments. In another a winged bomb had plunged through a thin crust, possibly into liquid lava (Figure 4), and was intact, its nose exposed protruding down into a tunnel below. Great blobs of glassy lava lay on the surface of pahoehoe silvery tongues, where explosions had flung them high. Rivers of liquid lava had escaped from some of the deep tunnel punctures, where the



Fig. 4—Pointer bomb of black powder near Tarket 1 with nose in cavern beneath; and Forester L. W. Bryan. Photo by Jaggar.

explosion had opened the tube. Other places had halos fifty or sixty feet wide, platforms of black glass, around an immense circular hole, where the bomb had released an artesian well of lava. The edge of the hole was scalloped like a tiara (Figure 4). The upper Target A was thickly strewn with pieces of rusty steel, from a quarter-inch to ten inches across, thin and thick, terribly jagged shrapnel torn from the big 600-pound shells like so much pasteboard.

The source region one mile below its upper limit had been studied by Jaggar and Waesche on foot in March 1936. They had found the lower bomb-craters, recognized the slabs and upwellings, but *had not found any iron fragments. The* actual source at Target A is a channel twenty feet across bordered by a bank of froth lava, meandering slightly, and lined



Fig. 3—Demolition bomb fragments with protruding TNT; near Target 1. Photo by Waesche.

by a glassy pahoehoe floor, with windows revealing frozen streams and tunnel beneath. This channel begins abruptly at a ten-foot inclined shaft and transverse cracks. Up the mountain is a hill or flow-front of pasty-mixed lava of non-identifiable age. Down the mountain the torrent flowed in the channel, sometimes on the surface, sometimes deep in a tube. Mostly the margins are silver pahoehoe, but aa patches occur. Farther down a gush of pahoehoe begins and spreads in a fan. This is repeated five times in three miles. Underneath all this is a flow of aa. Down at Humuula the pahoehoe gushes unite at a river bending into a lake. They bend around the front of two large feather-shaped deltas of the aa of mid-December, 1935.

A striking feature of the bombed area was the existence upstream from some bomb-holes (Figure 5), of tunnel-openings where pudgy, pasty, stiff semi-aa lava welled up as a heap or pudding. The smashing of the tunnel had cooled the oncoming liquid so that it dammed itself. This confirmed the theory that the bombing solidified the tunnel lava back into the heart of the mountain. With twelve river hits out of sixteen, and liquid flung up hundreds of feet, there can be no question whatever that the bombing stopped the flow. The tunnels farther down the hillslope from the artificial damming were full of liquid which poured on for a week. But the bombardment of the river targets had cooled, dammed, solidified and freed from gas an enormous volume of slag, which froze where it lay, and the

very smallness of the natural vents proves how large was the artificial effect of this human achievement. The whole flow was in a single pipe, and the collective bomb craters were much bigger than that pipe. The pipe was a natural sewer tunnel twenty to forty feet underground and ten to fifteen feet across. A single one of sixteen bomb punctures was eighty feet across and forty feet deep to the roofed-over flow. No slag-stream full of gas could take such a bombardment, flinging up its substance, with several tons of high explosive, distributed along a mile of stream-way, and fail to thicken and solidify.

The source stream of the Humuula flow when active, at elevation 8,900 feet, glowed and steamed in a line of vents that were pahoehoe where the lava emerged, and this heap was visited by Ranger G. E. Olson, Philips and Ignacio November 25, 1935, as is shown by the photograph, Figure 7. An air photograph by Dod at the same period shows that the line of vapors ended abruptly against older dark lava uphill. This was the lower glow-spot, Figure 5, Volcano Letter 429, and the upper limit of bombed stream, Volcano Letter 442 frontispiece. The conclusion is that this channel and tunnel was a crack in the mountain that vomited out the Humuula flow of 1935, and that the dark lava uphill is part of the cold 1880 torrent. The line of vapors and glows ended against this older lava, and the crack beneath emerged downhill from it but did not break it.

The event was on December 27, 1935, when the front of the lava flow was pushing toward Hilo a mile a day, twelve miles from the city, and fifteen miles downhill from this source tunnel. The United States Army Air Corps all day long bombed the two targets of the source tunnel from the air. The next day the front slowed down, and five days later it stopped.

This camping trip of a week shows that the scientists can live in the high lava of Mauna Loa in comfort, that the danger slope above Hilo can be critically studied with new markers and air photographs, and with the proposed barriers for deflection of the most rapid flows that may rush to the sea near Hilo, we can eventually, if supported with men and trails and additional upper Mauna Loa lands in the Park, make the inhabitants of this fair land take pride in their defense against volcanoes.

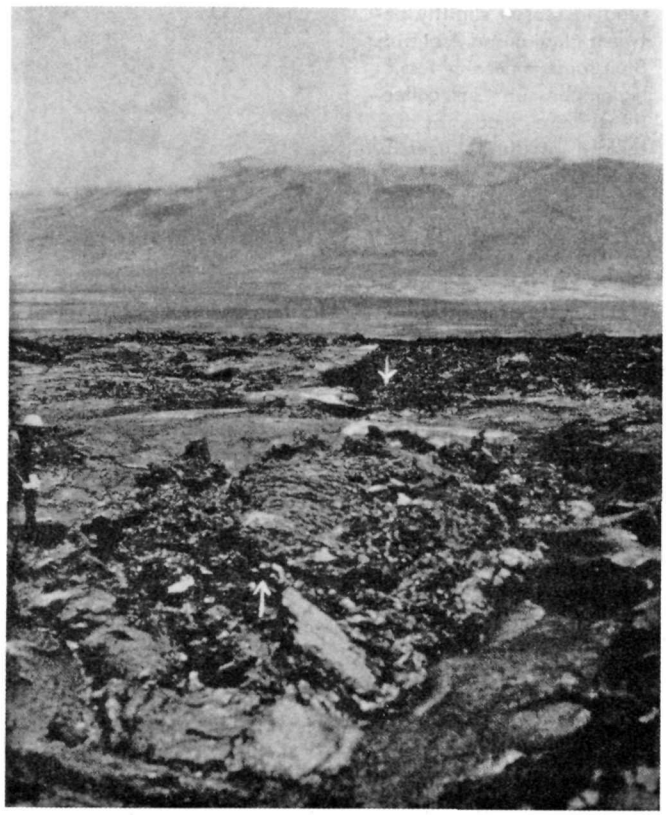

Fig. 5.—Pasty lava plug welled up, as result of bomb damming, in main stream tunnel; Mauna Kea in distance; Target 1. Photo by Jaggar.

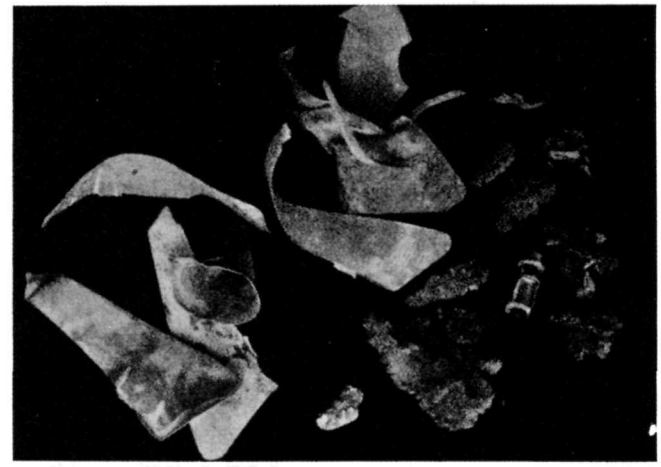

Fig. 6—Miscellaneous fragments of bombs and vanes collected. Photo by Cunningham.

Hawaiian Volcano Observatory Report for July-September 1939

VOLCANOLOGY

July 1939

Halemaumau had few rock slides, but the month showed uneasy working of fault blocks on Chain of Craters, and at Hilina Cliff south of Kilauea fresh avalanche scars were found July 13. A strongish shock July 14 originated there five miles underground. Three slides on Hilina Cliff July 25 occurred about 4:20 p.m. A slide from the northwest wall of Halemaumau July 30, 11:30 a.m., made a cloud of dust.

The cracks parallel to Halemaumau rim, of which 28 are measured weekly, showed aggregate closing for the first and third weeks of July, a condition not recorded since October, 1938. It is of interest that Chain of Craters measured fault cracks, four miles southeast, also closed for these weeks.

Sulphur fume was reported July 7 on Mauna Loa trail as an odor one mile below 1935 cone. Fuming in Halemaumau bottom has decreased, but was observed at the stain southeast the second week, and on July 28.

Messrs. Bullard, Schulz and others camped at Mokauweo-*weo rest house, summit of Mauna Loa, July 20-21. Abundant* fumes were found on the crater floor, heat was rising from the summit part of 1935 rift northeast, and sulphur was being deposited in cavities on southwest flank of 1935 cone at 11,000 feet.

The numbers of local and distant seismic disturbances recently, by months, have been:

	Local	Distant
April	66	5
May	184	3
June	337	3
July	203	3
August	287	2
September	101	1

The swarm of June-July is evident, but the July disturbances were mostly tremors. Sixteen Kilauea shocks and five from Mauna Loa were located for July, two of the latter 35 miles deep. A distant earthquake of July 6, 3,550 miles away, was reported as 550 km. deep between Fiji and Tonga.

Of the 203 shocks and tremors of local origin registered on the seismographs for July, 21 were located by seismometric method, and, of these, 10 were under Kilauea crater, 5 were under Mauna Loa, 3 under Kilauea rifts, and 3 at the Hilina Cliffs.

The following are the local data for July:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
July 9	0	3.0 mm. closed	40
" 16	0	7.5 mm. opened	56
" 23	0	2.0 mm. closed	70
" 30	1	3.5 mm. opened	37

August 1939

The month at Kilauea crater exhibited some movement in the Hilina-Chain of Craters fault blocks which border the Kilauea rift on the southeast. (See map Volcano Letter 462.) A roadside crack at the edge of Aloi pit opened 2 feet in an hour of the early afternoon August 2, and extended 20 feet in depth. The motion did not continue.

The next event was a swarm of earthquakes about August 17, several of them felt, centering at the Hilina Pali fault system, including greatly increased frequency of very feeble movements and tremors.

A remarkable feature of this period, enduring for two weeks, was cumulative closing instead of opening, of the 27 concentric rim cracks around Halemaumau edge which are measured once a week. On the week ended August 18, of the rim cracks 19 closed, 8 were unchanged, and none opened, with aggregate closing of 15 millimeters. Along Chain of Craters, also, the measured cracks showed temporary closing of 8.5 millimeters. As these measurements were made the day after the Hilina disturbances, and the following week showed restorative opening of cracks, it appears that the fault movements caused this unusual compression normal to the fault planes, and both Halemaumau and the Chain of Craters took the squeeze, as both are on the major Kilauea rift.

Of two distant earthquakes both in New Hebrides region, 3,270 and 3,500 miles away, August 11 and 17, the second coincided in date with the moderate local earthquakes, preceding them by about six hours.

Slides in August were observed as follows:

August 2, 10:20 a.m., at north wall of Pauahi Pit;
" 2, 10:00 a.m., west wall Halemaumau, small;
" 6, Kilauea Iki scars north wall;
" 15, north wall Halemaumau, 11:19 a.m.;
" 17, scars in Pauahi crater.
" 20, north wall Halemaumau, 3:17 p.m.;
" 27, dust streaks north and west walls Halemaumau.

Of the 287 local shocks and tremors counted on the seismograms for August, 20 were located, and of these 7 were from Hilina Cliffs, 6 from Kilauea crater, 3 from Mauna Loa, 1 each from Kilauea southwest rift, Kona, Kohala and Hualalai.

The following are the local data for August:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
August 6	1	2.5 mm. opened	57
" 13	0	1.5 mm. closed	50
" 20	2	15.0 mm. closed	86
" 27	0	11.0 mm. opened	52
Sept. 3	0	5.0 mm. opened	42

September 1939

For six weeks following August 20 the decline in local earthquake frequency, and in numbers of tremors that determine technical seismicity, was steady and progressive. There were some feeble earthquakes felt that preceded equinox. Nothing volcanic was remarkable. An earthquake near Kamchatka under Bering Sea occurred September 8, 2,800 miles from Kilauea station.

Slides in September were observed as follows:

September 8, 12:40 and 12:59 p.m., northwest wall Halemaumau;
" 29, 10:33 a.m., north rim Halemaumau;
" 29, fresh fall of debris in road crack Pauahi Pit.

There was gradual movement detectable along the fractured rim of Devil's Throat, and humps in the road increased slightly between Hiiaka and Aloi pits. Blue fume is notably less at Halemaumau. Gas collections were made by Dr. Ballard of the University of Hawaii in Mokuaweoweo September 14. The three members of the expedition felt a sharp earthquake on the Mauna Loa crater floor at 10:07 a.m. of that date. This registered as a tremor at Kilauea seismographs.



Fig. 7—Pahoehoe steaming heap with glow-hole in foreground, November 25, 1935, at 8,900 feet elevation, Humuula. Photo by Olson.

Of the 101 local shocks and tremors recorded in September, 16 were located, and of these 6 were from Kilauea crater, 4 from Mauna Loa, 3 from Kilauea rifts, 2 from Hualalai, and 1 from Hilina Cliff region.

The following are the local data for September:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
September 10	2	2.0 mm. opened	39
" 17	0	1.5 mm. opened	28
" 24	0	3.0 mm. opened	19
October 1	1	2.0 mm. opened	15

T. A. J.



Fig. 8—Concretion balls on supposed 1880 lava. Photo by Jaggar.

SEISMOLOGICAL AND GEODETIC DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
July 9....	34	4	1	1	0	1	13.50
" 16....	48	7	0	0	1	0	19.50
" 23....	66	4	0	0	0	2	18.50
" 30....	33	4	0	0	0	0	10.25
August 6....	50	6	1	0	0	0	17.00
" 13....	46	2	2	0	0	1	14.50
" 20....	66	16	1	1	2	1	35.50
" 27....	50	2	0	0	0	0	13.50
September 3....	36	5	1	0	0	0	12.50
" 10....	35	3	1	0	0	1	11.25
" 17....	22	4	2	0	0	0	9.50
" 24....	16	3	0	0	0	0	5.50
October 1....	13	2	0	0	0	0	4.25

* Including teleseisms or earthquakes over 5,000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the station operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

July 5, 12:20 am, slight, 12.0 miles deep in Hilina Pali area 2.5 miles S of Makaopulii 19° 20.2' N., 155° 10.2' W. Felt slightly in Hilo and by a few persons in Hawaii National Park.

July 7, 5:46 pm, very feeble, probably originated in SE rim area of Kilauea Crater.

July 7, 7:23 pm, very feeble, probably originated in SE rim area of Kilauea Crater.

July 7, 8:04 pm, feeble, probably originated in E rim area of Kilauea Crater.

July 8, 3:32 pm, very feeble, probably originated Kilauea SE rift near Kalapana.

July 11, 5:51 pm, very feeble, of Kilauea Crater origin.

July 12, 11:30 pm, very feeble, of Kilauea Crater origin.

July 14, 3:51 am, moderate to strong, 5.0 miles deep, Hilina fault system about 5.0 miles SE of Makaopuhi. 19° 19.5' N; 155° 07.0' W. All instruments at the Observatory were dismantled with the exception of the strong motion seismograph. The quake was generally felt on the island with the greatest internicity centered in the Kau-Puna area. Most sleepers were awakened in Hawaii National Park and in Hilo. Reported unusually strong at Pahoa.

July 15, 9:46 pm, very feeble, of shallow origin in Kilauea Crater E of Halemaumau.

July 16, 7:14 am, very feeble, about 35.0 miles deep, Mauna Loa NE rift, 13.0 miles NE of Summit Crater. 19° 33.5' N; 155° 25.5' W.

July 16, 3:57 pm, very feeble, probable origin Hilina Fault system about 3.5 miles S of Makaopuhi Crater.

July 19, 11:38 am, very feeble, 1.5 miles deep, Chain of Craters, near Puhimau. 19° 23.6' N; 155° 14.9' W.

July 19, 10:15 pm, very feeble, 1.4 miles deep, 1.3 miles W of Hiiaka Crater. 19° 22.6' N; 155° 15.1' W.

July 21, 9:04 pm, very feeble, Mauna Loa NE rift about 12 miles SW of Hilo.

July 25, 11:00 am, very feeble, originated about 1.7 miles NW of Volcano Observatory, 4.2 miles deep. 19° 26.9' N; 155° 16.3' W.

July 25, 11:45 am, very feeble, 35.0 miles deep, Mauna Loa NE rift, 16.0 miles NE of Summit Crater.

July 27, 2:02 am, very feeble, 23.0 miles deep on W slope of Mauna Loa, 14.0 miles W by S of Mauna Loa Summit Crater. 19° 26.0' N; 155° 48.0' W.

July 28, 5:12 pm, very feeble, probably originated in Kilauea Crater 1.3 miles SW of Observatory.

July 31, 8:58 am, very feeble, of shallow origin Mauna Loa NE rift 16 miles from Summit Crater.

July 31, 8:18 pm, very feeble, probably originated in Kilauea Crater near Halemaumau.

July 31, 8:21 pm, very feeble, of shallow origin, Kilauea Crater rim area near Kilauea Iki. 19° 25.1' N; 155° 15.3' W. Reported felt by few persons in Hawaii National Park and dismantled NS component of Pit seismograph.

August 4, 3:16 pm, very feeble, of shallow origin near S rim of Keanakakoi Crater. 19° 24.1' N; 155° 16.0' W.

August 4, 11:56 pm, very feeble, 2.2 miles deep, 4.0 miles NW of the Observatory. 19° 28.5' N; 155° 18.8' W.

August 5, 1:46 pm, very feeble, 8.0 miles deep, 5.0 miles SW of Kailua. 19° 31.0' N; 156° 02.0' W. Reported felt at Holualoa and Hookena.

August 6, 5:09 pm, very feeble, origin was 40.0 miles under Hualalai. 19° 41.5' N; 155° 35' W.

August 7, 7:19 am, very feeble, probably originated under N rim area of Kilauea Crater.

August 8, 4:32 am, feeble, originated in Hilina Fault system, 3.0 miles N of Apua Point, 6.0 miles deep. 19° 18.0' N; 155° 11.5' W. Reported felt in Hilo.

August 8, 6:50 am, feeble, 10.0 miles deep in Hilina Fault system 4.0 miles S of Makaopuhi. 19° 19.0′ N; 155° 10.0′ W. Reported felt in Hilo.

August 11, 6:39 pm, very feeble, probably originated in Kilauea SW rift near sea coast.

August 15, 2:52 pm, very feeble, probably originated in Mauna Loa NE rift.

August 16, 10:29 am, very feeble, originated in area between Makaopuhi and Hilina Fault.

August 16, 2:20 pm, very feeble, originated near Uwekahuna, NW rim, Kilauea Crater. 19° 25.5′ N; 155° 17.6′ W.

August 16, 2:40 pm, very feeble, Mauna Loa NE rift about 5.0 miles SW of Puu Ulaula.

August 17, 5:57 am, moderate, 8.0 miles deep in Hilina Fault system, 4.5 miles SE of Makaopuhi. 19° 19.5′ N; 155° 06.5′ W. Unusual in that it was not reported felt.

August 17, 6:18 am, moderate, 4.0 miles deep in Hilina Fault system, 4.0 miles ESE of Makaopuhi. 19° 21.5′ N; 155° 07.0′ W. Not reported felt.

August 17, 6:58 am, very feeble, probably in Hilina Fault system, about 15.0 miles deep and N of Keahou Point.

August 17, 11:51 pm, slight, probably of shallow origin in Hilina Fault system 3.5 miles S of Puu Ohale.

August 18, 9:03 pm, very feeble, probably originated under NE portion of Mauna Loa Summit Crater.

August 20, 10:01 am, very feeble, 12.0 miles deep, 3.0 miles W of Kulani Cone near NE rift of Mauna Loa. 19° 31.7′ N; 155° 21.0′ W.

August 27, 4:19 pm, very feeble, NE rim area of Kilauea Crater.

August 28, 6:21 pm, very feeble, probably originated in Kohala district.

September 3, 6:17 am, very feeble, Mauna Loa Summit Crater origin.

September 3, 6:54 am, very feeble, of shallow origin in Chain of Craters near Kokoolau and Devil's Throat. 19° 23.0′ N.; 155° 14.7′ W.

September 3, 8:10 pm, feeble, 7.0 miles deep, Mauna Loa NE rift, 3.0 miles SE of Puu Ulaula. 19° 30.0′ N; 155° 26.0′ W. Reported felt at Kilauea Military Camp accompanied by mild roaring noise.

September 4, 12:28 am, very feeble, 5.0 miles deep, Mauna Loa NE rift near Pukauahi Crater. 19° 31.5′ N; 155° 31.0′ W.

September 7, 1:32 am, feeble, 15.0 miles deep, Hualalai Volcano. 19° 41.0′ N; 155° 51.0′ W. Reported strongly felt at Puu Waawaa.

September 7, 10:46 am, very feeble, 4.0 miles deep under Waldron Ledge, NE rim Kilauea Crater. 19° 24.4′ N; 155° 15.4′ W.

September 8, 1:39 pm, very feeble, NE portion of Kilauea Crater.

September 13, 6:49 am, feeble, 9.0 miles deep Kilauea SW rift, 6.0 miles from the Observatory. 19° 24.0′ N; 155° 20.0′ W.

September 13, 4:20 pm, feeble, 13.0 miles deep Hilina Pali about 4.0 miles N of Apua Point. 19° 18.0′ N; 155° 10.0′ W.

September 14, 10:07 am, a tremor, reported felt on Mauna Loa.

September 14, 12:10 pm, very feeble, probably originated from relatively great depth under Hualalai.

September 15, 6:13 pm, very feeble, NW rim of Kilauea Crater, 0.6 mile N of Uwekahuna. 19° 25.9′ N; 155° 17.5′ W.

September 17, 3:33 am, very feeble, of shallow depth, Kilauea Crater near Halemaumau.

September 20, 10:41 am, very feeble, about 2.5 miles deep in Kilauea Crater near Halemaumau.

September 27, 11:24 am, very feeble, Kilauea SW rift.

September 28, 9:11 am, very feeble, probably from SW portion of Kilauea Crater.

Teleseisms

July 6, "P" waves began recording at 12h 18m 54.0s pm. This was reported by the Jesuit Seismological Society as a deep earthquake (550 km) which originated in the area between the Fiji and Tonga groups of the S. Pacific. 24° S; 18° W. Distance from Kilauea approximately 3,550 miles.

July 17, unidentified portion at 5h 11m 36s pm. No reports received.

July 23, 5h 03m am, unidentified portion.

August 11, "P" waves, 3h 46m 11s pm, J. S. A. location in vicinity of New Hebrides 13° S; 169° E. Distance from Kilauea, 3,270 miles.

August 17, surface (L) waves at 12:10 am, U. S. C. and G. S. location 18° S; 168° E in New Hebrides area. Distance from Kilauea, 3,500 miles.

September 8, 1h 42m 19s am, "P" waves began. U. S. C. and G. S. location near Kamchatka in Bering Sea. 51° N; 175° E. 2,800 miles from Kilauea.

Microseismic Motion

July

Light—5, 7-9, 18-21, 24-29, 31.
Moderate—3, 4, 6, 10-12, 15, 17, 22, 23, 30.
Strong—13, 14, 16.

August

Light—3-6, 8-10, 12-15, 19, 21-31.
Moderate—1, 2, 7, 11, 16-18.
Strong—20.

September

Light—1-3, 5-12, 18, 27-29.
Moderate—4, 13-17, 20, 23, 24, 26, 30.
Strong—19, 21, 22, 25.

Time used throughout is Hawaiian Standard, 10h 30m slower than G. C. T.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum toward or away from the Pit as indicated by tilt stations on the W and SE rims respectively.

At the Observatory the total accumulated tilt for the year ending July 30, was 2.05" S and 4.0" W.

For the year ending August 27, it was 1.53" S and 3.43" W.

For the year ending October 1, it was 1.24" S and 3.20" W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
July 9	0.50" N 20° E	6.97" S 26° W
" 16	0.97" N 26° E	3.13" S 23° W
" 23	0.66" N 21° W	2.98" N 79° W
" 30	1.05" N 20° W	5.72" N 60° W
August 6	0.88" N 51° W	5.63" N 66° W
" 13	2.05" N 63° E	6.82" N 9° E
" 20	0.27" N 89° E	3.03" N 80° W
" 27	0.48" N 33° E	2.15" N 69° W
Sept. 3	1.00" N 10° E	4.65" N 80° W
" 10	1.34" N 50° E	1.58" S 60° W
" 17	0.35" N 42° E	1.97" S 27° E
" 24	0.30" S 3° W	0.00
October 1	0.50" N 86° E	2.68" N 30° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
July 9	4.92" N 79° E	7.15" from
" 16	3.34" N 31° W	1.91" toward
" 23	4.86" N 17° W	1.71" toward
" 30	7.71" N 44° E	3.62" from
August 6	2.43" N 69° W	4.31" from
" 13	3.63" N 39° W	5.36" toward
" 20	11.99" N 50° W	8.83" toward
" 27	0.78" N 66° E	2.10" from
Sept. 3	3.11" N 38° E	3.66" from
" 10	10.37" S 81° W	3.52" toward
" 17	10.89" S 69° W	3.66" toward
" 24	8.29" S 44° W	1.45" from
October 1	12.02" N 75° W	8.20" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory were made twice during the month of July. On July 7, these measurements indicated opening of 0.58" for the Halemaumau value and closing of 0.61" for the Crater value compared with similar measurements of June 17. Between July 7 and July 29, the Halemaumau value showed closing of 2.73" and the Crater value showed opening of 1.58". Total, June 17 to July 29: Pit closed 2.25" and Crater opened 0.97". The Halemaumau value is measured between the seismograph station on the SE rim and the NW Pit bench mark. The Crater value is measured between a station on the SE rim of Kilauea Crater and the Uwekahuna station.

Angle values August 17, indicated opening of the Halemaumau value of 4.42" and closing of the Crater angle of 2.75".

Two measurements were made during September. On September 12, the Halemaumau angle had closed 0.17" and the Crater angle had closed 0.25". Between September 12 and September 27, Halemaumau value closed 2.41" and Crater value opened 2.41". Total change August 17 to September 27, Halemaumau closed 2.58" and the Crater opened 2.16".

Total change at Halemaumau, June 17 to September 27: Halemaumau closed 0.41" and the Crater opened 0.38".

Spirit Levelling around Halemaumau

Between August 25 and 30, a line of levels on Kilauea Crater floor was run for a complete circuit around Halemaumau. Comparison with a similar run made March 20-21, 1939 shows that the NW Pit BM had lowered since that period 4.4 centimeters relative to the Spit B. M.

Chain of Craters Road Cracks

Date	101	102	103	104	105	106	107
July 28	404.40 cm.	64.45	101.45	17'19⅛"	87.30	88.70	39.60
Sept. 1	404.45	64.50	101.55	17'19⅛"	87.35	88.80	39.55
Sept. 29	404.65	64.55	101.55	17'19⅛"	87.30	88.75	39.65
Total change in mm. since June 30..	+3.0 mm.	+0.5	+1.0		+0.5		

Plus (+) = open. Minus (—) = close.

New cracks developed in the side of the road nearest Aloi Crater and on its S rim. One crack was parallel to the road and the other was across the road surface. Measurement of these two cracks was started August 2, 1939. They were designated 108 and 109 respectively. On September 29 No. 108 had opened from 102.55 cm to 102.70 cm, a total of 1.5 millimeters. No. 109 remained unchanged at 97.70 cm.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, is leased and operated by the United States Government, Department of the Interior, National Park Service.

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THE VOLCANO LETTER

No. 466 Department of the Interior National Park Service October-December, 1939

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Edward G. Wingate, Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

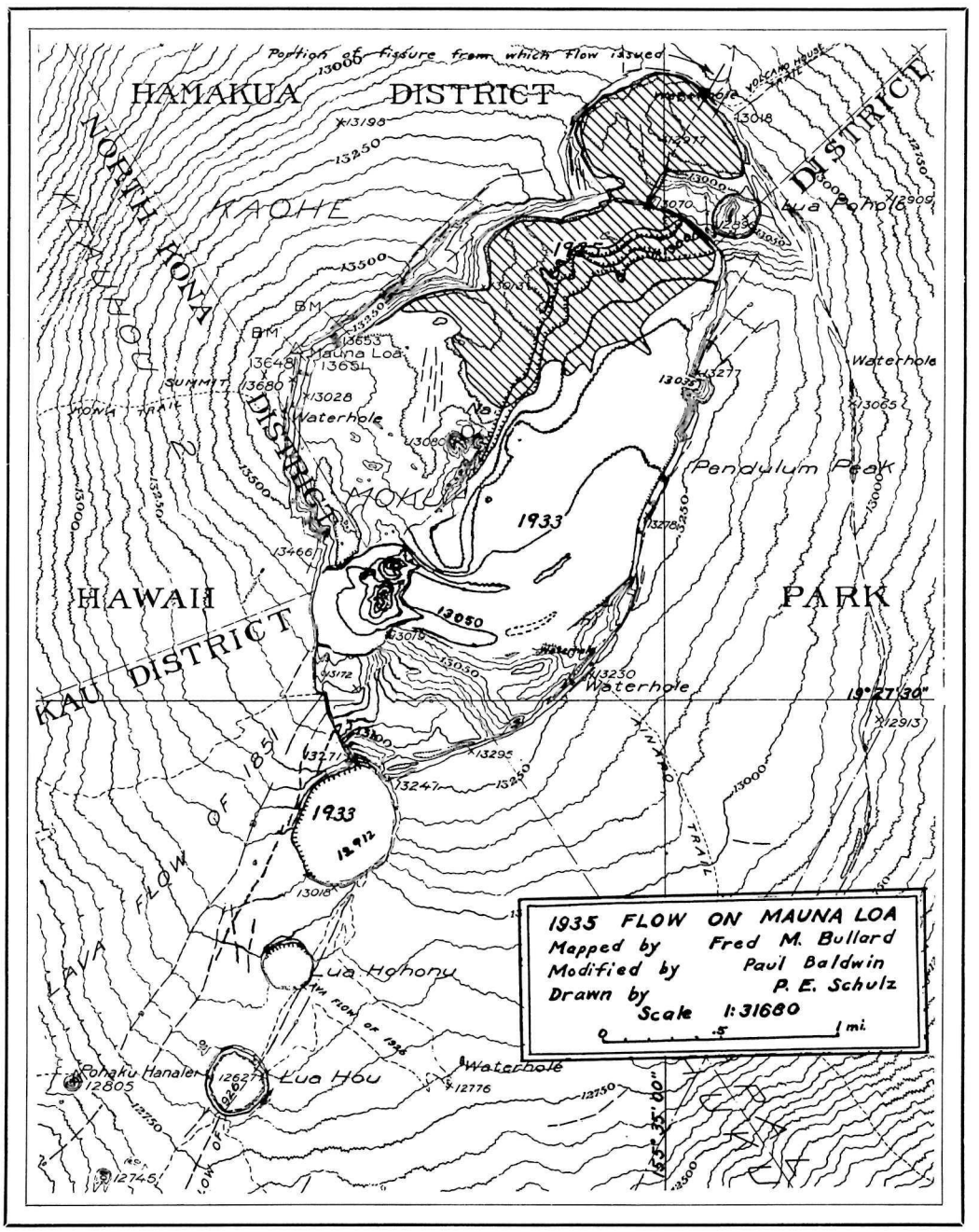

Figure 1

1935 LAVA IN MOKUAWEOWEO CRATER

By HUGH H. WAESCHE, Assistant Geologist

In the evening of November 21, 1935 about 6:30 p.m., Hawaiian Time, Mauna Loa began an eruption which was to last well over six weeks and which was to exhibit all phases of activity common to Mauna Loa eruptions. The major portion of the activity was a spectacular outflow with large streams of lava descending the north slope of the mountain into the saddle between Mauna Loa and Mauna Kea.

Just what occurred in the early hours of the eruption is vague. It was a cloudy evening and the activity was not visible from the Observatory until about 10:00 p.m. At that time a minimum of 8 fountains were playing along the northeast slope of the mountain from the summit crater to a point about five miles along the rift. Apparently the NE rift had cracked open over this distance. By 2:00 a.m. all of the upper fountains had diminished slightly and the activity was concentrating at the two lowest fountains near the 12,000 foot elevation. At approximately 6:00 a.m., Lt. Carl Truesdale of the United States Army Air Corps flew over the Crater of Mokuaweoweo and reported some activity there still in progress. By 10:00 a.m. when the writer flew over the area of activity with Lt. Campbell all activity in the Summit Crater had ceased. The two fountains at 12,000 feet continued for approximately ten days. The remainder of the time, lava issued from what appeared to be a rift hidden by old lava flows on the north flank of the mountain. At most the crater activity lasted hardly more than twelve hours.

Later when National Park rangers went to the summit of Mauna Loa, they found that the fissure indicated on the map (near top) had opened within 100 feet of the rest house and that lava had poured into the crater and down the northeast slope in great quantities from it. The lava was a brownish-black, frothy type of pahoehoe indicating that it had probably been highly charged with gases. The Volcano House Trail was covered and eliminated for about three-quarters of a mile. (For photographs see Volcano Letter No. 445, March 1937.) It is possible that the fissure extended southwest toward the center of Mokuaweoeo in the general direction of the 1903 and 1914 cones but was covered by lava pouring into the main crater from the higher elevation bay to the northeast.

The attention of almost everyone had been concentrated on the flows resulting from this eruption so consequently the crater had received little attention. In 1934 Mr. A. E. Jones had made a detailed map showing the extent of the 1933 crater flow.* Dr. Jaggar has described that eruption. Mr. E. G. Wingate had mapped the 1926 flow. It was desirable that the series be completed, therefore on July 18, 1939, Dr. Fred M. Bullard, professor of geology at the University of Texas and temporarily employed by the National Park Service at the Volcano Observatory, made the trip to the summit. Using a United States Geological Survey preliminary sheet of the area as a base, he made a Brunton Compass survey of the crater inflow which is indicated by the hatched area toward top of map. The work was done July 19, 20, and 21. Mr. Paul Baldwin, temporary National Park ranger, repeated the work of Dr. Bullard about three weeks later. His map was identical to Bullard's with the addition of the tongues and other slight modification of the southeast edge of the flow.

Apparently the 1935 lava covered a sizeable portion of the 1933 flow as indicated by the dotted boundaries of the latter flow as mapped by Jones.

The 1935 flow is little more than a veneer over pre-existing flows and has changed the contour of the crater little. It may attain a thickness of 5 feet in a few spots particularly where it adjoins the 1933 flow which in some places is aa in character.

* The Volcano Letter No. 309, September 1936.

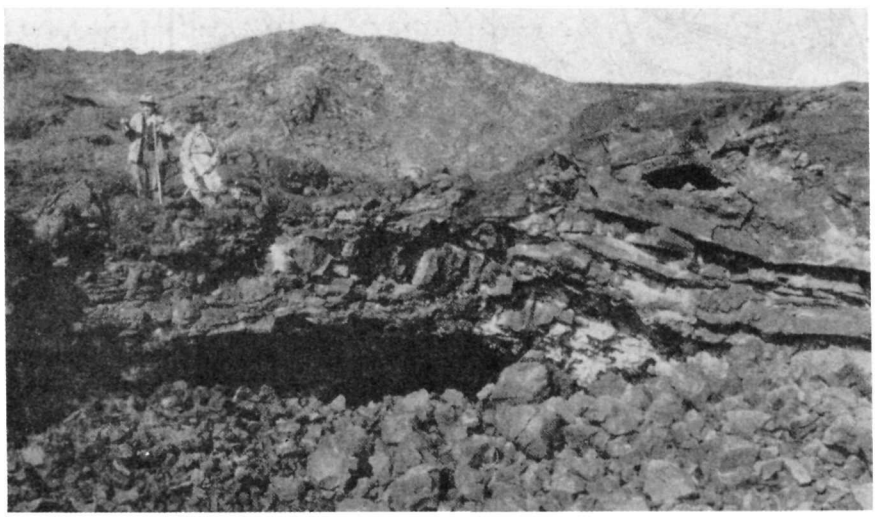

Fig. 2—Dr. Jaggar on an exploration of a Mauna Loa rift. Pit in 1881 pahoehoe dome northwest of Puu Ulaula. (October 4)

Hawaiian Volcano Observatory Report for October-December, 1939

VOLCANOLOGY

October 1939

October had no special volcanic events. For the first week seismic activity increased and northeast tilting of the ground at the observatory was marked but normal for this time of year. The second week this tilt increased as well as the number of earthquakes; one of these was sharply felt on the floor of Mokuaweoweo, the summit crater of Mauna Loa, at 2:27 p.m. October 11, and on the same day at 3:42 p.m. a shock resembling a powder blast was felt at Kilauea. On the 15th a rock slide at 10:32 a.m. sent a dust cloud up the north wall of Halemaumau. The third week held a similar seismicity and thin fume rose from the southeast marginal crack of Halemaumau floor; the northwest solfatara had dimmed in color and ceased to fume. During the last week things quieted down and the measured rim cracks which changed closed instead of opening, just as in July-August.

Distant earthquakes were registered October 3 and October 16, the last located near the New Hebrides. The local shocks were distributed between Mauna Loa and Kilauea with the last most abundant, and one shock of October 19 was from Hualalai or beyond that mountain.

Exploration of NE Rift of Mauna Loa

Dr. Jaggar, with Mrs. Jaggar and Ranger Jess, camped at Puu Ulaula, 10,000 feet elevation, northeast rest house of Mauna Loa October 2-5, to identify lava flows with those seen in Humuula trip of September, (Volcano Letter No. 465) to collect specimens for spectrograph tests, and to take photographs in Kodachrome and monochrome. Some of the latter are reproduced here. (Figures 2, 3, 4, 5, 6, 7.)

Puu Ulaula is old shell pahoehoe and cinder (Figure 5) with other old cones northeast of it, over the rift line here trending ENE and bifurcating to the NE. Southeast from the hills lying a mile WSW, extends the Kapapala aa flow of November 1880, entirely distinct from the pahoehoe black flow and cones (Figures 3, 6, 7) of 1881 which originate above and to the west of Puu Ulaula and trend NE, dominated by the large square-topped black cone of 1881 at elevation 9,617 feet lying a mile and a half NE of the Rest House, (from summit of which photographs 6 and 7 were taken). The aa lava of 1880 is distinct from the later 1881 source basalt: the former has a red porridge-like surface (Figure 4), its pahoehoe being bronzy and frequently frothed on the surface to coarse brassy pumice.

The 1899 lava is black pahoehoe all around the cone Puka Uahi and overriding the 1880 flows. Just northeast under the 1880 floods are the red and bright-colored cones of 1855 with surfaces of fine-grained brassy pumice a half inch thick. The black, smooth torrent of 1899 flowed off to the north from Puka Uahi, and was explored far to the north in September trip. On the engraved Humuula sheet U.S.G.S. the northeast Hilo flow is misnamed 1880 and the southeast Kapapala flow is misnamed 1881: these names should be exchanged. To all appearances it is possible to ride on the 1899 pahoehoe to Humuula by the routes explored in September.

The black floods of the 1881 Hilo-flow NW of Puu Ulaula are like the Kilauea floor lavas, and extraordinarily like the smooth piles of Mauna Iki in Kau Desert. Figure 2 shows the rim and cavernous overhang of a circular pit 60 feet across, with tumble of debris of collapse, that was in 1881 a lava lake on top of a pahoehoe dome. This was a source-heap over a crack of the NE Mauna Loa rift belt, a half-mile WNW from Puu Ulaula rest house. In the background of the photograph is one of the older cones of possibly 1855 cinder. The general view up the rift belt from the top of the 1881 black cone (elevation 9,617 feet) includes this slag heap near the skyline (Figure 6). The floods of pahoehoe from it fill the picture. The near line of conelets curving to the right, is the 1880-81 rupture. This pahoehoe is the later phase of 1881 that pressed forward in tunnels seven months to Hilo. Among the distant cones on the right is Puka Uahi (11,068 feet). In the early months of the 1880-81, floods of lava that pushed towards Mauna Kea from the Puka Uahi region, and towards the Hilo slope, were all stirred to become aa in the lower lands and some of these came from the Black Cone line of vents. The plexus of cones around Puka Uahi were sources of 1855, 1880, 1881 and 1899.

Before leaving the 1881 Black Cone, let us look at a photograph from its summit to the northeast, Figure 7. This is towards Puu Oo ranch lands, in the extreme distance across the sag of the upper Wailuku drainage above Hilo. In the foreground the open gash of the rift is bordered by pumice cones and aa lava. On the left appears the 1881 pahoehoe which sweeps to the right across the distant lands.

Outside the extreme right of the picture is the source of the aa of 1852 which gushed from a vent only 8,500 feet above the sea, but as always, with pahoehoe at its source and down its middle stream for three miles. Its flowing was short lived, so it never sent its vitreous lava to Hilo by the tunnel method. If its rushing torrent of liquid aa, 13 miles long between elevations 8,300 feet and 3,300 feet, had not been preceded by the emission of great volumes higher up the mountain twice, respectively 6 months, and 3 days, before the lowest Hilo outburst, this 1852 flow would have been in Hilo harbor in a week. The duration of the Hilo flow including decadence was 17 days, February 20 to March 8, the front stopping 12 miles from Hilo shore. As in all the outflows there was an extension of the crack up to the summit, this gushed from summit downwards with tremendous power February 17-18 for forty hours, and these upper 1852 floods are quite unidentified on the landscape of today.

The extension of the mapped crack from its cone at 8,420 feet elevation, takes us past the south side of Puu Ulaula, where a flood of black lava with phenocrysts of feldspar makes a sharkskin type of pahoehoe. This is overlapped by the 1880 Kapapala flow and is shown on the right in Figure 4. It may be part of the upper floods of 1852. A line of conelets heads almost due east from Puu Ulaula to Kulua and Puu Kipu, showing how cracks radiate from Puu Ulaula, as an important subsidiary dome on the ENE rift.

The map of all these features is Humuula Sheet, 1930, County of Hawaii, United States Geological Survey. Any later eruption may bury the lava of any former one. The concretion-ball aa lava supposed 1880 (Figure 8, Volcano Letter 465) discovered in September at elevation 7,000 feet, 4½ miles SSW from Humuula sheep station, came from near Puka Uahi, and its source pahoehoe is obscure in that vicinity until some petrogenic distinction, chemical or mineralogic, is discovered characteristic of date or age. Progressively later date means stage of internal alteration of magma. Age means stage of external weathering. In order to map thoroughly all these flows and recount their histories, specimens for comparison are being collected.

Microscopical petrography is not enough when a single flow may differ more in samples from source to front than two flow specimens of separated ages differ from each other. For this

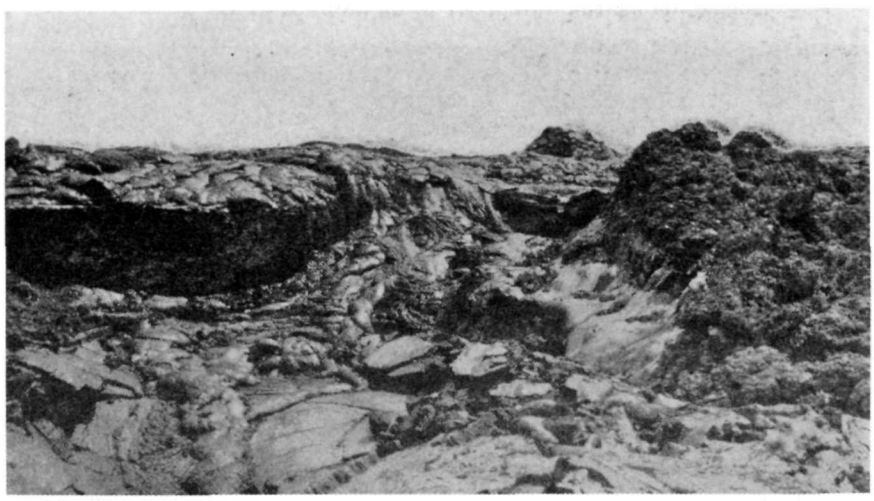

Fig. 3—Cascades of 1881 pahoehoe along line of cones, north of Puu Ulaula. (October 4)

reason it is proposed to submit samples of known different years to arc vaporization in spectrograph for possible qualitative or quantitative differences in elements, and also to test for hydration and some other analytic distinctions, that may be characteristic of year of emission, apart from chemical or crystal differences exhibited within a single eruption. If discovered, this would mean secular magmatic change throughout a century, and identity of year could be established for two flows reaching different fronts, if both had the same characteristic of a specific date.

The color pictures that were taken of the interior brilliant ochre glazes of 1855 and 1935 vents showed brick red, bronzy green, orange and coffee-colored surfaces within cracks and pits. Similar colors mark the pumices. Here are gas-fluxing phenomena. Vent basalt can be gas-melted to recrystallization and reglazing like the glazing of pottery. The recrystallization within Hawaiian basalt stalactities, by gas melting, of augite and feldspar shelled over by hematite and magnetite, as described by Edward Dana ("Characteristics of Volcanoes," J. D. Dana, p. 339. The quotation from Brigham of water origin is totally erroneous.) shows that cavern linings remelted by gas heat demonstrate the power of gas fluxing to recrystallize the lava's own substance in a gas-filled chamber. The small droplets on the stalactites and glazes show they were very liquid. The small bubbles on the pumiceous skin of gassy source lavas again show intense liquidity; these by their rainbow tints produce the brass color mentioned.



Fig. 4—The 1880 flow near source, aa in foreground, on Kapapala side of rift, south of Puu Ulaula, looking north. (October 5)

Geologists do not realize that gas-reactions approaching 1500° C., in enormous volumes of suddenly released carbon gases and hydrogen, make the high-energy phase of the dike-rupture called "a volcanic outbreak". This foaming incandescence and its gas, freed in confinement (pits and caverns), are melting agents. The gas-tight shell over a flowing lava stream can increase the temperature of that stream, by confining its reacting gases; and those gases can glaze and recrystallize the under-surface of the shell. If such a gas-melt were re-digested by rising lava, we would have a feldspar-augite-iron oxide concentrate assimilated by normal basalt.

Now imagine the inbreak (irruption) of an intrusion in a foreign rock doing the same thing, and gas-fluxing that rock. The rock might be highly siliceous or calcareous. The deep chamber of rupture would be gas-tight and confine the vesiculate foam, but the rise of temperature would be great and the melting assimilation by basalt would proceed to whatever andesitic crystallinity the final gas-free magma achieved. Just as in the beautiful aggregates of feldspar crystals synthesized in Mauna Loa glazes and stalactites, totally different in grouping, and somewhat in chemical composition, from the lava, so where gas-fluxing melts to dripping a quartzite or shale, it is easy for anyone who has seen in Hawaii glowing caverns, red hot fuming and Mauna Loa fountains, to envisage the evolution of hybrid magmas from pre-existing solid phases when attacked by olivine-basalt glass in process of gas effervescence. There is a field for experiment in solution of gases in such glass, pressure release from solution, and in gas-fluxing various rocks to a glaze.

The following are the local data for October:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
October 8	0	3.0 mm. opened	22
" 15	1	2.0 mm. opened	33
" 22	0	2.5 mm. opened	44
" 29	0	6.5 mm. closed	19



Fig. 5—Summit of Puu Ulaula, showing flag, wind gauge, and azimuth plate. (October 5)

November 1939

The month of November was notable for steady decline of the seismic index. The first week showed a slight increase over the end of the preceding month in seismic activity of both Mauna Loa and Kilauea. Fresh rocks on the floor of Makaopuhi Crater indicated there had been small slides from the southwest wall. There was a return to the opening of Halemaumau rim cracks, whereas the previous week had been extraordinary in that none had opened. Tilting of the ground at the Observatory was away from the crater. A slight shock November 3 and a feeble one November 4 were of Kilauea origin but not reported felt.

The second week produced a moderate rock slide sending up dust at the north

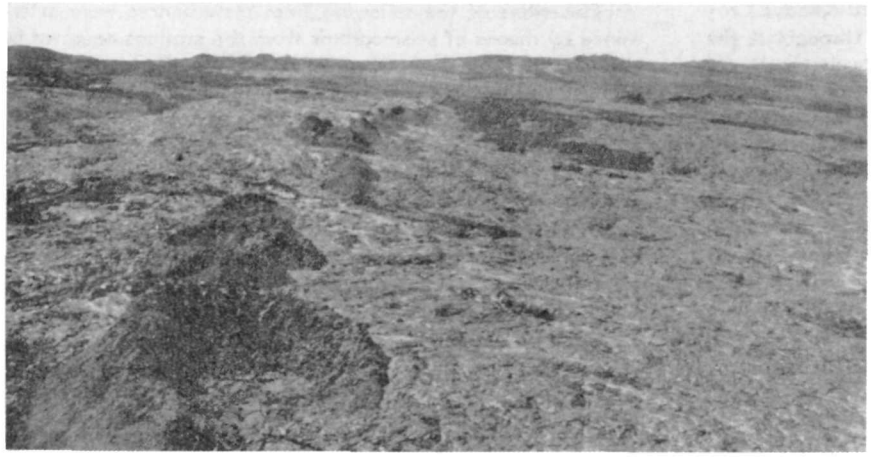

Fig. 6—Looking up rift from 1881 Black Cone; Puu Ulaula on left skyline.

wall of Halemaumau 10:22 a.m. November 10. There was one feeble earthquake under Kilauea Volcano and felt there. Tilting of the ground at the Observatory was away from the crater.

The third week recorded one rock slide Halemaumau north rim 10:20 a.m., November 14. Earthquakes were very feeble. The rim cracks resumed excessive closing. Tilting of the ground continued NNE.

The fourth week showed excessive microseismic activity along with a storm at sea causing waves to wash over Hilo breakwater. Seismic activity was locally very small though earthquakes were reported all over the world. Observatory tilt was still away from the crater.

The following are the local data for November:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
November 5	0	8.0 mm. opened	25
" 12	1	4.0 mm. opened	21
" 19	1	1.5 mm. closed	19
" 26	0	2.0 mm. opened	13

December 1939

The month of December was seismically quiet and, in accordance with the habit of the last five years, the solstice week about December 21 was particularly peaceful. This is the more remarkable in that during the active years of the last two cycles December has been the eruption month. Seismic activity increased at the beginning of the month and Observatory tilt changed to the crater direction. The second week fume was noted in Halemaumau probably from the solfatara along SE edge of floor. On December 8 at 10:35 a.m. rocks were heard falling at Halemaumau wall NW. Distances of earthquakes indicated Hualalai, Mauna Loa and Kilauea. Tilting was resumed away from Kilauea Crater. The third week produced a moderate slide at 2:55 p.m. December 12 making noise and sending out dust at Halemaumau NW wall and two other slides from the rim N and NE occurred at 3:25 and 3:29 p.m. A very feeble earthquake under Halemaumau completely dismantled the seismograph there, was felt at Uwekahuna but registered as very feeble. Observatory tilt was towards the crater.

The fourth week with earthquakes reported from Costa Rica, Manila, London, Kamchatka and the Celebes nothing happened at the Observatory except registration of some distant shocks and a feeble earthquake near noon December 23 indicating origin 15 miles deep under Mauna Loa northeast rift with epicenter eight miles from Mokuaweoweo. Sources at this locality command close attention because of the menace to Hilo. Observatory tilt was away from the crater. The end of the year produced outbreaks of disastrous earthquakes in Turkey. Some fume could be seen over Halemaumau on calm humid days, rim cracks closed and Observatory tilt was inward.

The following are the local data for December:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
December 3	0	3.5 mm. opened	26
" 10	1	0.5 mm. opened	18
" 17	3	0.5 mm. closed	33
" 24	0	5.5 mm. opened	18
" 31	0	0.5 mm. closed	20

Change of Annual Tilt

A significant change of importance is indicated by the following table showing in seconds the amount of tilt and its direction at the Observatory, NE rim of Kilauea Crater, for the year preceding the date indicated respectively in north-south azimuth and east-west azimuth at the seismographs.

January 29, 1939	S 1.15 seconds	W 5.93 seconds
February 26, 1939	S 1.0 "	W 1.73 "
April 2, 1939	S 3.08 "	W 4.85 "
April 30, 1939	S 4.0 "	W 5.35 "
May 28, 1939	S 3.92 "	W 4.75 "
July 2, 1939	S 3.75 "	W 2.60 "
July 30, 1939	S 2.05 "	W 4.00 "
August 27, 1939	S 1.53 "	W 3.43 "
October 1, 1939	S 1.24 "	W 3.20 "
October 29, 1939	S 1.15 "	W 1.48 "
December 3, 1939	N 2.20 "	W 1.56 "
December 31,1939	N 1.70 "	W 1.35 "



Fig. 7—From summit of 1881 Black Cone looking toward Puu Oo ranch lands.

This record of tilt south and west, or toward Kilauea Crater at the top of the NE wall of that crater, throughout the year 1939 as representative of the preceding twelvemonth for the end of each month, was also characteristic of many preceding years, checked by levels and readings of horizontal angles towards Kilauea and Halemaumau that have all agreed in indicating since the explosive eruption of 1924 that the general trend has been downward and inward. Individual Halemaumau eruptions have produced temporary tiltings away from the crater, but the annual record for repeated monthly summaries has appeared to imply that the ground around Halemaumau pit was continuing to lower as it did in 1924, but in less angular amount.

Beginning with the record of December 3, 1939 the north-south component suddenly shows a change from the preceding month of a total of 3.35 seconds from the record of October 29, and this substantial northerly tilt for the year preceding the date of record is retained on December 31 as nearly two seconds to the north or away from Halemaumau. When a record of this kind is a resultant of accumulated change for an entire year it is much more significant of a change of habit in underground workings of the volcano than the mere tilt from one month to the next. It should be remembered that the spring and summer of 1938 produced first a big earthquake in Maui and then a visible rupture along Chain-of-Craters, east rift of Kilauea in May, with renewal of movement there in August 1938 and some seismic sequences of the same disturbance in 1939. As the average interval for Kilauea outbreaks in this century was about a year and a half up to 1934, it appears that an eruption was omitted in 1936, and was about due in 1938. This Chain-of-Craters disturbance may have been the equivalent of that eruption, absorbed in subterranean intrusion, and representative of the return of lava from the seaward direction to the east, where there was submarine outflow in 1924. This submarine outflow as a fundamental disturber of the mountain, producing intense subsidence, may have continued that subsidence by sluggish flow until the backing up of the lava achieved the 1938 intrusion. Meantime the succession of gushes on the Halemaumau bottom may have been offshoots from Mauna Loa. If now the change in tilt at the Observatory means a resumption of swelling and elevation of Kilauea Crater, the lava that returns to Halemaumau about 1940 may have enduring characteristics more like the Kilauea activity of aforetime.—T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
Oct. 8	19	3	0	0	0	1	6.25
" 15	27	3	3	0	0	0	11.25
" 22	39	5	0	0	0	1	12.25
" 29	17	2	0	0	0	0	5.25
Nov. 5	16	7	1	1	0	0	10.50
" 12	17	3	1	0	0	0	6.75
" 19	12	7	0	0	0	0	6.50
" 26	11	2	0	0	0	0	3.75
Dec. 3	22	4	0	0	0	0	8.00
" 10	11	7	0	0	0	0	6.25
" 17	30	3	0	0	0	1	9.00
" 24	12	4	2	0	0	2	6.00
" 31	19	1	0	0	0	1	5.25

* Including teleseisms or earthquakes over 5,000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

October 3, 4:12 p.m., very feeble, probably originated Mauna Loa NE rift near summit crater.

October 5, 5:52 p.m., very feeble, probably originated in area south of Kilauea Crater near junction of Pali Lele o Kalinipaa and Pali Kalanaokuaiki.

October 8, 10:35 a.m., very feeble, originated in vicinity of NE rim of Kilauea Crater.

October 11, 1:11 a.m., feeble, probably originated in Hilina Fault system about 4.0 miles southeast of Makaopuhi.

October 11, 2:27 p.m., feeble, 8.0 miles deep, Mauna Loa NE rift about 3.0 miles SW of Puu Ulaula. 19° 30.5′ N; 155° 29.0′ W. Reported sharply felt at Mauna Loa resthouse.

October 11, 3:42 p.m., feeble, 0.8 mile deep, east portion of Kilauea Crater. 19° 24.7′ N; 155° 16.0′ W. Reported felt in Hawaii National Park.

October 14, 3:55 p.m., very feeble, originated near east central portion of Kilauea Crater.

October 15, 4:38 a.m., very feeble, originated 22.0 miles under Mauna Loa summit crater, 19° 28.5′ N; 155° 36.0′ W.

October 15, 11:03 a.m., very feeble, east central portion of Kilauea Crater.

October 16, 10:25 a.m., very feeble, of Kilauea Crater origin.

October 16, 1:35 p.m., very feeble, of Kilauea Crater origin.

October 17, 6:33 a.m., very feeble, probably originated in Chain-of-Craters near Puhimau.

October 19, 7:33 p.m., very feeble, under west slope of Hualalai, 5.0 miles NNW of Kailua, 19° 42.0′ N; 156° 01.0′ W.

October 26, 6:18 p.m., very feeble, probably originated in Mauna Loa NE rift about 10.0 miles SW of Hilo.

October 29, 12:02 a.m., very feeble, about 7.0 miles deep, Mauna Loa NE rift, 19° 35.5′ N; 155° 23.0′ W.

November 1, 2:38 p.m., very feeble, of shallow origin about 0.6 mile west of Kokoolau Crater, 19° 23.2′ N; 155° 16.0′ W.

November 3, 12:15 a.m., very feeble, probably originated in Hilina Fault system, near Laeapuki.

November 3, 3:38 p.m., slight, 3.0 miles deep in the vicinity of Cone Peak along Kilauea SW rift. 19° 23.5′ N; 155° 18.3′ W.

November 4, 3:07 a.m., feeble, probably of same origin as preceding shock.

November 4, 3:54 p.m., a tremor at the Observatory recorded on Mauna Loa as a feeble shock probably originating in the NE rift.

November 4, 10:58 p.m., very feeble, 25.0 miles deep under Mauna Loa 8.0 miles NW of Pahala. 19° 17.5′ N; 155° 34.0′ W. Reported felt in Pahala.

November 7, 5:34 a.m., very feeble, 2.7 miles deep, 1.4 miles east of Puu O Hale in Kalanaokuaiki Pali near junction with Pali Lele O Kalihipaa. 19° 21.4′ N; 155° 15.4′ W.

November 8, 11:23 p.m., very feeble, of shallow origin east central portion of Kilauea Crater. 19° 25.0′ N; 155° 16.0′ W.

November 10, 7:06 a.m., feeble, of shallow origin east rim of Kilauea Crater under SW portion of Kilauea Iki. 19° 25.0′ N; 155° 15.0′ W.

November 10, 11:06 a.m., very feeble, probably of same origin as preceding quake.

November 13, 1:02 a.m., very feeble, of Kilauea origin.

November 13, 1:59 p.m., very feeble, of shallow origin east central portion of Kilauea Crater.

November 14, 7:55 a.m., very feeble, from Mauna Loa NE rift about four miles from Summit Crater.

November 14, 9:56 a.m., very feeble, of Kilauea origin, probably Hilina Fault system south of Makaopuhi Crater.

November 19, 3:21 a.m., very feeble, of relatively shallow origin under Summit Crater of Mauna Loa.

November 19, 6:08 a.m., very feeble, of Mauna Loa NE rift near Summit Crater.

November 19, 7:23 a.m., very feeble, of shallow origin, SE rim of Halemaumau in Kilauea Crater.

November 20, 4:29 p.m., very feeble, 7.0 miles deep, Mauna Loa NE rift about 5.0 miles from Summit Crater. 19° 31.0′ N; 155° 31.5′ W.

November 24, 5:34 a.m., very feeble, from Hilina Fault Zone, 5.0 miles west of Kalapana.

November 27, 10:30 p.m., very feeble, of shallow origin, Kilauea Crater, 1.0 mile NE of Pit seismograph.

December 1, 12:35 p.m., very feeble, probably originated in Mauna Loa NE rift.

December 2, 8:48 a.m., very feeble, 0.8 mile deep, 1.0 mile SSE of Halemaumau. 19° 23.5′ N; 155° 16.6′ W.

December 3, 5:21 a.m., very feeble, 18.0 miles deep under Mauna Loa Summit Crater. 19° 31.0′ N; 155° 32.5′ W.

December 5, 6:29 a.m., very feeble, probably originated under ocean floor to SE of Island of Hawaii.

December 6, 10:56 p.m., very feeble, of shallow origin Mauna Loa NE rift 5.0 miles from center of Summit Crater.

December 8, 12:18 a.m., very feeble, probably originated under sea floor to SE of Island of Hawaii.

December 8, 3:49 a.m., very feeble, of shallow origin, NE rim of Mauna Loa Summit Crater. 19° 30.0′ N; 155° 34.3′ W.

December 8, 11:54 p.m., very feeble, from Chain-of-Craters near Devil's Throat.

December 10, 2:24 p.m., very feeble, of shallow origin 1.0 mile SE of Pit seismograph. 19° 23.8′ N; 155° 16.3′ W.

December 13, 1:56 a.m., very feeble, probably originated under sea floor about 23 miles west of Hualalai.

December 17, 2:48 p.m., very feeble, of shallow origin, south rim of Kilauea Crater, 1.0 mile south by east of Pit seismograph. 19° 23.5′ N; 155° 16.8′ W. Dismantled both components of Pit seismograph and reported felt in residential area of Hawaii National Park.

December 19, 1:11 p.m., very feeble, of shallow origin, Kilauea Crater.

December 21, 8:15 a.m., very feeble, about 20.0 miles deep and 12.0 miles south of Mauna Loa Summit Crater, 8.0 miles NW of Pahala. 19° 17.5′ N; 155° 34.0′ W.

December 22, 5:36 a.m., feeble, 9.0 miles deep, 8.0 miles SE of Summit Crater of Mauna Loa. 19° 24.4′ N; 155° 29.0′ W. Reported strongly felt at Kapapala Ranch House.

December 23, 12:06 p.m., feeble, 15.0 miles deep, Mauna Loa NE rift, 8.0 miles from Summit Crater. 19° 32.0′ N; 155° 29.0′ W.

December 23, 10:54 p.m., very feeble, 1.7 miles deep, 0.7 mile SE by south of Pit seismograph. 19° 23.8′ N; 155° 16.4′ W.

December 26, 8:50 p.m., very feeble, Kilauea SW rift near junction with Hilina Pali. 10.0 miles deep. 19° 15.5′ N; 155° 23.0′ W.

December 13, 8 minutes of continuous tremor began recording 6:02 a.m.

Teleseisms

October 3, 3h 18m 40.0s, a.m., "P" waves? Distance undetermined.

October 17, 8h 01m, p.m., located in New Hebrides area. Reported to have originated at a depth of 100 km. Distance from Kilauea, about 3,500 miles. Epicenter 16° S; 168° E, by U.S.C. and G.S.

December 16, 12h 25m 48s, a.m., "P" waves. Distance undetermined.

December 21, 10h 42m 55s, a.m., "P" waves. Distance from Kilauea approximately 5,505 miles, probably originated in Celebes.

December 21, 6h 25m 13s, p.m., "P" waves. Distance from Kilauea, approximately 4,625 miles. No reports received on location.

December 26, 2h 16m, p.m., surface waves. Distance undetermined; origin the disaster near Erzerum in Asiatic Turkey.

Microseismic Motion

October

Light—6, 8, 11, 14.
Moderate—1, 4, 5, 7, 9, 10, 12, 13, 15-20, 27.
Strong—2, 3, 21-26, 28-31.

November

Light—
Moderate—4-9, 20.
Strong—1-3, 10-19, 21-30.

December

Light—
Moderate—14, 20.
Strong—1-13, 15-19, 21-31.

Time used throughout is Hawaiian Standard, 10h 30m slower than Greenwich Time.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum toward or away from the Pit as indicated by tilt stations on the W and SE rims respectively.

At the Observatory the total accumulated tilt for the year ending October 29, was 1.15″ S and 1.48″ W.

December 3, 2:20″ N and 1.56″ W.

December 31, 1.70″ N and 1.35″ W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
October 8	1.85″ N 45° E	4.47″ S 60° W
" 15	1.45″ N 52° E	5.16″ N 15° W
" 22	0.50″ S 58° W	0.00 ——
" 29	0.77″ N 79° E	2.98″ W
November 5	1.43″ N 35° E	3.81″ N 53° W
" 12	0.56″ N 30° E	4.41″ N 74° W
" 19	0.74″ N 11° E	0.00 ——
" 26	0.00 ——	0.00 ——
December 3	0.60″ N 53° W	0.00 ——
" 10	0.27″ W	3.13″ S 55° W
" 17	0.27″ S 6° E	5.99″ S 30° E
" 24	0.21″ N 67° E	4.47″ N
" 31	1.17″ S 48° W	0.00 ——

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
October 8	4.86″ S 50° E	8.55″ from
" 15	9.23″ N 47° E	0.09″ toward
" 22	4.96″ N 67° E	0.97″ from
" 29	15.10″ N 83° W	6.90″ toward
November 5	3.79″ N 25° E	0.90″ from
" 12	1.94″ S 65° E	5.64″ from
" 19	3.60″ N 30° W	4.86″ toward
" 26	14.45″ S 30° E	4.25″ from
December 3	0.00 ——	No change
" 10	4.76″ N 30° W	1.86″ toward
" 17	6.58″ S 17° W	1.52″ from
" 24	6.48″ N 30° W	6.93″ toward
" 31	6.48″ S 30° E	6.48″ from

Crater Angles

Measurements of horizontal angles across Kilauea Crater from the Observatory were made October 10 and 26, November 15 and December 7 and 19. On October 10 the measurements indicated opening of 1.16″ for the Halemaumau value and opening of 0.92″ for the Crater value, compared with similar measurements made on September 27. Between October 10 and October 26 the Halemaumau angle remained unchanged and the crater angle closed 2.08″. Total, September 27 to October 26, Pit opened 1.16″ and Crater closed 1.16″. The Halemaumau value is measured between the seismograph station on the SE rim and the NW Pit bench mark. The crater value is measured between a station on the SE rim of Kilauea Crater and the Uwekahuna Station.

Angles November 15 had changed by the Halemaumau value opening 0.59″ and the Crater value opening 0.24″ compared with October 26 determinations.

Two more angle determinations were made during December. On December 7, the Halemaumau angle had opened 0.16″ and the Crater angle had opened 1.09″ since November 15. Between December 7 and 19, the Pit angle closed 1.25″ and the Crater angle remained unchanged. Total change November 15 to December 19; Halemaumau angle closed 1.09″ and the Crater angle opened 1.09″.

For the period September 27 to December 19, both angles showed an increase. The Halemaumau value increased 0.66″ and the Crater value increased 0.17″.

Chain-of-Craters Road Cracks

Date	101	102	103	104	105	106	107
October 27	404.65	64.55	101.50	17′9⅛″	87.30	88.75	39.55
November 24	404.60	64.60	101.50	same	87.35	88.75	39.60
December 29	404.55	64.60	101.55	same	87.35	88.75	39.50
Total change in mm. since September 29	—1.0	+0.5	.....	.....	+0.5	.....	—1.5

The two cracks which opened at the road edge of Aloi Crater rim during August showed no changes in the past three months.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

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