The Valley of Ten Thousand Smokes

Katmai National Park and Preserve

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Acknowledgements

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"A Mountain Has Burst . . ."

Kaflia Bay, June 9, 1912

My dear wife Tania:

First of all I will let you know of our unlucky voyage. I do not know whether we shall be either alive or well. We are awaiting death at any moment. Of course do not be alarmed. A mountain has burst near here, so that we are covered with ashes, in some places 10 feet and 6 feet deep. All this began on the 6th of June. Night and day we light lamps. We cannot see the daylight. In a word it is terrible, and we are expecting death at any moment, and we have no water. All the rivers are covered with ashes. Just ashes mixed with water. Here are darkness and hell, thunder and noise. I do not know whether it is day or night. Vanka will tell you all about it. So kissing and blessing you both, good-bye. Forgive me. Perhaps we shall see each other again. God is merciful. Pray for us.

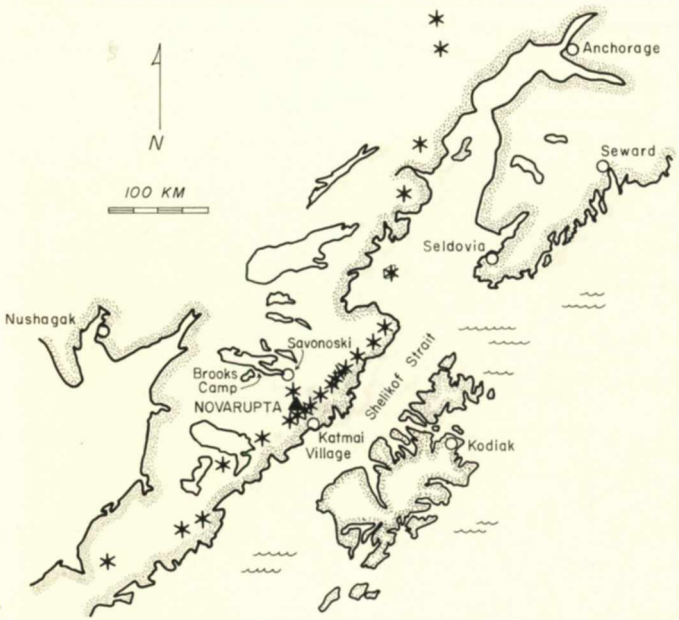
Your husband,
Ivan Orloff

The earth is trembling; it lightens every minute. It is terrible. We are praying.

(1) Ash covered Kodiak, June, 1912.

On June 6, 1912 the greatest volcanic eruption of the 20th century exploded from a previously unknown vent and devastated the Katmai region of southwestern Alaska. Villagers along the Katmai coast had already fled their homes, forewarned by the increasingly severe earthquakes of the preceding days. Many of them sought refuge at the fishing station in Kaflia Bay, but were caught there in suffocating ashy darkness for three days and nights while, 32 kilometers (20 miles) away, the violent explosions of the later-named Novarupta volcano hurled forth pulses of molten rock. Fortunately, Ivan Orloff and his fellow refugees survived to tell of their ordeal.

Explosions were heard 230 kilometers (140 miles) away on the morning of June 6, and at 1:00 p.m. the first towering eruption cloud was witnessed by crew members of the steamer *Dora,* then in Shelikof Strait. Two hours later darkness abruptly enveloped the vessel as it was overtaken by the choking ash. Lightning flashed from the black cloud overhead as Capt. McMullen changed course from the intended stop at Kodiak and headed toward the open Gulf of Alaska. Even "full steam ahead" the *Dora* remained under the ash cloud until early the next day. At Kodiak, 160 kilometers (100 miles) southeast of the eruption center, the air was thick with ash, and, for 60 hours, darkness was so complete that a lantern held at arm's length could scarcely be seen. The terrified townspeople, some temporarily blinded by the acidic volcanic fumes, crowded onto the U.S. Revenue Cutter *Manning* while 30 centimeters (one foot) of ash smothered their town.



(2) Location Map for the Upper Alaska Peninsula: Triangle is the 1912 vent at Novarupta. Stars are active or potentially active volcanoes.

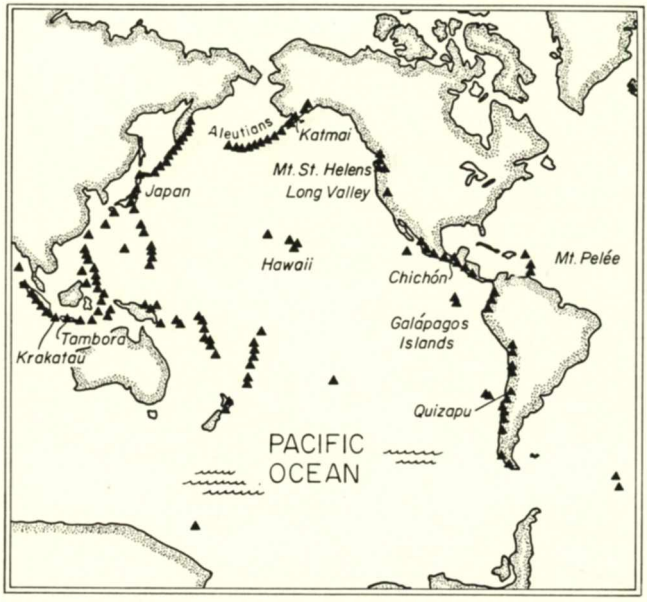
The huge ash column was seen for hundreds of miles and rose so high that it was carried around the world by stratospheric winds. Even Seattle, 2400 kilometers (1500 miles) away, was dusted with ash. This great quantity of ash caused unusually brilliant sunsets and, by shielding the sun's rays, lowered average temperatures by about 1°C (2°F) in the Northern Hemisphere for more than a year. But no one knew what had happened in the immediate vicinity of the volcano. "American Pete," chief of the inland village of Savonoski, said:

> The Katmai Mountain blew up with lots of fire, and fire came down trail from Katmai with lots of smoke. We go fast Savonoski. Everybody get in bidarka. Helluva job. We come Naknek one day, dark, no could see. Hot ash fall. Work like hell.

Not until four years later did Robert F. Griggs, outfitted by the National Geographic Society, hike across the Katmai Pass to the heart of the eruption area where he discovered and named Novarupta (meaning "newly-erupted"), the thousands of columns of steam that he aptly called "The Valley of Ten Thousand Smokes," and the awe-inspiring Katmai Caldera. As Griggs began to publicize his discoveries, the world learned that an eruption of historic proportions had occurred in this remote region of Alaska. Though most of the smokes have now died out, the fascination that the Valley of Ten Thousand Smokes holds for geologists and adventurers of all kinds has continued unabated since Griggs' day.

Katmai Volcanism

Katmai has not always been a land of "fire and ice." The 150-million-year-old continental shelf sediments of the Naknek Formation testify to a quieter time in the region's history. These sedimentary rocks, deeply dissected by glaciers, stand out in a strikingly stratified wall on the northwestern flank of Mt. Katmai and form the prominent ridges of Mt. Katolinat and the Buttress and Barrier Ranges to the north, west and south of the Valley of Ten Thousand Smokes. Fossil-bearing rocks of the Naknek Formation can be seen along the Ukak River below Three Forks Overlook.



(3) Circum-Pacific "Ring of Fire."

Accompanying Novarupta are five other volcanoes of the Katmai Group – Mts. Griggs, Katmai, Trident, Mageik, and Martin – that partially encircle the Valley and form part of a volcanic veneer overlying these older sediments. These are just a few of about 80 active volcanoes that form the Aleutian Chain, itself only a segment of the chains of volcanoes ringing the Pacific Ocean. This "Circum-Pacific

Ring of Fire" marks the boundaries of the shifting plates that make up the earth's crust. Great stress accumulates along these boundaries as the plates move under, over and past each other. Throughout the earth's history, plate movement, or "tectonics," has often been associated with magmatic and seismic activity around plate perimeters.

These stresses continue today, and the Katmai volcanoes are all quite active. Gas vents near the summit of Mt. Griggs emit the unmistakable rotten-egg smell of hydrogen sulfide and build up yellow mineral deposits that contrast with fresh dustings of snow. Hot vapors rising from the craters of Mts. Mageik and Martin condense in cold air to form white plumes easily seen on clear days. Black, blocky lava extruded from Trident Volcano betweeen 1953 and 1968 marks the most recent eruption of the Katmai Group. These slow extrusions of lava over a 15-year period went almost unnoticed, in marked contrast to the explosive three-day pumice eruption of 1912 that attracted world-wide attention.

The Eruption Center: A Closer Look

No one could have survived in the Valley of Ten Thousand Smokes at the onset of the eruption, and the cloud of ash that rapidly obscured Mt. Katmai and all its surroundings prevented any accurate first-hand observations. But geologists can use the volcanic deposits themselves to piece together the eruptive events.

(4) Ash flow: Hot pumice and ash that filled much of the Ukak Valley in 1912 has since been cooled and eroded by streams. The ash-flow deposit forms tall, massive cliffs below the Three Forks Overlook and is capped by less than one meter (three feet) of distinctively banded air-fall deposits.

Ash-flow and Air-fall Pumice

Two kinds of ash deposits are seen in the Valley of Ten Thousand Smokes: the main ash-flow deposit and the layered air-fall pumice. As their names imply, the two differ mostly in how they got there.

Ash Flow

After 1:00 p.m. on June 6, while those on board the *Dora* watched the towering eruption cloud, pulses of magma from beneath Novarupta reached the earth's surface. Depressurizing gases in the magma escaped, explosively hurling the liquid skyward, where it chilled quickly to volcanic glass, or pumice. The volume of pumice and ash rushing out of the vent was so great that not all of it could get airborne. A flood of pumice rushed from the choked vent and actually flowed as a dense, tumbling mixture of pumice blocks, fine ash, and hot gas that moved down the former Ukak River valley to form the nearly flat-surfaced valley we see today. Deeper parts of this massive ash-flow deposit were welded by its own heat and compacted by its great weight.

Ash Fall

Fragments of pumice hurled skyward by the force of the explosions, and further assisted by the convective lift of hot gases, rained from the sky, blanketing the region with "air-fall pumice." The next two eruptions, one beginning around noon on June 7 and the other during the night of June 8-9, blasted more ash into the stratosphere and formed pumice layers that still mantle both the ash-flow deposit and the surrounding terrain. This airborne ash fell most heavily on downwind settlements, such as Kodiak, southeast of the eruption center. Ash-fall deposits within a few kilometers of Novarupta are at least 10 meters (30 feet) thick but total only one meter (three feet) near Three Forks Overlook 12 kilometers to the north.

Flow, Fall and Fenner's Interpretation

Seven years after the eruption, botanist Griggs invited the eminent volcanologist Clarence Fenner to help him puzzle over the origins of the smoking valley. They distinguished the less structured ash-flow deposits from the overlying layered deposits of air-fall pumice. Fenner coined the idea of an "incandescent sand-flow" of pumice and hot gas that he imagined had welled up from a number of fissure vents at the heads of both arms of the Valley of Ten Thousand Smokes. Though this suggested that Mt. Katmai was not the sole source of the 1912 eruption, both Fenner and Griggs always believed that Mt. Katmai had produced the towering cloud that carried airborne ash all over the world. Not until 1953 was Novarupta's role in the eruption made clear.

Novarupta and Katmai Calderas: Caldera Collapse

During those three days in 1912, 15 cubic kilometers (four cubic miles) of molten rock was ejected from the Novarupta vent. Hot gases escaping from the ascending magma more than doubled the liquid's volume in the form of frothy pumice and ash. The release of so much magma resulted in the collapse of two large craters, or calderas. The Novarupta caldera is a shallow pumice-filled depression within which sits the small lava dome. On Mt. Katmai's summit, however, is a steep-walled, glacier-rimmed caldera more than 330 meters (1000 feet) deep and so impressive that upon its discovery Griggs mistakenly thought it had been the outlet for most of the ejected pumice.

Mt. Katmai did indeed collapse in 1912, but not until 1953 did Garniss Curtis show that the ash-fall deposits thicken away from Mt. Katmai and toward the true eruption source, Novarupta. If no magma erupted from Mt. Katmai in 1912, why did it collapse? Perhaps Mt. Katmai's own reservoir of magma was joined with another beneath Novarupta by an interconnected underground "plumbing" system. Accordingly, the Katmai caldera formed as magma flowed from beneath Mt. Katmai

(5) Katmai's Caldera and Lake: Westward view toward Novarupta and the flat-surfaced Valley of Ten Thousand Smokes. Beyond Mt. Katmai is Trident Volcano with the knobby head of Mt. Mageik on the left skyline and the strata of the Buttress Range on the Valley's western border.

toward Novarupta, replacing the ejected Novarupta magma. The Katmai caldera continued to settle after its initial collapse and created a fractured foundation so that the 10-meter-deep (30 foot) lake that filled the caldera floor between 1916 and 1919 was dry when Fenner and Charles Yori ascended Mt. Katmai in 1923. Fenner photographed boiling pools, mudpots, and mud geysers on the caldera floor which, after that year, again filled with water. Though the water level is slowly rising, about two meters (six feet) yearly, it will probably never overflow the rim because water can seep through the porous pyroclastics interlayered with the lava flow that make up the caldera wall.

Novarupta's Lava Dome

Compared to the explosive violence of June 6-9, the growth of the Novarupta lava dome was not much more than an afterthought of molten rock that oozed out of the vent. Though the exact timing is not known, extrusion of the dome was over at the time of its discovery in July, 1916; it probably took place in the summer of 1912. The ring of ejecta that encircles the lava dome represents the dying phases of explosive activity that predated extrusion of the dome itself.

(6) Novarupta Lava Dome Inside Novarupta Caldera: Beyond the dome, rocks still clatter down the steep face of Falling Mountain, a larger lava dome that was extruded hundreds of years ago at the southern edge of the 1912 caldera and that was truncated during the 1912 eruption.

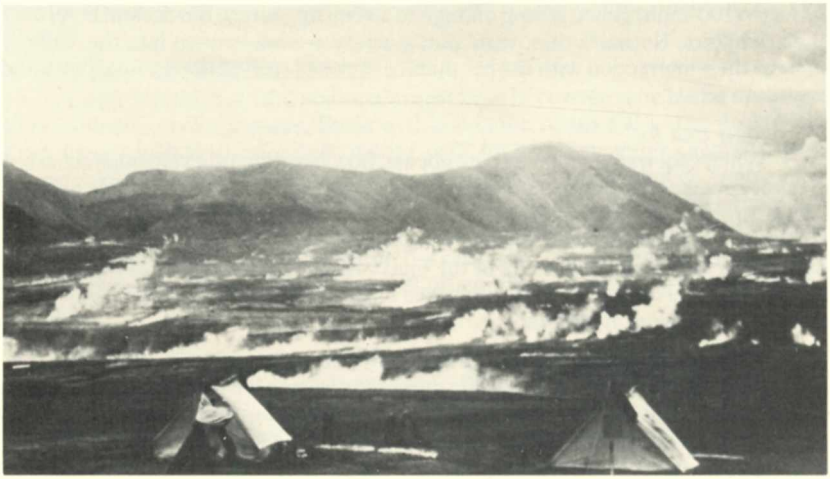
The Ten Thousand Smokes

As the ash flow buried the Ukak River valley, all the water that came in contact with it was vaporized into hissing curls of steam. The hot volcanic deposits, erupted at 800° to 1,000°C (1,400° to 2,000°F), were cooled over the next two decades by the rain, snow, and streams that drained into the Valley and caused the myriad columns of steam and hot gases, the fumaroles that inspired Griggs' name "The Valley of Ten Thousand Smokes." When Fenner and Griggs first contemplated the heat source for the fuming valley, they suggested that a large magma reservoir lay beneath the Valley's axis and gave off the heat responsible for the "smokes." Though the "smokes" began to lose steam by 1920 they remained a matter of continued curiosity. In 1953, Howel Williams and Garniss Curtis pointed out the "rootless" origin of the fumaroles, that is within the ash-flow deposit itself, and with no connection to a magma chamber below. After the eruption no new heat was available beneath the pumice deposits, so most of the fumaroles were short-lived.

As the hot escaping gases filtered up through the cracks and fissures in the ash flow, they deposited their dissolved minerals in the vesicles and interstices at or near its cold surface. Shades of yellow, white, red, and black mark this mineral deposition, colorful reminders of the once-vigorous fumarolic activity that virtually died out by the 1930's.

Warm vapors still rise from a few places around the Novarupta vent and along the margins of Baked, Broken, and Falling Mountains as the groundwater percolating through underground fractures turns to steam as it approaches the still-hot rock beneath Novarupta. These few remaining fumaroles tap a deep heat source

quite different from the "rootless" heat source of the extinct fumaroles. So, 9,900 of the "smokes" were superficial; only about 100 were deep-seated near the actual vent of 1912.



(7) During Griggs' exploration, prudently situated tents were heated by warm steam vents, while the mess hall was located close to vents hot enough to fry the bacon.

(8) Father Hubbard and "The Abomination of Desolation": Father Hubbard, a Jesuit priest, explored the Valley of 10,000 Smokes in the 1920s and 30s with a troupe of adventurous football players from the University of Santa Clara and two faithful dogs, Katmai and Mageik equipped with gas masks and protective clothing.

Climate and Weather: Effects on the 1912 Pumice

Overcast skies, so typical of the Katmai area, often shroud the Valley and its surrounding peaks in dense fog. Battling air masses from the Gulf of Alaska and the Bering Sea at times rush through Katmai Pass at the head of the Valley in 160-kph (100-mph) gusts, strong enough to sweep up pumice blocks and bowl over unwary hikers. Katmai's rain, wind and glaciers are interwoven into the Valley's story as their interaction with the hot pumice deposits caused floods, mudflows and explosion pits.

"Fire and Ice"

When cool water contacted the hot ash flow large steam explosions occurred that left circular craters surrounded by rings of ejecta. Along the north side of Knife Creek, probably following the buried stream channel, is a string of more than 50 of these 20- to 60-meter-wide (60 to 180 foot) explosion pits, many of which remain well-preserved today. Remnants of the ejecta rings line the banks of present-day Knife Creek, the new course of which was in part determined by the basins of the now-eroded explosion craters.

The Big Flood and Erosion of the Ash Flow

Ponded water from temporarily dammed streams led to local accumulations of mud, sand, and gravel. One especially large basin in upper Knife Creek was dammed by a concentration of debris from explosion pits. More than 15 meters (45 feet) of lake sediment accumulated in this depression. When the dam was finally breached, a torrent of water coursed down the Knife Creek channel for about six kilometers (four miles) and then spread out across the central valley with such force that it stripped away the overlying layers of ash fall, scoured the underlying ash flow, and deposited the debris farther down the valley. Exactly when this big flood took place is not known, but it was probably in the summer of 1912 or 1913, because the river gorges, already as deep as 20 meters (60 feet) when first seen by Griggs in 1917, would have confined the flow had it occurred any later.

Flora and Fauna

Revegetation of the Valley of Ten Thousand Smokes

The once lush greenery of the Ukak valley was completely burned and buried by the 1912 ash flow, and vastly more extensive areas of vegetation were affected by the warm airborne ash that fell from the high eruption plume. The National Geographic Society expeditions headed by Griggs were originally undertaken in 1915 to study revegetation of Kodiak Island but Griggs was lured from Kodiak to the site of the eruption.

In 1916 while the "smokes" were still vigorously steaming, Griggs found mosses and algae beginning to colonize in the warmth and moisture around the fumaroles. These simple plants were joined by colonies of lichens and liverworts. With the waning of the fumaroles after 1920, many of these plants began to die out as temperatures declined around fumarolic orifices and upset the delicate microclimates essential for survival amidst Katmai's harsh climate.

Though wind is a relentless foe to a struggling seedling, it also blows in new seeds from more vegetated areas. Horsetails and fireweed sprout in the shelter of rivulets and seeps trickling onto the ash flow from the surrounding hills. Today, clumps of grass, sedges, some dwarf willow, and even a few wildflowers brighten the nooks and crannies that provide water and shelter from the sandblasting effects of wind-blown pumice.

Around Brooks Camp and King Salmon the dense green mat that now conceals the 1912 ash layer and the remains of pre-1912 vegetation contrasts strikingly with the still largely barren Valley of Ten Thousand Smokes. As determined by

Griggs, the ash contains all the minerals required for plant life, but, having been derived so recently from magma, it was at first devoid of organic matter, microorganisms, and other essential soil ingredients. However, areas distant from the eruption site that were not buried so deeply soon developed such ingredients, which readily changed the sterile 1912 ash layer into an admirable substrate for new growth.

Fauna Survivors

Large numbers of land mammals must have been overcome by the onslaught of hot ash and choking gases. Birds with ash-laden wings fell on the deck of the *Dora.* Once a lush garden for bear, moose, wolf, fox and lynx, today's sparse vegetation provides little cover and meager food for the few animals that do venture into the Valley of Ten Thousand Smokes. According to fishery biologists, the major part of the 1912 salmon run had not yet begun when Novarupta erupted. Reduced spawning in the years immediately following the eruption caused a decade-long decline in the local salmon catch, though the salmon runs were thought to be normal again by 1921.

(9) View northward down the Valley of 10,000 Smokes from atop Falling Mtn.: The Buttress Range is the ash flow's western border; Mt. Katolinat to the north marks its snout, and Baked Mtn. rises in the middle.

Valley Highlights

The Valley of Ten Thousand Smokes has provided scientists with a natural laboratory in which to study a wide variety of geologic and biologic phenomena. Scientists as well as as visitors who venture into the Valley are struck by its bleakness, one of the world's finest examples of the effects of a very large, explosive volcanic eruption; but the beauty is striking as well, particularly in the Valley's colors. Clean, rounded pumice blocks washed up near riverbanks have been abraded by the tumbling action of the water to produce polished surfaces accenting the different compositions: white rhyolite, grey dacite, and black andesite (see glossary) interspersed with fumarolically altered pumice of all three types. Also found here is Novarupta's world-famous "banded pumice" – blocks with black and white swirls produced when a little of the rhyolitic, dacitic, and andesitic magmas mixed during the eruption.

Fossil Fumaroles

Brightly colored altered pumice marks the now-extinct fumaroles that crisscross the Valley floor. While the ash flow was still hot, the escaping gases, especially chlorine, fluorine, carbon dioxide, and sulfur, combined with heated groundwater to form acids. These, in turn, dissolved minerals from the pumice and redeposited others at or close to the surface as the colored fumarolic "alteration deposits." E.G. Zies, a chemist who accompanied Griggs, found sulfur (yellow), gypsum (white or clear), arsenic sulfide (orange), and iron sulfides (blues), among others, to be common lower-temperature alteration minerals. Fumaroles as hot as 650°C were measured in 1919, though in 1912 some were probably as hot as 900°C. Metallic minerals such as hematite (red), magnetite (black), and pyrite (gold) were subsequently leached by hot water and weak acids.

The loose pumice was cemented together by deposition of these minerals and formed resistant walls on the fumarolic pipes and fissures from which the steam and vapors once fumed. Remnants of such fissure walls form constrictions in upper Knife Creek, because the cemented pumice is more resistant to stream erosion than unaltered pumice.

Slosh Marks and the "High Sand Mark"

Accumulations of the ash-flow deposit 30 to 60 meters (90 to 180 feet) above the floor of the upper Valley along the Buttress Range were called the "high sand mark" by Fenner because they indicate the highest level reached by the ash flow when it buried the Ukak Valley. Shortly after the ash flow stopped moving it settled and compacted; as it sagged downward, faults around the margins acted as hingelines that finally broke, leaving remnant benches of the ash flow on the bordering hillsides. These benches are highest in the upper Valley, where the ash flow was thickest and, therefore, compacted the most.

Marginal ash deposits of a different sort are seen a little further from the vent where the Valley floor narrows from seven to three kilometers (four to two miles). This narrow area, 10 kilometers (six miles) downstream from Novarupta, constricted the ash flow so much that it rode up along the sides of the bordering hills on its way toward lower ground. This process left veneers of ash as "slosh marks" on the Valley walls. The constricted ash flow also piled up in mounds now seen along the margins of its otherwise smooth surface.

Mt. Griggs: Active Fumaroles and Summit Craters

Eruptions from Mt. Griggs' summit have burst from three successive summit craters nested one inside the other. Yellow sulfur continues to be deposited by the hot gases that stream from the volcano's near-summit fumaroles, which are often visible from the Valley floor.

(10) Initial lava flow from February, 1953 eruption of Trident Volcano.

Mt. Mageik and its Boiling Crater Lake

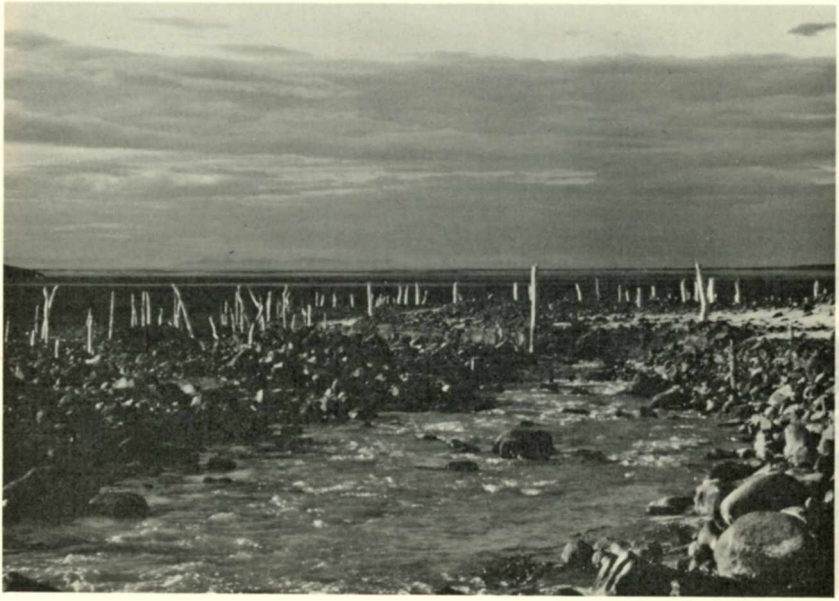
The dark flanks and glacier-clad summit (2200 meters high) of Mt. Mageik can be seen from Three Forks Overlook on clear days. A white plume of vapor commonly visible above the volcano gives only a hint of the furious activity within its summit crater where curls of sulfurous vapor rise above the strongly acidic crater lake. Though only 70°C, the lake appears to boil owing to gases vigorously bubbling up through the water. For properly equipped climbers who reach the summit, Mt. Mageik provides a glimpse into a veritable "devil's cauldron." At lower eleva-

tions hikers can readily visit the Mageik Lakes, among the most beautiful spots in the Valley. When the hot ash flow melted the toes of the Mageik glaciers, water collected in ponds at the ice fronts. Often milky blue, these lakes are picturesque base-camp settings from which to explore the upper reaches of the Valley.

Beyond Katmai Pass: Recent Trident Lava Flows, Ghost Forest and Great Delta Fan of Katmai River

Before 1912, Katmai Pass was used as a rugged shortcut across the Alaska Peninsula by Natives, traders, geologists and even a few gold seekers on their way to Nome. This was also the route used by Griggs when he discovered the Valley of Ten Thousand Smokes. The Pass, guarded by the dacitic lava domes Mt. Cerberus and Falling Mountain, is notorious for the furious gales that funnel through it. Dark, blocky andesitic lava just south of Katmai Pass crept down the flanks of Trident Volcano between 1953 and 1968. These lava flows represent the area's most recent eruptions and lie on top of the 1912 pumice deposits.

About 10 kilometers (six miles) beyond Katmai Pass is the junction of Mageik Creek and Katmai River. Here the Katmai River is a braided tangle of rushing streams carrying loose pumice and ash toward Shelikof Strait. In 1912, the massive influx of ash and pumice was so much more than the river could carry that the debris piled up in a delta-fan along the lower reaches of the river. This accumulation dammed and flooded the canyons. Trees not totally buried by the pumice were drowned by widespread flooding. Grey stalks are all that remain of these drowned "ghost forests."



(11) The Ghost Forest: Kodiak Island is on the horizon, barely peeking through the haze across Shelikof Strait.

Through Griggs' efforts, Katmai National Monument (a National Park and Preserve since 1980) was established in 1918. Though the ash flow has cooled and the "miracle of nature" Griggs sought to preserve is not "smoking" anymore, the Valley of Ten Thousand Smokes is still a reminder of the destructive power unleashed during one of the world's largest historic eruptions. In time, today's sparse patches of grasses and willows will overwhelm the barren desert that not long ago was a steaming wasteland of newly erupted pumice.

(12) Novarupta lava dome surrounded by ring of ejecta: Mt. Griggs, left, still has an apron of 1912 ash.

Glossary

Ash: volcanic dust

Ash Fall: (also airfall) an airborne shower of volcanic ash and pumice

Ash Flow: a dense, hot, chaotic mixture of pumic, ash, and volcanic gases that travels along the ground surface

Andesite: extrusive volcanic rock with about 52% to 63% silica

Caldera: a large, roughly circular depression caused by volcanic collapse

Dacite: extrusive volcanic rock with about 63% to 70% silica

Fumarole: an opening from which gases and vapor are emitted

Lava: a general term for molten rock extruded onto the earth's surface; used also for the solidified rock

Lava Dome: a dome-shaped pile of solidified lava

Magma: molten rock still beneath the earth's surface

Pumice: frothy volcanic glass that forms when trapped gases burst out of hot magma as it rises to the surface and is quickly chilled. It is so full of gas-bubble holes that it is very light and will sometimes float

Pyroclastics: "fire" and "broken pieces"; a general term for rock fragments formed by volcanic explosion and aerial ejection from a volcanic vent

Rhyolite: extrusive volcanic rock with about 70% to 77% silica

Vent: a volcanic opening in the earth's surface

Vesicles: holes in volcanic rock created by the escape of gas from hot magma

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