SUNSET CRATER GEOLOGICAL REPORT

By Vincent W. Vandiver, Regional Geologist

INTRODUCTION

The almost perfectly preserved crater of an extinct volcano, known as Sunset Crater, was established as a National Monument on May 26, 1930. The name is derived from the various shades of red color of the cinders in the upper portion of the cone which gives the appearance of being illuminated by the setting sun. To the Hopi Indians Sunset Crater was called "Kana-asKatchinki" which refers to the house of Kana-asKachinas, a group of friendly spirits who are supposed to dwell in the crater. The reserve area of the monument contains much of interest besides the remarkable crater and includes very recent lava flows, fissures or vents, contacts of the different flows, and ice caves. The reserve covers 3,040 acres and is located some ten miles east of the summit of San Francisco Mountain. The distance from Flagstaff is seventeen miles. It lies approximately ten miles north of U. S. Highway 66 and is therefore most accessible to a main route of transcontinental tourist travel.

NATURE OF REPORT

H. H. Robinson has given an admirable geological report on the "San Franciscan Volcanic Field of Arizona" in the United States Geological Survey Professional Paper No. 76. Since the facts covering this area, of which Sunset Crater is a part, are presented in such detailed manner in this report that there seems no need for duplication as regards to minute description of the geology. It is not considered possible at any rate to make meritous contribution to such a treatise without months or even years of field work.

It will therefore be my endeavor on the following pages to outline briefly the geological history of the area of Sunset Crater and vicinity; to indicate certain important features connected with this history, which should be brought to the attention of the visitors, by signs along the roads or trails or in a wayside shrine, in order that they will carry away a more complete and vivid picture; and to point out my observations which you may care to consider in any development of the monument, which in my opinion will best portray the geological phenomena of the area. It is also hoped that this resume will be useful to the Rangers assigned to this monument.

PHYSIOGRAPHY

The volcanic field of the San Francisco Mountains occupies a large part of the southern portion of the Colorado plateau region, wherein is located so many of the natural wonders now included in the National Park chain. This field has an area of some 3,000 square miles. Within the large plateau area are lesser plateaus, outlined by canyons trending generally north and south (with the exception of the Grand Canyon of

the Colorado), fault scarps with the same general trend, and erosion escarpments trending mainly east and west. Strictly speaking there are no mountains in the plateau region with the exception of the volcanic masses of Mount Trumbull and the San Francisco Mountains.

The most conspicuous landmark of the San Francisco Mountains is the San Francisco Peak, which attains an elevation of 12,611 feet above sea level, rising approximately 5,000 feet above the surrounding plain. This mountain is surrounded by several other large peaks ranging in elevation from 8,500 to 10,500 feet above sea level. The general area of the volcanic field is studded with cinder cones, but since few of them are more than 700 feet in height, they appear insignificant as one drives among them. They are indeed more impressive when viewed from the tops of some of the larger peaks or if studies on the U. S. G. S. topographic map of the Flagstaff quadrangle. Sunset Crater is one of the more prominent of these cinder cones, having an elevation of 8,000 feet above sea level, and rising some 1,000 feet above the level of the adjacent country.

The drainage for the volcanic area finds its way in due course to the Colorado River. The water courses or washes are comparatively few in number and they naturally radiate from the higher portions of the field. Oak Creek is the only perennial stream existing in the region and it is fed by several large springs which come to the surface at the intersection of two fault planes at the head of the canyon. The climate of the plateau country as a whole ranges according to altitude from semi-tropical to temperate.

Robinson (1) mentions some special characteristics of the lava flows which have caused numerous minor changes in the drainage system of the area. He states that the damming of the water courses has given rise to small lakes, some of which still persist, while others have been drained by the cutting down of the obstruction that formed them, although not before they had been more or less filled with sediment. The grass covered glades, which are a picturesque feature of the landscape throughout the pine forest, generally indicates the location of former lake sites. Two typical examples of drainage modification by lava flows may be observed on the Little Colorado River at Black Falls and Grand Falls. It may be worth while to consider side trips to these two points for people visiting Sunset and Wupatki National Monuments. At least some interesting models could be made of these features for a wayside shrine which would depict the encroachment of lava on the stream and the changes resultant therefrom.

GEOLOGIC HISTORY

The Paleozoic Era of the plateau is admirably represented in the section which is exposed at the Grand Canyon of the Colorado. Various types of sedimentation are represented in this section, extending from

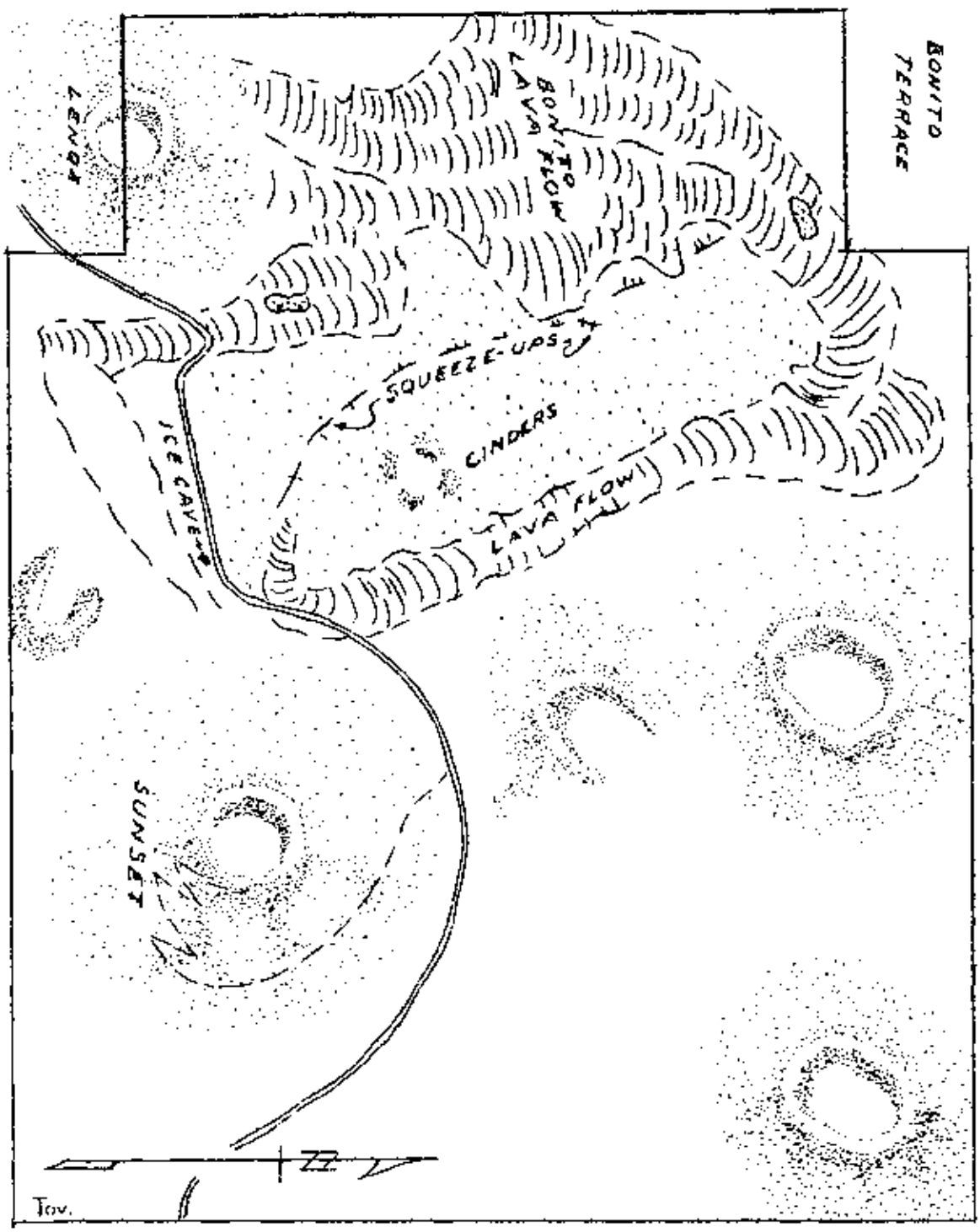

PLATE NO 1

SUNSET CRATER NAT. MON.

the Tonto platform to the rim of the canyon. Deposits of marine sediments are present which contain shells and corals; beach and flood plain deposits are represented by formations bearing sea weeds and the remains of crab-like animals; also formations of continental origin, such as great thicknesses of dune sands, containing tracks of primitive reptiles or amphibians. Thus during this era there is evidence of repeated fluctuations in the land surface with the resultant encroachment and withdrawal of the seas. At the close of the era the seas had invaded most of northern Arizona as indicated by the widespread distribution of the Kaibab limestone formation and the abundant fossil record of marine life which it includes. This formation forms the rim rock at the Grand Canyon and may be observed in most any direction near Sunset Crater.

The Paleozoic is followed by the Mesozoic Era and from a study of the formations included during this interval it is evident that there were also fluctuations of the sea during this time but in the main the lands were generally depressed. Great thicknesses of sandstones, shales and limestones were deposited on top of the Kaibab formation. At the close of the Mesozoic (Age of Reptiles) the waters retreated and the era of recent life of the Cenozoic followed.

The surface of the earth is rarely stable and constant adjustments are being made even at the present time. When strains or stresses are too great during these crustal movements, faulting and fissuring takes place, and oftentimes quantities of molten lava is poured out on the earths surface through these vents or lines of weakness. Adjustments on a huge scale were in vogue at the close of the Mesozoic when the great Rocky Mountain construction took place.

During the Miocene period of the Cenozoic the area west of the Little Colorado River was rising to form what is known as the Little Colorado Monocline. This may have been due to an intrusion of molten lava which did not reach the surface which is termed as a laccolith. Following this general uplift erosion proceeded at a much more active rate and the Mesozoic formations of the San Francisco Mountains was almost entirely eroded away. In fact parts of the Permian formations of the Paleozoic were stripped.

During the Pliocene period (late Cenozoic) we have the First Volcanic Period of the San Francisco Mountain area. Huge fissures gave vents for the pouring out of sheets of basaltic lava, from 50 to 300 feet in thickness, covering a wide area and extending from the Tonto Rim to Cedar Wash. Following in the latter part of this period the uplifting continued when great north-south faults cut the earth's crust and the Second Volcanic Period began. As tremendous quantities of lava was poured forth on the surface, such prominent peaks as Bill Williams Mountain, Kendrick Peak, Sitgreaves Peak, the San Francisco Peaks, and O'Leary Peak (near Sunset Crater) as well as others were formed. A variety of different types of lava was extruded at this time

but in general they were more acid, contained more quartz, and were therefore lighter in color than the basalt of the First Volcanic Period.

As the plateau continued to rise the erosive agencies became more severe and great canyons were carved on the surface. Several thousands of feet of volcanic rocks were no doubt removed from the crests of the San Francisco Peaks as is indicated by a projected profile of their surface. With physiographic features of the plateau much as it is today the Third Volcanic Period began. To the Third and last general period of volcanic activity in this field, covering a considerable interval of time (beginning near the close of the Second Period and extending into comparatively recent geologic time), some 200 basalt cones and lava flows over 1,200 square miles represent the volcanic activity during this period. Sunset Crater is one of the cones formed at this time. This activity certainly occurred during the quaternary period and presumably during the latter part of this period according to Robinson (1). The state of preservation of the cones and lava flows is so perfect that they may date from historic time. Due to their presence, however, in an arid to semiarid region they naturally retain a much fresher appearance than would otherwise be the case in a humid climate.

Generally speaking throughout the geologic history of the plateau there have been two opposing forces which have produced the detailed topography - erosion, which is destructive; and volcanism, which is constructive.

One question that will probably be asked many times, due to the recent character of the surface evidence of volcanic activity, and that is has the activity actually ceased in this region. Robinson (1) advises as follows on this subject: Broadly speaking it may be said to have ceased. There may be further small outbreaks of basalt, but this does not seem probable in view of the insignificant volume of the latest eruptions compared with the total volume of lava of the last general period of eruption. These very latest outbreaks may be looked upon as representing the final feeble manifestations of a long and very complete cycle of volcanism.

SUNSET CRATER

Sunset Crater is the most dominant feature of the monument. It rises to a height of about 1,000 feet from its base, and its summit has an unbreached crater about one-fourth mile in diameter and 400 feet deep. The upper portion of the cone is covered with tinted cinders and lapilli (little stones). The mountain has received its name from the rainbow effect, where the color of the cinders grades downward from the summit of the cone through the various shades of yellow, orange and red into the black material of the lower slopes. There is practically no evidence that the cone has been shattered by explosions and the fact

that erosion has not produced any noticeable change of form attests somewhat as to its recent age.

Basaltic lava is exposed around the rim of the crater. It has been altered and bleached to tones of yellow and pink by fumarole action. Hot spring minerals may be found in this zone. Sulphur crystals, gypsum and limonite are present. Fragments of sandstone and limestone which have been ejected from the crater are found around the rim. Some of the specimens of sandstone have their stratification preserved in part but the edges have in most cases been well altered due to the action of heat. Most of the limestone has likewise been metamorphosed so that it is now classed as marble.

The eastern rim of Sunset Crater is 150 feet or more higher than the western rim. This characteristic is common among the two hundred cinder cones of the last period of activity. The fact is explained by the reason of the prevailing westerly winds during the main eruption when ash, cinders and lapilli fell in this direction and thereby building up the eastern rim to greater heights.

Because of the various indications of recent activity at Sunset Crater and vicinity, which are more or less visible to the visiting public, the determination of the age of the last eruption has always been an interesting question. Robinson (1) states that the latest cones and flows are older than the pine trees growing at the edge of Bonito lava flow, west of Sunset Peak, which would make them not less than 300 years old and possibly not more than 1,000 years old. A possible Hopi tradition of the eruption of Sunset Crater is mentioned by Dr. Colton (4). Geologists, who are generally credited with being unable to think in terms of a few years, have been content to call it a very recent cone. Exact determinations in this regard have required other means of approach. The ash from this crater undoubtedly covered hundreds of square miles. It is known that this black sand buried numerous pit houses of an ancient people (pueblo) which had been constructed on Bonito Terrace. A number of these houses have been excavated by archeological expeditions of the Museum of Northern Arizona, McGregor (5). Attempts were made to collect additional data from the sites that had been abandoned before, or at the time of the eruption of Sunset Crater. Charred beam material was particularly desirable, as well as information collected as to the nature of the ash fall accumulated above and in the sites, with data as to the pottery in use, artifacts, and types of houses contributing factors.

A trail leads to the summit of the crater and the round trip can be made in one hour if one is rushed for time. It is best however to spend at least a half day on the rim and in the event that the interesting details of the mouth of the crater fails to hold one, there is the magnificent panorama of the Painted Desert, San Francisco peaks, and the Bonito Lava flow below with its many interesting features.

BONITO LAVA FLOW

This lava flow is probably the second most important feature of the monument and is almost entirely contained within the boundaries. The map, Plate 1, which accompanies this report shows the relationship of the lava flow with Sunset Crater. This lava escaped from a vent opened through an older flow of the Third Period and spread out quietly into an intercone basin. As the lava could not flow far it has probably piled up to depths of several hundred feet.

A badly disrupted cone known as Yapuncha Crater is located in the central portion of the flow. The exact nature of this cone is not known. It is possible that it has been the source of some of the lava and that it was disrupted at the time of the flow. Another explanation is that it may have been more or less floated on the lava and thereby disintegrated.

Along the surface of the Bonito flow to the west of the above-mentioned cone and extending in a northwest direction is a large vent or fissure which has also been termed "Anosma" or "squeeze-up." After the surface of the flow had solidified, the fissure tore the surface, and semi-plastic lava was squeezed upward. In places the lava has been forced some ten feet in the air and frequently crumpled under their own weight. This type of flow seems to be rather unique among volcanic phenomena and it has been suggested that there may be some relation to the fact that the main lava flow was dammed.

The Ice Caves immediately west of Sunset Crater on the Bonito flow seems to be the principal attraction to a great many people. In fact at the time of my last visit some people were asking how they could get to the Ice Caves and seemed little concerned or anxious to ask questions regarding the multitude of volcanic phenomena about them. The cave has only been explored a few hundred feet. It is likely that the roof has collapsed in places and it may well be rather extensive. This type of cave is typical of lava flows where the lava has drained away, leaving the solidified roof standing. It is most unusual to enter the cave in summer and find it filled with ice. The details as to the method of the formation of ice caves is not fully understood. Lava is a poor conductor of heat and the cold air which settles to the bottom portions of the cave is protected to a certain extent. It is possible that some interesting information could be collected which might have a bearing on this feature if temperature readings were taken at regular intervals in the cave.

Besides the above-mentioned important points in connection with the Bonito flow there are several others worthy of attention. There are a number of fumaroles at the base of Sunset Crater and vicinity where gases escaped during the last active stage of the crater. A sink hole is shown on the map just east of the Yapuncha crater. In this case the lava flowed out from under the crust forming the sink.

The remains of a hot spring is also shown on the map. It is located very near the large fissure of "squeeze-up" previously discussed. A considerable portion of the Bonito flow is covered by a more recent ash fall. Examples are numerous illustrating this feature and it has been noted that considerable more ash fell on the southern than on the northern end of the flows. Cooling cracks, contacts of the different flows and other fascinating features are prevalent and it is considered that as the monument is developed many other interesting facts will be divulged of interest and importance.

ARCHEOLOGICAL

The Hopi legends of the Sunset Crater region have been described by the staff of the Museum of Northern Arizona. The Museum Notes (4) give a vivid picture of Yaponcha, the Wind God and the Kana-a Kachinas of Sunset Crater. We have endeavored to show how determination of the age of the last eruption of the crater has been made by a study of the remains of pit houses. This type of material when authenticated will form a most important background for a story of the monument.

FUTURE DEVELOPMENT

I do not know if detailed plans have been formulated as to the development of this monument. It seems to me that one custodian could probably take care of Sunset and Wupatki as is now the case. It is my thought that a Wayside Shrine near Sunset could portray all the facts of the monument and that directions from this point could be given to the various trails to illustrate the features in place. Exhibited in the shrine we could arrange generalized sections and inexpensive models to show the different stages of volcanic activity in this field. A collection of the various types of lava, hot spring minerals, rocks and material from the outcrops of sedimentary formations in the surrounding area and corresponding material which has been ejected from the crater would all no doubt prove of considerable interest. I believe that panorama photographs could be taken in this general area and that ink sketches could be made therefrom to serve as a guide to the various trails. Actual trail construction should be kept down to a minimum and it is thought that with the proper use of signs the visitor will be directed sufficiently to see all of the points of interest. It is possible that some sort of a guide to prominent features of the landscape will prove essential from the summit of the crater. Some of these things will of course not be necessary if a permanent ranger is maintained for this monument.

POINTS OF INTEREST

It is considered that the following features of the monument will be worth while calling to the attention of the public when it is developed:

1. Sunset Crater - Signs is what seems to be needed most at the present time especially in view of the fact that there is no permanent ranger present and there is no pamphlet available.

2. Benito Lava Flow should have markers at different points to better depict the facts for the visitor.

3. Attention should be called to the most important fissures or "squeeze-ups" with signs.

4. An explanation of what we know of the formation of ice caves might well be posted at the entrance of the caves.

5. Fumaroles, sink holes, spatter cones, hot spring remains, contacts of different flows of lava should all be marked by directions from the main road or "turn-around." A sign could very well be erected at each feature explaining briefly its origin.

I am aware that some people object to too many signs but I see no recourse under the present setup of the monument. I am sure that many people go there and see the ice cave and go away with very little knowledge of what has gone on about them. The monument is most accessible to a main artery of travel and many more people will visit the area if a little money is spent on the development. It seems to that there is every justification for some development as Sunset Crater is really one of the most important monuments in the Southwest.

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