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GEOLOGY OF BEAR BUTTE, A QUATERNARY
LAVA CONE
BLAINE COUNTY, IDAHO

BY

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ABSTRACT

Bear Butte is a basaltic lava cone located about 50 km south of Arco, Idaho on the Snake River Plain. The cone stands approximately 60 m above the surrounding younger flows and has an areal exposure of about 19 km². Although covered by varying thicknesses of soil, primary geomorphic features such as collapse depressions, lava channels, and spatter ramparts are well preserved. Bear Crater is the triangular summit vent of Bear Butte and is approximately 780 m long and 250 m wide. The irregular shapes of the butte and the crater are the result of a southward migrating eruptive center. There appears to have been a sequence of three major eruptive periods and several minor eruptive intervals. The first two major periods were cone building stages with flow unit thicknesses of 1 to 3 m forming flows from 25 to 30 m in thickness. These are exposed in the crater walls. The lava from the third major period breached the southeast corner of the cone and flowed to the south forming two large lava channel systems. Each of these systems extends about 2.9 km to the south where they are buried by younger lavas. The channels range in depth from 2 to 10 m and are from 3 to 60 m in width. The minor eruptions resulted in the formation of shelly pahoehoe at several stratigraphic levels and also in the formation of late stage spatter ramparts.

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INTRODUCTION

PURPOSE OF THE STUDY

This study was undertaken with a three-fold purpose, 1) to define a geologic history for Bear Butte, 2) to determine the relationships of several volcanic flow features associated with Bear Butte, and 3) to provide criteria for formulating geologic histories of possible martian analogs. The study includes field mapping of surficial and bedrock geology and petrographic analysis of the basaltic rocks of Bear Butte. The field investigations were conducted during June and July 1974, with the laboratory studies done during the 1974-1975 academic year.

Bear Butte was chosen for investigation because of the presence and fine preservation of several primary surface features. These features include a network of lava channels, aligned collapse depressions, and the summit vent, Bear Crater. Although there are several other volcanoes in the area which have lava channels, none of the channel systems is as extensive as is that of Bear Butte. The collapse depressions on Bear Butte show an alignment of their long axes and their presence and configuration appear to be important in the formulation of an eruptive history. Bear Crater, the summit vent of Bear Butte, is triangular (fig. 1) instead of the

normal round shape. This irregular shape appears to give a clue to the eruptive history of Bear Butte. Furthermore, the study could contribute to the literature on irregular shaped vents.

PHYSICAL SETTING OF BEAR BUTTE

Bear Butte is 50 km south of Arco, Idaho near the axis of the central part of the Snake River Plain (fig. 2). It is in Blaine County (T4S, R26, 27E; 43°04'N, 113°31'W). and is accessible only by jeep trails from the Great Rift National Landmark or from either Minidoka or Arco, Idaho. Bear Butte is mapped on the Army Map Service Pocatello (1:125,000) quadrangle. No 15 minute or 7½ minute quadrangles are available although topographic mapping has been initiated in the area by the U.S. Geological Survey and preliminary 7½ minute sheets are available.

Bear Butte is on a dry, barren portion of the Plain that is locally called the Arco Desert. During the two months of field investigation there was no precipitation and the temperatures ranged from 40°F to 110°F. The average relative humidity during this period was 15 percent. These conditions are fairly typical for this region, where the average annual precipitation is 10 inches (Mundorf, 1964). Most of the precipitation occurs in the winter and spring.

PREVIOUS INVESTIGATIONS

Geologic investigations of the Snake River Plain have been carried out since the beginning of the twentieth century. Russell (1902) and Stearns (1938) conducted reconnaissance studies of the peripheral region of the Snake River Plain for the U.S. Geological Survey to ascertain the availability of ground water. During his surveillance of the Plain from the summit of Big Southern Butte (Russell, 1902) noted the existance of numerous volcanic craters, one of which possibly was Bear Butte. Prinz (1970) conducted a field study in the area of the King's Bowl Lava Field. In conjunction with this study he also did a photogeologic investigation of the Wapi Lava field and the open crack rift system. Bullard (1970) has studied the King's Bowl and the Craters of the Moon lava fields. The only study of Bear Butte and its surrounding area was done in reconnaissance by Greeley (1973).

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REGIONAL SETTING

SNAKE RIVER PLAIN

The Snake River Plain is a topographic and structural low (Malde, 1965) which extends in an arcuate belt 580 km across southern Idaho. The surface of the Plain is composed of basaltic lava sheets of Pleistocene to Holocene age (Stearns et al., 1938). The highlands which surround the Plain are composed of granite of the Idaho batholith, quartzites, and carbonates of Precambrian and Paleozoic ages (AAPG map, 1972). Upper Tertiary rhyolite and andesite flows which occur in the surrounding highlands and dip beneath the northern edge of the Snake River Plain apparently underlie the basalts (Stearns et al., 1938). These silicic volcanics crop out at several places on the Plain in the form of steptoes or kipukas, island-like projections of older lavas through the surrounding younger sheet basalts. Two examples of this are East Twin Butte and Big Southern Butte (Stearns et al., 1938). These are located southeast of Arco, Idaho near and on the Nuclear Reactor Testing Station and northeast of Bear Butte.

The Snake River Plain can be divided on the basis of structure and physiography into two provinces (Malde, 1965). The western Snake River Plain extends from the vicinity of the Oregon-Idaho border southeast to Glens Ferry and then east to about Twin Falls.

The eastern Snake River Plain extends from near Twin Falls east to Pocatello where it turns to the northeast and continues to the area of Yellowstone National Park near the Wyoming-Idaho border. Bear Butte lies on the portion of the eastern Snake River Plain between Twin Falls and Pocatello. The extrusives exposed on this part of the Snake River Plain range in age from the late Tertiary to Holocene, Stearns (1963) has estimated the minimum age for flows in the Craters of the Moon National Monument as being 1650 years by using a tree ring count. Bullard (1970) gave radiocarbon dates of 2085 ± 85 years B.P., 2140 ± 60 years B.P., and 2255 ± 60 years B.P. for flows in the Craters of the Moon. A radiocarbon age for lavas of the King's Bowl Lava Field was done on charred sagebrush from the base of the flow and is 2130 ± 130 years B.P. (Prinz, 1970). These are the youngest ages determined for lavas on the Plain. Potassium-argon ages for basalts from the Nuclear Reactor Testing Station range from 0.9 ± 0.8 to 2.7 ± 0.6 m.y. (Chase, 1972) representing the oldest ages for surface basalts.

The structure controlling the eastern Snake River Plain is not as well defined as the graben of the Western Plain (LeFehr and Pakiser, 1962; Hill et al, 1961). Kirkham (1931) described the Snake River Plain as a broad crustal downwarp, based on the inward dip of Tertiary beds at the edges of the Plain. A graben similar to that

in the west has also been suggested as the controlling structure of the eastern Plain. (LeFehr and Pakiser, 1962). Malde (1965) also suggested that faults could control the eastern Plain. He stated that small throw faults could account for the abrupt termination of the mountain ranges at the borders of the Plain. However, no current theory satisfactorily accounts for all the phenomena present on the eastern Snake River Plain.

BEAR BUTTE

Bear Butte is a kipuka in that it is completely surrounded by younger lavas (Greeley, 1973). A thin unconsolidated mantle has developed on the Butte but is absent on the neighboring 2000 year old Craters of the Moon lavas. (Stearns, 1973). The relationship of Bear Butte to other lavas and the mantle development on the Butte suggest that its age is probably early Holocene. IT MUST BE OLDER

No structural control is evident on Bear Butte. The only nearly structural feature is the open crack rift set described by Prinz (1970) which is 6.5 km to the east (fig. 2) and is parallel to the long axis of the major rift and are present on the Plain up to 10 km away. These may exert control on the shape of Bear Butte; however, no direct evidence of this was found during the study.

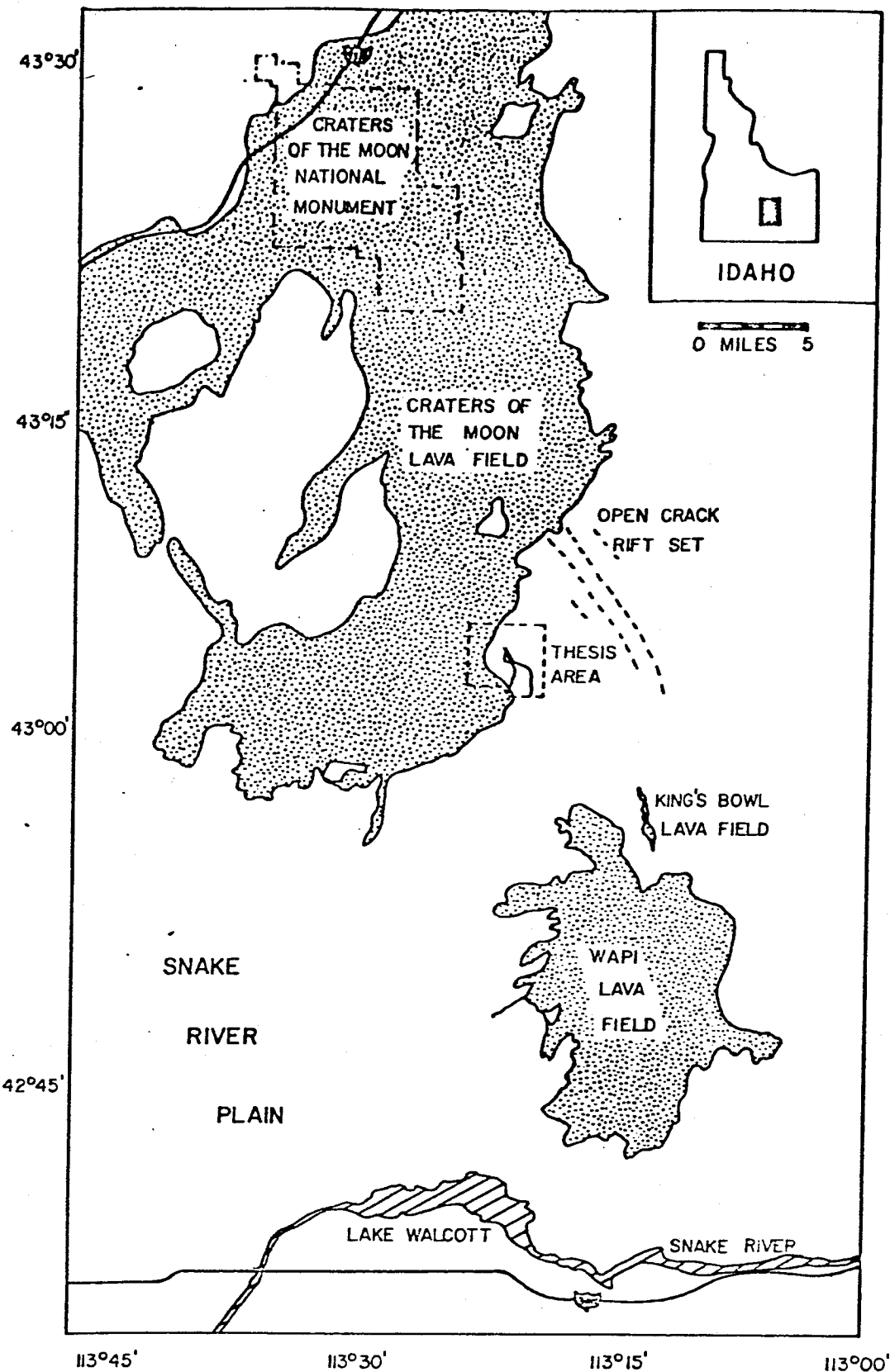


Figure 2. Location map of Bear Butte.

METHODOLOGY

FIELD WORK

GEOLOGIC MAPPING

A detailed geologic map (plate 1) was prepared in order to determine the time-space relationships of the flows. Geologic mapping of the Bear Butte area was done on a topographic base map (1:13,000) prepared through NASA-Ames originally for Greeley (1973). The base map, with a contour interval of 4 m was compiled from high resolution photographs. Aerial photographs were used in conjunction with this base map to choose and locate the positions of the mapping stations.

The geologic map units were defined in the field on the basis of hand specimen petrography and physical characteristics (table 1). Each map unit is a flow, composed of several flow units. Eight composite measured sections were made of the crater walls noting the stratigraphic relationships of characteristic flow units such as dense layers and thin-bedded, oxidized units. Detailed hand specimen descriptions were made of the flow units during measured section preparation. These data were then used to refine the definition of the map units.

GEOMORPHIC MAPPING

A detailed map of the primary flow features on the flanks of Bear Butte (fig. 3) was made to aid in the

TABLE I

GENERALIZED HAND SPECIMEN CHARACTERISTICS

FLOW	% PHENOCRYSTS	PHENOCRYST MINERALS	% OF TOTAL PHENOCRYSTS	% VESICLES	COLOR*
I	20	Plagioclase Olivine	75 25	45	Med. Grey
II	15	Plagioclase	100	20	Med. Grey
III	10	Plagioclase Olivine	90 10	30	Med. Dark Grey

* From GSA Rock Color Chart

formulation of a hypothesis of origin. This map was prepared on the same base as the geologic map. Specific flow features were located on the U.S. Geological Survey air photographs. Traverses were selected which allowed these features to be investigated in the field.

SAMPLE COLLECTION

Hand specimens were collected at 15 stations on the flanks of Bear Butte, and also from several stations on the neighboring flows (fig. 4). Samples were taken from outcrops wherever possible; however, some samples had to be taken from "float". The "float" samples were assumed to be reliable because of the low relief of the flanks of the cone. In addition, systematic sampling was done for the composite measured section number 4 of Bear Crater, where samples were taken from the center of each of the flow units.

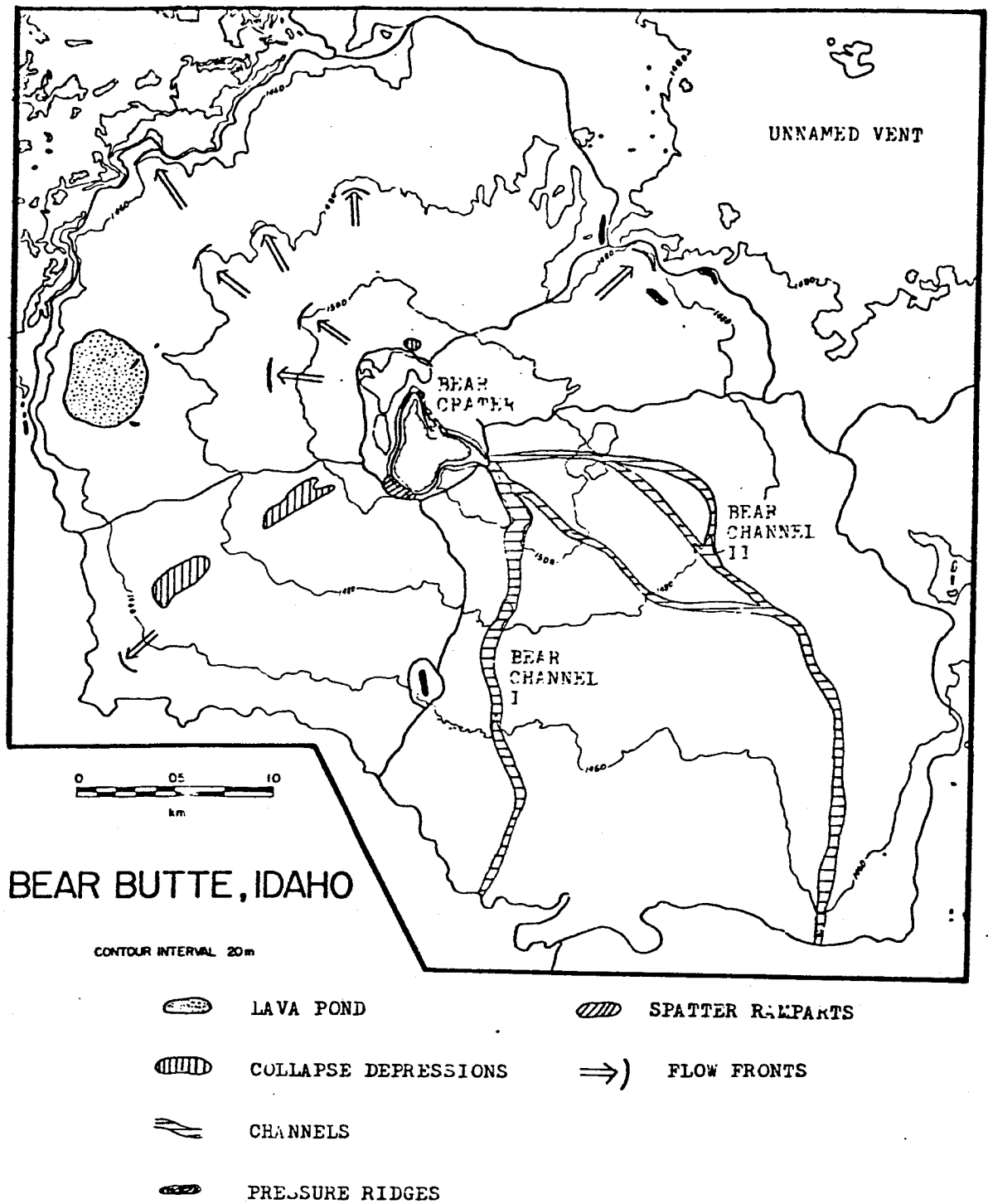


Figure 3. Geomorphic map of Bear Butte.

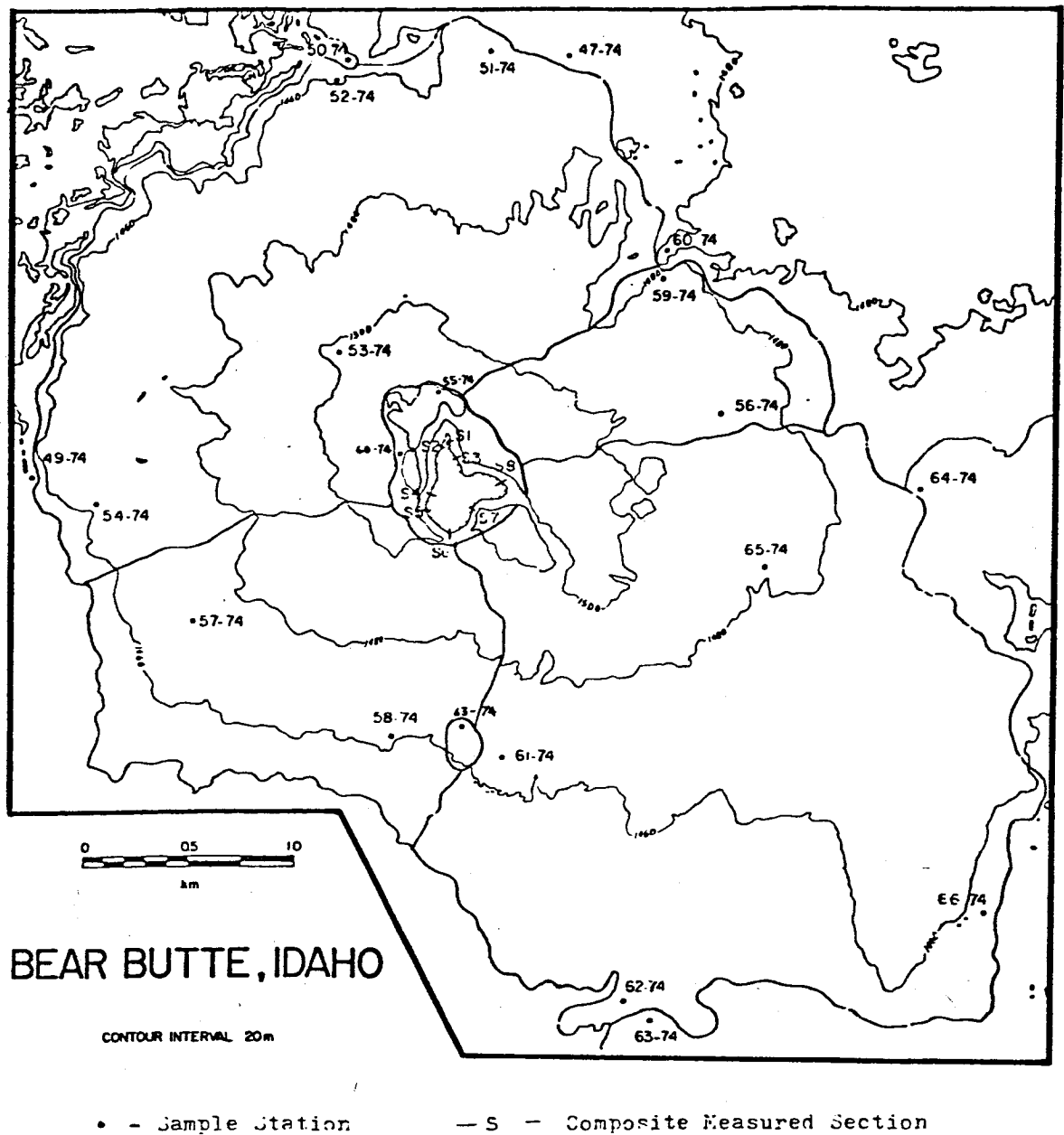


Figure 3. Sampling station location map.

LABORATORY WORK

Thin sections were prepared for most of the samples collected in the field. The petrographic study of these slides included description of the specimens and point count analyses. Using a point count reliability chart (van der Plas and Tobi, 1965) a standard of 1500 points was counted for each slide, giving results of ± 2 percent error at a .95 confidence level for the major components. The computed modal analyses are listed in Table 2. The textural terms used in the descriptions are from Williams, Turner, and Gilbert (1954).

Some plagioclase compositions were determined using the Slemmons method (1962). The optical axes and twinning angles of the phenocrysts and matrix laths were measured using a 4-axis universal stage. Data were plotted on a stereo net and the derived information was used to determine the compositions from Slemmons' charts.

The compositions of the olivine phenocrysts also were determined using optical methods. The 2V's of the crystals were measured on the universal stage. The angle was then plotted on the composition-2V graph and the composition determined.

Sample	51-74	52-74	53-74	54-74	56-74	57-74	58-74
% Plagioclase	12.9	15.2	14.5	13.7	13.3	11.7	14.6
% Olivine	4.3	5.0	6.8	5.6	3.8	2.7	5.5
% Pyroxene	<1	<1	<1	<1	<1	<1	<1
% Opaques	1.0	<1	2.2	1.1	<1	<1	<1
% Matrix	63.2	66.1	59.8	61.8	59.6	58.7	54.8
% Vesicles	18.4	13.1	16.0	17.2	22.6	25.8	24.0
Total	99.9	100.0	99.8	99.9	99.9	100.0	100.1

Sample	59-74	61-74	62-74	65-74	66-74
% Plagioclase	13.5	12.7	11.2	13.9	14.7
% Olivine	3.6	4.3	3.8	4.8	3.7
% Pyroxene	<1	<1	<1	0	<1
% Opaques	<1	1.2	<1	<1	1.5
% Matrix	57.9	57.7	63.9	58.6	45.8
% Vesicles	23.5	23.5	20.0	22.0	33.5
Total	100.0	99.9	100.0	100.0	99.9

Table 2. Modal compositions of Bear Butte samples.

DESCRIPTION OF FLOWS

FLOW I

LOCATION

Flow I, the oldest flow of Bear Butte, occupies the northwestern portion of the exposed shield of Bear Butte. It is bordered on the west and northwest by lavas associated with the Craters of the Moon flows and on the north by lavas originating from an unnamed vent to the northeast. Encroachment of these younger flows on the flanks of Bear Butte has resulted in a roughly semicircular border.

HAND SPECIMEN DESCRIPTION

The rocks of Flow I are dark grey, fine grained basalts. They have a cumulophyric texture with flow banding exhibited in only one of the collected specimens. Vesicles make up 15 percent while phenocrysts make up approximately 20 percent of the total hand specimen volume. Plagioclase laths and tabs constitute about 75 percent of the total number of phenocrysts with round, green olivine crystals making up the rest of the total phenocryst component.

THIN SECTION PETROGRAPHY

The rocks of Flow I have an intergranular texture with clusters of plagioclase laths and colorless olivine grains set in a fine matrix composed of plagioclase,

olivine, pyroxene, some glass, and opaques. The plagioclase phenocrysts occur as euhedral laths which range in length from 2 mm to 4 mm. The phenocrysts of olivine are colorless with diameters from 1 mm to 2.5 mm. The average size of the matrix minerals is .1 mm with a range from .05 mm to .25 mm. The plagioclase grains of the matrix are typically euhedral and in the form of laths with only a few resorbed crystals present. Round colorless olivines and brown pyroxenes are abundant in the matrix. The opaques are probably magnetite and ilmenite and are present in two forms, as equant grains and as needles. A small amount of brown glass is also found in the matrix. The vesicles contain secondary fillings of calcite and a cryptocrystalline substance which is probably montmorillonite.

Plagioclase phenocryst compositions in the rocks of Flow I range from $An_{50}-An_{67}$. The olivine phenocrysts in these rocks have an average composition similar to that of the phenocrysts at An_{50} .

PRESSURE RIDGES

Pressure ridges and tumuli are similar in form and origin, the only difference between them being that the pressure ridges are longer than the tumuli. The pressure ridges of Flow I average 30 m long, 3 m wide, and 2 m high. Most are characterized by medial cracks (fig. 5). The cracks are typically several decimeters wide and from

40 to 80 centimeters deep; they extend the length of the top of the ridge. The pressure ridges of Flow I are all near the margins of the map.

FLOW FRONTS

Flow fronts are expressed as a sudden break in topography on an otherwise even gradient (fig. 6). There are four flow fronts in the area of Flow I. The foreslopes have an average slope of 30° compared to the 15° slope of the flank, and are 3 to 4 m above the average surface.

LAVA POND

The lava pond (fig. 7) on the western side of Flow I (fig. 4) apparently formed when the advancing lava was stopped and a levee formed. The pond is about 230 m in diameter with the levee preserved on two sides. The levees have approximately 3 m of relief and are 4 to 5 m wide. The center of the pond is collapsed, probably through degassing of the lava contained in the pond during cooling (MacDonald, 1973).

FLOW II

LOCATION

Flow II occupies two wedge-shaped areas on either side of Bear Crater south of Flow I (plate 1). The wedge on the southeastern side of the crater is bordered by pahoehoe lavas from the Craters of the Moon flows. The northwestern wedge terminates under lavas erupted from an unnamed vent located to the northwest.

HAND SPECIMEN DESCRIPTION

The rocks of Flow II are dark grey, fine-grained basalts with a glomeroporphyritic texture. Vesicles make up 20 percent of the hand specimen by volume and are sub-spherical with no flow elongation evident. Plagioclase megaphenocrysts constitute 15 percent of the rock.

THIN SECTION PETROGRAPHY

In thin section the rocks of Flow II have an intergranular texture with cumulophyric plagioclase laths in a fine matrix of olivine, pyroxene, small plagioclase laths, and opaques. The average length of the plagioclase phenocrysts is 2 mm. The matrix minerals olivine, pyroxene, and plagioclase range in size from .01 mm to .2 mm with the average grain being .1 mm in diameter. The olivine crystals forming the groundmass are colorless and euhedral to subhedral. The brown pyroxene is subhedral to anhedral and is interstitial. The plagioclase

clase laths in the matrix are subhedral to euhedral with some resorption evident. They commonly appear "dusty" because of minute inclusions. The opaques are probably magnetite and again are present in two crystal habits, as tablets and needles. The vesicles average 4 mm in diameter and have secondary fillings of calcite, chalcedony, montmorillonite, and a zeolite.

COLLAPSE DEPRESSIONS

There are two collapse depressions on the southwestern wedge of the Flow II area (fig. 4). The depressions are aligned on a southwesterly trend from Bear Crater to a bend in the margin of the Craters of the Moon flows (fig. 8). The collapse depression nearest the vent is approximately 300 m long, 80 m wide, and several meters deep in the center (Greeley, 1973). The other depression, farther down the slope, is 325 m long, 129 m wide, and a few meters deep in the center. An uncollapsed section of crust 325 m long separates the tail of the upper depression from the head of the lower depression.

TUMULI

Two tumuli are located in the northwestern wedge of Flow II, one near the border of Bear Butte, and the other two-thirds of the way down the flank of the Butte (Fig. 4). These tumuli average 15 m in length and 3 to 4 m in relief. The axes of these tumuli parallel the border of

the Bear Butte exposure. A third tumuli occurs on the southwestern edge of Flow II 750 m from the crater near the eastern border of the area. Its axis is 20 m long and at a 60° angle to the border of the younger flows.

FLOW III

LOCATION

The southeast portion of the Bear Butte area is characterized by a third type of basalt and is mapped as Flow III. The basalt of Flow III has the largest areal exposure on Bear Butte, comprising almost one-half of the exposed cone. Flow III has a higher elevation than the rest of the Butte, resulting in less encroachment by younger lavas from other vents.

HAND SPECIMEN DESCRIPTION

The rocks of Flow III are dark grey, porphyritic basalts with 10 percent phenocrysts, 30 percent vesicles, and a fine grained matrix. Ninety percent of the phenocrysts are plagioclase which average 2 mm in length; the other 10 percent are olivine grains ranging from 0.5 mm to 2 mm in diameter. The phenocrysts have a glomeroporphyritic texture. The vesicles average 5 mm in diameter, and show no distortion.

THIN SECTION PETROGRAPHY

In thin section the rocks have an intergranular

texture. The minerals in the matrix are plagioclase, olivine, a pyroxene, and opaques. The matrix plagioclase grains occur as laths and anhedral grains with an average length of 0.5 mm. The interstitial olivine of the ground-mass is colorless and is usually found in areas of denser concentrations of plagioclase. The pyroxene is brown in plain transmitted light and is usually anhedral in shape forming interstitial fillings. The average diameter of both olivine and pyroxene grains is 0.05 mm. The opaques occur as both needles and tabular grains; they are of approximately the same size as the other matrix minerals, but tend to be euhedral. The vesicles have secondary fillings of calcite and a cryptocrystalline substance that is probably montmorillonite, although no qualitative study was made.

LAVA CHANNELS

Flow III has an extensive, well developed and well preserved system of lava channels (fig. 4). This system extends to the southeast from the southeast corner of Bear Crater and can be divided into two subsystems on the basis of preservation.

The best preserved subsystem is that of Bear Channel I, which trends 2.8 km to the south (Greeley, 1973). Its course can be easily followed throughout its entire length to where it becomes buried by lavas from the Craters of the Moon flows. Near Bear Crater the channel

is rather wide (100 m) and deep (24 m) and has a nearly straight course. The channel quickly narrows and shallows only 250 m from the crater to 70 m wide and 8 m deep. At a distance of 400 m from the head the channel makes a bend and starts to wind, still decreasing in size. The straight section of the channel occurs near the crater where the gradient is high. As the distance from the crater increases the gradient decreases, and consequently the sinuosity of the channel increases.

Along much of the length of Bear Channel I, overflow from the channel has built levees. Repeated overflows have resulted in a buildup of the lavas into a 468 m ridge with the channel running down the axis. This ridge is much like a delta in that while it lowers the gradient along the bed of the channel, it also raises the relative topographic height of the bed. The progression of this ridge allows a higher gradient to be maintained at increasing distances from the crater. Flow features associated with the channel include pahoehoe festoons, indicating drainage back into the channel.

Bear Channel II, the second subsystem, is more extensive and complex than Bear Channel I, and less well preserved. It trends eastward from the crater for 1.8 km and then turns to the south. After the turn the channel continues 1.6 km south where it is buried by lava associated with the Bear Trap Tube. The courses of the chan-

nels are not entirely exposed, but the directional trends can be observed on air photographs. The discontinuous exposure is probably the result of sections of the channel being lava tubes with uncollapsed roofs. The easterly trending system of channels from Bear Crater consists of three branches. These branches all follow arcuate paths with few bends, and are rather narrow (60 m) and shallow (3 to 4 m).

The channels merge into one sinuous channel where the trend of the system turns to the south. The channel initially deepens to 4.5 m but then shallows, and the sinuosity increases with distance from the crater. Repeated overflow of the channels built levees which accumulated into ridges with the channels along the axes. The higher elevation created by the ridges is the reason for the decreased encroachment on Flow III by the younger lavas.

ROOTLESS VENT

Near the western border of the map area is a 2600 m² region littered with small bombs and scoria. The axis of this oblong area is parallel to Bear Channel I. The axis of a central ridge parallels the trend of the area. The area is separated from the crater by a region which lacks pyroclastic material. The ridge fits MacDonald's classification of a rootless vent (MacDonald, 1973). A root-

less vent is defined as a break in the crust through which issues fluid lava from the interior of the flow. The density of pyroclastics decreases with the distance from the medial crack of the tumuli, suggesting that the tumulus is the source of the material.

SLAB-LAVA

LOCATION

Slab-lava surrounds much of Bear Crater (plate 1) and extends from 90 to 275 m from the lip of the crater. The slab-lava is not found in the channel heads or near the northwest apex of Bear Crater, due to nondeposition or burial.

DESCRIPTION

The slab-lava on Bear Butte was probably formed as shelly pahoehoe. Shelly pahoehoe is described by Jones (1943) as "thin, overlapping flows made up of numerous bubbles of weak structure." In solidified condition these large bubbles or hollow toes are easily broken into slabs (Swanson, 1973). On Bear Butte erosional forces have broken most of these bubbles into such slabs. They litter the area around the crater and are found in many orientations, the majority lying right side up as determined by the glassy surface.

In hand specimen the slab-lava is a highly vesicular medium grey basalt averaging 3 to 5 cm in thickness.

Nearly 50 percent of the rock volume is made up of small vesicles which average 2 mm in diameter. The rock contains no phenocrysts and the upper surface is commonly glassy with no evidence of oxidation.

THIN SECTION PETROGRAPHY

In thin section the slab-lava has a subophitic texture. The thin section was cut perpendicular to the lower surface of the rock and shows a definite increase in grain size from the glass at the top to the lower surface. The constituents of the rock are plagioclase laths, colorless olivine, pyroxene, opaques, and glass. Commonly near the surface secondary vesicle fillings were formed.

BEAR CRATER

DESCRIPTION

Bear Crater is the triangular shaped vent of Bear Butte (plate 1). It is about 780m long, 254 m wide, and 80 m deep (Greeley, 1973). The floor of the crater is covered with eolian deposits of sand, talus, and alluvium of an unknown thickness. The floor is bowl-shaped with two valleys extending into it (fig. 9), giving the triangular shape. The valleys, V-shaped due to filling by talus, are ramps; one to the northern end of the crater (fig. 10) and the other to the heads of the lava channels (fig. 9). The floor grades up to the talus piles at the base of the crater walls. The layers in the walls have an average dip of 15° away from the crater rim (Greeley, 1973). The only lava tube entrances found in the walls of the crater occur in the upper section of the northeast wall of the northern end (fig. 11). They are small tubes with diameters ranging from 0.5 m to 0.1 m and trend down dip towards "North Hole", a 66 m diameter collapse depression (Greeley, 1973), (fig. 12). These tubes generally show a series of concentric linings several centimeters thick which suggest that the tubes were conduits for lavas from more than one eruption. Also found in this area was a 6 m long fragmented set of nested channels (fig. 13). These trend toward the "North

Hole". The bottom channel is 1.2 m wide, and the smallest channel is 80 cm. wide.



Figure 9. Bear Crater (looking south).

SPATTER RAMPARTS

LOCATION AND DESCRIPTION

Spatter ramparts of agglutinate occur at two general locations on the rim of Bear Crater. Small ramparts (fig. 14) 2 to 3 m high and several meters in diameter occur around the northern apex of Bear Crater. A prominent rampart is on the rim of the southwestern apex of the crater (fig. 15). This rampart is 10 m high and approximately 40 m in diameter.

The spatter ramparts are composed of numerous layers of agglutinate (fig. 11). The layers of the large rampart on the southwestern apex of Bear Crater (fig. 16) have an average dip of 20° away from the crater rim. The downslope side of this rampart is littered with small bombs which average 30 cm in diameter.

HAND SPECIMEN DESCRIPTION

In hand specimen a layer of spatter is thin (7 to 10 cm), red, highly vesicular basalt. No megaphenocrysts were found in any specimens examined in the field. Secondary fillings of calcite are common vesicle fillings in the rock. The surface of the rock is characteristically dense and highly oxidized with increasing vesicularity toward the center of the layer. Some hand specimens show that several layers of spatter have been welded together with the dense layers marking the boundary of

each unit.

THIN SECTION PETROGRAPHY

In thin section spatter has a subophitic texture. The crystals are equigranular with a high percentage of opaques which fill the interstitial spaces and give the thin section a dark appearance. The crystals are plagioclase laths, colorless olivine crystals, and small numbers of brown pyroxene grains.

COMPOSITE MEASURED SECTIONS

Composite measured sections (fig. 17) were made at eight stations around the walls of Bear Crater (fig. 3). Because of slumping and talus blocks, it was not possible to measure a complete section vertically at any one location. The flow units in the wall of the crater indicate that Bear Butte was built up by the accumulation of several flows, each made of numerous flow units. The average dip of the flow units is 15° away from the crater rim. The sections show gradational changes in flow unit density within a single flow. The top and bottom flow units of each flow were more vesicular than those in the center. The flows are separated by varying thicknesses of thin, wavy, bedded, layers of oxidized basalt.

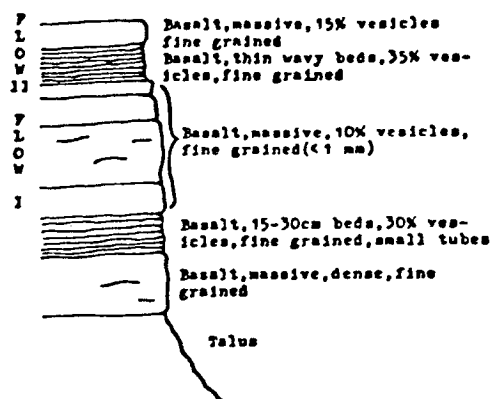


Figure 17a. Section 1.

Scale 1:250

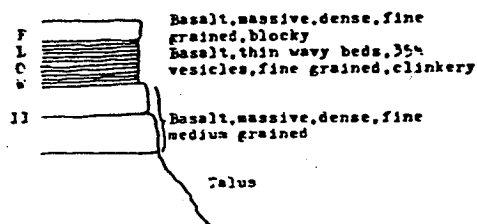


Figure 17c. Section 3.

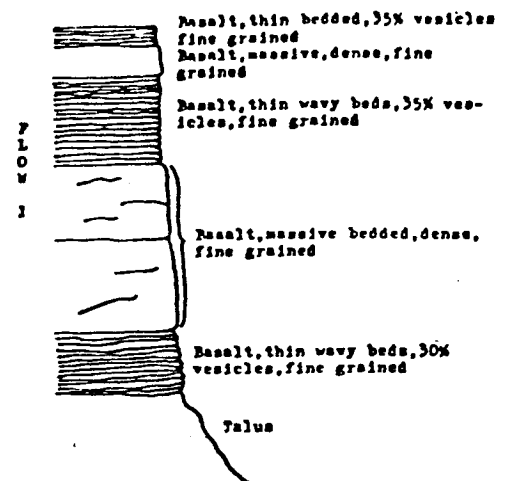


Figure 17b. Section 2.

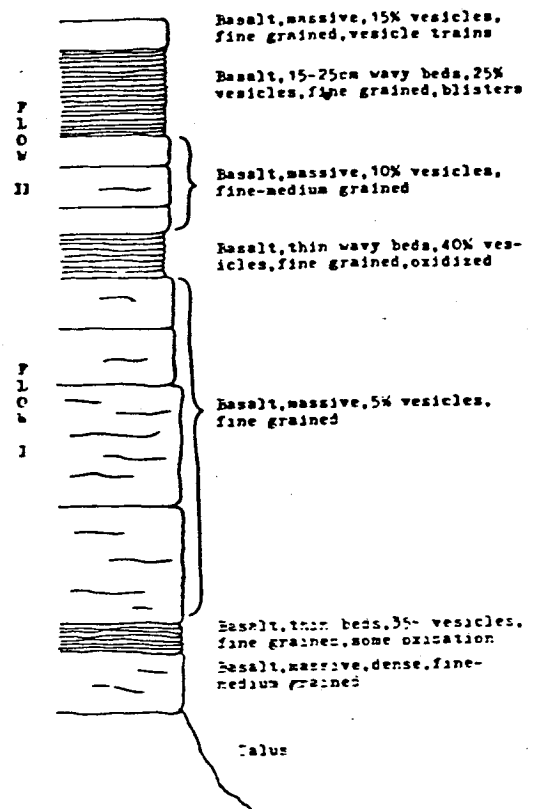


Figure 17d. Section 4.

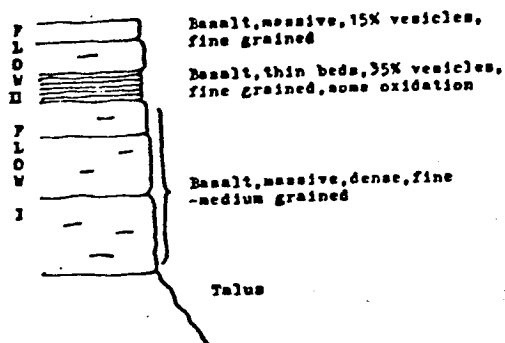


Figure 17e. Section 5.

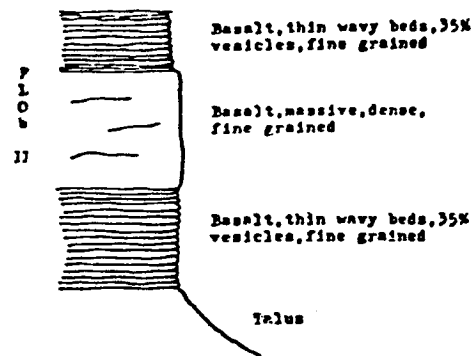


Figure 17f. Section 6.

Scale 1:250

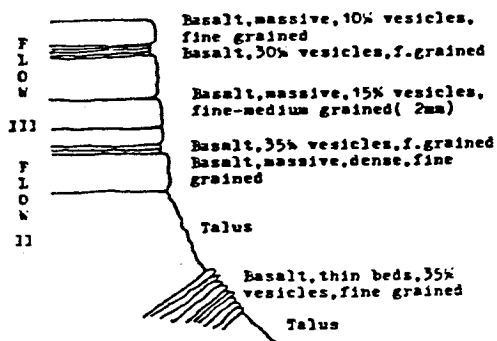


Figure 17g. Section 7.

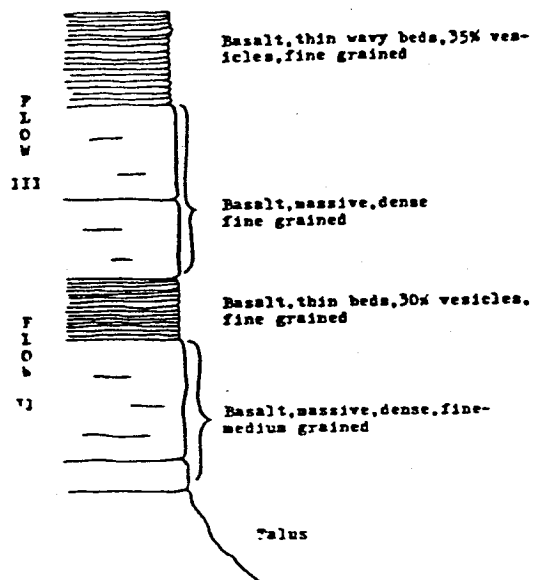


Figure 17h. Section 8.

GEOLOGIC HISTORY OF BEAR BUTTE

INTRODUCTION

The relationships and features of the associated flows suggest a definite eruptive history for Bear Butte. The history discussed below follows that suggested by Greeley (1973). The record of the earliest eruptions are buried below the present floor, but the type of eruptions marking the origin of Bear Butte are probably similar to those of modern volcanoes.

FLOW I

(The rocks of Flow I record the construction of a circular or nearly circular cone by the multiple eruption of lavas which flowed away from the vent in all directions (fig. 18a), building up a topographic high. A period of reduced eruption followed the construction of the primary cone. The record of this period is a sequence of thin, wavy, oxidized layers of basalt which probably represents small overflows of the lava lake in the crater.

FLOW II

(The eruptive center then shifted to the south several tens of meters and voluminous overflows from the crater again began. The flows from this period were restricted from flowing to the north by the previously built cone and tended to extend the cone to the south,

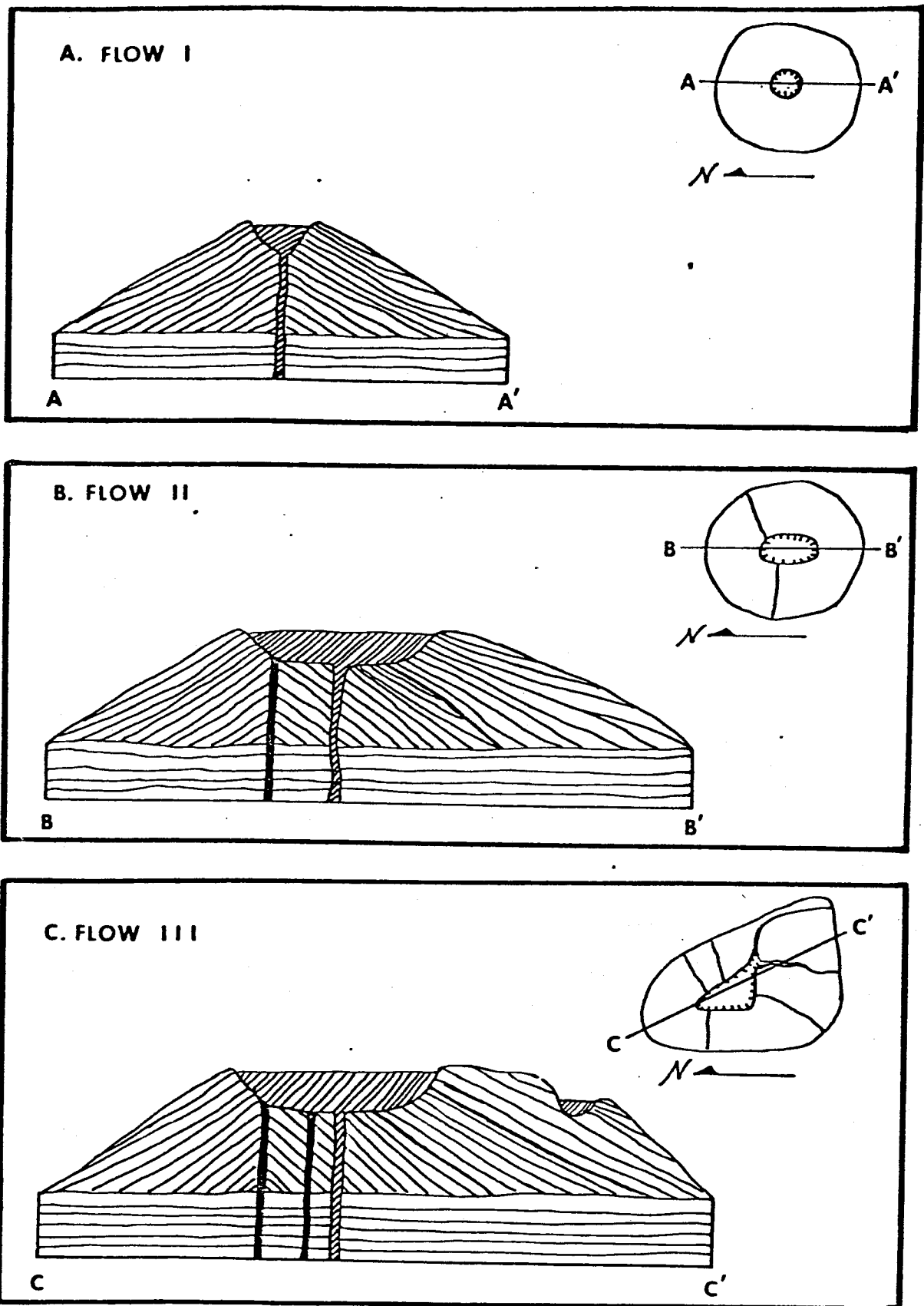


Figure 18. Diagrammatic developmental sequence of Bear Butte.

giving it an oval shape (fig. 18b). During this period foundering of crustal sheets resulted in the formation of the collapse depressions. Late in this period Bear Channel III and possibly the precursor of the other channels formed on the eastern side of the crater. Following this period, a short interval of reduced overflow again occurred, forming thin layers (10 to 15 cm) of oxidized, wavy bedded basalt.

FLOW III

The eruption of voluminous amounts of lava recommenced from a center a few tens of meters to the east of the former center. The Flow III lavas were primarily carried to the southeast by the Bear Channel II complex (fig. 18c). Sometime during these eruptions the head of the Bear Channel II complex was blocked. A second channel, Bear Channel I, was then formed to carry the lavas from the vent to the south.

During this eruptive period the rootless vent was formed. The lava from Bear Crater flowed under the crust, probably through a lava tube. Reaching a weak spot in the crust, or more probably a block in the tube, the lava, due to hydrostatic pressure, pushed the crust into a tumuli. The gas pressure of the lava under the tumulus was increased, probably by steam generated from water pooled at the block in the tube. This gas-charged lava

escaped through the medial crack of the tumulus as pyroclastic material.

FINAL ERUPTIONS

The final stages of eruption of Bear Butte were limited to small spillovers from the crater and to fountaining. The slab-lava around Bear Butte is probably the result of a process similar to that observed by Swanson (1973) during the eruption of Mauna Ulu, Hawaii. The cap of a lava lake in the vent is raised above the lip of the crater by gas pressure. Small amounts of highly gaseous lava escape from beneath the cap and flow a short distance down the flank. The bubbles, or blisters, of crust which typify shelly pahoehoe are formed by inflation of the plastic crust by exsolved gas. These bubbles were then broken to form the slab-lava.

The spatter ramparts on Bear Butte were probably formed in a manner described by MacDonald (1973). Spatter, produced by more or less continuous lava fountaining, was welded together in layers to construct the spatter ramparts. The preserved ramparts are so widely separated that it is unlikely that one lava fountain could produce both of them. There were probably two fountains in Bear Crater near the present locations of the spatter ramparts.

Withdrawal of the lava in the vent sown the feeder produced a crater floor some distance below the floors of the channels. Some slumping of the oversteepened walls probably accompanied the withdrawal of the lava. These events were separated in time by fairly short periods, because no soil has developed between the massive flows and the final eruption products.

BURIAL OF BEAR BUTTE FLOWS

All but the summit region of Bear Butte has been buried by younger lavas from three other vents. The relative ages of the surrounding flows were established by comparing the degree of mantle development at their surfaces, and also by determining the stratigraphic relationships at their margins. The first encroachment on the Bear Butte construct was by lavas erupted from an unnamed vent to the northeast. (fig. 19). The lavas from that vent were restricted in their flow to the southeast by the gradient of Bear Butte's cone. This resulted in only partial burial of the flows associated with Bear Butte. The shorter period of exposure to eolian deposition has also resulted in a rougher topography.

The second lavas to encroach on the southern flows of Bear Butte also buried the southern portion of the lava field of the unnamed vent. They are probably associated with flows from the rift system to the east.

These lavas show even less soil development than those associated with the unnamed vent, with an accompanying increase in outcrop.

The final stage in the burial of Bear Butte flows was the encroachment of pahoehoe lavas from an unknown vent in the Craters of the Moon lava field (fig. 20). These lavas are young, possibly only 2000 years old, and have essentially no soil cover.

DEGRADATIONAL HISTORY

The degradation of the Bear Butte shield continued through the burial of the peripheral flows. Slumping of the walls buried the floor of the central crater and the channel heads as is evidenced by large blocks which stand away from the crater wall (fig. 21). Movement of the blocks has jumbled the flow units and caused fracturing of them on a large scale. Accompanying the slumping was the development of an eolian and colluvial mantle on the flanks of Bear Butte as well as in Bear Crater. The mantle is composed primarily of sand transported by the wind from the margins of the Plain. The slumping and mantle development have smoothed and rounded the crater, channels, and shield of Bear Butte.

CONCLUSIONS

Bear Butte is a basaltic lava cone near the geographic axis of the central Snake River Plain. The volcanic cone is a kipuka, completely surrounded by younger flows. Comparison of the relative degradation of the Bear Butte area with flows in the Craters of the Moon field which are approximately 2000 years old suggest that Bear Butte is older, but still of Holocene age.

The shield of Bear Butte is constructed of layers of basalt from multiple eruptions. The triangular shape of Bear Crater, the summit vent of Bear Butte, has resulted from a southward migrating eruptive center. The irregular shape of the exposed shield area is due to raising of the topography by lava channels. The sinuosity of these channels seems to be inversely related to the gradient, i.e., increasing with decreasing gradient.

The shield of Bear Butte has numerous well-preserved primary surface features which include collapse depressions, spatter ramparts, flow fronts, tumuli, a lava pond, and a network of lava channels. Recognizing, interpreting, and understanding the origin of these features contributes to the knowledge of volcanic processes and provides data which aid in the interpretation of similar appearing extraterrestrial features.

APPENDIX A

Sample Number	Analysis*		Normalized	
	53-74	56-74	53-74	56-74
SiO ₂	44.80%	44.20%	45.72%	45.56%
Al ₂ O ₃	14.23	13.91	14.52	14.34
FeO	13.00	12.42	13.27	12.80
Fe ₂ O ₃	1.56	1.40	1.59	1.44
CaO	9.58	10.75	9.78	11.08
MgO	7.43	7.17	7.58	7.39
Na ₂ O	2.62	2.54	2.67	2.62
K ₂ O	0.73	0.73	0.74	0.75
TiO ₂	3.06	2.94	3.12	3.03
MnO	0.23	0.23	0.24	0.24
P ₂ O ₅	0.75	0.72	0.77	0.74
Total	97.99	97.01	100.00	99.99

*Chemical analyses done by Carol Clemency

C.I.P.W. Normative Analyses		
Sample Number	53-74	56-74
Apatite	1.683	1.617
Ilmenite	5.926	5.755
Orthoclase	4.373	4.432
Albite	22.593	19.516
Anorthite	25.450	25.154
Magnetite	2.305	2.088
Nephelite	0.0	1.440
Olivine total	20.339	18.949
Forsterite	9.820	9.183
Fayalite	10.519	9.766
Diopside total	15.327	21.044
Diopside (Wo)	7.742	10.632
Diopside (En)	3.846	5.299
Diopside (Fs)	3.739	5.113
Hypersthene total	2.006	0.0
Enstatite	1.017	0.0
Ferrosillite	0.989	0.0
Total	100.003	99.995

APPENDIX B

Ceranius Tholus,
A Possible Martian AnalogINTRODUCTION

The Amazonis Tharsis region of Mars is a relatively young area (Carr et al., 1973) as is evidenced by the small number of impact craters. The majority of martian volcanic cones and craters occur in this plains area. The Tharsis Ridge is a northeast-southwest trending feature which stands approximately 3 to 5 km above the mean Mars level (Kliore et al., 1973). Along the axis of this ridge lie three of the largest volcanic constructs on Mars, and two of the smaller ones. The three large features are Arsa Mons, Pavonis Mons, and Ascraeus Mons, and all are interpreted as being shield volcanoes (Carr, 1973).

Ceranius Tholus is one of the smaller volcanic constructs on the northern part of the Tharsis Ridge (24.20°N, 97.59°W). Ceraunius Tholus has been classified by Carr (1973) as a dome to distinguish it from the larger shield volcanoes which lie on the southern part of the ridge. This distinction was made because of the steeper flanks and smaller size of the construct. It is an oblate cone approximately 130 km long and 110 wide, with the major axis trending east-west (fig. A). Several features of Ceraunius Tholus observed on three Mariner IX

imagery frames (DAS numbers 7183783, 10061454, and 10061524) are similar to those described on Bear Butte. The martian construct has a similar-appearing central crater, and several features interpreted to be lava channels on its flanks.

DESCRIPTION

CRATER

The crater of Ceraunius Tholus is oblate with the long axis trending northwest-southeast (fig. A.) The dimensions of the crater are approximately 20 km by 25 km with an undetermined depth. The floor of the crater is domed and faulted, as evidenced by an arcuate scarp which cuts across the floor from wall to wall. A small volcanic cone with a summit crater approximately 1 km in diameter is on the northwest portion of the floor. Talus at the base of the crater walls suggests that slumping of the walls has occurred since the formation of the crater.

SHIELD

The shield of Ceraunius Tholus appears on the basis of tone to have two different gradients. A fairly steep gradient occurs for a distance of approximately 20 km from the crater rim. The slope then becomes more gentle to the limits of the shield, where another break occurs. The flanks of Ceraunius Tholus are lightly cratered,

probably by meteor impacts, suggesting a fairly young geologic age. Also occurring on the northwest flank is a series of small lava channels leading down the flank to the northwest, parallel to a long channel (fig. B). The large channel is approximately 2 km wide at the crater and extends down the flank, terminating in a shallow depression in the surrounding plain. This channel appears to have levees along its length caused by channel overflow.

GEOLOGIC HISTORY

The eruptive sequence of Ceraunius Tholus appears to be similar to that of Bear Butte. The shield of Ceraunius Tholus appears to be the result of multiple eruptions from a single center. The succession of flows from the vent flowed in all directions, building a circular dome. During the last part of the eruptions the crater wall was breached and the lavas spilling over the rim created a network of channels which near the topographic break merged into one channel. The velocity of the lava was checked by the lower gradient creating backups of lava in the channels which caused small flood sheets to overflow the channel walls. Also because of the decreased gradient the channel had a sinuous path which upon reaching the plain turned into a pond. Cooling of the ponded lava coupled with degassing allowed a

collapse of the surface, creating the present depression. The summit crater was formed by withdrawal of lavas down the vent. Subsequently, resurgence of the magma in the conduit caused the floor of the crater to dome. Due to some weakness in the crust a small vent was formed on the domed floor, and small flood sheets of lava formed a small cone. Withdrawal of the magma a second time resulted in the faulting and collapse of portions of the floor. The smoothed and rounded appearance of portions of the shield and crater may be the result of eolian erosion (Sagan, 1973; McCauly, 1973).

CONCLUSION

Bear Butte and Ceraunius Tholus are shield volcanoes which are in areas of high volcanic activity. The eruptive histories of these volcanoes seem to follow a similar pattern; a sequence of separated eruptions. Each of the cones also shows comparable geomorphic features, i.e., the networks of lava channels and lava ponds. The lava channels of both have several branches which become sinuous upon reaching low gradients. There is evidence on both cones of lava overflow from the channels building levees along the channel sides.

The degradation of these features also appears to have followed a similar pattern. The major erosional forces acting on them are slumping of the crater and

channel walls and erosion by eolian processes. One extra erosional force acting on Ceraunius Tholus not appearing on Bear Butte is cratering by impact.

A definitive comparative study of Bear Butte and Ceraunius Tholus is not possible for several reasons. The one order of magnitude difference in size, the lack of high resolution photographs of the martian feature, and the fact that no two volcanoes have an identical history all combine to make such a detailed comparison impossible. Nevertheless, studies of the type presented in this report help to formulate some of the answers needed to further interpret martian geology. Lunar analog studies such as the one using Bear Butte (Greeley, 1973) proved to be of great aid in the understanding of the genesis of the terrestrial features and has allowed the interpretation of similar-appearing martian features.

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