# Geological and Geophysical Investigations and Mineral Resources Potential of the proposed Great Rift Wilderness Area, Idaho

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Summary

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The proposed wilderness area has only a few recently staked mining claims. Mineral potential of the area is confined to decorative stone, consisting of filamented pahoehoe, and cinders. Based on ground reconnaissance, it is estimated that these are about 116,000 tons of indicated stone resources and a half-million tons of inferred resources, most of which are in the southern part of the study area. In the northern part, there are at least 27 million cubic yards of cinders. Mineral, petroleum, and geothermal resources may exist beneath the lavas of the study area but extensive geophysical exploration and drilling would be required to prove their existence.

Aeromagnetic, gravity, and magnetotelluric studies of the proposed wilderness area have yielded basic data on the nature of the crust beneath the young lava flows, and provided data for an assessment of potential resources. Magnetic anomalies in the area are complex and result from both strongly magnetized surface and near-surface lava flows and magnetic rocks underlying the flows. The magnetic data suggest that a deep intrusive body underlies the study area. Gravity anomalies are related to variations in the thickness of Cenozoic volcanic rocks and possibly to the inferred intrusive body. Magnetotelluric studies have provided data for interpreting the structure and possible rock types in the upper 10 km of the crust.

The proposed Great Rift Wilderness area is a region of volcanic rocks less than about 15,000 years old in the eastern Snake River Plain, Idaho. The area is located adjacent to the Craters of the Moon National Monument along the Great Rift, a linear array of cinder cones, eruptive fissures, and open cracks that extend for a distance of about 85 km from the southern Pioneer Mountains northwest of the map area, southeast through the Monument, to the southern margin of the Snake River Plain. The Great Rift is the site of volcanic vents that erupted lava flows of the Craters of the Moon, Kings Bowl, and Wapi lava fields. The Craters of the Moon lava field was formed between about 15,000 and 2,000 years ago during at least 7 periods of volcanic activity, each of which lasted about 1,000 years or less. The Kings Bowl and Wapi lava fields were both formed during a brief eruptive period about 2,250 years ago.

## Introduction

This report summarizes geological, geophysical, and mineral resource data currently available for the proposed Great Rift Wilderness Area in the eastern Snake River Plain (ESRP). The proposed wilderness area consists of two study areas. The northern area studied for wilderness contains 287,800 acres, adjoins the Craters of the Moon National Monument, and includes most of the Craters of the Moon (COM) lava field. The southern area studied for wilderness contains 86,600 acres and includes most of the Wapi lava field (Map A). The lava fields consist of latest Pleistocene and Holocene predominantly basaltic lava flows and volcanoes.

The existing Craters of the Moon National Monument and Wilderness Area occupies 392 sq km adjacent to the northern part of the proposed Great Rift Wilderness Area (Map A). The Monument contains numerous cinder cones, eruptive fissures, pit craters, lava tubes and a variety of lava flows. Lava flows of the COM lava field extend as much as 60 km to the east, south, and west from their source vents, many located within the boundaries of the Monument.

## Methods of study

Field mapping by D. E. Champion (1971-72, 1978-79), H. R. Covington (1976-77), M. A. Kuntz (1977-79), R. H. Lefebvre (1974-1979) and L. A. McBroome (1978-79) constitutes the geological data on which this report is based. Geophysical work by W. D. Stanley was conducted in 1978-79 and appraisal of economic deposits by J. Ridenour and R. B. Stotelmeyer was completed in 1978-79. Previously published reports covering the map area include Russell (1902), Stearns (1928), Murtaugh (1961), Prinz (1970), Champion (1973), Lefebvre (1975), Leeman, Vitaliano, and Prinz (1976), Leeman and Vitaliano (1976), Covington (1977), LaPoint (1977), Stanley and others (1977), Stout and Nicholls (1977), Armstrong and others (1978), and Mabey (1978).

Correlation of individual lava flows and groups of flows in the proposed Great Rift Wilderness Area was made using radiocarbon dating, paleomagnetic studies, and physical and chemical characteristics of lava flows. Excavations along flow margins have revealed organic soils buried by lava flows of the COM and Wapi lava fields. Radiocarbon dating of these soils has yielded ages of variable accuracy, but the relative ages of major groups of flows for the COM lava field were determined with reasonable accuracy (see figure 2). The direction of remanent magnetization of individual lava flows is preserved at the time of their solidification, thus flows erupted at different times record different directions of remanent magnetization. Identification and correlation of lava flows and eruption events in the proposed Great Rift Wilderness Area were facilitated by the paleomagnetic studies (see Table 2).

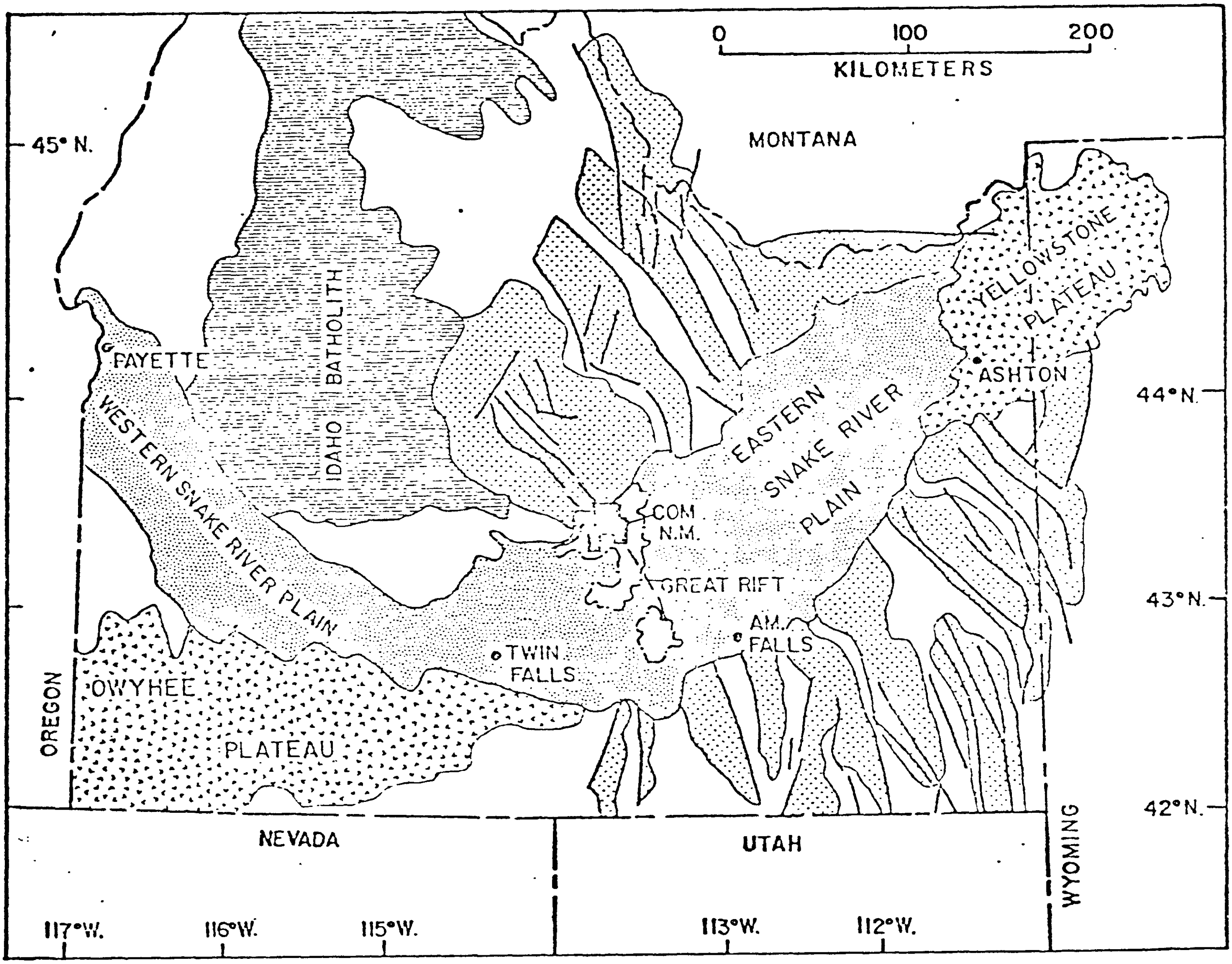



Figure 1.--Map of southern Idaho showing location of areas discussed in the text. Dotted pattern shows areas of Basin-Range Mountains. Major faults are shown as heavy lines. Approximate boundaries of proposed Great Rift Wilderness Area shown with dashed and dotted line. COM N. M. is area of Craters of the Moon National Monument.

## Regional Setting

The Snake River Plain is an arcuate topographic depression 50 to 100 km wide that extends from Payette, Idaho on the west for about 250 km southeastward to Twin Falls and then for about 300 km northeastward to near Ashton, Idaho (see. fig 1). The plain is bounded on the north by Mesozoic and early Tertiary granitic rocks of the Idaho batholith and by folded Paleozoic and Mesozoic rocks uplifted along NW-trending normal faults in the Tertiary and Quaternary during Basin-Range tectonism. The Basin and Range Mountains are also located on the southeast side of the plain, and Tertiary rhyolitic and basaltic rocks of the Owyhee Mountains bound the plain on the southwest. Late Tertiary and Quaternary rhyolitic and basaltic rocks of the Yellowstone Plateau are located at the northeast end of the plain.

## General features of the eastern Snake River Plain

The eastern Snake River Plain (ESRP) (east of 114° 30′ W. longitude) is a broad, flat, lava plain consisting, at the surface, of basalt lava flows and thin, discontinuous, interbedded loess, eolian sand, and alluvial fan materials that together have a total thickness of about 1-2 km near the proposed wilderness area (Doherty and others, 1979; Zohdy and Stanley, 1973; Stanley and others, 1977). Lava flows of the ESRP were erupted from low volcanic vents that are generally alined along volcanic rift zones that trend mainly at right angles to the long axis of the ESRP. Many volcanic rift zones appear to be extensions of NW-trending faults that bound block-fault mountains on the margins of the ESRP (Kuntz, 1977a and b; 1978).

Available geological, geophysical, radiometric, and drilling data suggest that the ESRP apparently has been the site of a northeasterly propagating rhyolitic caldera system which began about 15 m.y. ago. Models describing formation of the caldera system are discussed by Armstrong and others (1975), Eaton and others (1975), Christiansen and McKee (1978), and Mabey and others (1978).

## Great Rift and associated volcanic deposits

The Great Rift (Stearns, 1928; Prinz, 1970) is a set of volcanic vents, eruptive fissures, and open cracks that extends approximately 85 km from the southern Pioneer Mountains southeastward through Craters of the Moon National Monument to Pillar Butte, located about 30 km northwest of American Falls (fig. 1, Map A). The Great Rift is the best example of a volcanic rift zone of the ESRP.

Three Holocene and latest Pleistocene lava fields are alined along the trend of the Great Rift. The COM lava field is composite; it consists of more than 40 lava flows erupted from more than 25 cinder cones and fissure vents, most of which are located in the Craters of the Moon National Monument. The Kings Bowl lava field is made up of lava flows erupted during a single volcanic episode from fissures on the southern part of the Great Rift. The Wapi lava field is a broad shield volcano with a vent located at Pillar Butte on the southern part of the Great Rift. Paleomagnetic indicate that the lava flows of the Wapi lava field and the Kings Bowl lava field were erupted simultaneously in a period of a few tens of years and, possibly, as short as several weeks or months.

Cinder cones and eruptive fissures are found along a 43 km-long, N. 35° W.-trending segment of the northern part of the Great Rift, principally in the Craters of the Moon National Monument. The Great Rift emerges from beneath the southeastern limit of the COM lava field as four parallel sets of open cracks that trend N. 27° W. to N. 43° W., from which no lava has erupted. Farther south, the Kings Bowl lava field formed along an 11 km-long, N. 15° W.-trending segment of open cracks and eruptive fissures in the Great Rift. The lava flows of the Wapi lava field were erupted from at least 5 craters that form the vent complex at Pillar Butte. The elongated vents are alined in a N. 20° W. direction and suggest that a segment of the Great Rift is buried beneath the Wapi lava field.

These lava flows (informal units in the upper part of the Sanke River Group), cinder cones, and eruptive fissures of the three lava fields lie on older lava flows of the Snake River Group. The younger (Holocene and latest Pleistocene) lavas are dark-colored and dense in hand specimen, they have fresh, nearly unweathered glassy (typically blue) crusts, and they are not covered by eolian deposits. The older (Pleistocene) lavas are generally covered by a variable thickness of eolian deposits and exposed parts of the flows are light colored, less dense, weathered, weakly to strongly oxidized, and typically contain olivine phenocrysts.

## Craters of the Moon (COM) lava field

The COM lava field consists of 1,600 sq km of volcanic vents and lava flows that were erupted less than approximately 15,000 years ago, and it represents the largest accumulation of dominantly Holocene lava in the Snake River Plain. The COM lava field formed during at least 7 eruptive intervals that were less than 1,000 years in duration and separated by periods of quiescence lasting from several hundred years to perhaps several thousand years.

### Lava flows

Most flows of the COM lava field are pahoehoe; they have hummocky, billowy, ropy, and wrinkled surfaces which reflect the fluid nature of the lava. The upper centimeter of many, fresh, unweathered flows consists of vesicular to dense glass that has striking irridescent blue to green colors. Pahoehoe flows are typically fed through lava tubes and tube systems. Localized collapse of the roofs of the tubes has formed "skylights" and entrances to the lava tunnels that are important attractions to visitors in the Monument. Pressure ridges and pressure plateaus are common large-scale features of the surfaces of the pahoehoe flows.

Some flows in the field are of a'a (pronunced "ah-ah") lava that has a rough, jagged, clinkery surface. Large areas of the surface of a'a flows consist of irregular blocks of broken lava, some of which may be broken slabs of pahoehoe. The inner parts of a'a flows are typically massive. Many surfaces of a'a flows in the COM lava field are littered with huge blocks and monoliths of well-bedded cinders and spatter which were broken from cinder cones at the source vent. A few flows consist of block lava, characterized by irregular blocks of dense, glassy lava with smooth surfaces.

## Eruptive fissures

Eruptive fissures are strikingly displayed in the Craters of the Moon National Monument in the area between Big Cinder Butte and The Watchman cinder cones. Early in eruptions along these fissures, fountains of lava, commonly called a "curtain of fire," erupted on segments of the fissures as long as several kilometers. The fountains built low walls of agglutinated spatter along several kilometers of the fissures and produced spatter ramparts. Copious volumes of lava flowed away from the fissures to form extensive flows. After the curtain of fire phase of a fissure eruption, lava typically erupted from one or two places along the fissure and formed spatter and cinder cones.

## Cinder Cones

Cinder cones are found widely scattered throughout the eastern Snake River Plain but they are best developed in size, shape, and number, along the Great Rift. More than 25 major cones occur along a segment of the Great Rift in a zone as much as 2.5 km wide. Cinder cones are composed of cone-like accumulations of spatter, tephra, and thin lava flows around volcanic vents that lie on an eruptive fissure. Cones formed as tephra from fountaining lava accumulated around the vent. In the Monument area, prevailing winds from the west and southwest caused greater downwind accumulation of tephra on the east or northeast sides of many cinder cones. Composite cinder cones formed by overlapping accumulation of ejecta from several lava fountains. The composite cones contain many pits and have crater walls alined along the eruptive fissure. Generally, many of the cinder cones are breached on the northwest and (or) southeast flanks. The breaches probably formed by burrowing of lava flows erupted along a feeder fissure after the cones formed or by removal of ejecta by a lava stream that flowed from the feeder fissure during formation of the cones. Some cinder cones appear to have had a multi-stage history. Rejuvenated activity in or near older cinder cones erupted younger lava from vents in North Crater, The Watchman, and Sheep Trail Butte cinder cones.

## Volcanic history of the COM lava field

We have combined individual lava flows and groups of flows that are believed to have similar ages, based on field, radiometric, and paleomagnetic data, into what we term "eruptive intervals." Seven eruptive intervals have been recognized in the COM lava field (Table 1). Figure 2 illustrates the approximate age and duration of each eruptive interval and shows the approximate length of periods between eruptive intervals. Because our radiocarbon studies have yielded only preliminary data, the age of the beginning, end, and duration of each interval is uncertain. The time between eruptive intervals may have been periods of volcanic quiescence or periods of reduced volcanic activity; we cannot be more specific because many lava flows have not been dated and they can not be dated in the foreseeable future. Table 1 also lists informal names for major flows in each eruptive interval. Table 2 lists paleomagnetic data for lava flows in each of the seven eruptive intervals.

The earliest recognized eruptive interval (G) produced pahoehoe lava flows that are now located near the margins of the field and along the Great Rift south of Crescent Butte more than 14,000 years ago. Source vents have not been identified for these flows, but their distribution and flow directions suggest a source vent on the Great Rift, possibly at Echo Crater and (or) Crescent Butte.

Table 1.--Eruptive intervals, informal names of lava flows of upper part of Snake River Group and source vents in the Craters of the Moon, Kings Bowl, and Wapi lava fields.

| Eruptive interval and map unit | Informal name and lava type of major flows* | Source vents (queried where uncertain) |
|---|---|---|
| | Broken Top (p) | Broken Top, east and south sides |
| | Blue Dragon (p) | Eruptive fissures south of Big Craters cinder cone |
| | Trench Mortar Flat (p) | Eruptive fissures between Big Cinder Butte and The Watchman cinder cone |
| A | North Crater (p) | North Crater cinder cone |
| (Qba) | Big Craters (Green Dragon) (p) | Eruptive fissure at north end of Big Craters cinder cone |
| | Kings Bowl (p) | Fissure vents north and south of Kings Bowl |
| | Wapi (p) | Vents at Pillar Butte |
| | Serrate-Highway-Devils Orchard (a-b) | North Crater cinder cone (?) |
| | Vermillion Chasm (p) | Eruptive fissures at Vermillion Chasm |
| | Deadhorse (p) | Eruptive fissures north and south of Black Top Butte cinder cone |
| B | Devils Cauldron (p) | Devils Cauldron |
| (Qbb) | Minidoka (p) | Obscure vents located about 5 km northeast of New Butte cinder cone |
| | Larkspur Park (p) | |
| | Rangefire (p) | Black Top Butte cinder cone (?) |
| | Indian Wells north (a) | Big Cinder Butte cinder cone(?) |
| | Indian Wells south (a) | Big Cinder Butte cinder cone(?) |
| | Sawtooth (a) | Big Cinder Butte cinder cone |
| | South Echo (p) | Eruptive fissures south of Echo Butte cinder cone |
| C (Qbc) | Sheep Trail Butte (p-a) | Sheep Trail Butte cinder cone |
| | Fissure Butte (p-a) | Fissure Butte cinder cone |
| | Sentinel west (p) | The Sentinel cinder cone |
| | Sentinel south (p) | The Sentinel cinder cone |
| | Silent Cone (a) | Silent Cone cinder cone |
| | Carey Kipuka (a) | Silent Cone cinder cone (?) |
| D | Little Park (a) | Silent Cone cinder cone (?) |
| (Qbd) | Little Laidlaw Park (a) | Silent Cone cinder cone (?) |
| | Lava Point (a) | Silent Cone cinder cone (?) |
| | Unnamed flows (a) | Silent Cone cinder cone (?) |
| E | Grassy Cone (p) | Grassy Cone cinder cone |
| (Qbe) | Laidlaw Lake (p) | Grassy Cone cinder cone |
| | Pronghorn (p) | Echo Crater and (or) Crescent Butte (?) |
| F | Bottleneck Lake (p) | Echo Crater and (or) Cresecent Butte (?) |
| (Qbf) | Sunset-Carey (p) | Sunset Cone cinder cone |
| | Lava Creek (p-a) | Vents near Lava Creek |
| | Kimama (p) | unknown |
| | Bear Den Lake (p) | unknown |
| | Baseline (p) | unknown |
| G | Heifer Reservoir (p) | unknown } Echo Crater and (or) Crescent Butte (?) |
| (Qbg) | Little Prairie (p) | unknown |
| | Lost Kipuka (p) | unknown |
| | No Name (p) | unknown |
| | Brown flow (p) | unknown |

* (p) chiefly pahoehoe flows
(a) chiefly a'a flows
(a-b) a'a and block flows
(p-a) pahoehoe and a'a flows

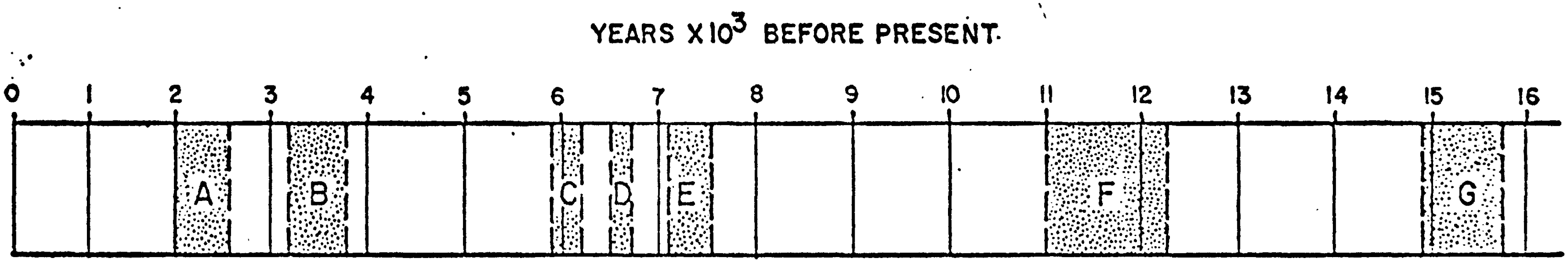



Figure 2.--Approximate age and duration of eruption intervals (A-G) of the Craters of the Moon, Kings Bowl, and Wapi lava fields. On Map A and Tables 1 and 2; A=Qba, B=Qbb, C=Qbc, D=Qbd, E=Qbe, F=Qbf, and G=Qbg.

Table 2.--Paleomagnetic data for lava flows in the proposed Great Rift Wilderness Area.

| Eruption interval and map unit | Informal names of flows making up paleodirectional group (upper part of Snake River Group) | Number of sites | Kappa* (k) | c.s.d.* (σ) | alpha-95 (α 95) | Latitude of VGP* (degrees) | Longitude of VGP* (degrees) |
|---|---|---|---|---|---|---|---|
| | Broken Top flows | 2 | 1,227 | 2.31 | 7.14 | 79.45 | 186.37 |
| A | Blue Dragon flows | 8 | 1,244 | 2.30 | 1.57 | 84.43 | 185.43 |
| (Qba) | Wapi-Kings Bowl flows | 2 | 10,246 | 0.80 | 2.47 | 80.39 | 327.80 |
| | Highway-Serrate flows | 2 | 185 | 5.96 | 18.47 | 84.73 | 280.05 |
| | Vermillion Chasm flows | 4 | 1,409 | 2.16 | 2.45 | 81.85 | 128.60 |
| B | Devils Cauldron flows | 5 | 1,405 | 2.16 | 2.04 | 85.67 | 116.41 |
| (Qbb) | Minidoka-Larkspur Park flows | 3 | 1,816 | 1.90 | 2.89 | 86.88 | 98.40 |
| | Rangefire flows | 3 | 1,755 | 1.93 | 2.94 | 84.36 | 87.50 |
| C (Qbc) | Indian Wells north and south, Swatooth, Sheep Trail Butte, and Fissure Butte flows | 6 | 2,028 | 1.80 | 1.49 | 79.71 | 236.14 |
| | Sentinel flows | 2 | 448 | 3.83 | 11.83 | 72.00 | 264.82 |
| D (Qbd) | Silent Cone, Carey Kipuka, Little Park, Little Laidlaw Park, Lava Point, and other flows | 7 | 322 | 4.52 | 3.37 | 79.21 | 23.34 |
| E (Qbe) | Grassy Cone-Laidlaw Lake flows | 4 | 3,376 | 1.39 | 1.58 | 83.69 | 132.24 |
| | Pronghorn flows | 7 | 1,701 | 1.96 | 1.46 | 79.29 | 352.32 |
| F | Bottleneck Lake flows | 5 | 1,057 | 2.49 | 2.36 | 76.76 | 185.22 |
| (Qbf) | Sunset-Carey flows | 7 | 2,412 | 1.65 | 1.23 | 76.09 | 339.30 |
| | Lava Creek flows | 1 | --- | --- | --- | 78.64 | 94.85 |
| | Kimama flows | 1 | --- | --- | --- | 85.84 | 57.52 |
| G | Bear Den Lake and other flows | 3 | 904 | 2.69 | 4.10 | 75.66 | 64.36 |
| (Qbg) | Heifer Reservoir flows | 2 | 120,279 | 0.23 | 0.72 | 83.20 | 95.20 |
| | Unnamed flows | 3 | 340 | 4.39 | 6.70 | 78.50 | 37.79 |

Abbreviations:

1. Kappa--statistical parameter, ranging from zero to infinity, that measures dispersion of measured field direction.
2. c.s.d.--radius of circle enclosing 63% of all data points.
3. alpha-95--radius of circle surrounding mean field direction, within which the mean field direction is located with a 95% statistical certainty.
4. VGP--virtual geomagnetic pole

-- no data

About 11,000 to 12,500 years ago, eruptions (inverval F) took place from at least 4 vents al=ng an extension of the Great Rift in the Southern Pioneer Mountains northwest of Sunset Cone near the headwaters of Lava Creek. The a'a flows erupted from the Lava Creek vents traveled as much as 19 km to the east onto the Snake River Plain. The complex Sunset Cone cinder cone and its associated flows were also formed during this eruptive interval, and voluminous pahoehoe (Sunset flows) flowed as much as 20 km to the northeast over the Lava Creek flows and as much as 53 km to the southwest (Carey flows). Pahoehoe flows (Pronghorn, Bottleneck Lake) along the southwestern margin and isolated exposures of pahoehoe flows along the southeast and east margins of the COM field are also believed to have been erupted during interval F. The distribution and flow directions of these pahoehoe flows suggest a source vent on the Great Rift near Echo Crater and Crescent Butte.

Eruptive interval E took place about 7,300 years ago with the formation of Grassy Cone, a complex cinder cone on the Great Rift in the northern part of the Monument. Pahoehoe flows from Grassy Cone traveled as much as 52 km to the south and formed the Grassy and Laidlaw Lake flows which, together, created the long, narrow, composite flow along the western and southwestern margins of the COM lava field.

Eruptive interval D, which took place about 6,700 years ago, is characterized by monolith-strewn a'a flows that are located south and southwest of the Monument. All of the a'a flows are covered by younger flows, but their flow directions and paleomagnetic data suggest that all or most of them may have been erupted from Silent Cone.

Eruptive interval C took place about 6,000 years ago. Eruptions along a segment of the Great Rift between Sheep Trail Butte and Echo Crater produced the Sentinel, Fissure Butte, Sheep Trail, and South Echo lava flows. These flows consist of pahoehoe near their source vents but several change to a'a several miles away from the vent. Eruption interval C ended with the formation of the largest cinder cone along the Great Rift--Big Cinder Butte. The monolith-strewn Sawtooth, Indian Wells South, and Indian Wells North a'a flows were probably erupted from the slumped and broken southern part of Big Cinder Butte.

Eruptive interval B began a little less than 4,000 years ago and lasted for about 500 years. Large amounts of pahoehoe were erupted from fissures along the central part of the Great Rift and produced the Vermillion Chasm, Deadhorse, and Rangefire flows. Pahoehoe lava erupted from obscure vents located about 20 km southeast of Sheeptrail Butte produced the Minidoka and Larkspur Park flows.

The youngest eruptive interval (A) began approximately 2,500 years ago and ended about 2,000 years ago. The interval began with an eruption in North Crater that produced a large, viscous, block lava flow that destroyed a large part of North Crater and possibly other cinder cones to the north and northeast of North Crater. The Highway flow moved northward into the valley between Sunset and Grassy Cones and continuation of the eruption formed the monolith-strewn Serrate and Devils Orchard flows.

The youngest eruptions in the COM lava field occurred about 2,000 years ago and formed the characteristically irridescent blue pahoehoe flows that now cover about 20 percent of the COM lava field. These eruptions were mainly from fissures and cinder cones in the northern part of the Great Rift in the area between Inferno Cone and North Crater and from the area of eruptive fissures between Big Cinder Butte and The Watchman cinder cones. Big Craters, located between Silent Cone and Inferno Cone, are the largest cinder cones associated with the youngest eruptions in the COM lava field.

## Kings Bowl lava field

The Kings Bowl lava field consists of an area of 3.3 sq km of pahoehoe lava erupted about 2,220±125 years ago from a 5 km-long section of the Great Rift known as the Kings Bowl Rift set (King, 1977). The Kings Bowl rift set is located about 20 to 25 km south of the southeast margin of the COM lava field. Eruptive sections of the Kings Bowl Rift are marked by spatter ramparts and several explosion pits. The largest pit, Kings Bowl, is 85 m long, 30 m across, and about 30 m deep. The pahoehoe lava formed lava lakes at several localities along the rift. A tephra blanket, evidence for the explosive nature of the latter stages of the eruption, covers an area of about 0.15 sq km to the west of the Kings Bowl.

A unique feature and public attraction of the Kings Bowl lava field is Crystal Ice Cave, which contains columns, stalagtites, and stalagmites of ice.

## Wapi lava field

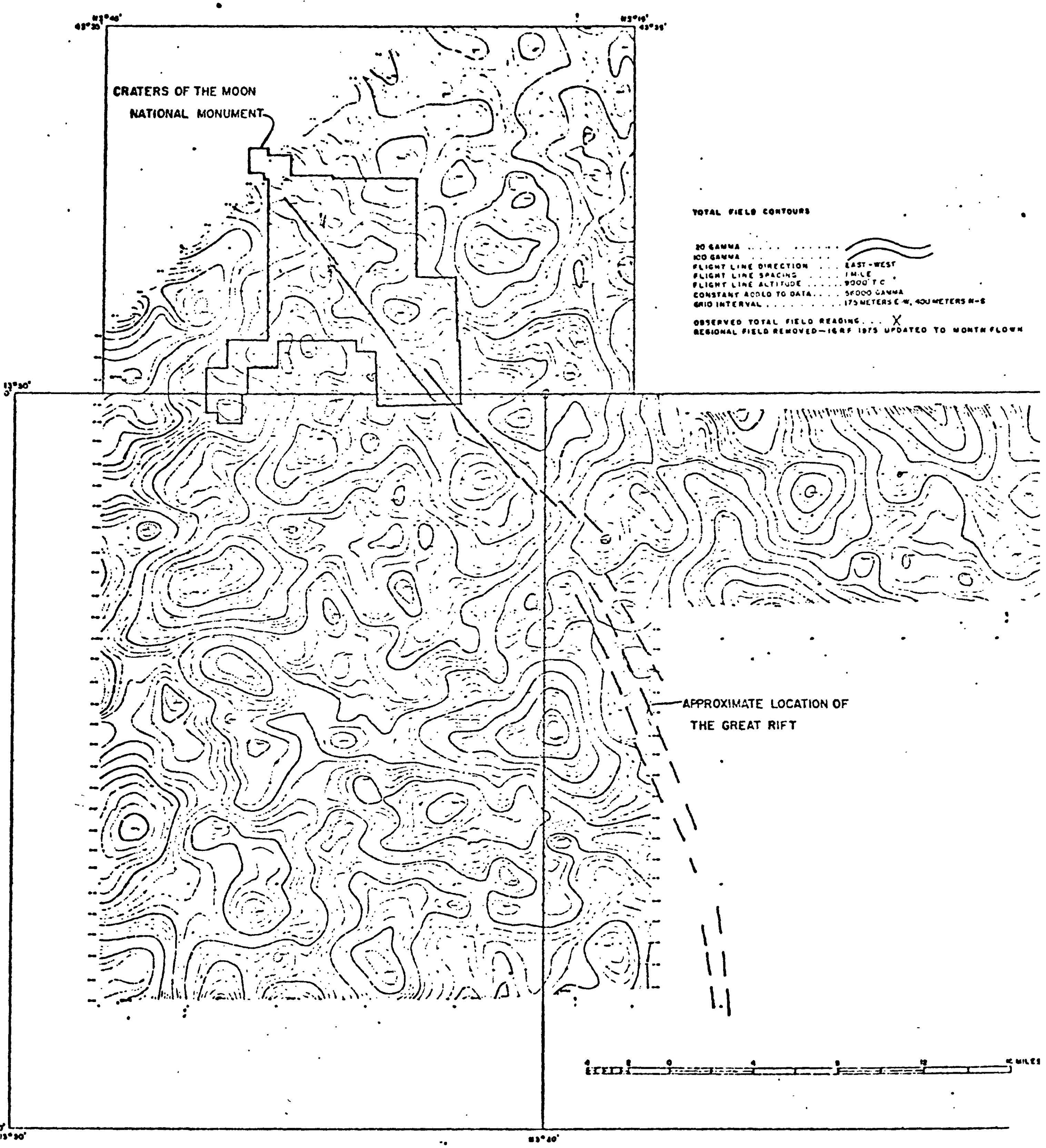
The Wapi lava field (Champion and Greeley, 1977) covers 317 sq km in the southeastern part of the proposed wilderness area. The flows in the Wapi lava field display "shelly" and "slab" pahoehoe, lava channels and gutters, driblet spires, pressure ridges and plateaus, tumuli, lava tubes, skylights, and ice caves. The lava field is a low shield volcano, flow thicknesses near the edge of the field are about 1 to 10 m and near the source vent are probably 100 m thick. The volume of lava in the field is approximtely 10 $km^3$, and, based on well-studied Hawaiian eruptions and our paleomagnetic data, this volume of lava was probably erupted during a period lasting several months to possibly as much as several years. A radiocarbon age of $2,270 \pm 50$ yrs b.p. (S. Robinson, USGS, written commun., 1980) has been obtained for charcoal from beneath the flow. The radiocarbon ages and paleomagneitc data for the Kings Bowl and Wapi lava fields indicate that the two lava fields were formed simultaneously.

## Geophysical Investigations

### Aeromagnetic Data

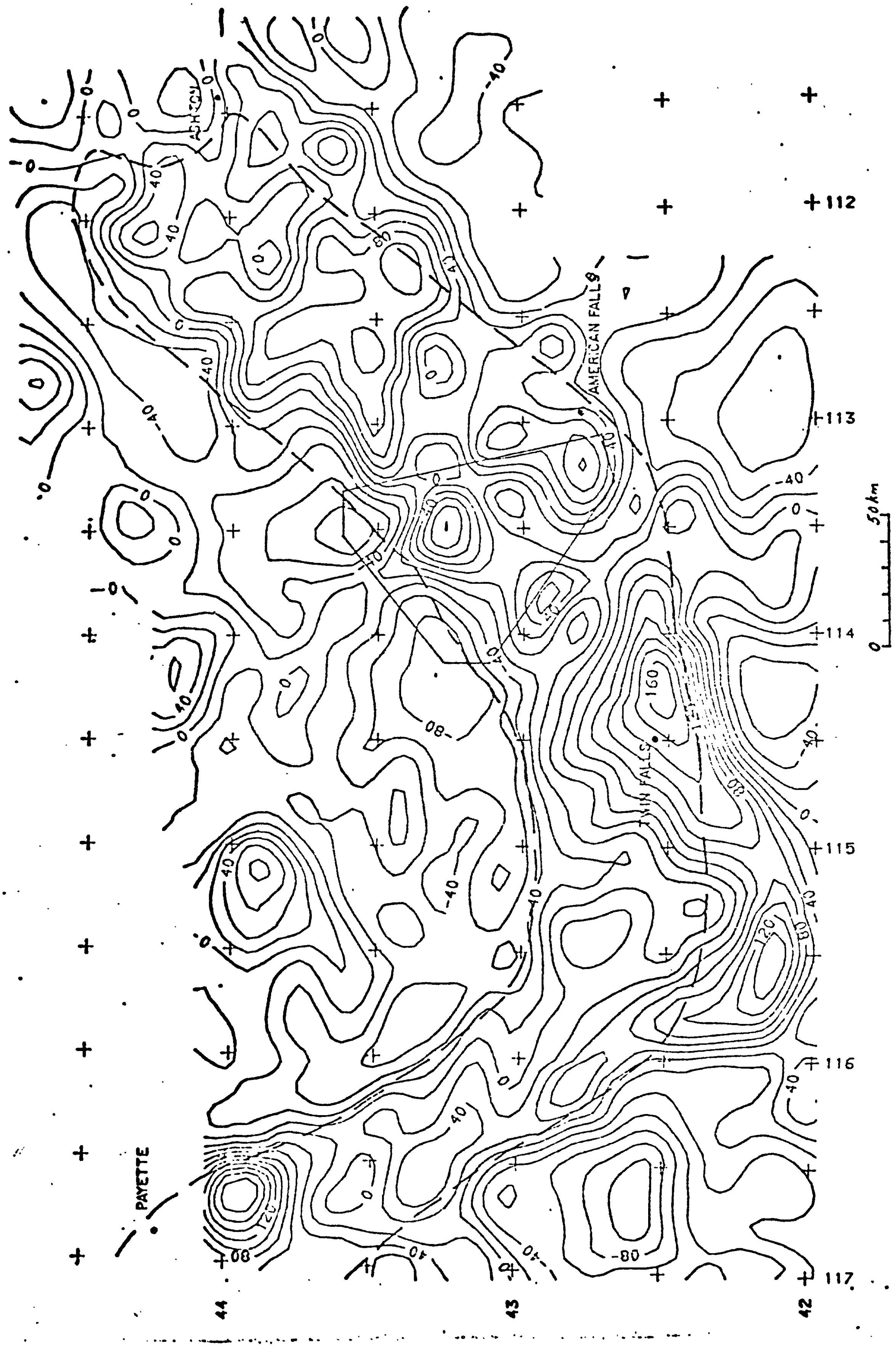
An aeromagnetic survey of the study area was flown in 1979 with flight lines 1.6 km apart and 2,350 m above sea level. The data were compiled as a residual total intensity contour map (Map B) by removing an IGRF 1975 field updated to the month flown. The same data have been published at 1:62,500 scale (USGS, 1979). A more regional survey with east-west flight lines 9.3 km apart and 3,650 m above sea level is also available (USGS, 1972) and the data from the latter survey have been continued upward to levels of 7.6 and 11.4 km above sea level.

The basalt flows that underlie most of the eastern Snake River Plain in and around the study area are strongly magnetized. Both normal and reverse magnetization occur in the flows at the surface and in the shallow subsurface. The magnetic anomalies produced by the basalt are very complex, and reflect three primary factors: 1) local surface relief, 2) direction of magnetization, and 3) thickness and depth of sequences of flows with normal or reverse magnetization. The thickness of the basalt flows cannot be determined from magnetic data, but the measured anomalies with near-surface sources can be produced by 500 m of basalt. However, the thickness may be much greater. The magnetic field also reflects magnetic masses underlying and within the basalt flows, including intrusive basalt related to sources of the basalts flows, volcanic rocks older than the basalt, large silicic intrusives, and perhaps a magnetic basement complex.




Map B.--Residual total intensity aeromagnetic map of the proposed Great Rift Wilderness area and surrounding areas.

The most prominent magnetic anomaly reflecting a deeply buried source is a magnetic high in the area of Craters of the Moon National Monument. Although this anomaly is apparent in Map B, a different perspective on the anomaly is provided by the regional contour map (Map C) where the effects of the basalt flows are reduced. The regional magnetic field in the area of this anomaly was analyzed by a multibody inversion technique developed by Bhattacharyya (1980), and the analysis indicated that the primary source of the anomaly is a highly magnetized body of rock with a top from 1 to 3.5 km below sea level and a base 10.5 to 11.5 km below sea level. The anomaly extends northwestward beyond the Snake River Plain and is continuous with a northwest-trending magnetic high over a zone of Tertiary intrusive rocks extending for about 90 km northwest of the plain. The southeast edge of the magnetic anomaly as defined on the low-level map is a linear feature parallel to the ESRP and coincident with the southeast limit of vents along the northwestern segment of the Great Rift. The magnetic data strongly suggest that a deep-seated intrusive body underlies the ESRP in the area of the Craters of the Moon National Monument and that the intrusive is related to a northwest-trending structure that extends northward beyond the plain.

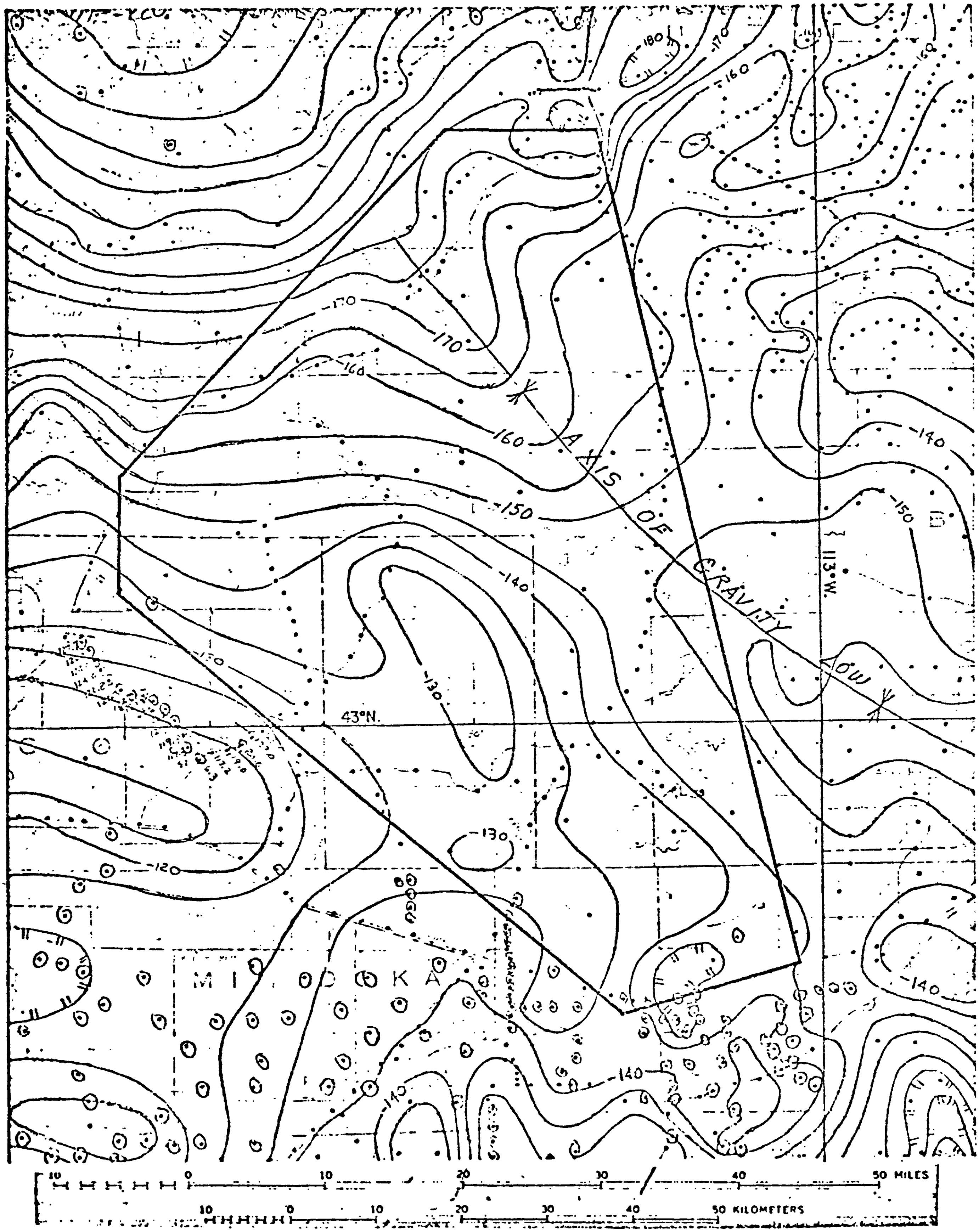



Map C.--Regional magnetic map of the proposed Great Rift Wilderness area and surrounding areas at an elevation of 11.4 km. Contour interval is 20 gammas. Outline of area of Map A shown is as solid line. Approximate topographic boundary of Snake River Plain shown by dashed line.

The elevation of the base of the magnetized crust was also obtained from the inversion of the magnetic data and ranged from 9 km below sea level a few kilometers north of the study area, to 21 km below sea level a few kilometers south of the study area. At Craters of the Moon National Monument the elevation of the base of the magnetized crust was computed to be at 13.5 km below sea level. The base of the magnetized crust may coincide with the Curie-point isotherm; thus, the thin magnetized crust indicated for the northern part of the study area may reflect anomalously high temperatures in the crust.

## Gravity Data

Reconnaissance gravity data for the study area are available from the gravity map of southern Idaho (Mabey and others, 1974) and as part of this study four additional gravity stations were established. The Bouguer anomaly gravity anomaly map of the general area (Map D) shows a large gravity high over the Snake River Plain that reflects isostatic compensation of the relatively low surface elevation of the plain. Superimposed on the regional gravity high is a complex of highs and lows. Although the cause of highs and lows is not known, the two probable sources are: 1) variations in the thickness of the Cenozoic volcanic and sedimentary rocks which have an average density lower than the older rocks, and 2) mass anomalies within the pre-Cenozoic rocks. A low gravity trend superimposed on the regional gravity high extends southeastward across the Snake River Plain from Craters of the Moon National Monument to American Falls Reservoir. The northeastern part of the gravity low is approximately coincident with the magnetic high in the area of Craters of the Moon National Monument. A granitic intrusive would probably have a density lower than the average density of pre-Cenozoic rocks of the region. Thus the gravity low and the magnetic high may be produced by the same intrusive body. Southeast of the axis of the plain the gravity low is larger and may indicate an area where Cenozoic rocks are thicker than adjoining areas to the southwest and northwest.




Map D.--Bouger gravity anomaly map of the proposed Great Rift Wilderness area and surrounding areas. Contour interval is 5 milligals. Hachured contours indicate areas of low gravity. Gravity stations are shown by dots and dots in circles.

## Magnetotelluric Data

A study of the earth's electrical structure across the area of the Craters of the Moon National Monument using the magnetotelluric technique (Vozoff, 1972), provided data for construction of the resistivity cross-sections shown in figure 3. Within the limitations of accuracy of one-dimensional models, the following interpretations can be made:

1) Four major units are apparent on the cross-section. The shallowest layer consists of material from 300-500 ohm-m in resistivity, probably Quaternary basalt lava flows and minor interflow sediments. The layer is generally less than 1 km thick.

2) Immediately below the basalts is a layer with interpreted resistivities of 8-17 ohm-m, a thickness of 1-2 km, and postulated to consist of basalts, rhyolite flows and tuffs, and sediments. A deep well near site C-5 at the Idaho National Engineering Laboratory (Doherty and others, 1979) penetrated about 2,360 m of mostly rhyolite ash-flows in the depth interval corresponding to this zone.

3) The third layer, with interpreted resistivities of 200-400 ohm-m is basement complex, but we are unable to specify rock types. The basement could be carbonate rocks, but probably not shales or sandstones, because the latter rocks are less resistive than the interpreted values. The basement could also be igneous or metamorphic rocks or combinations of carbonate, igneous and metamorphic rocks. Older volcanic rocks cannot be a major component of the third layer, because alteration and decreased porosity of old volcanic flows cause them to become more conductive and generally below the resistivities observed.

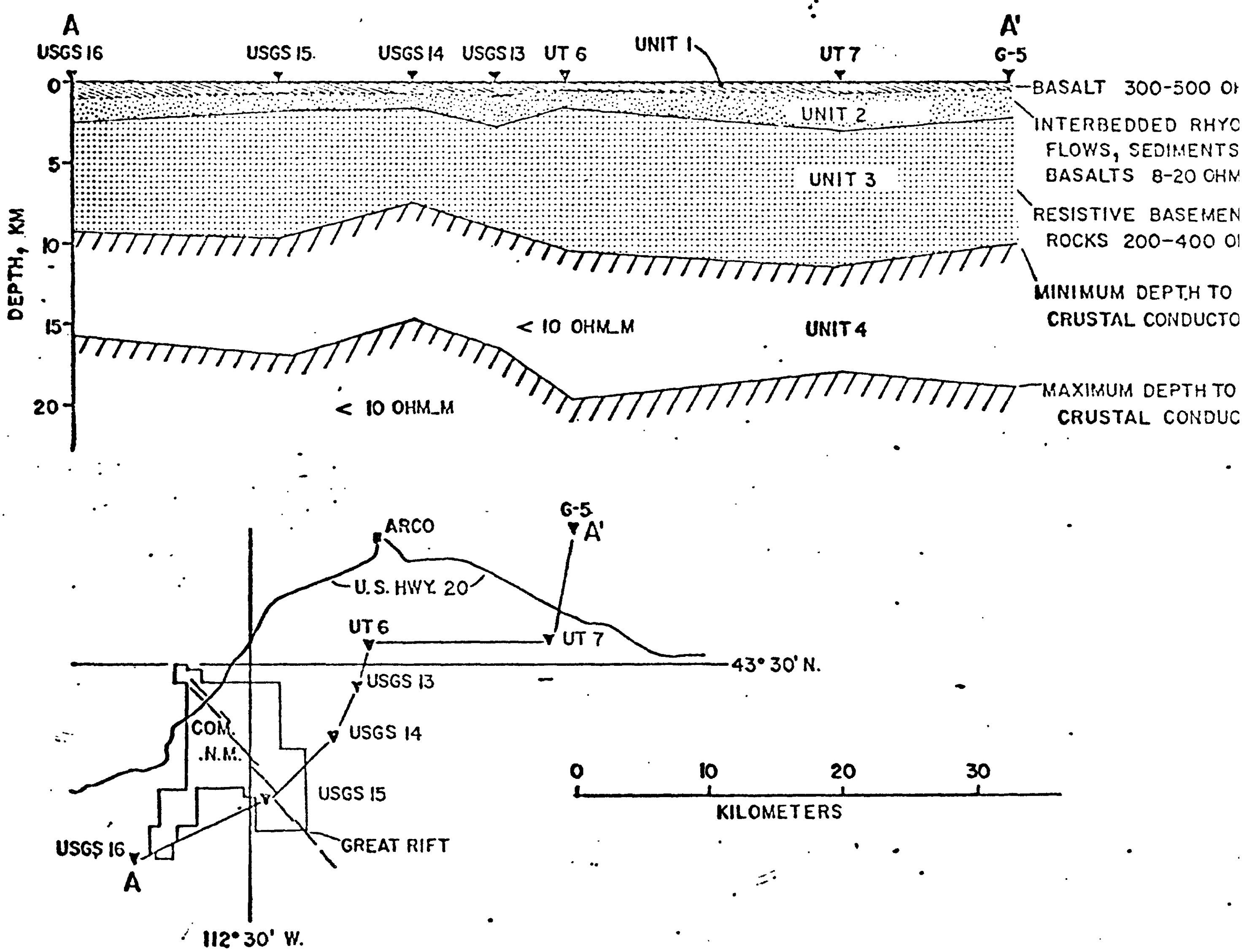



Figure 3.--Magnetotelluric sounding cross-section in the eastern Snake River Plain in and near the proposed Great Rift Wilderness area. Scale refers to horizontal distance in both the cross-section and the location map for sounding stations.

4) The lowermost layer is a transitional conductive zone with resistivities of less than 10 ohm-m. The significance of this zone has been discussed by Stanley and others (1977), who concluded that the transition to low resistivities occurred at about the $500^{o}$ C isotherm in the granitic upper crust.

## Mineral resources potential

U.S. Geological Survey and U.S. Bureau of Mines

A thick series of Pleistocene to Holocene lava flows mantle most of the proposed Great Rift Wilderness Area. The area has only a few recently staked mining claims, and the lavas appear to contain no mineral deposits of economic significance. The proposed wilderness area is bounded on the north by the Lava Creek mining district (figure 4, and Anderson, 1929) but only a small amount of that district's host rocks containing base and precious metals, are exposed at the surface in the study area. Buried channels, possibly containing placer gold, may extend from the Lava Creek district beneath lavas into the northern margin of the proposed Great Rift Wilderness area and adjacent parts of the Craters of the Moon National Monument, but exploration for these deposits would be prohibitively expensive.

Sand and gravel and volcanic cinders, removed from two sites adjacent to the eastern boundary of the northern part of the study area (fig. 4), constitute the only known mineral production. A cinder pit, about 60 m in diameter and 15 m deep, has been dug in a small cinder cone near the Huddles Hole road (SE 1/4, SE 1/4, sec. 27, T. 2 N., R. 26 E.). The cinders were used locally as road metal. Sand and gravel have been removed from a small pit near Pratt Lake (NE 1/4, NE 1/4, sec. 24, T. 1 S., R. 27 E.)

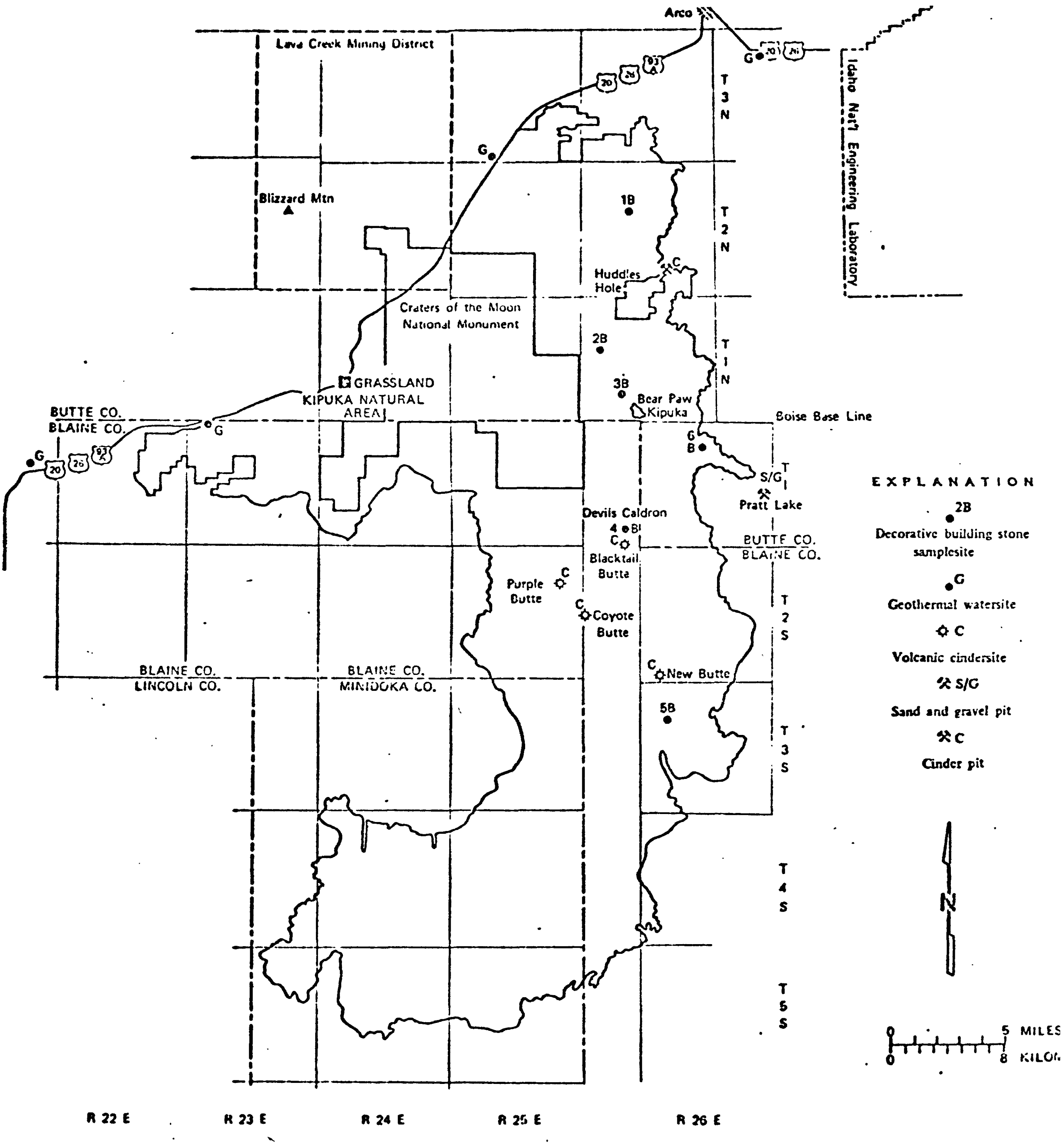



Figure 4.--Map of the northern part of the study area showing location of areas and resources discussed in the text.

Mineral resources within the northern part of the study area are mainly confined to decorative building stone, consisting of polygonal plates of pahoehoe ranging in thickness from 2 to 5 cm, and to volcanic cinders (fig. 4). Slabs of pahoehoe occur mainly along flow margins and at the rims of lava lakes; cinders occur on low cinder cones around the margins of the 3 Holocene lava fields and along the Great Rift.

Six sites (figure 4) were examined where decorative building stone was noted during aerial reconnaissance. Indicated resources of this stone total 6,000 tons; an additional 10,000 tons is inferred. Volcanic cinders at Black Top Butte (Blacktail Butte) cinder cone (43° 17′ 30" N., 113° 22′ 30" W) are estimated to be 26,600,000 cubic yards (20,300,000 $m^3$) Other sources of volcanic cinders are found mainly in older cinder cones surrounded by the Holocene lava flows, such as Purple Butte (SE 1/4, Sec. 11, T. 2 S., R. 25 E.), Coyote Butte (SE 1/4, sec. 13 and NE 1/4, sec. 24, T. 2 S., R. 25 E.), and New Butte (43° 12′ 10" N., 113° 20′ 30" W.) (see fig. 4 and Map A for locations).

The southern part of the study area, which includes the area of the Wapi lava field, contains no known mining districts. In 1980, after field work was completed, a group of 8 claims was located on Pillar Butte. Bonanza Bar, with gold placers, lies approximately 10 km southeast of the southern tip of the Wapi lava field.

Decorative building stone has been removed from several sites within, and adjacent to, the Wapi lava field. The decorative building stone consists of polygonal plates of filamented pahoehoe ranging in thickness from 2 to 10 cm. This material was observed at the following places: 1) at the margins of primary and secondary flows, 2.) in the vicinty of the crater rim at Pillar Butte, and 3.) in squeeze outs.

Four areas, shown on figure 5, representing approximately 16 percent of the southern part of the study area, were investigated by aerial reconnaissance, aerial color photographs, and on foot. These areas contain an estimated 100,000 tons of decorative building stone. Reconnaissance studies and examination of air photographs of the southern part of the southern study area reveal that inferred surfaces resources of the area may approach a half million tons of useable stone.

A thin soil is locally developed on lava flows of the COM, Kings Bowl, and Wapi lava fields, and its thickness is invariably less than one-half meter.

Ground water in the Snake River Plain aquifer lies at depths of 150 to 300 meters below the surface in the proposed wilderness area (Crosthwaite, 1973). Surface water occurs in depressions and lava tubes in lava flows and in crevices and fissures along the Great Rift during summer months.

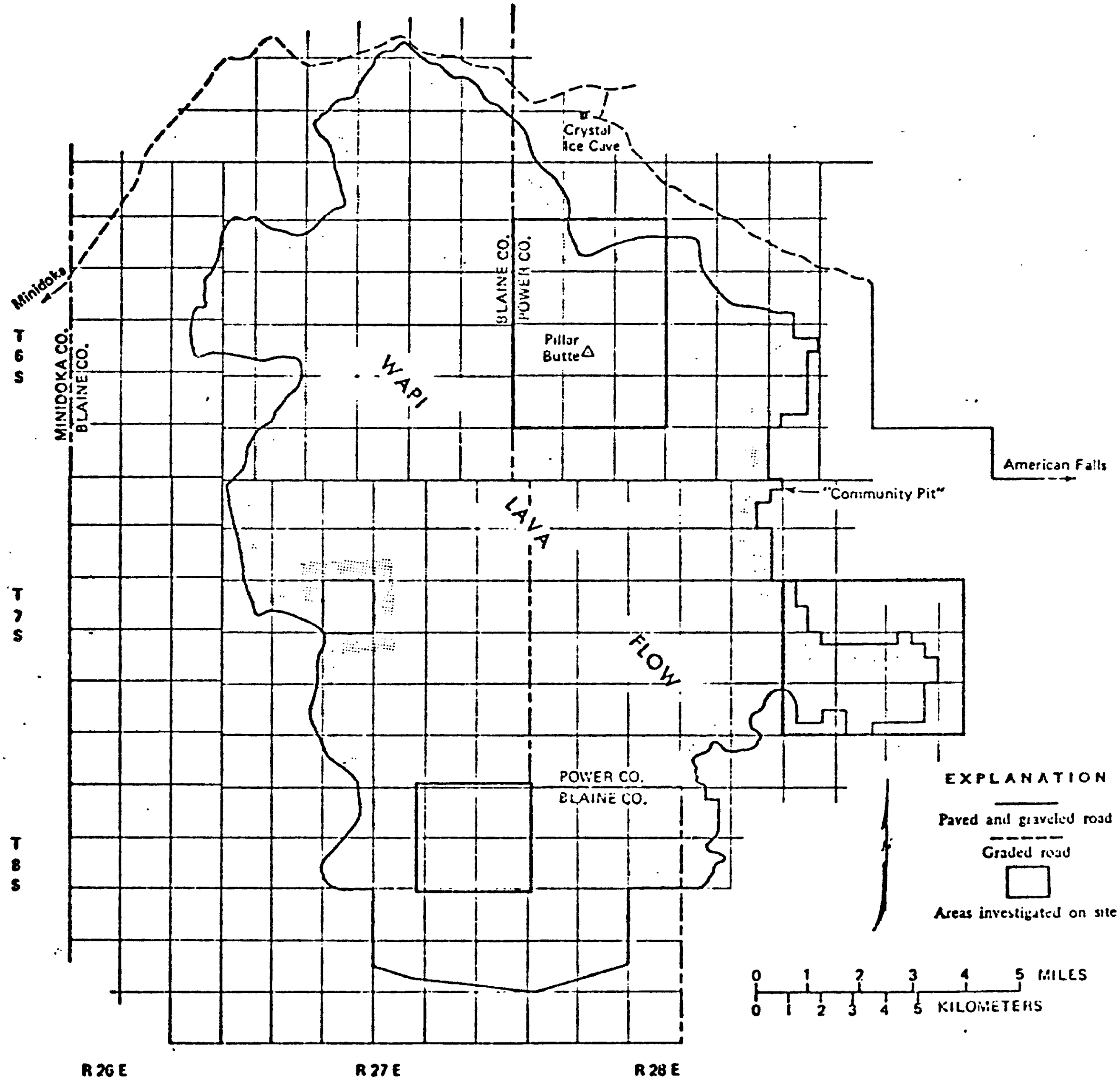



Figure 5.--Map of the southern part of the study area showing sites investigated for decorative building stone.

Lava for use as dimension stone and cinders for road metal occur throughout the areas of the COM and Wapi lava fields, but suitable materials are also present at many nearby localities outside the boundaries of the proposed wilderness area. Volcanic cinder resources, while relatively plentiful, are generally remote.

The presence of petroleum-bearing rocks beneath the lava-sediment cover of the study area is uncertain. The only deep drill hole on the eastern Snake River Plain encountered rhyolitic ash-flows and lava flows beneath the basalt-sediment cover (Doherty and others, 1979), and inclusions in surface lavas in the study area are exclusively of Eocene Challis Volcanics and Precambrian, high-grade metamorphic rocks. Locating potential oil and gas resources in the study area would require extensive geophysical exploration and drilling.

No thermal water is known in the study area but warm water has been encountered in wells near the northwest edge of the Snake River Plain (fig. 4). Depths to the regional water table in excess of 150 meters and the southwesterly flow of the Snake River Plain aquifer across the study area are factors that would inhibit near surface expression of any geothermal features. Thermal gradient measurements in deep drill holes at the Idaho National Engineering Laboratory, about 50 km northeast of the Craters of the Moon National Monument, indicate average gradients of about 40°C/km (David Blackwell, written commun., 1979). These gradients indicate that a hydrothermal convection system would be required to produce a geothermal system of economic interest. No such convection systems have been recognized in the study area or elsewhere in the eastern Snake River Plain.

Large quantities of heat were transported to the surface in the study area during the eruption of the basalt lava. The lava is thought to have originated at depths near 60 km in the mantle (Leeman and Vitaliano, 1976; Stout and Nicholls, 1977) and to have moved to the surface rapidly without long residence times in magma reservoirs in the upper crust that would provide heat sources for local geothermal systems. A major program of geophysical exploration and drilling would be required to evaluate the geothermal resource of the study area, and it would be expensive and not economically feasible in the forseeable future.

DESCRIPTION OF MAP UNITS

(See Table 1 for list of informal names of lava flows in each eruptive interval-map unit)

Lava flows of the (upper part of the Snake River Group)--Craters of the Moon, Kings Bowl, and Wapi lava fields

Qba BASALTIC PAHOEHOE, BLOCK, AND A'A LAVA FLOWS AND ASSOICATED PYROCLASTIC DEPOSITS OF ERUPTIVE INTERVAL A (HOLOCENE-APPROXIMATE AGE: 2,000 TO 2,500 YRS. B.P.)--Chiefly voluminous pahoehoe lavas and lesser amounts of a'a lava flows erupted from fissure vents along the Great Rift in Craters of the Moon National Monument. Includes the Broken Top, Blue Dragon, and North Crater pahoehoe flows, and Serrate-Highway-Devils Orchard block and a'a flows. Also includes the voluminous pahoehoe lava flows of the Wapi lava field and minor amounts of pahoehoe lava and tephra of the Kings Bowl lava field

Qbb BASALTIC PAHOEHOE AND MINOR A'A LAVA FLOWS AND ASSOCIATED PYROCLASTIC DEPOSITS OF ERUPTIVE INTERVAL B (HOLOCENE--APPROXIMATE AGE 3,500-4,000 YEARS B.P.)--Unit consists of pahoehoe lava flows erupted chiefly from fissure vents at Vermillion Chasm and along the Great Rift for several km northwest and southeast of Black Top Butte. Pahoehoe flows are typically shelly, slabby, and hummocky. Some flows appear dusty brown due to weathering of highly vesicular glassy surfaces, particularly flows consisting largely of shelly pahoehoe. The fissures are paralled by spatter ramparts and thin blankets of spatter and ash. Two vent areas at Devils Cauldron appear to have been lava lakes that underwent significant amounts of withdrawal of lava. The vent area for the Minidoka-Larkspur Park flows presently shows only a small driblet spire which must surmount a larger, buried vent complex

Qbc Basaltic A'A AND PAHOEHOE LAVA FLOWS AND ASSOCIATED PYROCLASTIC DEPOSITS OF ERUPTIVE INTERVAL C (HOLOCENE--APPROXIMATE AGE 6,000-YEARS B.P.)--Unit consists of a later sequence of bulbous a'a lobes with flow fronts as high as 25 m, and an earlier sequence of pahoehoe-a'a lava flows. The a'a lobes are long (as much as 35 km) flows with clinkery, jagged surfaces that contain monoliths of bedded cinders and spatter (fragments of a shattered cinder cone) as large as 100 meters in longest dimension. Some a'a flows are covered by younger a'a and pahoehoe flows at their proximal ends, but flow directions and distribution of flows suggest that Big Cinder Butte cinder cone is the source vent. The pahoehoe-a'a flows were erupted from fissure vents on the Great Rift that extend from Echo Crater southeast to Sheep Trail Butte. The flows are mainly pahoehoe lava near their source vents and change to a'a lava several km along their length

Qbd BASALTIC A'A LAVA FLOWS AND ASSOCIATED PYROCLASTIC DEPOSITS OF ERUPTIVE INTERVAL D (HOLOCENE--APPROXIMATE AGE 6,700 YEARS B.P.)-Unit consists of bulbous a'a lobes with flow fronts as high as 25 m. The a'a lobes have jagged, clinkery surfaces that contain monoliths and blocks of bedded cinder and spatter (fragments of a shattered cinder cone) as large as 100 meters in longest dimension. All a'a flows of this unit are covered by younger flows at their proximal ends, but the distribution and flow directions of the flows suggest that many or all of them were erupted from Silent Cone cinder cone

Qbe BASALTIC PAHOEHOE AND A'A LAVA FLOWS AND ASSOCIATED PYROCLASTIC DEPOSITS OF ERUPTIVE INTERVAL E (HOLOCENE--APPROXIMATE AGE 7,300 YEARS B.P.)--Pahoehoe lava erupted from Grassy Cone cinder cone forms a long, narrow, composite flow (Grassy and Laidlaw Lake flows) located between the main and western lobes of the COM lava field. Parts of the Grassy and Laidlaw Lake flows consist of a'a lava, particularly where pahoehoe lava flowed over steep slopes. A thin blanket of volcanic ash covers the proximal parts of the Grassy flow within several kilometers of Grassy Cone

Qbf BASALTIC PAHOEHOE AND A'A LAVA FLOWS AND ASSOCIATED PYROCLASTIC DEPOSITS OF ERUPTIVE INTERVAL F (HOLOCENE-LATE PLEISTOCENE, APPROXIMATE AGE 11,000-12,500 YRS. B.P.)--Pahoehoe lava flows are located along the southwest margin and in the central part (Pronghorn, Bottleneck Lake) of the main lobe of the COM lava field; source vent(s) are unknown. Pahoehoe flows moved east (Sunset) for distances of as much as 35 km and southwest (Carey) for distances of as much as 55 km from a source vent at Sunset Cone cinder cone. The Sunset flow is covered by a thin sheet (<2 m) of volcanic ash within 5 km to the east (downwind) of Sunset Cone. Before the eruption of the flows from Sunset Cone, a'a flows with jagged, blocky, clinkery surfaces erupted from 4 or more vents near Lava Creek in the southern Pioneer Mountains. The flows from the Lava Creek vents moved to the east for distances of as much as 35 km onto the Snake River Plain and for a distance of about 3 km to the north in a tributary of Dry Fork Creek. Pyroclastic deposits of unknown thickness mantle vent areas

Qbg BASALTIC PAHOEHOE LAVA FLOWS OF ERUPTIVE INTERVAL G

LATE PLEISTOCENE--APPROXIMATE AGE MORE THAN ABOUT 14,000 YRS. B.P.)--Pahoehoe lava flows are located along the southwestern (Kimama flows) and western margins (Bear Den Lake flows) of the main lobe of the COM lava field; their source vents are unknown. Unit also includes isolated exposures of pahoehoe lava east of the Great Rift near The Watchman and Two Point Butte cinder cones; isolated exposures of pahoehoe lava with no known source vents are located on the south margin (Brown flows) and on the east margin (Heifer Reservoir, Baseline flows) of the main lobe of the COM lava field

Surficial deposits

Qs SURFICIAL DEPOSITS (LATE PLEISTOCENE)-- Chiefly alluvial deposits along streams and colluvial deposits at the base of steep slopes. Thin deposits of eolian sand and silt are not mapped

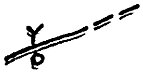
Basalt flows of the lower part of the Snake River Group

Qbs BASALT LAVA FLOWS AND ASSOCIATED PYROCLASTIC DEPOSITS (PLEISTOCENE)--Chiefly pahoehoe lava flows, cinders, and ash, with minor amounts of a'a lava. Older units are covered by eolian deposits as much as 2-3 meters thick. Younger flows have fresh, glassy surfaces and thin (<1 m), localized mantles of eolian sediment. Pyroclastic deposits occur mainly near vents

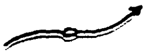
Pre-Tertiary rocks of the Pioneer Mountains

pTu Mesozoic and Paleozoic sedimentary and igneous rocks, undivided

## Description of Map Symbols



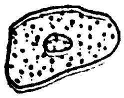

CONTACT==Dashed where approximately located, particularly between lava flows that are veneered by thin deposits of windblown sand and loess. Letters Y and O are used to denote younger and older flows along contact. Dash-dot contact between flows of the same map unit and between units erupted from the same vent.



FLOW LINE==Linear flow features and lava tubes, arrow shows flow direction. Open circles on flow lines are locations of skylights in lava tubes

LAVA CHANNEL==Arrow shows direction of flow within lava channel

CRATER==Outline of crater rim on volcanic vent, barbs point toward central depression. Barbs not shown on smaller craters



CINDER CONE==Pattern shows area covered by cinders, agglutinated spatter, and volcanic ash around a crater

CONE==Vent for small lava cones, cinder cones, and spatter cones

ERUPTIVE FISSURE==Fracture in rock through which lava was erupted, generally bordered by spatter ramparts

ROOTLESS VENTS==Secondary source of lava not directly related to conduits that brought magma to the surface from deep magma reservoir, chiefly openings in lava tubes


LAVA POND--Shows location of levees surrounding lava pond


CRACKS--Fractures in rock through which lava has not been erupted. Width generally less than 1 m


FAULT--Ball and bar on downthrown block, dashed where inferred or covered

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# CORRELATION OF MAP UNITS