

The Geology of Big Southern Butte, Idaho

by

Dallas B. Spear¹ and John S. King²

ABSTRACT

Big Southern Butte is the largest of three prominent buttes which rise above the relatively flat accumulations of Quaternary basalt flows between Arco and the Idaho Falls-Blackfoot area on the eastern Snake River Plain in Idaho. It stands 760 meters above the plain and has a diameter of 6.5 kilometers at its base. It is a 300,000 year old rhyolitic dome complex that consists of two coalesced cumulo domes and an elevated section of older basalt flows approximately 350 meters thick. The basalt section covers most of the northern slope of the butte.

Big Southern Butte began its development as a accolithic intrusion but due to its shallow emplacement broke through to the surface and continued its evolution by endogenous growth. The emplacement of the rhyolite was controlled by two intersecting structural trends: one, northeast-southwest, paralleling the long axis of the plain and the other, northwest-southeast, reflecting the extension of basin and range faulting onto the plain. The northeast-southwest trend is defined by the concentration of large eruptive centers and may be due to a high thermal input concentrated along the axis of the Snake River Plain at depth.

INTRODUCTION AND SETTING

Three buttes rise prominently above the relatively flat accumulations of Quaternary basalt flows between Arco and the Idaho Falls-Blackfoot area on the eastern Snake River Plain in Idaho. These unique features are aligned on a northeast trend and from southwest to northeast are known as Big Southern Butte, Middle Butte, and East Butte (Figure 1). Big Southern Butte and East Butte are rhyolite domes, and Middle Butte is an elevated block of basalt flows, dipping about 10 degrees to the south. Although no

rhyolite crops out at Middle Butte, magnetic and gravity data suggest that a silicic intrusion underlies the basalt cap rock (Schoen, 1974).

Big Southern Butte is by far the most prominent topographic feature of this entire area. It is about 6½ kilometers across at its base and stands 760 meters above the surrounding terrain (Figure 2). The slopes of Big Southern Butte are steep—commonly in excess of 30 degrees—and are dissected by ravines and canyons which contribute debris to the broad apron of talus surrounding the butte. On the northwest side a deep canyon merges at the lower end with a broad alluvial fan. The slope up this fan and canyon allows

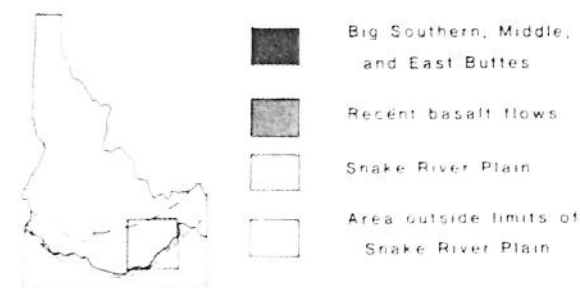
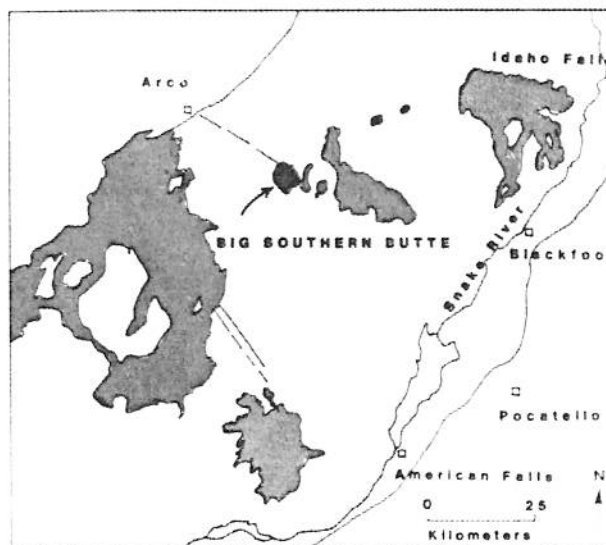


Figure 1. Eastern Snake River Plain, Idaho, showing location of Big Southern Butte.

¹Arco Exploration Company, Houston, Texas 75221.

²State University of New York at Buffalo, Amherst, New York 14226.

Spear, D. B. and J. S. King, 1982. The geology of Big Southern Butte, Idaho, in Bill Bonnichsen and R. M. Breckenridge, editors, *Cenozoic Geology of Idaho*. Idaho Bureau of Mines and Geology Bulletin 26, p. 395-403.



Figure 2. Big Southern Butte rises 760 meters above the eastern Snake River Plain between Arco and the Idaho Falls-Blackfoot area in southern Idaho.

access up the butte by way of a Bureau of Land Management service road which runs to the top.

Mapping of Big Southern Butte at a scale of 1:12,000 (Spear, 1979) revealed that it consists of two coalesced cumulo domes and a 350-meter-thick section of older basalt flows which dominates the northern slope (Figure 3, note scale is reduced). The basalt block was uplifted and tilted as a contiguous unit by the developing domes. The flow sequence of the block dips about 45 degrees to the northeast and has resulted in a large, prominent, flat area on the northern side of the butte (N $\frac{1}{2}$ sec. 23, SE $\frac{1}{4}$ sec. 15, NE $\frac{1}{4}$ sec. 22).

The contact between the two cumulo domes is not obvious. Rather, the division is based on overall morphology in combination with minor, but nonetheless characteristic, lithologic differences. The two domes which make up Big Southern Butte are aligned along a trend of N. 45° W., resulting in a slight northwest-southeast elongation of the butte. Radioisotope dates (Armstrong and others, 1975; Dalrymple, 1978) suggest that Big Southern Butte developed about 300,000 years ago. East Butte is dated at 600,000 years and Middle Butte remains undated inasmuch as the intrusive dome, which is inferred to have uplifted the basalt block, is not exposed at the surface.

GEOLOGY OF BIG SOUTHERN BUTTE

Big Southern Butte is made up of two coalesced domes, which are here identified as the northwestern and the southeastern dome, and a fault block of older basalt flows.

SOUTHEASTERN DOME

The southeastern dome was the first of the two domes to develop. It is characterized by lavender gray, aphyric rhyolite containing abundant devitrification spherulites. Flow-layering is also common, on the order of a few centimeters or less; attitudes of the layering are generally tangential to the flanks of the dome. The flow-layered rhyolite locally grades upward through a transition zone of a few meters into a white sugary-textured rhyolite. The transition can be seen clearly in the deep canyons on Big Southern Butte's southern slope.

The sugary rhyolite is interpreted to be the early upper crust of the gradually expanding dome. Although it appears to be more susceptible to erosion than the flow-layered variety, and undoubtedly much has been removed in that manner, it does not seem to have been present over the entire dome. Supporting evidence for this interpretation comes from the locations of numerous autoclastic breccias that occur above, but not below, the upper limits of the sugary rhyolite. Based on the criteria of Fisher (1966) autoclastic breccias form as a dome expands and grows, and they result from localized ruptures of the solidified dome surface. They are typified by non-sorted, nonbedded angular clasts set in a fine-grained matrix. The lithology of the clasts at Big Southern Butte is predominantly flow-layered rhyolite, although obsidian and white rhyolite are also found. The sizes of the clasts range from less than 1 centimeter to over 1 meter, and average about 10 centimeters. We suspect that during latter periods of dome development accelerated growth produced two primary results: the formation of autoclastic breccias from

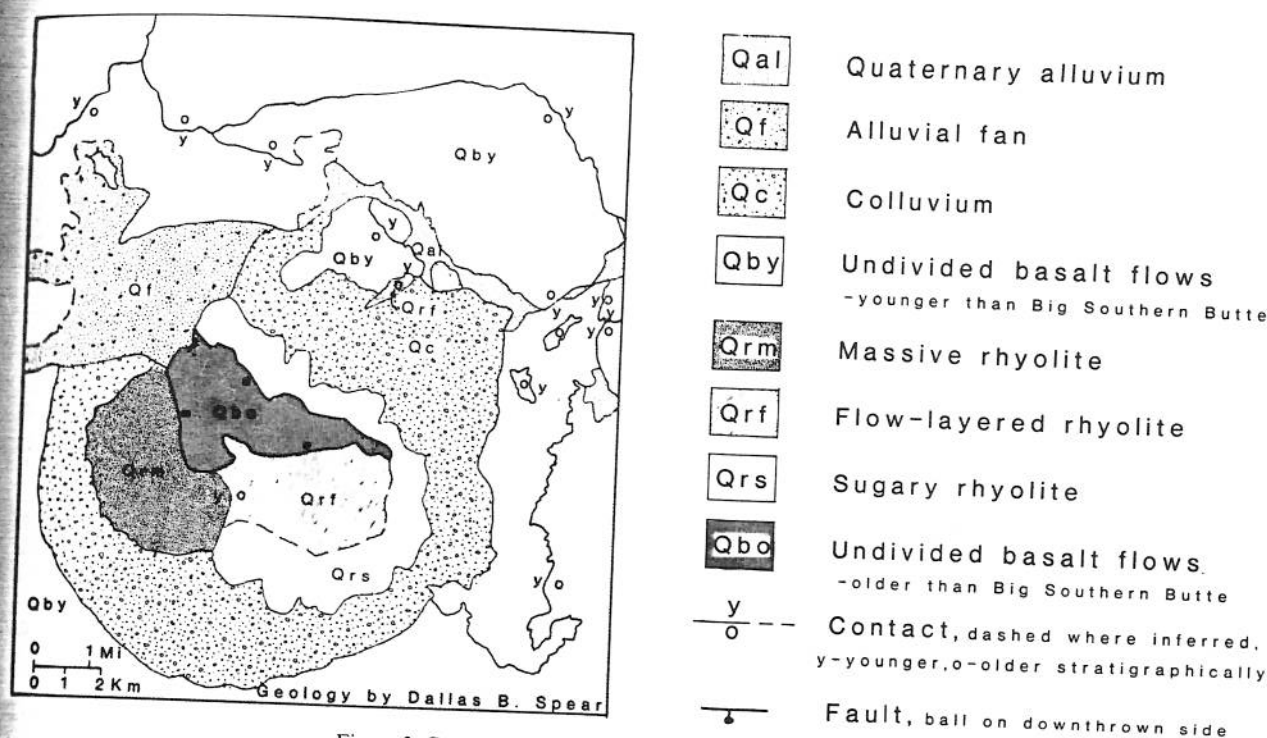


Figure 3. Generalized geologic map of Big Southern Butte, Idaho.

localized ruptures of the surface and the development of flow-layered rhyolite rather than sugary rhyolite on the surface.

Two other types of breccias also occur on the southeastern dome. Crumble breccia covers much of the lower two-thirds of the slopes. These blocky breccias are unconsolidated and have resulted from the destruction of early surfaces during dome growth. The other breccia is a graded sequence of explosion breccia which is exposed in a road cut near the top of the dome near the center of Big Southern Butte (Figure 4). It is at least 35 meters thick. The base is made up of a chaotic, heterolithologic assemblage of angular to subrounded blocks up to 1 meter in size. Much of the basal material has undergone some alteration and is distinguished by an earthy red and yellow color. The average clast size decreases upward and grades to well-sorted, bedded lapilli. Two prominent ash layers occur between the lower blocky section and the bedded lapilli.

This graded breccia is interpreted to have resulted from explosive venting through the surface of the flow-layered dome. It is not believed to mark the location of a primary vent or conduit at Big Southern Butte but simply preserves a local event or events in the on-going development of the dome. Explosive blowouts are common during the development of domes, and several eye witness accounts describe them (Williams, 1932). Washington (1926) described

explosions he witnessed on the upper part of the Santorini dome. These explosions occurred at many different points and often simultaneously at several points but never from any one point. Solid blocks were thrown out by the explosions and many of these fell back on the dome. It is this origin that is hypothesized for the Big Southern Butte roadcut breccia.

In addition to the various breccias, banded spherulitic obsidian, light gray pumice, and honey-brown welded pumice are present on the flow-layered southeastern dome. Small outcrops of obsidian are common on the upper parts of the dome and are interpreted to be rapidly cooled localized extrusions or, in some places, the rapidly cooled upper surface of the dome. The gray and the honey-brown welded pumices are minor rock types of limited extent, but their presence documents some short-lived vent activity or perhaps minor explosive outbreaks on the surface of the dome. Some fumarolic activity is indicated in at least two localities on this dome by sulfur encrustation and a tufa-like deposit.

In summary, the development of the flow-layered southeastern dome was predominantly by endogenous growth; that is, internal expansion. However, particularly during the later stages of its evolution, localized ruptures at the surface produced autoclastic breccias. Minor extrusions of viscous lava also contributed to the resulting dome morphology. The attitude of the

flow-layering, which is generally tangential to the slopes of the dome, and the distribution of the breccias support the hypothesis of a gradually expanding dome.

NORTHWESTERN DOME

The younger northwestern dome of Big Southern Butte is generally homogeneous and dominantly a massive aphyric white rhyolite distinct in its lack of abundant spherulites. Locally the rhyolite grades to a sugary variety similar to that observed on the southeastern dome, but this is not common. Flow layering was observed in only one outcrop on the northeast side of this younger dome (SW¼NE¼ sec.

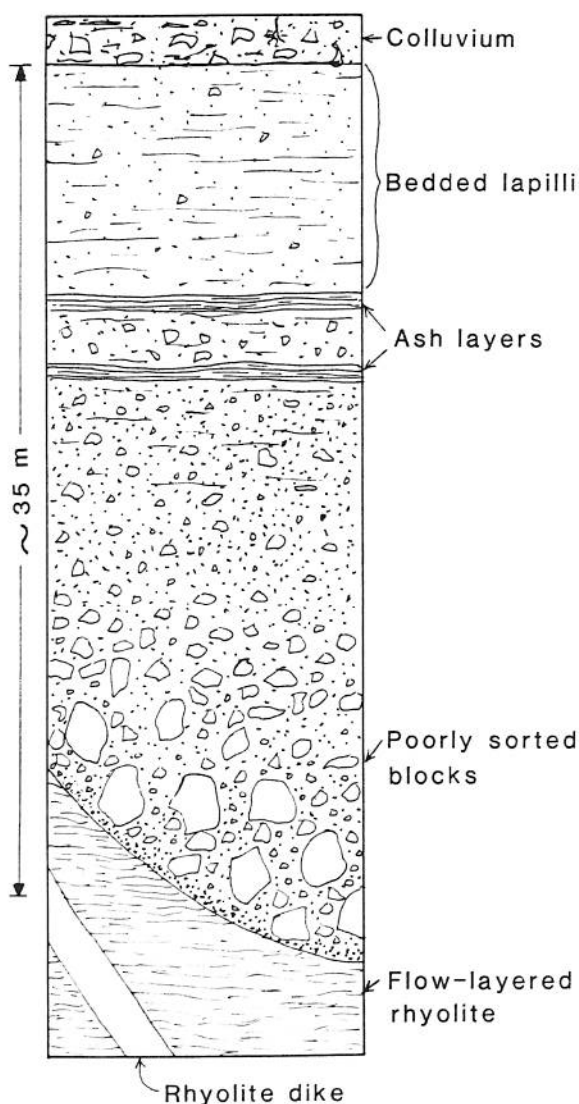


Figure 4. Generalized stratigraphic section of explosion breccia exposed in a roadcut near the top of Big Southern Butte.

22). Significantly, the only autoclastic breccia found on the entire northwestern dome occurs near this flow-layered outcrop. This association coupled with the observed relationship between flow layering and autoclastic breccia on the southeastern dome strongly suggests that the breccias are by-products of the flow-layering process. The flow layering is believed to result from local surges in the emplacement of a viscous magma.

Whereas the flow-layered southeastern dome has a varied topography with rugged slopes, the massive northwestern dome has relatively smooth, unbroken slopes. It has an arcuate outline, and apparently it developed symmetrically around an intrusive center. A shallow, circular basinlike depression approximately 800 meters in diameter occurs in the center of the top of the northwestern dome (center of sec. 22). This is believed to have formed as a result of deflation following withdrawal of magma down the conduit. Other factors which may have played a minor role in the development of this depression include both thermal contraction and the release of internal pressure through the escape of gasses from the magma. Daly (1925) proposed such an origin for a basined dome on Ascension Island.

BASALT FAULT BLOCK

A large block of older basalt flows at least 350 meters thick covers much of the northern slope of Big Southern Butte but does not extend all the way to the base (Figure 5). The basalt block has a steep slope, and a distinct break in slope marks the contact of this block with rhyolite near the base of Big Southern Butte. This basalt block was formerly part of the continuous flow surface of the Snake River Plain but was uplifted and tilted to its present orientation during the emplacement of the rhyolite domes. The contact between the basalt block and rhyolite is exposed only locally. Where exposed, it is demarcated by a narrow zone of basalt fragments in a rhyolitic matrix.

The basalt block is made up of fifteen to twenty individual flows or flow units which dip approximately 45 degrees to the northeast (Figure 6). The lower part of the block is exposed in a canyon on the northwest side of Big Southern Butte (NE¼ sec. 22). The oldest flows of the block have been extensively altered, probably from the action of hydrothermal fluids which accompanied the rhyolitic intrusion. This interpretation is supported by the occurrence of similarly altered basalt near another basalt-rhyolite contact higher in the section. Away from the contact this same flow is relatively unaltered.

A sequence of evolved tholeiite lavas is found near



Figure 5. View of the northern slope of Big Southern Butte from 8 kilometers. The flat area on the left (east) side of the canyon is part of the block of older basalt lavas uplifted and tilted during the emplacement of the rhyolite.

the base of the Big Southern Butte basalt block where it is interlayered between typical Snake River Plain olivine tholeiite flows. Evolved tholeiites form differentiated sequences and are distinctive for their high iron enrichment and high alkali content (see Leeman, 1982 this volume). Experimental work by Tilley and Thompson (1970) demonstrated that this is due to the fractionation of apatite, magnetite, olivine, plagioclase, and in the late stages, clinopyroxene. They further suggest that evolved tholeiite magmas developed through fractionation at the base of the crust from a parental Snake River Plain olivine tholeiite magma. These evolved tholeiite lavas are not common among the volcanic rocks of the Snake River Plain, and it is tempting to relate the Big Southern Butte sequence to Cedar Butte, a large shield volcano located about 7 kilometers east of Big Southern Butte which is composed of a differentiated suite of evolved tholeiite lavas. However, a ferrolatite flow known to be from Cedar Butte caps the entire basalt section on Big Southern Butte, and at least ten olivine tholeiite flows separate this cap from the evolved sequence near the base of the basalt block. Furthermore, some features associated with the evolved sequence of the Big Southern Butte basalt block, including both welded spatter and a single glassy layer, suggest that the source for this evolved flow was local.

Hamilton (1965) states that the upper 100 meters of the basalt section at Big Southern Butte is made up of interlayered basalt and rhyolite. No such interlayering was observed in this study, although a small conspicuous rhyolite dike was noted near the top of the basalt section.

Three large mounds, each 500 to 750 meters across at the base, occur in sections 11 and 12 near the northern base of Big Southern Butte (Figure 3). The mounds are covered with basalt rubble and, based on morphology alone, could be collectively identified as

a small shield volcano. However, flow-layered rhyolite occurs in outcrop near the base of the east side of the mounds and, on close examination, the rubble which covers the surface is found to be composed of many basalt lithologies. This rules out a single local source for this material. The mounds are interpreted to be small domal intrusions of rhyolite.

PETROLOGY

The rhyolite of Big Southern Butte is mineralogically and chemically homogeneous. The macroscopic characteristics, such as color variations and flow layering, which were used for the purposes of mapping, are not related to any significant compositional variations.

PETROGRAPHY

In thin sections, the rhyolite appears as fine-grained intergrowths of microcrystalline quartz and alkali feldspar. Fine-grained anhedral phenocrysts of quartz are rare. Mafic minerals are very rare and include microphenocrysts of variably altered fayalite and dark green, pleochroic clinopyroxene. Magnetite is present as small euhedral grains.

The flow-layered rhyolite has abundant devitrification spherulites, and the massive rhyolite is holocrystalline with a "snowflake" texture due to the slightly larger anhedral crystals of quartz distributed throughout the microcrystalline groundmass.

CHEMISTRY

Major element data and CIPW norms for seven



Figure 6. Northern slope of Big Southern Butte; view to the northwest. Note the steeply dipping (45° NE) layers of basalt.

samples of rhyolite representative of Big Southern Butte are presented in Table 1. The analyses document the relative homogeneity throughout the dome complex. Chemically, the rhyolite is mildly peralkaline (molecular excess of $\text{Na}_2\text{O} + \text{K}_2\text{O}$ over Al_2O_3) and is classified as comendite based on the criteria of Nicholls and Carmichael (1969).

EMPLACEMENT HISTORY OF BIG SOUTHERN BUTTE

The large tilted block of older lavas on the north side of Big Southern Butte attests to the fact that Big Southern Butte began its development as a laccolithic intrusion. However, both intrusion and extrusion of silicic magma interacted to form Big Southern Butte.

Initially silicic magma ascended along a fracture and intruded beneath the basalt sequence of the Snake River Plain to form an elliptical sill-like intrusion. This early phase underwent a period of

lateral growth that was followed by a laccolithic stage during which the intrusion began to dome the overlying basalt flows. Doming continued until the yield strength of the overburden was exceeded. When this occurred, it marked the transition in development of Big Southern Butte from intrusive to extrusive.

During the early stages of extrusive growth, the dome was mantled by blocky debris (crumble breccia) and a massive crust of white rhyolite. As the dome continued to increase in size by endogenous growth, the early crust was fractured, autoclastic breccias formed, and minor extrusions quickly chilled at the surface to form localized areas of obsidian. An explosion formed the breccia and lapilli tuffs now exposed near the top of Big Southern Butte.

Following these events, the intrusive center shifted to the northwest, and a second endogenous dome began to grow (the northwestern dome). Cessation of the supply of magma caused the top of the dome to sag slightly, producing the basined depression seen there today. These events essentially ended the volcanic development of Big Southern Butte. Figure 7 summarizes the sequence of events.

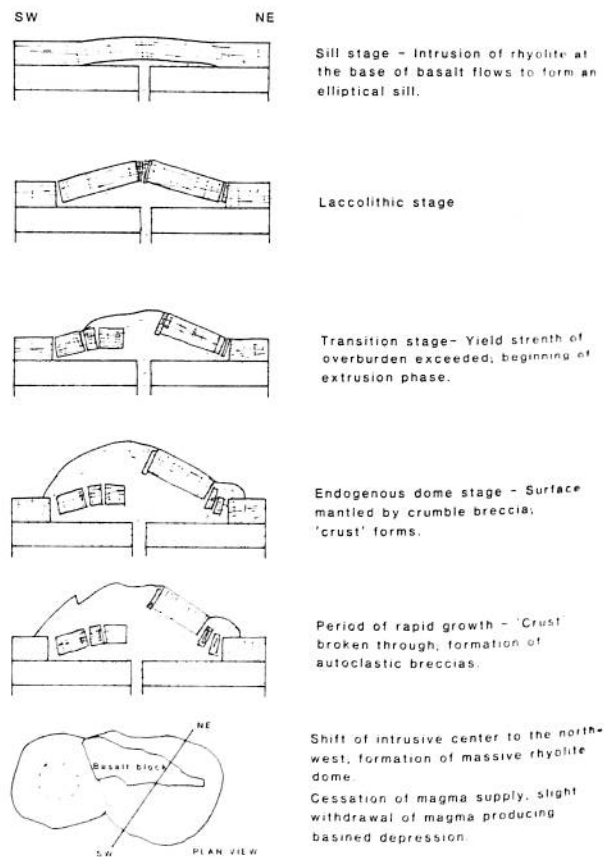


Figure 7. Summary of emplacement history of Big Southern Butte.

STRUCTURAL CONTROL OF VOLCANISM

One of the intriguing questions concerning Big Southern Butte is its location. With Middle Butte and East Butte, it is situated along a topographic high which coincides with the longitudinal axis of the eastern Snake River Plain.

Doherty and others (1979) suggest that Big Southern Butte, Middle Butte, East Butte, and two other volcanic centers, Cedar Butte and an unnamed rhyolite dome, lie along the ring fractures of a buried caldera complex. In addition to the location of the buttes, their interpretation is based on a thick sequence of rhyolitic rocks (which they interpret as caldera fill) found in an exploratory geothermal test well (INEL-1), on the absence of numerous basaltic

vents within the inferred rim, and on recent faulting on the north side of the plain.

It is generally accepted that caldera development has played an important role in the overall volcanic evolution of the eastern Snake River Plain. Probably the rhyolite of Big Southern Butte is genetically related to some late-stage caldera development. However, we do not believe that structural control for the emplacement of rhyolite at Big Southern Butte is directly related to ring fractures of a buried caldera complex as suggested by Doherty and others (1979).

Close inspection of the area shows two dominant, linear structural trends. One is northeast-southwest and parallels the longitudinal axis of the eastern Snake River Plain; the other is northwest-southeast, more or less perpendicular to the axis (Figure 8). The surface expression of these two trends differs considerably. The northeast-southwest trend is defined

Table 1. Major element analyses (weight percent) and CIPW norms for Big Southern Butte samples.

	BS-1 ¹	BS-2	BS-3	BS-4	BS-5	BS-6	BS-7 ¹
SiO ₂	76.22	75.32	75.84	76.02	75.99	76.08	75.82
TiO ₂	.09	.10	.10	.10	.10	.10	.09
Al ₂ O ₃	12.22	12.18	12.12	12.28	12.22	12.14	12.09
Fe ₂ O ₃	1.17	1.66	1.31	1.94	1.70	1.76	1.76
FeO	.72	.13	.44	.03	.10	.04	.06
MnO	.04	.05	.05	.03	.03	.03	.04
MgO	.00	.02	.03	.03	.03	.03	.01
CaO	.47	.44	.48	.40	.45	.48	1.03
Na ₂ O	4.40	4.32	4.27	4.24	4.31	4.35	4.32
K ₂ O	4.76	4.76	4.66	4.69	4.68	4.72	4.67
P ₂ O ₅	.01	.03	.02	.02	.03	.03	.02
H ₂ O ⁺	.30	.32	.27	--	--	--	.26
CO ₂	.01	.04	.03	.08	.05	.05	.44
Loss on ignition	--	--	--	--	--	--	--
TOTALS	100.36	99.56	99.55	99.73	99.59	99.71	100.51
Q	31.22	31.41	32.15	32.34	32.04	31.79	31.56
Or	28.03	28.25	27.66	27.79	27.77	27.97	27.46
Ab	36.23	36.31	36.30	35.98	36.62	36.27	36.00
An	--	--	.14	.63	.18	--	--
Ne	--	--	--	--	--	--	--
Ac	.77	.36	--	--	--	.57	.32
Di { Wo	.92	.73	.81	.30	.65	.78	.91
En	--	.03	.05	.02	.04	.04	.01
Fs	1.04	.79	.86	.32	.69	.84	1.02
Hy { En	--	.02	.03	.06	.04	.04	.01
Fs	.72	.73	.57	1.19	.73	.75	.50
Ol { Fo	--	--	--	--	--	--	--
Fa	--	--	--	--	--	--	--
Mt	.57	.69	.87	.96	.87	.59	.72
Il	.17	.19	.19	.19	.19	.19	.19
Ap	.02	.07	.05	.05	.07	.07	.05

¹Dave Borden, analyst; all others by D. B. Spear.

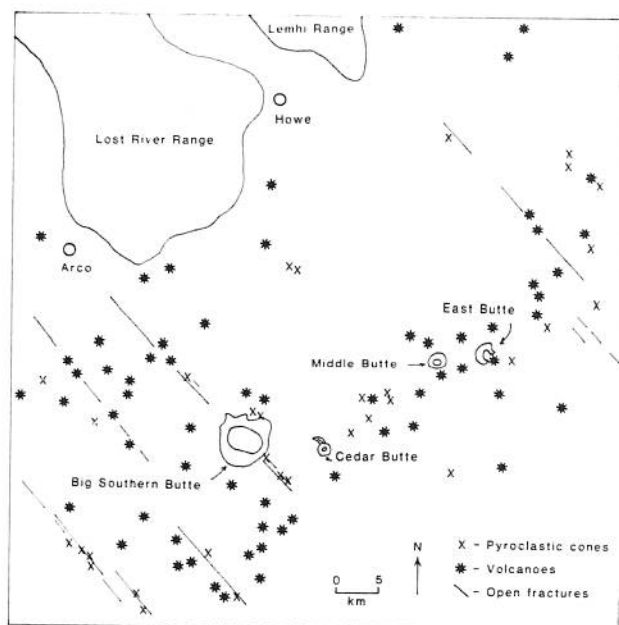


Figure 8. Localization of volcanism in part of the eastern Snake River Plain in the vicinity of Big Southern Butte. Two dominant structural trends, northeast-southwest and northwest-southeast, are defined by the concentration of volcanoes and northwest-southeast trending fractures.

by the concentration of large basaltic eruptive centers, Cedar Butte, a differentiated sequence of evolved tholeiite lavas, and Big Southern, Middle, and East Buttes. These constructs contribute to make the longitudinal axis topographically high. The northeast-southwest trend may also, in part, be due to a broad, gentle arching of the Snake River Plain related to a high thermal input concentrated along the axis at depth.

The northwest-southeast trend is marked by numerous open fractures, elongated craters, alignment of vents, and sites of recent small-scale fissure eruptions. Although not obvious in Figure 8, most of the volcanic vents not concentrated along the northeast-trending axis of the plain lie along fractures with a definite northwest-southeast trend. This trend probably owes its existence to the same stress field which produced the basin and range-type mountain front faults north of the plain. Extension of these faults onto the plain can be inferred from the aeromagnetic map of Zietz and others (1978).

We believe that the location of Big Southern Butte is best explained in the light of two intersecting linear trends rather than a more or less circular pattern as might be expected from a buried caldera. The rectilinear distribution of volcanic vents and the strong orthogonal pattern of the aeromagnetic data as interpreted by Zietz and others (1978) offer support for this hypothesis. These dominant structural trends,

coupled with a probable high thermal concentration along the longitudinal axis of the eastern Snake River Plain at depth, are the controlling factors responsible for the location of Big Southern Butte.

SUMMARY AND CONCLUSIONS

Big Southern Butte is a volcanic dome complex that formed approximately 300,000 years ago. It is composed of two coalesced rhyolite domes and an elevated block of older basalt flows covering most of its northern side. Big Southern Butte began its development as a laccolithic intrusion but due to its shallow emplacement broke through to the surface and continued its evolution by endogenous growth. Subsequent to its formation olivine tholeiite basalt flows, erupted from nearby vents, have surrounded it.

The rhyolite of Big Southern Butte is distinctive in outcrop for mapping purposes but mineralogically and chemically homogeneous. It occurs in thin section primarily as fine-grained intergrowths of microcrystalline quartz and alkali feldspar. Devitrification spherulites are characteristic in the flow-layered variety which occurs on the southeastern dome. Chemically the rhyolite is mildly peralkaline and is classified as comendite.

The emplacement of the rhyolite at Big Southern Butte was controlled by two intersecting linear trends: one northeast-southwest and the other northwest-southeast. These dominant structural trends coupled with high thermal concentration along the axis of the Snake River Plain at depth are responsible for the localization of Big Southern Butte.

ACKNOWLEDGMENTS

We wish to thank John C. Fountain, Dave Borden, and Charlie C. Clemency, State University of New York at Buffalo and Steven S. Oriel, Mel A. Kuntz, and Jack Barraclough of the U. S. Geological Survey for their help and suggestions during the course of this investigation. Naturally they are not to be held accountable for our interpretations. Financial support for most of this project was covered by NASA Planetology Grant NGR 33-014-108 awarded to John S. King.

REFERENCES

- Armstrong, R. L., W. P. Leeman, and H. E. Malde, 1975, K-Ar dating and Neogene volcanic rocks of

- the Snake River Plain, Idaho: *American Journal of Science*, v. 275, p. 225-251.
- Dalrymple, G. B., 1978, *in* M. A. Kuntz, Geologic map of the Arco-Big Southern Butte area, Butte, Blaine, and Bingham Counties, Idaho: U. S. Geological Survey Open-File Report 78-302.
- Daly, R. A., 1925, The geology of Ascension Island: *Proceedings, American Academy of Arts and Science*, v. 60, no. 1, p. 1-80.
- Doherty, D. J., L. A. McBroome, and M. A. Kuntz, 1979, Preliminary geologic interpretation and lithologic log of the exploratory geothermal test well (INEL-1), Idaho National Engineering Laboratory, eastern Snake River Plain, Idaho: U. S. Geological Survey Open-File Report 79-1248, 9 p.
- Fisher, R. V., 1966, Rocks composed of volcanic fragments and their classification: *Earth-Science Reviews*, v. 1, p. 287-298.
- Hamilton, W. C., 1965, Geology and petrogenesis of the Island Park caldera of rhyolite and basalt, eastern Idaho: U. S. Geological Survey Professional Paper 504-C, 37 p.
- Leeman, W. P., 1982, Evolved and hybrid lavas from the Snake River Plain, Idaho, *in* Bill Bonnichsen and R. M. Breckenridge, editors, *Cenozoic Geology of Idaho*: Idaho Bureau of Mines and Geology Bulletin 26.
- Nicholls, J. and I. S. E. Carmichael, 1969, Peralkaline acid liquids—a petrologic study: *Contributions to Mineralogy and Petrology*, v. 20, p. 268-294.
- Schoen, R., 1974, III. Geology, *in* J. B. Robertson, R. Schoen, and J. Barraclough, Influence of liquid waste disposal on the geochemistry of water at the National Reactor Testing Station, Idaho: U. S. Geological Survey Open-File Report, IDO 22053, 231 p.
- Spear, D. B., 1979, The geology and volcanic history of the Big Southern Butte-East Butte area, eastern Snake River Plain, Idaho: State University of New York at Buffalo Ph.D. dissertation, 136 p.
- Tilley, C. E. and R. N. Thompson, 1970, Melting and recrystallization relations of the Snake River basalts of southern Idaho, USA: *Earth and Planetary Science Letters*, v. 8, no. 1, p. 79-92.
- Washington, H. S., 1926, Santorini eruption of 1925: *Geological Society of America Bulletin*, v. 37, p. 349-384.
- Williams, Howel, 1932, The history and character of volcanic domes: *University of California Department of Geological Science Bulletin*, no. 21, p. 51-146.
- Zietz, Isidore, F. P. Gilbert, and J. R. Kirby, Jr., 1978, Aeromagnetic map of Idaho: color coded intensities: U. S. Geological Survey Geophysical Investigations Map GP-920.