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1969, pp. 108-115. https://doi.org/10.56577/FFC-20.108

in:

The Border Region, Chihuahua and the United States, Cordoba, D. A.; Wengerd, S. A.; Shomaker, J. W.; [eds.], New Mexico Geological Society 20th Annual Fall Field Conference Guidebook, 228 p. https://doi.org/10.56577/FFC-20

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VOLCANIC HISTORY OF THE BLACK MOUNTAIN-SANTO TOMAS BASALTS POTRILLO VOLCANICS, DONA ANA COUNTY, NEW MEXICO

by
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ABSTRACT

Volcanic activity of the Black Mountain-Santo Tomas area consists of cinder and spatter cones with at least seven periods of extrusive olivine alkaline basalt. The basalt flows, on the basis of phenocryst mineralogy, can be classified into three groups: those with phenocrysts rich in plagioclase, flows rich in olivine phenocrysts, or flows with almost equal amounts of plagioclase and olivine phenocrysts. Phenocryst mineralogy of the flows, along with K-Ar dates, has been used to establish tentative correlations from one center to another.

Preliminary K-Ar dates from four individual flows suggest an age for the extrusive activity of from 1.5 to 2.5 million years ago.

RESUMEN

La actividad volcánica del area de la Montana Negra-Santo Tomas consiste de cenizas y conos dispersos desarrollados por lo menos en siete periodos de extrusion de basalt() alcalino de olivino. El flujo de basalto en las bases de la mineralogia de los fenocristales puede ser clasificado en tres groupos: aquel que contiene fenocristales ricos en pagioclasa, flujos de fenocristales de olivino o con una cantidad casi igual de fenocristales de pagioclasa. La mineralogia de fenocristales de los flujos junto con las edades K-Ar se ha usado para establecer correlaciones tentativas de un centro a otro.

Preliminarmente las edades K-Ar de cautro flujos individuales sugiere una edad para la actividad extrusiva de 1.5 a 2.5 m.a.

INTRODUCTION AND LOCATION

The Potrillo volcanic field, occupying an area of more than 400 square miles in southcentral New Mexico and northern Mexico, consists of a series of basaltic volcanic cones, flows, and maare (Kottlowski, 1960; Dane and Bachman, 1961; DeHon, 1965; Hawley and Kottlowski, 1969; Hoffer, 1969a and 1969b) (Fig. 1) .

The western section, called the West Potrillo Mountains, is composed of numerous cinder and spatter cones and related flows; this area comprises more than eighty percent of the total field. The central section is represented by a series of maare, including Kilbourne Hole, Hunt's Hole, Potrillo Maar, as well as several associated cones and basaltic lava flows (DeHon, 1965a; DeHon, 1965b, DeHon, 1965c; Reeves and DeHon, 1965). The volvanic materials in this region cover approximately 75 square miles. The eastern section of the Potrillo field, called the Black Mountain-Santo Tomas chain, is located on the eastern margin of the La Mesa surface near the Rio Grande Valley (Kottlowski, 1960). Volcanic materials from this chain cover an area of about 15 square miles.

The Black Mountain-Santo Tomas chain is composed of four eruptive centers, each having one or more cones and associated flows (Fig. 1). From north to south, the four volcanic centers are called Santo Tomas, San Miguel, Little Black Mountain, and Black Mountain. Black Mountain to the south and Santo Tomas to the north show evidence of multiple eruption, but the two intervening centers, San

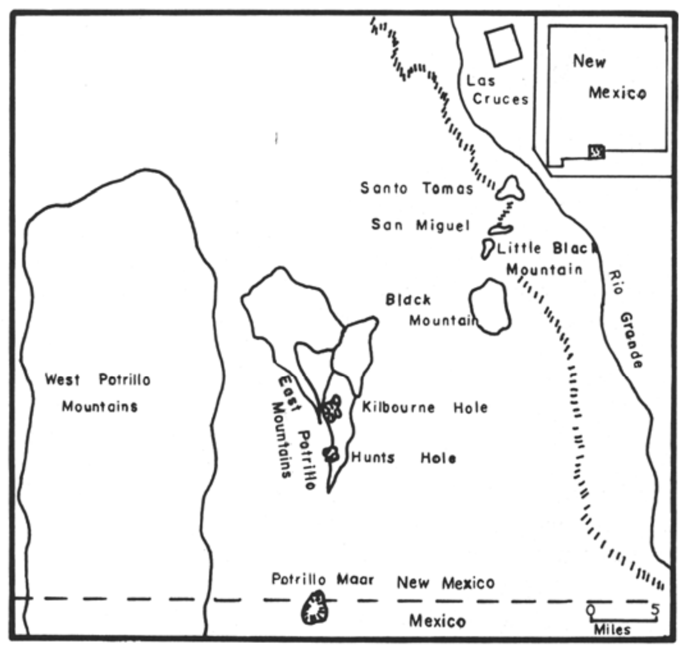

FIGURE 1.
Index map of the Potrillo Volcanics.

center coalesce with those from neighboring centers, but all appear to be closely related (Kottlowski, 1960).

DESCRIPTION OF THE VOLCANIC FEATURES

BLACK MOUNTAIN

The Black Mountain area consists of eight volcanic cones and at least six major lava flows (Hoffer, 1969a). Positive determination of the cone or cones from which each flow originated is almost impossible because of the cover of blow sand. Only the youngest flow, the Black Mountain flow, can be traced to a specific cone where it probably was erupted from a lateral vent.

Cinder cones and complex spatter-driblet cones occur at Black Mountain. The location and type of cone, with the associated lava flows, are shown in Fig. 2A. The spatter or driblet cones are the most common inasmuch as six of the eight cones are of this type. Fig 2B is a map of the largest spatter-driblet cone in the Black Mountain area illustrating the typical structure of such cones; this cone is located approximately 4,000 feet north of the Black Mountain cone. Typically these cones possess a low sloping base composed of cinder and spatter. Above the base is a steep rugged rim of agglutinated spatter and driblet with layers dipping predominantly inward; however, on some cones the spatter-driblet layers dip inward on the inside of a cone and outward on the outside of the cone. In most cones, the spatter rim is breached at several places by erosion. The spatter-driblet cones range in diameter from tens of feet to more than 250 feet and in height from 15 to 50 feet.

Larger and less dissected cinder cones in the area include Black Mountain, and Sand Hill located just north of Black Mountain. The Black Mountain cone is almost symmetrical in outline with a diameter of about 2,000 feet and a height of over 300 feet. Well-developed internal stratification with layers of cinder and included volcanic bombs and lapilli are exposed in a quarry on the north side of the cone with cinder layers dipping away from the center. The included bombs range in diameter from several inches to several feet and have hollow or dense interiors.

Just north of the Black Mountain cone is a small elongate ridge approximately 30 feet high and 60 feet long. Columnar joints, developed on each side of the hill, are nearly horizontal at the base, but dip into the center of the hill near the top (Fig. 3) . In the central portion of the mass are individual flows (or flow units), one to two feet thick which are oriented almost vertically. On the basis of the jointing and the presence of subvertical flow structures in the interior, the ridge is thought to represent a dike which probably supplied lava for one or more of the flows at Black Mountain. One of the flows from the interior of the dike has mineralogy similar to the Black Mountain flow (flow 6 in Fig. 2A.)

LITTLE BLACK MOUNTAIN AND SAN MIGUEL

The Little Black Mountain and San Miguel flows are located four and five miles north, respectively, of Black Mountain (Fig.1). Each center has only a single extrusive flow of olivine basalt.

The Little Black Mountain flow covers an area of less than one square mile (Fig. 2C). Located near the west-central portion of the flow are two small cones; the southernmost is a well-exposed spatter-driblet cone but the northern is virtually buried by sand. The spatter-driblet cone, a well-developed, steep rim of spatter resting on a gently sloping base of spatter and cinder, is approximately 1,500 feet in diameter and less than 100 feet in height. The sand-covered cone to the north is smaller being about 1,000 feet in diameter and 60 feet in height. The exact thickness of the basalt flow at Little Black Mountain is not known because the base is not exposed and most of the outcrops are partially covered by sand.

The San Miguel flow, locally termed the Finger flow because of its narrow elongate shape, extruded from a small cone, 50-60 feet high, on the La Mesa surface and flowed into the Rio Grande Valley (Fig. 2C) . This flow, probably extruded on a graded surface associated with an early stage of river valley entrenchment (Hawley, 1965, p. 194), covers an area of approximately one-half square mile, being a little more than two miles long and averaging one-fourth of a mile wide (Hoffer, 1969a). Because of the cover of sand at the west end of the flow the exact nature of the cone and the point of extrusion are not known.

SANTOS TOMAS

The Santo Tomas region contains a major cinder cone and three associated lava flows (Fig. 2D). The cone, near the southwest margin of the flows, is approximately 1,000 feet in diameter and more than 150 feet in height. A quarry exposure extending into the interior of the cone, shows an internal structure of dipping layers of cinder with included fragments of lapilli and bombs. Near the center of the Santo Tomas cone this exposure shows the presence of a unit of nonstratified, red, oxidized, cinder and brecciated lava fragments which dips vertically into the center of the cone. This zone, approximately 40 feet wide at the base of the exposure, but wider near the top of the cone, probably represents one of the extrusive vents that was active during the formation of the cone with the red color caused by rising gases.

In this area lava was extruded from the southwest, most probably from the Santo Tomas cone, and flowed northeastward from the La Mesa surface into the Rio Grande Valley. As in the case of the San Miguel flow, the lava probably was extruded onto a graded surface associated with an early stage of Rio Grande Valley entrenchment (Hawley, 1965, p. 194).

Three basaltic flows have been distinguished on the basis of topographic position. Each flow has a different phenocryst mineralogy. Flow 1, the oldest, is the most widespread occupying an area of about three square miles on the La Mesa surface and extending eastward onto the floodplain of the Rio Grande. After extrusion of this flow subsequent erosion by the Rio Grande has probably slightly reduced its total areal extent. Flow 2, or the middle flow, lies directly on flow 1, but covers a smaller area; its outcrop area is ap-

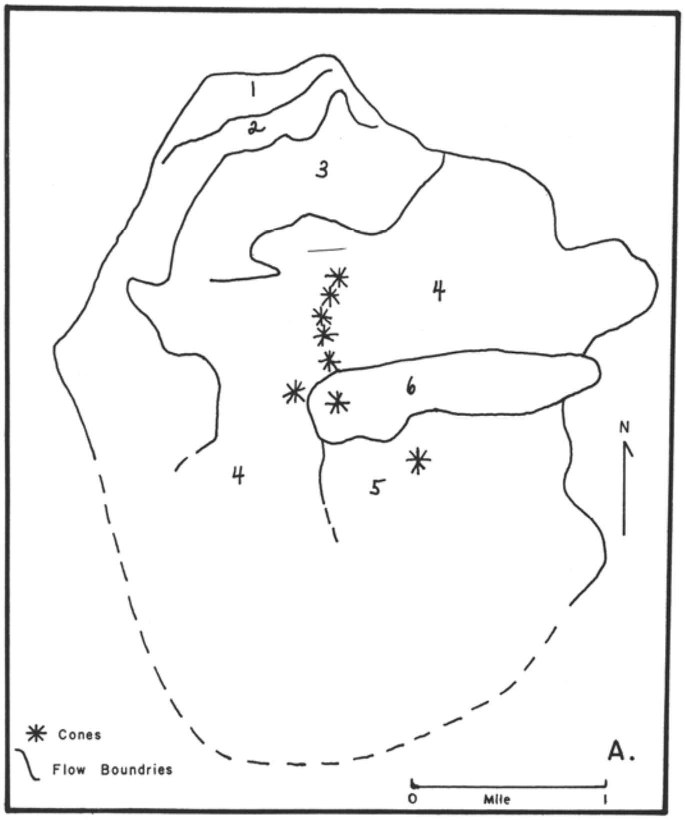

FIGURE 2A.
Cones and flows at Black Mountain.

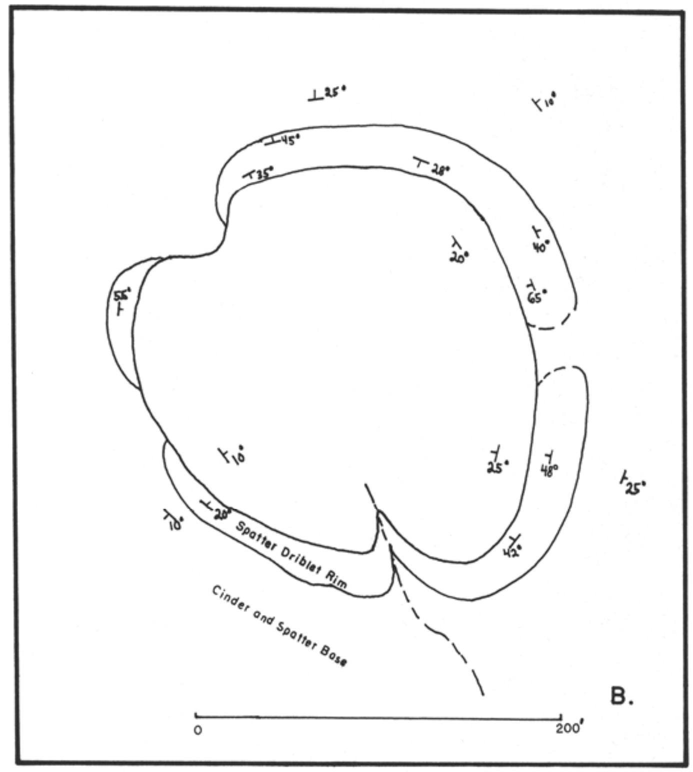

FIGURE 2B.
Map of a spatter cone, north of Black Mountain.

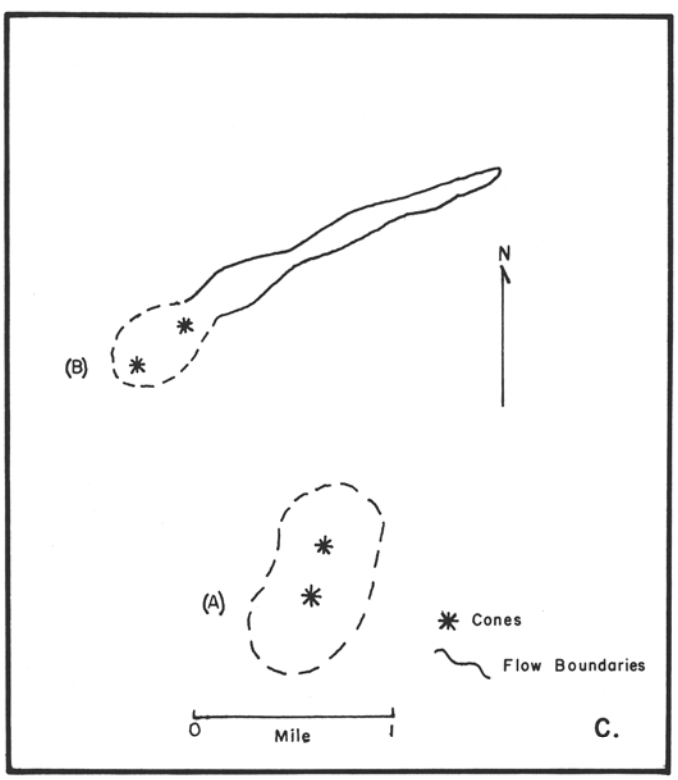

FIGURE 2C.
Little Black Mountain cones and flow (A) and San Miguel cones and flow (B).

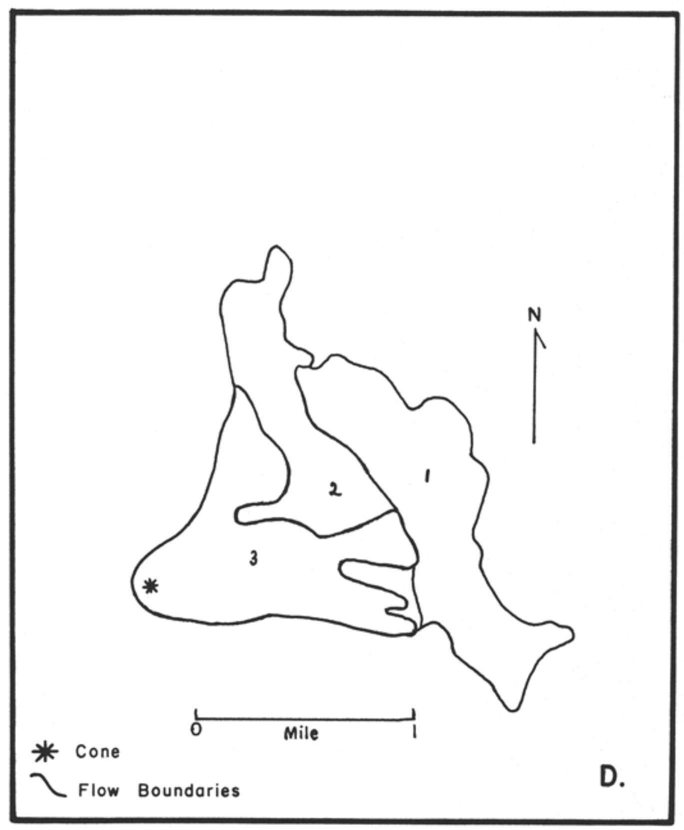

FIGURE 2D.
Santo Tomas cone and flows.

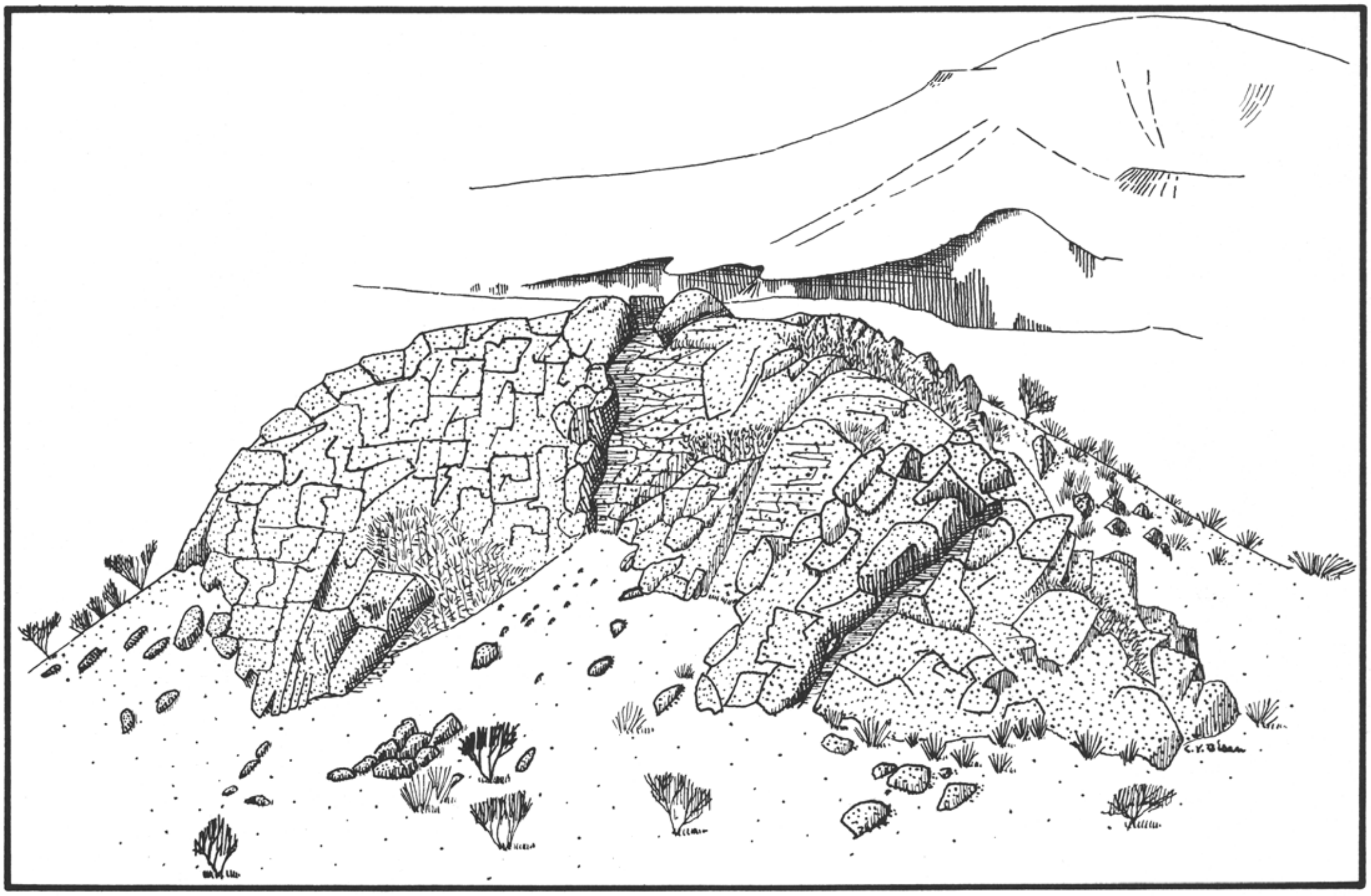

FIGURE 3.
Dike structure located just north of Black Mountain.

proximately one and one-half to two square miles. Its forward edge, where it is in contact with flow 1, is marked by a small but distinct break in slope. The youngest lava, flow 3, rests directly on flow 2 in most areas, but in the north and southeast it lies on flow 1 (Fig. 2D). Its areal outcrop is the smallest of the three flows, covering an area of less than one square mile.

The flows range in thickness from 7 to 18 feet, with flow 1 being the thickest. All three have highly vesicular and scoriaceous top and bottom zones with a dense, somewhat columnar interior. The columnar joint development and diameter of the columns seem to increase with the thickness of the flows. In several localities curved vesicle zones, two and three inches in diameter and two to four feet in length, indicate direction of flowage.

PETROGRAPHY OF THE LAVA FLOWS

TEXTURE

The Black Mountain-Santo Tomas basalts are porphyritic and hypocrystalline with the amount of glass ranging from approximately fifty percent in the quickly cooled, vesicular flow tops to less than five percent in the more slowly cooled flow interiors. Phenocrysts, ranging in size from 0.5 to 2 mm and composed of euhedral to subhedral crystals of plagioclase feldspare, olivine, and pyroxene, comprise from 15 to 30 percent of the rock. The fine-grained groundmass, averaging less than 0.1 mm contains small plagioclase laths and small anhedral grains of pyroxene, magnetite, and light-to-dark colored interstitial glass.

Parallel to subparallel orientations and flowage patterns around the phenocrysts are common for the groundmass plagioclase. Also abundant are glomeroporphyritic accumulations of olivine and areas of ophitic intergrowth of plagioclase and pyroxene.

GENERAL MINERALOGY

Plagioclase feldspar is the most abundant mineral in the Black Mountain-Santo Tomas basalts; it comprises from 22 to 48 percent of the total rock minerals occurring in both phenocryst and groundmass phases. The phenocryst plagioclase is generally subhedral to euhedral with some crystals showing irregular outline due to resorption reactions. These crystals are moderately zoned with calcic cores (An60-65) and more sodic exteriors (An_{55-60}) . Normal, reverse, and oscillatory zoning are present with normal being the most abundant type. The groundmass plagioclase, averaging 0.05 mm, is unzoned and less calcic than the phenocrysts averaging An_{40} (andesine) .

Pyroxene is present as phenocrysts but more abundantly as groundmass crystals. Phenocryst pyroxene is generally subhedral and less abundant than the phenocryst plagioclase. The phenocryst pyroxenes average 0.5 mm and are typically moderate to dark brown in color with a moderate 2V (40 to 60 degrees). The color and 2V suggests a composition of titanium-rich augite. The groundmass pyroxenes occur in small anhedral grains, averaging 0.05 mm diameter, and probably represent pigeonite.

Olivine, most abundant as subhedral to euhedral phenocrysts displaying locally strong glomeroporphyritic development, ranges in amount from 17 percent to 62 percent. As a groundmass constituent olivine is sparse, occurring as small subhedral to anhedral grains. Many of the phenocrystic olivines have irregular cracks and fractures with irregular edges, boundaries which may be due to resorption. A high 2V (80-85 degrees) and a negative sign indicate a high magnesium content, Fo_{80}-Fo_{65}, for the phenocryst olivines.

Subhedral to anhedral magnetite, ranging in size from 0.08 to 0.05 mm occurs as inclusions within olivine and pyroxene and as scattered subhedral crystals in the groundmass associated with the glass. The opaqueness is probably a function of the amount of included opaque oxides. Minor amounts of interstitial potassium feldspar and traces of feldspathoid (analcime?) have been seen in the groundmass. The presence of the feldspathoid was verified by methyl blue staining.

Calcite and opal represent secondary minerals introduced after crystallization of the primary minerals. They are found locally as vesicle fillings near the tops of the flows.

All samples examined appear to be essentially unaltered; however, in a few samples, especially near the top of the flows, evidence of minor alteration was noted. This consists of locally small brownish borders around some of the olivine phenocrysts (iddingsite?) and iron oxide stains from weathering of magnetite. Plagioclase and pyroxene appear to be quite fresh and unaltered.

PHENOCRYST MINERALOGY

The most distinctive characteristic of the individual Black Mountain-Santo Tomas flows is their phenocryst mineralogy. The mapping and identification of the individual flows was accomplished on the basis of their unique phenocryst mineralogy, as well as their relative topographic positions. Some flows, for instance flow 4 and flow 6 at Black Mountain, are rich in plagioclase and olivine, respectively, and can be identified megascopically. Other flows, although not as distinct megascopically, can be identified by determining the relative percentages of plagioclase, olivine, and pyroxene phenocrysts microscopically. Phenocryst mineral percentages, as well as the total rock mineralogy, were determined by point counting methods; five to six thin sections, per flow, were projected from a Bausch and Lomb microprojector onto a grid-ruled base. The mineral at each grid was identified and recorded; approximately 100 pheno cryst and 400 groundmass counts were made from each thin section. The individual percentages, per slide, were found to be reproducible within 5 percent.

At Black Mountain the six major basalt flows can be grouped into three compositional categories on the basis of phenocryst mineralogy (Table 1) : (1) Type A—flows rich in olivine phenocrysts, for instance, flow 1 (oldest) and flow 5. These flows average less than 20 percent phenocrysts of which almost 50 percent and 61 percent are olivine, respectively. Next in abundance is plagioclase followed by pyroxine. The abundance of olivine phenocrysts in flow 5 makes it a very distinctive flow megascopically. (2) Type B — flows rich in plagioclase, which are typical of flows 3, 4, and 6. In flow 4 and flow 6 the abundance of plagioclase, averaging 62 percent, is very distinct megascopically. Pyroxene is next in abundance, averaging 31 percent in flow 3, 20 percent in flow 4, and 28 percent in flow 6, followed by olivine which comprises approximately 18 percent of the phenocrysts in the three flows. (3) Type C—almost equal amounts of plagioclase and olivine phenocrysts with subordinate pyroxene; this is typical of flow 2 in which plagioclase and olivine average 42 and 38 percent of the phenocryst population respectively.

The single basalt flows at Little Black Mountain and San Miguel are typical of the type C flows with phenocrysts composed of approximately equal amounts of plagioclase and olivine with minor pyroxene (see Table 1).

At Santo Tomas the three flows, on the basis of phenocryst mineralogy, show correlation with all three phenocryst types. The youngest flow is plagioclase-olivine rich, averaging 45 percent each, and therefore belongs to the type C group. The oldest and intermediate flows are plagioclase and olivine-rich, respectively, and typical of types B and A (see Table 1) .

Very little variation in phenocryst or total rock mineralogy was detected within any one of the Black Mountain-Santo Tomas flows. Wherever a complete flow exposure was present at least three vertical samples were obtained and analyzed mineralogically, one each from the top and bottom vesicles zones and one from the more dense interior. In addition, samples were obtained at various places along the flows to check for the existence of lateral variations.

Small mineralogical variations can be seen in the San Miguel flow in which three to four samples were obtained and analyzed from each of six sections along the flow. The mineralogy of the phenocrysts in all zones of the flow is nearly constant with only a slight increase in total phenocrysts in the central, more dense portion of the flow (Hoffer, 1969b). A slight increase in phenocryst olivine and pyroxene and total olivine and pyroxene, with a corresponding decrease in plagioclase is observed in the central part of the flow. These variations could indicate a small amount of crystal settling; however, it is more likely that these variations are caused only by a longer period of crystallization in the more insulated interior of the flow. Significant lateral variations in mineralogy were not found within this flow, nor in any flow in the Black Mountain-Santo Tomas area.

TABLE 1. CLASSIFICATION OF FLOWS BASED ON MINERALOGY OF PHENOCRYSTS
(P — plagioclase, O — Olivine, and Py — pyroxene).

FLOW TYPES	BLACK MOUNTAIN	LITTLE BLACK MOUNTAIN	SAN MIGUEL	SANTOS TOMAS
A (olivine-rich)	Flow 1—P — 35% O — 47% Py — 18% Flow 5—P — 27% O — 62% Py — 11%			Flow 2—P — 21% O — 71% Py — 8%
B (plagioclase-rich)	Flow 3—P — 43% O — 26% Py — 31% Flow 4—P — 63% O — 17% Py — 20% Flow 6—P — 59% O — 13% Py — 28%			Flow 1—P — 51% O — 32% Py — 17%
C (plagioclase-olivine-rich)	Flow 2—P — 42% O — 38% Py — 20%	Flow 1—P — 45% O — 38% Py — 17%	Flow 1—P — 45% O — 48% Py — 7%	Flow 3—P — 45% O — 45% Py — 10%

Sequence and Age of Lava Extrusion

The sequence of the flows at Black Mountain and Santo Tomas has been established on the basis of topographic position. In addition, because of the distinctive phenocryst mineralogy of the flows within each of the four major areas a tentative correlation is attempted among the flows of these centers (see Fig. 4) .

The first extrusive activity of the area, represented by the oldest flow at Santo Tomas, is a flow rich in plagioclase phenocrysts. The second period of basalt extrusion produced a flow rich in olivine phenocrysts and is seen as the middle flow at Santo Tomas (flow 2) and oldest flow at Black Mountain (flow 1). These flows were followed by simultaneous eruption of plagioclase-olivine phenocryst basalt at all four centers. This third period of activity is represented by the youngest flow at Santo Tomas (flow 3), next-oldest flow at Black Mountain (flow 2), and the single flows at Little Black Mountain (flow 1) and San Miguel (flow 1). The two oldest flows at Santo Tomas have been dated by K-Ar at 2.35 ± 0.35 and 2.65 0.20 m.y. whereas the single flow at San Miguel gives a K-Ar age of 1.84 0.1 m.y. (Hawley and Kottlowski, 1969, Table II), thus giving support to the interpretation that the San Miguel flow is younger than the first two flows at Santo Tomas, based on phenocryst mineralogy correlations.

The later periods of extrusions were confined to the Black Mountain area where four successive basalt extrusions are present; these are represented by two flows rich in plagioclase phenocrysts (flow 3 and 4, respectively) a flow rich in olivine phenocrysts (flow 5), and the youngest flow with abundant plagioclase phenocrysts (flow 6). The youngest dated flow in the Black Mountain-Santo Tomas area is flow

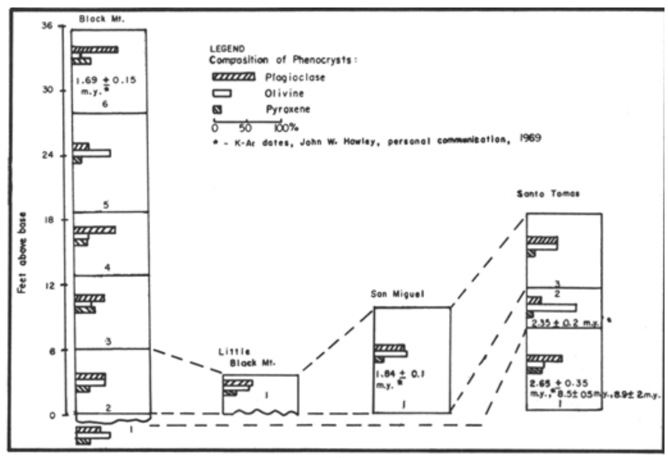

FIGURE 4.
Correlation of the Black Mountain, Little Black Mountain Santo Tomas, and San Miguel basalts.

6 at Black Mountain giving a K-Ar date of 1.69 ± 0.15 m.y. (Hawley and Kottlowski, 1969, Table II).

K-Ar dates on the Black Mountain-Santo Tomas basalts give ages ranging from 1.69 to 9.0 m.y. (see fig. 4). However, Hawley and Kottlowski (1969, Table II) report that vertebrate remains found in ancestral Rio Grande gravels in the upper Santa Fe Group that underlie the Black Mountain-Santo Tomas volcanics, show that the basalts should be middle Pleistocene or younger. Middle Pleistocene Irvingtonian vertebrate faunas should definitely be younger than 2.2 m.y. and possibly younger than 1.36 m.y. (Evernden and others, 1964). In addition, these gravels contain rounded rhyolite pumice fragments, which according to

Hawley (personal communication), were probably derived from an ash-fall unit within the Bandelier rhyolite tuff sequence in the Valles Caldera area of north-central New Mexico. The maximum age of this pumice would provide a maximum value for the age of the underlying upper Santa Fe Group gravel unit and provide a lower (older) limit on the age of the Black Mountain-Santo Tomas basalts.[1]

The 1.69 m.y. to 2.65 m.y. dates from the flows seem reasonable and fit the proposed sequence of units as proposed on the basis of phenocryst mineralogy. However, the 8.5 to 9.0 m.y. dates on flow 1 at Santo Tomas flow seem unreasonable, since a 2.65 0.35 m.y. has also been found for the same flow. Further K-Ar dating on the La Mesa basalts is in progress (Hawley, personal communication).

SUMMARY AND CONCLUSIONS

The volcanic features of the Black Mountain-Santo Tomas area consist of basaltic cinder cones, spatter-driblet cones, and alkaline olivine basalt flows.

Three major types of olivine basalt have been identified on the basis of phenocryst mineralogy: Type A—phenocrysts predominantly of olivine; Type B— phenocrysts rich in plagioclase; and Type C—phenocrysts of approximately equal amounts of plagioclase and olivine.

On the basis of phenocryst mineralogy, correlations have been made with the flows among the four centers which indicate seven major periods of basalt extrusion. The first period of basalt eruption is represented by the oldest flow at Santo Tomas. The second period is expressed by the middle basalt at Santo Tomas and the oldest flow at Black Mountain. The youngest flow at Santo Tomas, next to oldest basalt at Black Mountain and the single flows at San Miguel and Little Black Mountain represent the third period of extrusion. The fourth through seventh periods are represented by flows 3 through 6 at Black Mountain, respectively.

The K-Ar ages and dates from vertebrate remains in sediments underlying basalts, although giving somewhat conflicting ages, indicate general Pleistocene age for the Black Mountain-Santo Tomas basalts.

1. Robert Smith, Roy Bailey and G.B. Dalrymple of the U.S. Geological Survey are currently working on the Bandelier Tuff. Their intensive studies include K-Ar age measurements.

ACKNOWLEDGMENTS

Thanks are expressed to Dr. John W. Hawley, U.S. Department of Agriculture, University Park, New Mexico for helpful discussions and reading of the manuscript. Appreciation is also expressed to D. F. Stahmann and John Chandley, of Stahmann Farms, Inc., for access to the Santo Tomas area.

Funds for the investigation were furnished by a University Research Institute Grant, 1968-69, University of Texas at El Paso.

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East Potrillo Range and La Mesa surface in foreground and middleground; Mt. Riley to right and West Potrillo Volcanic Hills in near distance. Air photo NW from 8000 feet by Sherman A. Wengerd.