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1982, pp. 279-284. https://doi.org/10.56577/FFC-33.279

in:

Albuquerque Country II, Wells, S. G.; Grambling, J. A.; Callender, J. F.; [eds.], New Mexico Geological Society 33 rd Annual Fall Field Conference Guidebook, 370 p. https://doi.org/10.56577/FFC-33

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TECTONIC SETTING AND HISTORY OF LATE-CENOZOIC VOLCANISM IN WEST-CENTRAL NEW MEXICO

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INTRODUCTION

Extensive late-Cenozoic basaltic volcanism occurred in west-central New Mexico along the central portion of the Jemez lineament (Mayo, 1958). Although the Jemez lineament is usually defined by the northeast-trending (N52°E) alignment of volcanic fields extending from the San Carlos—Peridot area of Arizona in the southwest to the Raton-Clayton area in northeastern New Mexico, our work has concentrated on that portion of the lineament between the Arizona border and Grants, New Mexico. This portion of the lineament is made up of two concentrations of volcanic centers: the Zuni-Bandera field south of Grants and a cluster of small fields in northwestern Catron County (fig. 1). The map of Luedke and Smith (1978) distinguishes about 200 individual vents within the two fields; flows from these vents cover approximately 3,290 km'.

During the past decade, interest has grown in the tectonics and volcanism of this region. New structural, petrological, geochemical, geophysical, and geochronological data have been reported, and integration of these data is in progress. This paper is a progress report.

TECTONIC SETTING

Mayo (1958) originally defined the Jemez lineament to include a northeast-trending trough in southern Colorado, the Jemez Mountains volcanic field (Valles Caldera), Mount Taylor, and the northwestern border of the Datil volcanic field. Since then most workers have defined the lineament on the basis of the alignment of late-Cenozoic volcanic fields (Suppe and others, 1975; Laughlin and others, 1976; Chapin and others, 1978; Ander, 1980; and Aldrich and others, in press). If the location of volcanic centers is used to define the lineament, then it is approximately 50 km wide between the Arizona border and Grants.

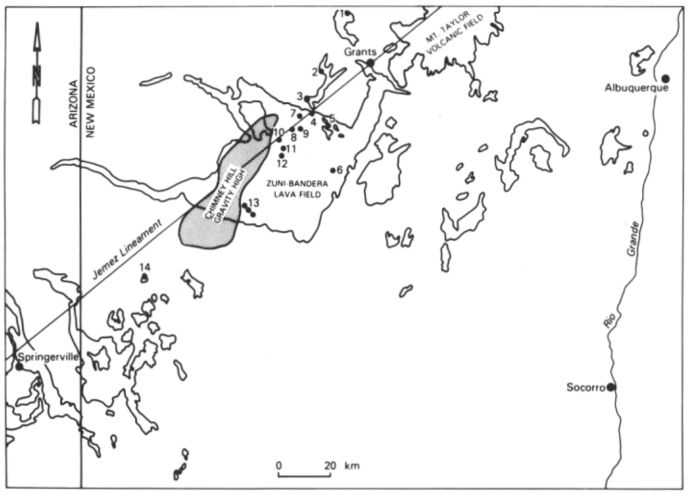

Figure 1. Index map of volcanic rocks of west-central New Mexico. Significant vents are identified by number: (1) El Tintero, (2) Cerro Colorado, (3) Paxton Springs, (4) Bandera Crater, (5) El Calderon, (6) McCartys, (7) Cerrito Arizona, (8) Cerro Negro, (9) Cerro Hueco, (10) Cerro Piedrita, (11) Cerro Lobo, (12) Cerro Chato, (13) Cerros de las Mujeres, and (14) Zuni Salt Lake.

Tectonic and structural control of lineament volcanism is evident at several scales. The lineament is one of a series of northeast-trending shear zones which cross New Mexico and southern Colorado (Chapin and others, 1978). This shear system, in turn, is believed to be part of a larger system of major northeast-trending mineral belts in the western United States (Landwehr, 1967). Landwehr (1967) suggested that these belts have a common geologic history and structure, originating in response to a regional left-lateral shear during the Precambrian. These shear zones have since acted as loci for repeated crustal adjustment in response to later regional stresses. He also suggested a genetic relationship between the formation of crustal magma reservoirs, from which mineralizing fluids were derived, and crustal rupture associated with shearing. Aldrich and Laughlin (1981a, b) cited evidence for early Laramide left-lateral motion along the Jemez lineament.

Numerous workers (Lipman and Mehnert, 1979; Ander, 1980; Chapin and Cather, 1981; and Aldrich and others, in press) have noted the approximate coincidence of the Jemez lineament and the boundary between Precambrian age provinces (Silver, cited in Cordell, 1978; Van Schmus and Bickford, 1981). The northeast-trending, Precambrian-age boundary predates the activation of the shear system, and the boundary may have acted as a zone of weakness, focusing volcanism along the Jemez lineament during Cenozoic time.

A number of lines of evidence indicate that structural flaws associated with the Jemez lineament penetrate the lithosphere to great depths. Laughlin and others (1971), Kudo and others (1972), and Laughlin and West (1976) discussed the strontium-isotopic and petrologic evidence for mantle derivation of the Zuni-Bandera basalts and the ultramafic inclusions found at Bandera Crater and in the Puerco volcanic necks. Preliminary results of a teleseismic P-wave delay study indicate that the Jemez lineament, from the Zuni-Bandera volcanic field to the Jemez Mountains, is associated with a seismic low-velocity zone 25-to-140 km deep and 5-to-120 km wide (Spence and others, 1979; W. Spence, personal commun., 1980). Results of both a detailed magnetotelluric/audiomagnetotelluric (MT/AMT) sounding survey and a regional MT sounding survey indicate that the Jemez lineament is also associated with a zone of extremely shallow electrical conductivity within the crust (Ander, 1980; Ander and others, 1980a, b). The detailed survey, covering 161 km' near the town of Zuni on the Zuni Indian Reservation, consisted of 119 AMT soundings and 25 MT soundings. The regional MT survey consisted of 56 MT soundings spaced along four profiles crossing the Jemez lineament. The soundings penetrated well into the upper mantle. The high electrical conductivity associated with the Jemez lineament is believed to be caused by the presence of interstitial magma within the crustal rocks.

Recently, attention has been focused on the nature of the boundaries of the Colorado Plateau. Citing a variety of geophysical, structural, and physiographic evidence, workers have suggested that the northwestern, southwestern, southeastern, and eastern boundaries are being encroached upon or consumed by the Basin and Range and Rio Grande rift provinces. Kelley (1979) suggested that the Rio Grande rift represents a foundered eastern boundary of the plateau. Keller and others (1979) cited seismic evidence for thinner, Basin and Range type crust extending 100 km into the plateau on the northwestern and southwestern boundaries and suggested "that zones of extension (rifting?) bounding the plateau appear to be growing at the plateau's expense." Thompson and Zoback (1979) also noted the extension of Basin and Range and Rio Grande rift geophysical characteristics 50 to 100 km into the plateau. In addition, they found different stress field orientations between the interior of the plateau and the surrounding Basin and Range and Rio Grande rift provinces.

A similar encroachment of Basin and Range extension into the Colorado Plateau in western New Mexico is now becoming well documented. Based upon a geophysical study of lithospheric thinning beneath the central Rio Grande rift and the adjacent Colorado Plateau in New Mexico, Ander (1980, 1981, in press) suggested that recent northwest migration of the Basin and Range province boundary has made the Colorado Plateau boundary coincident with the Jemez lineament. Ander showed that the region southeast of the Jemez lineament, containing classical Colorado Plateau physiography, has a thinned lithosphere resembling that of the Basin and Range Province, and he correlated this with elevated heat flow (Reiter and others, 1975) and with changes in the stress field (Thompson and Zoback, 1979; Zoback and Zoback, 1980). Stress studies by Zoback and Zoback (1980), Aldrich and Laughlin (1981a, b, 1982), and Aldrich and others (in press) indicate that changes in stress orientation exist across the lineament. From these data, Aldrich and Laughlin (1981b) also suggest that the Jemez lineament is the present tectonic boundary between the Colorado Plateau and Basin and Range provinces. Recent geologic mapping by Baldridge and others (1981, 1982) indicates that the region of classical physiographic Colorado Plateau just south of the Jemez lineament contains large horst and graben blocks of Miocene or younger age characteristic of the Basin and Range province. Lipman and Mehnert (1979) recognized north-northeast-trending Basin and Range faulting near Mt. Taylor concurrent with a 3.0-2.5 m.y. peak in volcanic activity.

On a smaller scale, foliation in Precambrian metamorphic rocks of the Zuni Mountains generally strikes northeast to east-northeast (Goddard, 1966). Results of the detailed MT/AMT survey (Ander, 1980; Ander and others, 1980a, b) indicate an electrical strike direction of approximately N60°E within the Precambrian basement rocks, a trend almost parallel to the strike of the gneissic foliation and of the Jemez lineament (N52°E). Electrical strike directions measured away from the Jemez lineament by the regional MT study also indicate that a northeast strike pervades the entire crust. This suggests that the orientation of the Jemez lineament may have been guided by the fabric of the deeper Precambrian rocks.

Gravity modelling (Ander, 1980; Ander and others, 1981; Ander and Huestis, in press) indicates that the Zuni-Bandera volcanic field is localized by a shallow mafic intrusion. This intrusion is marked by a large, positive, north-northeast-trending gravity anomaly, 90 km long and 30 km wide, extending southwest from the Zuni uplift. Most of the basaltic vents coincide with the eastern edge of the intrusive body. Gravity analysis indicates that the top of the body is no deeper than 3.5 km.

VOLCANISM

Description of the Zuni-Bandera Volcanic Field

Research to date has concentrated on the basalts of the Zuni-Bandera volcanic field; work on the Catron County fields is still incomplete (Vaniman and Laughlin, in preparation). In scope, the investigations have ranged from the morphological studies of Nichols (1946) and Hathaway and Herring (1970) to recent field, petrologic, chemical, isotopic, and geophysical studies by workers at the University of New Mexico, New Mexico Institute of Mining and Technology, Kent State University, and the Los Alamos National Laboratory. An extensive bibliography is given in Ander and others (1981).

Within the Zuni-Bandera held, the volcanic centers are largely oriented N38°E with the exception of two centers in the Zuni Mountains that lie on north-trending faults (Goddard, 1966), and a N52°W alignment of cones near the southeast end of the Zuni uplift that includes the cones of Bandera Crater, La Tetera, Cerro Candelaria, and El Calderon. The north-northeast direction is also reflected in the well-defined elongation of many cones and spatter ramparts. Most eruptions began along fissures that are parallel to north-northeast-trending normal faults. The orientations of these elongations were measured to provide additional structural information and the results show a distinct north-northeast maximum oblique to the Jemez lineament (fig. 2) (Ander and others, 1981). The cone elongations are parallel to recent faults in the southern Zuni lava field (Baldridge and others, in preparation) and to north-northeast-trending faults near Mt. Taylor (Lipman and Mehnert, 1979).

As a general rule, tholeiitic fissure eruptions preceded central vent eruptions. Because the axis of the Jemez lineament in this region is roughly coincident with the Continental Divide, the flows followed drainages away from the divide, sometimes for great distances. For example, the Fence Lake basalt flowed approximately 90 km to the west. On the eastern side of the field the McCartys tholeiitic lava flow and underlying Laguna flows drained north along a valley parallel to the Continental Divide. The McCartys flow turns to the east, continuing down the valley of the Rio San Jose for a total distance from vent to distal end of 50 km. Interstate 40 follows and crosses this flow in many places (see Maxwell, this guidebook).

Vent types within the Zuni-Bandera volcanic field include simple cinder cones, spatter cones and ramparts, small shields, maars, and collapse pits. These vents erupted both tholeiitic and alkalic lavas and tephra. Descriptions of individual vents within the Zuni-Bandera field are given in Ander and others (1981).

Petrology of Flows

Detailed petrologic studies have been completed on the McCartys flow (Carden and Laughlin, 1974), on the Paxton Springs and Cerro Colorado flows (Dellechaie, 1973), and on flows from the Cerro Negro—Cerrito Arizona chain (Gawell, 1975). Ander and others (1981) present a summary of petrologic data from many of the individual flows within the field.

As might be expected from the large number of individual flows, there is a considerable variation in basaltic lava types and textures. In general, the rocks are aphanitic to microporphyritic. Where micropor-

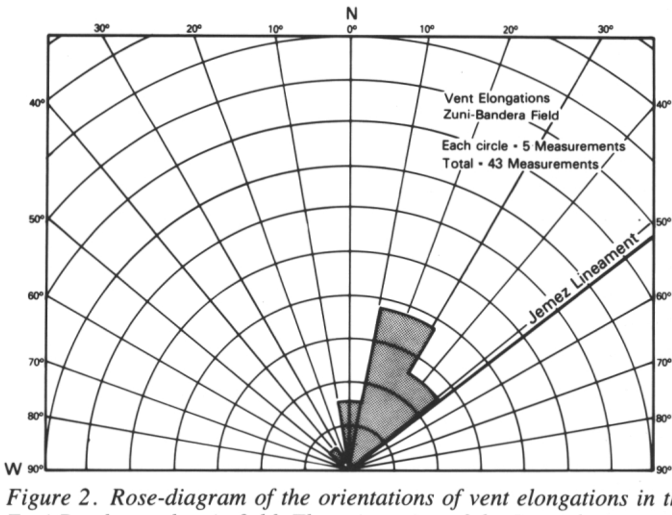

Figure 2. Rose-diagram of the orientations of vent elongations in the Zuni-Bandera volcanic field. The orientation of the Jemez lineament is shown for comparison.

phyritic or porphyritic textures occur, plagioclase and/or olivine are the typical phenocryst phases. Clinopyroxene phenocrysts are less common. Large plagioclase phenocrysts characterize basalts from the Cerro Chato—Cerro Lobo cluster, the older basalts from Cerro Rendija, many of the North Plains basalts, and samples from near the McCartys vent. Groundmass constituents are olivine, plagioclase, clinopyroxene, and tachylite, commonly dusted with very fine-grained opaque minerals. Frequently, the tholeiitic basalts can be distinguished from alkaline basalts by diktytaxitic textures.

Samples from three representative cones describe the typical mineralogy of these basalts. The first cone is Cerro Piedrita, a nepheline-normative lava with abundant olivine and plagioclase phenocrysts and minor pale-green clinopyroxene phenocrysts. The second is Cerro Hueco, an olivine-hypersthene normative basalt with only rare olivine phenocrysts. The last is Cerro Lobo, a quartz-normative tholeiite with plagioclase and resorbed olivine phenocrysts.

The Cerro Piedrita nepheline-normative basalts contain olivine phenocrysts that range in composition from Fo„ to Fon. The olivine cores in this alkaline basalt are more Mg-rich than the equilibrium olivine (Fo82) that would be expected to crystallize from the host-rock composition. This disparity suggests that incomplete olivine fractionation has led to the low Mg/(Mg + Fe) ratio (0.59) in this basalt, leaving some remnant Mg-rich olivine cores precipitated from the original liquid. Pyroxene phenocrysts occur in two populations: (1) large grains (>0.5 mm) with pale green to green-brown pleochroism and (2) smaller sector-zoned crystals. Both pyroxene types are chrome-free diopsides (Wo46En42Fs,2; 001-sectors of the sector-zoned grains are Wo„En,Fs,())• The larger phenocrysts, however, have higher titanium, aluminum, and sodium contents than the smaller sector-zoned phenocrysts and microphenocrysts, suggesting earlier crystallization of the larger grains. Plagioclase phenocrysts range from An„ to An„ in composition, with more sodium-rich plagioclase (An65.50) in the groundmass along with very fine-grained anhedral alkali feldspar.

The Cerro Hueco olivine-hypersthene normative basalt has a composition near the alkaline-tholeiitic basalt divide of Macdonald and Katsura (1964). This basalt can be classified as a hawaiite. As with the alkaline basalt of Cerro Piedrita, the olivine phenocryst cores (Fo„) of samples from Cerro Hueco are too Mg-rich to be in equilibrium (Fo8,) with the host rock Mg/(Mg + Fe) ratio of 0.58. Again, incomplete olivine fractionation is indicated. Clinopyroxenes (Wo95En25Fs20) are very rarely seen in the groundmass, and the plagioclase laths of the groundmass range from An„ to An58. Anhedral alkali feldspars occur with the late-stage clinopyroxenes.

The resorbed olivine phenocrysts (Fo78) in the quartz-normative tholeiite of Cerro Lobo are in equilibrium with the host-rock composition of Mg/(Mg + Fe) = 0.50. This equilibrium relationship suggests re-equilibration as well as resorption. Orthopyroxene does not occur in the groundmass of this sample, and small anhedral clinopyroxenes are very rare. Plagioclase laths and microphenocrysts may have relict cores of An„ to An„, but they have typical rim compositions of Ans, to Ar146.

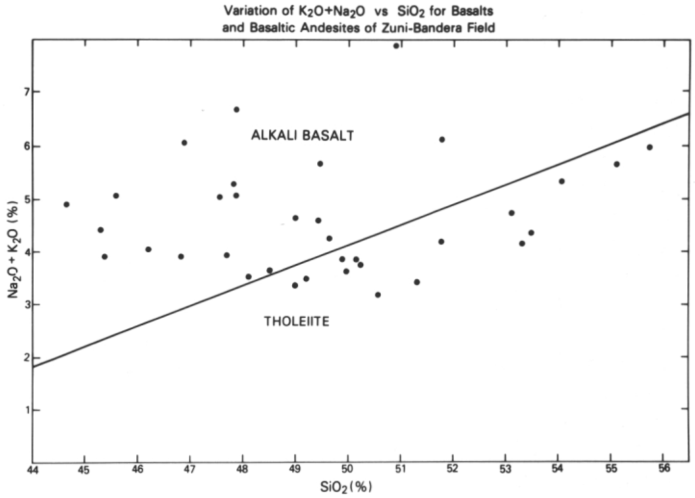

Figure 3. Harker variation diagram for basaltic volcanic rocks of the Zuni-Bandera volcanic field.

Xenoliths of sandstone and xenocrysts of quartz are fairly common in many of the flows and in the tephra. These xenoliths are typically rimmed by clinopyroxene. At Bandera Crater, volcanic bombs contain inclusions of sandstone, anorthoclase, jasper, granite, gabbro, and a variety of ultramafic rocks (Laughlin and others, 1971). The ultramafic inclusions are discussed below.

The volcanic rocks of the Zuni-Bandera field exhibit a wide range in chemical compositions. Particularly large ranges occur in the Si02, MgO, K20, and TiO2 contents. In Figure 3, the variation of total alkalies with Si02 indicates a continuum in compositions from low-SiO, alkali basalts through tholeiitic basalts to basaltic andesites (SiO, > 54%). The basalt chemistry is summarized in Ander and others (1981) and more briefly in Table 1.

Laughlin and others (1972) and Brookins and others (1975) examined the variation in "Sr/"Sr ratios along the McCartys flow and found a range from 0.7037 to 0.7081. They were unable to correlate the vari- ation with distance from the vent, whole-rock chemistry, or the fre- quency of xenoliths in the flow and concluded that the contamination resulted from incorporation of small amounts of crustal material with very high "Sr/"Sr ratios. Other basalt samples from the Zuni-Bandera field have "Sr/"Sr ratios of 0.7031 to 0.7046 (Laughlin and others,

Table 1. Representative compositions of basaltic rocks of the Zuni-Bandera volcanic field.

Vent or Flow	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	Total	Reference
Bandera Crater	44.47	15.22	4.39	8.42	9.30	8.80	3.38	1.60	3.04	0.15	0.58	99.35	Laughlin and others, 1972
McCartys Crater	49.93	16.62	1.54	9.25	8.45	8.90	2.89	0.75	1.38	0.17	0.25	100.13	Renault, 1970
Cerro Piedrita	47.83	14.97	11.3		8.83	8.95	3.86	1.44	2.16	0.17	0.52	100.06	Ander and others, 1981
Cerro Hueco	49.75	15.41	11.7		8.43	8.69	3.36	0.91	1.63	0.17	0.42	100.35	Ander and others, 1981
Cerro Lobo	53.11	16.79	11.07		5.44	8.61	3.69	1.06	1.70	0.16	0.33	101.96	Ander and others, 1981
Cerro Colorado (North flow)	45.4	14.5	10.4		10.3	9.6	3.28	1.62	2.19	0.18	--	97.47	Dellechaie, 1973
Paxton Springs (South flow)	45.6	15.6	10.8		9.13	9.29	3.46	1.62	2.75	0.23	--	98.48	Dellechaie, 1973
Cerros de las Mujeres	50.89	10.56	8.4		9.31	8.94	3.30	4.57	2.30	0.13	1.05	99.42	Ander and others, 1981
Fence Lake Flow	50.22	15.25	1.62	10.01	8.40	9.30	2.64	0.42	1.34	0.17	0.16	100.05	Laughlin and otHers, 1979

1972). Crustal contamination in general is indicated by an inverse correlation between "Sr/"Sr ratio and total Sr content.

Significant variations in whole rock composition occur within some of the individual flows and between samples from centers along cone alignments. Carden and Laughlin (1974) showed that basalts from near the McCartys vent are quartz-normative tholeiites, while at distances greater than 4 km from the vent samples are olivine-normative tholeiites. Gawell (1975) examined chemical variations among samples from centers along the Cerro Negro—Cerrito Arizona cinder-cone chain, finding a gradual change from alkalic to tholeiitic basalts from southwest to northeast. This change correlates with an apparent decrease in age (based on geomorphological evidence) to the northeast. At the Paxton Springs and Cerro Colorado centers, however, there are no consistent patterns of variation with space or time (Dellechaie, 1973). Flows from the Cerro Colorado center and the southern flow from the Paxton Springs volcano are chemically homogeneous, while the northern flow or flows from Paxton Springs are more heterogeneous.

Ultramafic Inclusions from Bandera Crater

Cinder pits on the north side of Highway 53 adjacent to Bandera Crater contain many small, cored volcanic bombs. Laughlin and others (1971) and Gallagher (1973) described the ultramafic rocks that make up a large percentage of the cores in these bombs. These inclusions are typically about 4 cm in diameter, but a few as large as 12 cm in diameter have been found. In shape, they vary from rhombohedral or rectangular to well-rounded blocks. The basalt coatings of the inclusions range in thickness from several centimeters to about 1 mm. In the latter case, the basalt coating resembles a coat of black paint over the inclusion.

Megascopically, two general groups of ultramafic inclusions can be distinguished. One group is bright green and contains red spinel. The second is gray-green or steel gray and contains green spinet. The red spinel-bearing inclusions range in composition from dunite to lherzolite and the green spinel-bearing inclusions range from websterite to lherzolite. Gallagher (1973) described one layered inclusion that consists of a 3-cm-thick red spinel-bearing layer and a 1-cm-thick green spinel-bearing layer.

The red spinel-bearing inclusions typically contain more than 70 percent olivine, and more than 95 percent of the rock is formed of olivine, clinopyroxene, and orthopyroxene. In addition to red spinel, which is characteristic, phlogopite is present in some samples. The olivine occurs as 0.5-1.0 mm xenoblastic grains that form a tight mosaic between grains of pyroxene. Triple-point junctions of 120° are common among olivine grains, indicating solid-state recrystallization. The compositional range of olivine is F089-92. Onhopyroxene (E1186-89) makes up 10 to 20 percent of these inclusions and chrome-rich diopside occurs

Table 2. Summary of K-Ar ages of late-Cenozoic basaltic rocks of west-central New Mexico.

Location	Rock Type, Comments, Sample No.	Age (m.y.)	Reference
34° 44'55"N 108° 21'55"W	Olivine tholeiite from Fence Lake flow. FL-3-74	1.41 ± 0.29	Laughlin and others, 1979
35° 05'12"N 108° 44'18"W	Olivine tholeiite near Black Rock, N.M. Flowed west down Zuni River Valley. BR-2-74	0.700 ± 0.550	Laughlin and others, 1979
35° 00'36"N 108° 05'47"W	Alkali basalt. Overlies San Andreas limestone and underlies Bandera Crater. B-1-74	0.199 ± 0.042	Laughlin and others, 1979
35° 07'31"N 107° 47'33"W	Tholeiite. Flow underlies McCartys basalt in Rio San Jose valley, 5 km east of Grants. AWL-2-77	1.570 ± 0.260	Laughlin and others, 1979
34° 56'02"N 108° 07'30"W	Plagioclase-rich basalt. Underlies Cerro Rendija.	3.80 ± 0.40	Ander and others, 1981
34° 41'54"N 108° 02'30"W	Plagioclase-rich basalt. Hummocky flow of North Plains.	3.70 ± 0.40	Ander and others, 1981
34° 47'10"N 108' 16'53"W	Flow from Cerro Alto. Olivine tholeiite basalt.	1.50 ± 0.30	Ander and others, 1981
34° 45'48"N 108° 10'40"W	Flow from Cerro Brillante. Olivine tholeiite basalt.	0.940 ± 0.400	Ander and others, 1981
34° 39'28"N 108° 20'00"W	Cerros de las Mujeres Plug. Basalt	16.7 ± 0.8 15.5 ± 0.8 17.0 ± 0.8	Ander and others, 1981

in abundances up to 10 percent. The red spinel occurs as xenoblastic grains up to 1.5 mm in diameter, often with opaque borders. Phlogopite may be present either as sub-idioblastic grains or as fracture fillings.

Green spinel-bearing inclusions usually contain less than 10 percent olivine; orthopyroxene ranges from 9 to 70 percent and clinopyroxene from 8 to 87 percent. Kaersutite has been observed in amounts up to 15 percent. Petrographic and microprobe evidence indicate the presence of two generations of olivine, larger grains with Fo83_84 and small grains with Fo85,87. The orthopyroxene has a composition of and the clinopyroxene is chrome diopside. Texturally, the green spine' inclusions contain more voids than the red spinel inclusions and there is abundant evidence of shearing and alternation.

Laughlin and others (1971) reported "Sr/"Sr ratios of 0.7045-0.7055 for the red spinel-bearing inclusions, 0.7023-0.7040 for the green spinel-bearing inclusions, and 0.7028-0.7034 for the host basalt.

Age of Volcanism

A summary of the K-Ar ages of the volcanic rocks is presented in Table 2. The older ages obtained on one of the Cerros de las Mujeres plugs (ultrapotassic shonkinites) represent a part of the mid-Tertiary volcanism of southwestern New Mexico (Elston and others, 1976). The Mujeres plugs are more closely related to the Colorado Plateau ultrapotassic suite (Roden and others, 1979). In any case, these rocks are considerably older than the Plio-Pleistocene basalts of the Zuni-Bandera field and they are also chemically different from these younger basalts.

The alkalic and tholeiitic basalts of the Zuni-Bandera lava field are all younger than 3.8 m.y. Major tholeiitic volcanism occurred at about 1.5 my. as evidenced by dates of the Fence Lake flow, the Laguna flow of Nichols (1946) and Laughlin and others (1979), and for Cerro Alto and Cerro Brillante (Ander and others, 1981). Because of the large error on the age, the tholeiitic flow sampled at Black Rock near Zuni is essentially coeval. These flows are also almost identical in composition. The youngest K-Ar age (199,000 years) was obtained on an alkalic basalt from a flow under Bandera Crater. Interpretation of Landsat images suggests that this flow is considerably older than the flows from Bandera. Nichols (1946) reported an archeological age of about 700 A.D. for the McCartys flow. Comparison of the degree of weathering and erosion of the McCartys flow, the flows from Bandera Crater, and the flows underlying the crater suggests that Bandera Crater is probably much closer to 1,000 years in age than to 200,000 years.

SUMMARY

In west-central New Mexico the Jemez lineament has localized late-Cenozoic basaltic volcanism. A wide range of basaltic compositions was erupted during the past 4 m.y., producing a variety of volcanic landforms and covering large areas with flows. Although strontium-isotopic evidence indicates that some of the flows were contaminated by crustal material, the amounts assimilated were small and had little effect on whole-rock chemical compositions. Mineral chemistry suggests that olivine fractionation was the dominant factor in modifying basalt compositions.

The Jemez lineament is one of a series of northeast-trending lineaments that cross the western United States. These structures apparently first developed during Precambrian time and have since been repeatedly reactivated. The Jemez lineament is approximately coincident with the boundary between 1.7 b.y. and 1.6 b.y. Precambrian provinces and is parallel to the foliation in Precambrian metamorphic rocks of the region. Geophysical and structural evidence indicates that the lineament is the present boundary between the Colorado Plateau and Basin and Range provinces and that this boundary has moved northwestward with time.

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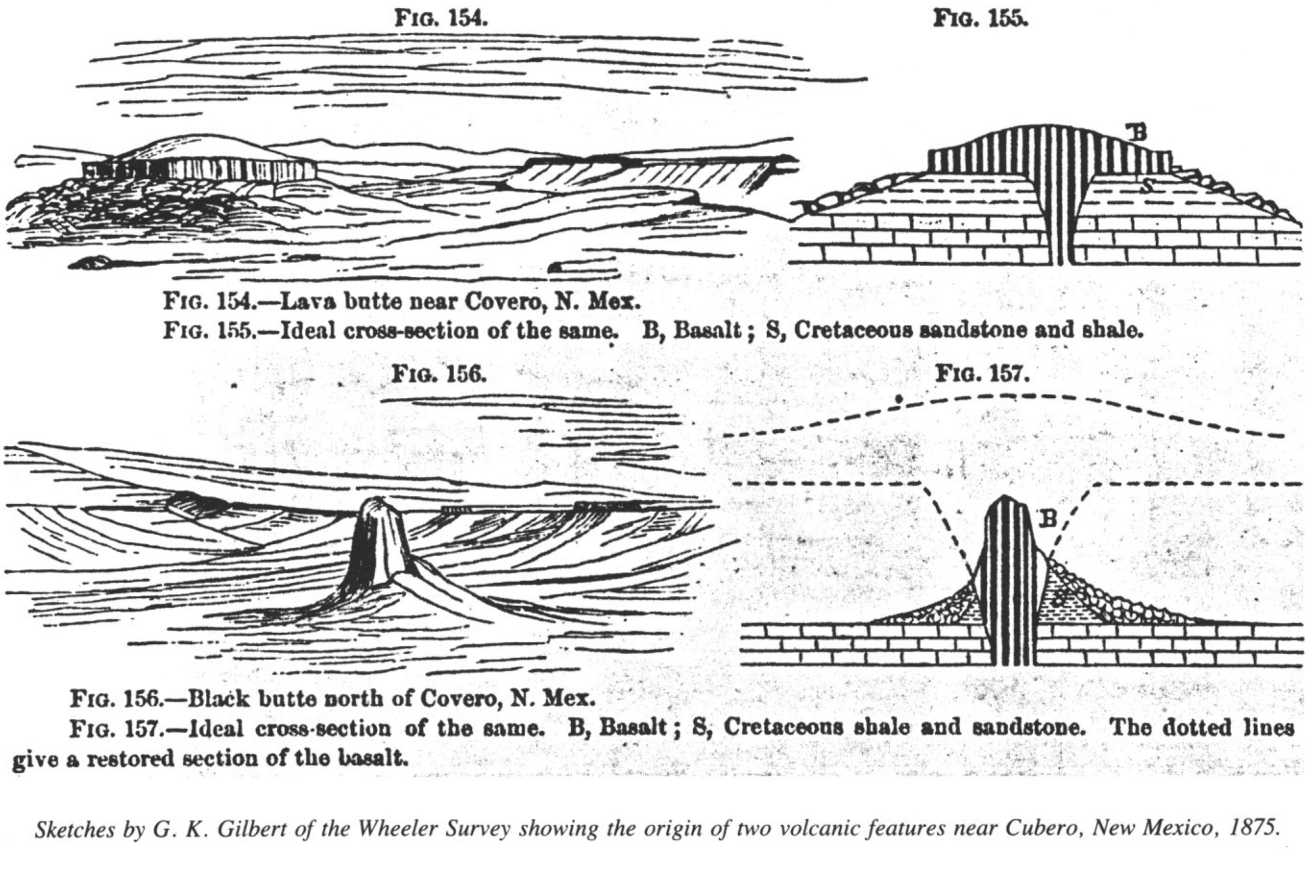

Sketches by G. K. Gilbert of the Wheeler Survey showing the origin of two volcanic features near Cubero, New Mexico, 1875.