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RIFT VOLCANICS OF THE ALBUQUERQUE BASIN: OVERVIEW WITH SOME NEW DATA

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INTRODUCTION

This paper summarizes and describes volcanic rocks and features of the Albuquerque basin. Although most of the data come from a review of publications (Aoki and Kudo, 1976; Kelley and Kudo, 1978; Baldridge, 1979; Zimmerman and Kudo, 1979), new data also are presented. Three major volcanic fields, the San Felipe, Albuquerque, and Cat Hills, and approximately eleven other small centers occur in the basin (fig. 1). The greatest volume of material erupted is basalt, both olivine tholeiite and hypersthene-normative alkali basalt with a characteristically high-Al_2O_3 content; however, calc-alkalic high-K andesite, and very minor syenite and rhyolite are present. The oldest exposed volcanic centers may be at Black Butte at the southern end of the basin, at 24 my. (Bachman and Mehnert, 1978), and at Mohinas—Hidden Mountain (no date available) on the west side of the basin and west of the Lucero uplift. The youngest volcanic feature is Cat Hills, dated at 140,000 years (Kudo and others, 1977).

Geomorphically, not a great variety of volcanic features are found in the basin. Volcanoes are generally small, but such features as shield and cinder cones, cone sheets, maar craters-diatremes, and lava-capped mesas are common. Cinder cones at Cat Hills are truly outstanding, displaying symmetrical hills topped by shallow summit craters. Lava flows are intermediate between aa and pahoehoe.

In the following sections, volcanic features are treated in chronological order. Where new data are available for some centers, these are presented in some detail; otherwise, only a summary is given. This paper attempts to redefine conditions for magma generation within the rift.

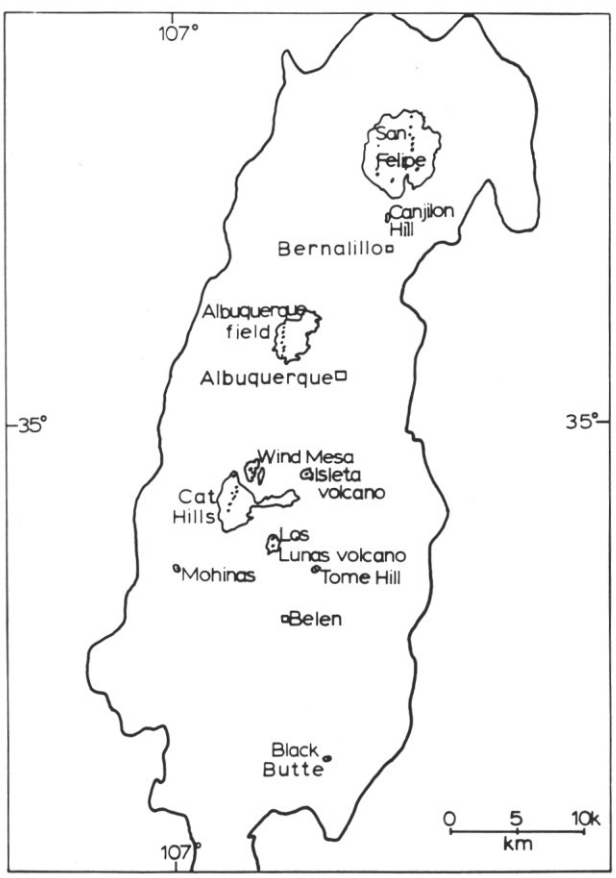

Figure 1. Location of major volcanic features in the Albuquerque basin (outlined by dark heavy lines). From Kelley and Kudo, 1978.

BLACK BUTTE

The oldest volcanic feature occurs in the southern Albuquerque basin, 11 km east of the Rio Grande and south of U.S. 60 (fig. 1). It has been dated by Bachman and Mehnert (1978) to be 24.3 my. Rising over 100 m above the surrounding plain, Black Butte is either a plug dome or an exhumed volcano which probably existed prior to deposition of the Santa Fe Group. A porphyritic and aphyric andesite with plagioclase, augite, and minor hypersthene and olivine occurs with flow-banded rhyolite. These rock types are typical of the early rift.

MOHINAS AND HIDDEN MOUNTAINS

About 25 km west of Los Lunas and south of the junction of Carrizo Arroyo and the Rio Puerco, Hidden and Mohinas mountains consist of alkali basalt and olivine diabase intrusions into Santa Fe sandstone and mudstone (fig. 1). The basalt contains plagioclase and olivine phenocrysts in a matrix of titaniferous augite, plagioclase, olivine, and opaques. The basalt is nepheline normative (fig. 2; Table 1). A syenite dikelet composed of sanidine and interstitial augite, hornblende, and opaques is slightly nepheline normative also (fig. 2; Table 1) with high alkalis (12.05 percent) and normative wollastonite.

TOME HILL

About 8 km south of Los Lunas and 1.5 km east of N.M. 47, Tome Hill stands over 100 m above the floodplain (fig. 1). Tome Hill, now a dome-shaped feature, was probably a larger extrusive volcanic area. It is dominated by a series of cross-cutting dikes and several cone sheets. Bachman and Mehnert (1978) reported an age of 3.5 m.y. The rocks at Tome Hill are typical calc-alkalic high-K andesites with SiO_2 ranging from 56.96 in the older rocks to 62.39 percent in the youngest (fig. 2). Typical phenocrysts are plagioclase with minor augite, hypersthene, and hornblende. Numerous xenoliths of Santa Fe sediments, as well as Precambrian granites and gneisses, are common occurrences in the early andesites. Excellent maps, chemical and mineralogical data, and Sr-isotopic data can be found in Kasten (1977). Zimmerman and Kudo (1978) have published some microprobe data on these andesites. These authors demonstrate that fractional crystallization plus or minus contamination can explain the diversity.

WIND MESA VOLCANO

Wind Mesa volcano is a small shield volcano about 10 km west of the Isleta volcano (fig. 1). Although no age has been reported, this volcano is probably younger than Tome Hill but older than the Isleta eruptions. It has been cut by numerous north-south block faults which

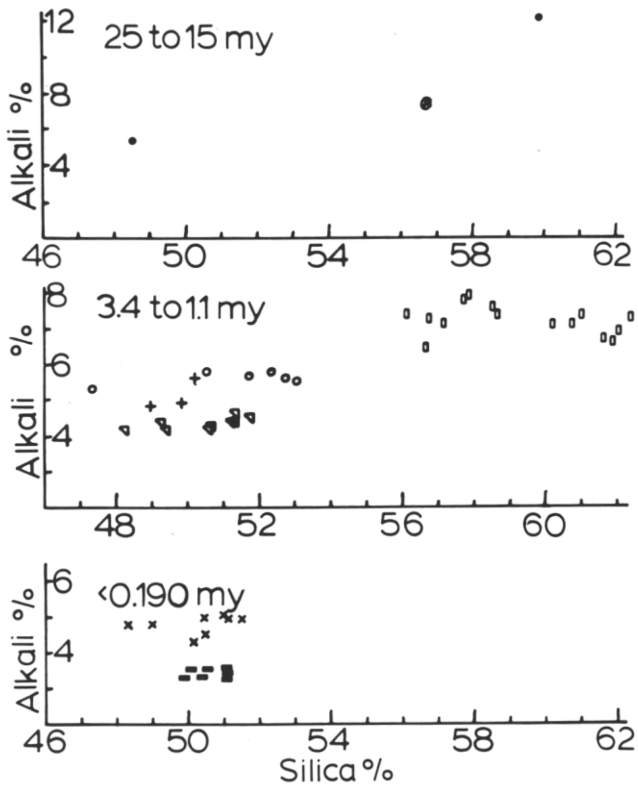

Figure 2. Alkali-silica plot of basalts and andesites of the Albuquerque basin according to ages. Data from Baldridge (1979), Kasten (1977), Kelley and Kudo (1978), and this report.

formed a dominating central graben. Kelley and Kudo (1978) reported one analysis with over 52 percent Si02. An analysis of their youngest flow (Table 1) indicates an alkali-rich basalt with 47.34 percent Si02. Rather than differentiating to a more silicic composition as inferred from the petrography by Kelley and Kudo (1978), the opposite is indicated. This appears to be supported by the data given by Baldridge (1979), although it is uncertain where his samples were collected (fig. 2). Chemically, these samples appear related to Cerros del Rio, El Alto, and Group C of Baldridge (1979).

ISLETA VOLCANO

Isleta volcano is a compound volcano composed of a basal maar crater overlain by several flow units (fig. 1). This volcano hs been dated at 2.78 m.y. by Kudo and others (1977). The basalt composing the volcano is alkali-rich and hypersthene normative, but it appears to become slightly nepheline normative in younger flows near the top. New microprobe data support the alkaline nature of the basalt. Plagioclase phenocrysts are calcic (An72-An48), but the groundmass plagioclase grades from An56 to anorthoclase to sanidine of 0r52A1346An2 (fig. 3) which is typical of alkali basalts. The pyroxene is augite of about Wo,,En„Fs,, (fig. 4) and averages over 1.30 percent Ti02. Strong differentiation is not reflected in the plagioclase or pyroxene, but a trend to more magnesium-rich compositions is suggested by olivine (fig. 5). Although flow 1, the oldest flow, has olivine phenocrysts in the range Fo„ to Foi, with a peak at Fo„, flow 2 has a phenocryst average of Fo„, flow 3 has an average of Fo„, and flow 4 has an average of Fo„,,. Flow 5, the youngest of the group, lacks olivine phenocrysts but its groundmass olivine has compositions between Fo,„ and Fo„ which contrasts strongly with the groundmass olivine in flow 2 with a range from Fo62 to F046.

Table 1. New chemical analyses and some Niggli norms for selected samples of rift volcanics.

	Mohinas		San Felipe			Wind Mesa	Albuquerque Inclusions	
	M-2b	M-3	SF-8	SF-11	SF-15	W-13		
SiO_2	48.57	59.92	51.80	51.35	49.26	47.34	84.48	81.43
TiO_2	1.77	1.12	1.43	1.41	1.40	1.82	0.22	0.27
Al_2O_3	15.80	16.80	17.04	16.71	15.85	14.08	6.37	7.89
Fe_2O_3	2.55	3.30	1.64	2.43	1.90*	2.52*	0.55	0.62
FeO	7.62	1.98	8.06	7.08	9.34*	7.56*	0.72	1.27
MnO	0.16	0.08	0.15	0.15	0.17	0.17	0.03	0.03
MgO	7.00	0.98	5.59	5.52	6.54	4.88	0.35	0.44
CaO	7.95	2.32	9.15	9.41	9.42	10.18	0.88	1.81
Na_2O	3.68	5.50	3.37	3.53	3.58	3.37	1.34	1.88
K_2O	1.54	6.55	1.16	1.12	0.82	1.85	2.54	2.76
H_2O, CO_2	2.14	1.39	0.53	0.39	0.54	3.06	2.23	1.43
P_2O_5	0.55	0.24	0.32	0.34	0.25	0.76	0.04	0.05
	99.33	100.19	100.29	99.44	99.55	98.33	99.75	99.88
Ap	1.17	0.51	0.51	0.72	0.53	1.71		
Il	2.52	1.56	1.58	1.98	1.98	2.72		
Mt	2.73	2.46	1.73	2.57	2.01	1.41		
Hm		0.66						
An	22.60	1.55	28.18	26.70	25.13	19.18		
Ab	33.70	46.70	30.50	32.05	32.60	27.70		
Or	9.30	38.70	6.90	6.70	4.90	11.75		
Ne	0.06	1.92				2.88		
Di	11.32	5.40	12.80	14.60	16.48	23.80		
Wo		0.64						
Hy			13.86	11.60	0.34			
Ol	16.59		3.96	3.09	16.02	8.85		

*The Fe_2O_3/FeO ratio has been adjusted to match the other rocks in the field.

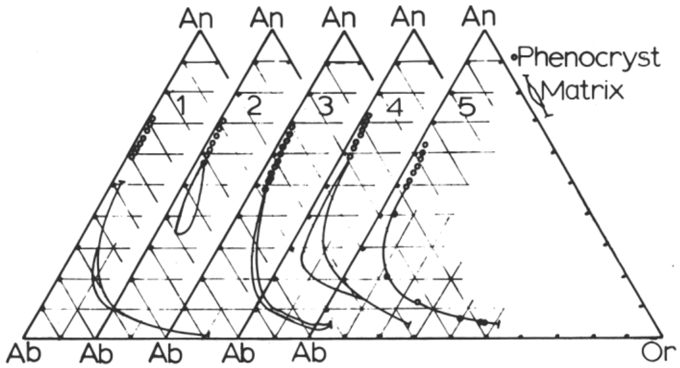

Figure 3. Plagioclase compositions for the Isleta volcano plotted according to flow units. The numbers refer to flow units and are in sequence according to age with the oldest flow numbered 1.

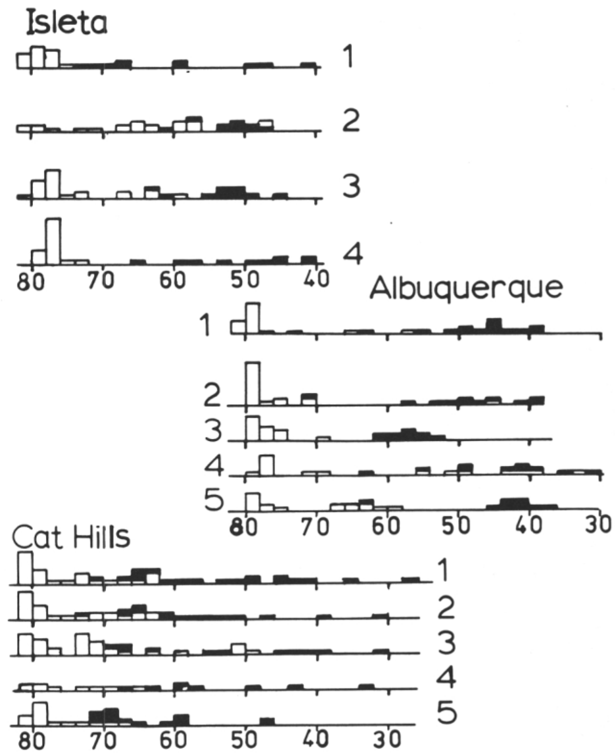

Figure 5. Olivine compositions plotted on histograms for the Isleta volcano, Albuquerque volcanoes, and the Cat Hills volcanic field. Numbers refer to flow units and are in chronological sequence with oldest flow numbered 1. Open bars = phenocrysts, solid bars = groundmass.

SAN FELIPE VOLCANIC FIELD

Penecontemporaneously with the Isleta eruptions, San Felipe volcanism took place about 2.6 (Graustein, written commun., 1973) to 2.5 my. (Bachman and Mehnert, 1978). This field is the largest in the basin, covering over 100 km' (fig. 1). Most of the field is underlain by flows of olivine tholeiite which cap the high Santa Ana Mesa north of the junction of the Rio Grande and the Jemez River. At least four flows have been recognized by Kelley and Kudo (1978) who have found them to overlie an ash layer exposed on the east side of the mesa. Above the flows are two subparallel belts of aligned cinder cones and centers; 26 centers are aligned roughly in a north-south direction on the east side and 40 on the west side. This is interesting since the Jemez lineament of Mayo (1958) and Laughlin and others (1976) passes through this zone in a northeast-southwest direction. It is difficult to understand how the San Felipe volcanic field can be part of the tranverse zone and the Jemez lineament when no surface manifestation of this alignment can be seen.

As in most basalts of the Rio Grande rift, these basalts have phenocrysts of olivine and plagioclase. Only a few of these contain minor augite phenocrysts. Basalts are mostly hypersthene normative with a few samples being quartz or nepheline normative. Three new analyses of the younger basalts are shown in Table 1 and Figure 2 which supplement data reported by Kelley and Kudo (1978) and Baldridge (1979). Unlike Baldridge (1979), I would group the San Felipe basalts separately from the Cerros del Rio field which is definitely more diverse, having a range from basanite to silicic andesite. Moreover, it is the earliest flows (see Kelley and Kudo, 1978) which are the most saturated; whereas, subsequent basalts are more undersaturated and the youngest basalt (SF-15 of Table 1) almost nepheline-normative. Such a sequence cannot be explained by fractional crystallization given the observed phenocrysts .

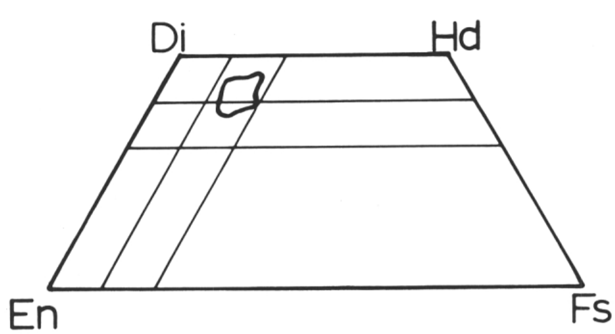

Figure 4. Pyroxene compositions on pyroxene quadrilateral for the Isleta volcano. All flow units are plotted.

CANJILON HILL

About 1 km south of the southernmost exposure of lava flows from the San Felipe field lies Canjilon Hill (fig. 1), an eroded maar crater composed of tuff with palagonitic glass, breccia, basaltic plugs, dikes, flows, and a cone sheet. Being more resistant to erosion than the surrounding Santa Fe Group sediments, Canjilon Hill stands over 70 m above the floodplain and has four subcenters composed of centroclinal tephra and flows. Three of the subcenters are aligned in a roughly north-south direction. According to a K-Ar age date of 2.61 my. (Kudo and others, 1977), the Canjilon activity occurred penecontemporaneously with the San Felipe eruptions. These basalts plot on the same chemical trends as San Felipe basalts (fig. 2); therefore, it is likely that the two basalts are related. Because of the small size of the eruption and the lack of overlapping contacts, no relative age sequence can be obtained for the basalt. The basalt has tiny phenocrysts of olivine, plagioclase, and pale-brown augite set in an intergranular to intersertal to diktytaxitic groundmass of brown augite, olivine, opaques, and minor glass.

LOS LUNAS VOLCANO

Los Lunas volcano has been dated by Bachman and Mehnert (1978) at 1.3-1.1 my. The volcano is located about 6 km west of Los Lunas and is composed of two eastern centers, which have erupted eight flows, and several smaller centers to the southwest. Several high-angle north-trending and one east-trending normal fault dissect the volcano. The andesite here is similar to the andesite at Tome Hill. Both contain phenocrysts of plagioclase, augite, hypersthene, and basaltic hornblende. The SiO, content ranges from 56.12 in the oldest flow to 62.02 percent in the youngest which is almost identical to the range found at Tome Hill (fig. 2). Kasten (1977) and Zimmerman and Kudo (1979) suggest that fractional crystallization plus contamination was responsible for the observed sequence.

ALBUQUERQUE VOLCANOES

The next to youngest volcanic feature in the basin is the Albuquerque volcanoes dated at 190,000 years (Bachman and Mehnert, 1978). Lying 10 km west of downtown Albuquerque, five large cones are aligned north-south on the western skyline (fig. 1). Eight lava flows erupted along fissures and covered over 80 km' mostly to the east of the fissures. The earliest two cover the greatest area; subsequent flows appear to have been more viscous, showing a less expansive, hummocky surface. The amount of cinder erupted near the vents is minor in comparison to those at San Felipe and Cat Hills.

The rocks are olivine tholeiite with phenocrysts of plagioclase and olivine and a groundmass composed of opaques, plagioclase, olivine, augite, and low-Ca augite and pigeonite. Plots of the mineral chemistry are shown in Figure 3. The olivine from flow 1 of Kelley and Kudo (1978) has phenocryst cores in the range F078-82 (fig. 5). The most differentiated flow according to olivine compositions appears to be flow 4 with phenocrysts between F076 74 and fayalitic rims to Fo,. Flow 5 is less differentiated with phenocryst cores peaking between Fo78 80 and rims to Fo58. This is supported by the plagioclase and pyroxene com- positions. Flow 4 has groundmass and phenocryst plagioclase of An„ and An, respectively, but flow 5 has An54 and An„ (fig. 6), respectively. Pigeonite (fig. 7) is present in flow 4; flow 3 has the most Fe-rich clinopyroxene measuring over Fs,. The pyroxenes in flow 5 have lower Ca and more Fe than in flows 1 and 2 but lack pigeonite. All pyroxenes have TiO, contents less than 1.4 percent. The initial eruptions differ- entiated to more tholeiitic mineralogies and became more Fe-rich with two pyroxenes, but the central vent eruptions, represented by flow 5, may represent a resurgence of new magma. This differentiation up to flow 4 can be explained by shallow fractionation of olivine and pla- gioclase (the phenocrystic phases) which has driven the magma to become more saturated in SiO2.

The frothy, glassy inclusions of Santa Fe(?) Group sediments reported by Kelley and Kudo (1978) to be found in basalt and cinders in the northern part of Black Cone and the east side of Vulcan have been analyzed (Table 1). These inclusions, which are composed of partially melted clasts of feldspar and quartz in a glassy groundmass, resemble typical sandstones. Assuming P.20 of about 0.5 kb, temperatures of at least 780°C are suggested by phase relations observed in the Q-Ab-Or- H20 system.

CAT HILLS VOLCANOES

This is the youngest volcanic field in the basin, dated at 140,000 years by Kudo and others (1977). This field was built initially by several flows erupted from fissures. These are capped by 23 cinder cones aligned

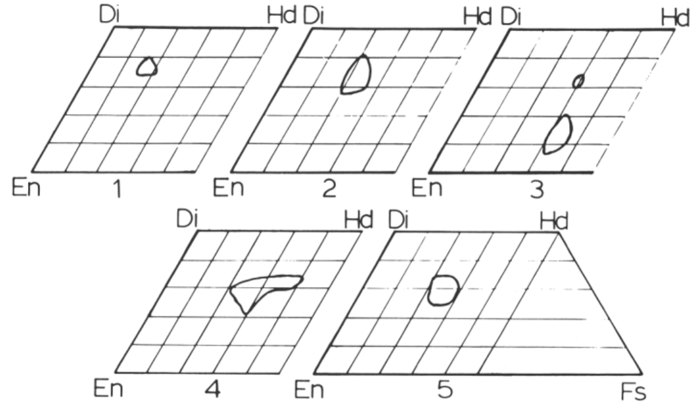

Figure 7. Pyroxene compositions on pyroxene quadrilateral for the Albuquerque volcanoes. Numbers refer to the flow units and are in chronological sequence, the oldest being number 1.

roughly in a north-south direction (fig. 1). These rocks are alkali rich (fig. 2), hypersthene to nepheline normative, with olivine (fig. 5) and plagioclase phenocrysts (fig. 8) set in a groundmass of brown augite, olivine, plagioclase, and opaques. Kelley and Kudo (1978) suggested a differentiation trend to more nepheline normative compositions. This is supported by microprobe data on augite (fig. 9). The earliest flows have very Fe-rich augites (averaging about Wo45En32Fs24) with TiO, up to 3 percent, but in contrast the last two flows have augites which are more Mg-rich (Wo„En„Fs.). Successive tapping of a more Mg-rich magma is suggested; the classic shallow differentiation trend cannot be invoked here because of differentiation toward more Mg-rich compo- sitions.

SUMMARY

From this short review, it is apparent that the volcanic rocks younger than 4 my. are restricted to andesites, olivine tholeiites, and alkali basalts. Of these the olivine tholeiites (including alkali-rich hypersthene normative basalts) appear to be the most abundant; however, two dif- ferent types are apparent as illustrated by the Albuquerque volcanoes and a group including the San Felipe—Canjilon, Cat Hills, Isleta, and Wind Mesa fields. The former basalts have lower alkalis, lower Al203 (less than 15.5 percent), and high normative hypersthene. The presence of two pyroxenes becomes apparent in some of the flows. The early flows appear to differentiate to a more saturated basalt with time as suggested by Kelley and Kudo (1978). On the other hand the latter basalts have higher alkalis and alumina (greater than 15.5 percent) and low normative hypersthene and can be called hypersthene-normative alkali basalts. The one pyroxene tends to be titaniferous with slightly

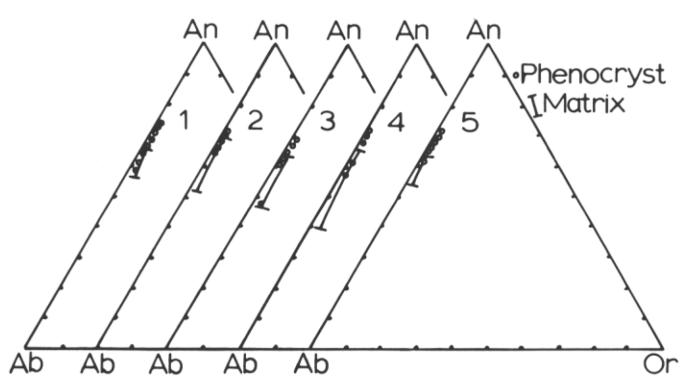

Figure 6. Plagioclase compositions for the Albuquerque volcanoes. Numbers refer to the flow units and are in chronological sequence, the oldest being number 1.

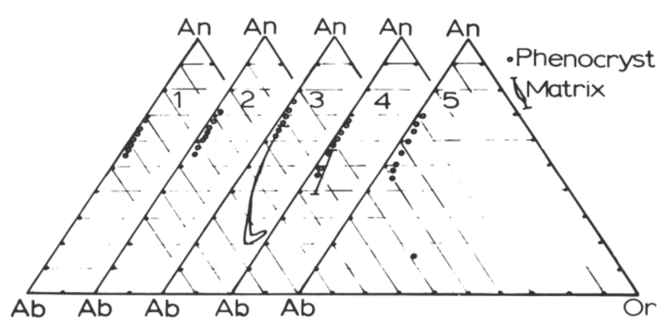

Figure 8. Plagioclase compositions for the Cat Hills field. Numbers correspond to flow units and are in chronological sequence, with the oldest flow numbered 1.

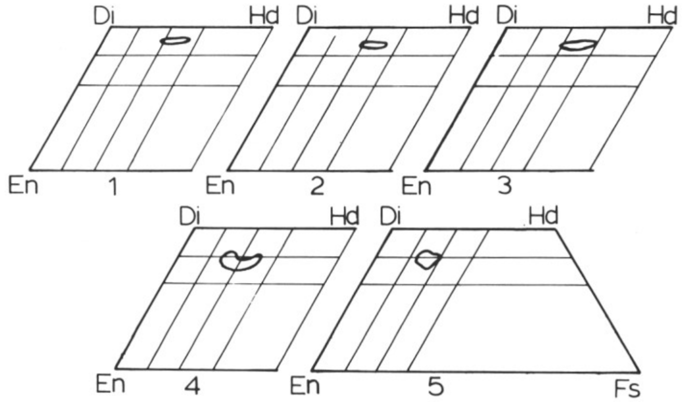

Figure 9. Pyroxene compositions on pyroxene quadrilateral for the Cat Hills field. Numbers refer to the flow units which are in chronological sequence with the oldest flow numbered 1.

brown tints and TiO, over 3 percent. With time, these hypersthene-normative alkali basalts appear to become more undersaturated, moving toward nepheline-normative compositions. The less abundant andesites are definitely more silica rich, have high alumina and K20, two pyroxenes, and basaltic hornblende. Crystal fractionation plus possible contamination can explain the observed trends.

Baldridge's (1979) suggestion that the basalt compositions are controlled by the intersection of the Jemez lineament with the Rio Grande rift, resulting in tapping magma deeper in a mantle diapir below the rift, cannot be invoked. The existence of high-alumina alkali basalts at Cat Hills, Isleta, and Wind Mesa, over 40 km south of this tranverse zone, clearly indicates that deep tapping of magma has occurred away from this zone. Moreover, shallow origin is also indicated by the presence in the south of low-alkali olivine tholeiites and high-K andesites at Albuquerque and Los Lunas—Tome, respectively. The lone occurrence of the low-alkali olivine tholeiite at the Albuquerque volcanoes is abnormal. The occurrence of hypersthene-normative alkali basalts is the norm for most of the rift. Perhaps the geothermal gradient is such that most basaltic magma is generated deeper below the moho in a zone where high-alumina alkali basalts are formed; only rarely does the gradient become elevated enough that olivine tholeiites or andesites can be generated. The trend toward more undersaturated basalts with time at the alkali basalt centers may be explained by a process which involves a decreasing degree of partial melting as the volcanism progresses. Initial eruptions at all centers suggest a more fluid and voluminous magma; in contrast, the fluidity and volume is restricted during the last stages of the volcanism. The olivine tholeiites and andesites, because of their fractionation trends toward more saturated material, are being fractionated at shallow depths at less than 10 kb pressure. The high-K andesites may be related to the hypersthene-normative alkali basalts.

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