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GEOLOGY AND PETROLOGY OF TETILLA PEAK, SANTA FE COUNTY NEW MEXICO

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INTRODUCTION

TetiIla Peak is the southernmost andesite volcano in the Cerros del Rio volcanic field (fig. 1). The field predominantly consists of alkali olivine basalt flows and cinder cones erupted approximately 2.6 m.y. ago to form the Caja del Rio plateau, upon which andesite lavas were extruded (Aubele, 1978, this guidebook). The plateau is located on the La Bajada-Jemez constriction separating the Espariola and Santo Domingo basins of the central-northern Rio Grande rift (Kelley, 1952). This structural setting of the Cerros del Rio, within a shear zone transversely oriented to the north trend of the rift, may be an important factor in magma genesis and the chemistry of lavas found on the plateau (Baldridge, 1978). This paper describes the geology, petrography and geochemistry of the TetiIla Peak andesites and discusses their origin in light of a general model for andesite magmatism in this portion of the Rio Grande rift (Zimmerman and Kudo, 1979).

GEOLOGY AND PETROGRAPHY

A geologic map of the TetiIla Peak area is shown in Figure 2. The oldest rocks in the area (not shown in the map) are early plateau-forming alkali olivine basalt flows that make up the La Bajada escarpment. Oxidized vent agglomerate, pyroclastic material and alkali olivine basalt intrusives related to construction of a cinder cone one kilometer southeast of TetiIla Peak were the subsequent products of volcanic activity. This highly eroded cone lies on a north-northeast trend of older cinder cones believed to predate alkali olivine basalt flows on the plateau (vents 34 to 37 of Aubele, 1978). This interpretation is evidenced further by the relative elevations of the top of the cinder cone (2030 m, 6650 ft) and a vent (2050 m, 6730 ft) 1.4 km north-northwest of the cone that was a source for later alkali olivine basalt lavas which flowed around the cinder cone to the south and southeast.

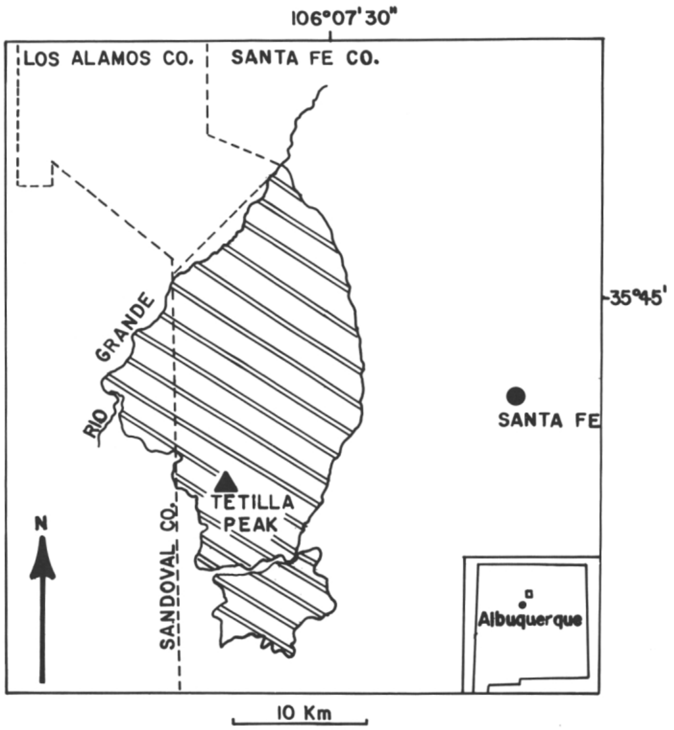

Figure 1. Location map of the Tetilla Peak volcano in the southern Cerros del Rio volcanic field (diagonal stripes), Santa Fe County, New Mexico.

Following basaltic volcanism, andesites were intruded into and erupted onto the alkali olivine basalt. The source for the andesites appears to have been on the southeast side of the present peak because of the occurrence of oxidized andesitic material in that area. Given the observed textural and mineralogic gradations between pyroxene andesites at the bottom of the flows and hornblende andesites towards the top of flows, without any stratigraphic break, the andesite lavas are believed to have erupted from a rapidly evolving or zoned magma chamber. The replacement by hornblende of pyroxene as the stable precipitating phase in andesite magmas is controlled probably by the alkali and water contents of the melt (Cawthorn and O'Hara, 1976). The final extrusive pulse of this magma body produced the more viscous hornblende dacite dome that forms the lighter-colored top of TetiIla Peak. Minor erosion has had little effect on the original morphology of this volcano.

Basalts, andesites and the dacite of the Tetilla Peak area are discernible readily by their weathering colors (black, gray and beige, respectively). The alkali olivine basalts of the plateau and those intrusive into the cinder cone are variably vesicular and contain olivine phenocrysts set in a black dense microcrystalline groundmass. Xenocrysts of quartz and feldspars up to 3 mm in maximum dimension commonly occur in these lavas. In thin section, the matrix consists of plagioclase crystallites, olivine and Fe-Ti oxide granules, and black glass. Subhedral olivine phenocrysts, commonly exhibiting oxidized rims and veins, may be as large as 2 mm across and comprise up to three percent of the mode.

Pyroxene andesites are slightly more porphyritic and less vesicular, and have a more glassy groundmass than alkali olivine basalts. These rocks contain hypersthene and augite phenocrysts up to 0.5 mm across and rare plagioclase phenocrysts set in a microcrystalline pilotaxitic groundmass of plagioclase crystallites and black glass. Some samples are cumulophyric, exhibiting aggregates of pyroxene grains. The transition between andesites with pyroxenes as the most abundant mafic phyric phase and those with hornblende is marked by: (1) an increase in phenocryst size; (2) a greater volume of plagioclase phenocrysts in the mode; (3) reaction textures of

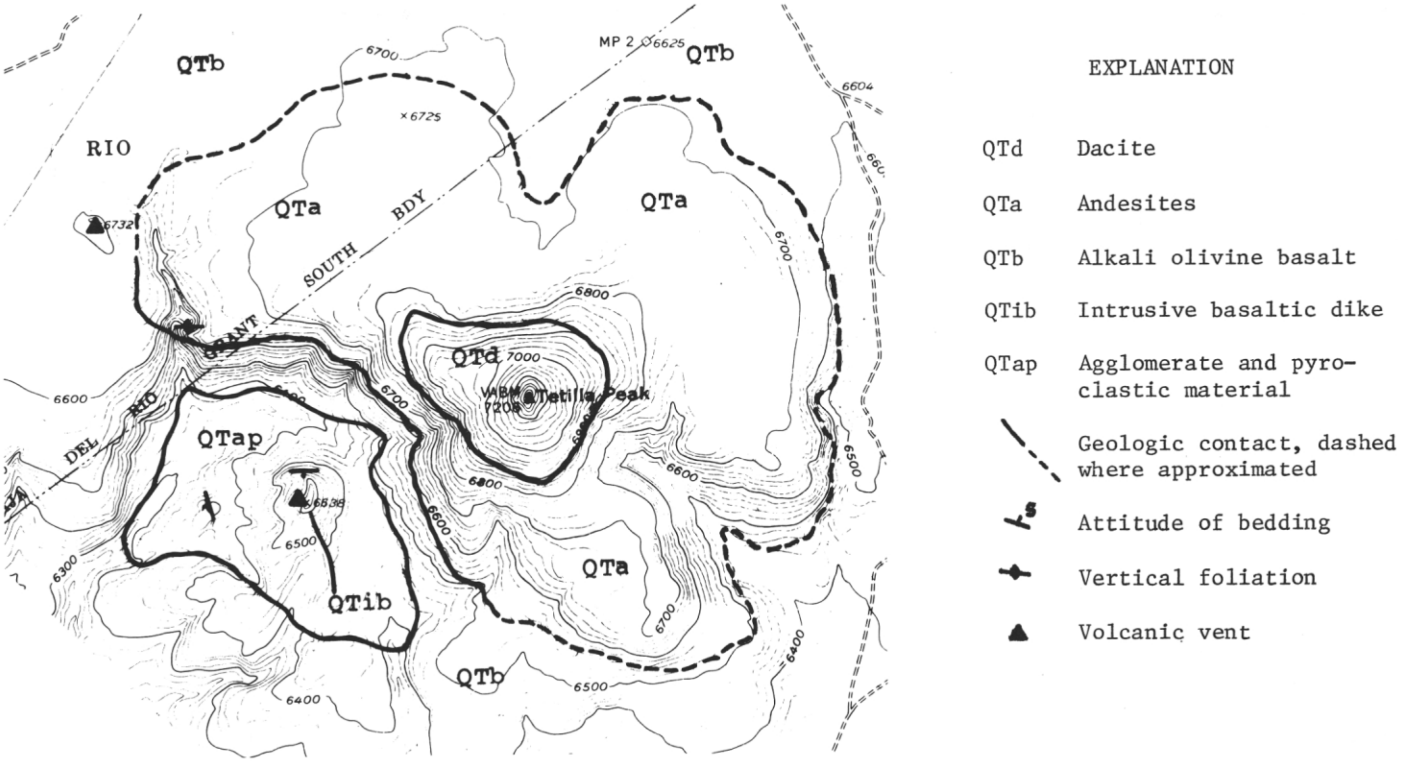

Figure 2. Geologic map of the Tetilla Peak volcano, Santa Fe County, New Mexico. Oldest rocks in the area, plateau-forming olivine basalts, are not shown.

hypersthene going to hornblende; and (4) the appearance of Fe-Ti oxides and lighter-colored glass in the groundmass. Hornblende andesites are seen easily in hand specimen because of large prisms of hornblende phenocrysts that make up 4 to 11 percent of the mode. The dacite possesses a more glassy groundmass with only minor plagioclase crystallites and Fe-Ti oxide granules.

Inclusions found in the andesites and dacite of Tetilla Peak include gneissic, gabbroic, dioritic and granitic samples of the crust beneath this portion of the Rio Grande rift. These xenoliths are considered to be accidental. An olivine gabbro inclusion may be the intrusive equivalent of the alkali olivine basalts erupted in the Cerros del Rio volcanic field. A hornblende-plagioclase cumulate inclusion found in the dacite appears to be related genetically to its host rock. This cognate xenolith is comprised of the two phenocryst phases, with the same 3:1 ratio found in the dacite. These represent fractionating phases subtracted out of an andesitic magma from which the dacite was generated.

WHOLE-ROCK AND MINERAL CHEMISTRY

Bulk chemical analyses of the alkali olivine basalt intrusive associated with the cinder cone, a pyroxene andesite and a hornblende dacite, are given in Table 1. These samples chemically belong to the Rio Grande rift calc-alkalic suite described by Zimmerman and Kudo (1979) for andesitic and more silicic rocks and associated basalts of the central-northern rift.

Mineral chemistry of phenocrysts and groundmass grains from alkali olivine basalts, andesites, the dacite and grains from the gabbroic and cumulate inclusions obtained by electron probe microanalysis are reported in Tables 2-5. Oxidized

Table 1. Whole-rock analyses and molecular norms for Tetilla Peak lavas.

	Basalt TP-4	Andesite TP-5	Dacite TP-10
SiO_2	51.83	60.82	63.05
TiO_2	1.43	0.76	0.64
Al_2O_3	15.04	15.50	15.37
Fe_2O_3	4.19	3.22	3.33
MnO	0.15	0.10	0.09
MgO	7.10	3.20	2.44
CaO	8.40	5.58	4.32
Na_2O	3.84	4.36	4.10
K_2O	2.10	2.46	3.08
P_2O_5	0.88	0.66	0.44
SrO	0.13	0.12	0.11
H_2O	0.61	0.46	1.51
TOTAL	100.17	99.38	99.78
q	0.00	11.91	15.69
an	17.58	15.61	14.75
ab	34.44	39.53	37.59
or	12.39	14.67	18.58
di	14.92	6.65	3.61
hy	7.23	5.77	5.08
ol	5.23	0.00	0.00
il	1.98	1.06	0.91
ap	1.83	1.39	0.93
mt	4.37	3.39	1.46
hm	0.00	0.00	1.39

Table 2. Representative olivine analyses and structural formulae for basalts of the Tetilla Peak area.

	TP-3	TP-3	TP-7	TP-7	TP-4	TP-4
S102	40.6	37.9	39.6	37.8	40.0	37.5
TiO2	0.0	0.1	0.1	0.1	0.0	0.1
Al203	0.0	0.0	0.0	0.2	0.0	0.0
FeO	15.1	28.4	21.5	30.0	16.3	28.3
MgO	44.9	33.8	39.9	32.2	43.8	33.6
CaO	0.2	0.3	0.3	0.4	0.2	0.4
	100.8	100.5	100.4	100.7	100.4	99.9
Si	1.01	1.01	1.01	1.01	1.01	1.01
Ti	0.00	0.00	0.00	0.00	0.00	0.00
Al	0.00	0.00	0.00	0.01	0.00	0.00
Fe	0.31	0.63	0.46	0.67	0.34	0.63
Mg	1.66	1.34	1.51	1.28	1.64	1.34
Ca	0.01	0.01	0.01	0.01	0.01	0.01
	2.99	2.99	2.99	2.98	3.00	2.99
%Fo	84.2	68.0	76.8	65.6	82.7	67.9
%Fa	15.8	32.0	23.2	34.4	17.3	32.1

and unoxidized olivine phenocrysts and groundmass grains possess average forsterite contents of Fo74, Fo83 and Fo64, respectively. Many olivine phenocrysts exhibit compositionally distinct rims. Pyroxenes are hypersthene-bronzites, augites, sub-calcic augites and rare pigeonites. Plagioclase phenocrysts are andesine to labradorite in composition, and exhibit normal, reverse and oscillatory zoning. Plagioclase groundmass grains range in chemistry from labradorite to oligoclase, whereas K-rich grains and quench products are anorthoclase to sanidine in composition. Hornblendes are Ti-rich ferroan pargasites and pargasitic hornblendes based on Leake's (1978) classification and the recalculation for ferric iron using the method of Papike and others (1974). Fe-Ti oxides consist of members of the magnetite-ulvospinel solid-solution series, ilmenites and chrome spinel inclusions in olivine phenocrysts.

DISCUSSION

The chemical, mineralogical and textural features of andesitic lavas from Tetilla Peak, as well as their intimate association in space and time with basaltic magmatism, allow for their inclusion as part of the calc-alkalic andesite suite from the central-northern Rio Grande rift studied by Zimmerman and Kudo (1979). This regional petrologic study utilized isotopic and trace-element geochemistry, and computer modeling, along with the geologic, petrographic and chemical characteristics of the suite, to construct a model for the origin and evolution of these lavas. In this model, low-silica andesitic magmas are derived by small degrees of partial melting of an upper mantle source rock with hornblende left as a residual accessory phase. Subsequent to their emplacement in the crust beneath the rift, the magmas undergo crystal fractionation coincident with variable amounts of crustal assimilation to produce the compositional range of lavas observed in this portion of the rift.

Table 3. Representative pyroxene analyses and structural formulae for Tetilla Peak basalt and andesites.

	BASALT	ANDESITES				
	TP-3	TP-9	TP-6	TP-11	TP-11	TP-9
Si02	46.2	55.4	54.8	55.7	53.8	55.6
TiO,	3.0	0.1	0.2	0.3	0.7	0.1
Al203	7.8	2.0	2.0	1.8	1.7	1.0
FeO	9.6	17.3	5.4	13.0	7.1	16.9
MgO	12.2	24.5	16.8	28.9	15.7	25.7
CaO	21.6	1.2	21.1	1.4	21.1	1.1
	100.4	100.5	100.3	101.1	100.1	100.4
Si	1.73	1.99	1.99	1.96	1.97	2.00
Ti	0.08	0.00	0.01	0.01	0.02	0.00
Al	0.35	0.09	0.09	0.07	0.07	0.04
Fe	0.30	0.52	0.16	0.38	0.22	0.51
Mg	0.68	1.32	0.91	1.52	0.86	1.38
Ca	0.87	0.05	0.82	0.05	0.83	0.04
	4.01	3.97	3.98	3.99	3.97	3.97
%En	36.8	69.9	48.0	77.7	45.1	71.5
%Fs	16.3	27.6	8.6	19.6	11.4	26.4
%Wo	46.9	2.4	43.4	2.7	43.5	2.1

Table 4. Representative plagioclase analyses and structural formulae for Tetilla Peak lavas.

	BASALTS			ANDESITES		DACITE
	TP-1	TP-3	TP-7	TP-9	TP-8	TP-10
SiO,	59.9	58.5	51.2	57.7	63.42	55.6
Al20,	25.7	26.4	30.9	27.8	22.62	28.7
CaO	6.7	8.3	13.6	9.3	3.96	10.6
Na2 0	6.7	6.3	3.2	5.6	6.85	4.8
K20	1.6	0.7	0.2	0.3	2.55	0.3
	100.6	100.2	99.1	100.7	99.40	100.0
Si	10.66	10.46	9.37	10.25	11.44	9.99
Al	5.38	5.55	6.66	5.81	4.78	6.07
Ca	1.28	1.59	2.67	1.78	0.76	2.04
Na	2.30	21.9	1.15	1.92	2.37	1.69
	0.35	0.15	0.05	0.08	0.58	0.06
	19.97	19.94	19.90	19.84	19.93	19.85
%An	32.6	40.5	69.1	47.0	20.3	53.8
%A b	58.5	55.7	29.6	50.9	64.1	44.6
%Or	8.9	3.8	1.3	2.1	15.7	1.6

Table 5. Representative hornblende analyses and structural formulae for Tetilla Peak andesites and dacite.

	AND ESITES			DACITE
	TP-8	TP-8	TP-9	TP-10
SIC),	43.1	43.1	44.6	41.7
TiO2	2.8	2.4	1.3	3.0
Al203	11.6	11.1	12.4	12.5
Fe203	2.5	3.2	0.0	4.7
FeO	12.1	11.7	14.2	9.1
MgO	12.0	12.2	10.2	13.6
Ca0	11.1	10.8	12.4	11.5
Na2 0	2.1	2.1	2.4	2.3
K20	0.7	0.7	0.9	0.7
	98.0	97.3	98.4	99.1
Si	6.34	6.39	6.56	6.06
Ti	0.31	0.27	0.14	0.32
Af"	1.66	1.61	1.44	1.93
	0.36	0.33	0.71	0.20
Fe"	0.27	0.36	0.00	0.52
Fe"	1.49	1.45	1.75	1.11
Mg	2.64	2.69	2.23	2.94
Ca	1.75	1.72	1.95	1.80
Na	0.44	0.42	0.65	0.54
	0.13	0.14	0.17	0.13
	15.39	15.38 15.55	15.60	

The gradational nature of the intermediate rocks from TetiIla Peak indicates that pyroxene-plagioclase fractionation is followed by hornblende-plagioclase fractionation. This differentiation process is similar, in part, to that modeled for the entire rift suite. Differentiation calculations using the method of Wright and Doherty (1970) indicate that the dacite (TP-10 in Table 1) evolved from the stratigraphically lower pyroxene andesite (TP-5 in Table 1) by the subtraction of 11 percent hornblende and 4 percent plagioclase crystals, about the same volumes of these phases found as phenocrysts in the dacite.

Attempts to derive the andesites of TetiIla Peak from spatially related alkali olivine basalts using this computer modeling do not produce good fits for the fractionation of various anhydrous assemblages. An excellent fit is obtained when 40 percent (by volume) of hornblende is subtracted from the alkali olivine basalt (TP-4 in Table 1) in generating the pyroxene andesite (TP-5 in Table 1). Hornblende fractionation from basaltic magmas has been cited recently as a viable mechanism for the generation of andesites (Allen and others, 1975; Boettcher, 1977; Cawthorn and O'Hara, 1976), and is quantitatively supported by the calculations for the TetiIla Peak lavas. However, this process does not seem likely for the generation of the TetiIla Peak or other rift andesites since hornblende phenocrysts and/or reacted grains (Boettcher, 1977) have not been found in any rift basalts. Thus, the TetiIla Peak lavas provide important geochemical data and petrologic constraints for understanding the origin and evolution of andesite magmas in the central-northern Rio Grande rift.

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