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DIFFERENTIATION AND ALKALI METASOMATISM IN DIKE SWARM COMPLEX AND RELATED IGNEOUS ROCKS NEAR CAPITAN, LINCOLN COUNTY, NEW MEXICO

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INTRODUCTION

The prominent dike swarm between the villages of Capitan and Nogal has attracted the attention of almost every geologist who has travelled through the area. It extends from the vicinity of Sierra Blanca some 40 miles to the north-northeast, into the Jicarilla Mountain area. The longest individual dikes are tens of feet wide and about 3 miles long, but the majority are much smaller. Their best development is around Indian Divide and the area immediately to the southwest.

Air photos of the outcrop belts of the Mancos Shale, Mesaverde Group and Cub Mountain Formation show hundreds of low NNE-trending ridges, marked by prominent tree lines. On the ground, each ridge turns out to be a composite dike, made up of many individual dikes with complex cross-cutting relationships. The ridges are covered by innumerable dark boulders formed by spheroidal weathering of various types of diabase. Outcrops are poor except in cuts along U.S. Highway 380 and the abandoned railroad between Carrizozo and Capitan.

The dikes show features of more than local interest. The older dikes are various types of diabase; the younger dikes include both quartz-bearing rhyolite and nepheline-bearing phonolite. The plagioclases of altered diabase dikes generally show replacement of labradorite by oligoclase, a feature more commonly associated with the marine spilitic volcanic rocks of eugeosynclines than with dikes in a continental environment. Secondary potassium feldspar occurs in some of the dikes but seems to be more common in the nearby Carrizo Mountain stock. There, late magmatic or post-magmatic orthoclase progressively replaces plagioclase phenocrysts near the roof of the intrusion.

The only previous publication on the dikes (Patton, 1951) is confined to a brief description of olivine-free diabases. It lacks an discussion of field occurrences. This article is based on field work done by Elston for the New Mexico Bureau of Mines and Mineral Resources in 1956, followed by examination of 123 thin sections by Elston in 1957-58 and by Snider in 1962-63.

DIKE ROCKS

The dikes consist of seven rock types, which are, in order of age: (1) labradorite-olivine diabase porphyry, (2) olivine diabase porphyry, (3) diabase, (4) hornblende-biotite diabase, (5) rhyolite, (6) latite (grading into trachyte), and (7) phonolite. For brevity, these rocks are referred to as Types 1 through 7 throughout this paper.

The diabases, especially Types 3 and 4, are the most abundant; rhyolite is locally abundant but absent

in some places; latite is rare and phonolite is confined to a few occurrences.

The most important properties of the dike rocks are summarized in table 1 and photomicrographs of typical examples are shown in figure 1. Detailed studies to determine exact composition of the minerals have not been made, and would be difficult because of alteration.

Field Relationships

As shown in figure 2, the dikes are irregular in shape. They are intrusive-magmatic rather than metasomatic, judging by the disruption of invaded rocks, sharp contacts, fine-grained chilled borders, and flow-lin-eation of crystals. Rhyolite has a distinct tendency to form sills in incompetent shale beds; other rock types tend to form dikes controlled by fractures.

Most relative ages could be established by cross-cutting relationships, but even where two dikes were parallel the younger could usually be recognized by its fine-grained chilled border. Also, irregular apophyses, a few inches long, of the younger dike locally invade the older dike.

The relationship of Type 2 to Type 1 is based on a single weathered outcrop (figure 2A). Microscopically, the Type 2 olivine diabase porphyry is finer-grained at the contact than a foot away from it, indicating chilling against pre-existing Type 1 rock. These age relationships are important because Type 2 is the most mafic rock in the complex. As for the remaining age relationships, detailed examination of composite dikes in 21 road and railroad cuts failed to show any exceptions to the order of intrusion given here. Away from artificial cuts only a few outcrops show conclusive cross-cutting relationships, and these also follow the same sequence. In none of the composite dikes examined were all seven rock types seen; the sequence was pieced together from several occurrences. The sketches in figure 2 show all rock types except Type 7 phonolite, but a phonolite dike cuts a Type 6 latite dike 0.1 mile east of the roadcut shown in figure 2C.

Differentiation Trends

The dikes do not follow a simple differentiation trend from mafic to felsic or mafic to alkalic. If the field relationships have been interpreted correctly, labradorite-olivine diabase porphyry (Type 1) is older than the more mafic olivine diabase porphyry (Type 2). Possibly, Type 1 is representative of the parent magma and Type 2 has been enriched in early-formed crystals.

Further differentiation would follow a clearly alkalic trend ending in phonolite (Type 7) if it were not for

Table 1.—Description of dike rocks of Capitan area.

	(1) Labradorite- olivine diabase porphyry	(2) Olivine diabase porphyry	(3) Diabase	(4) Hornblende- biotite ¹ diabase	(5) Rhyolite	(6) Latite	(7) Rhonolite
Andesine-labradorite	60-70	40-50	50-65	55-75			
Albite-oligoclase					pr.	40-60	5-15
Potassium feldspar					65-85	20-50	60-90
Quartz					15-20		
Nepheline							5-10
Olivine	3-8	10-25	1-8	tr.-2			
Augite	15-30	15-30	15-30	12-35			pr.-8
Orthopyroxene		tr.	tr.				
Hornblende							
Biotite				2-15		tr.-5	
Opaque minerals	5-10	5-10	8-15	2-8	0.5	tr.-3	tr-3
Accessory minerals			Apatite tr., zircon tr.	Apatite tr.-2		Apatite tr.2	
							Texture Alteration
							Trachytic, with sparse phenocrysts of oligoclase and orthoclase. Calcite pseudomorphous after phenocrysts of a ferromagnesian mineral (pyroxene?). Secondary cancrinite and sodalite may be present in traces around nepheline.
							Texture Alteration
							Phenocrysts (sparse in some specimens) augite up to 3.0 mm long, sparse oligoclase. Groundmass felted intergrowth of K-spar and albite. Secondary quartz and calcite in cavities, green biotite flakes probably from alteration of augite; kaolinite, sericite, chlorite, zeolite (scolecite ?) present in some specimens.
							Texture Alteration
							Fine-grained (0.125 mm) flow-banded granular aggregate of quartz and K-spar, sparse phenocrysts of embayed quartz, altered albite. Potassium feldspar partly unmixed to perthite, sericitized. Some xls. rimmed with albite. Sparse albite phenocrysts, sericitized. Secondary calcite abundant.
							Texture Alteration
							Diabasic, plagioclase phenocrysts sparse, less than 2.5 mm long. Generally fresher than diabase, but andesine-labradorite commonly replaced by oligoclase. Biotite formed by reaction from hornblende, secondary orthoclase, chlorite, serpentine, zeolite present.
							Texture Alteration
							Fine-grained, felty groundmass, phenocrysts less than 2 mm long, less abundant than in other diabase types. Intensely altered. Plagioclase sericitized, olivine replaced by calcite and chlorite; augite by secondary green biotite, more rarely by chlorite with magnetite rims. Zeolite present in some specimens, also trace of secondary orthoclase.
							Texture Alteration
							Diabasic; phenocrysts 2.5 mm long, make up 50-60% of rock, are less conspicuous in outcrops than in labradorite-olivine diabase porphyry. Tends to be deeply weathered. In fresh specimens, olivine has magnetite rims, is partly serpentinized.
							Texture Alteration
							Diabasic; conspicuous phenocrysts, mainly labradorite laths 5.0 mm long, make up 30-40% of rock. Olivine partly replaced by calcite and serpentine, some crystals have magnetite centers.

¹Most magmatic hornblende is "basaltic" hornblende (lamprobolite); magmatic biotite is reddish-brown, deuterite biotite is green.

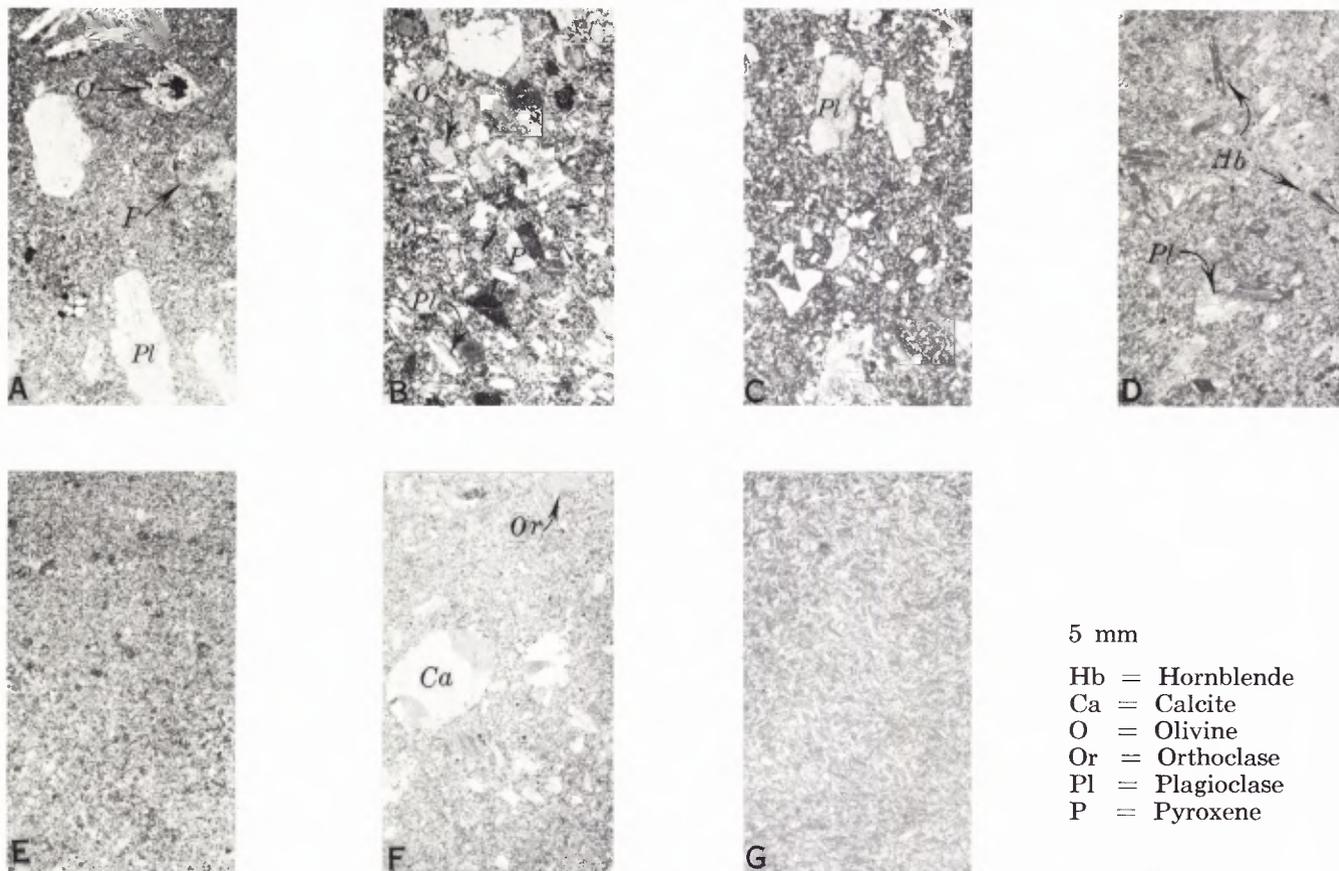


Figure 1. — Photomicrographs (crossed nicols) or rock types from a dike-swarm complex in Capitan quadrangle. Specimens from road cuts on U.S. Highway 380 west of Indian Divide.

A, labradorite-olivine diabase porphyry (Type 1); B, olivine diabase porphyry (Type 2); C, diabase (Type 3); D, hornblende diabase (Type 4); E, rhyolite (Type 5); F, latite (Type 6); and G, phonolite (Type 7).

the appearance of rhyolite (Type 5). As explained below in connection with the Carrizo Mountain intrusion, the rhyolite seems to be related to the larger granitoid stocks and laccoliths of the area; possibly it is not genetically related to the other dike rocks.

Alteration and Alkali Metasomatism

Deuteric and post-magmatic alteration is common in all types of dikes, particularly the diabase of Type 3. Olivine is altered to serpentine, calcite, penninite, magnetite, and goethite; pyroxene to chlorite, biotite, and calcite; and plagioclase is saussuritized to sericite, clays, calcite, zeolites, and opal.

The sodium content of plagioclase increases progressively with the degree of alteration. Throughout narrow Type 3 diabase dikes labradorite has generally been replaced by cloudy oligoclase. The centers of Type 3 diabase dikes more than 10 feet wide contain unaltered labradorite with extinction angles of about 30° on albite twins cut normal to (010). The margins of the same dike contain partially kaolinized or saussuritized oligoclase (extinction angles 0-18°). Secondary orthoclase commonly appears in the matrix of rocks as plagioclase becomes more sodic. Figure 3 shows the progressive

changes in plagioclase of a Type 3 diabase dike, 24 feet wide. The samples were collected in a road cut on U.S. Highway 380, 7.0 miles west of the western village limit of Capitan. Going from the center of the dike towards the border, labradorite crystals first become cloudy and skeletonized, then are enveloped by ovoidal overgrowths of clear oligoclase. The sodium content increases gradually.

Most of the calcium displaced by the increasing amount of sodium in plagioclase goes into secondary calcite. Calcite is common not only in the matrix of altered rocks but also in small veinlets and in the wall-rock around dikes. Directly next to the dike that yielded the specimens for figure 3, sandstone of the Cub Mountain Formation has a calcite matrix. Only a trace of calcite is present in sandstone 6 feet away from the contact.

The kind of alteration and sodium metasomatism of plagioclase characteristic of Type 3 diabase dikes occurs in other types of diabase also, but to a lesser degree. In some dikes the chilled borders are relatively unaltered and contain calcic plagioclase. Table 2 summarizes the data. Since, at this stage of investigation, it is not known whether the rocks contain plagioclase or high- or low-temperature optical properties, extinction angles but no Ab:An ratios are given.

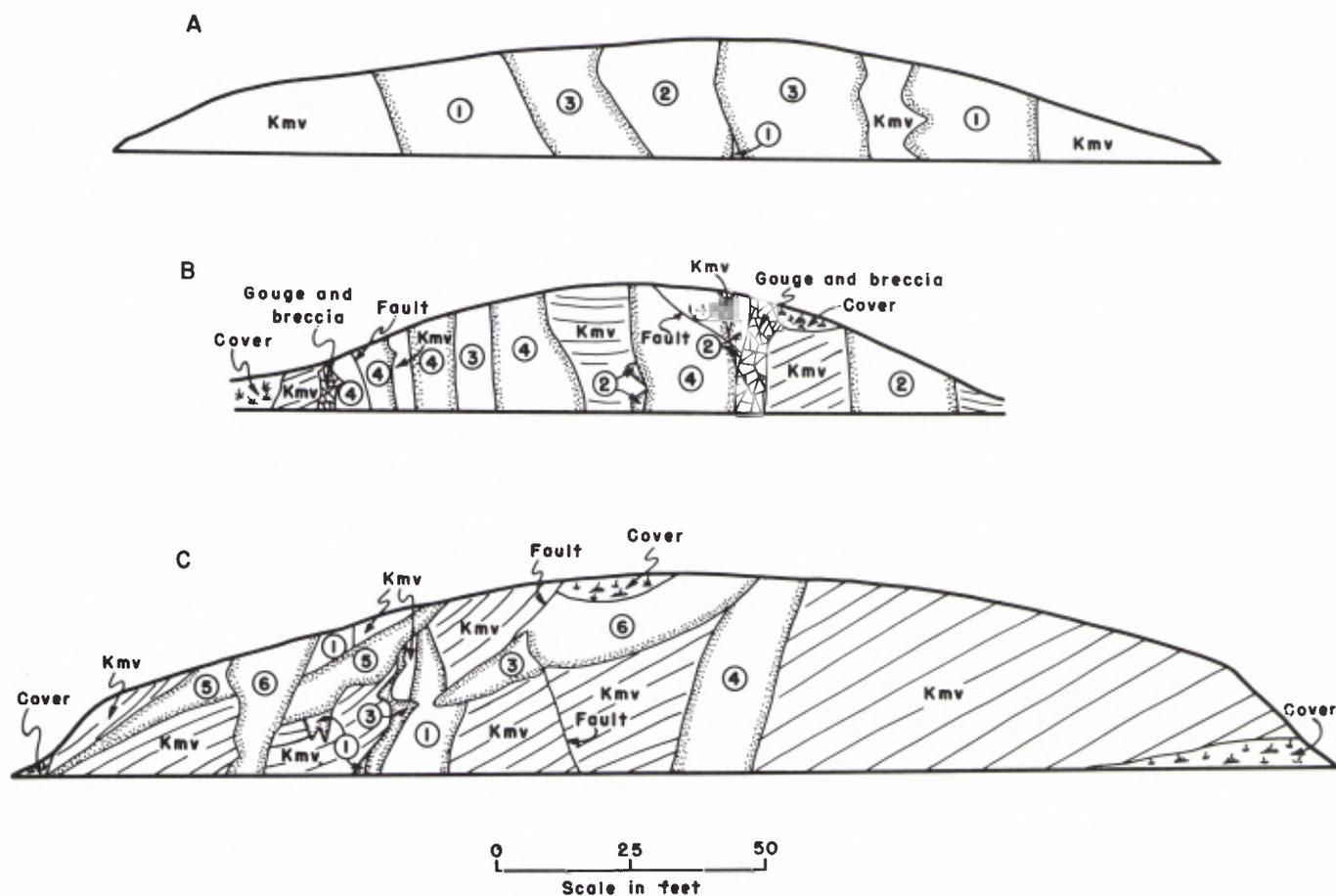


Figure 2. Sketches of road cuts along U.S. Highway 380, illustrating field relations of different rock types in dike swarm. ① Labradorite-olivine diabase porphyry. ② Olivine diabase porphyry. ③ Diabase. ④ Hornblende-biotite diabase. ⑤ Rhyolite. ⑥ Latite, Kmv-Mesaverde Formation. Stippling indicates chilled border. Locations west of western village limit of Capitan: A-3.4 miles, B-3.7 miles, C-6.6 miles.

NOTES ON CARRIZO MOUNTAIN

In addition to the detailed work on the dike swarm along Highway 380, a few reconnaissance traverses were run in 1956 across Carrizo Mountain to the north and the volcanic complex of the Sierra Blanca to the south. While the work was insufficient for definite conclusions, some interesting relationships became apparent.

Work on Carrizo Mountain showed that the top of the Mesaverde Formation does not dip under it and that it is not an "extrusive plug dome," as stated earlier (Anonymous, 1951). Instead, it is a steep-sided intrusive body. At least, the Mesaverde beds that dip westward off Tucson Mountain toward the east side of Carrizo Mountain sharply reverse their dip within a few hundred feet of the igneous contact, and appear to be arched by the Carrizo Mountain intrusion. While diabase and rhyolite sills are common in westward-dipping Mesaverde beds, none were seen in the arched beds near Carrizo Mountain. It is possible that the sills do not

reverse dip but continue beneath Carrizo Mountain, joining sills dipping inward from the west and forming flat cone sheets. If so, the sides of the cones would dip less than 30° , or half as much as in the famous Scottish cone sheets.

Patton (1951) gave the impression that the larger intrusive masses of the Capitan quadrangle, which make up the bulk of Capitan, Patos, Vera Cruz, and Carrizo Mountains are all varieties of alaskite (alaskite, kalialaskite, orthosite). Carrizo Mountain, however, is a differentiated body. A specimen of the border facies collected in Johnnie Canyon at the intrusive contact, about 2,200 feet below the summit, is fine-grained spherulitic rhyolite with vertical flow bands. It contains no phenocrysts. The groundmass consists of parallel potassium feldspar laths 0.1 mm long and about 20 percent quartz in the interstices. Opaque minerals make up 3 to 5 percent of the rocks and biotite 2 percent (figure 4D). The interior of the intrusion consists of a granite rock too dark to be called an alaskite. A specimen collected 0.6

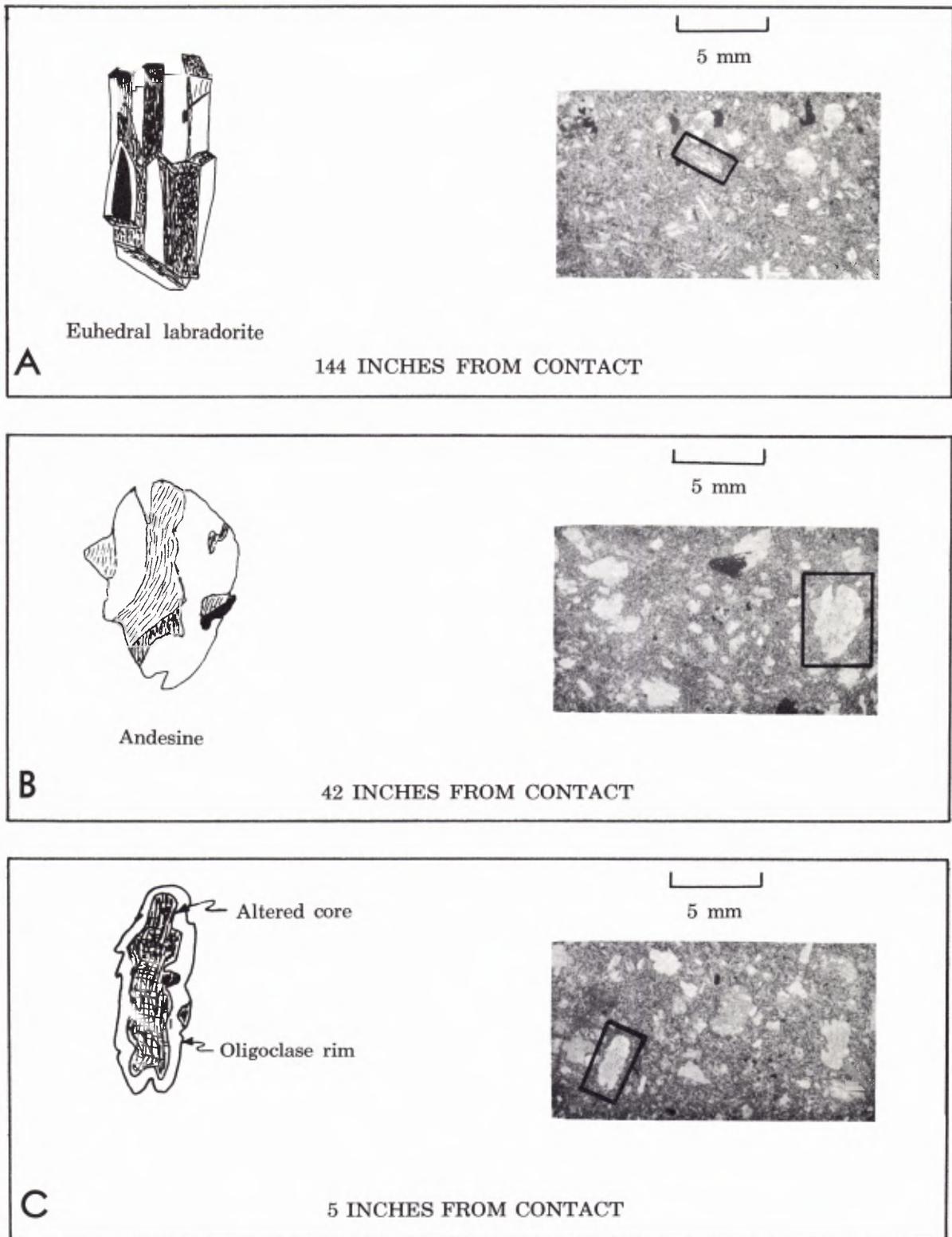


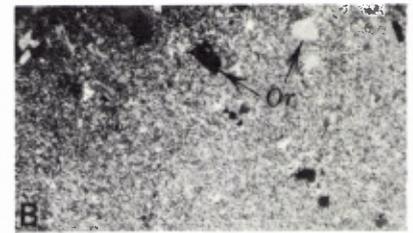
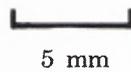
Figure 3. — Photomicrographs (crossed nicols) and drawings illustrating progressive sodium metasomatism of plagioclase in a diabase dike in Capitan quadrangle. (the crystal in the drawing is outlined on the photo to right). A, euhedral labradorite from Type 3 diabase similar to fig. 1C; B, partially rounded and altered plagioclase (andesine) showing faint curved twin planes; C, highly altered and rounded plagioclase phenocryst with clear oligoclase rim around saussuritized core.

Table 2. — Variation of extinction angles of plagioclase in diabase dikes with distance from border of dike.

Rock type number	Location on U.S. Highway 380, in miles west of western limit of Capitan	Distance from border of dike, inches	Maximum extinction angle of albite twins in plagioclase phenocrysts cut normal to (010)	Secondary orthoclase, percent
2	4.5	72	37	20
		0	22	
3	3.4	48	27	tr.
		0	0	
3	3.4	24	35	
		0	0-3	
3	7.0	12	20	
		144	32	
4	4.2	30	10	
		1	6	
4	4.2	60 ^a	9	
		8 ^b	30	
4	4.5	72	24	4
		3	19	10
		0 ^b	21	5-8

^aAltered rock.

^bFine-grained chilled rock with partly glassy matrix.



Or = Orthoclase
Sp = Spherulite
Pl = Plagioclase

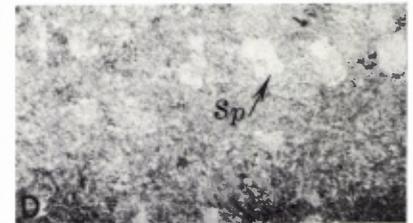


Figure 4. — Photomicrographs (crossed nicols) of rocks from Carrizo Mountain in Capitan quadrangle. A, granite from central part of mass, 0.6 miles from contact in Johnnie Canyon, about 1,800 feet below summit; B, alaskite from SW¹/₄ sec. 17, T. 7 S., R. 13 E., about 800 feet below summit; C, rhyolite from summit of Carrizo Mountain. Note orthoclase crystals; D, spherulitic rhyolite from contact of intrusion, Johnnie Canyon, SW¹/₄ sec. 21, T. 7 S., R. 13 S., about 2,200 feet below summit.

miles west of the eastern contact in Johnnie Canyon and about 1,800 feet below the summit has abundant phenocrysts of oligoclase-andesine rimmed and partly replaced by orthoclase, set in a granitoid matrix of quartz and slightly perthitic orthoclase crystals about 0.2 mm in diameter. Opaque minerals and biotite phenocrysts make up about 13 percent of the rock (figure 4A). Higher up in the intrusion, orthoclase progressively replaces plagioclase phenocrysts. Rocks 800 feet below the summit (figure 4B) have abundant phenocrysts, or porphyroblasts, of orthoclase containing only ragged cores of plagioclase. They have less than 10 percent of dark minerals (partly chloritized biotite and opaque minerals) and could properly be called kalialaskite. At the summit (elevation 9,656 feet) the rocks again belong to the fine-grained border facies, showing that the top of the mountain is not far below the top of the original top of the intrusion. Unlike the border facies lower down, however, the rock at the summit lacks spherulites but contains abundant orthoclase phenocrysts or porphyroblasts, about 3 mm in diameter. Sparse quartz crystals are also present.

The evidence suggests that the larger orthoclase crystals near the roof of the intrusion were formed by metasomatic replacement of earlier minerals. Where plagioclase phenocrysts are present they are progressively replaced by orthoclase. The presence of orthoclase crystals in chilled border facies at the summit, and their absence lower down, suggest a post-magmatic origin.

The rhyolitic border facies of the Carrizo Mountain intrusion suggests an affinity with the rhyolitic (Type 5) phase of the dike swarm complex. Rhyolite sills and plugs are, in fact, most abundant in the country directly east of Carrizo Mountain. Further evidence can be found just north of the O-Bar-O ranch headquarters. There, a tongue of the Carrizo Mountain intrusion cuts across diabase dikes and is in turn cut by a phonolite dike. The age of the Carrizo Mountain intrusion relative to rocks in the dike swarm appears to be the same as that of the rhyolite.

NOTES ON THE VOLCANIC COMPLEX OF THE SIERRA BLANCA

A reconnaissance traverse from the village of Nogal to the head of Nogal Canyon, and from there to the top of Nogal Peak, showed the country rock to be pyroxene andesite flows and flow breccias for the entire distance. Their thickness must be in the thousands of feet. Diabase and rhyolite dikes, the continuation of the dike swarm studied along Highway 380, intrude the andesite. A body of brecciated quartz-bearing biotite syenite, intrusive into the andesite, was traversed for about a mile, beginning 6.0 miles from Nogal. Alteration is intense in this area. Thin sections of syenite show relict phenocrysts of andesine largely replaced by orthoclase, reminiscent of the rocks from Carrizo Mountain. Quartz makes up less than 5 percent of the rock. Prior to potassium metasomatism the rock was probably a quartz-bearing monzonite or quartz-poor granite.

Another type of alkali metasomatism is indicated by a specimen collected on the south side of Nogal Canyon, 3.3 miles from the fork of State Highway 37 and the Nogal Canyon road. About 80 percent of the rock is feathery albite-oligoclase in sheaves and spherulitic aggregates

2 to 7 mm in diameter; the rest is quartz, orthoclase, magnetite, calcite, and leucoxene. It appears to be an adinole, a rock formed by "a type of metasomatism brought about by the agency of liquid solutions of magmatic origin . . . , which involves an accession of soda or sodic compounds" (Harker, 1950, p. 128-130, especially figure 56). Most adinoles form by the albitization of argillaceous sediments next to albitized mafic igneous intrusions; the field relations of this occurrence are not yet known. It is mentioned merely because it illustrates the pervasive nature of alkali metasomatism in this region.

Traverses up Bonito Canyon and to the top of Monjeau Mountain showed field relations similar to those in Nogal Canyon. A quartz-bearing monzonite that underlies Bonito Lake and Monjeau Mountain again shows plagioclase crystals mantled and partially replaced by orthoclase. Augite phenocrysts are partially replaced by biotite. A dike of diabase porphyry cuts the monzonite on the west side of Bonito Lake, in a cut by the side of the Bonito Canyon Road, 5.1 miles from its junction with State Highway 48. The rock is highly altered and consists of phenocrysts of sericitized oligoclase-andesine up to 5 mm long and chloritized ferromagnesian minerals, in a fine-grained altered matrix. It somewhat resembles altered Type 1 labradorite-olivine diabase porphyry. The monzonite is either older than the dike swarm and therefore older than the Carrizo Mountain intrusion, or there is a second generation of diabase younger than the dikes studied along Highway 380. According to R. H. Weber (personal communication), post-phonolite diabase porphyry dikes are common in the Carrizozo area; and T. B. Thompson (personal communication) found numerous mafic dikes cutting across monzonitic intrusions in the Sierra Blanca. It appears that the rocks whose age relations were worked out in the Indian Divide-Carrizo Mountain area are only part of a more complex regional sequence.

SUMMARY AND CONCLUSIONS

The most probable sequence of magmatic events in the Carrizo Mountain-Indian Divide-Nogal region is as follows:

- (1) Eruption of thousands of feet of pyroxene andesite flows and flow breccias in the southern part of the area.
- (2) Intrusion of a NNE-trending dike swarm, extending from the vicinity of Sierra Blanca Peak some 40 miles into the Jicarilla Mountain area. The dikes fall into at least seven types, which are in order of age:
 - Type 1 — Labradorite-olivine diabase porphyry
 - Type 2 — Olivine diabase porphyry
 - Type 3 — Diabase
 - Type 4 — Hornblende-biotite diabase
 - Type 5 — Rhyolite
 - Type 6 — Latite grading into trachyte
 - Type 7 — Phonolite
- (3) Intrusion of felsic stocks and laccoliths, probably contemporaneous with Type 5 rhyolite dikes.

Additional magmatic events may have occurred in surrounding areas. The age of the igneous rocks has not been determined, other than that they are younger than the Cub Mountain Formation (late Cretaceous to early Tertiary) and older than the late Tertiary high-level terrace deposits south of Indian Divide.

Magmatic differentiation resulted in a strong concentration of sodium and potassium in the late magmatic and post-magmatic stages. Evidence for this is seen in the following phenomena:

- (1) Development of phonolite as the last phase of the dike-swarm complex.
- (2) Replacement of labradorite by oligoclase dikes.
- (3) Development of minor secondary orthoclase and biotite in some diabase dikes.
- (4) Replacement of andesine phenocrysts by orthoclase in the upper part of the granitoid Carrizo Mountain intrusion and development of orthoclase porphyroblasts in the chilled border facies at the roof of the same intrusion.
- (5) Replacement of andesine by orthoclase in the felsic

intrusive rocks of the Nogal Canyon-Bonito Canyon region.

- (6) Possible occurrence of adinole, a contact metasomatic rock produced by the introduction of sodium, in Nogal Canyon.

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