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PRECAMBRIAN ROCKS OF THE SIERRA OSCURA AND NORTHERN SAN ANDRES MOUNTAINS

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INTRODUCTION

The Sierra Oscura and San Andres Mountains provide an almost continuous exposure of Precambrian rocks in a north-trending zone through south-central New Mexico. These rocks are part of a Precambrian crustal province ranging in age from about 1.0 to 1.8 b.y. which extends northeastward across the United States from southeastern Arizona to Ohio (Goldich and others, 1966). Whole-rock Rb-Sr ages and zircon ages from Precambrian rocks in northern New Mexico fall in the range of 1.5 to 1.8 b.y., while similar ages from the Franklin Mountains near El Paso, Texas and other locations in central and west Texas fall in the range of 0.95 to 1.2 b.y. (Wasserburg and others, 1962; Denison and Hetherington, 1969; Fullager and Shiver, 1973; Barker and others, 1974; Brookins, 1974).

Muehlberger and others (1966) report a single Rb-Sr whole rock age of 1.3 b.y. on a granite from the Sierra Oscura and an age of 1.36 b.y. on muscovite of the same granite, determined by the K-Ar method. The same authors determined ages of 1.38 and 1.4 b.y. (K-Ar) on biotite from gneiss of the San Andres Mountains..

Since these ages are not Rb-Sr isochron ages or zircon ages, their interpretation is uncertain although they probably represent minimal ages for the Precambrian rocks in the Sierra Oscura and San Andres Mountains. The exposures in these ranges are particularly important as they may include rocks that form a transition zone between 1.8 b.y. old rocks in northern New Mexico and 1.0 b.y. old rocks in the Franklin Mountains.

The Sierra Oscura and San Andres Mountains are north-trending, block-faulted ranges with Precambrian rocks exposed in the lower elevations. The Sierra Oscura block is tilted east and Phanerozoic rocks, which form the crest of the range, dip eastward at angles of 5 to 10 degrees. On the west, the range is bounded by a series of major high-angle faults. Although much of this normal faulting is obscured by alluvial deposits, normal faults (down on the west) are exposed in the bedrock along the steep western slope of the range (Fig. 1). The San Andres Mountains north of Rhodes Canyon expose Precambrian rocks along its eastern slope (Fig. 2). According to the geological mapping of Bachman (1965, 1968) and Bachman and Myers (1969), their structure is that of a complexly faulted north-trending range, tilted westward. Normal faulting is present along the steep eastern slope (Fig. 3). Low-angle gravity glide structures have emplaced tectonic outliers of the Phanerozoic sedimentary sequence at lower elevations along the mountain ront.

Outcrops along the steep slopes are plentiful and allow, in most places, collection of unweathered samples of Precambrian rock types. Arroyos have cut the thin veneer of pediment gravels, and extensive bedrock exposures show relaionships between the various lithologic varieties. Precambrian -exposures of the Sierra Oscura and San Andres Mountains are within the boundaries of the White Sands Missile Range, a military reservation under the jurisdiction of the Department of Defense. The authors wish to express their gratitude to the personnel of W.S.M.R. and in particular to Felix Sedillo and Ismael Rel for the cooperation received in the course of the geological field work.

SIERRA OSCURA

The predominant rock type in the Sierra Oscura is gray to pinkish gray, medium- to coarse-grained biotite granite, with local porphyritic development. Feldspars and quartz make up more than 90 percent of the rock constituents. Foliation is lacking except near the border of townships 7 and 8, where the gray granite has a gneissic texture with a northwest trend and a near vertical dip. The foliated granite has a high content of biotite (up to 25 percent) and may represent a partially assimilated septum of country rock of gneissic parentage, into which the granite intruded.

In the field, the gray granite contains lens-shaped and more irregular bodies of a red granite which weather reddish brown. In the course of the fieldwork, and on the geological map, this granite was separated from the gray granite (Fig. 1). Petrographic and mineralogical investigations, however, do not show any significant difference in the composition or in the mineralogy of the two rock types. In thin section, the feldspars appear to have been altered to a somewhat greater extent in the red variety, but this is not a universal characteristic. Pending further investigation of their chemical composition, it must be tentatively concluded that the gray and red granites represent the product of one igneous intrusive event, and that post-magmatic changes, possibly under the influence of hydrothermal solutions, have been responsible for their different appearance.

A third variety of granite, named leucogranite, shows a clear cross-cutting relationship with respect to the gray and red varieties. It is fine grained, white to pale red and contains less than 2 percent mafic constituents. One variety of leucogranite, from sec. 26, T. 7 S., R. 5 E., contains idiomorphic garnet crystals.

The main Oscura granite is homogeneous in composition, but shows locally dark segregations rich in biotite. Pegmatite dikes, up to 50 cm wide, cut all granite varieties.

Mafic constituents of the granite are, in order of decreasing abundance, biotite, green hornblende, and chlorite. Muscovite is present in some varieties, and forms large, poikilitic crystals. It does not appear to belong to the main crystallization sequence, but has formed after most constituents of the rock crystallized. The mafic minerals compose from 7 to 10 percent of the total rock. Accessory constituents include sphene, zircon, apatite, epidote, and opaque minerals. Sphene is quite common, and may form as much as one percent of the rock. Pale reddish brown, lozenge-shaped crystals show an idio-

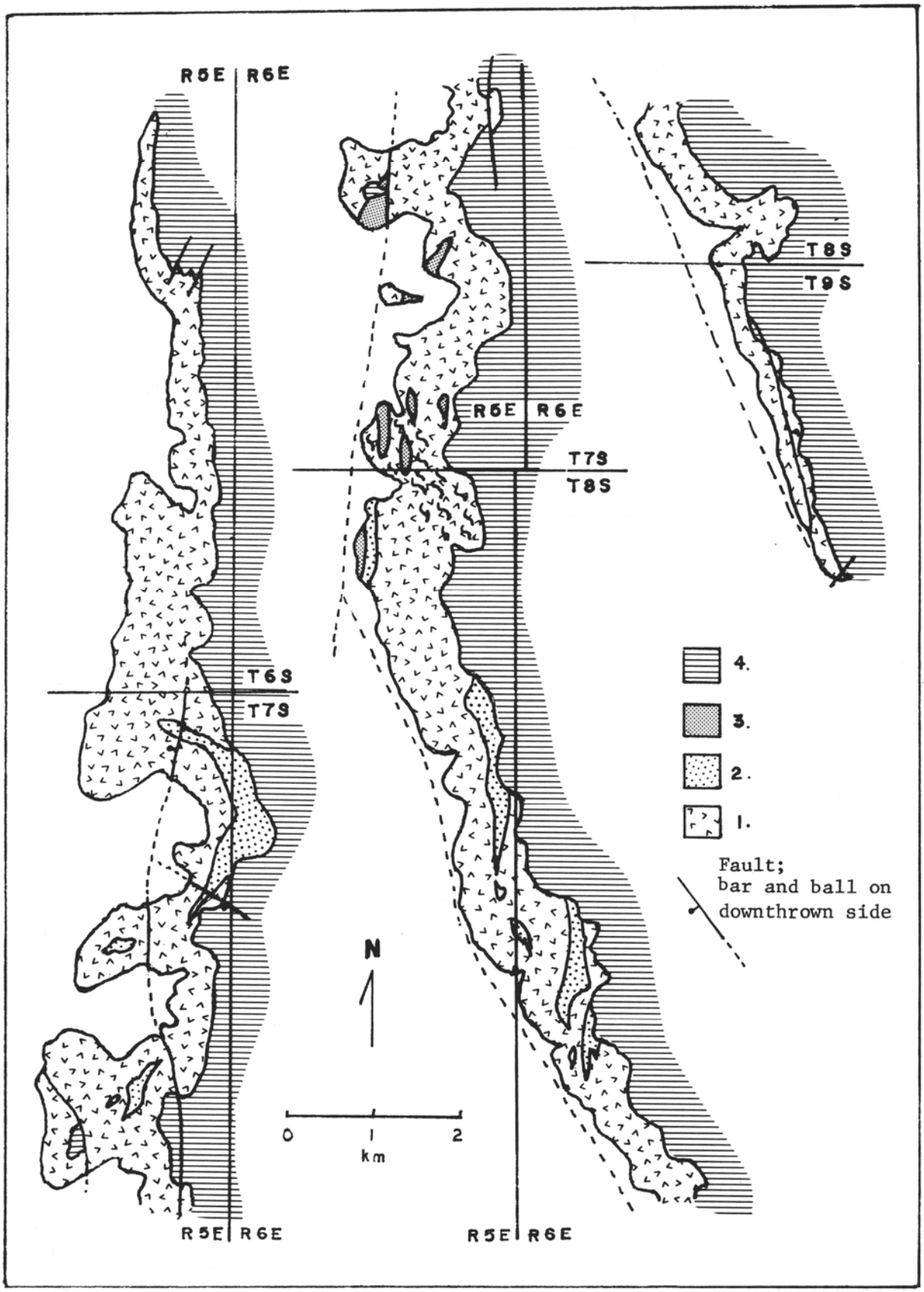

Figure 1. Geologic map of Precambrian of Sierra Oscura. 1 = Gray granite, in part gneissic; 2 = Red granite; 3 = Leucogranite; 4 = Phanerozoic. Quaternary deposits along mountain front have been left blank. Geology in part after Bachman (1968).

Figure 2. View of Capitol Peak from the east. Nearly horizontal Precambrian—Paleozoic contact is slightly above the middle of the slope.

morphic overgrowth on a rounded earlier core; the boundary between the two zones is outlined by opaque mineral grains. Similar crystals have been described from quartz-albite veins cutting aegirine granulites in Scotland (McLachlan, 1951), but the origin of this remarkable overgrowth is obscure.

Plagioclase composes from 25 to 40 percent of the granite, and forms twinned euhedral crystals. Grains show oscillatory zoning with a compositional range from 23 to 28 percent anorthite. In contrast with the potassium feldspar, which is clear, the plagioclase is somewhat clouded with fine-grained alteration products, among which sericite is readily recognizable. Where in contact with potassium feldspar, the plagioclase shows a clear albitic border zone, optically continuous with the main plagioclase grain. Some albitic plagioclase is also associated with quartz in the form of myrmekitic intergrowths.

Quartz forms from 20 to 35 percent of the rock and exhibits undulatory extinction. Alkali feldspar, commonly microperthitic microcline with "gridiron" twinning, averages from 20 to 35 percent. In order to investigate the crystal form, alkali feldspars were separated from seven samples with the aid of heavy liquids and subjected to X-ray investigation. The presence of perthitic plagioclase in the potassium feldspar is indicated from plagioclase reflections, especially (T31), (131), and (132). According to Smith (1956), these reflections can be used for an estimate of the anorthite content, by determining the values of 20(131)-20(131), and 20(132)-20(131). In all cases, the perthitic plagioclase has the composition of nearly pure albite.

The structural state of the host potassium feldspar can be derived from the nature of the (131) and (131) reflections. (Goldsmith and Laves, 1954) or from additional reflections (Wright, 1968). Of the seven alkali feldspars investigated, two samples, one each from a gray granite and a red granite showed a structural state intermediate between orthoclase and micro-cline. The five remaining samples, one from a gray granite, one from a red granite, and three from leucogranites showed a highly ordered structural state, characteristic of microcline.

The petrologic significance of the orthoclase/microcline transformation in granitic and metamorphic rocks has been the subject of much investigation. It is most likely, from experimental work, that at magmatic temperatures alkali feldspars crystallize in the disordered form (orthoclase) and that transition to the ordered form is essentially a solid-state process. Goldsmith and Laves (1954) placed the probable transition temperature at 500°C. The retention of orthoclase in granites cooled below the transition temperature has been ascribed to different processes, for example, the cooling history of the rock. Orthoclase may be retained in rocks that underwent a rapid cooling from magmatic temperatures, whereas the transition from orthoclase to microcline would be favored by a slow cooling rate. The role of volatiles in the transformation process may also be important as demonstrated by the occurrence of orthoclase in rocks of the granulite facies, which were metamorphosed under conditions of high temperatures, but low water content.

On the basis of the above-mentioned petrographic and mineralogic observations, the following crystallization history is proposed for the granitic rocks of Sierra Oscura Mountains. Derivation of these rocks from a granitic melt is indicated by the presence of oscillatory zoning in the plagioclase, which can be explained as the result of imperfect crystal-melt equilibrium. Refractory minerals such as sphene may have been present in the (anatectic?) melt as rounded grains, which developed their oriented overgrowths during the main stage of crystallization. Alkali feldspar probably crystallized in the monoclinic form and contained albite in solid solution. After the main stage of crystallization, and upon reaching solvus temperatures, the alkali feldspar separated into a potassium-rich phase and a sodium-rich phase, the latter of which now forms a perthitic intergrowth. The albite component was sufficiently mobile to form oriented overgrowths on earlier crystallized plagioclase (An26) crystals when in contact with the potassium feldspar. At somewhat lower temperatures, ordering of the potassium feldspar converted the monoclinic feldspar to microcline, although this process is by no means complete, as indicated by the presence of potassium feldspars with structural states intermediate between orthoclase and microcline.

The processes of exsolution and increased ordering of the potassium feldspar occurred in the solid state, and may very

Figure 3. Normal fault along the front of the San Andres Mountains. Photograph was taken at the entrance to Johnson Park Canyon, looking north. Fault trace passes through saddle. Light colored outcrops are Precambrian granite; darker, bedded rocks in hill on right are Paleozoic sedimentary rocks.

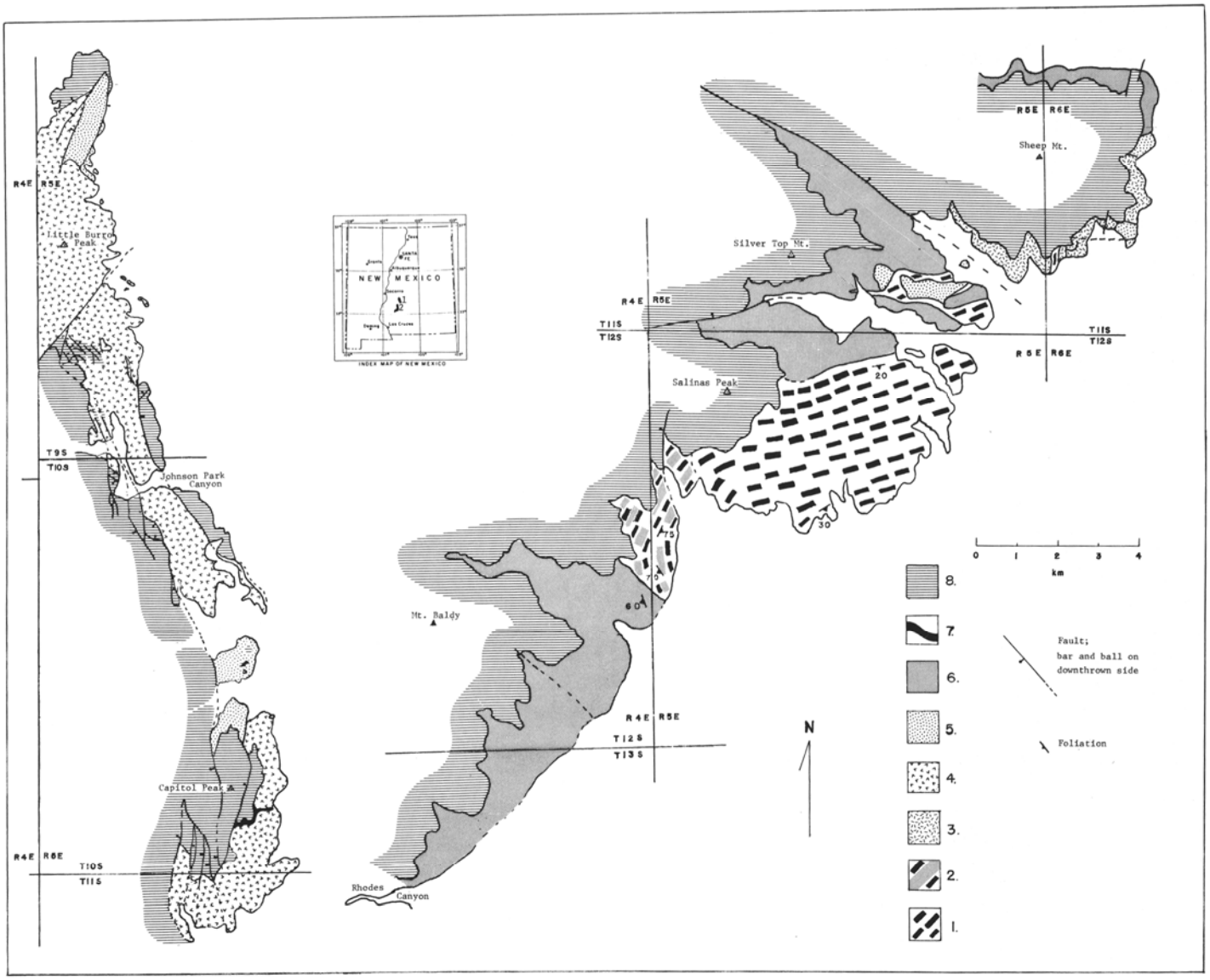

Figure 4. Geologic map of Precambrian of San Andres Mountains north of Rhodes Canyon. Numbers on location map refer to coverage of Figures 1 and 4. 1 = Amphibolite and hornblendite; 2 = Amphibolite migmatite; 3 = Gneiss migmatite; 4 = Gray granite; 5 = Red granite; 6 = Leucogranite; 7 = Mafic dike; 8 = Phanerozoic. Quaternary deposits along mountain front have been left blank. Geology in part after Bachman (1965, 1968).

well have been brought about by the catalytic action of hydrothermal solutions. Such changes as the partial chloritization of biotite, the partial conversion of garnet in leucogranite to green biotite, and the formation of epidote would necessitate the addition of water. These changes may record the last stages of recrystallization that can be observed in the granitic rocks.

SAN ANDRES MOUNTAINS NORTH OF RHODES CANYON

In the northern San Andres Mountains, granites again form an important part of the Precambrian complex. However, in the vicinity of Salinas Peak, extensive outcrops of impure quartzite, biotite gneiss, augen gneiss, amphibolite, and hornblendite occur. These rocks form a northeast- to east-trending belt approximately 10 km wide and are intimately mixed with granitic rocks giving rise to gneiss migmatite and amphibolite migmatite (Fig. 4). Available structural data indicate the exist ence of a synformal body of metamorphic and migmatitic rocks, trending about N60E and plunging southeast. Granitic rocks extend north of this belt to the Mockingbird Gap area, with gray and red varieties predominating. South of this belt, leucogranite is the dominant rock type to Rhodes Canyon. The metamorphic rocks of the Salinas Peak sequence are partly derived from sediments, and are partly of igneous origin. The metasediments are represented by quartzite, biotite gneiss, and meta-arkose. Prograde mineral assemblages include quartz-microcline-oligoclase-biotite, characteristic of the amphibolite facies, while chlorite and muscovite appear in rocks which have undergone retrograde metamorphism.

Amphibolite and related rocks are represented by several varieties. Coarse-grained rocks contain aggregates of dark green hornblende several millimeters in size, which show an ophitic or subophitic relationship to the plagioclase and are most likely the metamorphic products of mafic sills. Hornblendites, i.e., rocks almost exclusively made up of green hornblende,

may represent metamorphosed ultramafic rocks. Amphibolites, with a grain size less than 0.5 mm may be the product of metamorphism of mafic lavas, although no direct evidence (such as pillow structure) for this interpretation was found.

In thin section, the mafic rocks are predominantly composed of a green to brownish green hornblende and andesine in about equal proportions. In many rocks, the plagioclase is altered to prehnite; other constituents include chlorite, epidote, quartz, apatite, ilmenite, and sphene.

The association hornblende-andesine in the metamorphosed rocks indicates metamorphism under amphibolite-facies conditions. The actual temperature and pressure conditions may be those of the upper part of this facies, as indicated by the lack of muscovite and presence of potassium feldspar in some of the gneisses, the proximity in the field to large masses of granite, and the observed occurrence of sillimanite in gneisses of the San Andres Mountains south of Rhodes Canyon.

The granitic rocks of the northern San Andres Mountains show many similarities with the granites of Sierra Oscura. Predominant types include gray and red biotite granite and hornblende granodiorite. South of Salinas Peak, the granites are mainly of the leucocratic variety; all have numerous inclusions, mainly of amphibolite.

A number of dike rocks of mafic composition cut the Precambrian rocks at several locations. It is suspected that these rocks are of Tertiary age, as some dikes appear to widen out along the Precambrian-Phanerozoic contact to form interformational sheets. The dikes are olivine diabases, with olivine, titaniferous augite, labradorite to bytownite, reddish brown biotite, and ilmenite as major constituents. Altered varieties have, in addition, serpentine, actinolite, chlorite, epidote, and calcite.

SUMMARY

The Precambrian of the Sierra Oscura and northern San Andres Mountains shows considerable variation in composition and lithology. Comparison with neighboring Precambrian terrane exposed in the Magdalena Mountains, Polvadera Peak, and Los Pinos Mountains indicates several differences. In the Magdalena Mountains, a thick sequence of impure quartzites and siliceous metavolcanic rocks is intruded by metagabbro and granite. A similar sequence is exposed near Polvadera Peak. In the Los Pinos Mountains, metasedimentary rocks of detrital origin are overlain by a thick sequence of siliceous metavolcanic rocks with minor amphibolite intercalations, all of which are intruded by granites.

A possible increase in metamorphic grade is observed from north to south. Whereas in the Magdalena and Los Pinos Mountains the metamorphism has reached high greenschist facies to low amphibolite facies, the Precambrian rocks in the San Andres Mountains show evidence of metamorphism in the upper amphibolite facies. In considering the distribution of sedimentary and igneous rock types, the following characteristics stand out:

1) No systematic pattern can be distinguished in the distribution of clastic sediments. Although relatively mature sediments such as quartzites and argillites dominate in the Los Pinos and Magdalena Mountains, similar rock types are represented in the San Andres Mountains, albeit of higher metamorphic grade.

2) Supracrustal igneous rocks show a definite trend, with siliceous volcanics predominating in the Los Pirios Mountains and mafic rocks more abundant in the San Andres Mountains.

2) Although granitic rocks occur throughout the Precambrian, their greatest abundance is in the Sierra Oscura. The Precambrian rocks of this range and the San Andres Mountains north of Salinas Peak may represent a granitic dividing zone between a sedimentary and siliceous-volcanic terrane to the north and a sedimentary and basalt-gabbro terrane to the south. However, a complete interpretation of this interesting section of the New Mexico Precambrian will have to wait until the geochronology, particularly of the granitic rocks, is better known.

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