PETROGRAPHY AND STRUCTURE OF A PART OF THE GNEISSIC COMPLEX OF THE SANTA CATALINA MOUNTAINS, ARIZONA

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INTRODUCTION

The general geology of the Santa Catalina Mountains has been described briefly by DuBois (19). Reference is made to that paper for description of the principal features of the range and for a summary of previous geologic work.

General Geologic Setting

The gneissic rocks called the Catalina gneiss (DuBois, 19) are in the southern part of the Santa Catalina Mountains and are bounded on the north and east by sedimentary and metamorphic rocks. Metasedimentary units crop out locally along the western front of the range. The original contact between the gneissic granitic rocks and metasedimentary units was considered by Peirce (1958) to be depositional in the Summerhaven area. Elsewhere the contact is faulted or unknown.

The distribution and occurrence of the metasedimentary rocks are important clues to the nature of the original material and the characteristics of the metamorphism of the gneiss. Immediately to the north of the area of gneiss (fig. 46), Peirce (1958) mapped a series of schistose metamorphic rocks that range from quartzite to quartz-muscovite-plagioclase schist and locally contain epidote, biotite, or garnet. These metamorphic rocks are stratigraphic equivalents of all the formations of the Precambrian Apache group except the Mescal limestone. Metamorphic equivalents of the Scanlan and Barnes conglomerates are especially valuable in stratigraphic control because of their distinctive pebbles.

Metamorphic rocks derived from the Cambrian Troy and Santa Catalina formations range from quartzite to quartz-biotite-muscovite schist and, northwest of Summerhaven, to quartz-biotite-muscovite-staurolite schist. Lower Paleozoic limestone is also present in east-west trending units on Marble Peak and in areas to the east. The metamorphism of these units includes local development of tremolite and epidote and general recrystallization of calcite and dolomite.

The area mapped by Peirce (1958) contains, in addition to the metasedimentary rocks, metamorphosed intrusive igneous rocks of the post-Cretaceous Leatherwood quartz diorite. In addition, two large bodies of granite crop out in the central part of the area (fig. 46). Peirce considers the northernmost of these to be equivalent to the Precambrian Oracle granite and the western body to be post-Cretaceous in age. In the extreme northern part of Peirce's area (1958), outcrops of the Apache group and of lower Paleozoic formations are repeated by faulting. These rocks are only weakly metamorphosed, and in this respect contrast to the metasedimentary rocks near Summerhaven.

In the general vicinity of Rice Peak (figs. 18C, 46), Wallace (1954) mapped the Apache group, including limestone he considers to be the Mescal formation. In this area the rocks of the Apache group are unmetamorphosed and crop out in two broad northwest-trending belts, one of which is a continuation of the weakly metamorphosed Apache rocks mapped by Peirce. The two belts are generally separated by metadiorite but merge immediately south of where they are cut off by the Mogul fault.

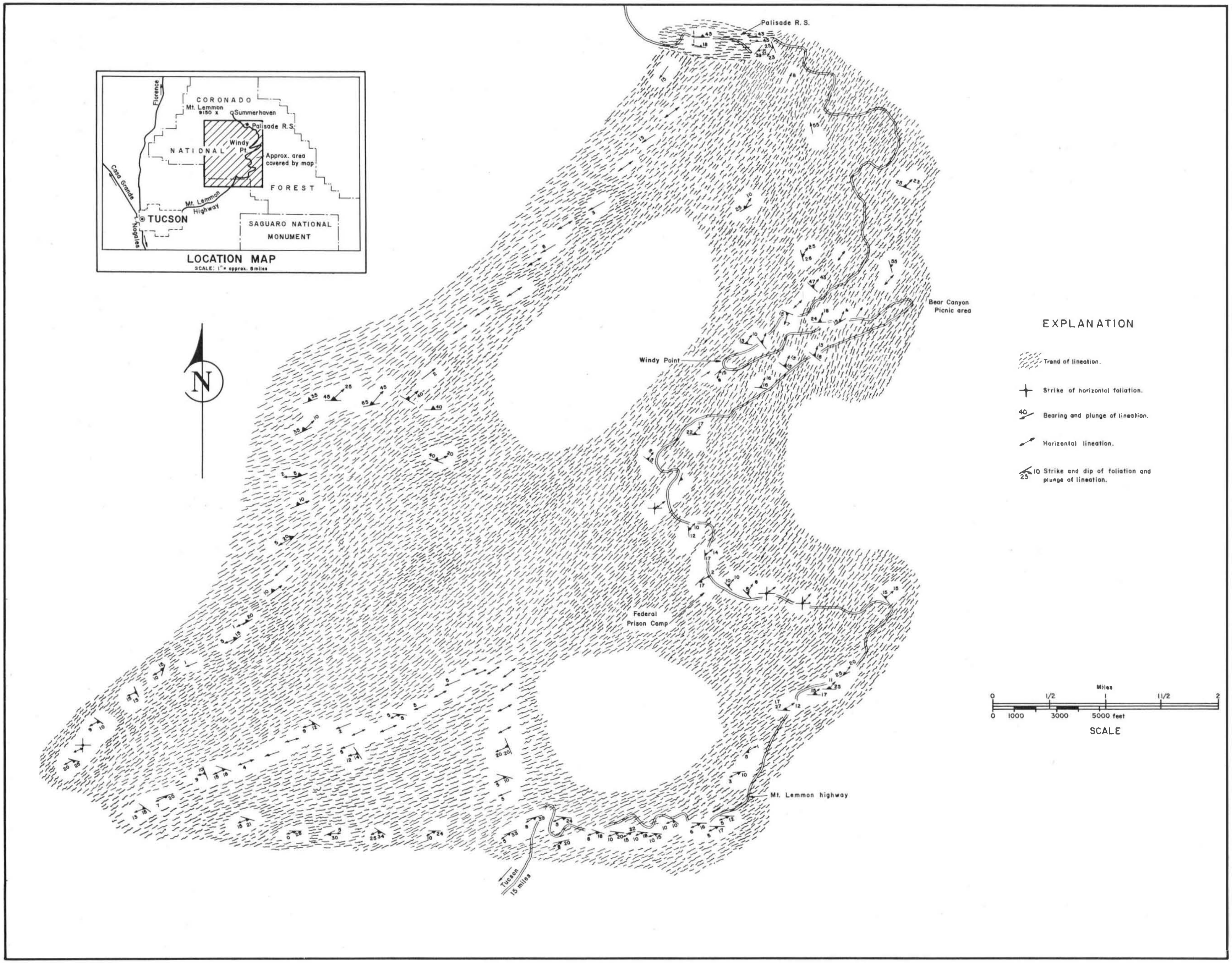


FIGURE 20. Structure map of the Catalina gneiss in the southern part of the Santa Catalina Mountains.

Both of these broad belts contain, in addition to rocks of the Apache group, essentially unmetamorphosed Paleozoic limestone, quartzite, and other clastic rocks.

Near Redington, similar sequences of metasedimentary rocks may be metamorphosed units of the Apache group and remetamorphosed Pinal schist. On the western side of the Santa Catalina Mountains, metasedimentary rocks of unknown age also crop out as septa in granite.

PETROGRAPHY

The south-central part of the Santa Catalina Mountains (fig. 46) is composed of a gneissic complex that has a generally uniform mineralogical composition. The rocks for the most part are phacoidal (Heinrich, 1956) and can be divided into three broad groups -- banded augen gneiss, augen gneiss, and granitic gneiss-gneissic granite. The term granitic gneiss is applied to rocks of granitic composition in which the gneissic structure is visible megascopically. The term gneissic granite is applied to rocks of a similar composition in which the gneissic structure is discernible only by careful megascopic or microscopic examination.

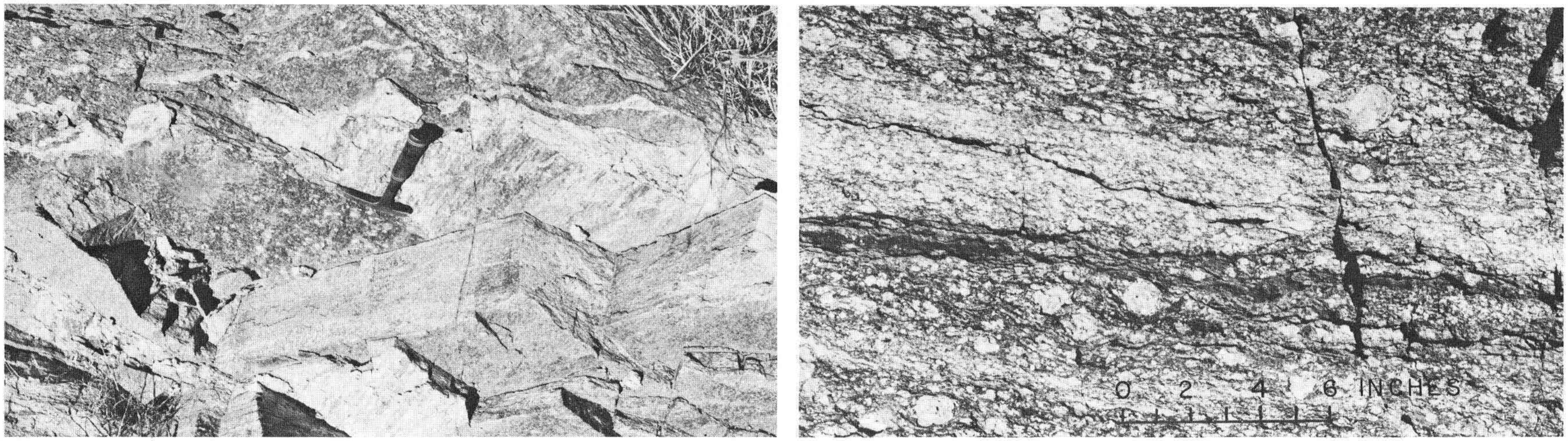
The contacts between the various types of gneissic rocks are gradational, and outcrops of one type are commonly present in areas in which a different type predominates. The different types of gneiss are not mappable on the scale of figures 20 and 46.

Banded Augen Gneiss

Banded rocks predominate in the southern part of the area shown in figure 20. They crop out along the Mount Lemmon road, along the Sabino Canyon road, and form the high hills between the two roads. Northward, the banded features decrease gradationally and the banded augen gneiss grades into augen gneiss.

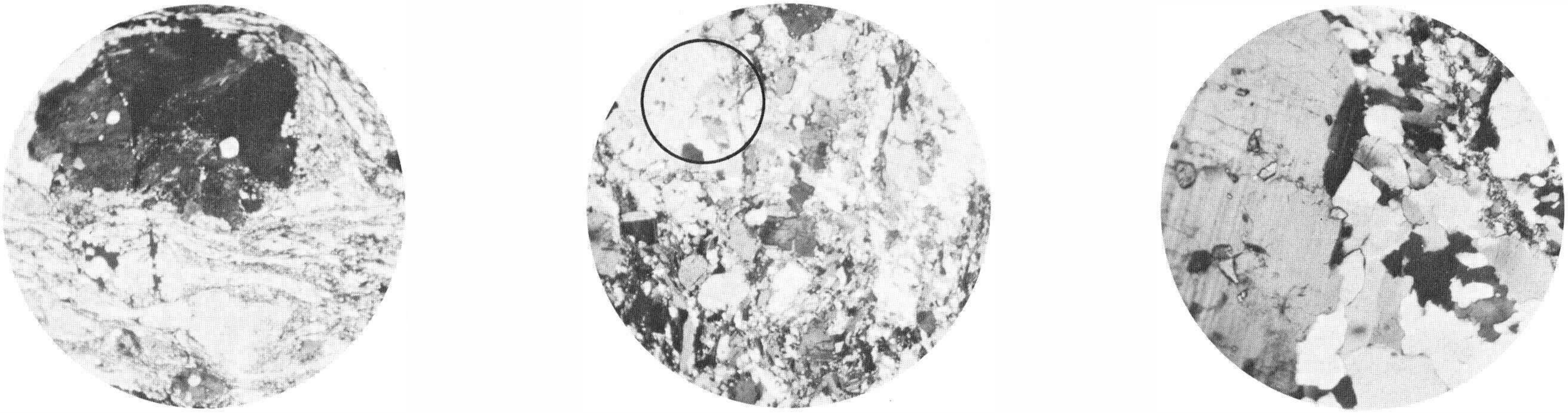
The banding of these rocks varies considerably. In general, it consists of parallel alternating light and dark bands which in most places are parallel to the trend of the regional structure. Locally, however, the light-colored bands transect the dark bands and there are all degrees of angular intersections. In some areas there even are ptygmatic folds. The thickness of the light-colored bands ranges from a fraction of an inch to several feet. Planar structure is shown by oriented concentrations of biotite, of sheared and streaked zones of felsic minerals, and of aligned ellipsoidal crystals (fig. 21A). Linear structure is shown by the orientation of ellipsoidal grains and by the distribution of micaceous minerals (fig. 21A). The planar structure is aligned in the "a-b" plane, and the linear structure is considered to be a "b" lineation.

The banded augen gneiss is composed mainly of quartz, plagioclase, orthoclase, biotite, and muscovite. Some rocks also contain varying amounts of staurolite, tourmaline, garnet, epidote, zircon, or "opaque". The word "opaque" is here used as a common noun to describe unspecified opaque material present in thin-sections. Ellipsoidal crystals of plagioclase and orthoclase as much as 6 inches long and 3 inches wide are generally present in the dark bands of the gneiss. They were originally porphyroblasts but most of them have been converted to porphyroclasts by cataclastic action (figs. 21B, C, D). Only in a few areas have the original porphyroblastic characteristics been preserved. In the light-colored bands there are similar porphyroblasts and porphyroclasts of orthoclase, plagioclase, and quartz. Minor minerals, such as staurolite, tourmaline, and zircon, generally occur as rounded grains but epidote, as single crystals or as inclusions in plagioclase, occurs in



A. Banded augen gneiss with well developed planar and linear structure. The attitude of planar features changes, but the trend of the linear features is consistently N. 50°-60° E.

B. Banded augen gneiss with large porphyroclast of feldspar derived from original porphyroblastic crystals developed during an early stage of feldspathization.



C. Banded augen gneiss with feldspar porphyroclasts set in sheared matrix of quartz and biotite. x12, crossed Nicols.

D. Meta-quartz diorite occurring in banded augen gneiss of Molino Canyon area. x12, crossed Nicols.

E. Enlarge portion of figure 21D, showing small inclusions of epidote in plagioclase and general crystal fabric. x38, crossed Nicols.

FIGURE 21. Photographs and photomicrographs of Catalina gneiss. Photos by R. L. DuBois.

subhedral to euhedral forms. The garnets are anhedral to euhedral and occur primarily in the light-colored zones or along their margins.

The biotite has been drawn out and concentrated locally in bands as a result of a metamorphic differentiation promoted by both mechanical and chemical action. The quartz has been sheared in zones that "flow" around the remaining feldspar porphyroclasts (figs. 21 C, D). Locally, the cataclastic deformation has been so intense that mylonitic rocks have formed. The minerals have reacted differently to this deformation. In areas where strain was least, the mica minerals are oriented and the quartz crystals are elongated. The effect of further deformation was to draw out the biotite and shear the quartz. Under these conditions the feldspar porphyroblasts show evidence of becoming ellipsoidal. Still further deformation has thoroughly sheared the quartz and developed ellipsoidal or rounded forms in the feldspars. More intensive deformation has crushed and abraded the feldspars until only fine-grained, completely sheared material remains.

The occurrence of rounded zircon, staurolite and a high percentage of quartz suggests that the banded gneiss was derived in part from sedimentary rocks. Other parts of the gneiss, such as those in Molino Canyon, may have been derived from igneous masses. In one area in Molino Canyon, the dark bands contain plagioclase, epidote, and biotite, and only minor amounts of quartz and orthoclase. In part, the plagioclase crystals have a distribution of fine inclusions within their central core, suggesting an earlier euhedral form that predates their present highly anhedral shape (figs. 22A, B). Some plagioclase crystals have a faint zoning and abundant inclusions of epidote within their central cores. The high percentage of plagioclase, the low quartz content, the relict euhedral form of the plagioclase and the associated epidote inclusions suggest metasomatic metamorphism of an igneous diorite or quartz-dioritic rock.

It is postulated that the originally more basic plagioclase underwent crystal growth in the solid state and became more sodic. The released calcium formed epidote inclusions. The change from an original calcic mafic mineral to biotite plus epidote required the introduction of potassium.

The light bands parallel to or transecting the structure were formed by metasomatic metamorphism. Introduction of potassium, sodium, and silica would explain their mineralogical composition. Under metasomatic action the biotite was reduced in volume and partly converted to muscovite, with the release of magnesium and iron. These elements are now tied up in the garnets occurring in and along the light bands. Such metasomatic metamorphism, occurring contemporaneously with deformation, could also bring about the formation of feldspar porphyroblasts in the dark bands.

Augen Gneiss

Augen gneiss occurs mainly north of the banded augen gneiss and south of the granitic gneiss-gneissic granite. The augen gneiss grade into these other units over distances of several hundred feet. Local zones of the other rock types occur in the central area of augen gneiss and zones of augen gneiss are present in the other units.

These rocks lack the pronounced banding of the banded augen gneiss, but in most areas have equally well-developed planar and linear structures. The planar feature is evidenced by concentrations of minerals and by an orientation of ellipsoidal feldspar crystals. As in the banded gneiss, the linear structure is oriented along the "b" axis of lineation. The linear element consists of strings of mica crystals alternating with strings of feldspar crystals (fig. 22D).

The mineralogy of the augen gneiss is similar to that of the light-colored bands of the banded gneiss. Quartz, muscovite, biotite, orthoclase, and plagioclase predominate, but minor amounts of epidote, garnet, zircon, and opaque are also present. In most of these rocks the quartz and mica crystals have been sheared and concentrated in elongate zones. The orthoclase and plagioclase porphyroclasts have ellipsoidal outlines (fig. 22E). Locally, there are two generations of plagioclase. The older generation has a more calcic composition and tends to be smaller in size and more euhedral in outline than the younger (fig. 22E). The orthoclase crystals are larger than the plagioclase crystals of either generation and frequently include plagioclase of the first generation.

The effects of cataclastic deformation on the augen gneiss are similar to those on the rocks of the banded augen gneiss. Augen and the associated sheared matrix of quartz form the predominate part of the rock. Local zones of mylonite are also present.

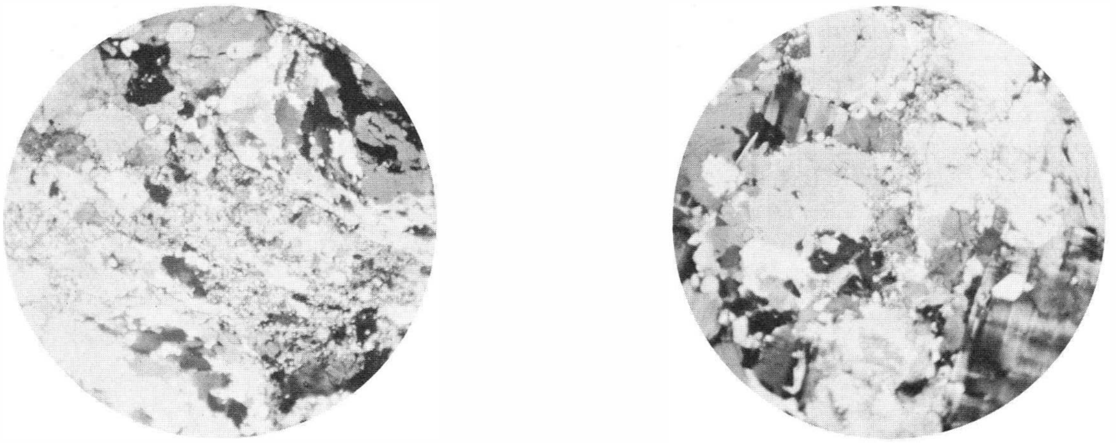
The similarity of mineralogical composition and textural features of the banded augen gneiss to the augen gneiss and the local preservation of areas of banded materials in the augen gneiss suggest that the original material of the augen gneiss is probably similar to that of the banded gneiss. The augen gneiss may represent a more advanced development of the same metasomatic transformation that formed the light-colored bands of the banded gneiss. The early generation of plagioclase has textural features that suggest an igneous origin for at least a part of the augen gneiss. Conclusive evidence for the original rock types is lacking because the metasomatic effects have altered the original chemical composition and most of the primary textures.

Granitic Gneiss-Gneissic Granite

Rocks of this unit crop out north of the augen gneiss. The granitic gneiss-gneissic granite lack the well-developed structural features of either of the augen gneisses. In contrast to the augen gneisses, the granitic gneiss-gneissic granite does not everywhere show both planar and linear features. Locally in the northern part of the area, two structural trends may occur in a single outcrop and the earlier trend is commonly obscured by the younger. The latest structures are parallel to those observed in the augen gneiss and in the banded augen gneiss.

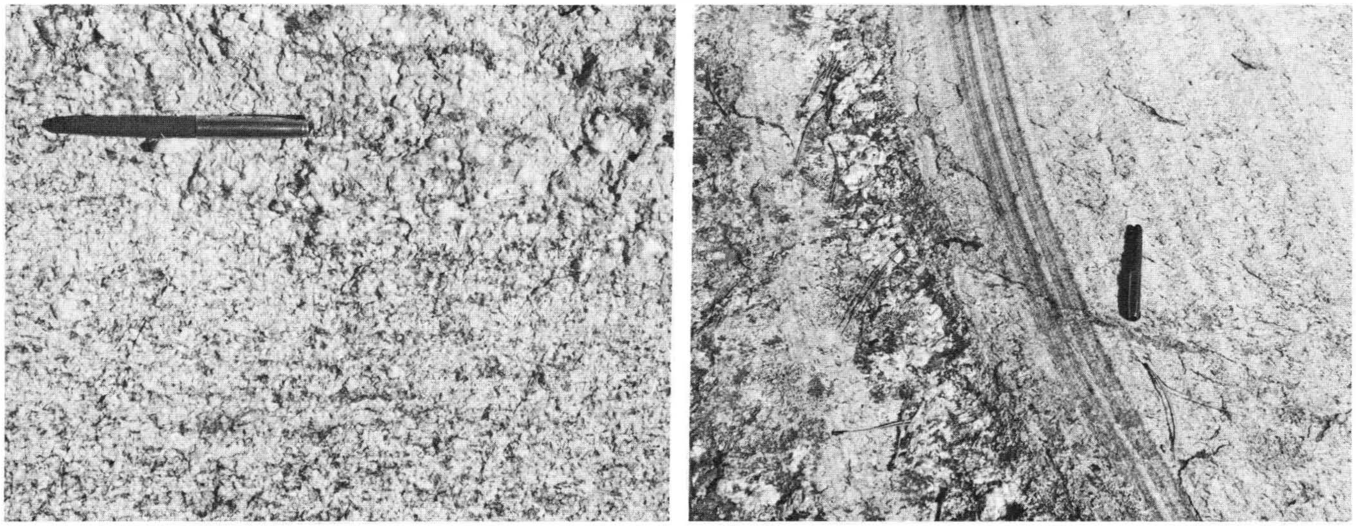
The mineralogy of the granitic gneiss-gneissic granite is similar to that of the rocks already discussed. Quartz, plagioclase, orthoclase, and microcline are the major constituents, but also present are minor amounts of muscovite, biotite, garnet, zircon, and opaque (fig. 24C). The plagioclase occurs both as euhedral inclusions in the potassium feldspars and as large anhedral to subhedral crystals. Microcline and orthoclase have formed porphyroblasts that are locally up to 1 inch in maximum dimension. They generally have irregular border zones containing abundant inclusions. As in the augen gneiss, there are two generations of plagioclase and the potassium feldspars postdate both generations.

The formation of these rocks involved, during the last phase, a period of potassium metasomatism to bring about the formation and crystal growth of potassium feldspars. The plagioclase crystals show evidence of crystal growth either just preceding potassium feldspar growth or contemporaneous with it, and some sodium



A. Augen gneiss containing large porphyroclasts of feldspar with euhedral inclusions of feldspar set in a sheared matrix of mostly quartz. x12, crossed Nicols.

B. Granitic gneiss lacking the prominent cataclastic features prevailing in other gneissic rocks. x12, crossed Nicols.



C. Augen gneiss (lower part) in contact with pegmatite (upper part). Pegmatite and augen gneiss show the same linear structure.

D. Pegmatite cutting Leatherwood quartz diorite. Dark bands to left of fountain pen are strings of garnet crystals.

FIGURE 22. Photomicrographs of Catalina gneiss and photographs of pegmatite contacts with Catalina gneiss and Leatherwood quartz diorite. Photos by R. L. DuBois.

transfer is inferred. Only partial evidence is available as to the original material of these rocks. Textural features suggest that, prior to the main period of metamorphism and metasomatic activity, these rocks had a metamorphic fabric that was in part oriented. Some petrographic features of the first generation of plagioclase suggest igneous origin and possibly an earlier period of metamorphism acted on an igneous or partially mobilized granitic rock. This hypothesis, of course, does not necessarily suggest an origin for all of the rocks of the granitic gneiss-gneissic granite.

Pegmatite

Pegmatite dikes (figs. 22D, E) in the area range in width from a few inches to hundreds of feet. Not only do they range widely in width, one from another, but the width of a single dike may vary. Some of the pegmatitic zones are parallel to the structure of the host rocks and others either transect the structure or spread out to form large irregular bodies. A zone parallel to the structure in one place may cut across the structure irregularly in other places.

The dikes are composed mainly of quartz, orthoclase, microcline, plagioclase, and muscovite, with minor amounts of biotite and garnet. The crystals are up to several feet in length. Biotite and/or garnet is concentrated along the margins of some of the pegmatite dikes (fig. 22E). A few of the pegmatites show cataclastic effects, evidently predating the cataclastic phase of the metamorphism. But the majority show no cataclastic effects and are therefore younger.

An origin by replacement is suggested by offsets, by small-scale basic fronts, and by retention of crystal orientation parallel with those on the nearby host rocks in dikes of post-deformational age.

STRUCTURE

The gneissic rocks of the Santa Catalina Mountains in most areas have a single pronounced planar and linear structure. Locally, there is also a second, less prominent, planar and linear orientation. For the purpose of discussion the less pronounced structures are designated "stage-one" and the more pronounced structures are designated "stage-two."

Stage-One Structures

Stage-one structures are visible mainly in the granitic gneiss-gneissic granite, some parts of which also exhibit superposed stage-two structures. The stage-one structure is both a planar and a linear type and is evidenced by oriented mica and feldspar crystals. In general the planar structure strikes east-west and dips to the north, and the linear structure trends east-west.

Petrographic features of rocks exhibiting well preserved stage-one structures suggest a period of metamorphism preceding the metamorphism associated with stage-two structures. It is likely that the stage-one structures were developed during this early period of metamorphic activity. However, it is possible that the stage-one structures may have been formed during mobilization, may be relicts of a phase of igneous activity, or may have developed during the same general period of deformation that resulted in stage-two structures.

Stage-Two Structures

Stage-two structures are predominant in the area. They are both planar and linear and are mainly evidenced by oriented crystals, strings of crystals, and ellipsoidal feldspar crystals. Local areas of mylonitized materials also show these orientations.

The trends of the planar elements change direction considerably and are expressed as anticlines, synclines, and domes (fig. 18B). The structural planes undulate and in many areas form small folds or domes. These undulations make interpretations of outcrop data difficult, and their presence suggests the use of distance observations in working out broad structures. The linear trends of stage-two structures generally range from N. 50° E. to N. 60° E. but locally swing to east-west (fig. 20).

Stage-two structures partly preceded pegmatite formation. Stage-two structures are also present in the post-Cretaceous Leatherwood quartz diorite, and the stage-two structures in the Catalina gneiss are considered to be the same age.

PETROGENESIS

The gneissic rocks of the Santa Catalina Mountains apparently have been metamorphosed at two different times. The effects of the earlier metamorphism are less pronounced than those of the later metamorphism, which formed the present gneissic structure.

The Catalina gneiss was derived from both igneous and sedimentary materials. The original sedimentary rocks were probably argillaceous and deficient in calcium. The strata best conforming to these requirements are older Precambrian Pinal schist, younger Precambrian Apache group, and Cretaceous (?) rocks. The lack of metasomatic effects in the metamorphosed Apache and Paleozoic rocks in the Summerhaven area, suggests that the original materials of the Catalina gneiss may have been pre-Apache in age and that the Pinal schist was the rock transformed.

The synkinematic metasomatic metamorphism of the post-Cretaceous Leatherwood quartz diorite and the strong development of stage-two structures within it, indicate that the principal period of metamorphism and cataclastic deformation was post-Cretaceous. The occurrence of pegmatite dikes cutting Leatherwood quartz diorite also suggests a post-Cretaceous age for the pegmatite.

During the main period of metamorphism of the Catalina gneiss, potassium, sodium, and silica were introduced. This activity was contemporaneous with deformation, and formed porphyroblasts in the banded and augen gneisses. At the same time, concentrations of quartz and feldspar formed light-colored bands in some areas. As the intensity of deformation increased, the cataclastic structures were developed. There may have been some associated metasomatic activity during this time. After the formation of cataclastic structures, the rocks were fractured and pegmatites were formed by replacement.

The age of the earlier phase of metamorphism noted in the granitic gneiss-gneissic granite could be early Precambrian. This age is suggested by a lack of polymetamorphic effects in Apache or Paleozoic rocks. The metamorphism could have been associated with the metamorphism that formed the Pinal schist during early Precambrian time.