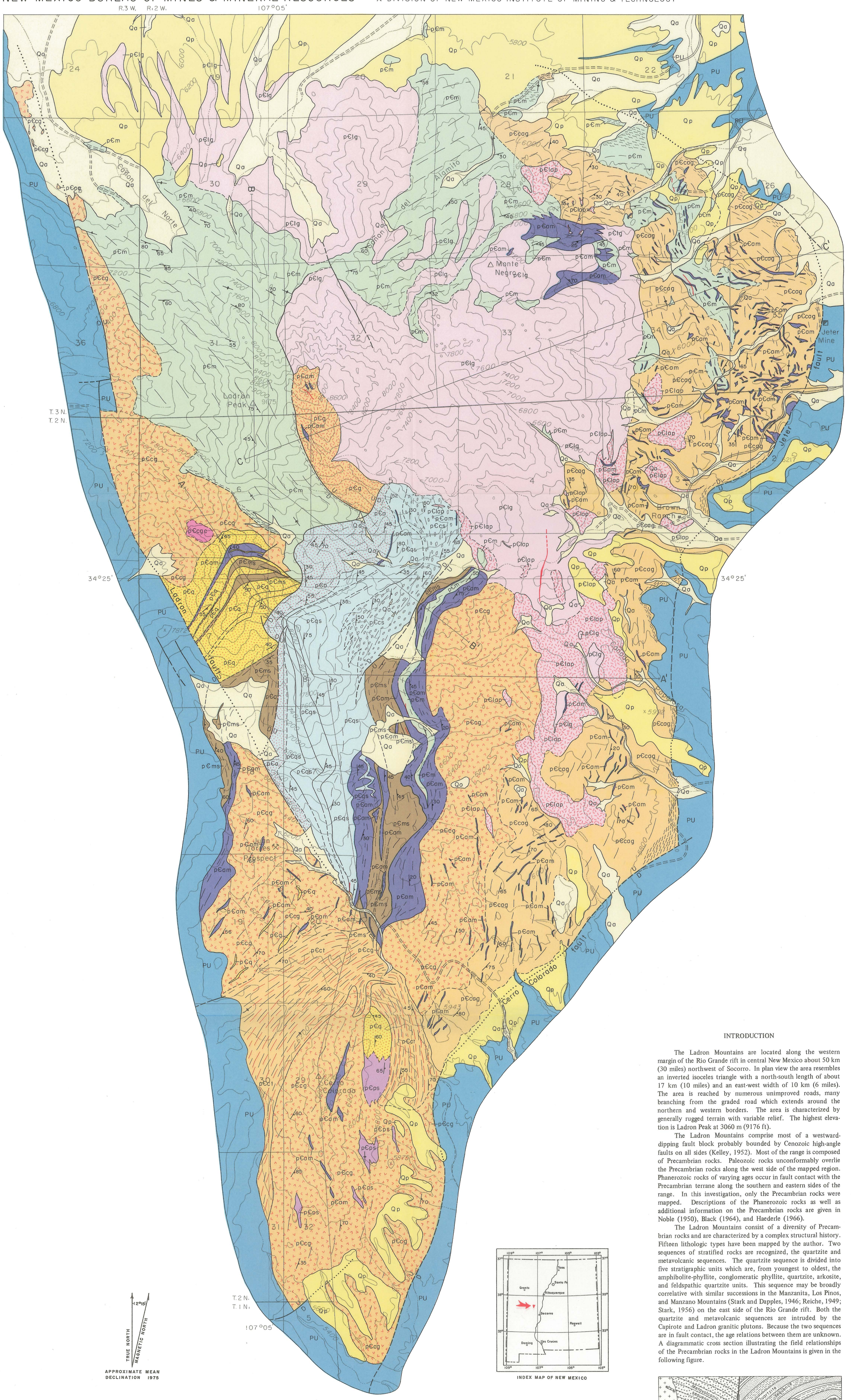


Geology by K.C.Condie 1970-1975 with minor contributions from Black (1964) and Haederle (1966)

Qa — Alluvium
Chiefly stream sands and gravels, alluvial-fan and talus deposits

Qp — Pediment gravels

QUATERNARY

PU — Sedimentary rocks, undifferentiated

PHANEROZOIC

GRANITIC ROCKS

Ladron quartz monzonite

p€lg — Buff, coarse-grained quartz monzonite; p€lap — Late-stage, white quartz monzonite, aplite, and pegmatite

Capirote granite

p€cg — Medium-grained granite; p€cgc — Coarse-grained granite; p€cag — Altered facies of the granite; p€ct — Transition zone composed of partially granitized metasedimentary and metavolcanic rocks; p€am — Amphibolite inclusions; p€m — Siliceous metavolcanic inclusions; p€ps — Porphyroblastic schist; p€q — Feldspathic quartzite and siltite

METAVOLCANIC SEQUENCE

p€g — Granophyre; p€m — Siliceous metavolcanic rocks; p€am — Amphibolite inclusions

QUARTZITE SEQUENCE

Amphibolite-phyllite unit

p€am — Amphibolite inclusions; p€ms — Muscovite-quartz, muscovite-quartz-chlorite; and muscovite-quartz-chlorite-chloritoid phyllite and schist; p€qs — Quartzite and quartz-muscovite-phyllite

Conglomeratic quartzite unit

p€cs — Conglomeratic quartzite and phyllite; quartz phyllite; p€am — Amphibolite inclusions

Quartzite unit

p€qs — Quartzite and quartz-muscovite phyllite and schist; p€am — Amphibolite inclusions

Arkosite unit

p€a — Arkosite and feldspathic quartzite; p€am — Amphibolite inclusions

Feldspathic quartzite unit

p€q — Feldspathic quartzite and siltite; p€ms — muscovite-quartz-chlorite phyllite and schist; p€am — Amphibolite inclusions

PRECAMBRIAN

Contact (dashed where inferred or gradational)

General trend of foliation or bedding

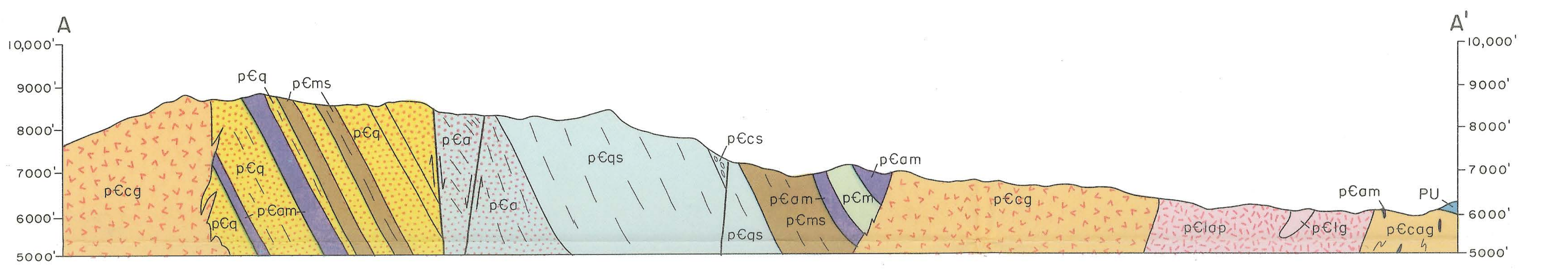
Fault

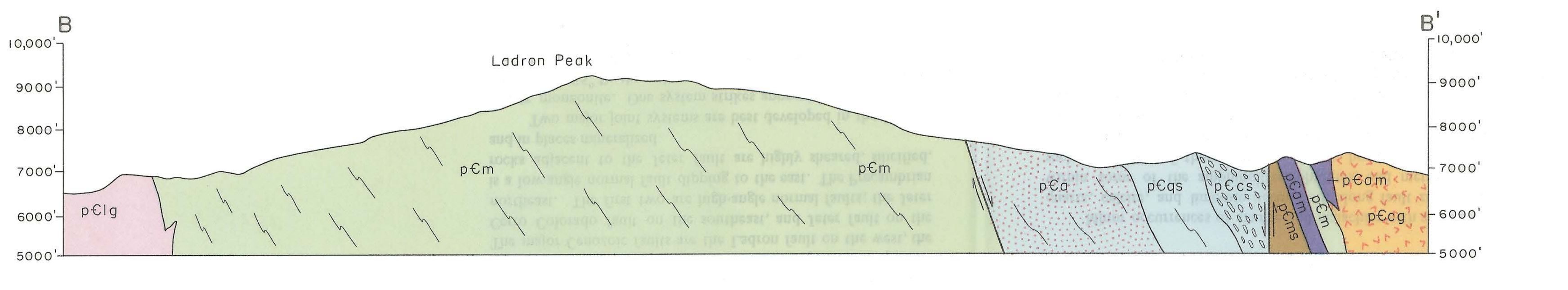
Shear zone

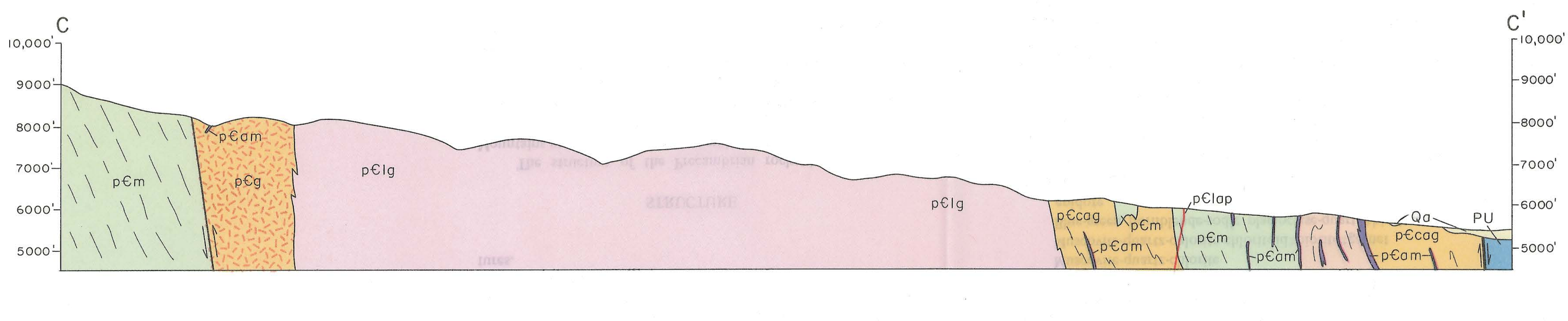
Strike and dip of foliation or bedding (double barb denotes vertical)

Mine or shaft

Prospect





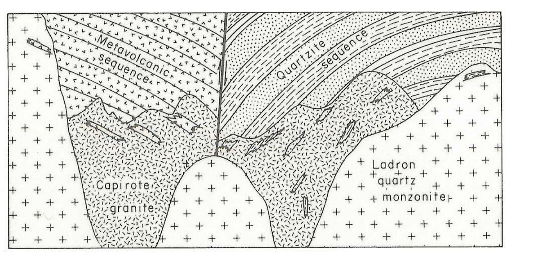


INTRODUCTION

The Ladron Mountains are located along the western margin of the Rio Grande rift in central New Mexico about 50 km (30 miles) northwest of Socorro. In plan view the area resembles an inverted isoceles triangle with a north-south length of about 17 km (10 miles) and an east-west width of 10 km (6 miles). The area is reached by numerous unimproved roads, many branching from the graded road which extends around the northern and western borders. The area is characterized by generally rugged terrain with variable relief. The highest elevation is Ladron Peak at 3060 m (9176 ft).

The Ladron Mountains comprise most of a westward-dipping fault block probably bounded by Cenozoic high-angle faults on all sides (Kelley, 1952). Most of the range is composed of Precambrian rocks. Paleozoic rocks unconformably overlie the Precambrian rocks along the west side of the mapped region. Phanerozoic rocks of varying ages occur in fault contact with the Precambrian terrane along the southern and eastern sides of the range. In this investigation, only the Precambrian rocks were mapped. Descriptions of the Phanerozoic rocks as well as additional information on the Precambrian rocks are given in Noble (1950), Black (1964), and Haederle (1966).

The Ladron Mountains consist of a diversity of Precambrian rocks and are characterized by a complex structural history. Fifteen lithologic types have been mapped by the author. Two sequences of stratified rocks are recognized, the quartzite and metavolcanic sequences. The quartzite sequence is divided into five stratigraphic units which are, from youngest to oldest, the amphibolite-phyllite, conglomeratic phyllite, quartzite, arkosite, and feldspathic quartzite units. This sequence may be broadly correlative with similar successions in the Manzanita, Los Pinos, and Manzano Mountains (Stark and Dapples, 1946; Reiche, 1949; Stark, 1956) on the east side of the Rio Grande rift. Both the quartzite and metavolcanic sequences are intruded by the Capirote and Ladron granitic plutons. Because the two sequences are in fault contact, the age relations between them are unknown. A diagrammatic cross section illustrating the field relationships of the Precambrian rocks in the Ladron Mountains is given in the following figure.



Diagrammatic cross section showing field relationships of Precambrian rocks in the Ladron Mountains.

STRATIGRAPHY

Quartzite Sequence

The quartzite sequence is best exposed along the ridge trending southeast about 2 km (1.2 miles) south of Ladron Peak and in the canyon north of this ridge. The sequence strikes northeasterly and dips from 45° to 60° SE. Well-preserved crossbedding in the quartzite and feldspathic quartzite indicate the section is upright. The base and top of the section are not exposed due to intrusion by the Capirote granite. The observed thickness of the quartzite sequence of about 3000 m (9800 ft) is a minimum due to faulting.

Feldspathic Quartzite Unit

The feldspathic quartzite unit is the oldest recognized succession in the Ladron Precambrian section. It is best exposed on the southeast trending ridge 2 km (1.2 miles) south of Ladron Peak where a minimum thickness of 900 m (2900 ft) occurs. Neither the base nor the top of the unit are exposed due to, respectively, intrusion by the Capirote granite and faulting. The upper limit of exposure of the unit is marked by a northeasterly-trending fault beginning in sec. 7 and ending near the center of sec. 5, T. 2 N., R. 2 W. The unit is composed dominantly of feldspathic quartzite and siltite with minor interlayered beds of quartzite and conglomeratic quartzite. Muscovite-quartz-chlorite phyllite and schist and amphibolite comprise about 20 percent of the section. Festoon crossbedding, and less commonly, planar crossbedding are well preserved in the quartzitic beds. Intraformational conglomerates and pull-apart structures are also occasionally preserved. Individual quartzite layers range from 10 cm (4 inches) to over 50 m (160 ft) thick. Quartzites are composed of quartz (50 to 95 percent), K-feldspar (0 to 30 percent), sodic plagioclase (0 to 5 percent), muscovite (2 to 10 percent), and minor amounts of magnetite, chlorite, and epidote. The conglomerate units contain quartz and quartzite pebbles ranging from 1 to 5 cm (0.5 to 2 inches) in diameter.

Arkosite Unit

The arkosite unit, which is about 400 m (1300 ft) thick, is in fault contact with the feldspathic quartzite unit. It is best exposed in the major canyon and along the adjacent north ridge about 2 km (1.2 miles) southeast of Ladron Peak. The upper contact is gradational over tens of meters with the overlying quartzite unit. The arkosite unit is composed chiefly of buff to white, coarse-grained arkosite and feldspathic quartzite often containing more than 50 percent of K-feldspar and granitic rock-fragment clasts. Smaller amounts of quartzite, muscovite-quartz schist, and amphibolite also occur interbedded with the arkosite and feldspathic quartzite.

Quartzite Unit

The quartzite unit is composed of approximately 200 m (650 ft) of massive white quartzite overlain by up to 400 m (1300 ft) of quartz-muscovite phyllite and schist. Rocks in the unit are typically fine grained and range in color from buff to pale green. Crossbedding is rarely preserved in some of the mica-poor beds. Minor amphibolite and muscovite-quartz-chlorite beds also occur in the section.

In thin section, quartz and fine-grained quartzite rock fragments dominate (75 to 90 percent) in the phyllites followed in abundance by K-feldspar and sodic plagioclase (10 to 15 percent). Accessory minerals are muscovite, epidote, and magnetite. Mortar textures and augen-shaped clasts reflect varying degrees of cataclastic deformation.

Conglomeratic Quartzite Unit

The conglomeratic quartzite unit is gradational with the underlying quartzite unit and appears to taper out in a southernly direction. The maximum exposed thickness is about 400 m (1300 ft). The overall appearance of this unit both in the field and in thin section is similar to that of the underlying quartzite unit. It differs chiefly by containing an abundance of stretched-pebble conglomerates. Clasts in the conglomerates are usually deformed into augen and lensoid shapes and range from a few millimeters to 10 cm in maximum dimension. They are most commonly quartzite, quartz phyllite, and granite.

Amphibolite-Phyllite Unit

The amphibolite-phyllite unit rests conformably on the quartzite unit and is in fault contact with the conglomeratic quartzite unit. The maximum exposed thickness is about 1800 m (5900 ft). The upper contact is not exposed due to intrusion by the Capirote granite. Remnants of amphibolite, schist, and metavolcanic rocks in the Capirote granite, however, suggest that the sequences continued eastward and perhaps graded upwards into the metavolcanic sequence. A small part of the unit is exposed west of the Ladron fault (in secs. 18 and 19, T. 2 N., R. 2 W.). The amphibolite-phyllite unit is composed chiefly of amphibolite and muscovite-quartz schist and phyllite; minor intercalated quartzite and quartz-muscovite phyllite beds are also present. The muscovite-quartz phyllite and schist sometimes contain chlorite and chloritoid. One siliceous metavolcanic bed occurs in the upper part of the exposed section. This unit, which reflects the onset of siliceous volcanism in the Ladron area, lends some support to the possibility that the metavolcanic sequence overlies the amphibolite-phyllite unit.

The amphibolites range from massive and fine grained to layered and foliated. They are composed principally of blue-green hornblende (60 to 75 percent), sodic plagioclase (10 to 30 percent), quartz (5 to 15 percent), and minor amounts of biotite, chlorite, epidote, and magnetite. Local crosscutting relationships and the occasional presence of relict plagioclase phenocrysts suggest that most or all of the amphibolites are of mafic igneous parentage, probably basalt flows, sills, or dikes.

The phyllite part of the sequence is characterized by fine- to medium-grained, well-foliated, black phyllites and schists. These rocks are composed chiefly of muscovite (20 to 80 percent), quartz (20 to 70 percent), chlorite (1 to 5 percent), chloritoid (0 to 5 percent), and smaller amounts of feldspars, biotite, magnetite, epidote, and rarely garnet.

Metavolcanic Sequence

The metavolcanic sequence is best exposed on the summit ridge of Ladron Peak and on the northwest side of the range. The lower contact is not exposed due to intrusion with the Ladron quartz monzonite and the Capirote granite. The distribution of amphibolite and metavolcanic inclusions in these plutons suggests that the sequence overlies, and is perhaps continuous with, the amphibolite-phyllite unit. The top of the sequence is not exposed due to intrusion by the Capirote granite about 1 km (0.6 mile) south of Ladron Peak. The minimum exposed thickness of the sequence is 1800 m (5900 ft) and occurs on the northwest slope of Ladron Peak.

The metavolcanic sequence is composed chiefly of pink to purple siliceous volcanic rocks with minor black amphibolites. Much of the section northwest of Ladron Peak is not greatly affected by low-grade regional metamorphism; primary textures and structures are well preserved. Field and petrographic studies indicate an abundance of flattened rock fragments, broken and imbricated phenocrysts, resorbed phenocrysts, and the probable existence of compaction foliation. These features suggest that as much as 75 percent of sequence is represented by ash-flow tuffs. The remainder is composed of siliceous air-fall tuffs and lava flows, and perhaps 5 percent of basalt flows (represented by the amphibolites). Mafic flows appear to become more abundant in the lower part of the sequence, now represented chiefly by the amphibolite remnants in the altered facies of the Capirote granite in the northeastern part of the range.

In thin section, the siliceous volcanic rocks are composed chiefly of phenocrysts of sodic plagioclase (10 to 20 percent) engulfed in a now completely recrystallized groundmass of feldspar, quartz, and muscovite. Biotite and epidote are common accessory minerals. Estimates of the proportions of K-feldspar, plagioclase, and quartz suggest a rock composition mostly of rhyolite or quartz latite. Amphibolites are similar petrographically to those in the amphibolite-phyllite unit.

A distinctive granophyre unit east of Ladron Peak is in fault contact with the main volcanic section and intruded by the Ladron quartz monzonite. The unit contains discontinuous inclusions of amphibolite ranging in thickness from 1 to 3 m (3 to 9 ft). The rock is pink and massive and, in thin section, characterized by partially resorbed sodic plagioclase phenocrysts in a groundmass of micrographic intergrowths of quartz and K-feldspar. The granophyre is tentatively interpreted as a fragment of a sill or shallow pluton associated with the metavolcanic sequence.

GRANITIC ROCKS

Capirote Granite

The Capirote granite (Noble, 1950) is a heterogeneous granitic pluton exposed on the western, southern, and eastern sides of the Ladron Mountains. It is intrusive into both the quartzite and metavolcanic sequences. Four facies of the Capirote granite are distinguished on the map: medium-grained (3 to 5 mm) facies, coarse-grained (3 to 10 mm) facies, an altered facies, and a transition zone. The color of the medium- and coarse-grained varieties ranges from buff to rusty orange, and grain borders are characterized by ubiquitous iron oxide stains. The medium-grained variety occurs in four discontinuous outcrop areas along the western and central parts of the range, while the coarse-grained facies is distinguished as such in only one small area about 1 km (0.6 mile) south of Ladron Peak.

In the southern part of the range and in the altered facies, the Capirote granite contains numerous inclusions of amphibolite, quartzite, and siliceous matavolcanic rocks. Such inclusions compose from 20 to 40 percent of the outcrop area in these regions. The larger exposures are shown on the map; size ranges from greater than 1 km to a few centimeters and they exhibit textures suggesting varying degrees of digestion and granitization and often show sharp contacts with surrounding granitic rocks. A transition zone containing from 40 to 80 percent of partially granitized quartzites, phyllites, and siliceous metavolcanic rocks is distinguished on the map. This zone appears to wrap around the northern end of Cerro Colorado.

The altered facies of the Capirote granite is exposed along the eastern side of the range and is gradational with the medium-grained facies. The altered facies is characterized by fracturing and shearing, textural inhomogeneities, and varying degrees of alteration. Granitic rocks in this facies range from orange to white in color, from medium to fine grained, and from massive to gneissic. The intensity of fracturing and shearing appears to increase along the eastern margin of the outcrop area and may be related to Tertiary faulting on the Jeter and Cerro Colorado faults. In some areas such as south and east of the Brown (Lazy C Bar J) Ranch, shear zones occur in the granitic rocks adjacent to the Jeter fault. Local areas of unaltered Capirote granite occur within, and are gradational with, the altered facies. Small apophyses of the late-stage facies of the Ladron quartz monzonite also occur within and adjacent to the altered Capirote facies; some of the larger bodies are shown on the geologic map. Granitized remnants of schists and quartzites (containing abundant porphyroblasts of K-feldspar) occur in the vicinity of Cerro Colorado and are mapped as porphyroblastic schists. They are gradational with a large quartzite inclusion about 0.5 km (1500 ft) east of Cerro Colorado.

Typical samples of unaltered Capirote granite contain 45 to 55 percent K-feldspar, 25 to 30 percent sodic plagioclase, and 15 to 25 percent quartz with traces of magnetite and limonte. K-feldspar commonly exhibits coarse perthitic textures while the plagioclase occurs as small interstitial grains. In the southern part of the range and in the altered facies, the rocks contain bent and crushed grains and often exhibit sieve textures. Secondary minerals such as quartz, chlorite, epidote, limonite, and sericite occur in variable amounts in samples from the altered facies.

Ladron Quartz Monzonite

The Ladron quartz monzonite (originally named Ladron granite by Black, 1964) is the youngest recognized Precambrian pluton in the Ladron Mountains. It occupies a large portion of the north-central part of the range, discordantly intruding all other Precambrian rocks. In the field, the quartz monzonite is characterized by a light-orange to buff color and a knobby weathering habit. Remnants of amphibolite, metavolcanics, and quartzite occur in some areas—although much less abundant than in the Capirote granite. A white facies of the quartz monzonite (larger occurrences shown on the geologic map) appears to represent a late, hydrous phase. This phase is gradational with aplites and pegmatites. Such aplites and pegmatites are not common in the Ladron quartz monzonite but when found, range

Continued on back — fold up

PRECAMBRIAN ROCKS OF LADRON MOUNTAINS, SOCORRO COUNTY, NEW MEXICO

by Kent C. Condie 1976

Scale 1:24,000

0 — 1 — 2 Miles

Contour interval 200 ft

Continued from front

in size from thin dikes with thicknesses of 2 cm to 5 cm to irregular pods a few meters across. Locally abundant quartz veins also cut the quartz monzonite.

The Ladron quartz monzonite is coarse grained, exhibits a rather uniform texture, and is composed of approximately equal amounts of K-feldspar, sodic plagioclase, and quartz. It differs most strikingly from the Capirote granite in containing biotite and muscovite and in lacking foliation. Accessory minerals are apatite, magnetite, and epidote. K-feldspars exhibit typical gridiron twinning of microcline and usually possess sieve textures.

STRUCTURE

The structure of the Precambrian rocks in the Ladron Mountains varies from simple to complex. The quartzite sequence appears to represent the eastern limb of a north- to northeast-trending anticline. The western limb is not exposed. Although foliation is generally parallel to bedding, small-scale (a few centimeters to a few meters) isoclinal and monoclinal folds occur in some areas. In the northern part of the range, the granitic plutons have greatly disrupted the metavolcanic sequence which occurs as a large roof pendant between (and within) the Capirote granite and the Ladron quartz monzonite, and as inclusions in these bodies. Complex development of folded migmatites occurs along the northeastern border of the Ladron quartz monzonite in Cañon del Alamito and vicinity.

Faults of both Precambrian and Cenozoic age occur in the range. The most complex development of Precambrian faults, which appear to be chiefly high-angle normal faults, occurs about 2 km (1.2 miles) south of Ladron Peak in the quartzite sequence. The major Cenozoic faults are the Ladron fault on the west, the Cerro Colorado fault on the southeast, and Jeter fault on the northeast. The first two are high-angle normal faults; the Jeter is a low-angle normal fault dipping to the east. The Precambrian rocks adjacent to the Jeter fault are highly sheared, silicified, and in places mineralized.

Two major joint systems are best developed in the Ladron quartz monzonite. One system strikes approximately north and dips 75° - 85° E; the other strikes northwest and has a vertical dip. A minor subhorizontal joint systems also occurs in this area and, together with the two major systems, is responsible for the knobby weathering habit of the Ladron quartz monzonite.

METAMORPHISM

Metamorphic mineral assemblages in the Precambrian rocks of the Ladron Mountains are summarized as follows:

- Muscovite-quartz-chlorite-sodic plagioclase±biotite
- Muscovite-quartz
- Muscovite-quartz-chlorite
- Muscovite-quartz-chlorite-chloritoid±biotite±garnet
- Blue-green hornblende-sodic plagioclase-quartz±biotite± epidote

These assemblages indicate the transitional greenschist-amphibolite facies of regional metamorphism. This low-grade metamorphism was not sufficiently intense to completely destroy primary textures and structures in the metasedimentary and metavolcanic rocks. Foliation ranges from poorly (or not at all) developed in some of the quartzites and volcanic rocks to well-developed in the phyllites and schists. Cataclastic foliation and related structures are present in the upper part of the quartzite sequence and in the southern and eastern parts of the Capirote granite.

The effects of contact metamorphism around the granitic plutons are minimal. Contact metamorphic mineral assemblages were not recognized. Such evidence together with the overall sparsity of aplites and pegmatites in the granitic rocks suggests the parent magmas were relatively dry when emplaced.

MINERAL DEPOSITS

Minor occurrences of azurite and malachite with associated quartz, calcite, and limonite occur both along fault zones and within some of the amphibolites, phyllites, and metavolcanic rocks. Neither of these copper minerals, however, appears to have economic potential. Galena, fluorite, and amethyst quartz occur at the Juan Torres prospect about 3 km (1.8 miles) northwest of Cerro Colorado. Fault gouge is also mineralized with malachite along the Ladron fault north of this prospect. Barite veins, some which have been mined, occur in the altered facies of the Capirote granite in the northeast part of the range. Black (1964) reports minor deposits of specular hematite in veins and replacing quartz in the Ladron quartz monzonite. The only deposit of economic importance in the Ladron Mountains was the oxidized uranium deposit at the Jeter mine. This deposit, located about 2 km (1.2 miles) northeast of the Brown (Lazy C Bar J) Ranch, occurs in fault breccia along the Jeter fault. It is associated with limonite, azurite, malachite, barite, and quartz, all of which partially replace the fault breccia. Most of the mineralization in the Ladron Mountains appears to be of Cenozoic age.

GEOLOGIC HISTORY

The oldest event recorded in the Precambrian section of the Ladron Mountains is the accumulation of clastic sediments rich in quartz and feldspar. The detrital feldspar in these rocks appears to reflect both a tectonically active source area of granitic or gneissic composition and rapid erosion and burial. Amphibolite in the section, which becomes progressively more abundant in the amphibolite-phyllite unit, reflects the onset of basaltic magmatism. The abundance of phyllites in the upper portion of the quartzite sequence records more distant, although not necessarily more tectonically stable, source areas. Then follows a rather abrupt onset of siliceous volcanism and corresponding decline in basaltic volcanism. Next, the area is buried, metamorphosed, folded about northeast-trending fold axes, and intruded by the Capirote granite. This pluton appears to represent a syntectonic body emplaced at relatively shallow levels. During its emplacement, the quartzite and metavolcanic sequences are deformed and partially granitized. The final event in the Precambrian is the shallow intrusion of the Ladron quartz monzonite.

Like other Precambrian rocks in New Mexico, the Precambrian rocks in the Ladron Mountains are rather unusual in terms of plate-tectonic rock associations. The association of immature clastic sediments with bimodal igneous rocks in which siliceous and members greatly dominate is not widely recognized in the Phanerozoic. The absence of andesites, granodiorite, and graywackes seems to eliminate a convergent plate-boundary model; the absence of ophiolites does not favor a divergent plate-boundary setting. The early stages of development in the Ladron Mountains characterized by vertical uplift and basaltic volcanism may record the development of an incipient continental rift system. However, the dominance of siliceous volcanism and plutonism do not characterize Phanerozoic rift systems. Such voluminous siliceous magmatic activity may have reflected partial melting of the lower crust in response, perhaps, to an ascending mantle diapir. A lower crustal source for siliceous igneous rocks in other Precambrian terranes in central New Mexico is favored by trace-element model studies in progress by the author.

ACKNOWLEDGEMENTS

The author gratefully acknowledges Mr. and Mrs. R. D. Lauer of Los Lunas, New Mexico and Mrs. E. J. DeGeer of San Francisco, California for permission to work on their ranch lands. Also I thank Mr. J. R. Kiger, Manager of the Sevilleta National Wildlife Refuge for permission to cross the wildlife refuge. The manuscript was critically reviewed by A. J. Budding and J. M. Robertson who made valuable suggestions for its improvement.

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