



## *Precambrian Rocks of the Tusas Mountains*

E. C. Bingler

1974, pp. 109-113. <https://doi.org/10.56577/FFC-25.109>

in:

*Ghost Ranch*, Siemers, C. T.; Woodward, L. A.; Callender, J. F.; [eds.], New Mexico Geological Society 25<sup>th</sup> Annual Fall Field Conference Guidebook, 404 p. <https://doi.org/10.56577/FFC-25>

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*This is one of many related papers that were included in the 1974 NMGS Fall Field Conference Guidebook.*

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# PRECAMBRIAN ROCKS OF THE TUSAS MOUNTAINS

by

E. C. BINGLER

Nevada Bureau of Mines and Geology

University of Nevada • Reno

Reno, Nevada 89507

## INTRODUCTION

Precambrian rocks in the Tusas Mountains range from nearly monomineralic quartzite, in which the principal result of metamorphism has been simple recrystallization, through locally metasomatized schist and gneiss profoundly modified by potash-rich fluids during the intrusion of pegmatite. Texturally, the rocks range from schist and phyllite containing penetrative and pervasive cleavage or schistosity that has completely transposed earlier planar structures, to unfoliated porphyritic granite.

Geologic studies of the Precambrian in the Tusas Mountains include an early reconnaissance by Just (1937), and quadrangle mapping by Barker (Las Tablas quadrangle, 1958), Jahns, Smith, and Muehlberger (Ojo Caliente quadrangle, 1960), Bingler (La Madera quadrangle, 1965), Muehlberger (Brazos Peak quadrangle, 1968), and Doney (Cebolla quadrangle, 1968). Just (1937) established an early stratigraphic framework by naming the Ortega Quartzite, the Picuris Basalts, the Vallecitos Rhyolites, the Tusas Granite, and the Petaca Schist. Barker (1958, 1970) subdivided and revised Just's nomenclature. Muehlberger's (1960) comprehensive review of the Precambrian of the Tusas Mountains follows the nomenclature of Barker (1958). Detailed studies include Lindholm's (1964) structural petrologic analysis of the Ortega Quartzite in the type area, Ritchie's (1969) remapping of 12 square miles in the Poso Lake area, and a geologic map of the same area by Stensrud (1970), and Hutchinson's (1968) map of the Hopewell Lake area.

Formal stratigraphic names have been used by other workers for the Precambrian of the Tusas Mountains (Just, 1937; Barker, 1958, 1970; Muehlberger, 1960) and correlations based upon lithology but implying continuity have been made linking distant exposures, in particular from the Tusas Mountains to the southern Sangre de Cristo Mountains (Montgomery, 1953; Miller, Montgomery, and Sutherland, 1963). In this report, stratigraphic units are given lithologic names to avoid generalizations regarding the original continuity of rock masses.

This article is a condensed version of the author's discussion of Precambrian rocks of Rio Arriba County (Bingler, 1968). The reader is referred to the 1968 report for a full-color geologic map of the Tusas Mountains.

## LITHOLOGY

### Quartzite

Medium- to coarse-grained, blue-gray to grayish white, prominently laminated quartzite is the most widespread Precambrian map unit. It forms the precipitous cliffs in the Brazos and Chaves boxes and underlies Jawbone Mountain, Kiowa Mountain, Quartzite Peak, the Ortega Mountains, and La Madera Mountain.

Quartzite in the Tusas Mountains ranges from even-grained,

relatively homogeneous rock with gray-white vitreous luster to a granular and slabby, greenish gray rock with dull matte luster. A prominent lamination due to the presence of specularite, kyanite, sphene, and zircon concentrated in laminae up to several millimeters thick is ubiquitous. Most of these laminae represent original bedding and cross-bedding that in some areas can be used to determine tops and bottoms of beds. However, in most quartzite exposures, particularly in the Ortega Mountains, intense shearing and plastic flow have so swirled and dislocated original bedding planes that they are no longer reliable indicators of tops of beds. Pebble beds, composed of quartzite layers with a maximum thickness of several feet, are common in the quartzite. These beds consist of relict pebbles of milky quartz, fine-grained specularite quartzite, and red and black quartz in a medium-grained matrix of recrystallized quartz sand. Foliation is generally well developed and for the most part appears to be "welded" relict fracture cleavage or relict bedding. This foliation invariably contains a prominent lineation defined by parallelism of kyanite blades or stretched pebbles. Lens-shaped segregations and veins of white, coarse-grained quartz are widely developed.

Gray quartz-pebble conglomerate exposed near Big Rock and Hopewell Lake is included in the quartzite unit. Clasts consist of light-gray, red and black quartz and range up to about one foot in diameter (Barker, 1958, p. 25); these clasts are well rounded but, where deformation has been locally intense, tend to be flattened in the principal foliation plane. The pebbles are set in a matrix of gray to bluish-gray kyanite quartzite containing numerous specularite laminae.

Principal accessory minerals in quartzite are kyanite, manite, and specular hematite. Kyanite laths from a few millimeters to several centimeters long are common on foliation planes in the matrix of the quartzite and also as rosettes in quartz-kyanite veins. Kyanite is normally present up to 2 or 3 percent, but in the Ortega Mountains it is locally concentrated in schist and gneiss layers and constitutes up to 10 percent of the rock. On La Jarita Mesa near Big Rock (T. 27 N., R. 8 E.), kyanite segregations contain up to 50 percent kyanite (Corey, 1960, p. 60). Sillimanite is present in the quartzite of La Madera Mountain as tufts generally less than one centimeter in diameter. These tufts commonly have a reddish tint produced by iron-oxide film. Other accessory minerals in quartzite are zircon, epidote, tourmaline, sphene, and allanite.

Contacts between quartzite and other metamorphic rocks are generally sharp and well marked, except where quartzite grades into muscovitic quartzite. Greenish-black amphibolite is intercalated with quartzite near Kiowa Creek (T. 27 N., R. 8 E.).

Quartzite as described in this report includes the Ortega Quartzite of Just (1937), and the Ortega Quartzite and Kiawa Mountain Formation of Barker (1958, 1970).

### Muscovitic Quartzite

Muscovitic quartzite includes muscovite-rich variants of quartzite, leptite, and granitic gneiss. The bulk of this unit ranges in composition from muscovitic quartzite to quartz-mica schist with increasing muscovite content. The muscovite is arranged in prominent laminae with an average thickness of 0.5 mm. These micaceous laminae alternate with layers of fine- to medium-grained quartz. Muscovite content averages about 30 percent, ranging from 10 to 60 percent. In exposures where the rock contains less than 10 percent muscovite, it passes into gray to greenish-gray quartzite. The rock ranges in color from grayish white to pinkish gray, depending upon whether it grades into quartzite or a feldspathic rock such as leptite or granite gneiss. Common accessory minerals include specularite, epidote, chlorite, biotite, and garnet.

Muscovitic quartzite is exposed in a three- to four-mile-wide area extending from Poso Lake southward to Petaca and along the southwestern flank of Mesa de la Jarita from Vallecitos south to Ancones. West of Las Tablas, several masses of muscovitic leptite and quartzite grade into muscovitic quartzite.

Muscovitic quartzite includes the Petaca Schist of Just (1937) and of Barker (1958, 1970). Just believed the Petaca Schist resulted from metasomatism related to the Tusas Granite. Barker (1958) accepted the metasomatic hypothesis but held that the numerous pegmatites of the Petaca area constituted the source of the metasomatizing fluids. Bingler (1965) argued against pegmatitic metasomatism on the basis of detailed structural evidence and favored a sedimentary origin for the muscovite. Gresens and Stensrud (1974) argue for a metasomatic origin wherein muscovitic quartzite is derived from metarhyolite by a process of "hydrogen metasomatism."

### Quartz-Muscovite-Biotite Schist

Fine-grained, equigranular, quartz-rich schist composed of quartz, albite, muscovite, and biotite as essential minerals crops out in a one-half- to three-mile-wide, northwest-trending belt along the eastern base of Mesa de la Jarita, in the Vallecitos valley two miles north of Ancones, and in a one-mile-wide west-trending belt on the north flank of Cerro Colorado two miles north of Ojo Caliente.

In the area between Petaca and Ancones, this unit is uniformly soft, fine- to medium-grained, gray to yellowish gray, and is speckled with small flakes of biotite. The schistosity is well developed, and elongate plates of biotite in the plane of schistosity form a pronounced lineation. Poorly defined, widely spaced hematite laminae usually occur parallel to the schistosity. Common accessory minerals are garnet, epidote, specularite, and chlorite.

Jahns, Smith, and Muehlberger (1960) mapped quartz-muscovite-biotite schist near Ojo Caliente Mountain, and it appears from the brief description accompanying the map that the schist contains essential garnet, and hornblende and pyroxene are local additional phases.

### Hornblende-Chlorite Schist

This unit includes amphibolite and greenschist exposed as tabular masses intercalated with quartzite, muscovitic quartzite, and quartz-muscovite-biotite schist and as irregular bodies of considerable extent. Included are the Moppin Metavolcanics

and Amphibolite Member of the Kiawa Mountain Formation of Barker (1958) and the Picuris Basalts of Just (1937).

Hornblende-chlorite schist is exposed as irregular small masses adjacent to, and interlayered with, quartzite near Brazos Peak. It constitutes much of the bedrock north and east of Hopewell Lake and underlies most of Burned Mountain and Tusas Mountain, where it forms a nearly mile-wide outcrop belt and is prominently interlayered with quartz diorite gneiss. Under La Jarita Mesa, it consists largely of thin layers, often discontinuous, interfingering with quartzite and muscovitic quartzite.

Between Hopewell Lake and Petaca, this unit includes greenschist and amphibolite (Barker, 1958). The greenschists are fine-grained, dark-green, schistose rocks composed of chlorite, albite, epidote, and calcite. Aggregates of chlorite that impart a streaked and spotted texture in outcrop are common. These clots are generally elongate and produce a pronounced lineation. Many of the chlorite aggregates represent retrograde replacement of hornblende crystals (Barker, 1958, p. 17). Biotite and sericite-chlorite-albite pseudomorphs of plagioclase are locally present.

Oligoclase-epidote-hornblende-biotite amphibolite containing a trace of apatite and several percent of magnetite is interlayered with quartzite and schist south of Tusas Mountain. Texture ranges from fine-grained and equigranular to coarse-grained and porphyritic. In general, grain size in the amphibolite masses increases eastward from Tusas Mountain.

Thin, discontinuous layers of conglomerate, phyllite, gneiss, and schist intercalated with hornblende-chlorite schist are present under Mesa de la Jarita (Barker, 1958, p. 21). These layers of metasediment range in thickness from a few feet to several hundred feet, and contain well-developed schistosity and pronounced lineation defined by the preferred orientation of tabular hornblende and stretched pebbles.

Farther south along Mesa de la Jarita, between Vallecitos and La Madera, thin, continuous layers of hornblende-chlorite schist with an average thickness of about 30 feet occur in muscovitic quartzite and quartz-muscovite-biotite schist. Most of the schist in this area is hard, compact, greenish black, and prominently porphyroblastic. Schistosity is well developed, and lineation is produced by aligned hornblende crystals and elongate aggregates of fine-grained quartz and plagioclase.

The conclusion that the amphibolites and greenschists of the Tusas Mountains were originally igneous rocks, either intrusive sills and dikes or flows, is supported by the widespread occurrence of concordant contacts, relict porphyritic texture, and bulk composition.

### Leptite

Areas designated *leptite* are underlain by pinkish red to gray-white, fine- to medium-grained, granular and quartzofeldspathic, prominently laminated, and porphyritic rock termed *Vallecitos Rhyolites* by Just (1937, p. 44), *Burned Mountain Metarhyolite* by Barker (1958, p. 54), *Feldspathic Schist* by Bingler (1965, p. 29).

Leptite is exposed along the entire length of the Tusas Mountains from north of Brazos Creek south to Ojo Caliente. Principal exposures are under Burned Mountain, under Mesa de la Jarita near Poso Lake, north of Cañon Plaza, along the Rio Vallecitos from Vallecitos to Ancones, and along the north flank of Cerro Colorado.

There is considerable variability in the lithologic character

## PRECAMBRIAN ROCKS—TUSAS MOUNTAINS

of leptyte. In general, it is pinkish red to reddish orange to greenish white, compact and flinty, with a marked fissility due to segregation of fine-grained muscovite into layers less than a millimeter thick. The principal identifying features of leptyte include a fine-grained matrix of equant quartz and feldspar (average grain size, 0.01 mm); large, rounded, clear quartz (average diameter, about 1 mm); and large, pink to white, euhedral to subhedral plagioclase (average grain diameter, about 3 mm). East and south of Vallecitos along the scarp that bounds the Rio Vallecitos on the east, Bingler (1965, p. 33-34) identified a gray-brown to brownish-black, biotite-rich phase and a mica-deficient, compact, gneissic variety of leptyte.

Leptyte becomes progressively more schistose from Jawbone Mountain south to La Madera. A sample collected from a thin layer in quartzite near the Jawbone Mine is compact and flinty with a nearly vitreous appearance. The matrix includes wispy, lenslike aggregates of quartz and feldspar that appear to represent an original texture of flattened lithic fragments similar to that found in welded ash-flow tuffs. This crude layering is transected by a penetrative fracture cleavage. A sample of leptyte taken from near Petaca is markedly schistose with an average muscovite content of about 20 percent and no apparent pre-schistosity structure.

Long (1972) reported an age of  $1425 \pm 15$  m.y. for leptyte (metarhyolite) from the La Madera quadrangle based on a two-point whole-rock/mica isochron. Initial  $\text{Sr}87/\text{Sr}86$  ratios from two leptyte isochrons (0.720 and 0.716) exceed values found for most igneous rocks, and Long concludes that a lengthy crustal history predates the pervasive regional metamorphic effects evident in these rocks.

### Granitic Gneiss

Well-foliated, and for the most part nearly schistose, rock composed of quartz, microcline, albite, and mica crops out as relatively small masses along the eastern margin of the crystalline province in the Tusas Mountains. Although most of this rock has nearly the composition of average granite (Barker, 1958, p. 61), it is entirely recrystallized, and few relicts of igneous texture survive. A penetrative schistosity and lineation produced by the preferred orientation of constituent micas is exhibited in nearly all outcrops. The contacts between granitic gneiss and other metamorphic rock units are sharp, along the Rio Tusas north of Las Tablas, as well as gradational, as in the Cribbenville district where the gneiss grades into muscovitic quartzite and leptyte.

In outcrop, granite gneiss is pink to reddish orange to yellowish brown, schistose, fine- to medium-grained, equigranular, and consists of quartz, microcline, microcline-microperthite, albite, muscovite, and biotite. Common accessory minerals include epidote, specularite, pink garnet, and myrmekite.

Granitic gneiss includes the Tusas Granite (Just, 1937) and the Tres Piedras Granite (Barker, 1958).

### Quartz Diorite Gneiss

Gray, foliated, quartz diorite gneiss was included in the Tusas Granite by Just (1937), but was mapped separately as the Maquinita Granodiorite by Barker (1958) in the Las Tablas quadrangle. Barker described the lithology as follows:

"The Maquinita granodiorite is gray, homogeneous, well foliated, and strongly lineate. Both the foliation and lineation are defined by the distribution and orientation of biotite knots, 1/4-1 inch long. In some exposures the foliation is faint,

but the lineation is well marked in all of the granodiorite. The granodiorite has been strongly sheared in the dikes that cut the Moppin series and in the plutons exposed in the area from Deer Trail Creek to American Creek. The feldspar and quartz are granulated, and locally the rock is essentially a flaser (lenticular) granodiorite.

Under the microscope the Maquinita granodiorite is composed of moderately sericitized and saussuritized calcic oligoclase to calcic albite, altered orthoclase and microcline, quartz in grains of very irregular shapes and sutured boundaries, biotite and epidote in irregular lenses or clusters, and accessory magnetite-ilmenite, apatite, and calcite. The least sheared granodiorite is exposed along part of Duran creek, in secs. 32 and 33, T. 29 N., R. 7 E. This rock has been moderately sheared; plagioclase grains, which originally appear to have been subhedral and 1-5 mm in length, have been fractured and ground against neighboring grains so that they now are rounded to very irregular. Quartz occurs either as rounded to angular aggregates, 1-4 mm across, or as much finer interstitial grains. Biotite and epidote are associated in irregular clusters that are mostly intersertal to the larger grains of light-colored minerals.

Alteration of the Maquinita granodiorite is very similar in all of the exposed bodies. Plagioclase and orthoclase have been moderately to thoroughly sericitized and slightly saussuritized. The markedly altered feldspar now appears as a thick network of sericite and saussurite, which contains epidote and rounded, interstitial grains of clear albite or oligoclase. Some of the altered plagioclase also is rimmed with clear albite or oligoclase. All of the albite-oligoclase present may well have been formed during the alteration. Similarly, the disseminated grains of epidote and biotite may be alteration products of hornblende.

In the plutons from Deer Trail Creek to American Creek as much as two thirds of the granodiorite has been sheared to a fine-grained aggregate that is interstitial to the original grains. This aggregate consists largely of equant to irregular grains of quartz and untwinned feldspar, with lesser amounts of biotite, epidote, muscovite, and saussurite, all of which range from about 0.02 to 2 mm. Even in this highly granulated rock, which almost merits classification as a flaser-granodiorite, most of the biotite and epidote occurs as discrete, well-lineated knots. The amount of shearing is variable, even in the same pluton, and does not appear to increase toward the boundaries; however, too few specimens were gathered to warrant a definite conclusion."

Quartz diorite gneiss crops out along the ridge extending from Jawbone Mountain to Tusas Mountain. Near Tusas Mountain, it occurs as a wedge in hornblende-chlorite schist and in contact with granitic gneiss. It is well exposed in Maquinita Canyon northeast of Burned Mountain and crops out as a group of isolated small masses enclosed by hornblende-chlorite schist north of Hopewell Lake.

### Granite Porphyry

In the Tusas Mountains, granite porphyry underlies Cerro Colorado and crops out in irregular hills four miles north of Jawbone Mountain. This granite is coarsely porphyritic and contains large ovoid aggregates of quartz referred to as "quartz eyes" by Muehlberger (personal commun.). He also noted the similarity between "quartz eye" granite and the rock underlying Cerro Colorado west of Ojo Caliente that Jahns, Smith, and Muehlberger (1960) referred to as porphyritic metarhyolite.

## METAMORPHISM

In the Tusas Mountains, Precambrian rocks have been modified by an early period of regional metamorphism that converted all original rocks to quartzite, schist, gneiss, and

phyllite. Subsequent hydrothermal and pegmatitic metasomatism was widespread but particularly severe near Petaca where numerous pegmatites were intruded.

Facies of regional metamorphism developed in the southern part of the Tusas Mountains include the chlorite and biotite subfacies of the greenschist facies and the almandine amphibolite facies. Identification of these facies is based upon the presence of albite-chlorite-muscovite, muscovite-albite-biotite-epidote, and andesine-hornblende assemblages (Bingler, 1965). In the northern part of the Tusas Mountains, basic rocks were converted to chlorite-albite-epidote-sericite-carbonate and oligoclase-epidote-biotite-hornblende; pelitic assemblages are muscovite-oligoclase-staurolite-kyanite-magnetite and quartz-muscovite-biotite-plagioclase-almandine (Barker, 1958).

Hydrothermal metamorphism in the Tusas Mountains has resulted in the enlargement of pre-existing phases; for example, blades of kyanite in quartzite, growth of new phases such as andalusite filling fractures, retrograde hydration of anhydrous aluminosilicates in replacement of kyanite by pyrophyllite, and prograde crystallization of fibrous sillimanite. The association of these textural and mineralogic changes with obvious channelways such as schistosity and cleavage has led to their interpretation as hydrothermal features. However, no satisfactory source for the hydrothermal fluids has yet been postulated.

Pegmatitic metasomatism, striking at outcrop scale, refers to the replacement of chlorite and hornblende by biotite, minor feldspathization, pronounced muscovitization, the formation of garnet in pelitic schist, and tourmalinization. All these effects are local, spatially related to intrusive pegmatites, and accompanied by a general coarsening of wall-rock textures.

Bedding, schistosity, fracture and slip cleavage, mineralogic and textural lineation, and drag folds are present in the Precambrian rocks. Some, or all, of these structures have been mapped by Barker (1958), Bingler (1965), and Muehlberger (1968).

Bedding and festoon cross-bedding have been identified locally in quartzite. Individual bedding planes are marked by thin, layered concentrations of specular hematite and rounded zircons that presumably represent heavy-mineral concentrations in an original quartz sandstone. Thin, pebbly layers up to one foot thick are common indicators of bedding. These planar structures are well displayed at Jawbone Mountain and the large quartzite mass near Hopewell Lake. Farther south in the Ortega Mountains, the sedimentary structures are intensely deformed and accompanied by much pseudo-bedding of tectonic origin (Lindholm, 1964; Bingler, 1965).

Schistosity produced by the preferred orientation of small muscovite, biotite, and chlorite flakes is ubiquitous in the Precambrian rocks other than quartzite and granite porphyry. A mineralogic lineation is invariably present in the plane of schistosity. In La Madera-Vallecitos area of the southern Tusas Mountains, Bingler (1965) found this schistosity to be an axial-plane cleavage to southwest-trending isoclinal folds. The lineation paralleled the axis of the folds. In 1966, Bingler and Muehlberger (reconnaissance survey) found the same structural relationships exposed in the canyon of the Rio Brazos, in the northern Tusas Mountains. Whether or not this ancient fold system will be found throughout the Precambrian of the Tusas Mountains must await further detailed structural study.

Fracture cleavage in quartzite and slip cleavage in micaceous

rocks are present throughout the Tusas Mountains. These cleavages are axial-plane structures of several fold systems and occur superimposed in numerous outcrops. They tend to occur in zones of closely spaced cleavage development, especially along the axial region of both small-scale and regional folds. Between zones of intense development, cleavage planes are widely spaced or absent. Lineation produced by the intersection of these axial-plane cleavages with bedding, schistosity, or another generation of cleavage identifies the orientation of regional fold axes.

Planar structures are concentrated into northwest and west trends in the Tusas Mountains. Schistosity, which is parallel to bedding except in the noses of isoclinal folds, generally dips to the southwest and strikes northwest. Axial-plane cleavage in northwest-trending folds has a similar orientation. In the La Madera and Hopewell Lake areas, late fracture and slip cleavages strike west and have a steep dip.

Because of repeated deformation of regional extent in the Tusas Mountains, the relationship between various generations and orientations of cleavage and lineation is exceedingly complex. Bingler (1965) gives a detailed analysis of these structural features in the southern part of the range.

Three fold systems of regional extent have been recognized in the Tusas Mountains. The earliest system consists of isoclinal flow folds, much sheared and flattened, with northwest-striking axial planes and axes that bear and plunge to the south-southwest. The second system consists of nearly isoclinal folds overturned to the northeast and trending northwest (Bingler, 1965; Barker, 1958; Muehlberger, 1960). These folds change trend from northwest to west at La Madera Mountain, Kiowa Mountain, and Jawbone Mountain, producing a sinuous fold belt with prominent left-lateral offsets or "steps." The third system consists of broad warps and cleavage step folds (Bingler, 1965) mapped in the La Madera area.

## REFERENCES

- Barker, F., 1958, Precambrian and Tertiary geology of the Las Tablas quadrangle, New Mexico: New Mex. Bur. Mines and Min. Res., Bull. 45.
- Barker, F., 1970, Ortega Quartzite and the Big Rock and Jawbone Conglomerate Members of the Kiowa Mountain Formation, Tusas Mountains, New Mexico: U.S. Geol. Survey, Bull. 1294A, p. A21-A22.
- Bingler, E. C., 1965, Precambrian geology of the La Madera quadrangle, Rio Arriba County, New Mexico: New Mex. Bur. Mines and Min. Res., Bull. 80.
- Bingler, E. C., 1968, Geology and mineral resources of Rio Arriba County, New Mexico: New Mex. Bur. Mines and Min. Res., Bull. 91.
- Corey, A. F., 1960, Kyanite occurrences in the Petaca District, Rio Arriba County, New Mexico: New Mex. Bur. Mines and Min. Res., Bull. 47.
- Doney, H. H., 1968, Geology of the Cebolla quadrangle, Rio Arriba County, New Mexico: New Mex. Bur. Mines and Min. Res., Bull. 92, 114 p.
- Gresens, R. L. and Stensrud, H. L., 1974, Recognition of more meta-rhyolite occurrences in northern New Mexico and a possible Precambrian stratigraphy, *Mountain Geologist* (in press).
- Hutchinson, R. A., 1968, Geology of the Burned Mountain area, Rio Arriba County, New Mexico: M.S. thesis, Colorado School of Mines, 96 p.
- Jahns, R. H., Smith, C. T., and Muehlberger, W. R., 1960, Ojo Caliente quadrangle: New Mex. Bur. Mines and Min. Res., open-file map.
- Just, E., 1937, Geology and economic features of the pegmatites of Taos and Rio Arriba Counties, New Mexico: New Mex. Bur. Mines and Min. Res., Bull. 13.
- Lindholm, R., 1964, Structural petrology of the Ortega quartzite,

## PRECAMBRIAN ROCKS-TUSAS MOUNTAINS

- Ortega Mountains, Rio Arriba County, New Mexico: M.A. thesis, University of Texas.
- Long, L. E., 1972, Rb-Sr chronology of Precambrian schist and pegmatite, La Madera quadrangle, northern New Mexico: *Geol. Soc. America Bull.*, v. 83, p. 3425-3432.
- Miller, J. P., Montgomery, A., and Sutherland, P. K., 1963, *Geology of part of the southern Sangre de Cristo Mountains, New Mexico*: New Mex. Bur. Mines and Min. Res. Mem. 11.
- Montgomery, A., 1953, *Pre-Cambrian geology of the Picuris Range*: New Mex. Bur. Mines and Min. Res. Bull. 30.
- Muehlberger, W. R., 1960, *Precambrian rocks of the Tusas Mountains, Rio Arriba County, New Mexico*: New Mex. Geol. Soc., Guidebook to the Rio Chama County, 11th Field Conf., p. 45-47.
- Muehlberger, W. R., 1968, *Geology of Brazos Peak quadrangle, New Mexico*: New Mex. Bur. Mines and Min. Res., Geol. Map 22.
- Ritchie, A. W., 1969, *Geology of part of Las Tablas quadrangle, Rio Arriba County, New Mexico*: Univ. Texas M.A. thesis.
- Stensrud, H. L., 1970, *Trace and minor element geochemistry of Precambrian muscovites of northern New Mexico*: Ph.D. dissertation, Univ. Washington.