



## *An overview of the Precambrian geology of the Tusas Range, north-central New Mexico*

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## AN OVERVIEW OF THE PRECAMBRIAN GEOLOGY OF THE TUSAS RANGE, NORTH-CENTRAL NEW MEXICO

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### INTRODUCTION

The Tusas Range is a northwest-trending portion of the Brazos uplift of north-central New Mexico (Fig. 1). It is underlain predominantly by Precambrian crystalline and supracrustal rocks that are flanked and locally mantled by Tertiary and Quaternary volcanic and elastic sedimentary strata. Its subdued and partly forested ridges include some of the highest elevations between the Rio Grande depression to the east and the Chama Basin to the west, including Jawbone Mountain (3,256 m), Burned Mountain (3,106 m), Tusas Mountain (3,092 m), and Kiowa Mountain (2,968 m). The range loses its identity to the southeast at La Jarita Mesa, and to the northwest the Precambrian rocks become more thoroughly buried by volcanic rocks of the San Juan volcanic field in the Brazos Peak 15-min quadrangle.

The Precambrian (Proterozoic) rocks that form the core of the Tusas Range are of three general categories: bimodal metavolcanic and associated volcanoclastic metasedimentary rocks, a thick section of vitreous quartzite and interlayered pebble conglomerate, and several small stocks ranging in composition from quartz diorite to granite (Fig. 2). Except for the youngest of these stocks (the Tusas Mountain Granite), all of the Precambrian rocks have undergone regional metamorphism ranging from upper greenschist to middle amphibolite facies and are

weakly to moderately foliated. Folding about northwest-plunging axes was probably concurrent with regional metamorphism, but much of the high-angle faulting in the area is Tertiary and younger.

### PREVIOUS WORK

Many geologists have studied the Precambrian rocks of the Tusas Range and have reached a variety of conclusions concerning the stratigraphy of the layered metamorphic rocks and the history of igneous intrusion. In the first reconnaissance study of the area, Just (1937) interpreted the mafic metavolcanic rocks to be the oldest unit, overlain by a single quartzite and conglomerate sequence and interlayered with the felsic metavolcanics. Jahns (1946) restated Just's conclusions in his report on the Petaca pegmatite district. Barker (1958) mapped a large part of the Tusas Range in his study of the Las Tablas 15-min quadrangle (now subdivided into the Burned Mountain, Mule Canyon, Canon Plaza, and Las Tablas 7 1/2-min quadrangles). He concluded that there were two quartzite sequences with the metavolcanic rocks in between. Gresens and Stensrud (1974) returned to Just's earlier stratigraphic interpretation of a single quartzite unit overlying the metavolcanics. Burns and Wobus (1983) and Manley and Wobus (1982a) agreed with the single-quartzite stratigraphy of Gresens and Stensrud, Jahns, and Just in a re-study of the Tusas Range as part of the U.S. Geological Survey's mapping of the Aztec 1 x 2° quadrangle (Manley and others, 1978; Wobus and Manley, 1982; Manley and Wobus, 1982a, 1982b).

The plutonic rocks and the Precambrian geochronology of the Tusas Range have been discussed by Barker and Friedman (1974), Gresens (1975), Long (1972), Maxson (1976), Wobus and Dobson (1981), and Wobus and Hedge (1982). The economic geology of the Precambrian rocks was included in a report on Rio Arriba County by Bingler (1968).

### ROCK UNITS

#### Mafic Metavolcanic Rocks and Associated Metasedimentary Rocks

Originally named the Hopewell Series by Just (1937), these rocks were renamed the Moppin Metavolcanic Series by Barker (1958). They are best exposed in the creek valley southwest of Hopewell Lake and along Hopewell Ridge, where they form slab-like outcrops with a well-defined cleavage that is usually parallel to schistosity. The most common rocks in the unit are greenschists (chlorite schist and phyllite) and silver-gray sericite schists, interlayered with sericitic metagraywacke and porphyritic metabasalt with highly altered plagioclase phenocrysts. Rare interbeds of sericitic metaconglomerate with flattened, rod-like cobbles and of purplish, magnetite-rich schist also occur. The metabasalt locally contains well-preserved pillow structures in the Brazos Peak 15-min quadrangle northwest of the Tusas Range.

Also included within this rock unit are exposures of altered amphibolite (metabasalt) south of Kiowa Mountain, mapped by Barker (1958) as a part of the Kiowa Mountain Formation. Chemical analyses of all the metabasalts, provided by Barker and Friedman (1974), show that they are of tholeiitic affinity.

#### Felsic Metavolcanic Rocks and Associated Metasedimentary Rocks

Just (1937) named the felsic metavolcanic rocks the Vallecitos Rhyolites, interpreting them as rhyolite and trachyte flows that are inter-

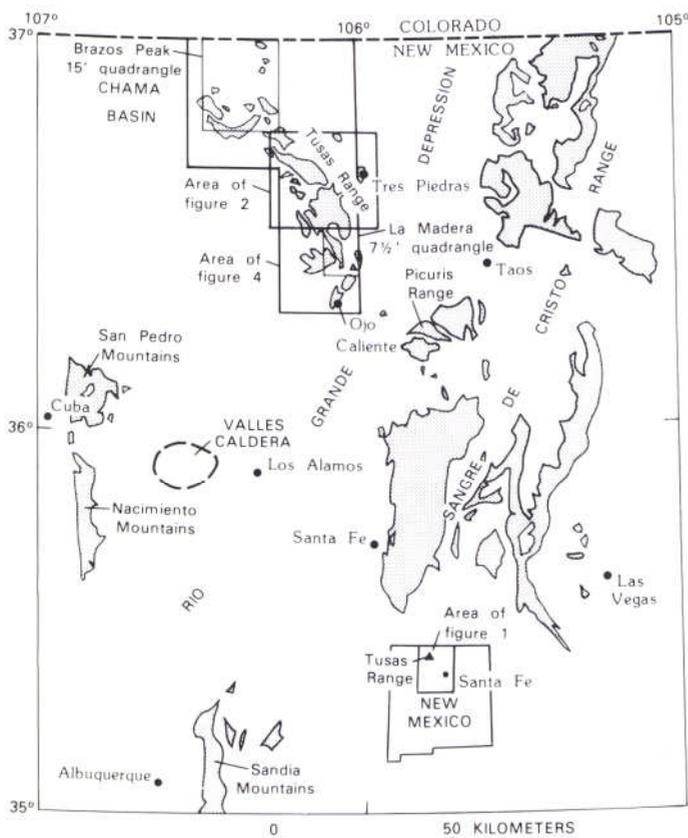


FIGURE 1. Distribution of Precambrian rocks (stippled pattern) in north-central New Mexico, showing location of Tusas Range and boundaries of Brazos Peak 15-min quadrangle and La Madera 7 1/2-min quadrangle.

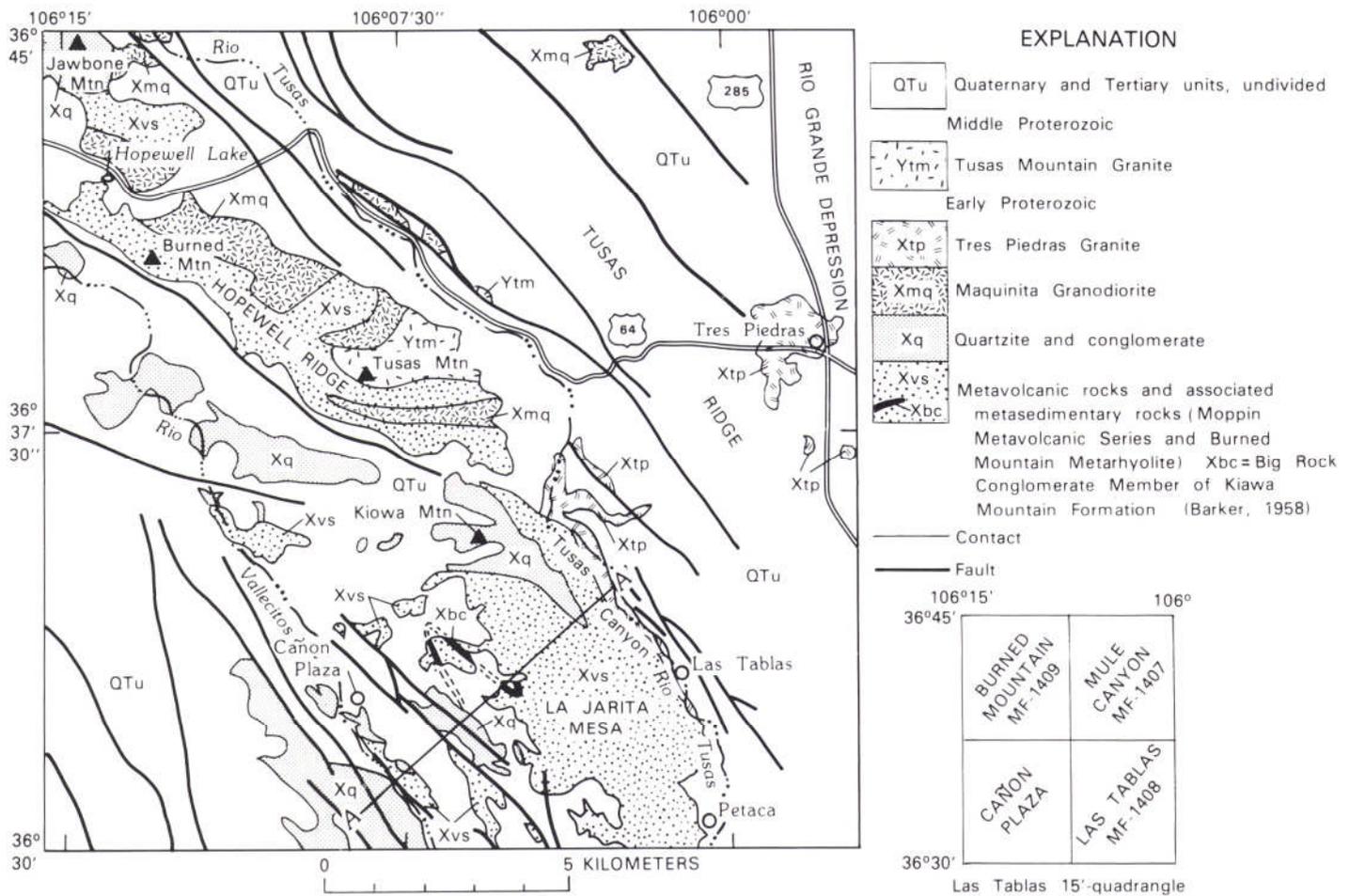


FIGURE 2. Generalized geologic map of the Tusas Range emphasizing Precambrian units. After Barker (1958), Manley, and Wobus (1982a, 1982b), and Wobus and Manley (1982).

layered with mafic rocks of the Hopewell Series and with some of the quartzites. Barker (1958) renamed these rocks the Burned Mountain Metarhyolite and noted that some of the metarhyolite formed sills and dikes that cut the mafic metavolcanic units (Moppin), whereas the rest represented flows and ash-flows interlayered with the mafic rocks near the top of the Moppin.

The typical metarhyolite, best exposed at Burned Mountain, on the south side of Jawbone Mountain, and on the western edge of La Jarita Mesa, is pink to gray to dark red. Texturally it is very fine-grained porphyritic with conspicuous rounded phenocrysts of red or gray quartz 1-2 mm in diameter. Many outcrops also show relic eutaxitic fabric, with devitrified flattened pumice fragments indicative of ash-flow origin. The rock has been dated as 1,775-1,725 m.y. by L. T. Silver of the California Institute of Technology, using the U—Pb method on zircon (Barker and Friedman, 1974).

Gresens and Stensrud (1974) recognized that much of the rock on La Jarita Mesa that Barker had mapped as quartzite was actually altered metarhyolite. Some of this rock retains remnants of quartz and feldspar phenocrysts, whereas the rest, though chemically identical to the porphyritic variety, is fine-grained, massive to weakly foliated, and probably represents metamorphosed silicic tuff. The most severely altered metarhyolite occurs on the southeastern side of La Jarita Mesa where the rock has been hydrothermally converted, with varying degrees of metasomatism, to quartz—muscovite schist (Petaca Schist of Just, 1937, and Barker, 1958). This area surrounds the Petaca pegmatite district (Jahns, 1946), where radiometric ages for altered metarhyolite and pegmatitic muscovite define a  $1,425 \pm 25$  m.y. Rb—Sr isochron (Long, 1972).

Discontinuous beds of micaceous conglomerate interlayered with the

felsic metavolcanics on La Jarita Mesa probably were deposited in a braided alluvial environment during the time of explosive volcanic activity (K. A. Eriksson, Virginia Polytechnic Institute, written comm. 1982). These conglomerate beds were named the Big Rock Conglomerate Member of the Kiawa Mountain Formation by Barker (1958); they contain elongated cobbles and pebbles of milky quartz, red and black quartz, gray—green phyllite, and white quartz—muscovite schist that is probably altered metarhyolite. Although the conglomerate beds are only a few meters to tens of meters thick, they form important marker horizons in the otherwise monotonous terrane of altered metarhyolite on La Jarita Mesa (Manley and Wobus, 1982a).

#### Quartzite and Conglomerate

Quartzite and interlayered pebble conglomerate in the Tusas Range were originally named Ortega Quartzite by Just (1937), who believed the unit to be younger than the metavolcanic rocks. The name was derived from the Ortega Mountains, southwest of the Tusas Range, which are underlain almost entirely by quartzite and minor interbeds of conglomerate. Dark laminations in the white bluish-gray quartzites contain hematite, kyanite, and viridine (manganian andalusite) and serve to accentuate bedding planes and crossbedding.

Barker (1958) accepted the name Ortega for quartzites he thought were older than the metavolcanic rocks, and he defined the Kiawa Mountain Formation to include supposedly younger quartzites that form the conspicuous ridge that trends northwest from Kiowa Mountain. Barker described the Kiawa Mountain Formation quartzite as ". . . dense, vitreous, light bluish-gray quartzite that contains irregularly dis-

TABLE 1. Comparison of stratigraphic interpretations of layered Proterozoic metamorphic rocks, Tusas Range, north-central New Mexico.

	Just (1937)	Barker (1958)	Wobus and Hedge (1982)
Massive porphyritic leucogranite at Tusas Mountain	TUSAS GRANITE	TRES PIEDRAS GRANITE	TUSAS MOUNMIN GRANITE
Foliated biotite quartz monzonite to granite at Tres Piedras and Tusas Canyon	TUSAS GRANITE	TRES PIEDRAS GRANITE	TRES PIEDRAS GRANITE
Foliated granodiorite to quartz diorite	TUSAS GRANITE	MAQUINITA GRANODIORITE	MAQUINITA GRANNIORITL

tributed pebbly layers . . . ,” noting that it was “. . . similar to the Ortega quartzite exposed west of the Rio Vallecitos . . . ” and that “. . . indeed, these two quartzites are essentially indistinguishable in outcrop” (Barker, 1958, p. 31).

Gresens and Stensrud (1974) and Burns and Wobus (1983) advocated a return to the single-quartzite stratigraphy of Just, arguing on the basis of locally well-preserved crossbedding that all of the quartzites are younger than the metavolcanic rocks and that the units are, in fact, structurally connected by large-scale folding. A comparison of the stratigraphic interpretations for the supracrustal rocks of the Tusas Range is found in Table 1.

**Intrusive Rocks**

Three kinds of intrusive rocks form small stocks that cut the layered metamorphic rocks of the Tusas Range. Foliated granodiorite to quartz diorite occurs primarily along Hopewell Ridge, foliated quartz monzonite to granite outcrops in Tusas Canyon and in and near the village of Tres Piedras, and a stock of porphyritic leucocratic granite that is nearly structureless underlies Tusas Mountain. As shown in Table 2, Just (1937) called all of these rocks Tusas Granite, but Barker (1958) abandoned that term; he re-named the latter two occurrences Tres Piedras Granite and named the granodiorite to quartz diorite the Maquinita Granodiorite. Wobus and Hedge (1982) provided field and isotope evidence that the granite porphyry at Tusas Mountain is considerably younger than the granite at Tres Piedras and in Tusas Canyon, proposing the name Tusas Mountain Granite for that occurrence.

For details on the petrography and chemistry of the intrusive rock units, see Barker (1958) and Wobus and Hedge (1982).

TABLE 2. Proterozoic rocks of the Tusas Range, north-central New Mexico.

Just (1937)	Barker (1958)	Wobus (this report)
Vallecitos Rhyolites	Burned Mountain Metarhyolite	
Petaca Schist phase of Ortega Quartzite		
Ortega Quartzite	Kiawa Mountain Formation*: upper quartzite Jawbone Conglomerate Member* amphibolite lower quartzite Big Rock Conglomerate Member*	Vitreous quartzite and interlayered pebble conglomerate (formerly assigned to Kiawa Mountain Formation and Ortega Quartzite but probably all Ortega Quartzite)
Hopewell Series	Moppin Metavolcanic Series	Bimodal metavolcanics and associated volcaniclastic metasedimentary rocks (Burned Mountain Metarhyolite and Moppin Metavolcanic Series; may include amphibolite of Kiawa Mountain Formation)
	Ortega Quartzite Petaca Schist (muscovitized parts of Ortega Quartzite and Kiawa Mountain Formation)	

\* Denotes names formally adopted in Barker, 1970

**Maquinita Granodiorite**

The Maquinita is dark-gray or greenish-gray (tan where weathered), medium-grained, generally well-foliated biotite granodiorite to quartz diorite. It is locally highly sheared and altered, particularly near Hopewell Lake. It intrudes the Moppin Metavolcanic Series at many locations along Hopewell Ridge and contains rounded to elongate inclusions of Moppin near these contacts. Its age has been determined radiometrically to be 1,725-1,675 m.y. by L. T. Silver (Barker and Friedman, 1974).

**Tres Piedras Granite**

The Tres Piedras Granite is well exposed in inselberg-like outcrops in and near the village of Tres Piedras and in the steep walls of Tusas Canyon. It is pink to buff, fine- to medium-grained quartz monzonite, generally well foliated and often weathering to coarse grus. Its contacts with the layered metamorphic rocks in Tusas Canyon are concordant, appearing as a series of thin sills within the altered metarhyolite it intrudes. No other contacts with Precambrian rock units are exposed.

The Tres Piedras Granite was probably emplaced during the same intrusive event as the Maquinita Granodiorite. Both foliated rock types bear the structural imprint of the single period of regional metamorphism that affected their wall rocks, and such syntectonic plutons in the southern Rocky Mountains characteristically give radiometric ages of about 1,700 m.y. (Hedge and others, 1977). The only published dates for the Tres Piedras Granite are those by Maxon (1976), but they are problematic because his sampling included rocks at Tusas Mountain that are

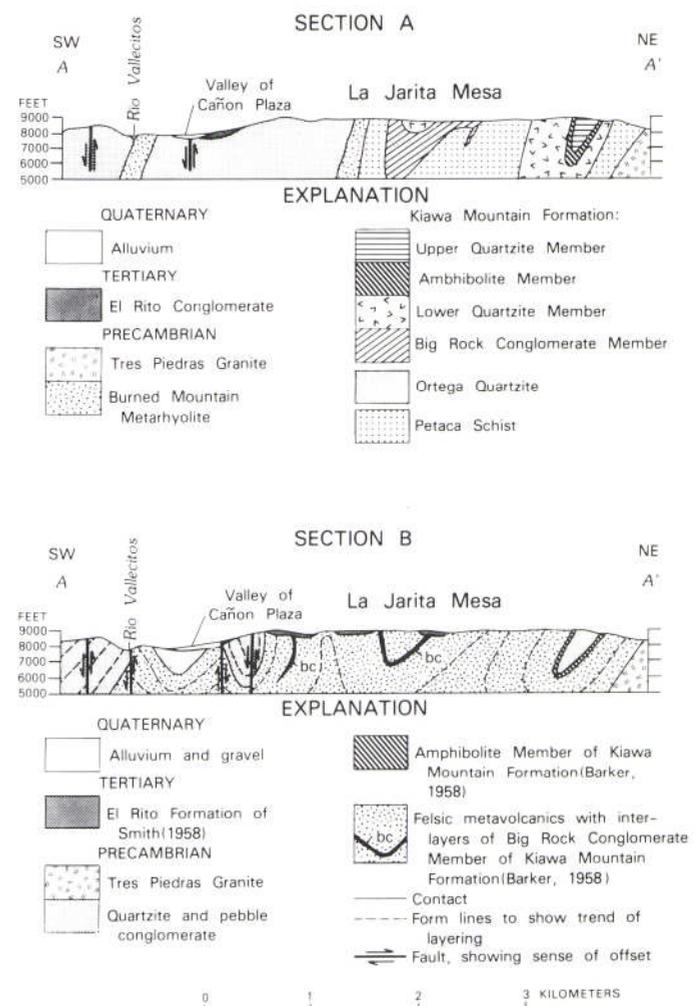


FIGURE 3. Comparison of geologic cross sections along line AA' in Figure 2, showing differences in interpretation of Precambrian structure and stratigraphy in southwestern part of Tusas Range. Section A from Barker (1958) and Section B after Manley and Wobus (1982a).

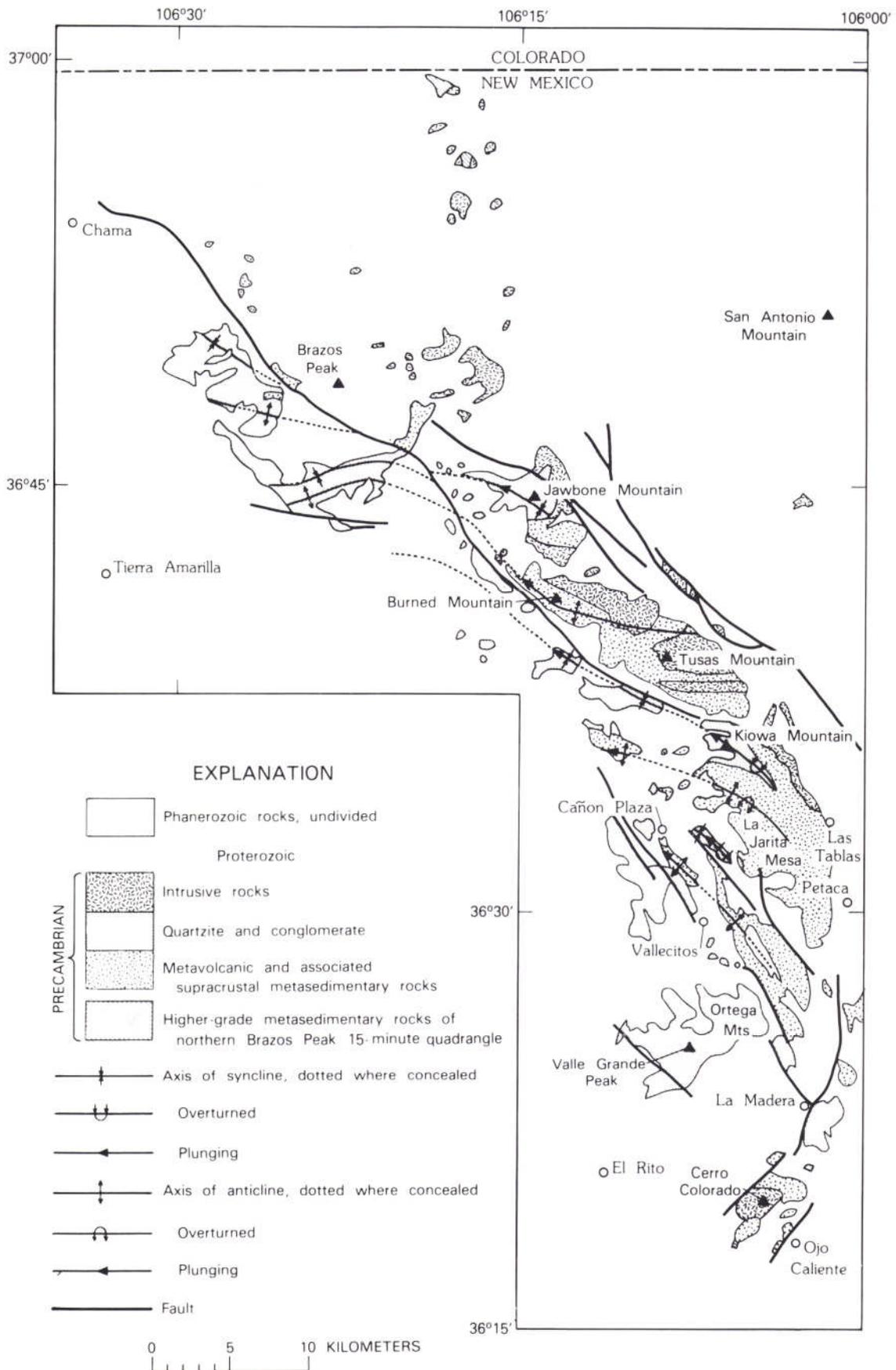


FIGURE 4. Small-scale geologic map of Precambrian rocks in eastern part of Aztec 1 × 2° quadrangle, New Mexico, showing trends of major fold axes. Revised from Manley and others (1978).

clearly of another intrusive generation (Wobus and Hedge, 1982). His U—Pb ages on zircon define a chord that intersects the concordia curve at 1,654 m.y. and 98 m.y., with a concordant data point at 1,654 m.y. that could serve as a minimum value for the age of the Tres Piedras Granite.

### Tusas Mountain Granite

This unit was named by Wobus and Hedge (1982) for the single stock of porphyritic granite that underlies Tusas Mountain and vicinity. The rock is characteristically light gray to pink and fine- to medium-grained porphyritic; it is generally structureless except for a weak primary-flow foliation preserved locally near, and parallel to, the margins of the stock. Phenocrysts of rounded, dark-gray quartz and subhedral pink microcline are 1-5 mm in diameter, and fluorite and muscovite are common accessory minerals. The rock is chemically similar to the average alkali granite and is enriched by a suite of trace elements (fluorine, beryllium, lithium, and tin) that are indicative of late vapor-phase activity during its cooling history. Rb—Sr whole-rock analyses and U—Pb dating of zircon from the Tusas Mountain Granite indicate an age between 1,500 and 1,430 m.y. (Wobus and Hedge, 1982).

### STRUCTURAL INTERPRETATION

Structural complexity and metamorphic grade increase from north to south in the Tusas Range. Through most of the area, metamorphic foliation or schistosity appears to be parallel to original sedimentary or volcanic layering, and crossbedding is locally well preserved in the quartzite and conglomerate. Near the southern edge of the map, however (particularly west of the Rio Vallecitos), and further south in the Ortega Mountains, more intense deformation of former crossbedding in the quartzite has rendered these primary structures useless for stratigraphic and structural purposes, as recognized by Bingler (1965) in the La Madera 7 1/2-min quadrangle.

On La Jarita Mesa northwest of Petaca, intense metasomatic alteration of former felsic metavolcanic rocks and associated metasedimentary units has nearly obliterated their original layering and converted them to a quartz—sericite schist (Petaca Schist of Just, 1937, and Barker, 1958) with a strong northwest-trending schistosity that may or may not parallel original layers. Only the preservation of quartz phenocrysts attests to the original nature of the rocks in that area.

The most obvious structures of the Tusas Range are a series of northwest-plunging anticlines and synclines, some overturned, that are defined by repetition of strata and by the preservation of crossbedding in the quartzites. Some of these folds were recognized by Barker (1958), but reinterpretation of his data and new mapping west of La Jarita Mesa require a re-evaluation of his structural and stratigraphic conclusions for the region as a whole (Manley and Wobus, 1982a). The differences are best shown in Figure 3, which is a comparison of NE—SW cross sections along line AA' in Figure 2. This remapping provides structural evidence for a single quartzite unit overlying the metavolcanic rocks in the Tusas Range. Using additional mapping by Muehlberger (1968) in the Brazos Peak 15-min quadrangle to the northwest and by Bingler (1968) in the La Madera 7 1/2-min quadrangle to the south, it is possible to portray the folded nature of quartzites and metavolcanic rocks through most of the exposed Precambrian terrane west of the Rio Grande rift in northern New Mexico (Fig. 4). Folds of about the same wavelength probably continue through the Ortega Mountains, but transposition of bedding due to shearing and the lack of continuous marker horizons in the quartzites there have precluded the delineation of fold axes.

Faults in the Tusas Range are generally high-angle and northwest-trending. They cut Precambrian and Tertiary rocks alike, offsetting units as young as the Pliocene Servilleta Basalt (Manley and Wobus, 1982b); many were likely developed during the evolution of the Rio Grande rift.

### SUMMARY AND CONCLUSIONS

The Precambrian supracrustal rocks of the Tusas Range consist of bimodal metavolcanic rocks (Moppin Metavolcanic Series and Burned Mountain Metarhyolite) overlain by a thick sequence of quartzite and conglomerate. These units are repeated by folding several times through

the region, with the older metavolcanic rocks being exposed only in the cores of large eroded anticlines. A radiometric age of 1,775-1,725 m.y. for the Burned Mountain Metarhyolite indicates that the supracrustal rocks are of late Early Proterozoic age; rocks of significantly greater age are not known anywhere in the southern Rocky Mountains.

The layered metamorphic rocks are roughly contemporaneous with other supracrustal assemblages (quartzites overlying metavolcanic rocks) in northern New Mexico and southern Colorado. These include the Picuris Range (Holcombe and Callender, 1982) and the Rio Mora portion of the Sangre de Cristo Mountains (Grambling and Coddling, 1982) in New Mexico, and the Needle Mountains in southwestern Colorado (Burns and Wobus, 1983). Condie (1982) recognized this same general trend in rocks of similar age throughout the Southwestern United States, suggesting that this suite of rocks may have been generated by the opening and closing of successive back-arc basins underlain by continental crust.

The intrusive rocks of the Tusas Range are likewise similar in age and structural style to those recognized elsewhere in the southern Rocky Mountains. Both the Maquinita Granodiorite and the Tres Piedras Granite are typical of syntectonic plutons emplaced prior to or during the single major regional metamorphic event about 1,700 m.y. ago.

The Tusas Mountain Granite, on the other hand, was intruded during a younger, anorogenic plutonic episode about 1,500-1,400 m.y. ago. This event was even more widespread than the 1,700 m.y. plutonism and is recognized from Labrador to California (Silver and others, 1977). The Tusas Mountain Granite is more alkaline, however, than granites typical of this event (Anderson, 1983). Significantly, the Tusas Mountain stock represents the only dated Precambrian pluton west of the Rio Grande in northern New Mexico that was emplaced during the major period of pegmatite formation and pervasive hydrothermal alteration about 1,400 m.y. ago.

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Fred Barker and Dick Jahns introduced me to the Tusas Range during a Penrose Conference field trip in 1971. Glenn Scott and Kim Manley of the U.S. Geological Survey were stimulating and helpful colleagues during the mapping of the Aztec 1 x 2° quadrangle, and I am grateful to numerous students from Williams College who helped as field assistants during the four summers devoted to that mapping. I also benefited from discussions in the field with Jack Reed, Carl Hedge, and Mike Williams.

### REFERENCES

- Anderson, J. L., 1983, Proterozoic anorogenic granite plutonism of North America: Geological Society of America, Memoir 161, pp. 133-154.
- Barker, F., 1958, Precambrian and Tertiary geology of Las Tablas quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 45, 104 pp.
- , 1970, Ortega quartzite and the Big Rock and Jawbone Conglomerate Members of the Kiawa Mountain Formation, Tusas Mountains, New Mexico: U.S. Geological Survey, Bulletin 1294-A, pp. A21—A22.
- , and Friedman, I., 1974, Precambrian metavolcanic rocks of the Tusas Mountains, New Mexico: New Mexico Geological Society, Guidebook 25, pp. 115-117.
- Bingler, E. C., 1965, Precambrian geology of La Madera quadrangle, Rio Arriba County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 80, 132 pp.
- , 1968, Geology and mineral resources of Rio Arriba County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 91, 158 pp.
- Burns, L. K., and Wobus, R. A., 1983, Correlations and revisions of Precambrian stratigraphy, Needle Mountains, southwest Colorado, and Tusas Mountains, north-central New Mexico (abstract): Geological Society of America, Abstracts with Programs, v. 15, no. 5, p. 424.
- Condie, K. C., 1982, Plate-tectonics model for continental accretion in the Southwestern United States: *Geology*, v. 10, pp. 37-42.
- Grambling, J. A., and Coddling, D. B., 1982, Stratigraphy and structural relationships of multiply deformed Precambrian metamorphic rocks in the Rio Mora area, New Mexico: Geological Society of America, Bulletin, v. 93, pp. 127-137.
- Gresens, R. L., 1975, Geochronology of Precambrian metamorphic rocks, north-

- central New Mexico: Geological Society of America, Bulletin, v. 86, pp. 1444-1448.
- \_\_\_\_\_, and Stensrud, H. L., 1974, Recognition of more metarhyolite occurrences in northern New Mexico and a possible Precambrian stratigraphy: *Mountain Geologist*, v. 11, pp. 109-124.
- Hedge, C. E., Houston, R. L., Tweto, O. L., Reid, R. R., Harrison, J. E., and Peterman, Z., 1977, The Precambrian of the Rocky Mountain region (abstract): Geological Society of America, Abstracts with Programs, v. 9, no. 7, p. 1010.
- Holcombe, R. J., and Callender, J. F., 1982, Structural analysis and stratigraphic problems of Precambrian rocks of the Picuris Range, New Mexico: Geological Society of America, Bulletin, v. 93, pp. 138-149.
- Jahns, R. H., 1946, Mica deposits of the Petaca district, Rio Arriba County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 25, 294 pp.
- Just, E., 1937, Geology and economic features of the pegmatites of Taos and Rio Arriba Counties, New Mexico: New Mexico School of Mines, Bulletin 13, 73 pp.
- Long, L. E., 1972, Rb-Sr chronology of Precambrian schist and pegmatite, La Madera quadrangle, northern New Mexico: Geological Society of America, Bulletin, v. 83, pp. 3425-3432.
- Manley, K., and Wobus, R. A., 1982a, Reconnaissance geologic map of the Las Tablas quadrangle, Rio Arriba County, New Mexico: U.S. Geological Survey, Map MF- 1408.
- \_\_\_\_\_, and \_\_\_\_\_ 1982b, Reconnaissance geologic map of the Mule Canyon quadrangle, Rio Arriba County, New Mexico: U.S. Geological Survey, Map MF-1407.
- \_\_\_\_\_, Scott, G. R., and Wobus, R. A., 1978, Preliminary geologic map of the Aztec 1-x 2° quadrangle, northwestern New Mexico: U.S. Geological Survey, Open-file Report 78-466, 7 pp.
- Maxon, J. R., 1976, Age and implications of the Tres Piedras Granite, north-central New Mexico (abstract): Geological Society of America, Abstracts with Programs, v. 8, no. 5, p. 608.
- Muehlberger, W. R., 1968, Geology of Brazos Peak quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 22.
- Silver, L. T., Bickford, M. E., Van Schmus, W. R., Anderson, J. L., Anderson, T. H., and Medaris, L. G., Jr., 1977, The 1.4-1.5 b.y. transcontinental anorogenic plutonic perforation of North America (abstract): Geological Society of America, Abstracts with Programs, v. 9, no. 7, pp. 1176-1177.
- Smith, H. T. U., 1938, Tertiary geology of the Abiquiu quadrangle, New Mexico: *Journal of Geology*, v. 46, no. 7, pp. 933-965.
- Wobus, R. A., and Dobson, P. F., 1981, Proterozoic intrusive history of the Tusas Mountains, north-central New Mexico (abstract): Geological Society of America, Abstracts with Programs, v. 13, no. 4, p. 230.
- \_\_\_\_\_, and Hedge, C. E., 1982, Redefinition of the Precambrian Tusas Mountain and Tres Piedras Granites, north-central New Mexico: *Mountain Geologist*, v. 19, pp. 105-114.
- \_\_\_\_\_, and Manley, K., 1982, Reconnaissance geologic map of the Burned Mountain quadrangle, Rio Arriba County, New Mexico: U.S. Geological Survey, Map MF- 1409.