Changes in the Nomenclature and Stratigraphy of Proterozoic Metamorphic Rocks, Tusas Mountains, North-Central New Mexico

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CHANGES IN THE NOMENCLATURE AND STRATIGRAPHY OF PROTEROZOIC METAMORPHIC ROCKS, TUSAS MOUNTAINS, NORTH-CENTRAL NEW MEXICO

By REINHARD A. WOBUS[1]

ABSTRACT

Stratigraphic interpretations differ for the Proterozoic metasedimentary and metavolcanic rocks of the Tusas Mountains, north-central New Mexico. Quartzite and interlayered conglomerate were originally named the Ortega Quartzite by Just (1937) and were considered to be younger than the Hopewell Series and older than the Vallecitos Rhyolites. Barker (1958) recognized two separate quartzite units, with the metavolcanic rocks (which he named the Burned Mountain Metarhyolite as a replacement term for the Vallecitos, and the Moppin Metavolcanic Series as a replacement term for the Hopewell) in between. Barker believed that the Ortega Quartzite was the oldest Precambrian rock, and he defined the Kiawa Mountain Formation and its Big Rock Conglomerate and Jawbone Conglomerate Members to include what he perceived as the younger quartzite and associated clastic metasedimentary rocks, as well as minor amphibolite interlayers. Gresens and Stensrud (1974) found that altered felsic metavolcanic rocks formed most of the lower part of Barker's Kiawa Mountain Formation; they suggested a return to the single-quartzite model and stratigraphic sequence of Just.

The present study of the Tusas Mountains, part of the mapping of the Aztec 1° x 2° quadrangle by the U.S. Geological Survey, has provided structural evidence in support of the stratigraphic interpretation favored by Gresens and Stensrud and by Just. In light of this evidence, it is proposed that the name Kiawa Mountain Formation be abandoned and its various units re-alloted. The vitreous ("upper") quartzite and Jawbone Conglomerate Member of the Kiawa Mountain are, in fact, the same as the Ortega Quartzite and constitute the youngest layered Precambrian rock unit of the region. Other "quartzites" within the Kiawa Mountain are largely altered felsic metavolcanic rocks; along with the Big Rock Conglomerate Member (former alluvial gravels within the metavolcanic sequence), they should be included as part of the Burned Mountain Metarhyolite, Barker's term adopted in this report. Amphibolites of the Kiawa Mountain Formation are more properly included with the Moppin Metavolcanics (name change from Moppin Metavolcanic Series of Barker, 1958), which consist of metamorphosed mafic volcanic and volcaniclastic rocks. The term Petaca Schist, defined by Just and used by Barker for muscovitic metarhyolite and quartzite on La Jarita Mesa, has no stratigraphic significance and is abandoned.

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These stratigraphic revisions simplify the Precambrian terminology for the Tusas Mountains and also assign as the oldest rocks of the region a bimodal metavolcanic assemblage, rather than a thick sequence of clean clastic metasedimentary rocks without an obvious source area. These revisions are also compatible with other recent studies in the Picuris Range and Rio Mora areas to the southeast in New Mexico, and in the Needle Mountains to the northwest in Colorado. In all of these areas, metavolcanic rocks have been found underlying quartzite and conglomerate (Ortega Quartzite in northern New Mexico, Vallecito Conglomerate in the Needle Mountains of southwestern Colorado), thus reversing previous stratigraphic interpretations.

INTRODUCTION AND PREVIOUS WORK

Layered Precambrian rocks of late Early Proterozoic age in the Tusas Mountains, north-central New Mexico (fig. 1), consist of quartzite, conglomerate, and bimodal volcanic rocks, all of which have been metamorphosed to upper greenschist to middle amphibolite facies. In the first reconnaissance study of the area, Just (1937) applied the name Ortega Quartzite to all the quartzite and conglomerate exposures from Ojo Caliente on the south to Jawbone Mountain, north of Hopewell Lake in the Burned Mountain 7½-minute quadrangle. He derived this name from the Ortega Mountains, which are immediately southwest of the Tusas Mountains and are composed almost entirely of quartzite with minor interlayers of pebble conglomerate.

In the same report, Just named the felsic metavolcanic rocks the Vallecitos Rhyolites, and the mafic metavolcanic rocks and associated metasedimentary layers the Hopewell Series. He believed the felsic metavolcanics were rhyolite and trachyte flows that were interlayered with the Hopewell Series and the Ortega Quartzite, and that the Hopewell Series was older than the Ortega. Jahns (1946) restated Just's conclusions in his report on the Petaca pegmatite district, which lies along the east side of La Jarita Mesa south of Las Tablas.

Barker (1958) mapped a large portion of the Tusas Mountains in his study of the Las Tablas 15-minute quadrangle (now subdivided into the Burned Mountain, Mule Canyon, Cañon Plaza, and Las Tablas 7½-minute quadrangles), using methods he stated would now be called "semireconnaissance" (Barker and Friedman, 1974, p. 115). He reversed Just's stratigraphy and recognized the Ortega Quartzite as the oldest unit in the Tusas Mountains, suggesting it was 14,000-20,000 ft (4,200-6,000 m) thick. Barker also believed that the thick section of quartzite extending northwesterly from Kiowa Mountain[2] was younger than the Ortega and was the youngest metasedimentary rock of the region. He

[2]The U.S. Forest Service used the spelling "Kiawa" Mountain until the 1950's (at the time Barker did his mapping), but the USGS changed the spelling to "Kiowa" on the Las Tablas 7½-minute quadrangle published in 1963.

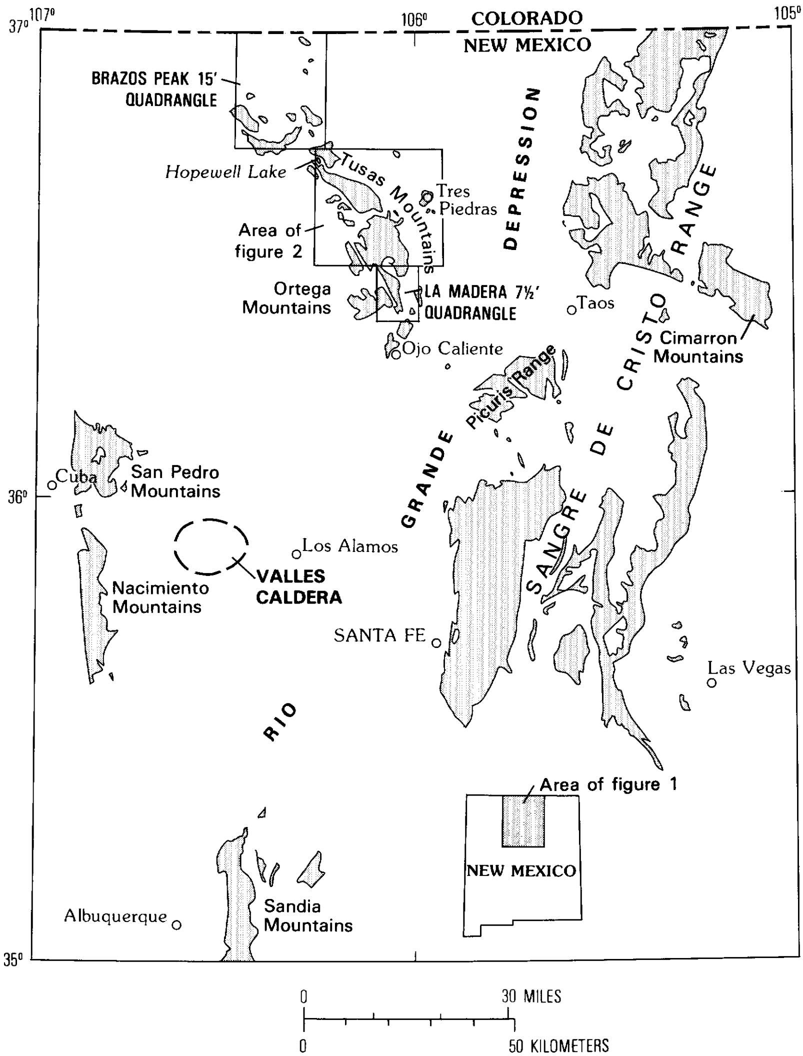


FIGURE 1.—Index map of northern New Mexico showing area of this study. Stippled pattern indicates distribution of Precambrian rocks.

described this supposedly younger quartzite as "... dense, vitreous, light bluish-gray quartzite that contains irregularly distributed 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).

Barker (1958) named the strata "overlying" the Ortega Quartzite the Kiawa Mountain Formation, with the vitreous quartzite defined as the uppermost member that was 5,000–10,000 ft (1,500–3,000 m) thick. The basal member was named the Big Rock Conglomerate Member, a thin, discontinuous layer of quartz-pebble conglomerate only 50-200 ft (15-60 m) thick that crops out on La Jarita Mesa. A similar but thicker conglomerate, with abundant quartzite, underlying Jawbone Mountain and supposedly cropping out in Placer Gulch south of Hopewell Lake was named the Jawbone Conglomerate Member. In his definition of the Jawbone, Barker (1958, p. 25) noted that it "... resembles the quartz-pebble beds in the Ortega and Kiawa Mountain quartzites".

A poorly delineated zone of "vitreous to micaceous quartzite" lying south of Kiowa Mountain was informally named the lower quartzite member of the Kiawa Mountain Formation, and sporadic thin interlayers of amphibolite below the upper vitreous quartzite were collectively named the amphibolite member (Barker, 1958). The name Kiawa Mountain Formation and the names of two of its members, the Big Rock Conglomerate and the Jawbone Conglomerate, were adopted by the U.S. Geological Survey in a subsequent report (Barker, 1970).

In his 1958 report, Barker also renamed the Vallecitos Rhyolite of Just (1937) the Burned Mountain Metarhyolite after exposures on the northwest side of Burned Mountain in sec. 8, T. 28 N., R. 7 E., and he renamed the Hopewell Series of Just the Moppin Metavolcanic Series after exposures in upper Spring Creek just north of the Moppin Ranch (sec. 25, T. 28 N., R. 7 E.). The Moppin, consisting of amphibolite, chlorite schist, phyllite, and minor conglomerates and iron-formation, was thought to represent metamorphosed mafic volcanic rocks (Barker, 1958, p. 23). Barker observed that the metarhyolite occurs as sills and dikes that cut the Moppin, but that some of the metarhyolite also represents flows and ash flows. He placed the Moppin stratigraphically between his "older" or Ortega Quartzite and the younger Kiawa Mountain Formation. Barker continued to apply the name Petaca Schist (Just, 1937) to highly muscovitized portions of what he considered to be Ortega Quartzite, Burned Mountain Metarhyolite, and the lower quartzite member of the Kiawa Mountain Formation.

Gresens and Stensrud (1974) discovered that Barker's lower quartzite member actually consists largely of altered metarhyolite. Some of this rock retains remnants of quartz and feldspar phenocrysts and some, though chemically identical to the porphyritic variety, is fine grained, massive, and may represent metamorphosed silicic tuff. The same authors reinforced Barker's suggestion that altered (muscovitic) metarhyolite forms a large part of the Petaca Schist in the central part of La Jarita Mesa. They also proposed that it would be more consistent stratigraphically to consider the Ortega Quartzite and the vitreous (upper) quartzite of the Kiawa Mountain Formation as a single unit, as in Just's usage. Moreover, they speculated, as did Just, that this single quartzite and conglomerate sequence is younger than the metavolcanic sequence, both in the Tusas Mountains and in the Picuris Range to the southeast across the Rio Grande Depression.

The metavolcanic and metasedimentary rocks of the Tusas Mountains were intruded by the Maquinita Granodiorite (a term of Barker, 1958, adopted in this report) and the Tres Piedras Granite about 1,700 m.y. ago and by the Tusas Mountain Granite about 1,500 m.y. ago. The Proterozoic intrusive history of the region has been dealt with in other reports and will not be discussed further here (Wobus and Dobson, 1981; Wobus and Hedge, 1982).

PRESENT STUDY

The Precambrian of the Tusas Mountains was re-mapped by the author during the summers of 1977 to 1980 as part of the U.S. Geological Survey's mapping of the Aztec 1° x 2° quadrangle (fig. 2). This study supports the stratigraphic conclusions and speculations of Gresens and Stensrud (1974), although it differs with some of their observations. Specifically, it provides structural evidence that (1) the Ortega Quartzite and the vitreous (upper) quartzite of the Kiawa Mountain Formation are the same unit, and that (2) this quartzite, including its interlayered pebble conglomerate but excluding the Big Rock Conglomerate Member, overlies the bimodal metavolcanic rocks and their associated metasedimentary layers.

The most critical areas in this structural reinterpretation are the Precambrian exposures south and east of the village of Cañon Plaza. South of the village, Barker (1958, pl. 1) shows Ortega Quartzite dipping to the northeast away from a ridge of Burned Mountain Metarhyolite in sec. 36, T. 27 N., R. 7 E. Barker did not discuss this locality, where his mapping actually suggests that Ortega Quartzite is younger than metarhyolite. Re-mapping of this area (location 1 in fig. 2) shows that the metarhyolite extends northwesterly about one-half mile (0.8 km) farther than Barker showed and that vitreous quartzite with well-preserved crossbedding overlies the metarhyolite along this entire distance. Interlayers about 20 ft (6 m) thick of metarhyolite and quartzite occur at the base of the quartzite section. Textures in the metarhyolite suggest that it might be a metamorphosed airfall tuff at this locality, because it lacks the eutaxitic fabric and abundant euhedral quartz phenocrysts observed elsewhere.

East of Cañon Plaza, on the western edge of La Jarita Mesa (location 2 in fig. 2), vitreous quartzite does indeed occur (contrary to the observations of Gresens and Stensrud, 1974, p. 117), although it becomes more highly muscovitic to the southwest. Crossbeds are well preserved in both the altered (muscovitic) and unaltered quartzites. Along with thin conglomeratic marker beds (part of Big Rock Conglomerate Member)

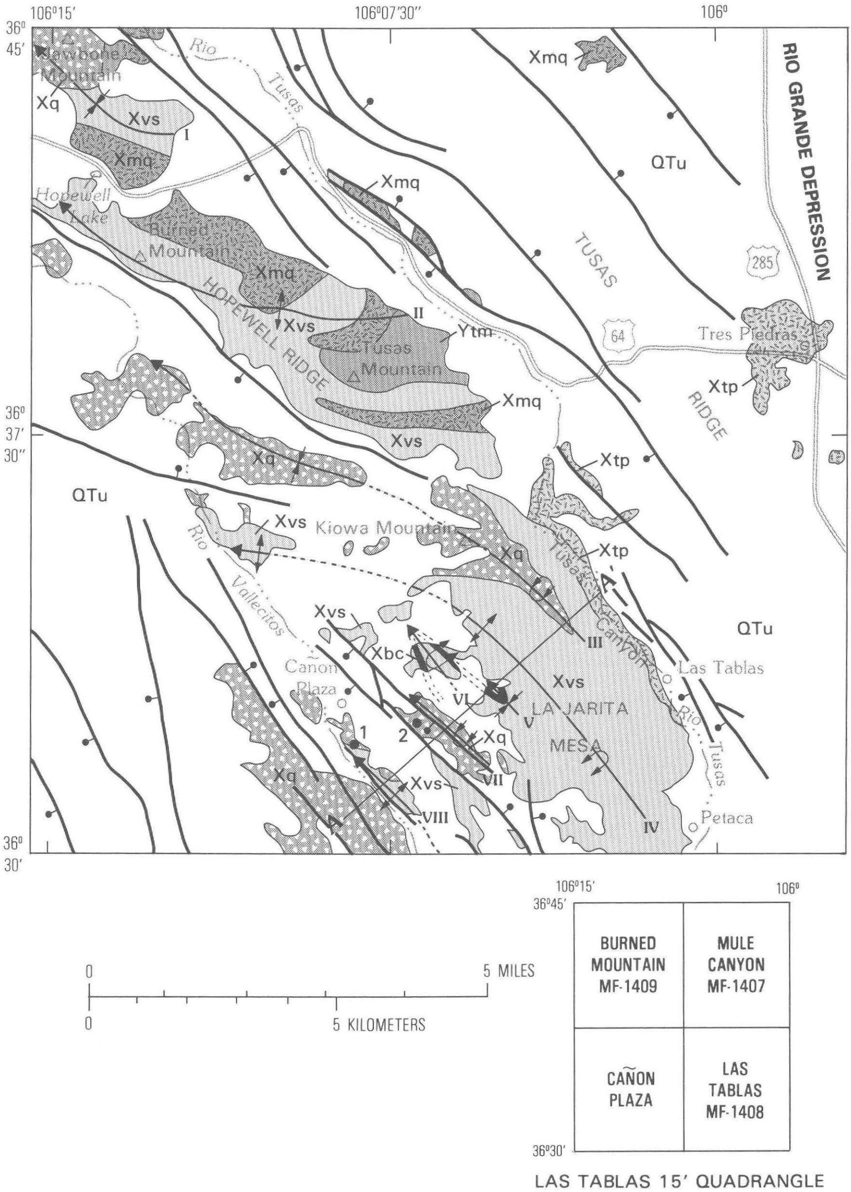


FIGURE 2.—Generalized geologic map of the Tusas Mountains, emphasizing Precambrian units and structure. After Barker (1958), Manley and Wobus (1982a), and Wobus and Manley (1982).

EXPLANATION

QTu — QUATERNARY AND TERTIARY UNITS, UNDIVIDED

MIDDLE PROTEROZOIC

Ytm — Tusas Mountain Granite

EARLY PROTEROZOIC

Xtp — Tres Piedras Granite

Xmq — Maquinita Granodiorite of Barker, 1958

Xq — Quartzite and pebble conglomerate

Xvs, Xbc — Metavolcanic rocks and associated metasedimentary rocks (includes Moppin Metavolcanics and Burned Mountain Metarhyolite). **Xbc**, Big Rock Conglomerate Member of Burned Mountain

CONTACT

FAULT—Bar and ball on downthrown side where relative displacement known

ANTICLINE—Showing trace of crestal plane and direction of plunge. Dotted where concealed

OVERTURNED ANTICLINE—Showing direction of dip of limbs and direction of plunge

SYNCLINE—Showing trace of trough plane and direction of plunge. Dashed where approximately located; dotted where concealed

OVERTURNED SYNCLINE—Showing direction of dip of limbs and direction of plunge

MAJOR FOLDS IN PRECAMBRIAN ROCKS

I Jawbone syncline

II Hopewell anticline[1]

III Kiowa syncline[1]

IV Poso anticline[1]

V Big Rock syncline

VI La Jarita anticline

VII Cañon Plaza syncline

VIII Vallecitos anticline

[1]Named by Gresens and Stensrud (1974)

•[1] LOCATION REFERRED TO IN TEXT

A — *A′* LINE OF CROSS SECTION SHOWN IN FIGURE 3 in altered metarhyolite, the crossbeds help to define a northwest-plunging faulted syncline and an adjacent overturned anticline that were not recognized by any previous workers. (For map details, see Manley and Wobus, 1982a). Another pair of previously unmapped faulted folds on the same scale is indicated by bedding in quartzite and layering in metarhyolite immediately southwest of La Jarita Mesa, along the valley southeast of Cañon Plaza.

Figure 3 shows in restored cross section the differences in structural and stratigraphic interpretation between the present mapping and Barker's mapping (1958). Figure 3A (from pl. 1, Barker, 1958) indicates that for a horizontal distance of more than 4 mi (6.5 km), steeply dipping Ortega Quartzite, with two thick interlayers of Burned Mountain Metarhyolite, is part of a large syncline, with its axis on La Jarita Mesa and with the Big Rock Conglomerate Member in its trough. The Ortega would have to be more than 20,000 ft (6,000 m) thick by this interpretation and would indeed be the oldest unit of the Proterozoic layered sequence.

The present interpretation (fig. 3B) shows five folds over the same 4-mi (6.5-km) distance, with Ortega Quartzite dipping to the northeast and southwest off a metavolcanics-cored anticline just east of the Rio Vallecitos. The Ortega is obviously younger than the metavolcanics in this interpretation, and structural restoration across La Jarita Mesa indicates that there is only a single quartzite unit.

The thickness of the Ortega Quartzite is still a problem, however. The top of the quartzite is apparently not exposed east of the Rio Vallecitos, and intense deformation of former crossbedding in the quartzite west of the Rio Vallecitos (including the Ortega Mountains) has rendered these primary structures useless for stratigraphic and structural purposes (as recognized by Bingler, 1965). There are probably several folds within the quartzite of the Ortega Mountains on the same scale as those to the northeast in the Tusas Mountains, but transposition of bedding due to shearing and lack of continuous marker horizons have precluded their delineation and, hence, the determination of the thickness of the Ortega.

In summary, the most significant features of this re-study of the Tusas Mountains, as shown in figure 3, include:

1. Vitreous quartzite of the upper part of Barker's Kiawa Mountain Formation, as exposed in the syncline at Kiowa Mountain (northeast end of cross sections in fig. 3), is repeated in a series of folds to the southwest across La Jarita Mesa, connecting with quartzite previously mapped as Ortega Quartzite. The "two" quartzites are thus the same unit.
2. An assemblage of metarhyolite, minor amphibolite (metabasalt), and associated volcaniclastic metasedimentary rocks everywhere underlies the quartzite. Much of the felsic metavolcanic rock of

this assemblage was incorrectly mapped by Barker (1958) as Ortega Quartzite and lower quartzite member of the Kiawa Mountain Formation, as pointed out by Gresens and Stensrud (1974) and confirmed in the present study.

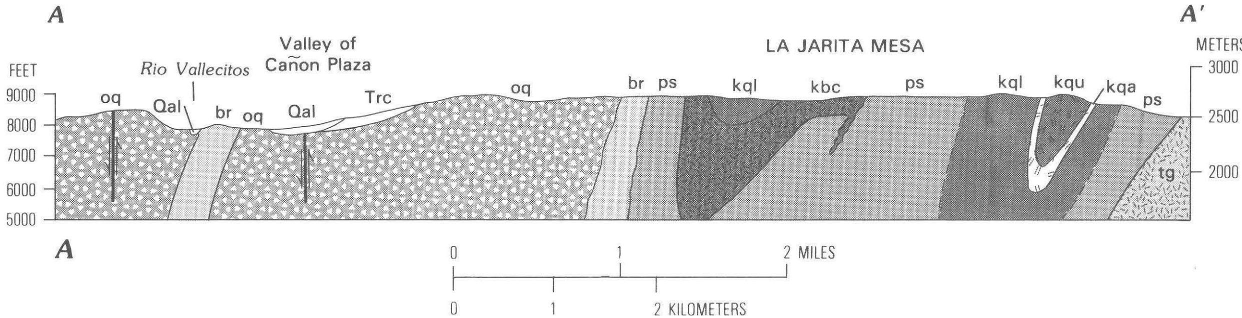
3. The Big Rock Conglomerate Member of Barker (1958, 1970) consists of conglomeratic layers and lenses that are wholly within the metavolcanic-metasedimentary section, not at the base of the Kiawa Mountain Formation as defined by Barker (1970). These conglomerate beds are locally highly deformed but contain recognizable cobbles and pebbles of metarhyolite; they were probably deposited in a braided alluvial environment (K. A. Eriksson, pers. commun., 1982).

In addition to the changes discussed above, there are differences between this report and Barker (1958, 1970) concerning mapping and interpretation of the Jawbone Conglomerate Member of the Kiawa Mountain Formation. As mentioned previously, Barker defined this unit for quartz-pebble conglomerate beds in vitreous quartzite at Jawbone Mountain. Re-mapping of the type locality (Wobus and Manley, 1982) shows that most of the rock there is quartzite showing crossbedding attitudes that define a northwest-plunging syncline. This structure is another one of a series of folds that repeat quartzite, with minor conglomerate interbeds, from the Ortega and La Madera Mountains in the southeast to the Brazos Box and Cañones Box (Brazos Peak 15-minute quadrangle) in the northwest (fig. 4). The Jawbone Conglomerate Member is thus part of the Ortega Quartzite. The only other "outcrop" of Jawbone outside the type locality supposedly extends across Placer Gulch about 1.5 mi (2.4 km) southwest of Hopewell Lake (Barker, 1958). This area was found to be composed of unconsolidated rounded cobbles of quartzite and other Precambrian rocks that are part of the Eocene and Oligocene El Rito Formation of Smith (1938) (Wobus and Manley, 1982).

RECOMMENDATIONS

In light of the substantial changes indicated by this most recent mapping of the Tusas Mountains and by the previous interpretations and conclusions of Gresens and Stensrud (1974), the following proposals are made, with a brief rationale for each:

1. The name Kiawa Mountain Formation is abandoned. The vitreous quartzite at Kiowa Mountain has been shown to be the same as the Ortega Quartzite to the southwest, and "Ortega," defined by Just in 1937, has precedence. The various members of the Kiawa Mountain Formation, as defined by Barker (1958, 1970), will be discussed individually below.



EXPLANATION

Qal — QUATERNARY
Alluvium

Trc — TERTIARY
Ritito conglomerate

PRECAMBRIAN

tg — Tres Piedras granite

br — Burned Mountain metarhyolite

ps — Petaca schist—Muscovitized quartzite and metavolcanics

Kiawa Mountain formation

kqu — Upper quartzite member

kqa — Amphibolite member

kql — Lower quartzite member

kbc — Big Rock conglomerate member

oq — Ortega quartzite

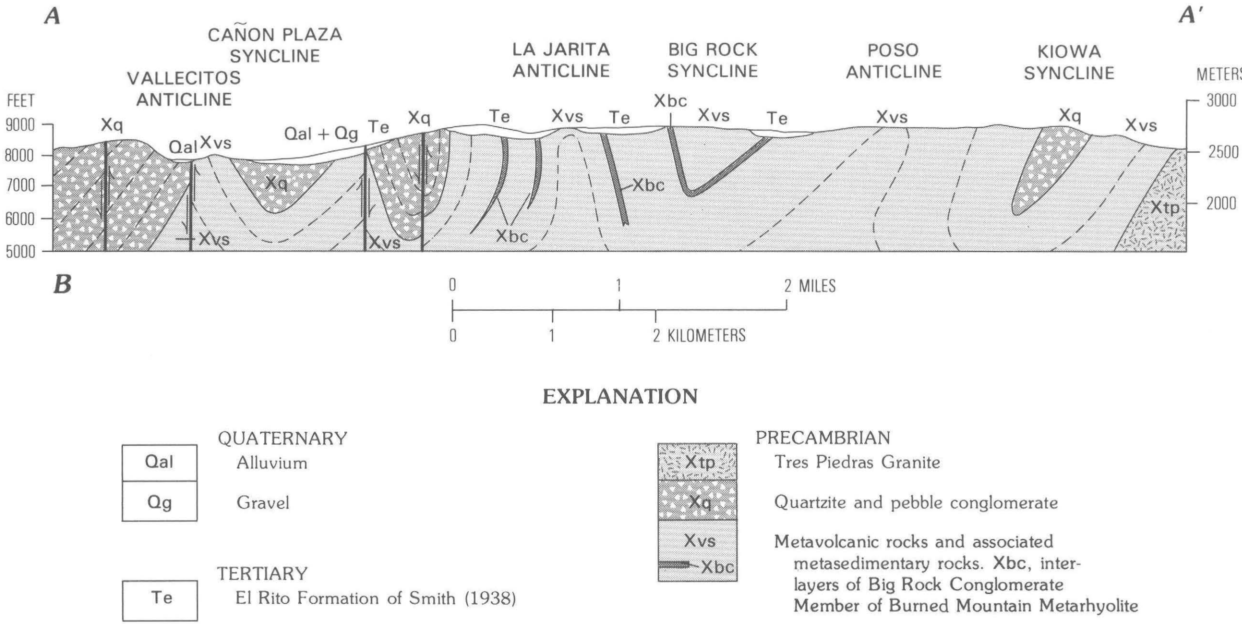


FIGURE 3.—Cross sections along A-A′ of figure 2 showing differences in interpretation of Precambrian structure and stratigraphy in southwestern part of Tusas Mountains. Opposed arrows show relative displacement of faults. *A*, From Barker (1958, pl. 1). Solid lines represent gradational contacts, dashed where position uncertain. *B*, From Manley and Wobus (1982a). Dashed lines represent trend of sedimentary bedding or volcanic layering.

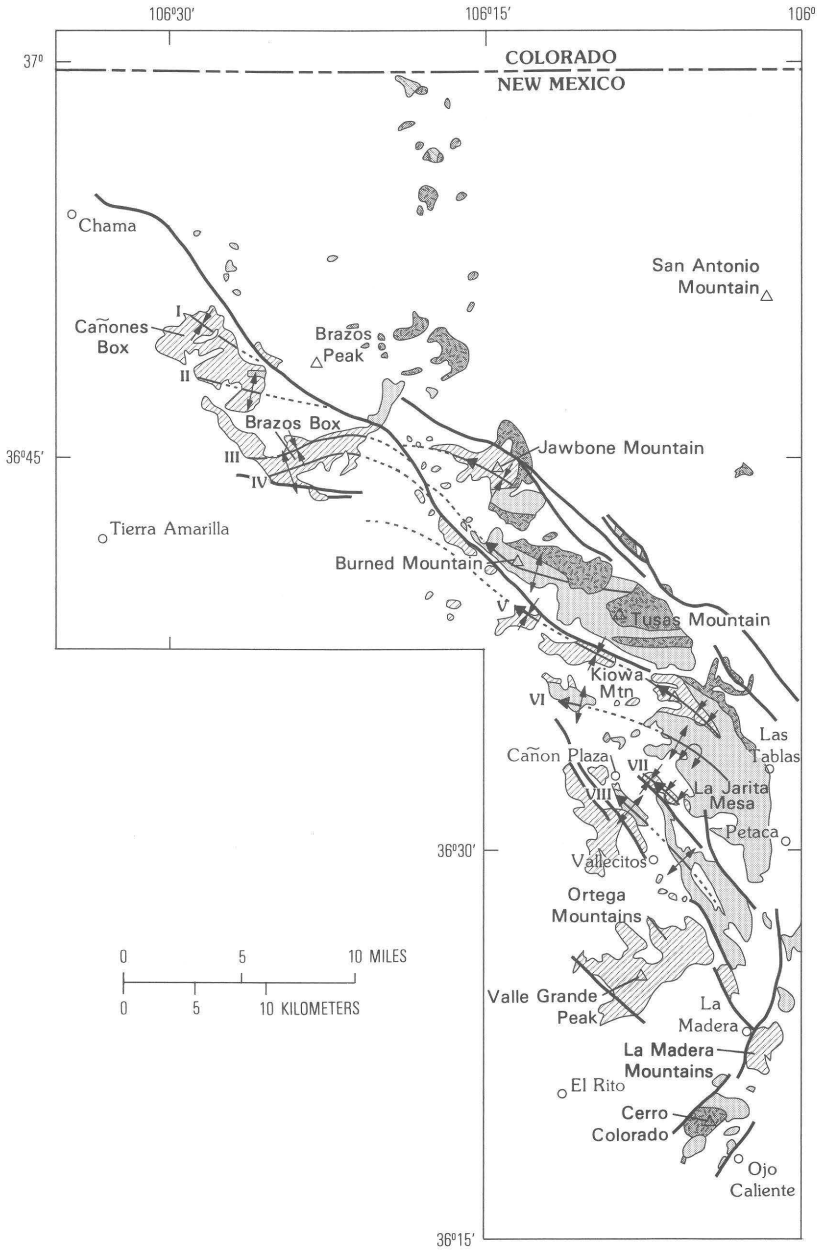


FIGURE 4.—Small-scale geologic map showing trends of major fold axes in Precambrian rocks of eastern part of Aztec 1° x 2° quadrangle, New Mexico. (Modified from Manley and others, 1978). Only the most continuous faults that cut Precambrian rocks are shown.

EXPLANATION

PHANEROZOIC ROCKS, UNDIVIDED

PROTEROZOIC

Intrusive rocks

Quartzite and conglomerate

Metavolcanic and associated supracrustal metasedimentary rocks

Higher-grade metasedimentary rocks

CONTACT

FAULT

ANTICLINE—Showing trace of crestal plane and direction of plunge. Dotted where concealed

OVERTURNED ANTICLINE—Showing direction of dip of limbs and direction of plunge

SYNCLINE—Showing trace of trough plane and direction of plunge. Dotted where concealed

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I Cañones syncline

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VI Poso anticline[1]

VII Cañon Plaza syncline

VIII Vallecitos anticline

[1]Named by Gresens and Stensrud (1974)

2. The name Ortega Quartzite should be applied to all the quartzite and quartz-pebble conglomerate horizons that are repeated by folding through the region shown in figure 4. Just (1937, p. 43) did not define a specific type locality for the Ortega Quartzite, naming it for exposures throughout the Ortega Mountains. The type locality selected by Barker (1970, p. A21) in the Las Tablas 15-minute quadrangle (sec. 25, T. 27. N., R. 8 E.) is inappropriate, as his map shows that entire section to be underlain by Petaca Schist. A principal reference locality in the Ortega Mountains is selected for the excellent exposures in a canyon of the Rio Vallecitos in the east-central part of sec. 34, T. 26 N., R. 8 E. of the La Madera 7½-minute quadrangle, about 3.5 mi (2.1 km) south-southeast of the village of Vallecitos.

3. The name Jawbone Conglomerate Member of the Kiawa Mountain Formation (Barker, 1970) is abandoned. The quartz-pebble conglomerate at Jawbone Mountain is part of a larger section of Ortega Quartzite that contains numerous interbeds of conglomerate throughout its extent. Just (1937, p. 43) recognized that "...conglomeratic phases of Ortega occur on the east end of Jawbone Mountain". There never was a need for a separate term for the conglomerate-quartzite sequence at Jawbone Mountain; bedding symbols (based on crossbed orientations) from Barker's map (1958, pl. 1) can be used to show that this sequence of clean clastics occupies the same stratigraphic position relative to the underlying Moppin and Burned Mountain metavolcanic units as does the quartzite-conglomerate section at Kiowa Mountain.

4. The informal lower quartzite and amphibolite members of the Kiawa Mountain Formation should be included with the appropriate previously recognized metavolcanic units of the Tusas Mountains. It has been shown (Gresens and Stensrud, 1974) and confirmed in this study that the lower quartzite consists largely of altered metarhyolite (flows and tuffs) with intercalated volcaniclastic sedimentary rocks, such as feldspathic sandstones. It would seem sensible to include these lithologies as part of the Burned Mountain Metarhyolite, a term Barker (1958) applied to all the silicic metavolcanic rocks he recognized in the Las Tablas 15-minute quadrangle. The amphibolite of the Kiawa Mountain Formation should be considered part of the Moppin Metavolcanics, applied by Barker to the mafic metavolcanic rocks (amphibolites) and associated metasedimentary layers (chlorite schist, phyllite, sericite schist) of the Tusas Mountains.

5. The Moppin Metavolcanic Series of Barker (1958) is adopted as the Moppin Metavolcanics. The term "series" is not used as a rank

term for a lithostratigraphic unit (North American Commission on Stratigraphic Nomenclature, 1983, Article 73).

6. The name Big Rock Conglomerate Member is retained, though not as a member of the Kiawa Mountain Formation. This distinctive conglomerate on La Jarita Mesa forms important marker beds (former stream channel deposits) in an otherwise monotonous terrane of muscovitized felsic metavolcanic rocks. The Big Rock would most appropriately be considered here as a member of the Burned Mountain Metarhyolite in its expanded usage, as recommended in the preceding section. Barker's description (1958, 1970) of the Big Rock Conglomerate Member is adequate, but his type locality is incorrectly located; no conglomerate occurs in the SE1/4, sec. 27, T. 27 N., R. 8 E. The unit is well exposed, however, in the NW1/4 of that section, and a principal reference section is defined as the northwest-trending ridge in the NW1/4, sec. 27, T. 27 N., R. 8 E., southeast of elevation 8,715 ft. This location is about 1.2 mi (2 km) southwest of the prominence known as Big Rock.
7. The name Petaca Schist is abandoned. This term was defined by Just (1937) as a quartz-muscovite schist phase of the Ortega Quartzite, which was developed only in pegmatite-rich areas of La Jarita Mesa, presumably due to alteration by volatile-rich granitic intrusions. According to Just (1937, p. 43), it was not to be regarded as a separate member of the Ortega for purposes of correlation. Barker (1958, p. 34) continued to use the term for highly altered (muscovitic) parts of "... the Ortega quartzite, part of the lower Kiawa Mountain formation, and many layers of Burned Mountain Metarhyolite". Most areas mapped by Barker as Petaca Schist retain original volcanic textures, especially quartz phenocrysts (many doubly terminated), and are better mapped as felsic metavolcanic rocks (Burned Mountain Metarhyolite); a stippled overprint has been used in mapping to indicate areas of most intense alteration (Manley and Wobus, 1982a). As the Petaca Schist has never held any particular stratigraphic significance, its continued use seems superfluous.

CONCLUSIONS AND POSSIBLE CORRELATIONS

The numerous changes in Proterozoic nomenclature and stratigraphy proposed here are summarized in table 1. In addition to the specific needs met by this re-ordering, as explained above, the revised stratigraphy also assigns as the oldest Precambrian units in the Tusas Mountains a bimodal metavolcanic assemblage, rather than a thick section of clean clastic metasedimentary rocks without an obvious source area. The

TABLE 1.—*Comparison of stratigraphic interpretations of layered Proterozoic metamorphic rocks, Tusas Mountains, New Mexico*

Just (1937)	Barker (1958)	Wobus (this report)[1]
Vallecitos Rhyolites	Burned Mountain Metarhyolite	
	Petaca Schist (includes muscovitized parts of Ortega Quartzite and Kiawa Mountain Formation)	
Ortega Quartzite (includes Petaca Schist phase)	Kiawa Mountain Formation[2]: Upper quartzite Jawbone Conglomerate Member[2] Amphibolite Lower quartzite Big Rock Conglomerate Member[2]	Ortega Quartzite (includes upper quartzite member formerly assigned to Kiawa Mountain Formation)
		Locally interlayered: Burned Mountain Metarhyolite (includes lower quartzite member and Big Rock Conglomerate Member formerly assigned to Kiawa Mountain Formation)
Hopewell Series	Moppin Metavolcanic Series	Moppin Metavolcanics (includes amphibolite formerly assigned to Kiawa Mountain Formation)
	Ortega Quartzite	

[1]Kiawa Mountain, Jawbone, and Petaca are abandoned in this report.

[2]Denotes names formally adopted by the U.S. Geological Survey in Barker (1970).

radiometric age of the Burned Mountain Metarhyolite is 1,725-1,775 m.y., as reported by L. T. Silver in Barker and Friedman (1974), with corrections for revised U-Pb decay constants; rocks of significantly greater age than this are not known anywhere in southern Colorado or in New Mexico. If the Ortega Quartzite were the oldest Precambrian unit of the region, the source of its clean quartzose sediment would indeed be problematic. Instead, pebbles and cobbles of milky quartz, ferruginous chert, and iron-formation described by all previous workers in conglomeratic beds of the Ortega could well have been derived from the Moppin Metavolcanics, which contain layers of iron-formation and are locally laced with veins of white (hydrothermal) quartz.

The foregoing stratigraphic revisions for the Tusas Mountains are compatible with recent reinterpretations of Precambrian stratigraphy in several other nearby parts of New Mexico and Colorado. In the Picuris Range, 30 mi (48 km) southeast of the Tusas Mountains, Ortega Quartzite was for many years considered to be the oldest Precambrian unit, overlain by rocks of a volcanic character in the Vadito Formation (Montgomery, 1953; Miller and others, 1963; Long, 1976). Schistose layers in the lower Ortega (also called Rio Pueblo Schist by Miller and others, 1963) were, however, found to be altered metarhyolite upon which the quartzites rest (Gresens and Stensrud, 1974). More recently, Holcombe and Callender (1982) have concluded that the Vadito Formation of the Picuris Range, consisting largely of amphibolite and felsite with associated metasedimentary rocks, probably lies beneath the Ortega.

About 25 mi (40 km) southeast of the Picuris Range in the Rio Mora portion of the Sangre de Cristo Range, Grambling and Codding (1982) have used crossbedding in quartzite to establish that the Vadito Formation, including metarhyolite and amphibolite, is older than the Ortega Quartzite. This once again represents a reversal of previous stratigraphic interpretation (Miller and others, 1963; Moench and Robertson, 1980).

The nearest Precambrian exposures northwest of the Tusas Mountains are about 80 mi (128 km) away in the Needle Mountains of southwestern Colorado. Barker (1969) had reversed the earlier stratigraphic sequence proposed by Cross and others (1905) by recognizing the Vallecito Conglomerate (a thick section of quartzite and conglomerate) as the oldest rock of that region. He believed the Vallecito to be overlain by the Irving Formation (amphibolite, some with pillow structures; iron-formation; and volcaniclastic metasedimentary rocks), the Twilight Gneiss (composed largely of felsic metavolcanic rocks), and the Uncompahgre Formation (thick quartzite units with minor meta-conglomerate and slate or phyllite). Burns and others (1980) have recently shown that crossbeds in the Vallecito point away from a scoured contact with the Irving and that cobbles in some of the conglomeratic beds of the Vallecito could well have been derived from unusual lithologies within the Irving.

Thus it appears that in the Needle Mountains, metavolcanic rocks of the Irving Formation are unconformably overlain by quartzite and conglomerate of the Vallecito Conglomerate, in general agreement with Cross and others (1905) but the opposite of the stratigraphic conclusions of Barker (1969). In spite of the higher metamorphic grade and structural complexity of the Needle Mountains rocks, general similarities of premetamorphic lithology, radiometric age, and revised stratigraphic sequence allow a cautious comparison with the Proterozoic section of the Tusas Mountains (Burns and Wobus, 1983).

On a regional scale in northern New Mexico and southwestern Colorado, late Early Proterozoic supracrustal assemblages appear to grade upward from a bimodal metavolcanic sequence to one composed largely of quartzite and conglomerate. Though not referring specifically to the Tusas or Needle Mountains sections, Condie (1981, 1982) recognized this same general trend in rocks of similar Proterozoic age throughout the southwestern United States. In terms of the plate-tectonics model, Condie (1982) suggested that this suite of rocks may have been generated by the opening and closing of successive back-arc basins underlain by continental crust.

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