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Kent C. Condie

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PRECAMBRIAN ROCKS OF THE TAOS RANGE AND VICINITY, NORTHERN NEW MEXICO

KENT C. CONDIE

Department of Geoscience

New Mexico Institute of Mining and Technology
Socorro, New Mexico 87801

INTRODUCTION

Precambrian rocks underlie much of the area in the Taos Range and vicinity northeast of Taos, New Mexico (fig. 1). In this region, the Precambrian terrane is intruded by Tertiary granitic plutons and overlain unconformably by upper Paleozoic and Mesozoic sediments and by Tertiary volcanics. It also is intruded extensively by Tertiary rhyolite and latite dikes. In general, exposures of Precambrian rock are poor with the only semi-continuous exposures occurring on the high mountain ridges. Precambrian rocks underlie most of the region from Rio Lucero on the south to Red River on the north (fig. 1). They also extend northward from the Moreno Valley and underlie part of the Cabresto Creek drainage.

Part of the Taos Range south of Rio Hondo was mapped in reconnaissance manner by Gruner (1920) who recognized most of the important Precambrian rock types in the area. McKinlay (1956, 1957) mapped Precambrian rocks in the northern part of the range as part of quadrangle mapping. Much of the Taos Range was mapped by Clark and Read (1972) as part of their study of the Eagle Nest region. These investigations served to define the distribution of the major Precambrian rock types. This investigation presents results of detailed mapping of Precambrian rocks in the Taos Range and vicinity by the author and students of the New Mexico Tech field course during 1976-77 and 1977-78. Also assisting with the course were F. J. Kuellmer and A. J. Budding.

Major Precambrian rocks in the area broadly fall into three categories: metasedimentary, metavolcanic and granitic rocks. In addition, minor diabase dikes of probable Precambrian age occur in some parts of the area. The metasedimentary terrane underlies much of the western part of the area and some of the area east of Red River (fig. 1). The metavolcanic terrane underlies several small areas roughly coincident with the crest of the Taos Range. Granitic rocks fall into two categories: granite (including quartz monzonite) and tonalite-trondhjemite. Tonalite-trondhjemite is intruded into the metavolcanic successions and partly into the metasedimentary successions in the crestal part of the Taos Range. These intrusive bodies are similar to the subvolcanic complex of Robertson and Moench (this guidebook). Major granite plutons occur in the southern and northeastern part of the area. Although the same rock types recognized by McKinlay (1956, 1957) were recognized by our mapping, we were unable to verify the map distributions proposed by McKinlay. We were unable to substantiate the four-fold subdivision of Precambrian rocks proposed by Clark and Read (1972). In addition, some of the lithologic types proposed by these authors are either nonexistent (i.e., granulite) or very minor (i.e., migmatite).

Although radiometric dates are not available from Precambrian rocks in the Taos Range, dates of similar rocks of Precambrian age in the Tusas and Picuris ranges probably give an indication of the general age of Precambrian rocks in the Taos

Range. The oldest plutonic rocks recognized in northern New Mexico are tonalites, trondhjemites and granodiorites, ranging in age between 1.65 and 1.7 b.y. (Barker and others, 1974; Brookins, 1974; Fullagar and Shiver, 1973; Long, 1974). All dates are recalculated with $X87 \text{ Rb} = 1.42 \times 10^{-11} \text{ yr}^{-1}$ and $X235\text{U} = 0.985 \times 10^{-9} \text{ yr}^{-1}$. Somewhat older (1.7-1.75 b.y.) felsic volcanic rocks have been reported from the Tusas and Nacimiento mountains (Barker and Friedman, 1974; Brookins, 1974). One or more periods of high-K granitic plutonism and regional metamorphism also are recorded between 1.3 and 1.4 b.y. B.P. (Callender and others, 1976; Gresens, 1975).

Mineral deposits in Precambrian rocks of this region have been summarized by Schilling (1960). Most deposits are Laramide or Tertiary in age. Quartz veins bearing minor amounts of sulfides and gold occur in many Precambrian rocks throughout the area. Small deposits of graphite and iron oxides of Precambrian age occur at a few locations in the region.

STRATIGRAPHY

Introduction

Because of poor exposures in the area, stratigraphic relations in the Precambrian supracrustal successions are not well known. The metavolcanic terrane, which is composed of felsic volcanic rocks and minor amphibolite, underlies about 30% of the crestal area of the Taos Range (fig. 1). The amphibolites appear to represent chiefly basalt flows and associated sills. The metavolcanic terrane occurs as four volcanic successions separated by intrusive tonalite-trondhjemite or granite, and the base of none of the sections is exposed. The stratigraphic relations among the four successions are unknown. The northern succession, which occurs between the Molycorp pit and Deer Creek, is composed dominantly of poorly exposed amphibolites. Although not well exposed, this succession appears to overlie paragneisses on the west. The central succession is composed of a felsic volcanic sequence (with minor amphibolite) in the Gold Hill-Goose Lake area and a poorly exposed amphibolite sequence in the Taos Ski Valley area. A minimum thickness of about 5 km is exposed in the central succession. The southern succession, well exposed along the Kachina Peak-Lake Fork Peak ridge and at Wheeler Peak, is composed of a felsic volcanic sequence with minor amphibolites. The fourth succession begins in the upper part of the Rio Lucero and extends southward into Taos Pueblo land. The metavolcanic successions are strikingly bimodal with felsic components exceeding mafic components in abundance. It is noteworthy that this distribution is opposite to that found in Archean bimodal greenstone successions, where mafic components dominate (Condie, 1976).

The metasedimentary terrane underlies much of the western and northern parts of the area and also occurs north of Moreno Valley and in the Blue Lake area south of Wheeler

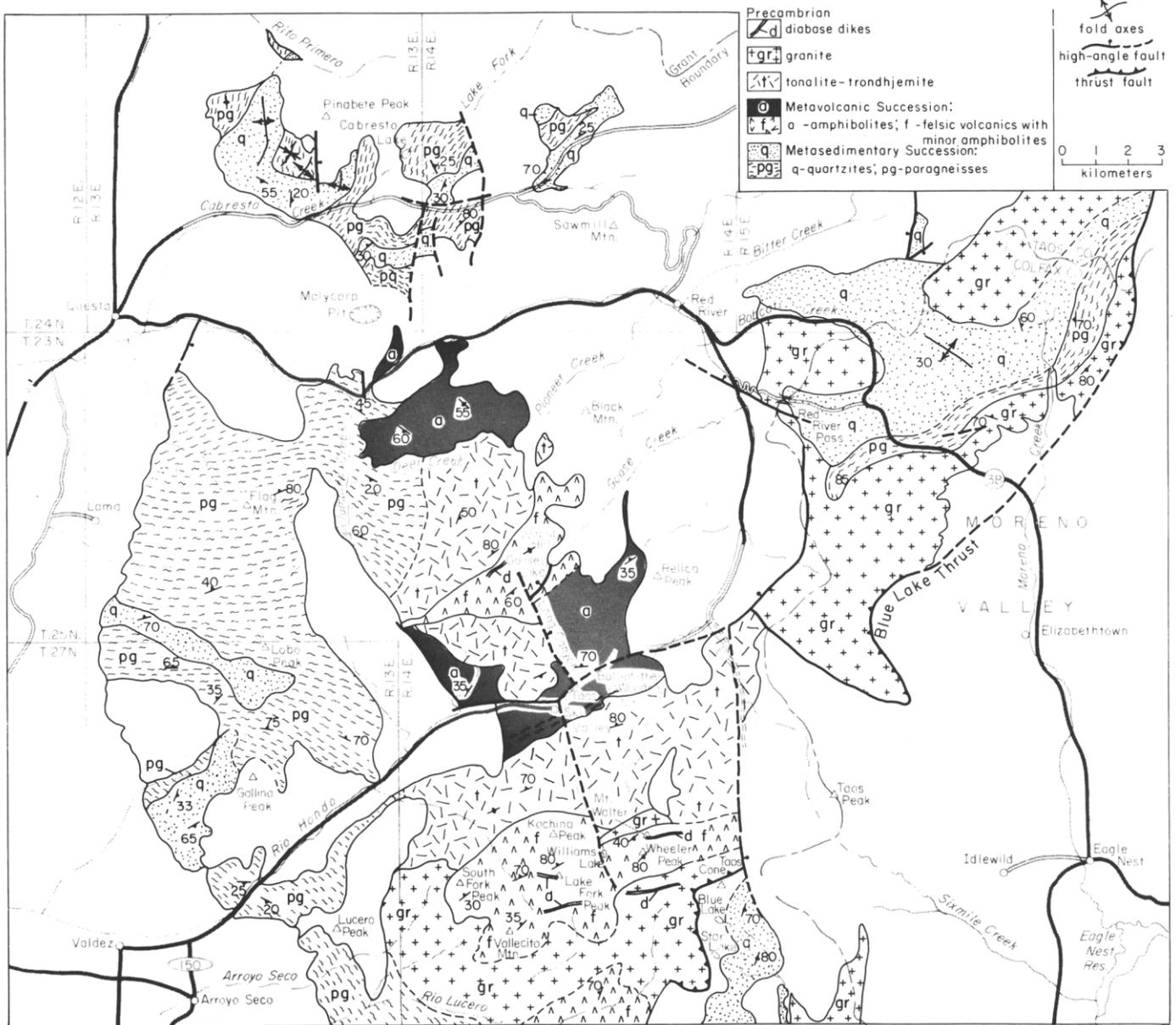


Figure 1. Geologic map of Precambrian rocks in the Taos-Red River area, northern New Mexico.

Peak (fig. 1). This terrane is composed chiefly of quartzofeldspathic paragneisses and quartzites with minor conformable amphibolite units. Neither the base nor the top of the metasedimentary succession is exposed, although as mentioned above, it appears to underlie the metavolcanic succession east of Columbine Creek. A minimum thickness of 1,500 m is exposed in the Cabresto Creek area and greater thicknesses may be present along the western front of the range between Hag Mountain and Rio Hondo.

Similar metavolcanic and metasedimentary successions have been described from the Precambrian of the Tusas, Picuris and southern Sangre de Cristo mountains in northern New Mexico (Barker, 1958; Montgomery, 1953; Robertson and Moench, this guidebook). Stratigraphic relationships in these areas are interpreted to indicate that the metavolcanic successions overlie the metasedimentary successions. Gresens and Stensrud (1974), however, have suggested the opposite relationship in the Tusas and Picuris ranges. Robertson and Moench (this

guidebook) suggest a lateral facies change from a volcanic to a sedimentary terrane in the Pecos area. The stratigraphic relationships in the Taos Range, although poorly exposed, tend to indicate that the metavolcanic succession overlies the metasedimentary succession.

The Metavolcanic Succession

Fe/sic volcanic rocks

Felsic volcanic rocks range in color from buff to brown, and are generally fine-grained. Where not highly deformed, bedding and other primary textures are preserved well. Individual beds range from a few centimeters to tens of centimeters in thickness. Graded bedding is preserved well in many beds, as for instance in the section on Lake Fork Peak. Crossbedding also is preserved locally. The presence of well shaped phenocrysts

of plagioclase and quartz, and of volcanic rock fragments strongly suggests that most of these rocks were tuffs and related volcanoclastic deposits. The phenocrysts comprise up to 25% of some beds and range in size from 1 to 3 mm. In general, foliation is parallel or subparallel to bedding in the felsic volcanics. Coarse felsic pyroclastic rocks or felsic flows were not recognized in the volcanic succession.

The felsic volcanics are composed principally of fine-grained quartz, sodic plagioclase and biotite with variable but generally minor amounts of magnetite, epidote and hornblende. Epidote, quartz and hematite occur in veinlets in some rocks. K-feldspar prophyroblasts are found in some volcanic rocks near granite intrusives, suggesting that potassium was introduced into the rocks during granite emplacement.

Amphibolites

Amphibolites are black to dark green, and generally occur in thick successions and as minor concordant units within the felsic metavolcanic and metasedimentary successions. Individual units range from 10 cm to many meters in thickness. Thick sequences composed dominantly of amphibolites occur in the Long Canyon area north of Taos Ski Valley and on the south side of Red River east of Columbine Creek (fig. 1). The former occurrence is very poorly exposed and highly altered, and its stratigraphic relationship to the Gold Hill volcanic succession is unknown. A great variety of textures occurs in the amphibolites, although only rarely are primary igneous textures preserved. Rocks range from massive to foliated and some have spotty textures. Some units are banded on a scale of millimeters to centimeters and appear to represent mafic or andesitic volcanoclastic deposits. Near granitic contacts, amphibolites are brecciated and migmatitic as exemplified well in the Deer Creek area. Alteration in the form of chloritization, epidotization, silicification and carbonation is variable in intensity, increasing near Cenozoic faults and shear zones. Thick successions of chloritized amphibolite occur along a shear zone near Bull-of-the-Woods Mountain east of Taos Ski Valley and along old state highway 38 east of Red River Pass.

Several genetically important variants of amphibolite occur in the metavolcanic successions. The most distinctive is an amphibolite which exhibits a relict cumulus texture in which primary pyroxene has been replaced by hornblende. These cumulus units occur as sills a few meters to tens of meters thick in the felsic volcanic sections. One readily accessible unit occurs in the saddle about 800 m south of Bull-of-the-Woods Mountain. Others occur in the succession along the ridge between Lake Fork Peak and Vallecito Mountain. These appear to represent basaltic sills that underwent in situ fractional crystallization. Another interesting variant is magnetite amphibolite. These rocks occur as narrow beds (5-20 cm thick) in the volcanic succession exposed on the ridge of Goose Lake cirque and contain unusual amounts of iron oxides. Some amphibolites of local extent contain >95% hornblende. One variety is composed chiefly of tremolite-actinolite. This rock, which is dark-green, occurs as sills up to 20 m thick. The major sills found in the area are along the north summit of Gold Hill and on the summit of Kachina Peak. These amphibolites may represent recrystallized ultramafic rocks. The only volcanic breccia found in the metavolcanic successions is exposed about 1,200 m south of Goose Lake. This rock, which is a chloritized amphibolite, contains partially stretched, angular volcanic-rock fragments in a fine-grained matrix.

Amphibolites are composed of variable amounts of hornblende and plagioclase with traces of sphene, quartz, epidote, magnetite and biotite. Locally, chlorite may be abundant, especially in altered varieties. Average grain size is 3-5 mm but locally can reach over 1 cm.

Although primary textures are rare in amphibolites, their field occurrence suggests that they represent mafic sills or flows; the tremolite-actinolite varieties may represent ultramafic sills. The thick successions east of Columbine Creek and in the Long Canyon area may be comprised chiefly of basaltic flows.

The Metasedimentary Succession

Paragneisses

Paragneiss is the most widespread metasedimentary rock in the map area. Paragneisses are gray to buff, well banded units, commonly interbedded with quartzite, amphibolite and a small amount of quartz-mica schist. Bands range from a few centimeters to many centimeters thick and can be followed without significant changes in thickness for long distances. The best exposures of paragneiss are in the Cabresto Creek area and at the mouth of Arroyo Hondo (fig. 1). Augen of feldspar are present in some of the gneisses. The paragneiss succession appears to dominate along the west side of the range between Arroyo Hondo and Red River, although it is, in general, poorly exposed. It is altered and silicified intensely in the Columbine Creek area and south of Lucero Peak. The paragneisses appear to represent metamorphosed shales and perhaps arkosic sandstones. A local variety of genetic importance is graphitic paragneiss found only in the Cabresto Peak area. It probably represents metamorphosed carbonaceous shales.

The paragneisses are composed principally of quartz, sodic plagioclase, K-feldspar and biotite. Locally, muscovite may be important. Some units in the Cabresto Creek and Moreno Valley areas contain small amounts of sillimanite which occurs as rosettes up to 1 cm in size. Small garnet prophyroblasts are also present in some samples. Magnetite, specularite and epidote are common accessory phases. Graphite composes a few percent of the graphitic paragneisses in the Cabresto Creek area. Locally, it may comprise up to 10% of the rock, as near the old graphite mine —2 km west of Pinabete Peak.

Quartzites

Quartzites are interbedded with the paragneisses, the best exposures occurring in the Cabresto Creek area, in the vicinity of Blue Lake, and at the north end of Moreno Valley (fig. 1). The rocks range from massive varieties composed of >95% quartz to fine-grained muscovite-quartz schists. The massive quartzites in the Cabresto Creek and Blue Lake areas have been called the Cabresto Metaquartzite (McKinlay, 1956) and the Pueblo Quartzite (Gruner, 1920), respectively. Because more than one massive quartzite unit occurs in each of these areas, however, these names are not adopted in this report. Foliation is generally subparallel to bedding in the quartzites, and contacts with surrounding paragneisses range from sharp to gradational over a few tens of centimeters. Colors are typically white to buff. Well banded varieties occur in the Cabresto Creek area. These units are up to 20 m thick and are composed of layers of biotite-quartzite up to a few centimeters thick. Crossbedding is preserved rarely in some massive quartzite units. Small units of conglomeratic quartzite containing cobbles of chiefly reworked quartzite occur in a few areas. Quartz-

ite beds taper out along strike, intertonguing with paragneiss. The thickest individual beds are of the massive, white variety and range up to 300 m thick. Several units of this thickness occur in the Blue Lake area where Clark and Read (1972) report a minimum thickness of 1,700 m.

In thin section, quartzites are fine- to medium-grained with quartz averaging 0.5 to 2 mm in size. Sutured boundaries between quartz grains are common in massive varieties. Although quartz generally ranges from 95-99% in abundance, some varieties contain up to 10% muscovite and locally grade into muscovite-quartz schist. Magnetite occurs as a minor constituent, commonly concentrated along bedding planes, and biotite is common in banded quartzites. McKinlay (1956) has reported kyanite in quartzites from the Precambrian of this region although none was found during our investigations.

GRANITIC ROCKS

Tonalite-Trondhjemite

Tonalite-trondhjemite is intrusive into the supracrustal successions. Contacts range from concordant to locally discordant. The rocks are gray to white, medium- to coarse-grained, and usually foliated. Foliation is parallel to that in supracrustal rocks. Most evidence suggests a syntectonic origin for the tonalite-trondhjemite. These rocks contain inclusions of amphibolite and felsic volcanic rock, both of which become more abundant near contacts with the metavolcanic successions. Inclusions range from a few centimeters to many meters in length. Locally, the rocks may contain K-feldspar and quartz porphyroblasts. These occur chiefly in areas where granites have been intruded into the tonalite and appear to have developed metasomatically during granite emplacement.

Tonalite-trondhjemite is composed of sodic plagioclase, quartz, biotite (<10%) and hornblende (<20%). K-feldspar, when present, appears to be of metasomatic origin.

Granites

Granites are intrusive into all older Precambrian rocks. Some are foliated and deformed, and appear to represent late, syntectonic plutons. An example is the large pluton in the northern Moreno Valley. Others, as represented chiefly by small dikes, are not foliated and are distinctly discordant, representing posttectonic intrusions. Two periods of post-tectonic dike emplacement are recorded in some outcrops. Granites are pink to orange and range from medium- to coarse-grained. Dikes range in thickness from a few centimeters to hundreds of meters.

The rocks are composed of approximately equal amounts of sodic plagioclase, K-feldspar (microcline) and quartz, with variable but small amounts of biotite, muscovite and epidote.

Pegmatites and Quartz Veins

Pegmatites are minor but widespread in the Taos Range. They range from <10 cm to several meters in width and are composed chiefly of K-feldspar and quartz; locally, muscovite may be important. As with the granites, both syn- and post-tectonic pegmatites occur.

Quartz veins are ubiquitous and associated commonly with epidote. They are chiefly posttectonic. One large, bulbous quartz vein (-100 m long) east of Long Canyon on the Gold Hill trail is highly brecciated.

DIABASE DIKES

The youngest Precambrian rocks in the Taos Range are diabase dikes which for the most part are posttectonic. These dikes range in thickness from -1 m to many tens of meters and weather to a distinctive chocolate-brown color. A relict subophitic texture is preserved commonly in the rocks. Although some of the diabases may be Tertiary in age, the fact that greenschist-facies mineral assemblages characterize most if not all dikes favors a Precambrian age.

STRUCTURE

Two periods of Precambrian folding are recorded in Precambrian rocks of the Taos Range and vicinity. The dominant set of folds trends N10E to N30E and plunges to the northeast. The wave length of these folds, which are exposed best in the Cabresto Creek area, ranges from tens to hundreds of meters, although locally centimeter-size folds are common. The felsic volcanic rocks exhibit varying degrees of deformation related to this period of folding. Small-scale folds, severe flattening, and local migmatization are recorded in some areas (such as on Kachina Peak). A second, probably older set of folds, with small amplitude and wave length, trends NW to W and plunges steeply to the SE. These are developed best in the Cabresto Creek, Moreno Valley and Flag Mountain-Rio Hondo areas. It is noteworthy that the earlier period of folding appears to be more important along the western edge of the map area where it controls the strike of the foliation (NW to W), whereas the younger period of folding (NE) controls the strike in the east.

Faults in the area are chiefly high-angle Tertiary faults. Shear zones are locally important in the Precambrian terrane. The largest is in the vicinity of Taos Ski Valley. This shear zone is up to 250 m wide and extends for several kilometers in an easterly direction. Copper mineralization of the Twinning district is concentrated along this shear zone and appears to be chiefly, if not exclusively, Cenozoic in age.

METAMORPHISM

Metamorphic mineral assemblages preserved in Precambrian rocks of the Taos Range and vicinity reflect the amphibolite facies. Holdaway (1978) has recognized the sequence kyanite andalusite → sillimanite in the Picuris Range and also has documented two periods of penetrative deformation. It is not clear if the same progression has occurred in the Taos Range. The medium-pressure facies series appears to characterize the Taos area, implying a geothermal gradient of -20°C/km, a maximum temperature of 500-600°C, and burial depths of 20-25 km.

The effects of contact metamorphism appear to have been minimal, reflected chiefly by K-metasomatism adjacent to Precambrian granite intrusives.

GEOLOGIC HISTORY

Because of uncertainties in stratigraphic relationships in Precambrian rocks of Taos Range and vicinity, only a provisional geological history can be presented at this time, as summarized in Table 1. Ages are assigned tentatively to major events from radiometric dates available from similar rocks in other Precambrian terranes in northern New Mexico. The first event recorded in the area is deposition of quartzites, shales and probably arkoses. How many sedimentary basins are represented is unknown. However, the fact that stratigraphic correlations between Precambrian sedimentary successions in northern

Table 1. Summary of major Precambrian geologic events in the Taos Range and vicinity.

Event	Suggested Age (b.y.)
Accumulation of shale, arkose and quartzite in one or more basins	1.7 – 1.75
Bimodal volcanism with felsic components predominating	
Deformation (D ₁ and D ₂), regional metamorphism and intrusion of tonalite-trondhjemite syntectonic plutons	1.65 – 1.7
Deformation and intrusion of syntectonic granite plutons	1.3 – 1.4
Intrusion of posttectonic granitic bodies	
Intrusion of diabase dikes	≤1.3

New Mexico do not seem likely suggests the existence of several basins. Following accumulation of the quartzite-shale succession, bimodal volcanism began in which felsic volcanic eruptions dominated.

The entire supracrustal succession was buried and deformed, and underwent regional metamorphism at 1.65-1.7 b.y. B.P. During this time, tonalite-trondhjemite plutons were intruded and at least two periods of folding (D1 and D2) occurred. The last period of activity in the region is assigned tentatively to a 1.3-1.4 b.y. age, and includes mild deformation (indistinguished in the present study from D1 and D2) and emplacement of syn- to posttectonic granite bodies and finally, of posttectonic diabase dikes.

Although the tectonic setting for the proposed succession of events is unknown, the lithologic association is consistent with the evolving continental rift model proposed by Condie and Budding (1979) for the Precambrian terranes in central and southern New Mexico.

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