# Precambrian rocks of Red River–Wheeler Peak area, New Mexico

By K. C. Condie

## Disscussion

### INTRODUCTION

This map covers an area bounded by Cabresto Creek drainage (north), Lucero Canyon (south), the escarpment of the Sangre de Cristo Mountains (west), and the Moreno Valley (east). Precambrian rocks underlie much of the area; they are intruded by Tertiary plutons and are unconformably overlain by late Paleozoic sediments and Tertiary volcanics. The rocks are also intruded by numerous felsic dikes of Tertiary age (some larger dikes are shown on map). Precambrian rock in the area is generally poorly exposed with the only continuous outcrop occurring on the high mountain ridges. Tertiary deformation and magmatism have resulted in varying degrees of alteration of the Precambrian rocks. The most intensely altered areas are noted on the map.

Precambrian rocks in the area comprise three categories: metasediments, metavolcanics (including hypabyssal rocks), and granites. All supracrustal rocks (rocks formed at or near the earth's surface) except the diabase dikes are metamorphosed to the amphibolite facies. Successions in which sedimentary rocks dominate occur around the outer part of the map area; those in which volcanic rocks dominate occur in the central part. The granitic rocks consist of two types: granite (including quartz monzonite) and tonalite-trondhjemite. Both are intrusive into supracrustal rocks; the granites also intrude the tonalite-trondhjemite. Although the rock types recognized by McKinlay (1956, 1957) were also recognized, the distribution he proposed could not be verified. The fourfold subdivision of Precambrian rocks proposed by Clark and Read (1972) could not be substantiated in any way. In addition, some of the lithologic types proposed by these authors are either nonexistent (such as granulite) or very minor (such as migmatite).

Although radiometric dates are not yet available from Precambrian rocks in this area, dates from similar rocks of Precambrian age in the Tusas and Picuris Ranges probably give an indication of the general age of Precambrian rocks in the Red River–Wheeler Peak area. The oldest plutonic rocks recognized in northern New Mexico are tonalites, trondhjemites, and granodiorites ranging from 1.65 to 1.75 b.y. (Condie and Budding, 1979). Many granites and quartz monzonites record ages of 1.3–1.4 b.y.

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; some may be of Precambrian age. Small deposits of graphite and iron oxides of probable Precambrian age occur at a few locations in the region.

Part of the area in upper Lucero Canyon was reconnaissance mapped by Gruner (1920) who recognized most of the important Precambrian rock types. McKinlay (1956, 1957) mapped Precambrian rocks in the northern part of the area as part of a quadrangle-mapping project in the northern part of the state. Much of the area is included on the map of Clark and Read (1972) as part of their study of the Eagle Nest region. The above investigations served to define the distribution of the major Precambrian rock types. The present investigation resulted in detailed mapping of Precambrian rocks in the Red River–Wheeler Peak area by the author during 1976–1979 and by his students in New Mexico Tech field geology courses during 1977 and 1978. The delineation of Phanerozoic geology is from McKinlay (1956, 1957) and Clark and Read (1972).

### STRATIGRAPHY

Stratigraphic relations among the supracrustal rocks in the Red River–Wheeler Peak area are poorly known due to inadequate exposure. Neither the base nor the top of the supracrustal succession has been identified. The exposed contacts are either intrusive or faulted. Supracrustal remnants are separated from each other by tonalite-trondhjemite or granite intrusions (cross section *B-B'*); the stratigraphic relationships between remnants is unknown. Three types of remnants can be identified: 1) those in which volcanic and volcaniclastic rocks dominate as in the Gold Hill and Wheeler Peak areas, 2) those in which sedimentary rocks dominate as in the Cabresto Creek drainage and in the upper Moreno Valley, and 3) those in which volcanic and sedimentary rocks occur in approximately equal amounts as represented solely by the succession in the Lobo Peak area. Although folding complicates estimates of stratigraphic thickness, apparently a minimum of 1.5 km is present in the Cabresto Creek section and a minimum of about 3 km in the section exposed along the west wall of Lake Fork Peak south of Twining.

As noted above, sedimentary rocks dominate the outer boundary area of the map while volcanic rocks dominate the central part. Possibly the succession in which mafic volcanics dominate in the Lobo Peak area continues eastward into the mafic succession in the Twining area. Quartzite and paragneiss, however, are not known in the Twining succession yet are major rock types in the Lobo Peak succession. This difference may be interpreted as a sedimentary-volcanic facies change with clastic sediments becoming more abundant to the west. Lateral facies changes may explain the peculiar distribution of supracrustal rocks in the Red River–Wheeler Peak area as a whole. Volcanic centers (both mafic and felsic) probably dominated the central part of the map area and were surrounded (except perhaps on the southwest) by sedimentary basins. Similar facies changes have been suggested in the Precambrian succession in the Pecos area to the south (Robertson and Moench, 1979).

Precambrian volcanic rocks in the Red River–Wheeler Peak area are part of a bimodal succession characterized by the virtual absence of rocks of andesitic to dacitic composition. Unlike typical bimodal Archean greenstone successions, however, where mafic rocks greatly exceed felsic rocks (Condie, 1976), mafic and felsic components occur in approximately equal abundance in the Red River–Wheeler Peak successions. Felsic volcaniclastic rocks dominate in the Gold Hill–Goose Lake, Vallecito Mountain–Wheeler Peak, and upper Rio Lucero areas and are interbedded with minor (less than 5 percent) mafic components.

**Felsic volcanic rocks (f)**

Typical felsic volcanics range from buff to brown and are fine to medium grained and occasionally crystal rich. Primary textures including graded bedding, crossbedding, and channel deposits are preserved in some of the volcaniclastic units. Such textures indicate that most of the rocks are arkosic tuffs and associated epiclastic deposits. Volcanic breccias and agglomerates, however, have not as yet been recognized. Crystals of plagioclase and quartz comprise up to 25 percent of some beds and range in size from 1 to 3 mm. Primary textures are not preserved in interbedded mafic units that are completely recrystallized to amphibolite. They may represent minor basalt flows or, more likely, sills.

Felsic volcanics and volcaniclastics consist principally of quartz, sodic plagioclase, K-feldspar, 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 porphyroblasts are found in some volcanic rocks near granite intrusives, suggesting that potassium was introduced into the rocks during granite emplacement.

**Mafic volcanic rocks (m, b)**

Mafic volcanic and/or hypabyssal rocks are the dominant supracrustal rocks in three successions: 1) south of Red River just east of Columbine Canyon, 2) the Twining area, and 3) the succession in the Lobo Peak area. Unlike the felsic volcanic rocks, the mafic rocks are poorly exposed, often fractured, and altered; rarely are primary textures preserved. The mafic rocks are now amphibolites composed of hornblende and plagioclase with minor but variable amounts of sphene, epidote, magnetite, quartz, and biotite. Some varieties are composed almost entirely of hornblende; others have an abundance of magnetite. Chlorite is a common secondary mineral in most samples. Grain size is highly variable averaging 3–5 mm but locally increasing to 1 cm.

Individual units range from 10 cm to many meters in thickness. A great variety of metamorphic textures occur in the mafic rocks ranging from massive to foliated and from medium to coarse grained. Some units are banded on a scale of millimeters to centimeters and may represent volcaniclastic deposits. Mafic volcanic rocks are interbedded with paragneiss (probably arkose) in the Lobo Peak succession. The only volcanic breccia found in the Red River–Wheeler Peak area is a mafic unit (**b**) about 1.5 km south of Goose Lake. This rock, a chloritized amphibolite, contains partially stretched, angular volcanic rock fragments in a fine-grained matrix. Tectonic brecciation and local migmatization occur in some mafic units. Secondary chlorite, epidote, quartz, and carbonate occur in altered mafic rocks, especially in shear zones. A major northeast-trending shear zone of probable Tertiary age cuts the mafic rocks in the Bull-of-the-Woods Mountain area east of Twining.

Although primary textures are rarely preserved in the mafic rocks, field occurrences and chemical compositions strongly suggest that most of the mafic rocks are volcanic flows or sills. Relict subophitic textures occur in a small number of samples. A relict cumulus texture is preserved in a few units that appear to represent sills. One readily accessible unit occurs in the saddle about 800 m south of Bull-of-the-Woods Mountain. These rocks contain what appears to be cumulus pyroxene now replaced by hornblende.

### Ultramafic rocks (u)

Ultramafic rocks are an extremely minor rock type in the Red River–Wheeler Peak supracrustal successions. They occur as sills and dikes up to 20 m thick in both the felsic and mafic volcanic successions. The rocks are composed chiefly of tremolite-actinolite, ranging from medium to coarse grained. Two large sills occur on the summit of Kachina Peak (1 km north of Lake Fork Peak) and one on the summit of Gold Hill.

### Gneisses (gn, gp)

Quartzofeldspathic gneisses **(gn)** are important in the Cabresto Creek drainage area and in the Flag Mountain–Columbine Creek area. In addition, a paragneiss unit occurs in the upper part of Moreno Valley; a remnant of a paragneiss succession occurs near the mouth of Rio Hondo Canyon. Paragneisses are gray to buff, well-banded units, often interbedded with quartzite and mafic volcanics and a small amount of quartz-mica schist. Bands range from a few to many centimeters thick and can be followed for long distances without significant changes in thickness. The best exposures of paragneiss are in the Cabresto Creek area and at the mouth of Arroyo Hondo Canyon. Feldspar augen are present in some of the gneisses. Clastic textures in some paragneisses suggest a sandstone origin. These rocks probably represent metamorphosed arkoses. Some of the more mica-rich gneisses may represent shales. Graphite paragneiss **(gp)**, found only in the Cabresto Creek area, appears to represent metamorphosed carbonaceous shale.

Significant amounts of orthogneiss are found in the region between Lobo Peak and Flag Mountain. Because of poor exposures, however, orthogneiss could not be distinguished from paragneiss on the map. Orthogneisses appear to represent syntectonic granites intruded into the paragneiss succession.

Gneisses are composed principally of quartz, sodic plagioclase, K-feldspar, and biotite. Muscovite may be important locally. Some units in the Cabresto Creek and Moreno Valley areas contain small amounts of sillimanite occurring as rosettes up to 1 cm in size. Small garnet porphyroblasts 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, the graphite may compose up to 10 percent of the rock, as near the old graphite mine about 2 km west of Pinabete Peak.

### Quartzites (q)

Quartzites occur: 1) interbedded with paragneiss in the Cabresto Creek area, 2) interbedded with mafic volcanic rocks in the Lobo Peak area, and 3) as the principal rock type in successions north of Moreno Valley and in the Blue Lake area. The rocks range from massive varieties consisting of more than 95 percent quartz to fine-grained quartz-muscovite schists. The massive quartzites in the Cabresto Creek and Blue Lake areas have been named, respectively, the Cabresto Metaquartzite (McKinlay, 1956) and the Pueblo Quartzite (Gruner, 1920). Because more than one massive quartzite unit occurs in each area, however, these names are not adopted in this report. Foliation is generally subparallel to bedding in the quartzites; 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 rarely preserved in some massive quartzite units as in the quartzite unit that crosses San Cristobal Canyon. Small units of conglomeratic quartzite containing cobbles of chiefly reworked quartzite occur in a few areas. Quartzite beds taper out along strike intertonguing with paragneiss. The thickest individual beds are 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 1.7 km.

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 the abundance of quartz generally ranges from 95 to 99 percent, some varieties of quartzite contain up to 10 percent muscovite and locally grade into muscovite-quartz schist. Magnetite occurs as a minor constituent, often concentrated along bedding planes; biotite is common in banded quartzites. McKinlay (1956) has reported kyanite in quartzites from the Precambrian of this region although none was found during the present investigation.

## GRANITIC ROCKS

### Tonalite–trondhjemite (t)

Tonalite–trondhjemite, intrusive into the supracrustal sequence, occurs in the central part of the map area. Contacts are generally concordant but may be discordant locally. The tonalite–trondhjemite is usually foliated; the foliation is parallel to the foliation in surrounding supracrustals (cross section *B-B'*), suggesting syntectonic emplacement. The three outcrop areas appear to represent portions of the same pluton. Inclusions of mafic and felsic volcanic rock occur in the tonalite–trondhjemite, becoming more abundant near contacts with these rocks. The inclusions range in size from a few centimeters to many meters and exhibit varying degrees of replacement by tonalitic minerals.

In the vicinity of granite dikes, the tonalite–trondhjemite contains K-feldspar porphyroblasts that appear to have developed metasomatically during emplacement of granite. Tonalite–trondhjemite is composed of sodic plagioclase, quartz, biotite (less than 10 percent), and hornblende (less than 20 percent). K-feldspar, when present, appears to be of metasomatic origin.

### Granite and quartz monzonite (gr)

Granite and quartz monzonite (hereafter referred to as granite) comprise two large plutons and numerous small dikes in the Red River–Wheeler Peak area. The largest pluton is north of Moreno Valley although the pluton in the Lucero Canyon area may be as large or larger extending south of the map area. The largest granite dike occurs about 1 km north of Wheeler Peak. Most dikes, however, range from a few centimeters to a few meters thick. Unlike the tonalite–trondhjemite pluton, the granite intrusives generally have sharp, discordant contacts and generally lack foliation. These features suggest late syntectonic to posttectonic emplacement. Two periods of posttectonic emplacement of small dikes are recorded in some outcrops.

Granites range in color from pink to white and from medium to coarse grained. They are composed of approximately equal amounts of K-feldspar, sodic plagioclase, and quartz, and have variable but small amounts of biotite and magnetite and secondary quartz, muscovite, and epidote. Pegmatites and quartz veins are associated with some of the posttectonic granite dikes. These veins range in width from about 10 cm to several meters and are composed chiefly of K-feldspar and quartz.

## DIABASE DIKES

The youngest Precambrian rocks in the Red River–Wheeler Peak area are posttectonic diabase dikes (**d**) that cut across all other Precambrian rocks. These dikes range in thickness from about one to many tens of meters and weather to a distinct chocolate brown. A relict subophitic texture is commonly preserved in the rocks. Although some of the diabase dikes may be Tertiary in age, the greenschist-facies mineral assemblages characterizing most of them plus the fact that the dikes are not observed to cut Phanerozoic rocks indicate a late Precambrian age. The diabases are composed chiefly of fine-grained sodic plagioclase, chlorite, epidote, and magnetite.

## STRUCTURE and METAMORPHISM

Two periods of Precambrian folding are recorded in Precambrian rocks of the Red River–Wheeler Peak area. The dominant set of folds trends N. 10°-30° E. and plunges to the northeast. The wavelength of these folds, best exposed in the Cabresto Creek area (cross section *A-A'*), ranges from tens to hundreds of meters although, locally, centimeter-size folds are common. 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 successions such as on Kachina Peak. A second, probably older, set of folds is best developed in the Cabresto Creek, Moreno Valley, and Flag Mountain–Rio Hondo areas; folds have small amplitude and wavelength, trend northwest to west, and plunge steeply southeast. These older folds are more important along the western edge of the map area where they control the strike of the foliation (northwest to west); younger folds (with northeast trend) control the strike in the east.

Faults in the area are chiefly high-angle Tertiary faults. Shear zones are locally associated with these faults and have resulted in intense fracturing and alteration of the Precambrian rocks. The most extensive fragmentation and alteration occurs in the area just east of Red River where blocks of Precambrian and Tertiary rock have been thoroughly mixed. Shearing and alteration are also widespread in the granites south of Lucero Peak and in the gneisses and amphibolites in the Columbine Canyon area. A mineralized shear zone extends east from Twining across Bull-of-the-Woods Mountain. Copper mineralization is concentrated along this shear zone.

Regional metamorphic assemblages in Precambrian rocks of the Red River–Wheeler Peak area indicate low amphibolite-facies grade. These assemblages are also consistent with a medium-pressure facies series reflecting a maximum temperature of 500-600°C and burial depth of 20-25 km. The effects of contact metamorphism appear to be minimal and are characterized chiefly by local development of K-feldspar in rocks injected with granite.

## GEOLOGIC HISTORY

The first Precambrian event recorded in the Red River–Wheeler Peak area is bimodal volcanism and deposition of quartzite, shale, and arkose. Volcanism was concentrated in the area near the central and south-central part of the map. Sedimentary basins developed around the edges of the map area. Although provenance studies are not complete, much of the sediment in these basins appears to have been derived from granite sources located outside the map area. The entire succession was then buried, deformed, metamorphosed, and intruded with syntectonic tonalite–trondhjemite. At least two periods of folding are recorded. The rocks were then uplifted to depths of less than 15 km and intruded with large volumes of post-tectonic granite and, later, with minor diabase dikes.

Although the tectonic setting for the proposed sequence 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.

## REFERENCES


Clark, K. F., and Read, C. B., 1972, Geology and ore deposits of Eagle Nest area, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 94, 152 p.

Condie, K. C., 1976, Trace-element geochemistry of Archean greenstone belts: Earth-Science Reviews, v. 12, p. 393–417

Condie, K. C., and Budding, A. J., 1979, Precambrian rocks of central and south-central New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 35, 58 p.

Gruner, J. W., 1920, Geologic reconnaissance of the southern part of the Taos Range, New Mexico: Journal of Geology, v. 28, p. 731–742

McKinlay, P. F., 1956, Geology of the Costilla and Latir quadrangles, Taos County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 42, 32 p.

__________, 1957, Geology of the Questa quadrangle, Taos County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 53, 23 p.

Robertson, J. M., and Moench, R. H., 1979, The Pecos greenstone belt, a Proterozoic volcanic-sedimentary sequence in the southern Sangre de Cristo Mountains, New Mexico: New Mexico Geological Society, Guidebook 30th field conference, p. 165–173

Schilling, J. H., 1960, Mineral resources of Taos County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 71, 124 p.