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GEOLOGY OF THE RED RIVER DISTRICT, TAOS COUNTY, NEW MEXICO

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Abstract—The Red River district encompasses a belt 15 km long and 6 km wide situated along the southeastern edge of the Questa caldera in the Sangre de Cristo Mountains of northern New Mexico. Caldera formation and associated plutonic activity represent the later stages in the evolution of the Latir volcanic field. Southernmost of the Rocky Mountain volcanic fields, the Latir field was active from 29 to 19 Ma and is located near the intersection between the Jemez lineament and the eastern margin of the Rio Grande rift. Along the southern margin of the caldera are postcaldera plutons which are characteristically rich in molybdenum. The Questa molybdenum mine and precious metal minralization are both products of this period of plutonism. Precious metal veins occupy radial and ring fractures associated with the caldera and normal faults associated with early rift related extension. Alteration in the district occurred in three stages: (1) regional propylitic alteration and smaller areas of intense acid alteration, both associated with molybdenum mineralization; (2) local argillic alteration and silicification along structures, associated with the precious metal mineralizing event; and (3) supergene alteration generated by weathering of the two previous stages. Mineralization occurs as quartz-cemented breccia zones and banded, massive or vuggy quartz veins, both of which occupy fault zones. Gangue mineralogy includes quartz, calcite and rare fluorite. Metallic mineralogy consists of pyrite, native gold, sphalerite, galena, chalcopyrite, pyrargyrite and argentite. Homogenization temperatures from two-phase liquid dominant inclusions average 237°C, and salinity averages 1.1 percent equivalent wt. NaCl. Salinity vs. homogenization temperature data are consistent with mixing between fluids of contrasting salinity. These characteristics are similar to epithermal deposits; however, additional geochemical and hydrologic studies are needed to support this origin.

INTRODUCTION

The Red River district is nestled high in the Sangre de Cristo Mountains of northern New Mexico, approximately 40 km northeast of Taos (Fig. 1). The district encompasses a northeast-trending belt about 15 km long and 6 km wide. The city of Red River is roughly in the center of the district. The famous Elizabethtown-Baldy district, the largest gold producer in the state, lies only 11 km to the southeast, and the Questa molybdenum mine is 8 km to the west. Southwest of Red River is the Twining district which hosts copper deposits of probable Proterozoic age (Clark and Read, 1972; North and McLemore, 1986).

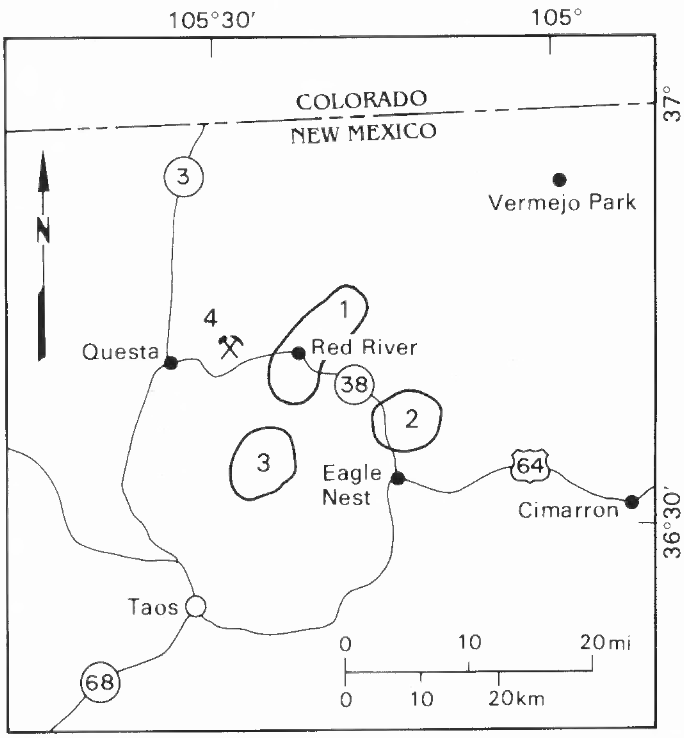

FIGURE 1. Location map of the Red River mining district. 1 = Red River district; 2 = Elizabethtown-Baldy district; 3 = Twining district; 4 = Molycorp Questa mine.

This paper is a review of data and interpretations, past and present, in light of new ideas concerning mineralization and tectonics of the Red River district.

HISTORY AND PRODUCTION

Legends tell of early mining activity in the Red River district by the Spanish (Reed, 1922). Although no conclusive physical evidence has ever been reported, the Spanish undoubtedly prospected the area and may have found some placer gold. The first real activity began after the Civil War in 1867, when the Waterbury Watch Company of Connecticut began development work on the Anaconda group, near the site of the future town of Red River. The Copper King mine officially opened on this group in 1879, and a small copper smelter was erected. After only two trial runs, the project was abandoned because of high costs and poor recoveries (Schilling, 1960). Several attempts to reopen the mine, the last in 1956, were also unsuccessful.

The first "gold rush" to the district did not occur until 1892 when prospectors explored the Red River and its tributaries for placer gold. It was during this rush that the town of Red River was established in 1894. Although no significant placer deposits were discovered, several mines sprang up on lode discoveries including the Midnight, Edison, Cashier, Memphis and Jay Hawk mines (Fig. 2). By 1897, Red River had a population of 2000, 14 saloons, two hotels, two bunkhouses and several boarding houses (Reed, 1922). The mines soon closed, in some cases after only a few months of operation, and the population of Red River gradually declined. Of these early operations, only the Memphis mine remained open on a fairly continuous basis until it closed about 1940.

A rich strike in 1904 at the Independence mine on Bitter Creek renewed interest in the area. In addition to the Independence mine, this rush resulted in opening the Caribel and Buffalo mines and prompted the reopening of the Cashier and Jay Hawk properties (Fig. 2). The rich discovery at the Independence proved only to be a small pocket, and no other ore was found. Second attempts at mining the Cashier and Jay Hawk mines were also failures. Extensive exploration work was done on the Caribel for several years, and some ore was treated at the June Bug mill on the Red River. The mine finally closed in 1921

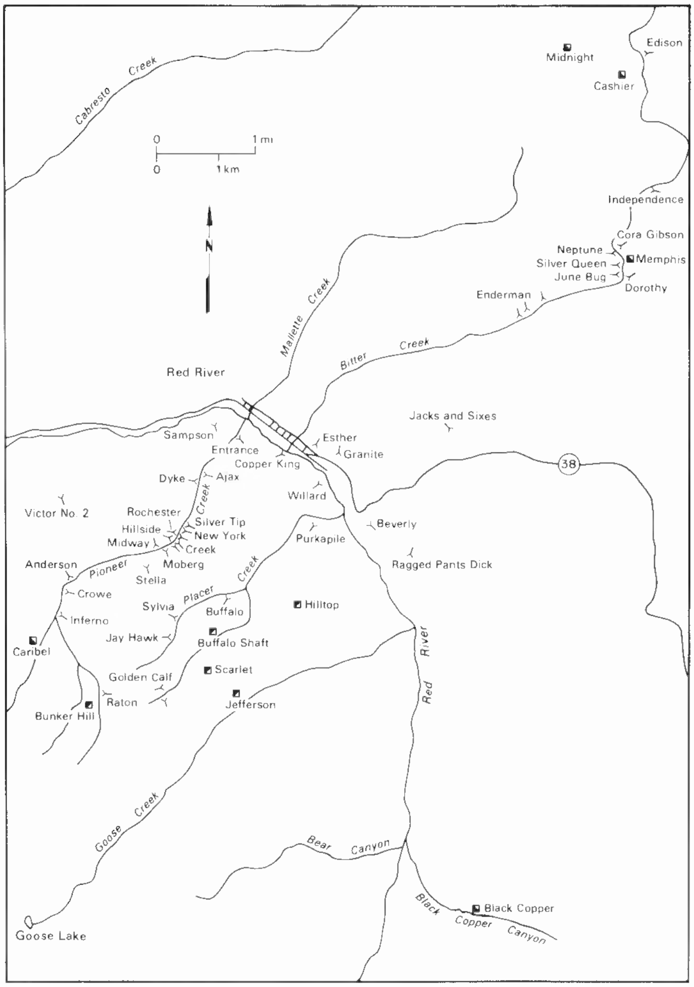

FIGURE 2. Mines and prospects in the Red River district.

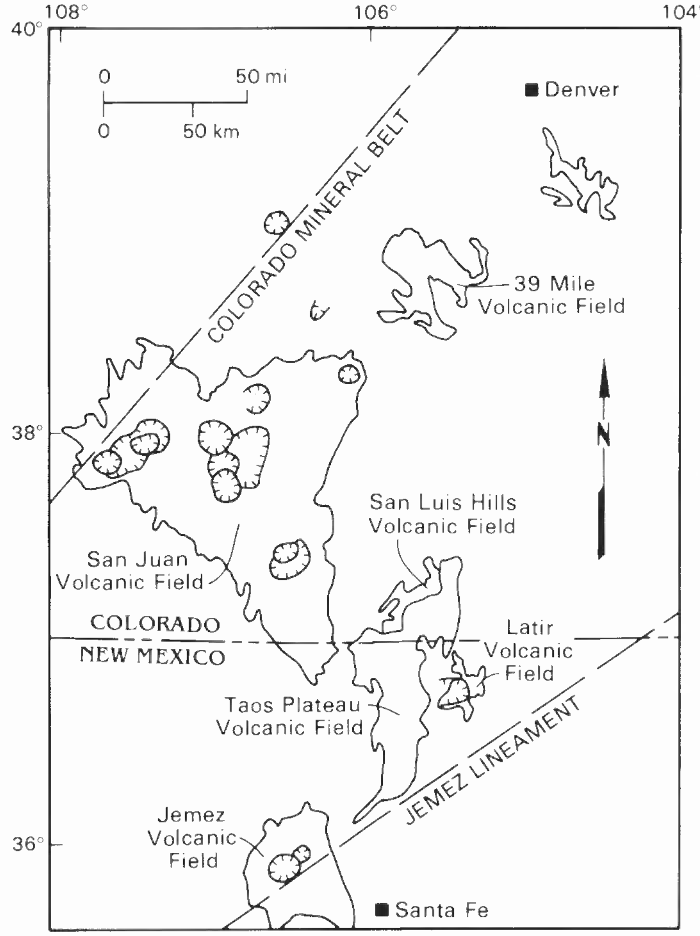

FIGURE 3. Regional volcanic geology showing the location of the Latir volcanic field. Simplified from Lipman (1981).

after a failed attempt at milling (Schilling, 1960). Development work continued in the Buffalo mine through the teens and twenties. A mill built in the late twenties was hampered by poor recoveries, and the mine finally closed in 1937 when the mill burned down (Schilling, 1960).

Sporadic activity continued throughout the district until the early 1950's and again in the 1980's, but no mine produced more than a few hundred tons of ore, except for the Memphis mine, which produced nearly 3500 tons of ore (Schilling, 1960). Clearly, most of the work in the district was strictly development and exploration. There are several reasons for failure of mining in the district, including poor milling practices, bad management, lack of sufficient capital, high operating costs, isolation of the district and generally low grades. Total gold and silver production is difficult to estimate, but North and McLemore (1986) report known production as 365 oz of gold and 8051 oz of silver for the period 1907–1956. About 17,000 lbs of copper was also produced. Total value of production from 1869 to 1956 probably did not exceed $100,000, not very impressive for a district with 90 years of recorded activity.

GEOLOGIC SETTING

Stratigraphy

The Red River district is intimately associated with the Latir volcanic field and the development of the Questa caldera. Southernmost of the Rocky Mountain volcanic fields, the Latir field (Fig. 3) presently occupies 1200 km^2, but was once much more widespread and probably interfingered with the San Juan volcanic field to the northwest (Lipman et al., 1986). In addition, the Latir field is the youngest and shortest lived of the major magmatic systems in the southern Rocky Mountains. A recent compilation of age determinations indicates the brief history encompassed only about 9 million years (Lipman et al., 1986). The Latir field, as exposed in the Taos Range, can be divided up into three groups: (1) precaldera lavas, ash-flow tuffs and hypabyssal intrusions, (2) caldera-related lavas and a regional ash-flow tuff and (3) postcaldera plutons and associated dikes and sills.

Intermediate composition stratovolcanoes generated the metaluminous mafic to felsic lavas and tuffs that characterize the 28–27 Ma precaldera volcanic sequence. The lavas range in composition from olivine basaltic andesite to quartz latite (Johnson and Lipman, 1988) and were deposited on local, early Tertiary sediments and Proterozoic basement. Figure 4 shows the generalized stratigraphy of the Latir volcanic field. Development of volcanism coincided with early southwest-oriented extension that ultimately led to formation of the Rio Grande rift, and is interpreted as back-arc extension related to shallow subduction under the Cordillera (Lipman et al., 1986).

Formation of the Questa caldera at 26 Ma is characterized by alkaline volcanism. Representatives of this stage include alkalic dacite, comendite and peralkaline rhyolite lavas (Johnson and Lipman, 1988). Collapse of the caldera signaled the eruption of the only regional ash-flow sheet, the high-SiO_2, peralkaline Amalia tuff. The Amalia tuff filled the caldera to a thickness of 2 km or more and spread as far west as the Tusas Mountains (Lipman et al., 1986).

Intrusive rocks of the Latir volcanic field are, for the most part, related to caldera resurgence and postcaldera plutonic activity (Fig. 4) and consist of a wide variety of plutons, porphyritic dikes, sills and

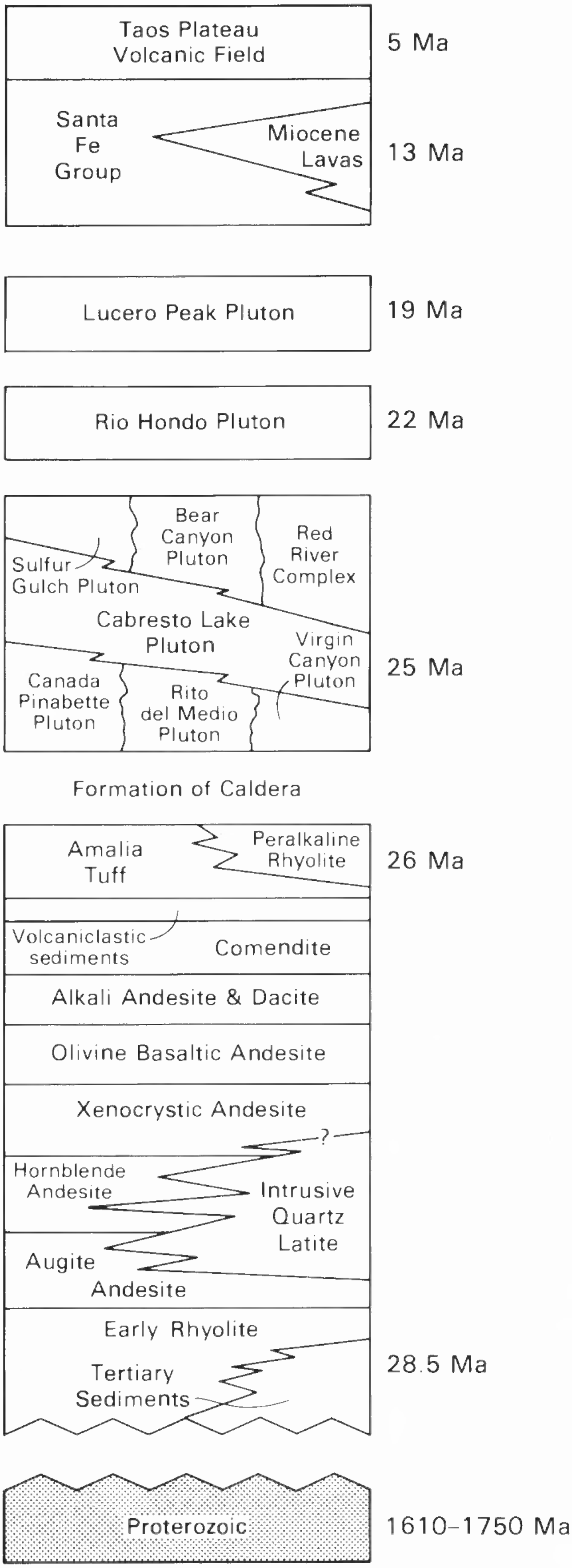

FIGURE 4. Schematic stratigraphy and K/Ar ages of the Latir volcanic field. Modified from Johnson and Lipman (1988).

laccoliths. The earliest representatives of intrusive activity are the intracaldera resurgent plutons of Virgin Canyon, Cañada Pinabete, Rito del Medio and Cabresto Lake. Lipman et al. (1986) have dated these plutons at 25–26 Ma. The plutons are rather complex, with the exception of the Rito del Medio pluton, and consist of peralkaline to metaluminous granite and granitic units, sometimes containing enclaves of mafic material (Dillet and Czamanske, 1987). Post-resurgent plutons were localized along the southern margin of the caldera and south of the caldera. The caldera-margin plutons include the Bear Canyon and Sulphur Gulch plutons and the Red River intrusive complex. Dating of these plutons by Laughlin et al. (1969) at 22–23 Ma was confirmed by Lipman et al. (1986). Monzogranite and syenogranite comprise the compositionally simple plutons of Bear Canyon and Sulphur Gulch, respectively. The Red River intrusive complex, on the other hand, is exceedingly complex and consists of granodiorite, syenogranite, alkali-feldspar granite and quartz-diorite units (Dillet and Czamanske, 1987). Monzogranite of the Lucero Peak pluton, and granodiorite and silicic granite of the Rio Hondo pluton make up the southern plutons. Ages of the Lucero Peak and Rio Hondo plutons are 19 Ma and 21 Ma, respectively (Czamanske et al., 1990). Numerous porphyritic dikes and sills crosscut all earlier lithologies in the area and represent the final felsic, volatile-rich magmas injected into the country rock from the interiors of the crystallizing plutons.

Proterozoic rocks form the basement in this region and underlie the volcanic rocks of the Latir field. In the Red River district, Precambrian rocks crop out only in the east-central portion and along the southwestern boundary (Fig. 5). Tonalite-trondhjemite and granite-quartz

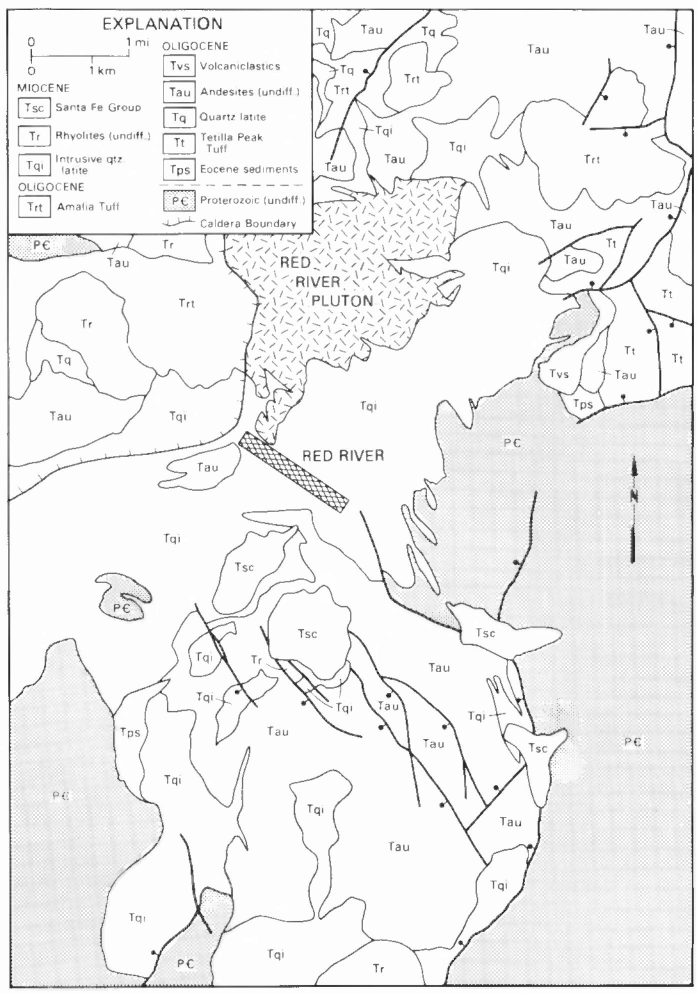

FIGURE 5. Geology of the Red River district. Simplified from Lipman and Reed (1989).

monzonite plutons comprise the eastern portion. Mafic and felsic metavolcanic rocks, and tonalite-trondhjemite occur along the southwestern end of the district (Condie, 1980). The metavolcanic sequence is part of the Gold Hill Complex (Bauer and Williams, 1989) that is found throughout the Taos Range.

Structure

The structural setting of the Latir volcanic field has been dominated by extensional tectonics which began during the late Oligocene and eventually produced the block-faulted topography that characterizes the Taos Range. Rift-related normal faults are oriented in two dominant trends, northwesterly and north-south. The former may be in response to early southwest-oriented extension and the latter to more recent west-oriented extension. The change in geometry of extension occurred subsequent to activity of the Questa caldera (Lipman, 1981). Subsidiary deformation is directly associated with development of the caldera and is localized along its margins, including east-northeast and north-south fractures.

Locally, in the Red River district, Tertiary dikes were emplaced along the strong east-northeast orientation. Tertiary dikes south of the Questa caldera are oriented along the strong northwest trend. Precious metal veins in the Red River district occupy both east-northeast and north-south structures (Reed, 1922; Park and McKinlay, 1948; Clark, 1968). Clark (1968) also noted that east-northeast veins are crosscut by north-south veins. Parkison et al. (1985) interpreted the vein structures as radial faults and ring fractures associated with development of the Questa caldera.

Recent structural work by the authors, however, reveals a slightly more complex structural picture. A stereographic projection of poles to veins (Fig. 6a) shows three distinct orientations: (1) a north-trending, vertical to east-dipping set; (2) a northwest-trending, vertical to subvertical set; and (3) an east-northeast-trending, north-dipping set. Perhaps the best explanation for the observed structural patterns is that the mineralizing event occurred during the waning stages of caldera activity and at the height of plutonism along the southern caldera margin. As a consequence, veins filled radial and ring fractures, as well as previous, extension related northwest-trending structures that undoubtedly underwent some rejuvenation. In the southern portion of the district the north-south- and east-west-trending structures correspond to radial and ring fractures, respectively, whereas in the northern portion of the district east-west-trending structures correspond to radial fractures, and north-south trending structures correspond to ring fractures. In addition, synchronous activity of fracturing and mineralization are indicated by vein textures which show multiple periods of brecciation and cementation.

A stereographic projection of post-mineralized structures (Fig. 6b) is similar to that of the mineralized structures and may suggest a continuance of caldera structural activity after the mineralizing event. Another possible interpretation is overprinting of west-oriented extension of the Rio Grande rift with localized doming or uplift. More data on post-mineralized structures are needed to address thoroughly this problem.

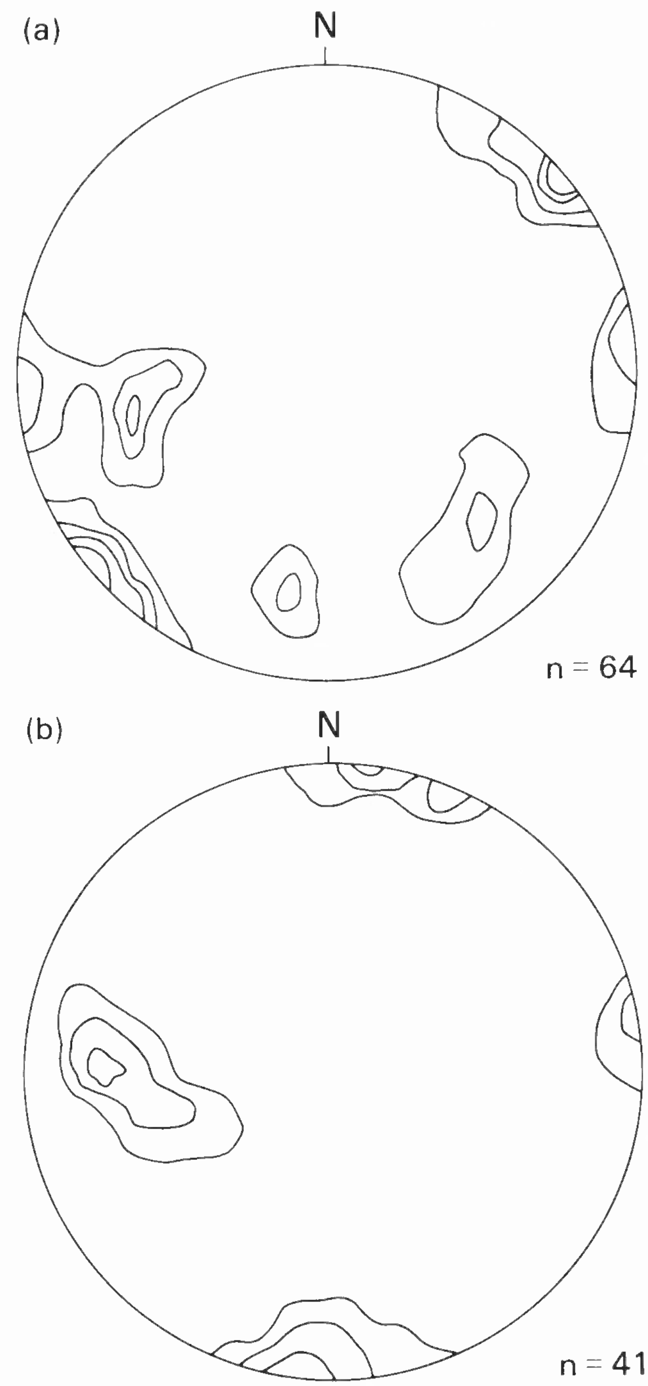

FIGURE 6. (a) Contoured stereographic projection of poles to veins in the Red River district. (b) Contoured stereographic projection of poles to post-mineral structures. Contours at 2, 4, 6 and 8% per 1% area.

ECONOMIC GEOLOGY

Current data suggest precious metal mineralization in the Red River district is related to the intense period of postcaldera plutonism from 25–19 Ma. The plutons from this period are characteristically enriched in molybdenum, but all except the Sulphur Gulch pluton are subeconomic. Molybdenum minralization is directly related to plutonic activity and is the product of magmatic fluids that evolved during crystallization (Leonardson et al., 1983). In contrast, precious metal mineralization may be an indirect product and is possibly derived from convective cells of warm water driven by an elevated geothermal gradient in response to magmatic activity (Buchanan, 1981).

Alteration

Alteration assemblages observed in the district today are the product of three stages: (1) regional propylitic alteration and smaller areas of intense acid alteration, both associated with molybdenum mineralization along the southern caldera margin; (2) local argillic alteration and silicification along structures, associated with the precious metal mineralizing event; and (3) supergene alteration generated by weathering of hypogene sulfides deposited in the two previous stages.

The regional propylitic alteration is pervasive and is centered around the plutons of the southern caldera margin. It is characterized by the assemblage: chlorite, epidote, calcite, sericite, pyrite and quartz (Clark and Read, 1972). Mafic minerals as phenocrysts and groundmass constituents are the most noticeably affected, being replaced by chlorite or epidote. Plagioclase is typically replaced by calcite and sericite. Quartz is an ubiquitous product of these alteration reactions, as well as filling fractures. Pyrite also occurs in fractures and as disseminated grains in groundmass in amounts up to 4%. All lithologic varieties are affected by the propylitic alteration, but those with a higher mafic content are most easily recognized. Both Ratcliff (1962) and Clark (1966) originally interpreted this alteration as deuteric in origin, but with further understanding of the alteration process, it is clearly of hydrothermal origin as later acknowledged by Clark and Read (1972).

The intense acid alteration is confined to faults, breccia zones and intrusive contacts (Ratcliff, 1962) and is the product of low pH hydrothermal solutions. Original lithologic textures in the host rocks are completely or nearly completely destroyed and are replaced by the assemblage kaolinite, sericite, quartz, pyrite, chalcopyrite, molybdenite and calcite (Clark and Read, 1972). Areas affected by this alteration are characterized by deeply eroded, brightly colored scars devoid of vegetation. Weathering of the acid alteration produces a supergene assemblage of hematite, goethite, jarosite, malachite, gypsum and ferrimolybdite.

Alteration associated with precious metal mineralization is localized within structures, generally extending less than 1–2 m into adjacent wall rock. Argillization and silicification, both containing pyrite, are the only types recognized. Rocks in the area were already in equilibrium with propylitizing fluids. The precise mineralogy of the argillic alteration is unknown. Argillization extends the farthest into the wall rock and is recognized by clay-altered feldspar phenocrysts and groundmass which impart a bleached appearance to the host lithology. Tiny grains of disseminated pyrite occur in the groundmass and within clays in altered phenocrysts. Silicification occurs in host rock fragments within the vein structures and in immediately adjacent wall rock. In the Dyke prospect, along Pioneer Creek (Fig. 2), silicified wall rock is virtually textureless except for lath-shaped cavities left by leaching of clay-altered feldspars. These cavities are commonly lined with drusy quartz. Narrow coxcomb quartz veinlets crosscut both silicified and argillically altered wall rock. Along the National vein, gold and silver values extend several feet into the wall rock and are associated with silicification (Parkison et al., 1985). Weathering of hypogene pyrite has produced iron-oxide staining and limonite pseudomorphs after pyrite. Manganese oxide staining is common along fracture surfaces.

Mineralization

Two types of structurally controlled mineralization occur: (1) quartz-cemented breccia zones and (2) banded, massive or vuggy quartz veins. Both types of mineralization occupy fault zones (Emmanuel et al., 1985). The "veins" in the district are often a composite of the above types with parallel and anastomosing quartz veins and veinlets enclosing brecciated and silicified wall rock. Vein textures suggest multiple periods of brecciation and quartz deposition within open fractures. Other textures include crustiform banding, coxcomb quartz and vugs. Individual veins are generally 0.5–4 m thick and discontinuous along both strike and dip, except for the National vein which can be traced along strike for 3600 m. Gangue mineralogy is quite simple with chalcedonic to "sugary" quartz being the dominant phase, and rare calcite and fluorite (Reed, 1922; Schilling, 1960). Metallic minerals are very fine grained (<200 μ) and comprise less than 5% of vein material (Parkison et al., 1985). Reported minerals include pyrite, native gold, sphalerite, galena, chalcopyrite, pyrargyrite and argentite (Schilling, 1960; Parkison et al., 1985). Geochemical analyses of surface and underground samples of altered rock range from <0.01–52 ppm Au, 0.07–225 ppm Ag, <25–4900 ppm Cu, 7–192 ppm Zn, <35–333 ppm Pb to <5–56 ppm Mo. Veins in the Bitter Creek area are moderately gold rich, with an average silver to gold ratio of 2:1, whereas veins southwest of Red River generally have significantly higher ratios, ranging from 30:1 to more than 100:1. Relatively recent exploration efforts in the district suggest that most veins at or near the surface are uneconomic in today's market. The National vein, however, appears to have the most potential for futher production.

Fluid inclusions in quartz are generally of the two-phase type and are liquid dominant (60–90%). Homogenization temperatures (uncorrected for pressure) for ore-stage quartz ranges from 300–330°C, in contrast to non-ore stage which ranges from 210–260°C (Parkison et al., 1985). Figure 7a is a histogram of homogenization temperatures from the Memphis and National veins which show a range of 170–340°C with an average of 237°C. Salinities from the two major veins (Fig. 7b) range from 0.5–3.0% equivalent wt. NaCl with an average of 1.1% equivalent wt. NaCl. According to Parkison et al. (1985) the fluid inclusions suggest that boiling occurred at some level below the sample localities, and they propose that gold deposition is the result of boiling. A plot of salinity vs. homogenization temperature (Fig. 8), however, reveals a variation in salinity without a corresponding variation in temperature, which is characteristic of mixing between fluids of contrasting salinity (Shepherd et al., 1985). Perhaps gold deposition was a result of mixing between gold-bearing hydrothermal solutions and ground water.

DISCUSSION AND CONCLUSIONS

Fissure-vein mineralization in the Red River district has been previously classified as pyrite-gold (Schilling, 1960), mesothermal (Clark and Read, 1972), Great Plains margin type (North and McLemore, 1986, 1988) and epithermal (Parkison et al., 1985; Emanuel et al., 1985). Based on the lithotectonic setting, mineralogy, vein textures, alteration and fluid-inclusion data presented in this paper, the most plausible classification is epithermal. The spatial relationship of the district with the Questa caldera is similar to other mid-Tertiary epithermal districts in New Mexico and southwestern Colorado associated with caldera-producing, silicic magmatism generated in an extensional environment.

Previous workers have generally considered the precious metal mineralization as a distal portion of the molybdenum mineralizing event (Clark, 1966; Clark and Read, 1972). However, gold is not associated with climax-type porphyry molybdenum deposits in either economic

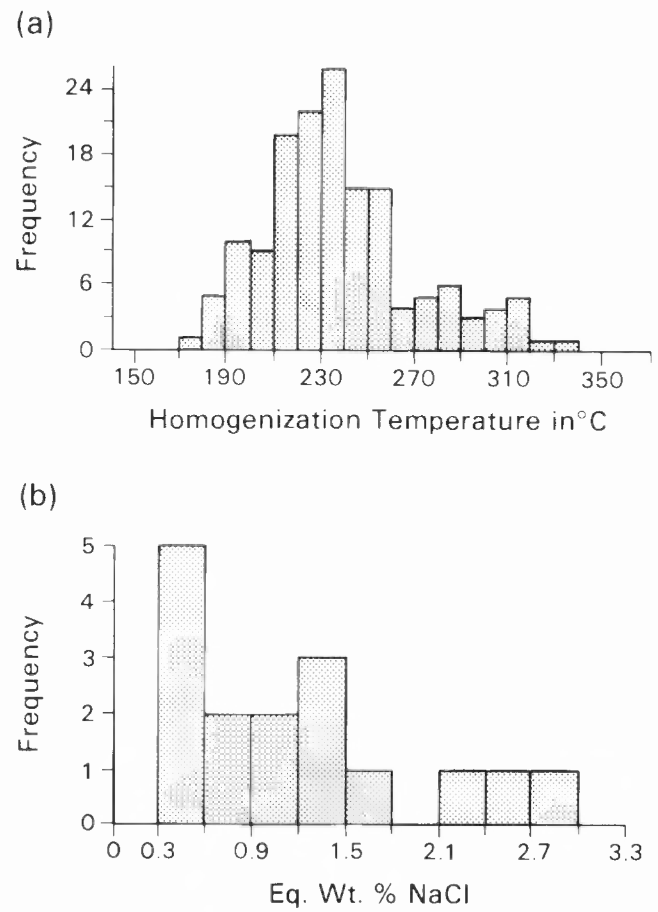

FIGURE 7. (a) Histogram of homogenization temperatures of fluid inclusions in quartz from the Memphis and National veins. (b) Histogram of salinities from the same samples. Data are uncorrected for pressure.

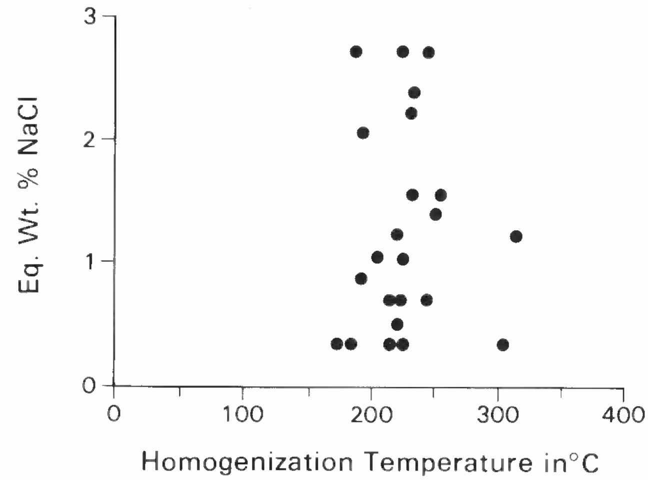

FIGURE 8. A plot of salinity vs. homogenization temperature in fluid inclusions in quartz from Memphis and National veins.

concentrations or anomalies in the trace-element halo (White et al., 1981; Ludington, 1986). Moreover, the ore fluids characteristic of precious metal mineralization in the Red River district do not have a magmatic signature; they are low in salinity, temperature and base metals. Also, the fluids appear to be low in total sulfur as suggested by the low sulfide-mineral content. These characteristics are similar to epithermal deposits described by Buchanan (1981). Additional detailed geochemical and hydrologic studies are needed to support an epithermal origin.

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