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GEOLOGY OF THE COCHITI MINING DISTRICT, SANDOVAL COUNTY, NEW MEXICO

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INTRODUCTION

The Cochiti or Bland mining district is located in Sandoval County in north-central New Mexico. The district lies about 80 km (50 mi) due north of Albuquerque and 50 km (30 mi) due west of Santa Fe on the southeast flank of the Jemez Mountains (Fig. 1). Elevations in the district range from about 2,100 to 2,500 m. The topography in the area is very rough, with steep northwest—southeast-trending canyons and intervening ridges. Two main drainages occur in the area, Bland Canyon to the east and Colle Canyon to the west. The old townsite of Bland has only a few buildings still standing and about three permanent residents.

HISTORY

Earliest prospecting and mining activity in the Cochiti district dates back to 1893 when the first claims were located. Work at the two largest mines in the district, the Albermarle and the Lone Star, was concurrent and lasted from about 1897 until 1903. Some smaller mines in the area, notably the Iron King, Washington, and Crown Point, were also active at this time. It has been estimated that nearly 1,000 people inhabited the area of the Bland townsite with perhaps an additional 250 at the Albermarle townsite during this peak of activity. Prior to 1903, estimated production from the district was $695,000 in gold and $345,000 in silver. The best description of the geology is by L. C. Gration in Lindgren and others (1910). Other historical accounts of the district were published by Wynkoop (1900), Barbour (1908), and Statz (1912). More recent descriptions of the geology are by Bundy (1958), Elston (1967), and Stein (1983). The largest mine in the district is the Albermarle, where total past production may have been 105,000 tons (95,250 mt) at an average grade of about 0.22 oz/ton (6.8 g/t) gold and 4.0 oz/ton (124 g/t) silver. Total recovered value is estimated to have been $667,500. The mine was developed by an inclined shaft some 220 m deep and a total of about 1,500 m of drifts. One of the first cyanide mills in New Mexico was installed at the mine site, with a capacity of approximately 250 TPD.

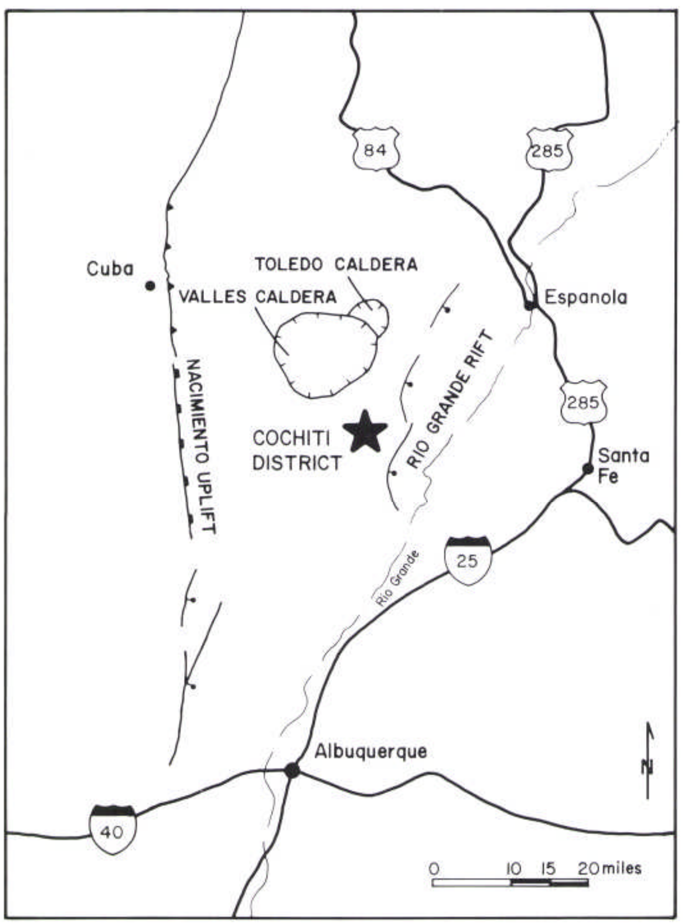

FIGURE 1. Map of north-central New Mexico showing location of the Cochiti district.

Total past production from the Lone Star mine is estimated to have been 65,000 tons (59,100 mt) grading 0.20 oz/ton (6.2 g/t) gold and 4.0 oz/ton (124 g/t) silver. About 30,000 tons (27,250 mt) of this ore were produced between 1897 and 1903. The production from this period was either direct-shipped or processed at the Woodbury mill at the mouth of Bland Canyon. From 1914 to 1916 about 33,000 tons (30,000 mt) were mined and milled at the recently constructed Cossak mill. This 20-stamp cyanide leach facility was constructed adjacent to the Lone Star mine. Lesser activity from 1932 to 1936 resulted in about 2,000 tons (1,800 mt) of ore being direct-shipped to the El Paso smelter.

Total production from the Washington, Iron King, and Crown Point mines was typically 5,000 tons (4,500 mt) or less each. This ore was generally hand-sorted and direct-shipped. A small flotation mill was built near the Iron King mine in 1947. After processing a total of 12 tons of ore, the mill was sold for back taxes in 1951.

REGIONAL GEOLOGY

The Cochiti district is located on the southeast flank of the Jemez Mountains. This late Cenozoic volcanic landform owes its present topographic relief to the evolution of the Toledo and Valles calderas, as well as development of the Rio Grande rift and Nacimiento fault systems. Much of the volcanic stratigraphy underlying the Cochiti district was formerly interpreted to be Eocene and Oligocene in age (Bailey and others, 1969; Smith and others, 1970). Stein (1983) reports a single K—Ar date which suggests that the volcanic stratigraphy of the Cochiti district might actually be of Miocene age and thus significantly younger than previously estimated.

The informal Bland group (Stein, 1983) is composed of a predominantly hypabyssal and extrusive suite of gabbro, basalt, basaltic andesite, dacite, and volcanic breccias. This sequence has been intruded by a composite sequence of quartz monzodiorites consisting of an older granular intrusion which has been injected by a younger porphyritic dike swarm (Fig. 2). These rocks appear to reflect the emplacement history of a single intrusive event. Outcrop exposures of the Bland group are dominated by quartz-monzodiorite porphyries followed by intimately mixed basaltic andesite and dacite collectively referred to as andesite. Outcrops of arkosic sandstone have been interpreted to be older than any rocks of the Bland group and may represent xenoliths or roof pendants within the younger intrusive rocks.

Overlying and intruding the rocks of the Bland group are those of the Keres Group which has been subdivided into the Paliza Canyon Formation and the younger Bearhead Rhyolite (Smith and others, 1970). The Keres Group is petrogenetically similar to the Bland group, al-

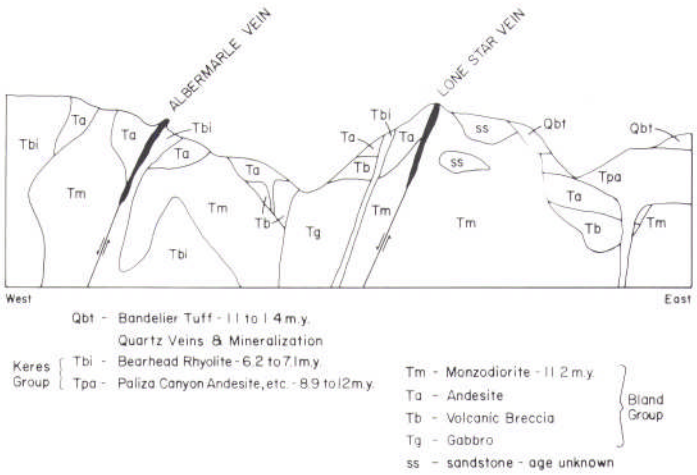

FIGURE 2. Diagrammatic cross section of the Cochiti district showing possible geologic relationships. Not to scale.

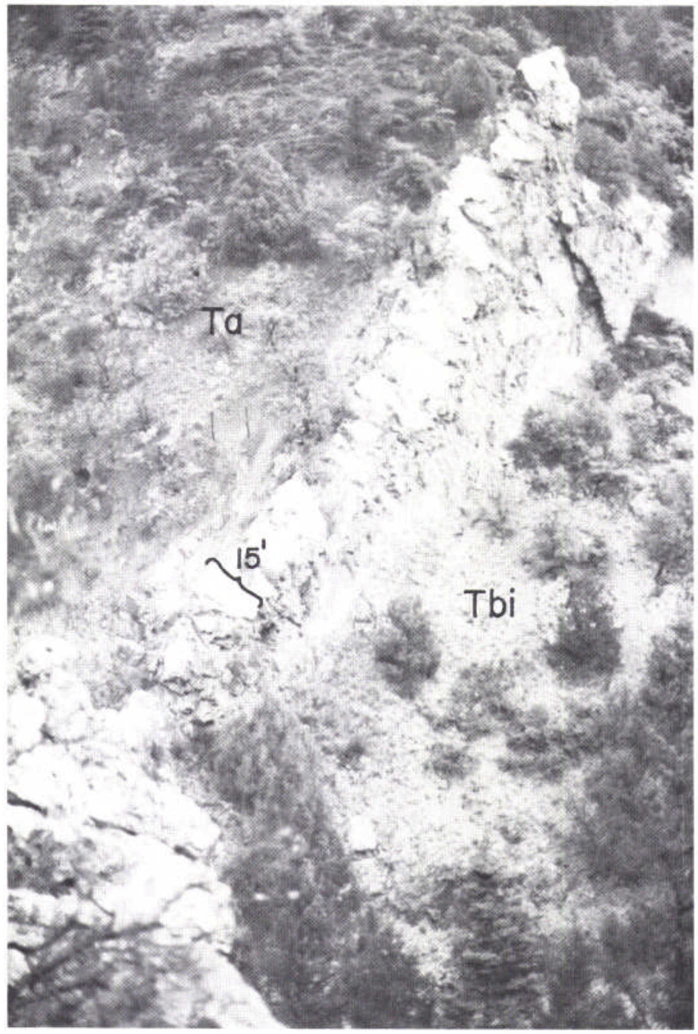

FIGURE 3. Photo of Albermarle vein just east of the Albermarle shaft. Ta – Andesite of the Bland group; Tbi – Bearhead Peak Rhyolite intrusion. (Photo by D. Wronkiewicz)

though stratigraphic continuity between the two groups has not been established as yet. The Paliza Canyon Formation generally consists of flow-banded rhyodacite, volcanic breccia, and massive andesite in about equal amounts. The Bearhead Rhyolite is generally seen to have intrusive contacts with older rocks. This unit is white to gray, flow-banded, and is generally restricted to the western part of the district.

The Tewa Group represents the latest episode of volcanism in the Jemez Mountains and is represented in the area by the Bandelier Tuff (Smith and others, 1970). The Bandelier has been subdivided into the basal air-fall and non-welded ash-flow deposits of the Otowi Member and the ovelrying welded ash-flow deposits of the Tshirege Member. The Tewa Group in the Cochiti district appears to occupy a paleovalley coincident with the present Bland Canyon. Quaternary surficial deposits cover large areas underlain by older units.

Geochronology of the rocks of the Cochiti district (Fig. 2) is based on correlations and radiometric-age data, and has recently been summarized by Stein (1983). From an extensive review of existing and new K—Ar dates, the Keres Group appears to range from 13 to 6 m.y. (Gardner and Goff, this guidebook). A single K—Ar date from quartz-monzodiorite porphyry (Bland group) of 1L2 m.y. suggests that the Bland group and Keres Group may, in part, be contemporaneous and could be locally equivalent (Stein, 1983; Gardner and Goff, this guidebook). K—Ar dates from 7.1 to 6.2 m.y. have been obtained from the Bearhead Rhyolite, establishing it as the youngest intrusive unit in the area (Bailey and Smith, 1978; Gardner and Goff, this guidebook).

The structure of the district is characterized by numerous generally north—south trending faults, fractures, and breccia zones. These dislocations may be related to the evolution of the Rio Grande rift, which has been active since 27 m.y.B.P. (Chapin, 1979) and currently forms the eastern margin of the Jemez Mountains. Areas of fractured and brecciated rock are ubiquitous throughout the district. The actual number of faults and the magnitude of fault displacements are difficult to determine due to the presence of widespread alteration, poor exposures, and the lack of reliable stratigraphic marker horizons. Brecciated margins between veins and wallrocks, and brecciated and locally resilicified quartz veins suggest that most veins have followed faults. Indeed, most faults have been noted by the presence of quartz veins. Faults are typically near-vertical or dip steeply to the west. Only rarely do faults cut through units of the Tewa Group; therefore, most faulting is older than 1.4 m.y.

In the Albermarle area, mineralized veins generally occupy a fault zone between andesite of the Bland group and the Bearhead Rhyolite (Figs. 2, 3). The observed relations suggest that the mineralization followed both the intrusion of the Bearhead Rhyolite (6.2 m.y.) and subsequent faulting. The volcanic rocks of the Tewa Group (1.4-1.1 m.y.) are not cut by the veins. These structural relationships suggest that mineralization occurred between 6.5 and 1.4 m.y. ago.

MINERALIZATION

Mineralization at the Cochiti district is fairly typical of epithermal quartz-vein-hosted gold—silver deposits (Buchanan, 1981). The mineralization is similar to better known epithermal districts such as Oatman (Arizona), Mogollon (New Mexico), and Creed (Colorado). Most of the quartz veins in the Cochiti district are quite similar, varying mostly in width and grade. Therefore, only a general description will be given for all veins of the district with variations noted where appropriate.

Veins generally strike north—south, but can vary, notably to a northeast trend at the Albermarle mine and a northwest trend at the Crown Point mine (Fig. 4). These flexures seem to localize ore shoots within dilatant zones, as do smaller bends at the Lone Star and Washington mines. Veins vary greatly in strike length, but the Lone Star vein system can be traced for over 3 km. This feature is the major system within the district and is locally composed of one or two subparallel veins, each up to 15 m in width, or a number of anastomosing smaller veins. Most mappable veins (more than 1 m wide) can be traced for at least 150 m. Veins generally dip steeply, ranging from about 65° W to 80° E. At least 13 separate significant veins or vein systems have been mapped for a total of 10 km of strike length.

Veins typically exceed 3 m in width and locally range up to 21 m or more when the silicified wallrock envelope is also included. Mining widths at the Albermarle mine were up to 18 m, at the Lone Star up to 14 m, and down to about 1 m at the Crown Point mine. Veins do not appear to be restricted to, or show a preferential development within,

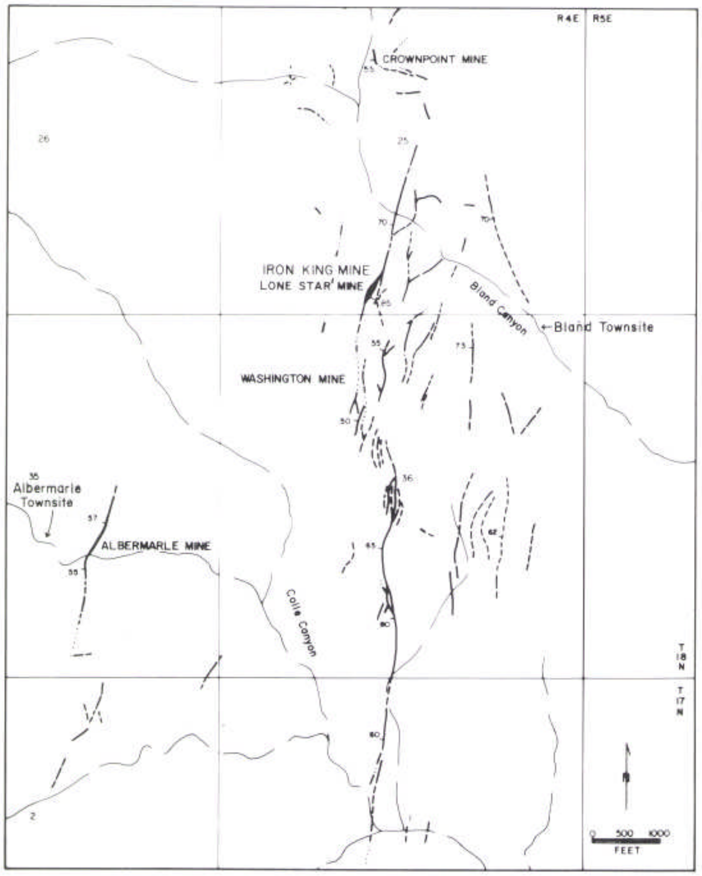

FIGURE 4. Map of veins in the central part of the Cochiti district.

specific type of wallrock. They are commonly brecciated, but are generally still cohesive. Multiple periods of quartz deposition followed by brecciation can be documented in many areas. Significant post-mineralization faulting has not affected the veins in most cases; when present, it has often been localized along the western wallrock contacts. Where hanging-wall stockwork zones are noted, precious-metal values appear to be restricted to quartz veinlets.

Mineralogy of the veins is quite simple. Most vein material averages 80-85% quartz and appears massive in outcrop. Coarse-grained calcite has been noted in drill holes. Quartz is generally white (although local amethyst has been locally noted), of a sugary texture and grain size, but can vary from chalcedonic to vug-lining crystals approaching 5 cm in length. Distinct banding in veins is uncommon; when present, it is generally manifested by changes in grain size of the quartz and by small, elongate vugs. Silicified wallrock horses and fragments are quite common and may locally exceed 50% by volume of some veins. Quartz-after-calcite textures have been noted, but are not common.

Metallic minerals in the veins are relatively sparse, rarely amounting to more than a few percent. Pyrite is the predominant sulfide phase and is often accompanied by related oxidation products. Only trace amounts of sphalerite, chalcopyrite, covellite, and galena have been noted. Native gold and electrum are generally not found to be hosted within, or directly associated with, pyrite. Silver minerals are predominantly argentite and proustite—pyrargyrite (ruby silver). Grain sizes of sulfides other than pyrite are generally less than 0.5 mm.

Paragenetic and cross-cutting relations suggest that a single mineralizing period occurred within the Cochiti district. While some veins show banded or layered quartz deposition, a consistent relation between varying pulses of quartz deposition and mineralization has not been demonstrated. Cross-cutting relationships within quartz veins cannot be definitely related to the timing of mineralization. Multiply brecciated and resilicified veins testify to at least three pulses of quartz deposition and brecciation. Paragenetic relations among the base-metal sulfides and the various precious-metal phases suggest near-simultaneous introduction and deposition, but with a slightly earlier base-metal stage followed by the introduction of gold and silver.

Higher grades of gold and silver mineralization are confined to irregular and vaguely defined ore shoots which generally appear to plunge vertically and have a larger vertical than horizontal dimension. Most production from the Lone Star and Albermarle mines came from single ore shoots. Higher grades are typically associated with greater vein widths. This suggests that ore shoots are related to dilatant zones along vein-filled faults which acted as conduits for ascending hydrothermal fluids.

It is difficult to find an outcrop within the district which has not been at least propylitically altered. More advanced alteration phases in wallrocks surrounding veins are generally present, but with quite variable widths (Bundy, 1958). Where alteration is most intense, an advanced argillic assemblage (dickite—kaolinite) occurs adjacent to veins and grades outward to an argillic zone (kaolinite—montmorillonite). Rarely present is a phyllic zone (sericite, quartz), which is found closest to the vein. Advanced argillic alteration is typically associated with the upper structural levels of veins systems, although some large areas of argillic alteration have been noted well away from known veins. In addition, certain rock types within the district are more susceptible to alteration than others; quartz monzodiorite is the most reactive, followed by andesite, dacite, and rhyolite.

FLUID-INCLUSION STUDIES

Three types of primary fluid inclusions were observed from quartz and calcite vein material. The most common type of inclusion contains a vapor-phase bubble occupying 2-30% of the inclusion volume. A second category of fluid inclusions, which has a higher vapor/liquid ratio (exceeding 90% by volume), is ubiquitous throughout the district and indicates boiling of the hydrothermal fluids (Roedder, 1979). A third type of inclusion is similar to the first type, but also contains an additional H_2S liquid phase. No true daughter minerals were observed in any of the inclusions.

Three hundred fifty filling temperatures and 100 freezing temperatures were determined from 34 doubly polished thick sections (Fig. 5). Overall homogenization temperatures ranged from 193 to 377°C, while salinities ranged from 0 to 5 wt% equivalent NaCI. Areas of higher-grade precious-metal values seem to correlate well with homogenization temperatures of 240-315°C.

Preliminary analyses of the vapor phase from all types of inclusions in vein material within previously mined areas show average compositions (in mole percent) of H_2S-3.50, organic compounds-3.30, CO_2—2.15, N_2-1.65, and H_2O-89.40.

SUMMARY AND ORE-DEPOSITION MODEL

A genetic model for ore deposition at the Cochiti district incorporates salient features from the above discussion as well as new information, and, hopefully, integrates them into a cohesive picture. Chronologically, the major events are:

(I) Deposition of the pre-Bland group arkosic sandstone which may have filled basins related to the early history of the Rio Grande rift, starting at 27 m.y.B.P. The sandstone is thought to have been later incorporated as xenoliths or roof pendants within the quartz-monzodiorite porphyry.

(2) The volcanic breccia and andesite, and hypabyssal intrusion of rhyodacite, andesite, and gabbro of the Bland group are similar to the rocks of the Paliza Canyon Formation of the Keres Group. Deposition of these units generally predated the intrusion of consanguineous quartz-monzodiorite stocks (11.7 m.y.), dikes, and sills within the district (Stein, 1983). The Bland group could, in part, be equivalent to the Paliza Canyon Formation (Gardner and Goff, this guidebook). These events may reflect the early stratovolcano-building stage of the Jemez Mountains volcanic field (Smith and others, 1970).

(3) Intrusion of the Bearhead Rhyolite (6.2-7.1 m.y.) mostly as subvolcanic stocks and dikes. These felsic intrusives acted as the heat source which drove a closed-cell ground-water convection system within the district (Berger and Eimon, 1982). The area affected by regional

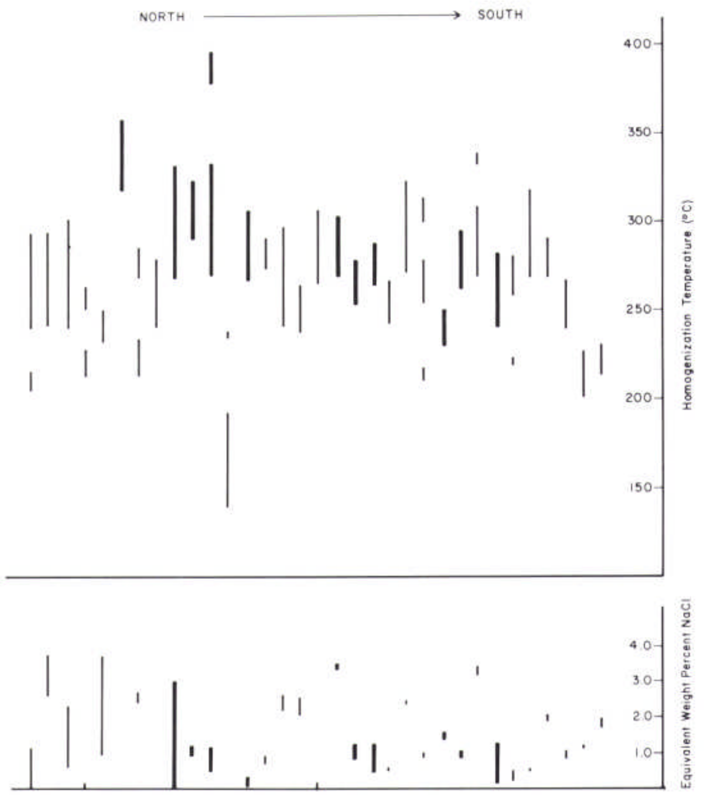

FIGURE 5. Fluid-inclusion homogenization temperatures and salinities from quartz and calcite vein material. Bars give ranges of temperatures and salinities observed. Thicker bars correspond to inclusions obtained from areas with higher-grade precious-metal mineralization.

propylitic alteration may mark the boundaries of this convection system. The main conduits for circulation were active tensional faults related to the Rio Grande rift. Scavenging of gold, silver, and quartz was accomplished by meteoric water as it circulated through the predominantly andesitic-composition stratigraphy.

(4) Hydrothermal fluids were typically quite dilute with an indicated 2% equivalent NaC1, which may reflect the concentration of organic compounds and H_2S alone. There may have been little NaCI in the solutions. Fluid inclusion studies suggest deposition of precious metals at or above the level of boiling at temperatures ranging from 240 to 315°C. Consequent effects of fluid boiling which may have caused deposition of metals and gangue minerals are oxidation, reduction of temperature and pressures, increase of pH, and the loss of H,S (Buchanan, 1981). Gold and silver were probably transported as bisulfide complexes (Barnes, 1979).

(5) Episodic boiling of solutions resulted in the deposition of both gangue and ore minerals and, in conjunction with recurrent faulting, gave rise to multiply brecciated and banded veins as well as local silicification of wallrock. Dilatant zones or cymoid structures along faults localized extensive fluid flow, which resulted in the formation of ore shoots.

(6) Boiling of the hydrothermal fluids was associated with a decrease in pH above the level of ore deposition, which caused widespread argillic alteration peripheral to veins and particularly in hanging wall zones.

(7) Gradual cooling of the intrusive rhyolite caused a cessation of the Cochiti hydrothermal-covection system.

(8) This was followed by continued faulting and significant erosion interrupted by a second episode of volcanism related to the collapse of the Valles and Toledo calderas.

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