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GEOLOGY AND MINERALIZATION OF THE EL CUERVO BUTTE BARITE–FLUORITE–GALENA DEPOSIT IN SOUTHERN SANTA FE COUNTY, NEW MEXICO

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INTRODUCTION

El Cuervo (Crow) Butte is in the Estancia basin, about 20 km northeast of Moriarty in southern Santa Fe County (Fig. 1). Barite–fluorite–galena veins occur along a north–northeast-trending fault in the Yeso Formation (Permian) and the Glorieta Sandstone Member of the San Andres Formation (Permian). The deposit occurs on state-trust mineral land and is essentially undeveloped. Although there is no reported production, shallow prospect pits and trenches expose the mineralization periodically along the fault. Mineralization is similar in composition and mode of emplacement to other sedimentary hydrothermal barite deposits in New Mexico. Fluid-inclusion studies suggest an origin similar to deposits in the Hansonburg district in Socorro County which are in part analogous to Mississippi Valley-type deposits (Roedder et al., 1968).

The El Cuervo Butte area was previously mapped as part of a regional reconnaissance study by Read et al. (1944). Williams et al. (1964) briefly described the barite mineralization at El Cuervo Butte based on a preliminary field investigation by the U.S. Bureau of Mines in 1958. McLemore and Barker (1985) briefly described the deposit as part of a study of barite deposits in north-central New Mexico. The mineralogy of the El Cuervo Butte deposit was described by North and McLemore (1985).

GEOLOGY

The oldest rocks exposed in the El Cuervo Butte area belong to the Yeso Formation and consist of red–brown to orange shale and siltstone with red to pink-sandstone and gray-limestone interbeds (Fig. 1; Needham and Bates, 1943). Sandstone beds dominate the upper portion of the Yeso Formation. The arkosic-sandstone beds are about 0.9–1.8 m thick, fine- to medium-grained and moderately well sorted. Planar and low-angle tabular cross-stratification are locally present. A few well-sorted, crossbedded quartz sandstones occur near the top of the formation. Discontinuous lenses of gray, unfossiliferous limestone, about 0.9 m thick, also occur near the top of the Yeso Formation. Small lenses of gypsum are found. The Yeso Formation ranges greatly in thickness throughout New Mexico, but could be expected to be about 200 to 450 m in the El Cuervo Butte area (Smith, 1957; Kelley, 1972a). Only the upper 91–122 m of the Yeso Formation are exposed at El Cuervo Butte. These rocks are probably lateral equivalents of the upper Joyita Sandstone Member and underlying Cañas Gypsum Member present farther south in Socorro, Valencia and Torrance Counties (Needham and Bates, 1943; Hunter and Ingersoll, 1981).

The Yeso Formation grades upward into the Glorieta Sandstone Member of the San Andres Formation (Milner, 1978; Needham and Bates, 1943). The Glorieta Sandstone ranges in thickness from 50 to 85 m (Kelley, 1972a). Less than 46 m of the Glorieta Sandstone are exposed at El Cuervo Butte (Fig. 1) and typically cap the ridges and buttes. The unit consists of resistant, white and light-gray to tan, iron-stained, fine- to medium-grained, well-sorted quartz sandstone. Bedding is massive to uneven, although planar cross-stratification is locally common. Conglomeratic lenses and graded bedding, fining upwards, are present locally.

A north–northeast-trending fault separates two small blocks of maroon to red–brown and grayish-red shale and siltstone of the Chinle Formation (Triassic) from the Glorieta Sandstone (Fig. 1). These two blocks may be continuous underneath Tertiary–Quaternary cover. Thin, discontinuous, flat-lying lenses of poorly sorted, medium-grained, gray to gray–pink or maroon sandstone and conglomerate occur within the Chinle. Bed forms, ripple marks and planar cross-stratification within the sandstones indicate a fluvial environment. The absence of thick, continuous, sandstone beds suggests that these rocks are correlative with the lower shale member of the Chinle Formation in eastern New Mexico (Kelley, 1972b).

Tertiary–Quaternary alluvial and eolian deposits cover much of the low, flat lands and rolling hills west of El Cuervo Butte, and are on top of the mesa east of El Cuervo Butte (Fig. 1). The deposits west of El Cuervo Butte, overlying the Permian and Triassic rocks, consist of poorly sorted coarse gravel, silt and clay with local eolian deposits. Thin caliche lenses are common in the western portion of the area. Correlations of these deposits are difficult because of poor exposure and vegetation cover. These alluvial and eolian deposits may be correlative with the upper Tertiary Ogallala Formation (Frye et al., 1982). The deposits on the mesa east of El Cuervo Butte, overlying the Glorieta Sandstone, consist dominantly of eolian deposits as well as coarse gravels and are probably Quaternary in age (Fig. 1).

Most of the Permian and Triassic rocks are flat-lying or dip gently to the east (Fig. 1), except where faulted. Near the faults dips increase up to 70°. Two major subparallel faults occur west of El Cuervo Butte. Only the eastern fault is mineralized at the surface, although the western fault could be mineralized at depth. The eastern fault separates the Yeso Formation from the Glorieta Sandstone or occurs within the Yeso Formation (Fig. 1). The western fault separates the Permian rocks from the Chinle Formation and is poorly exposed. Both faults trend north–northeast. The eastern fault dips steeply to the west at about 50–80°. The age of faulting is unknown, but may have occurred during periodic uplift of the Pedernal highlands to the south which has taken place since Permian time.

MINERALIZATION

Barite–fluorite–galena veins occur along the eastern fault within Permian rocks (Fig. 1). Barite veins and pods, up to 0.9 m wide, occur throughout the 0.3–3-m-wide fault zone (Fig. 2) and have been traced along the fault for about 4.8 km. The mineralization has been explored by small prospect pits and cuts. Mineralized veins and pods fill open spaces along bedding planes, in fractures and in brecciated zones of sandstone, siltstone and limestone in the Yeso Formation and in the Glorieta Sandstone adjacent to the fault. Replacement of limestone beds is minor. In addition, barite and calcite veins occur along fractures and bedding of sandstones in the Chinle Formation in sec. 22, T10N, R10E. The El Cuervo Butte deposits are not obviously associated with volcanic or intrusive rocks.

The mineralogy of the deposit is relatively simple, consisting of barite, some fluorite and minor galena in a quartz, calcite, sericite and K-feldspar gangue. A small amount of chrysocolla was identified in one sample. The barite occurs as coarse-grained, white and pink opaque blades (Fig. 3). The fluorite is transparent to translucent green, colorless or purple, and typically is intergrown with barite. A few thin veins, dominantly of fluorite with minor galena, are present locally. Green fluorite fluoresces bluish-purple. Galena occurs as small cubes (1–3 mm) intergrown with barite and fluorite.

Samples from the veins contain up to 92.9% $BaSO_4$ (Table 1). Selected additional samples contain up to 54.1% CaF_2, 2.31% Pb, 0.8 oz/ton (27.4 ppm) Ag and a trace of gold (less than 0.02 oz/ton). Chemically, the El Cuervo Butte deposits are similar to other deposits in north-central New Mexico (McLemore and Barker, 1985).

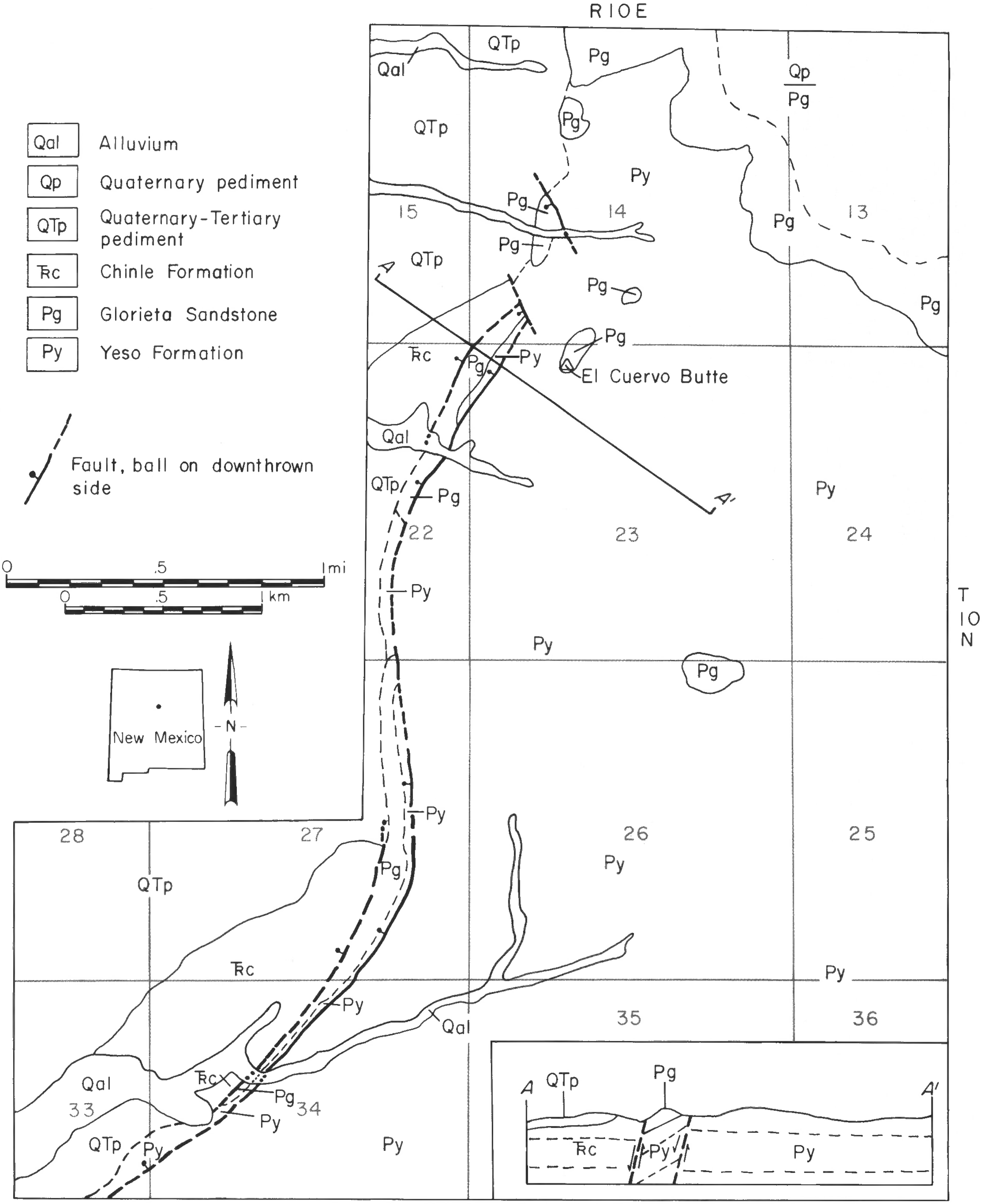

FIGURE 1. Geologic map and cross section of the El Cuervo Butte area, Santa Fe County, New Mexico.

FIGURE 2. Barite veins along steeply dipping fault. Looking north along a trench wall in sec. 23, T10N, R10E.

FIGURE 3. Massive, bladed, white, opaque barite in contact with fine-grained sandstone (Yeso Formation).

FLUID-INCLUSION STUDIES

A fluid-inclusion study was made on fluorite from El Cuervo Butte to obtain preliminary data on homogenization temperatures and salinities. The study was undertaken in order to compare the El Cuervo Butte deposit to the barite–fluorite–galena deposits of the Hansonburg district. The deposits have almost identical primary mineralogy, although the Hansonburg deposits contain a larger percentage of galena and quartz and have a small amount of chalcopyrite and sphalerite. Both deposits occur as mainly open-space fillings, are along major north-trending faults in central New Mexico and are not obviously associated with igneous activity. The Hansonburg deposits have been compared to Mississippi Valley-type deposits (Roedder et al., 1968).

Measurements were made on doubly polished thick sections of fluorite from four localities along the eastern fault. Homogenization temperatures and salinities (NaCl equivalent) were measured on 55 fluid inclusions in fluorite from all localities. In addition, homogenization temperatures were measured on 12 inclusions for which salinity was not determined and salinities were measured on 16 inclusions for which the temperature of homogenization was not determined. The results of those studies are summarized in Figures 4, 5 and 6.

Fluorite was the only mineral found which had fluid inclusions suitable for measurements. Fluid inclusions were observed in barite, but were too small for heating and freezing measurements. The fluorite contains ubiquitous two-phase (liquid-vapor) inclusions. The vapor bubble of the inclusions generally occupies an estimated 5% of the inclusion. Inclusions with no vapor bubbles are common. Solid inclusions of quartz are common, sometimes outlining growth banding in fluorite. Those crystals of fluorite exhibiting well-defined growth banding had few fluid inclusions large enough for measurements. Most fluid inclusions in the fluorite define fractures (presumably cleavage planes) in the crystals. Isolated fluid inclusions were generally larger and were assumed to be primary. Measurements were made on the inclusions defining the fractures in an attempt to determine if they were secondary or pseudosecondary. Measurements were also made on inclusions for which it was difficult to determine if they were isolated or along fractures. The three different types of inclusions (isolated, along fractues, undetermined) are identified in Figures 4, 5 and 6.

Salinities on all types of inclusions ranged from 6.4 to 15.4 wt. % NaCl equivalent (eq.). More than 85% of the salinities on isolated fluid inclusions fall between 12.3 and 14.3 wt. % NaCl eq., while the inclusions along fractures and those of uncertain position show considerably more range (Fig. 4).

Homogenization temperatures for all types of inclusions fall between 95 and 186°C (Fig. 5). The majority (78%) of isolated inclusions fall between 110 and 139°C. In general, inclusions along fractures homogenize at slightly lower temperatures, but not enough data are currently available to draw any conclusions. The homogenization-temperature data are not pressure-corrected.

The depth of formation of the El Cuervo Butte deposits can only be estimated. Studies on similar deposits (Roedder et al., 1968) have stated a maximum-pressure correction of +10°C (hydrostatic load) and +30°C (lithostatic load) assuming a 1500 m depth of formation. At 1000 m depth, hydrostatic pressure is approximately 100 bars and lithostatic pressure about 270 bars. Using the data of Potter (1977), this would result in a pressure correction at homogenization temperatures of 120°

TABLE 1. Chemical analyses of barite veins at El Cuervo Butte. *Trace of gold detected (less than 0.02 oz/ton). Gold was not detected in the other samples. +Accuracy is only about ±5%.

Sample No.	% $BaSO_4$	% CaF_2	Ag oz/ton (ppm)	% Pb	% SiO_2
4595*	27.28	---	0.22 (7.5)	2.31	---
4734	85.93	---	---	0.03	---
4731	87.77	---	---	0.008	---
7370	0.34	54.1+	0.12 (4.1)	---	<0.1
7371	91.72+	---	0.12 (4.1)	---	<0.1
7372	92.96+	---	0.00	---	<0.1
7373	68.20+	2.6	0.26 (8.9)	---	2.80
7374	51.40+	22.1	0.80 (27.4)	---	<0.1

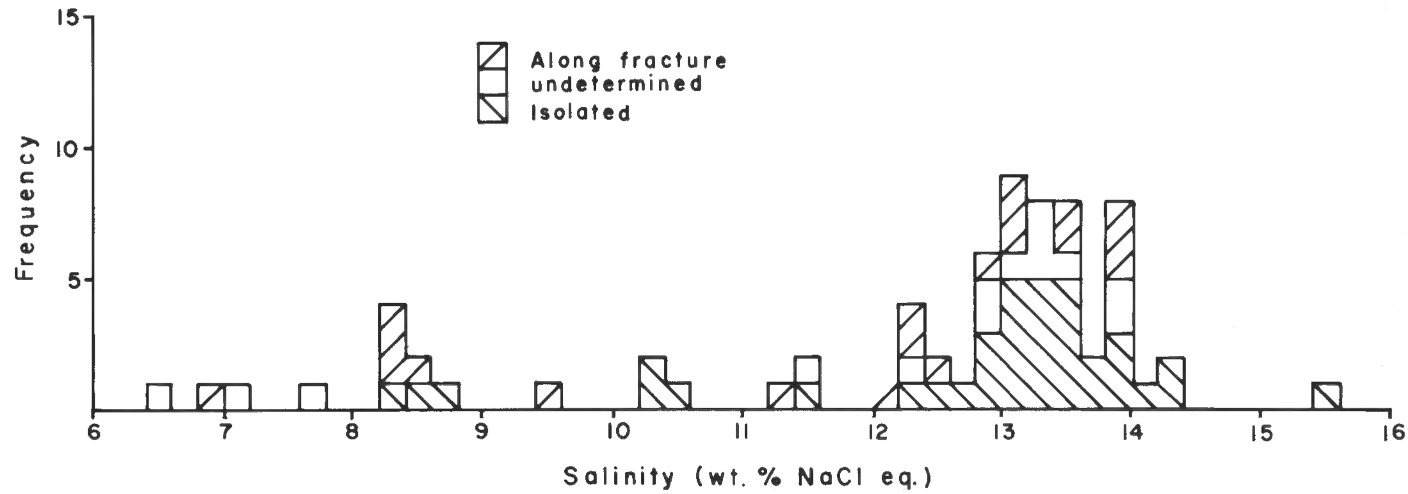

FIGURE 4. Histogram of salinities for fluid inclusions in fluorite from the El Cuervo Butte area.

and salinity = 10% of + 15°C (hydrostatic load) and + 40°C (lithostatic load). The El Cuervo Butte deposits probably formed under nearly hydrostatic load (i.e., the fracture in which they formed was open to the surface), and, although no hard data are available, a depth of 1000 m or less is reasonable. Therefore, a pressure correction of about + 15°C is necessary to convert homogenization temperatures to the actual trapping temperature of the included fluid.

Fluid inclusions were checked for stretching by performing multiple runs on single inclusions. The homogenization temperatures in inclusions which homogenized at 100°C originally would increase about 1°C after each run to 130°C. In inclusions with homogenization temperatures of 130°C, multiple heating to 130°C did not change the temperature of homogenization. However, after heating to about 150°C, stretching becomes a serious problem, and fluid inclusions with original homogenization temperatures of 100°C homogenized at temperatures of 110°C in subsequent runs. Some inclusions began to decrepitate at about 170°C. Because of these problems, once a sample was heated to over 150°C it was discarded.

The fluid-inclusion data are comparable with parameters presented by Roedder (1984, p. 416) for Mississippi Valley-type deposits. Roedder (1984) cites homogenization temperatures of 100–150°C and salinities of >15 wt. % NaCl eq. for Mississippi Valley-type deposits. Roedder et al. (1968, p. 346) report homogenization temperatures of 135–185°C and salinities of 8 to 13 wt. % NaCl eq. for fluorite from the Hansonburg district. Putnam (1980) reports ranges of 125–210°C for homogenization temperatures and salinities ranging from 10 to 18 wt. % NaCl eq. for fluorite from the Hansonburg deposits.

GENESIS

The barite–fluorite–galena deposits at El Cuervo Butte are similar in emplacement, geology, mineralogy and chemistry to sedimentary hydrothermal deposits along the Rio Grande rift in New Mexico (Putnam et al., 1983; McLemore and Barker, 1985). Relatively low fluid-inclusion homogenization temperatures and high salinities of the El Cuervo Butte deposit are similar to the Hansonburg deposit in Socorro County (Roedder et al., 1968; Putnam et al., 1983) and classic Mississippi Valley-type deposits in the central United States (Roedder, 1977, 1984; Ohle, 1980). Deposits of probable sedimentary hydrothermal origin, in part analogous to Mississippi Valley-type deposits (Ohle, 1959, 1980), are apparently widespread within or near the Rio Grande rift (McLemore and Barker, 1985) and differ from magmatic hydrothermal deposits by the absence of a nearby volcanic or intrusive source of ions, fluids and heat (Dunham and Hanor, 1967).

Sedimentary hydrothermal deposits are formed by water that is trapped within sediments during deposition and burial and by dehydration of minerals, chemical reactions, magmatic activity and downward percolation of meteoric waters (Hanor, 1979). These formational waters or brines accumulate in sedimentary basins and are heated by convection

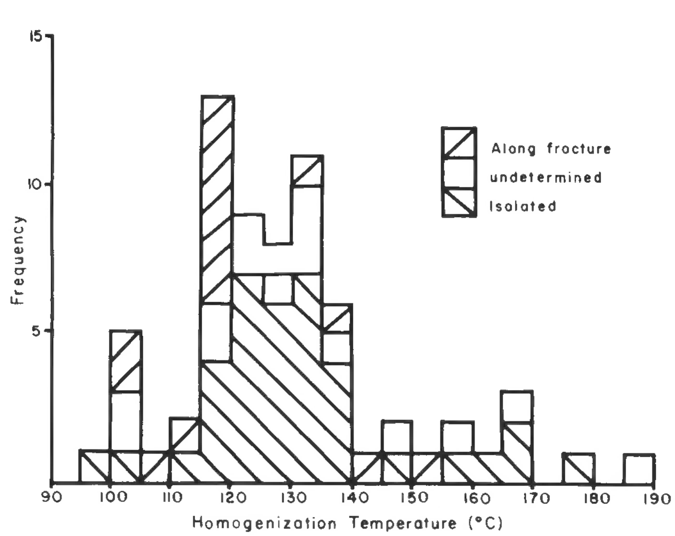

FIGURE 5. Histogram of homogenization temperatures for fluid inclusions in fluorite from the El Cuervo Butte area. The data are not pressure-corrected.

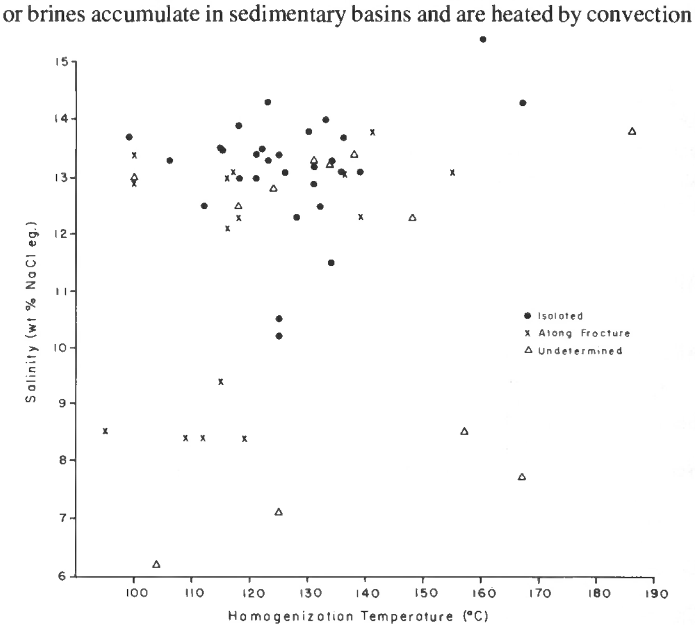

FIGURE 6. Plot of homogenization temperature vs. salinity for fluid inclusions in fluorite from the El Cuervo Butte area.

from high heat flow associated with the Rio Grande rift (Reiter et al., 1975, 1978, 1979) or older tectonic activity, magmatic activity or radiogenetic heat from Precambrian granitic plutons (Cathles, 1981). The warm convecting waters leach barium, sulfate and other associated elements from sediments derived from source rocks such as Paleozoic arkosic sediments and evaporites and Precambrian rocks. The mineralized waters are ejected along faults, fractures and contact zones by porosity reduction during burial and compaction of the sediment (Noble, 1963), or during tectonic activity (Hanor, 1979) such as uplift of the Pedernal highlands. Precipitation occurs as a result of simple cooling of the fluids (Putnam et al., 1983), decrease in pressure (Noble, 1963) or mixing of hydrothermal fluids with reducing subsurface brines (Beales, 1975). Fluid-inclusion studies indicate the solutions did not boil during deposition at El Cuervo Butte or in similar deposits (Roedder, 1984).

The age of mineralization at El Cuervo Butte is not known, but is limited by the age of the host rocks (Permian through Triassic) and the age of the mineralized fault (Permian or younger). Barite deposits in the Sandia, Manzanita and Manzano Mountains are similar to the El Cuervo Butte deposits and are probably older than uplift of the mountain ranges (McLemore and Barker, 1985). At least three episodes of uplift of these mountains occurred during the Cenozoic, the youngest event at 7–14 m.y. ago (Chapin, 1979). Although previous workers have attributed barite mineralization elsewhere in New Mexico to the Tertiary (Allmendinger, 1974, 1975; Beane, 1974; Ewing, 1979; Putnam et al., 1983), the evidence suggests that mineralization at El Cuervo Butte could be as old as Triassic or as young as Miocene.

ECONOMIC POTENTIAL

The most important commercial use of barite is as a weighting agent (Williams et al., 1964). Barite, with a specific gravity of up to 4.5 (commercial grade is 4.2), increases the weight of drilling muds to help control pressures in drill holes. Consequently, barite production is heavily dependent upon the needs of the petroleum industry.

The potential for barite at El Cuervo Butte is moderate to high. The vein has not been explored below about 5 m. The western fault between the Permian rocks and the Chinle Formation is a good exploration target. Geologic mapping of the surrounding area may also indicate favorable exploration targets (i.e., fault zones). Recent interpretation of the NURE (National Uranium Evaluation) and the HSSR (Hydrogeochemical and Stream Sediment Reconnaissance) data by McLemore (1984) indicates anomalous Ba and Pb values in stream-sediment samples in southern Santa Fe and northern Torrance Counties. These anomalies further suggest additional barite–fluorite–galena mineralization in the area, although other interpretations of these anomalies are possible.

ACKNOWLEDGMENTS

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Tucumcari Mountain and east side of Redonda Mesa from the caprock escarpment, approximately 9 mi east–northeast of Ragland, New Mexico. View is N20°W. Caliche developed in upper part of Ogallala Formation caps caprock escarpment at right. Camera station is in NW1/4 sec. 5, T7N, R32E. W. Lambert photograph No. 85L20. 6 April 1985, 4:40 p.m., MST.