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FLUID-INCLUSION AND TRACE-ELEMENT ANALYSES OF SOME BARITE–FLUORITE DEPOSITS IN SOUTH-CENTRAL NEW MEXICO

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Abstract—Fluid inclusions in fluorite collected from barite–fluorite (±galena) deposits in south-central New Mexico show they formed from fluids of similar temperatures and variable salinities. Deposits spatially associated with igneous rocks show salinities of less than 1.5 equivalent wt% NaCl, while those not obviously associated with igneous activity range from almost fresh water (0.1%) to 8%. Homogenization temperatures on all types ranged from 120 to 218°C, with most measurements falling between 140 and 180°C.

Trace-element analysis of barite showed considerable variation in samples from the same localities and no pattern was detected. The Y–Sr ratio in fluorite appears to separate igneous-associated deposits (e.g. Chise district) from sedimentary–hydrothermal deposits (e.g. Hansonburg district). The ratio is less than 1.5 in igneous-associated deposits and greater than 3 in known sedimentary–hydrothermal deposits.

INTRODUCTION

Most barite–fluorite (±galena, silver) deposits in New Mexico are located along the Rio Grande rift in central New Mexico or associated with magmatic activity in the southwestern corner of the state. The origin and distribution of the deposits in the central portion has been the subject of some debate concerning the source of hydrothermal solutions responsible for the formation of the deposits. Two major hypotheses have been proposed: (1) Sedimentary–hydrothermal deposits are formed from connate (±meteoric) water heated by high heat flow along the Rio Grande rift, expelled along basin-bounding faults, and deposited as open-space filling in response to decreased temperature, pressure, or other physical/chemical changes (Hanor 1979, Putnam et al. 1983, McLemore & Barker 1985, North & McLemore 1985). (2) Igneous-associated deposits are related to alkalic melts high in fluorine, generated in response to subduction of the Farallon plate beneath North America about 40–20 my ago. The magmas supply heat and fluorine for hydrothermal fluids which migrate up Basin and Range faults (Lamarre 1974, 1975, McAnulty 1975, Van Alstine 1976).

Perusal of previous work indicates at least two groups of barite–fluorite deposits based solely on geologic setting: those which are spatially associated with igneous activity and those that are not. The El Cuervo Butte and Hansonburg deposits typify the deposits not spatially associated with igneous activity, and the deposits at Fluorite Ridge and near the Organ cauldron typify deposits spatially associated with igneous activity. In some districts, such as the Florida Mountains, the deposit studied was in close spatial association with a Tertiary dike, but it is unlikely if dike emplacement would generate enough heat to be responsible for hydrothermal mineralization. As a first approximation, geologic setting alone was used to separate deposits into three groups: igneous-associated, not igneous-associated, and unknown. The fluid-inclusion and trace-element analyses were undertaken to determine if the first two categories had specific signatures and, therefore, if the last could be eliminated. The igneous-associated deposits studied were Fluorite Ridge, Chise, Tortugas Mountain, and Bishop Cap. The deposits not spatially associated with igneous activity included El Cuervo Butte, Hansonburg, Lemitar Mountains, Caballo Mountains, and Palm Park. The deposits studied in the unknown category were the Potrillo and Florida Mountains (Fig. 1).

PREVIOUS WORK

The first extensive fluid-inclusion study on barite–fluorite deposits in New Mexico was by Roedder et al. (1968), who found that the Mex-Tex deposit in the Hansonburg district (#3, Fig. 1) was formed by high-salinity, low-temperature solutions (Figs. 2, 3), similar to Mississippi Valley-type deposits. These data were confirmed and expanded by Putnam et al. (1983). Beane (1974) proposed similar deposits elsewhere in New Mexico were formed from ground water heated by shallow intrusions, forming hydrothermal solutions that leached metals and

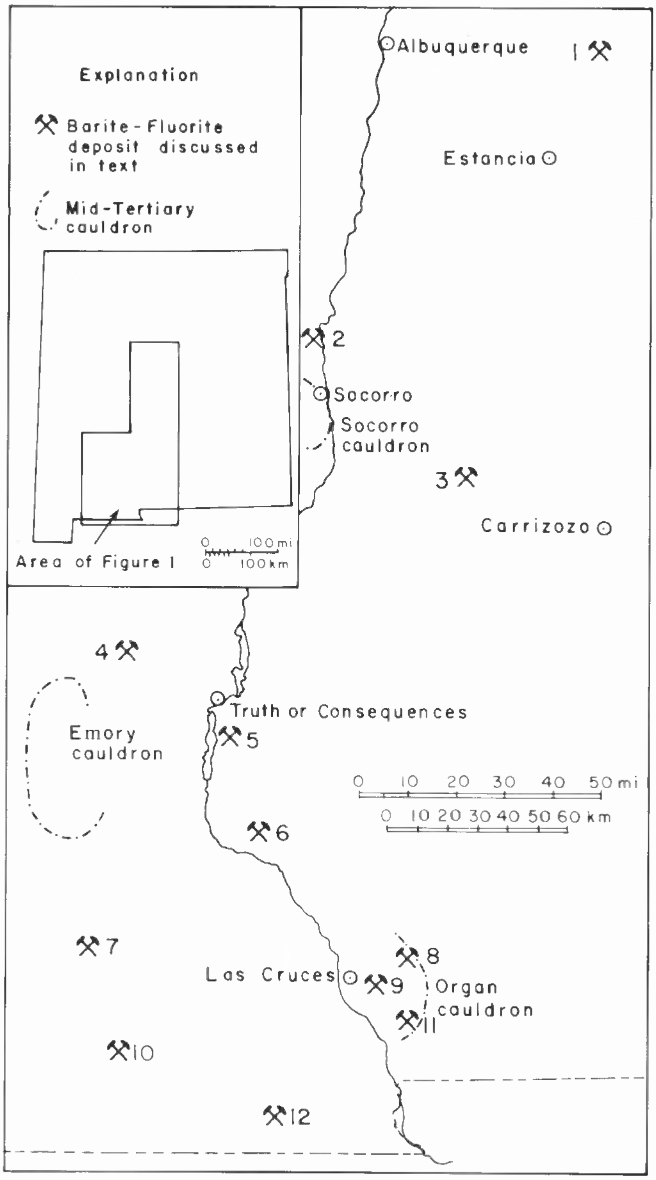

FIGURE 1—Location of barite–fluorite deposits discussed in the text. 1, El Cuervo Butte; 2, Lemitar Mountains; 3, Hansonburg; 4, Chise; 5, Caballo Mountains; 6, Palm Park; 7, Fluorite Ridge; 8, Organ Mountains; 9, Tortugas Mountain; 10, Florida Mountains; 11, Bishop Cap Hills; 12, Potrillo Mountains.

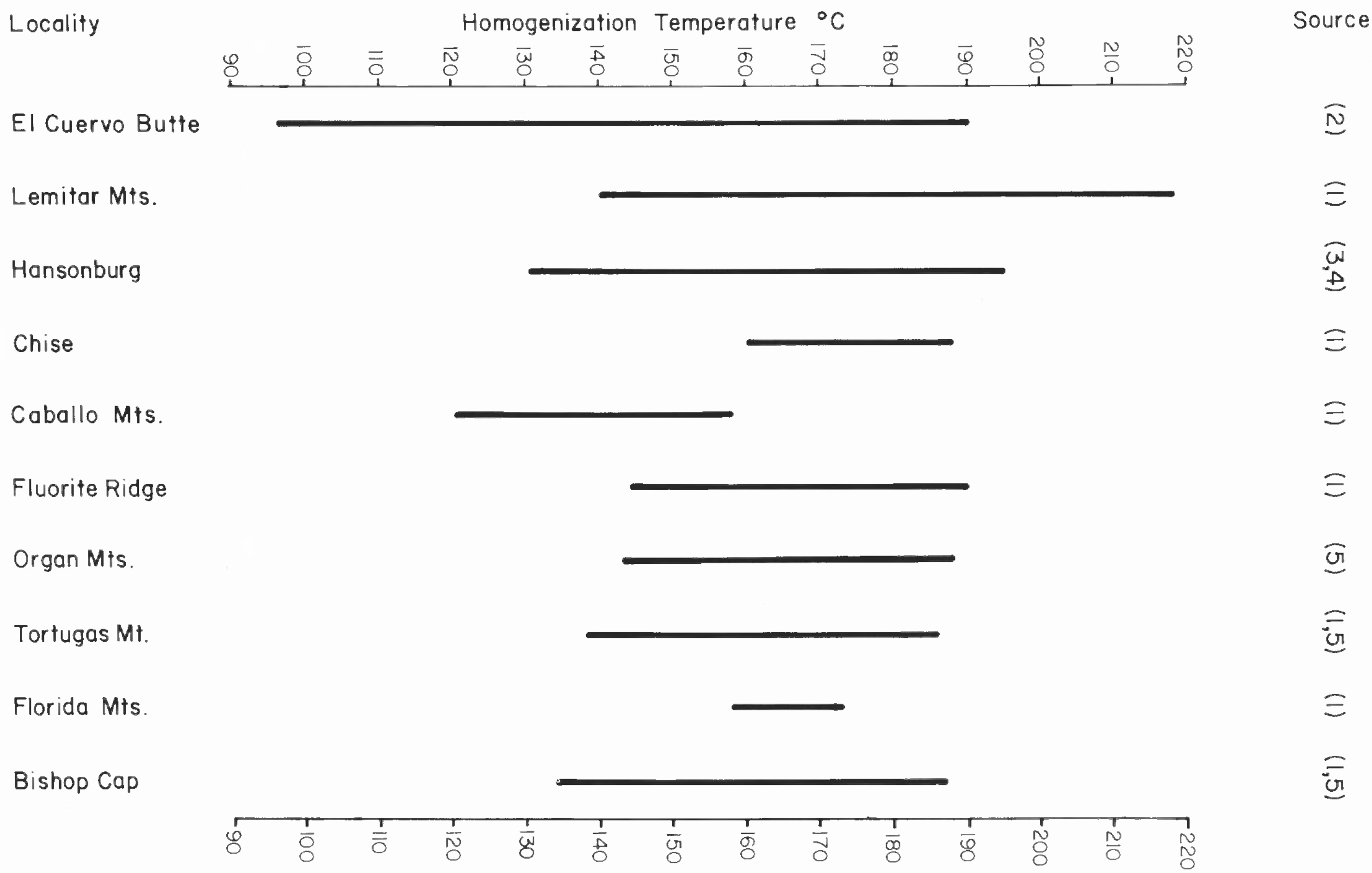

FIGURE 2—Comparison of homogenization temperatures (°C) of fluid inclusions in fluorite from this and other studies. Sources of information: (1) This study; (2) North & McLemore 1985; (3) Putnam et al. 1983; (4) Roedder et al. 1968; (5) Macer 1978.

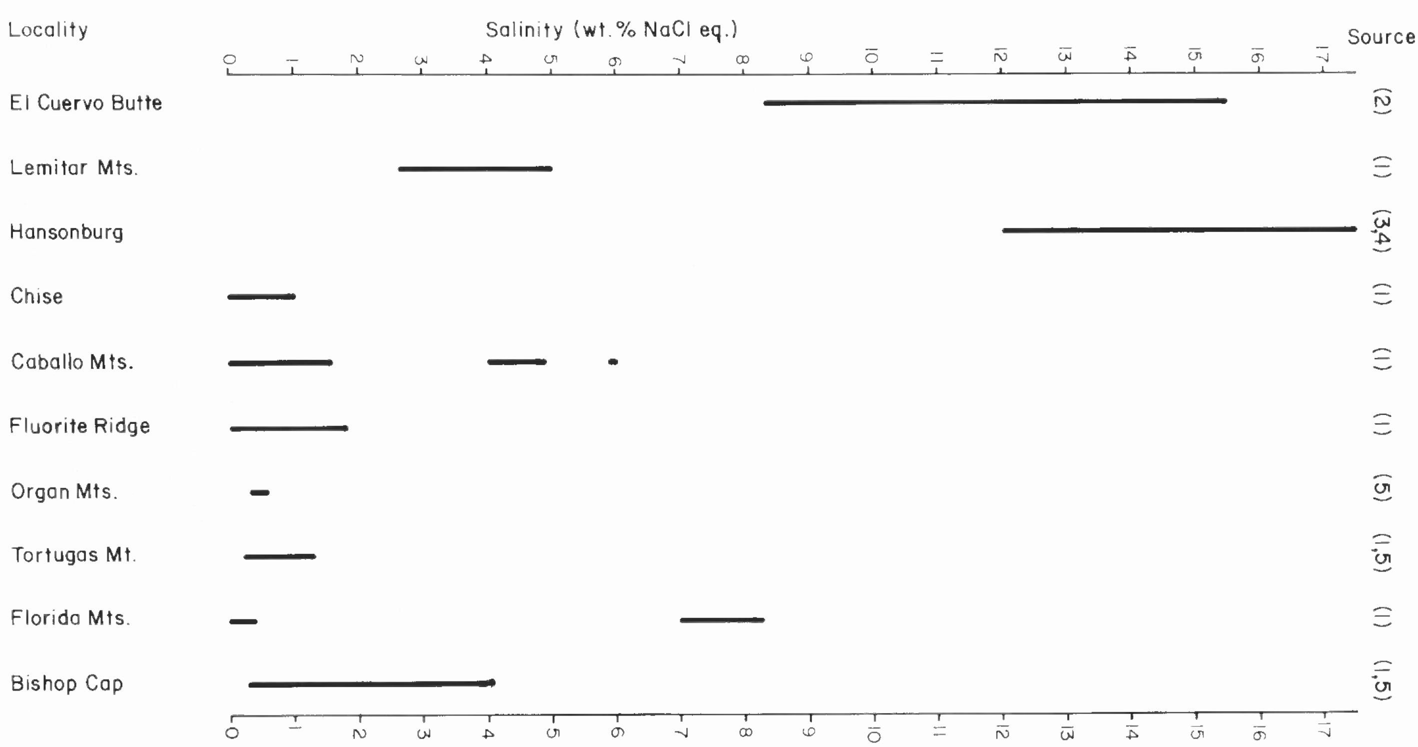

FIGURE 3—Comparison of measured salinities (wt% NaCl equivalent) of fluid inclusions in fluorite from this and other studies. Sources of information: (1) This study; (2) North & McLemore 1985; (3) Putnam et al. 1983; (4) Roedder et al. 1968; (5) Macer 1978.

halides from surrounding Permian sedimentary rocks. North & McLemore (1985) studied the El Cuervo Butte deposit in north-central New Mexico and found it had been formed by high-salinity, low-temperature solutions (see Figs. 2, 3). Price et al. (1985) reported homogenization temperatures of 120–170°C and salinities of 9–19 equivalent wt% NaCl for silver–copper–lead deposits near Van Horn, Texas, and postulated an age of 10–30 my. They concluded that the deposits are not associated with igneous activity, and compared them to the Hansonburg deposits. Macer (1978) studied deposits around the Organ cauldron (Fig. 1) and found them to have formed from low-salinity, low-temperature solutions. McLemore & Barker (1985) presented fairly consistent trace-element data for barites from north-central New Mexico. They proposed a sedimentary–hydrothermal origin for the deposits in that region based on their general lack of spatially associated igneous rocks. A review of deposits classed as sedimentary hydrothermal which contain silver was given by North & McLemore (1986). Lead-isotopic studies were reported by Slawson & Austin (1962) and Ewing (1979). General reviews of fluorite deposits in the state were given by Rothrock et al. (1946), McAnulty (1978), and Williams (1966), and of barite deposits by Williams et al. (1964) and Smith (1982).

GEOLOGIC SETTING

The barite–fluorite deposits considered here are of at least two types, those not obviously associated with igneous activity and those in close association with igneous rocks. The deposits in close association with igneous rocks may have a genetic link to the magmatism. Most districts along the Rio Grande rift are spatially associated with at least minor igneous activity, but a positive genetic link is difficult to prove. Mixtures of the two end members are likely.

Barite–fluorite (galena) mineralization that is not obviously associated with significant magmatism is common along rift as veins in a number of host rocks. Commonly, the host is Paleozoic limestone located near the unconformity with the Precambrian, such as at the Placitas, Hansonburg, Caballo Mountains, and Fra Cristobal Range districts (North & McLemore 1986). Jasperoid formation is common in the limestones. Precambrian igneous rocks host mineralization in some of these areas, such as the Caballo and Florida Mountains districts. Early Paleozoic carbonatite is spatially associated with some deposits in the Lemitar Mountains. Limestone and siltstone of the Permian Yeso Formation and Glorieta Sandstone Member of the San Andres Formation are mineralized at El Cuervo Butte. These deposits are thought to have a sedimentary–hydrothermal origin (North & McLemore 1986).

The igneous-associated occurrences are also mostly veins found in a variety of host rocks. At Chise, the Permian Abo Formation is host to vein and replacement deposits with jasperoid formation (McAnulty 1978). Deposits surrounding the Organ cauldron are mostly in Paleozoic carbonates, including the Permian Hueco Formation at Tortugas Mountain and in the Organ Mountains, and the Silurian Fusselman Formation in the Bishop Cap Hills (Macer 1978). In the Fluorite Ridge district, faults cutting Eocene granodiorite porphyry and Starvation Draw Member of the Rubio Peak Formation are mineralized (Clemons 1982, Griswold 1961). In general, the igneous-associated deposits contain very little barite in comparison to the sedimentary–hydrothermal deposits, and also have almost no galena.

FLUID-INCLUSION ANALYSES

Fluid inclusions in fluorite were examined from seven localities in south-central and southwestern New Mexico (Fig. 1). Data from the studies in New Mexico were compiled and compared to data obtained for the present study (Figs. 2, 3).

Samples obtained for this study were examined for fluorite, and separates made when specimens were found. Doubly polished thick sections were prepared and freezing and heating measurements made to determine the salinity of the included fluids (eq. wt% NaCl) and the homogenization temperature of the inclusion. Data from the literature shown in Figs. 2 and 3 are also from inclusions reported as primary. No pressure corrections were made; uncorrected data from the literature are used in Fig. 2. The microthermometry data obtained are summarized in Figs. 4 and 5.

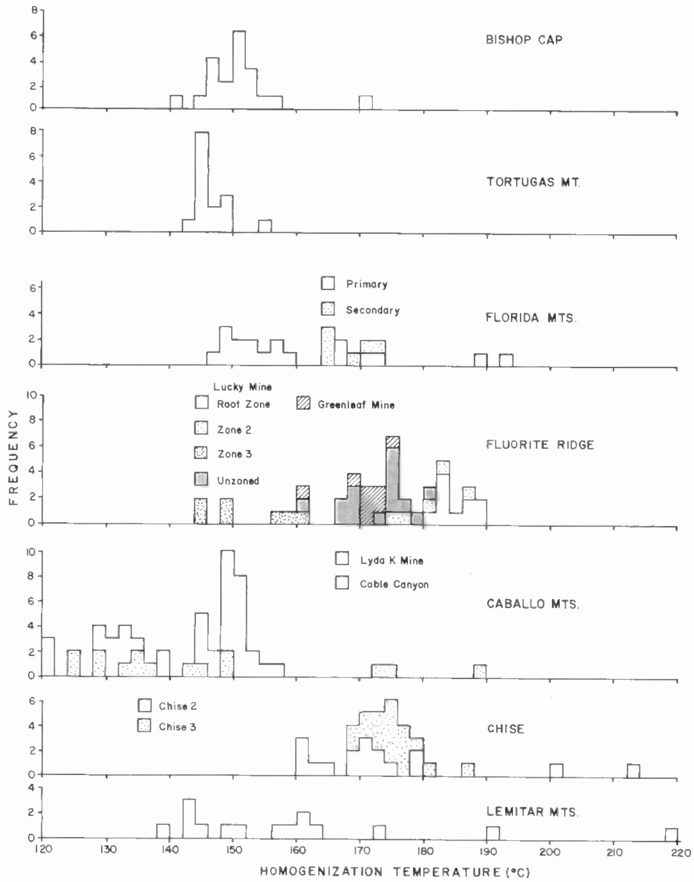

FIGURE 4—Histogram of homogenization temperatures for fluid inclusions in fluorite from the seven localities studied.

Lemitar Mountains district

Samples from the Lemitar Mountains (#2, Fig. 1) were examined because their mineralogy and occurrence are similar to sedimentary–hydrothermal deposits, but are spatially related to early Paleozoic carbonatite dikes (McLemore & North 1985). The samples examined were from a prospect in sec. 30, T1S, R1W. Many of the inclusions examined contained as many as eight isotropic daughter minerals. Some daughter minerals were doubtless halite, however, some anisotropic minerals were also observed. At temperatures in excess of 300°C daughter minerals did not redissolve, which would suggest minerals other than halite. These inclusions also contained vapor, which homogenized between 140 and 218°C (Fig. 4). In inclusions with daughter minerals the last ice melted between −1.8 and −2.3°C. Inclusions without daughter minerals had salinities of 3–4 eq. wt% NaCl (Fig. 5). These fluorites apparently formed from very high-salinity solutions, but do not readily fall into any sedimentary–hydrothermal or igneous-related category. The samples examined may be associated with the carbonatite intrusions and could thus be much different than those formed by processes in the Tertiary.

Chise district

Samples from the Chise district (#4, Fig. 1) were collected and examined as an example of fluorite associated with igneous activity. Igneous activity is common in the area, although the deposits are restricted to silicified limestone (McAnulty 1978). The samples were selected from two prospects in the NW¼ sec. 8, T12S, R7W. Sample 2 was a jasperoid breccia containing fluorite, calcite, and quartz from a fault zone trending N40E. Sample 3 was from a prospect in jasperoid breccia containing purple and green fluorite. The fluid-inclusion data are summarized in Figs. 4 and 5.

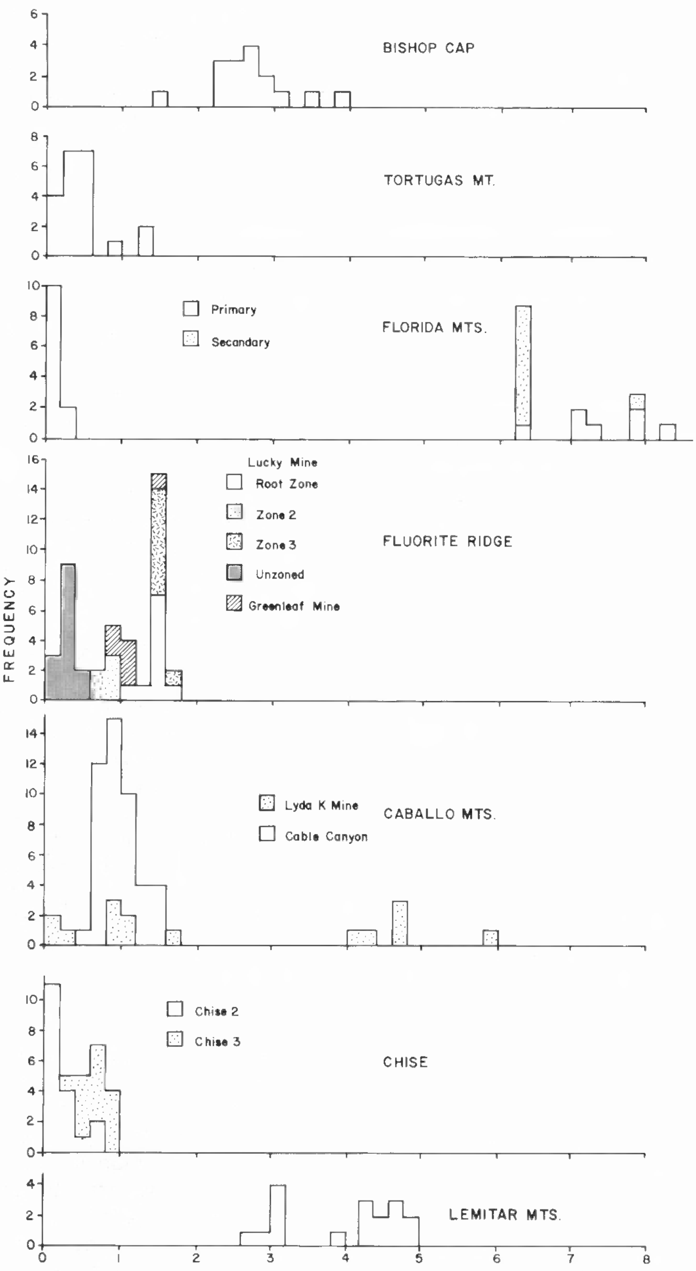

FIGURE 5—Histogram of salinities for fluid inclusions in fluorite from the seven localities studied.

The Chise deposits formed from low-salinity (<1 eq. wt% NaCl) solutions at temperatures typically ranging from 170 to 180°C. These values are consistent with those found by Macer (1978) for deposits near the Organ cauldron. Low salinities are also characteristic of epithermal base- and precious-metal deposits associated with igneous activity (Roedder 1984).

Caballo Mountains

Samples from the Lyda K mine in sec. 29, T16S, R4W and from a prospect in Cable Canyon, T16S, R4W (unsurveyed), are from the southern Caballo Mountains (#5, Fig. 1). The geology of the Lyda K mine is given by McAnulty (1978) and of the Caballo Mountains by Kelley & Silver (1952). The results are summarized in Figs. 4 and 5.

The Lyda K samples showed considerable variation in both salinity and homogenization temperature. Salinities ranged from 0.1 to 5.8 eq. wt% NaCl, homogenization temperatures from 125 to 189°C. The Cable Canyon samples were considerably more consistent, with salinities ranging from 0.4 to 1.5 eq. wt% NaCl (Fig. 8) and 120 to 156°C. The salinities cluster around 1%, homogenization temperatures around 150°C.

Fluorite Ridge

Fluorite samples were collected from the Fluorite Ridge district of Luna County (#7, Fig. 1) as an example of igneous-associated mineralization. Samples from the Lucky and Greenleaf mines in sec. 18, T22S, R8W were examined. Some of the samples from the Lucky mine showed color zoning, and inclusions from each of three zones were examined. The geology of this area is mapped by Clemons (1982) and of individual mines by Griswold (1961). The fluid-inclusion results are summarized in Figs. 4 and 5.

The Fluorite Ridge samples show a somewhat complicated history of formation based on their zoning, but variation in composition of the formation fluids is fairly small. In the zoned crystals from the Lucky mine there is a general cooling from the root zone (180–190°C) through zone 2 (175–185°C) outward to zone 3 (145–160°C). The salinities change from about 1.5 eq. wt% NaCl in the root zone to about 0.8% in zone 2, and rise to 1.5% in zone 3. Unzoned crystals have salinities measured at approximately 0.3% at the Lucky mine and 1.5% at the Greenleaf mine.

The samples from Fluorite Ridge serve to further define the fluid characteristics of igneous-associated deposits. They are slightly more saline than the fluids observed in samples from Chise (1.5% vs <1.0% at Chise), but have approximately the same temperature of homogenization.

Florida Mountains

Fluorite was collected from the Barite of America adit on the east side of the Florida Mountains in the extreme northwest corner of sec. 30, T25S, R7W. A description of this adit and the geology is given by Clemons & Brown (1983). The sample came from a small vein cutting early Paleozoic syenite (Clemons in press) which was intersected in a cross cut. A large Tertiary rhyolite dike is intersected in the adit. The vein is less than 10 cm wide, strikes N70W, and dips 83° north.

Fluid-inclusion data from this vein are summarized in Figs. 4 and 5. Some of the inclusions contain organic material and CO_2. There appear to be two populations of inclusions based on salinities: high (>6 eq. wt% NaCl) and low (<0.3%). Most of the inclusions measured in the high-salinity group were secondary, but some appear to be primary. The low-salinity group is all primary inclusions. Low-salinity inclusions homogenize around 150–175°C. The high-salinity inclusions homogenize between 165 and 175°C. These results are tantalizing, suggesting two distinct fluids, perhaps one sedimentary-hydrothermal and another associated with emplacement of the rhyolite dike. Unfortunately, the fluid-inclusion data are only enough to pose the question and do not answer it; further geochemistry and geology are also needed.

Organ cauldron area

Samples were collected from the SK Standard mine (#9, Fig. 1) at Tortugas Mountain (sec. 24, T23S, R2E) and from the Hiebert mine (#11, Fig. 1) at the Bishop Cap Hills (secs. 25 and 26, T24S, R3E) for comparison to Macer's (1978) data as well as for trace-element analysis. The fluid-inclusion data are summarized in Figs. 4 and 5.

The homogenization temperatures measured from both the SK Standard and Hiebert mines compare favorably to the ranges given by Macer (1978). However, the salinities measured from the Hiebert mine at Bishop Cap are higher (2.5–3.5 eq. wt% NaCl) than those reported for five measurements from the same mine by Macer (0.3–0.6%).

Macer (1978) postulated these fluorite deposits were formed from a hydrothermal system with connate and meteoric water driven by heat supplied by the Rio Grande rift. He further postulated that the meteoric water predominated over connate water, based on low salinity measurements. Our data suggest that the connant component may be larger at Bishop Cap, but are otherwise consistent with his conclusions.

Discussion of fluid-inclusion data

Fluid-inclusion analyses from previous studies indicate that deposits formed from sedimentary–hydrothermal solutions have salinities in excess of 10 eq. wt% NaCl (Putnam et al. 1983, North & McLemore 1985) and igneous associated deposits have salinities of less than 1% (Macer 1978). Homogenization temperatures of both types overlap and cannot, in themselves, be used to distinguish deposit types. The results presented here in part support earlier observations. Deposits that are obviously associated with igneous activity, such as Chise, Fluorite Ridge, and Tortugas Mountain, have low salinities, although at Fluorite Ridge salinities as high as 1.8% were measured (Fig. 5).

Districts that are somewhat problematical include the Lemitar Mountains, Caballo Mountains, Bishop Cap Hills, and Florida Mountains. The origins of these deposits are uncertain.

The Caballo Mountains deposits were suspected to be sedimentary–hydrothermal in origin (North & McLemore 1986), but this may not be the case. The salinity data are lower than known sedimentary–hydrothermal deposits (El Cuervo Butte; Hansonburg). Inclusion salinities from the Cable Canyon prospect are about 1 eq. wt% NaCl, suggesting the deposits are, at least in part, igneous-related. These deposits are in an area that shows absolutely no evidence of igneous activity at the surface, although it is located near the north end of the Goodsight–Cedar Hills volcano-tectonic depression (Seager et al. 1982). High heat flow is evidenced by the warm springs at Truth or Consequences, but this may be associated with rifting.

The Lemitar Mountains deposits are unlike other deposits that have been studied in New Mexico in that many of the fluid inclusions in fluorite have daughter minerals. Those inclusions that are free of daughter minerals have measured salinities from 3 to 5 eq. wt% NaCl. The fluorite was apparently deposited from a moderate- to high-salinity fluid. A thorough study of the daughter crystals and an explanation of their formation is needed to help explain the origin of the deposits.

The fluorites studied from the Caballo Mountains, Florida Mountains, and Bishop Cap Hills present some interesting problems to a simple twofold classification (igneous and sedimentary–hydrothermal). These deposits have salinities that are either bimodal or, in the case of the Bishop Cap Hills, between what would be expected for the two types. This may be evidence for mixing of connate, meteoric, and magmatic waters. Absolute proof of this mixing would be difficult to obtain, but the suggestion is offered to explain the data.

TRACE-ELEMENT ANALYSES

Trace elements were determined by wavelength dispersive x-ray fluorescence (XRF). Mixtures of high-purity reagent chemicals were prepared for use as standards. A 10-point linear-regression calibration curve was used for both barites and fluorites. The determination limit for each component was calculated from the reagent standards using the equation of Jenkins & DeVries (1970). Correction for matrix effects was made by measurement of compton scattered radiation from the rhodium tube. Two background measurements were made for each analytical line.

Barites were analyzed for strontium, iron, manganese, magnesium, silicon, aluminum, calcium, and potassium. An excitation voltage of 30 Kv was selected to avoid exciting the K lines of barium. Because of the selected low voltage, only elements with low atomic numbers (<39) were analyzed. The results are summarized in Tab. 1.

Fluorites were analyzed for molybdenum, yttrium, strontium, zinc, copper, lead, iron, manganese, barium, and silicon. The maximum tube voltage of 60 Kv was selected to more efficiently excite the high-atomic-number elements. The results are summarized in Tab. 2.

Discussion of trace-element data

Trace-element analysis was originally undertaken to determine if there was a trace-element signature for barite–fluorite deposits. It was especially hoped that barite trace elements would show some trend, since several deposits have little fluorite for fluid-inclusion analysis (e.g. Hatch, Potrillo Mountains).

The trace elements measured in barite ranged considerably, even in samples from the same mining district. McLemore & Barker (1985) reported much more consistent trace-element patterns for deposits from northern New Mexico. Part of the reason may be the deposit types they examined, however, the main reason is probably analytical technique; they used mostly atomic absorbtion analysis and a higher excitation voltage (>30 Kv) to determine Y by XRF. Trace-element analysis by wavelength-dispersive XRF appears to be of little use.

In the fluorite trace-element analyses there appears to be a correlation between the type of deposit and the ratio of yttrium to strontium. Samples from the sedimentary hydrothermal deposits at Hansonburg had a Y:Sr ratio of around 3.4:1. The deposits closely associated with igneous activity had a Y:Sr ratio of 1.3:1 or lower (Tab. 2). The Chise district, which is apparently associated with igneous activity, shows a very low Y:Sr ratio of ~0.40. The Lemitar Mountains sample also had a similar ratio, suggesting either an igneous affiliation, or perhaps indicating an association with local Paleozoic carbonatites. The fluorite from the Lyda K mine in the southern Caballo Mountains showed Y:Sr very near that of the Hansonburg district, suggesting, at least in part, a sedimentary–hydrothermal origin.

QUESTIONS

The fluid-inclusion and trace-element data obtained leave many unanswered questions. Examples that are obviously associated with igneous activity have fluid-inclusion salinities of less than 2 eq. wt% NaCl, but how high can we expect salinities to reach in igneous-associated, meteoric-water-dominated systems? Does a salinity of about 3% indicate a connate-water contribution? Will the Y:Sr ratio in fluorite prove useful in determining genesis? Are other trace elements, or perhaps further isotopic studies on lead or other elements needed to define deposit types? Are igneous-associated deposits always fluorite dominated? Probably the most important question is whether there indeed are two end-member types of barite–fluorite deposits, with mixtures between them. If so, is the igneous-associated deposit the "last gasp"

TABLE 1—Trace-element analysis of barites. All values in parts per million. Sample localities: BLNC = Blanchard mine, Hansonburg district; RF = Royal Flush mine, Hansonburg district; BC = Bishop Cap Hills; LEM = Lemitar Mountains; EC = El Cuervo Butte; PP,PPG = Palm Park area; PM = Potrillo Mountains.

Sample Map Loc.	BLNC 3	RF 3	BC2 11	BC3 11	LEM 2	EC-1 1	EC-8 1	PPG 6	PP 6	PM-1 12	Det. Limit
Sr	32450	16322	14756	30576	15965	18690	15308	22055	12923	27840	400
Fe	1440	495	561	666	718	570	561	525	498	945	300
Mn	47	31	28	ND	28	ND	ND	ND	30	ND	20
Mg	1244	ND	80	560	ND	ND	241	50	ND	ND	50
Si	9883	775	2677	824	9625	4995	561	928	45481	39195	300
Al	4040	ND	385	407	140	166	203	228	265	695	50
Ca	2170	ND	16898	59077	20669	129	2681	20	20	38	20
K	612	ND	ND	ND	ND	ND	ND	ND	ND	100	20

ND - Below determination limit.

TABLE 2—Trace-element analysis of fluorites. All values in parts per million. Sample localities: FR = Fluorite Ridge; BC = Bishop Cap Hills; LYDAK = Lyda K mine, Caballo Mountains; TM = Tortugas Mountain; RF = Royal Flush mine, Hansonburg district; CH = Chise district; Fl3 = Florida Mountains; LEM = Lemitar Mountains.

Sample	FR1	FR2	FR3	BC1	BC2	LYDA K	TM1	TM2	TM3	RF	CH2	CH3	F13	LEM	Det. Limit
Map Loc.	7	7	7	11	11	5	9	9	9	3	4	4	7	2	
Mo	33	33	33	34	40	32	33	30	33	32	32	31	30	20	20
Y	118	76	92	64	65	157	120	146	98	134	69	55	172	131	30
Sr	99	70	84	80	102	46	78	116	77	40	164	141	92	331	30
Zn	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND	4	4833	5
Cu	37	39	38	31	36	36	37	28	35	37	34	37	35	78	30
Pb	ND	ND	8	15	26	57	22	5	18	15	5	7	30	149	5
Fe	ND	ND	ND	52	ND	ND	ND	ND	ND	ND	10	15	16	758	10
Mn	ND	4	ND	22	9	ND	ND	ND	ND	ND	2	10	10	24	2
Ba	222	110	105	163	751	68	96	624	177	102	84	408	115	12828	10
Si	ND	1829	2588	997	1423	26491	17354	17354	348	ND	16481	556	40012	40012	50
Y:Sr	1.19	1.09	1.10	0.80	0.64	3.41	1.54	1.26	1.27	3.35	0.42	0.39	1.87	0.40	

ND - Below determination limit.

of a deeper, precious- and base-metal system? The data presented here place some restrictions on the formation of the deposits studied and data are presented to stimulate further thought and research on these types of deposits.

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