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BARITE/CELESTITE/SELENITE/CALCITE MINERALIZATION AT BELL LAKE SINK, LEA COUNTY, NEW MEXICO

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Abstract—Sulfur, carbon, oxygen and strontium isotope values of barite, celestite, selenite and calcite at Bell Lake Sink suggest that Bell Lake Sink may be a structure such as a breccia pipe which connects a brine reservoir at depth with the surface. The ultimate source of barium and strontium for the barite and celestite may be the anhydrites of the Castile and Salado Formations and also oil-field brines in the Bell Canyon Formation. Age of mineralization could be late Quaternary.

INTRODUCTION AND PAST INVESTIGATIONS

Bell Lake Sink is located in sec. 9, T24S, R33E, Lea County, New Mexico. Nicholson and Clebsch (1961, p. 46-47), who first discussed the origin of Bell Lake Sink, thought that it was a "collapse depression" and that the source of gypsum for the selenite dunes in the sink was "ground water seeping upward . . . from the Permian and Triassic formations. . . ." Anderson (1980a, p. 32) reported "large nodules of barite and celestite" occurring in selenite-gypsum dunes around the edge of a Pleistocene playa inside the sink. Anderson believed that Bell Lake Sink had developed due to collapse and that the selenite in the dunes originated from rising sulfate-rich water. Anderson also used Bell Lake Sink as a possible example of deep-seated dissolution and recent upward movement of fluids from a lower evaporite source (i.e., lower Salado and Castile Formations).

Barrows et al. (1983) showed a gravity profile of Bell Lake Sink and concluded that the sink had a complex density structure. Hill (1989a) reported on the celestite-barite-calcite mineralization at Bell Lake Sink to the Environmental Evaluation Group, Albuquerque, New Mexico. This paper is a condensed version of that report.

DESCRIPTION OF MINERALIZATION

Bell Lake Sink is a collapse structure along which "Mescalero caliche" and "Old Mescalero soil" has downdropped along sink-margin faults (Anderson, 1980b, p. 113, 115). The fault relationships suggest that the sink is younger than the "Old Mescalero sand" (less than about 100,000 years). Bell Lake playa, which is confined within the downfaulted center of the sink, is dry except in times of heavy rainfall. The playa is flanked by caliche and "old red soil," which contains quartzite, chert, basalt and caliche clasts possibly derived from the Ogallala Formation. No barite-celestite-selenite-calcite mineralization was found around the margins of Bell Lake playa.

Two smaller playas exist inside the larger playa and are directly surrounded by selenite-clay dunes approximately 5-10 m high. The southern small playa contains water (filled by ranchers for stock?), but the northern small playa is dry. Barite-celestite nodules occur around the dry northern playa at the contact between a red and yellow oxidized zone, located about 2 m above a former water level (small pond) in the playa. Selenite mineralization that composes the surrounding dunes occurs above the zone of barite-celestite mineralization in the playa. This sequence suggests a solubility-transport relationship between the three sulfate minerals, with the more insoluble barite and celestite being deposited nearer to the small pond by upward-moving capillary water, and the more soluble and abundant selenite being transported farther from the pond to a higher level.

The selenite at Bell Lake Sink is transparent to translucent, with crystals up to 10 cm long. Selenite roses about 5 cm in diameter are also interspersed within the clay of the dunes. The barite occurs as heavy nodules about 10 cm in diameter. The white, translucent, tabular barite of the nodules surrounds an intergrown core of clear, vitreous, transparent, euhedral celestite, most of which is colorless but some of which is slightly bluish on crystal tips. No calcite was found intergrown with the barite-celestite of these nodules. Celestite also occurs in other nodules as slightly bluish crystals imbedded in a fine-grained matrix of calcite. Celestite crystals extend into the centers of these nodules in a geode-like fashion.

ISOTOPE ANALYSES

Sulfur isotope analyses were performed on the selenite, celestite and barite mineralization of Bell Lake Sink and carbon-oxygen analyses were performed on the calcite matrix containing the slightly bluish celestite crystals. $^{87}Sr/^{86}Sr$ analyses were performed on the celestite of the barite-celestite nodules. The results of the isotopic analyses are listed in Table I.

DISCUSSION OF RESULTS

Sulfur isotopes and the source of sulfate

The sulfur isotope analyses of the selenite, celestite and barite of Bell Lake Sink support Nicholson and Clebsch's (1961) and Anderson's (1980a) claims that these minerals derived from sulfate-rich water rising

TABLE I. Isotopic analyses of selenite, celestite, barite and calcite, Bell Lake Sink.

Description	$\delta^{34}S$	$\delta^{13}C$ PDB	$\delta^{18}O$ SMOW	$^{87}Sr/^{86}Sr$
Bell Lake Sink				
Selenite, gypsum-clay dunes	+9.8			
Celestite, barite-celestite nodules	+9.2			0.708649 ±0.000005
Barite, surrounding celestite, in nodules	+10.2			
Calcite, in matrix enclosing celestite crystals of nodule		-5.4	+37.5	
Reservoir Brines				
Calcite, ERDA-6 (avg. of 5 samples); Popielak et al. (1983)		+6.4	+33.8	
Calcite, WIPP-12 (avg. of 5 samples); Popielak et al. (1983)		+6.7	+32.4	
Dolomite, WIPP-12 (avg. of 2 samples); Popielak et al. (1983)		+1.7	+36.9	
Sulfur Deposits				
Celestite, Culberson Mine, with sulfur; Hill (1989b)				0.707808 ±0.000005
Celesite, Leonard Minerals, with sulfur; Hill (1989b)				0.708138 ±0.000005
Bioepigenetic limestone, ass. with celestite and sulfur, Culberson Mine				0.707699 ±0.000005

from Permian evaporites at depth. The sulfur isotope values of these minerals are very close to that of anhydrite in the Castile and Salado Formations (Fig. **l).** In addition, the isotopic values of the celestite, barite and selenite also overlap with the SO_4-reservoir brines of ERDA6 and nearly overlap with those at WIPP-12, suggesting a possible subsurface reservoir-brine source for the Bell Lake Sink mineralization. Both the Bell Lake Sink sulfates and the ERDA-6 and WIPP- 12 reservoir brines are lighter than Castile anhydrite by about $3^0/_{00}$ (per mil, CDT) (Fig. 1). Popielak et al. (1983, p. C-21) interpreted the fractionation between reservoir brines and co-existing anhydrite to mean that "the brines are very old and may well be Permian in age." Another possible interpretation is that the slightly lighter values may be due to brine having mixed with meteoric water depleted in $8^{84}5$. Sarg (1981) thought this to be the case for recrystallized sulfate mineralization in the Seven Rivers evaporites of the Rocky Arroyo, Carlsbad area (Fig. 1). Yushkin (1969) also found this to be the case for recrystallized gypsum in the Shor-Su, Soviet Union sulfur deposits. Oil-field brines are descendants of modern meteoric precipitation (Clayton et al., 1966), so if oil-field brines of the Bell Canyon Formation were an ultimate source of sulfate for brine reservoir— and Bell Lake Sink—sulfates, this could explain the slightly depleted isotopic signatures of these deposits.

Carbon-oxygen isotopes and the source of calcite

The carbon-oxygen isotope values for calcite in the celestite-calcite nodules at Bell Lake Sink do not plot anywhere near the other calcite-spar types in the Delaware Basin (Fig. 2). The carbon isotope value is typical of meteoric-water spar, but the oxygen isotope value of the Bell Lake Sink calcite ($\delta^{18}O$ = +37.5 SMOW; +6.9 PDB) is not typical of any of the other calcite types. The only close match of this oxygen isotope value is to ERDA-6 and WIPP- 12 reservoir-brine calcite and WIPP-12 dolomite (Fig. 1). Again, these isotopic data suggest a possibly subsurface reservoir-brine source for the Bell Lake Sink mineralization.

Strontium isotopes and the source of strontium

The $^{87}Sr/^{86}Sr$ isotopic ratios of the celestite mineralization at Bell Lake Sink do not conclusively identify the source of strontium. The measured value of 0.708649 most closely matches surface caliche (Fig. 3) and it is possible that the strontium is derived from this source. However, if the strontium did concentrate from surface caliche (soil carbonates), then celestite crystallized with barite and selenite only at Bell Lake Sink and nowhere else in the caliche deposits of the region.

Another possible source of strontium for the celestite at Bell Lake Sink is the Bell Canyon Formation in the subsurface. The Bell Canyon has measured strontium values of 921 ppm and 1165 ppm (2 samples, this study) and oil-field brines in the Bell Canyon Formation have measured strontium values of 1750 ppm (Lambert, 1978). Celestite is known to exist within native sulfur deposits in the basin (e.g., at the Culberson, Pokorny and Leonard Minerals strikes), which can occur in breccia-pipe features that often root in the Bell Canyon (e.g., Crawford, 1990, fig. 4). The Bell Lake Sink celestite plots within the known isotopic range of strontium in the Bell Canyon Formation (Fig. 3). It also plots relatively close to the celestite in the Culberson and Leonard Mineral sulfur occurrences. This also suggests a connection between the mineralization at Bell Lake Sink and the deep subsurface, as hypothesized by Nicholson and Clebsch (1961) and Anderson (1980a).

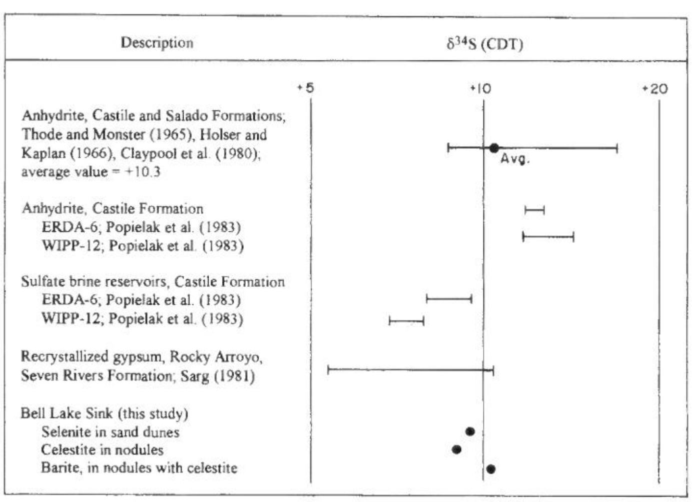

FIGURE 1. Sulfur isotope values of Bell Lake Sink selenite, celestite and barite compared with other sulfate values in the Delaware Basin.

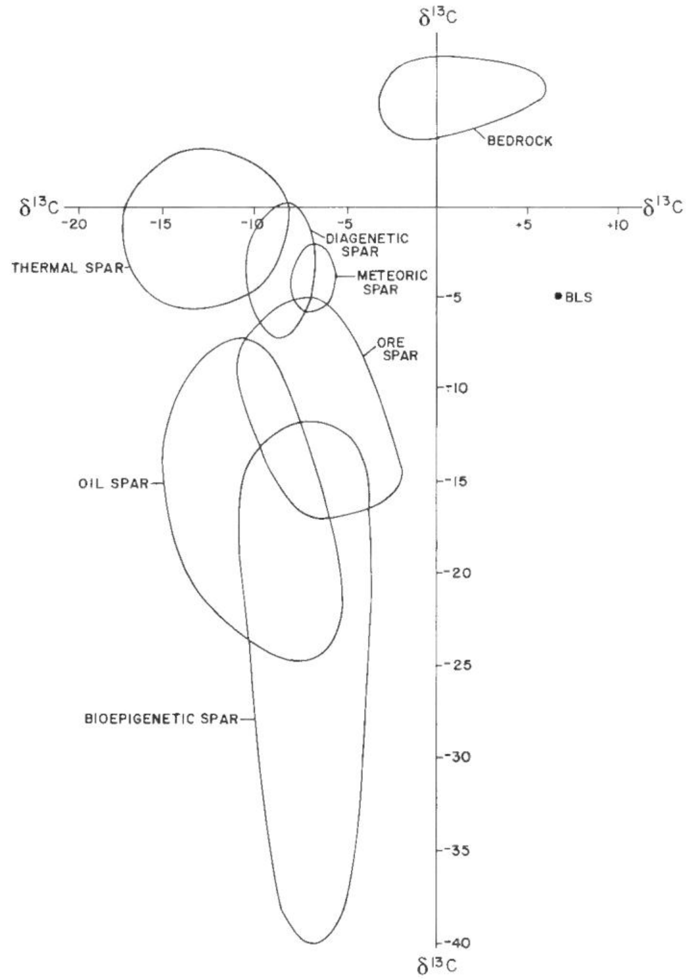

FIGURE 2. Carbon-oxygen isotope values of the different calcite types, Delaware Basin. Note that the Bell Lake Sink calcite (BLS) plots nowhere near the other values.

Source of barium

The source of barium for the barite at Bell Lake Sink may also be related to oil-field brines in the Bell Canyon Formation. Barium in higher stratigraphic units at Bell Lake Sink is very low (0.01-0.05 pm for the Rustler and Dewey Lake; Uhland et al., 1987). However, solids in subsurface reservoir brines (ERDA-6 and WIPP-12) in lower stratigraphic units (Castile Formation) contain >50% $BaS0_4$ (D'Appolonia, 1982) and barium in oil-field brines of the Bell Canyon Formation is known to be relatively high (e.g., 15.5 ppm in Bell Canyon State 0A#1, P. Goodell, personal comm. 1989). Yushkin (1969, p. 28) plotted the geochemical scheme for barite and celestite in the formation of native sulfur deposits in the Soviet Union and found that the ultimate source of the barium and strontium for these deposits came from sulfate rock and "Na-CI brines" (oil-field brines). Likewise, in the Delaware Basin, the barium (and strontium) for the barite (and celestite) probably came from the anhydrites of the Castile and lower Salado Formations

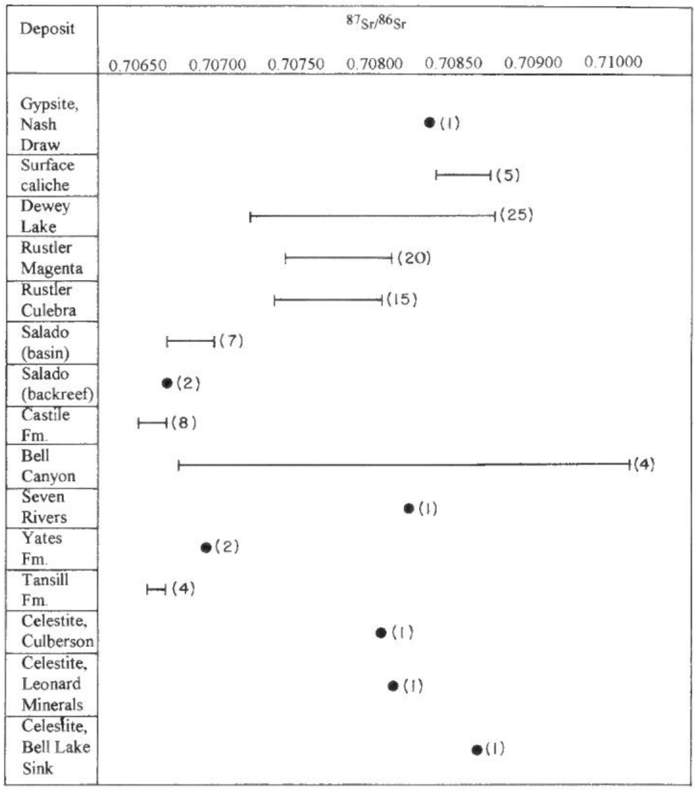

FIGURE 3. Strontium isotope ratios of different bedrock units and deposits in the Delaware Basin. Data for gypsite, caliche, Dewey Lake and Rustler (Magenta and Culebra) from Brookins and Lambert (1988); data for Salado (basin) and Castile from Brookins and Lambert (1988) and Holser and Magaritz (1987); data for the Salado (backreef) from Garber et al. (1989); data for the Bell Canyon from Holser and Magaritz (1987) and Lappin (1988); data for the Seven Rivers from Holser and Magaritz (1987); and data for Yates and Tansill from Garber et al. (1989). Numbers in parentheses indicate number of samples.

and also from the oil-field brines of the Bell Canyon Formation. This Bell Canyon—Castile source of barium also explains the occurrence of massive barite deposits at Seven Heart Gap, in the Apache Mountains section of the Delaware Basin, which occur at the contact of the Bell Canyon and Castile Formations.

AGE OF MINERALIZATION

The age of the barite/celestite/selenite/calcite mineralization at Bell Lake Sink is uncertain, but is most likely at least late Quaternary. Anderson (1980b) put the time of collapse of Bell Lake Sink at <0.1 Ma, and the mineralization seems definitely younger than the collapse. Also, Pleistocene climates have been dry enough only within the past 15,000 years or so (since the end of the Wisconsinan glacial) to account for the accumulation (rather than dissolution) of the selenite dunes at Bell Lake Sink. Finally, the correlation of the barite-celestite with an oxidized zone around a recent water level (pond) in the small, northern playa also suggests a young age for the mineralization.

In support of an older age is a consideration of the hydrology at Bell Lake Sink. Nicholson and Clebsch (1961) rightly pointed out that static water levels in wells of the area are not nearly high enough at present to permit the upward movement of water into Bell Lake Sink. Recent measurements of the hydraulic head at the Waste Isolation Pilot Plant (WIPP) site (located <20 km northwest of Bell Lake Sink) have shown that the hydraulic pressure of water (in the Bell Canyon aquifer) is about 915 m above sea level (Popielak et al., 1983); thus, water from this source should not reach the ground surface at the WIPP site or at Bell Lake Sink (at —1085 m elevation). It should be pointed out, however, that both the ERDA-6 and WIPP-12 reservoir brines were under pressure when drilled and that these hydraulic pressures reached >1670 m, much higher than the elevation of Bell Lake Sink. Therefore, if a subsurface brine reservoir in the Castile Formation had been breached by the Bell Lake Sink structure, these brines could have risen to the surface of Bell Lake Sink at any time up to the present.

CONCLUSIONS

Sulfur, carbon, oxygen and strontium isotope values of barite, celestite, selenite and calcite at Bell Lake Sink support Anderson's (1980a, 1981) model of deep-seated dissolution in the Delaware Basin. Sulfur isotopes of the Bell Lake Sink barite, celestite and selenite plot near the brine reservoirs of ERDA-6 and WIPP-12 (Fig. 1). Oxygen isotopes of the Bell Lake Sink calcite (intergrown with celestite) also plot near the calcite and dolomite of the ERDA-6 and WIPP-12 brine reservoirs (Fig. 1). Strontium ratios are within the range of values for the Bell Canyon Formation and near the values of celestites that occur with native sulfur deposits in the basin (Fig. 3). The data support a model of reservoir brines being connected to an oil-field brine source in the Bell Canyon Formation and of these reservoir brines rising to the surface along the Bell Lake Sink structure (a breccia pipe?).

ACKNOWLEDGMENTS

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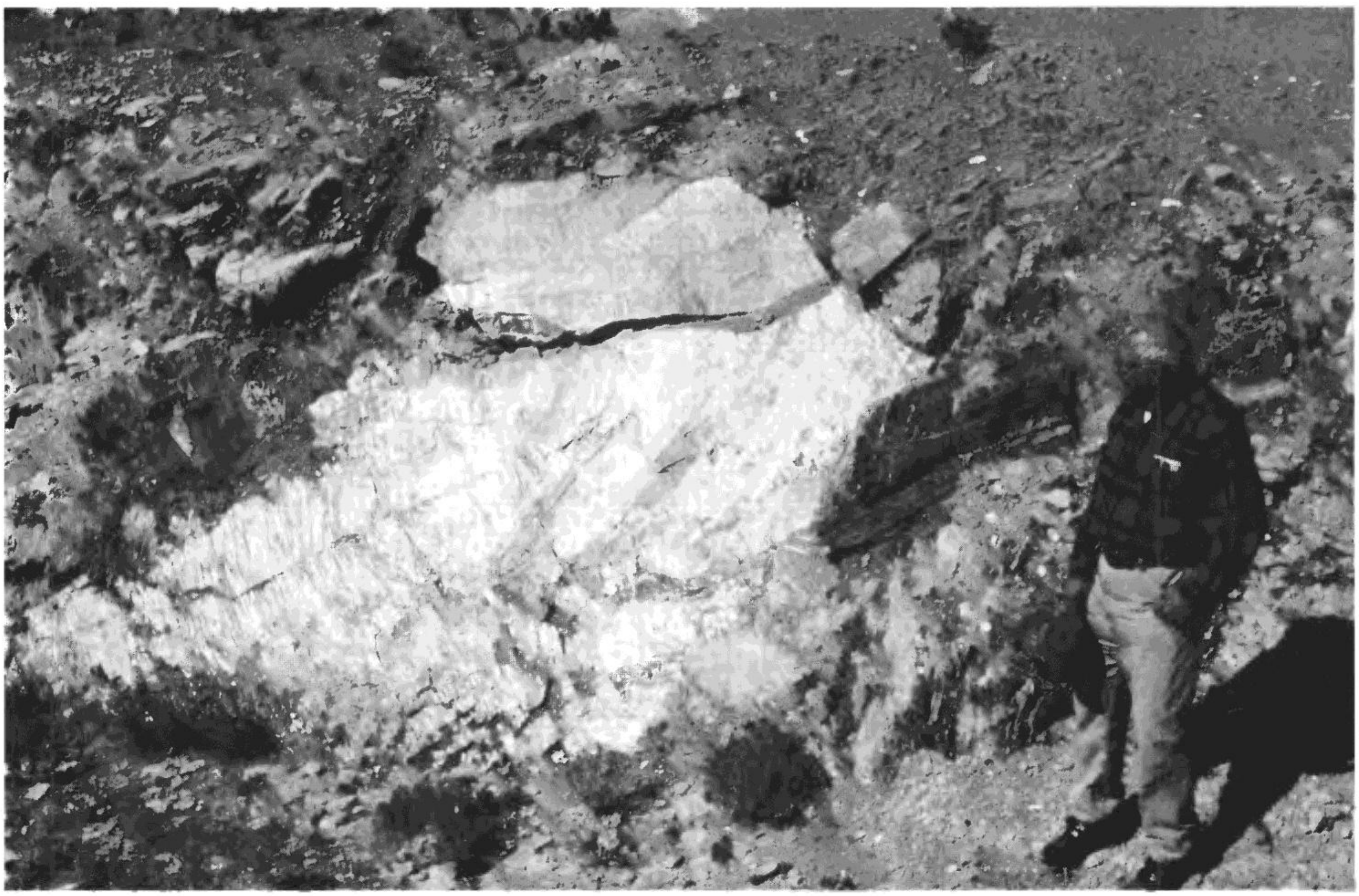

Complexly interlocking mass of large selenite crystals at Yeso Hills quarry (Day 1, Stop 1B).