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Hot Springs Mercury Deposition at McDermitt Mine, Humboldt County, Nevada

by Michael W. Roper

McDermitt mine is located southwest of McDermitt, Nev., ½ mile north of the old Cordero mine. Geologic structure of the district is that of a Miocene age collapse-type caldera in a region of Basin and Range normal faulting. The McDermitt ore body possess a tabular, gently dipping configuration within 150 ft of the surface over an area 2200 × 2500 ft. Indicated ore reserves are 3 million tons at 10 lb Hg per ton. The ore zone averages 20 ft in thickness and consists of cinnabar (HgS) and corderoite ($Hg_3S_2Cl_2$) deposited parallel to bedding in argillized Miocene age tuffaceous lacustrine sediments. The ore body is localized above a silicious sinter-silicified lake-bed breccia. This "opalite" breccia unit possesses a gently dipping, apronlike configuration, striking northeast, parallel the trend of the Cordero deposit, and thinning to the north and northwest.

McDermitt mine is located in northern Humboldt County, Nev., approximately 5 miles south of the Oregon-Nevada line (Fig. 1), within the Opalite Mining District. The operation is a joint venture between Placer Amex Inc., San Francisco, and Mineral Exploration Co. Ltd., a limited partnership.

The McDermitt ore body possesses a discontinuous, gently dipping blanketlike form within 150 ft of the surface over an area 2200 × 2500 ft. The ore zone averages 20 ft in thickness. The ore minerals consist of cinnabar (HgS) and corderoite ($Hg_3S_2Cl_2$) deposited parallel to bedding within argillized, Miocene age, tuffaceous lacustrine sediments. Exploration indicates reserves of approximately 3 million tons ore at a grade of 10 lb Hg per ton (0.5%).

An open pit mining operation utilizing scrapers and bulldozers supplies a concentrator with 700 tpd of ore. The milling operation consists of autogenous grinding, flotation concentration, concentrate dewatering, and tailing disposal, with a design capacity of 100 tph. The furnace section consists of a concentrate filter, vertical six-hearth furnace, mercury condensing system, and exhaust gas scrubbing systems. It has a design capacity of 1000 lb of dry concentrate per hr.

The McDermitt ore body is situated about 2000 ft north of the Cordero mine which, with adjacent properties, produced over 115,000 flasks (76 lb per flask) mercury from 1941 to 1970.[1] Two other major mercury producers in the district have been the Bretz and Opalite mines, located in southern Malheur County, Ore., within 5 miles of the Oregon-Nevada line. Bretz and Opalite have produced about 14,800 and 12,370 flasks mercury, respectively, from 1926 to 1965.[1]

Regional Geology

The geologic structure of the district is that of a collapse-type caldera in a region of Basin and Range normal faulting. The caldera is approximately 22 miles east-west by 20 miles north-south (Fig. 2). Erosion and structural adjustments have locally modified and obscured the caldera structure. Streams drain the caldera by flowing over the down-dropped and gravel-covered east rim. The south rim has also been somewhat modified and no longer retains a caldera-wall appearance. The north and west rims, however, appear only slightly eroded and exhibit an arcuate 30-mile fault scarp 1000 to 2000 ft high.

The regional volcanic sequence further suggests the evolution of a major volcanic center. Miocene age volcanism (18 to 16 million yr (m.y.)) progressing from andesitic to rhyolitic and terminating with large volumes of tuffs and pyroclastics coincident with caldera collapse has accumulated a volcanic pile in excess of 7000 ft thick.[1] The age of caldera collapse has been estimated to be 16 m.y.[1]

Geology and mercury mineralization within the district have been described by Schuette,[2] Yates,[3] Bailey and Phoenix,[4] Curry,[5] Greene,[6] Foord, et al.,[7] and Speer.[1] The dominant control for mercury mineralization within the district appears to be the caldera-rim fault system and intracaldera faults. The Opalite, Bretz, Cordero, and McDermitt ore bodies are located along these fault systems, associated with silicious rock units. The caldera structure and its relationship to the mercury deposits has been described by Albers and Kleinhampl.[8]

Geology of McDermitt Mine

Stratigraphy: The stratigraphy of the mineralized area consists of 10 to 40 ft postmineralization Quaternary gravel over-

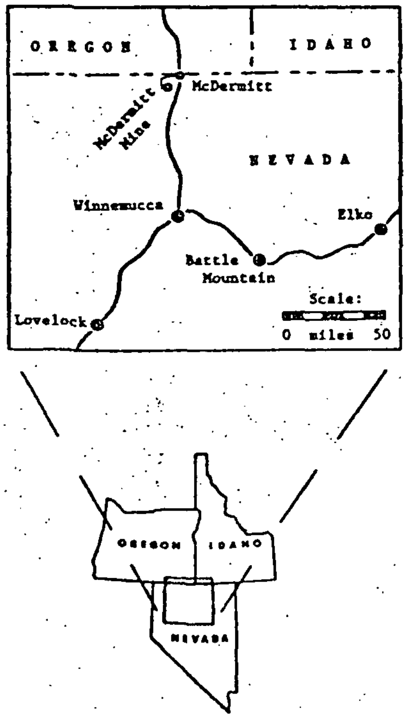

Fig. 1—Index map showing location of McDermitt mine.

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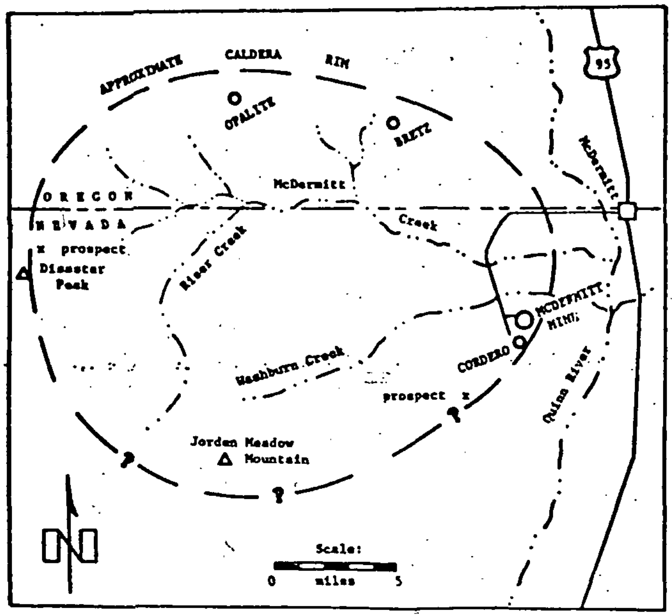

Fig. 2—Topographic map indicating approximate caldera perimeter and mercury deposits within the Opalite Mining District.

lying up to 200 ft of lacustrine sediments. The gravel consists of a variety of andesitic to rhyolitic volcanic boulders, cobbles, and finer materials derived from adjacent highlands.

The lake beds are Miocene in age[6,9,10] and composed of poorly consolidated, locally argillized tuffaceous material interstratified with bedded layers and discontinuous lenses of chalcedony. The lake beds are generally well bedded, varying from finely laminated clay, to more massively bedded silicious tuff, to less common, irregular layers of volcanic agglomerate, cobbles, and pebbles. The dominant clay mineral is montmorillonite,[11] apparently formed by diagenetic argillization of volcanic ash. Tuffaceous material within the lake beds includes glass shards in various stages of devitrification, poorly consolidated lapilli tuff, cinders, and silicious ash.

Mercury sulfide ore occurs dominantly within the lake beds localized above an apronlike body of opalite breccia. The field term "opalite" breccia is here used to describe a silicious sinter-silicified lake-bed breccia apparently formed by hot spring silicification and associated brecciation of lake-bed sediments. The opalite breccia unit appears to conformably overlie premineralization rhyolitic welded tuff and pyroclastics forming the caldera floor. The rhyolite welded tuff beneath the opalite breccia is underlain by dacite and andesite flows.

The opalite breccia unit has a knobby, rolling, upper surface and is up to 150 ft thick. It strikes northeast and dips gently to the northwest. The unit extends over an irregular rectangular area roughly 5000 ft northeast-southwest by 2000 ft northwest-southeast, outcropping along a northeasterly projection of the Cordero trend.

The opalite breccia is here interpreted as a stratigraphic unit of limited extent representing a period of silicious hot spring activity contemporaneous with tuffaceous lake-bed accumulation. The unit is coarsely vuggy, commonly containing interconnected solution channelways, and locally including fragments of botryoidal silicious sinter similar to that found encrusted about silicious hot springs, geysers, and fumeroles. The upper portion of the unit consists dominantly of a bedded, silicified tuffaceous matrix with up to 75%, ¼ to 1 in., sharply angular chalcedonylike fragments. The lower portion of the unit is composed of a porous, altered, silicious, tuffaceous matrix with breccia fragments varying from angular chalcedonylike clasts to more common rhyolitic, pyroclastic-welded tuff rock fragments.

Mineralization

Mercury minerals within the McDermitt ore body include cinnabar (75%) and corderoite (25%), with traces of metacinnabar and mercury oxychlorides, and rare native mercury. Ore minerals occur within the argillized tuffaceous lake beds and less commonly in the opalite breccia. The variety of textures and relationships with which cinnabar and corderoite are found suggest intermittent, alternate hot spring deposition of mercury sulfides and silica contemporaneous with tuffaceous lacustrine sedimentation, with subsequent alteration and local remobilization of mercury minerals.

Corderoite, a recently discovered photosensitive mercury mineral identified and described by Foord, et al.,[7] is ubiquitous to the lake-bed ore body, occurring in varying proportion with cinnabar. Fresh corderoite is light orange-pink in color, but rapidly turns charcoal gray upon exposure to light. Corderoite is most commonly found in the upper portion of the ore body, decreasing in quantity with depth. Corderoite occurs as fine grained replacement masses (apparently after cinnabar) and as alteration rims and coatings on cinnabar.[7] Almost without exception, cinnabar samples from the McDermitt ore body darken upon exposure to light, indicating the presence of a fine admixture of corderoite with cinnabar.

Cinnabar occurrences within the ore body as related to the postulated environment of deposition include:

1) Hot spring orifice-vent deposits within the opalite breccia consisting of very fine grained, dull-red, submetallic cinnabar as pseudo-breccia fracture fillings; thin vug-channelway coatings of bright-red cinnabar; and local interstitial cinnabar forming the matrix of the breccia.

2) Near-vent silicious occurrences such as fine grained, dull-red cinnabar interbedded with fine grained silicious tuffs, locally intricately convoluted.

3) Near-vent colloform textures such as very fine grained, dull-red cinnabar occurring in up to ½-in. thick layers of closely packed stalagmitelike growths interbedded with clay; and concretionlike forms up to 2 in. in diameter composed of concentric, radiating growths of dull-red cinnabar with minor clay impurities.

4) Various, apparently syngenetic, sedimentary occurrences such as 2- to 6-in. thick, cross-bedded, medium-grained silica sand layers containing several 1/16- to 1-in. thick, granular, locally crosscut cinnabar "sand" layers; very fine grained laminae of cinnabar deposited parallel bedding in lake-bed clay; and fine to medium sized cinnabar and corderoite grains discontinuously lineated parallel to bedding within lake-bed clays.

5) Coating, filling, or replacement of possible biogenic features varying from alternating cinnabar-silica layers lining 1/16 to 1/4 in. diam tubules resembling plant root molds, to cinnabar filling (or replacement) of gastropodlike forms and convoluted, worm burrowlike features within argillized tuff.

6) Epigenetic mercury sulfide mineralization or remobilization features such as fracture filling cinnabar in the opalite breccia unit, and slickensidefault coatings within argillized lake beds.

Observed mineral occurrences and their relationship to the genesis of the ore body are in some cases ambiguous and subject to multiple interpretation; however, the overall geometry of the ore body, appearing as multiple, coalescing blanketlike areas of mineralization (Fig. 3) suggest that a hot spring origin is the most reasonable interpretation of the evidence gathered thus far.

Corderoite has been interpreted as a secondary, supergene mineral produced by in-situ alteration of cinnabar by an acidic, chlorine-rich ground-water mechanism. This interpretation is supported in general by field relations in which the greatest concentration of corderoite occurs in the upper portion of the lake-bed ore body as coatings on cinnabar and local complete replacement masses. However, in some cases cinnabar concretions exhibit, in successive

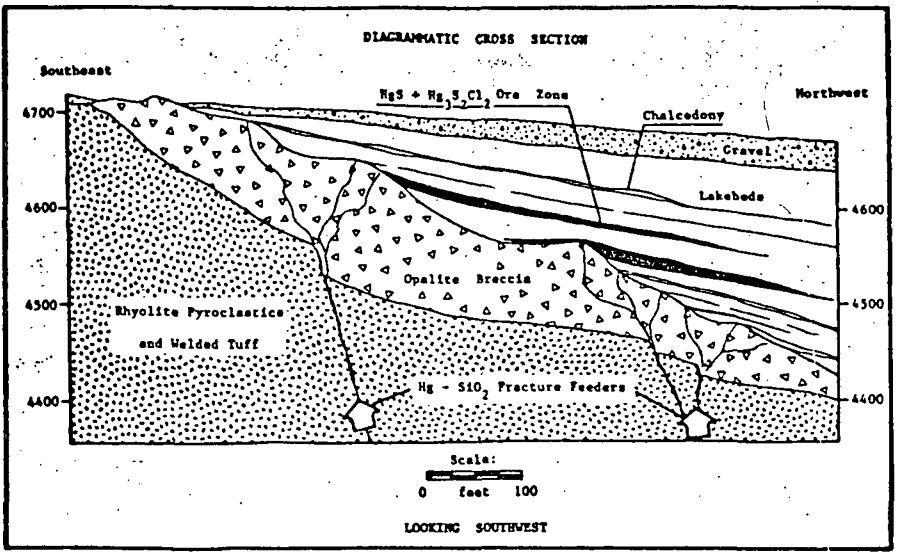

Fig. 3—Diagrammatic cross section through the McDermitt ore body showing configuration of ore zones and their relationship to lithologic units.

layers, a transition from dull-red, photosensitive cinnabar to bright-red, nonphotosensitive cinnabar, suggesting that changes in the chemistry of primary mineralizing solutions locally may have produced the variations in the cinnabar-corderoite ratio rather than secondary alteration.

A rarely observed, yellow photosensitive mineral with the composition $Hg_2(N, VO_4)(Cl, Br, VO_3, SO_4) \times H_2O$, tentatively named "McDermittite," has also been identified by Foord[11] within the lake-bed ore body. Occurrence of this mineral, as minute pseudo-hexagonal crystals lining vugs and fractures, and additional research by Foord suggest precipitation from a vapor phase.

Native mercury is observed very rarely in the opalite breccia unit as small, irregular blebs and globules lining vugs and solution channelways. Native mercury has not been observed within the lake beds on even a microscopic scale, however, there is a possibility of small quantities of native mercury occurring in lake-bed ore.

Accessory minerals identified within the lakebeds and opalite breccia include: montmorillonite, silica minerals, oxides of iron and manganese, calcite, gypsum, alunite, apatite, stibnite, and tripuhyite. Foord[11] has identified alpha quartz, alpha tridymite, alpha cristobalite, and amorphous silica polymorphs. The opalite breccia and the chalcedony layers and lenses are composed dominantly of alpha quartz, with minor alpha tridymite. Alpha cristobalite occurs as white, porous, powdery masses within the lake beds, as an external rind or coating on chalcedony (alpha quartz), and as irregular, porous, altered zones along vugs and channelways within the opalite breccia. Amorphous silica (opal) commonly occurs as clear, glassy, botryoidal fracture coatings and vug fillings, often coating cinnabar. Amorphous silica coatings are apparently due to late-stage supersaturated solutions precipitating silica very rapidly.

The alteration minerals present and their environments of deposition provide clues to the mineralizing processes affecting the McDermitt ore body. The association of mercury sulfides with silica minerals is consistent with their presumed environments of deposition though not necessarily with their mechanisms of transport.

Transfer of mercury is thought to take place in basic to neutral aqueous solutions with modest to high concentrations of sulfide, most probably as the sulfide complex HgS_2^{2-}, or in a vapor phase as elemental mercury, with deposition of mercury ore occurring within a temperature range of 80°C to 250°C.[12] Colloidal transport and supersaturation have also been recognized as possible transport mechanisms.[13,14]

Deposition of cinnabar appears to take place when the pH of solutions is near neutrality and confining pressure is low.[12] An environment of relatively low temperature and pressure, and alkaline to neutral aqueous solutions also favors the deposition of silica.[11] Research[7] has demonstrated that corderoite can be formed by the alteration of cinnabar under low temperature and pressure in acidic, chlorine-rich aqueous solutions.

Work by various researchers, summarized by White,[15] indicates a common association of mercury mineralization with hot spring phenomena and silica alteration minerals. White[15] further states that probably greater than 10% of all mercury deposits are associated with thermal, mineral, or gas enriched waters with abnormally high subsurface temperatures, and includes analyses of thermal waters from the Cordero-McDermitt mine area.

Recent analyses[16] of subsurface waters associated with the Cordero mine indicate temperatures up to 59°C, and a chemical composition typical of hot spring waters in other parts of the western U.S., and indeed hot springs do occur in the vicinity.

Summary

The McDermitt ore body appears to have been formed by alternate, intermittent, discontinuous deposition of cinnabar and silica from multiple vent sources within a hot springs field which developed contemporaneously with Miocene lake-bed deposition. Corderoite appears to have been formed dominantly as a supergene alteration product of cinnabar by an acidic, chlorine-rich, ground-water mechanism.

The sequence of mineralization would begin with the development of a silicious hot springs field within the southeastern margin of the caldera. The hot springs field was situated along the caldera lakeshore, perhaps localized above a deep-seated fracture zone cross-cutting the caldera rim fault zone. The field's horizontal extent is probably closely approximated by the present dimensions of the opalite breccia, roughly 2000 ft northwest by 5000 ft northeast, elongate along a northeasterly projection of the Cordero-caldera rim trend.

Lake-bed sediments and hot-spring sinter were perhaps brecciated by repeated, localized sedimentary capping and subsequent explosive release of multiple vent orifices within the hot springs field. Other mechanisms associated with the brecciation process may include wet laharic breccia flows and sublacustrine turbidity brecciation. Lake-bed sediments and sinter would thus have been brecciated, silicified, and incorporated within the hot springs field to form the opalite breccia unit.

Contemporaneously with this activity, alternate individual springs intermittently emanated silica-rich and mercury-

aqueous fluids. Periods of silica-rich emanation are recorded as bedded chalcedony layers interstratified with argillized tuffaceous lake beds. Hot silicious aqueous fluids were dumped upon the lakeshore, and perhaps beneath the surface of the lake waters, silicifying lake-bed sediments. Periods of silicious hot spring mineralization may have been more intense or long-lived than periods of mercury mineralization, as evidenced by the greater individual thickness and greater horizontal extent of the chalcedony layers. Mercury sulfide ore in the McDermitt ore body is restricted in horizontal extent to an area within the boundaries of the opalite breccia, while chalcedony occurs as a halo overlapping and surrounding the opalite breccia.

Periods of intermittent mercury-rich hot spring mineralization are evidenced by syngenetic, bedded cinnabar textures within silicious and argillized tuffaceous sediments, and perhaps by colloform textures, suggestive of local colloidal deposition. Further, somewhat circumstantial evidence is the overall geometry of the ore body, occurring in three dimensions as multiple, asymmetric lenselike bodies thinning and decreasing in grade away from the hot spring centers of mineralization (Fig. 3). Such centers of mineralization are typified by assay intersections of greater than 50 lb mercury per ton, thinning and decreasing in grade over horizontal distances of hundreds of feet to less than 2 lb mercury per ton. Multiple individual ore bodies locally overlap and coalesce to form the discontinuous ore blanket being mined as the McDermitt ore body.

The precise chemistry and environment of mineralizing solutions is unclear, but precipitation from thermal, neutral to alkaline, sulfide-bearing aqueous solutions seems likely. Evidence of hot spring deposition of cinnabar and metacinnabar from such solutions has been observed on a small scale at Amadee Hot Springs, Amadee County, Calif.; Boiling Springs, Valley County, Idaho;[12] and at Cederville Hot Springs, Modoc County, Calif.[16]

In addition, cinnabar was deposited epigenetically within the lake beds and opalite breccia unit. Such deposition could occur when channelways to surface hot springs were blocked and reactive mineralizing fluids were forced into poorly consolidated, porous lake beds along slickensides and slump features, and along fractures within the opalite breccia. Secondary replacement textures were thus developed. Epigenetic mineralization is also evidenced by the occurrence of "McDermittite" and native mercury, probably deposited from vapor phases.

Following cessation of the near neutral hot spring solutions which deposited silica, cinnabar, and probably pyrite, the environment of the mineralized area became acidic.[5] The transition to an essentially meteoric ground-water system allowed the oxidation of iron sulfides to produce acidic conditions above the ground-water table. Under acidic conditions, silica could have been locally altered to alpha cristobalite, and in the presence of excess chlorine cinnabar was altered to corderoite.

As pit stripping further reveals the ore body and investigation of chemical processes continue, the present interpretation of the genesis of the McDermitt ore body may be changed. At present, however, a thermal springs origin seems the most reasonable geologic interpretation of the evidence accumulated, and perhaps most importantly, is an effective guide to following ore in the mining operation.

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