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ORIGIN OF THE OPALITE BRECCIA AT THE McDERMITT MERCURY MINE, NEVADA

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Introduction

The McDermitt mine in the Opalite mining district is near the Oregon-Nevada border (Fig. 1). Mercury sulfides are disseminated in tuffaceous sedimentary and pyroclastic rocks associated with the 17.9- to 15.8-m.y.-old McDermitt Caldera Complex (Rytuba and Glanzman, 1978). The Opalite, Bretz, Cordero, and other mines in the district produced approximately 135,000 flasks of mercury between 1926 and 1972, of which the Cordero mine produced over 100,000 flasks between 1935 and 1970 (Speer, 1977). When Placer Amex Inc. began production at the McDermitt open pit in 1975, reserves were about 400,000 flasks (Mining Magazine, 1982). The average ore grade is about 0.5 percent Hg. McDermitt currently is the largest mercury mine in the United States.

The purposes of this communication are to describe and determine the origin of the opalite breccia at the McDermitt mine and to suggest its role in localizing ore. In the McDermitt caldera opalite is a field term that has been loosely applied to a variety of silicified fragmental rocks including fault breccias and stratigraphic units (Hetherington, 1983). Roper (1976) interpreted the opalite breccia at the McDermitt mine as lake beds that were silicified and brecciated during an inferred period of surficial hot-spring activity that caused the mineralization. The present study identifies the mineralized opalite breccia at the McDermitt mine as a lithic vitric ash-flow tuff (using the terminology of Ross and Smith, 1960, and Schmid, 1981). Hetherington (1983) presented a more detailed account of the results discussed here. Detailed geochemical studies of the deposit by Rytuba and by Placer Amex Inc. are still in progress.

Stratigraphy

Because of the tendency of earlier workers to term all silicified and fragmental rocks opalite breccia, the stratigraphy of the McDermitt mine has been controversial. Figures 2, 3, and 4 show the geology of the McDermitt mine, and Table 1 describes some of the units there. The unit most typically referred to as opalite breccia at McDermitt is a lithic vitric ash-flow tuff (referred to hereafter as the lithic tuff).

Brick-red to brown, porphyritic andesite is exposed in trenches east of the open pit and probably is in fault contact with rhyolite. Because the andesite is not exposed in the pit and has not been encountered in drill holes, it may be a dike. Curry (1960) described similar rocks southeast of the Cordero mine as thin flows and dikes.

The basal rhyolite is a minimum of 22 m thick and consists of two units: a light gray, slightly porphyritic, flow-banded rhyolite of uncertain origin and a light gray, nonwelded to partially welded vitric ash-flow tuff. Both units crop out east of the open pit and are exposed along its eastern and southern walls (Fig. 2). Where flow banding is not present, the units are nearly identical in outcrop; they were not differentiated in the field. Because all outcrops of Tr are fault bounded and other outcrops only contain one of the units, the stratigraphic relationship of the two units is unclear. Although the flow-banded member does not appear to be fragmental in thin section, it may be a welded, rheomorphic portion of the pyroclastic member. Limited exposure of Tr in the study area precludes a more definitive description. Because silicification hinders petrographic analysis, the compositions listed in Table 1 are approximate. The rhyolite correlates with the rhyolite flows and pyroclastics described by Curry (1960) at the Cordero mine and probably correlates with a portion of the alkali rhyolite of Long Ridge of Greene (1972), which is 15.6 to 15.9 m.y. old (Greene, 1976).

The lithic tuff has not been described heretofore. It is at least 12 m thick and has a partially welded base and a nonwelded top that was reworked and locally eroded. It is exposed in the open pit and is intersected by drill holes but does not crop out elsewhere.

The lithic tuff is unsorted and has a chaotic arrangement of angular to subangular fragments of rhyolite, which constitute 25 to 60 percent of its volume (Table 2). Fragments of quartz and anorthoclase average 0.2 mm. Euhedral fragments of anorthoclase have tartan twinning and patchy extinction. Subhedral to anhedral fragments of quartz are partially resorbed; undulatory extinction is typical. Mafic minerals are

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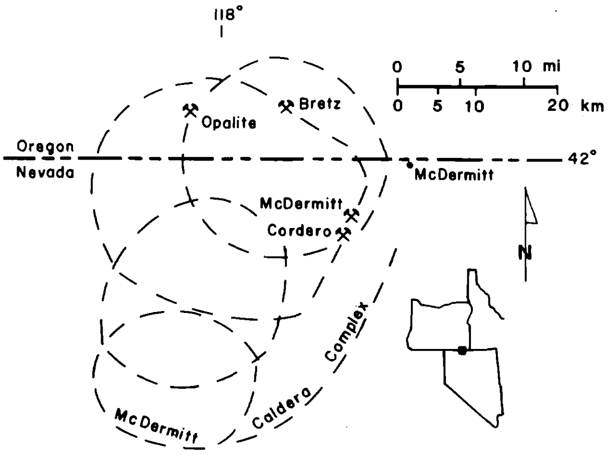

FIG. 1. Map showing the location of the four major mines of the Opalite district and the ring fractures of the McDermitt Caldera Complex (after Rytuba and Glanzman, 1978).

present in minute amounts but are too small to identify microscopically.

A sharp basal contact of the lithic tuff with the rhyolite is exposed along the southern and eastern walls of the pit (Fig. 2). Unlike the underlying rhyolite, the lithic tuff is variegated and is composed of conspicuous blocks and lapilli in an ashy matrix. The rhyolite is uniformly gray, essentially free of blocks and lapilli, and composed almost exclusively of ash or microcrystalline material. Because undeformed angular fragments of rhyolite exist in the lithic tuff, the rhyolite was deposited and indurated before the lithic tuff erupted. The nonwelded top of the lithic tuff is lithified but porous. Uncollapsed gas cavities are locally well preserved in undeformed pumice lapilli (Fig. 3). Compaction foliation is moderately developed in the partially welded base but is obscured by silicification and mineralization. The contact with the overlying fluvial sediments is gradational over approximately 1 to 2 m.

In thin section, eutaxitic texture is distinct and common in partially welded samples; it is best defined by flattened gas cavities and pumice lapilli. Glass shards are poorly preserved but tend to be more visible in nonwelded tuff. Devitrification textures are common in partially welded and nonwelded portions. Glass shards and pumice fragments have axiolitic structures. Spherulites are locally well developed. Altered dust in the groundmass is cloudy and dark brown. No vapor phase crystallization is discernible.

In the north-central portion of the pit, poorly consolidated, pink to beige fluvial strata overlie and are gradational downward into the lithic tuff. Moderately sorted, subangular to angular sandstones, composed of reworked volcanic and pyroclastic material, predominate. Graded bedding, crossbedding, and scour and fill structures are present but difficult to recognize because of alteration. The degree of sorting, crossbedding, and graded bedding and the absence of charcoal or other indicators of elevated temperature suggest that this unit is not a base-surge or avalanche deposit. Furthermore, these sandstones are overlain by lacustrine strata rather than an ash-flow tuff. The unit is a maximum of 15 m thick.

White to buff, massive to thinly laminated tuffaceous siltstones, shales, and mudstones overlie the fluvial rocks. They are well sorted; local variations include graded beds up to 20 cm thick, flame structures, and cross laminations. Root tubes are common. Gastropod fossils and worm burrows are present but rare. Glass shards and crystal fragments of ash and dust size comprise these lacustrine rocks. Lithic and pumice pebbles are rare. Several well-sorted, massive, pumice lapilli tuffs and ash tuffs are interbedded with laminated clays and silts. The tuffs probably were deposited by air fall. In the southern portion of the mine, the lacustrine unit lies unconformably on the lithic tuff or on the reworked top of the lithic tuff. The preserved thickness of the unit ranges from less than 3 to greater than 60 m.

Structure

A silicified, monolithologic breccia of the rhyolite previously identified as opalite breccia crops out east of the open pit. It occurs in a fault zone that is a minimum of 150 m wide. Displacement on the fault exceeds 32 m and the throw is west-side down. At the Cordero mine about 2.2 km to the south, northeast-trending faults mapped by Curry (1960) and Fisk (1968) appear to be on strike with this fault zone. All these faults are coincident with ring-fracture faults of the eastern portion of the McDermitt Caldera Complex (fig. 1, Rytuba and Glanzman, 1978).

Numerous small shears and faults in the McDermitt pit trend N 89° E to N 15° W, with dips ranging from 50° to 80°. Several are mineralized with cinnabar and corderoite but are unsilicified. Locally, the rhyolite in the south-central part of the pit is pervasively jointed and sheared but offsets cannot be determined.

A monocline, with an axial trace of N 62° W and with maximum dips of about 34° NE (Fig. 4), affects all pre-Quaternary units. Thus, north of the pit the lithic tuff and rhyolite are deeper than all holes cored to 1983. Smaller folds preserved on the limbs of the monocline have axial trends of roughly N 15° W and N 30° E. Locally, stratiformally silicified rocks have been folded, suggesting that folding postdated silicification and mineralization. Folding also either postdated or was contemporaneous with faulting. South of the monoclinal axis in the southernmost portion of the pit, the mineralized rocks are unconformably

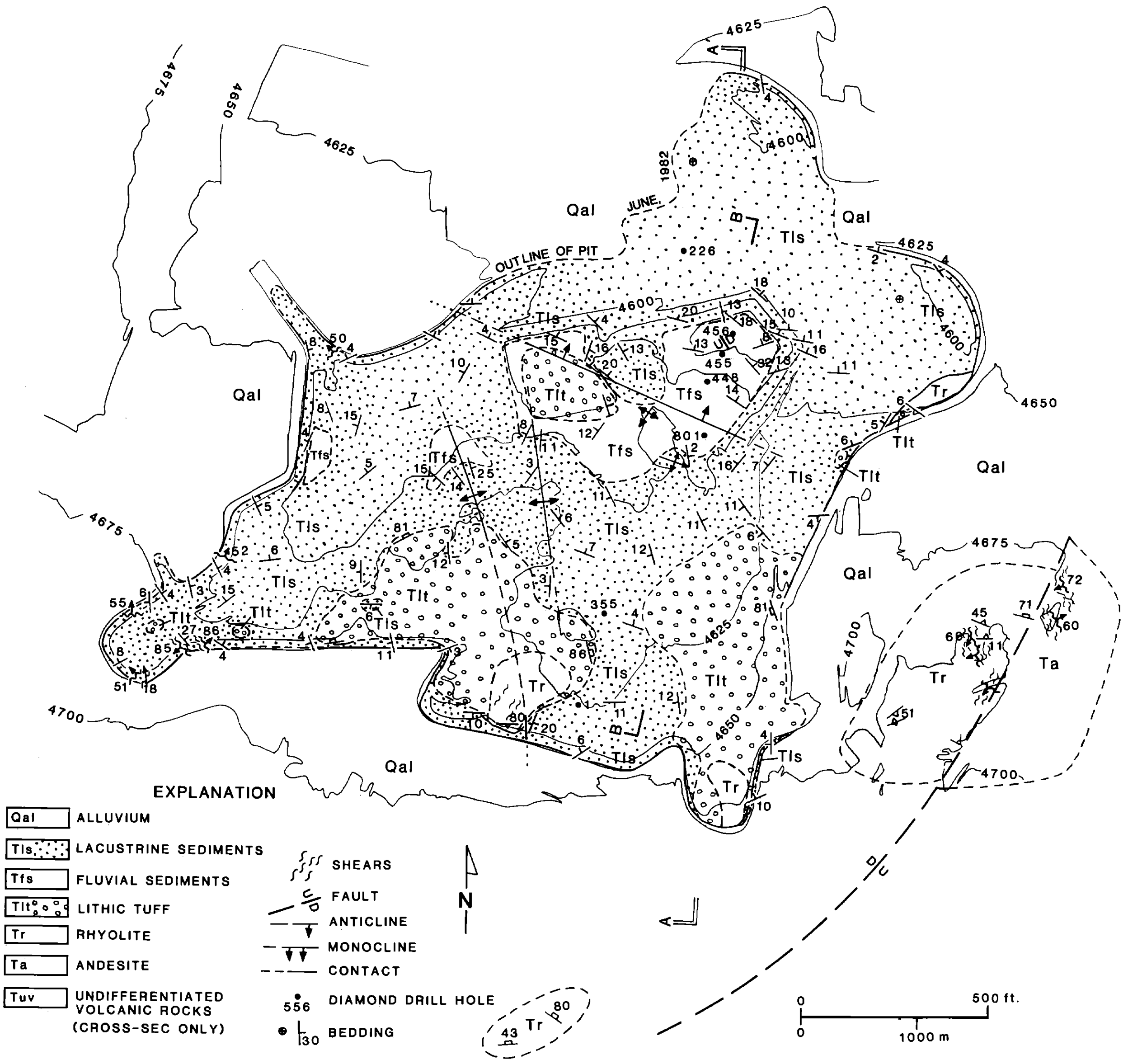

FIG. 2. Geologic map of the McDermitt mine.

overlain by Quaternary alluvium. Perhaps the folds are drape features over faults related to the collapse of the McDermitt Caldera or were caused by tilting of the central block against the ring faults.

Mineralization

Mineralization is closely associated with silicification and also crosscuts stratigraphy (Fig. 5). Although most of the disseminated mineralization extends above the upper surface of pervasive silicification and into argillized rocks by as much as 15 m, the bottom of a mineralized interval is within the zone of silicification (Fig. 5). Although not illustrated in Figure 5, the highest concentrations of ore are in the argillized fluvial and lacustrine units.

In general, the textures of cinnabar in argillized and silicified rocks are the same. Cinnabar is disseminated in all rock types as very fine grained to submicroscopic crystals and aggregates. In the sedimentary rocks, cinnabar is interstitial; it is as common in sandstones as in mudstones. Locally, mineralization is controlled by sedimentary structures such as cross beds and planar beds. In the lithic tuff, euhedral to subhedral, very fine grained cinnabar occupies intergranular spaces in the groundmass, coats fragments, lines vugs and gas cavities, and commonly is inter-

FIG. 3. Nonwelded lithic tuff. Note the pumice lapilli with uncollapsed gas cavities in the lower left and the large lithic fragment in the upper right. Hammer handle is 11 in. long.

grown with euhedral quartz in vugs. Cinnabar does not replace crystals or lithic fragments. Disseminated, rare radiating stibnite up to 13 mm long is locally associated with cinnabar in silicified rocks.

Rare veinlets up to 20 mm wide cut across the pervasive, disseminated mineralization and alteration. These veinlets occur in rhyolite and lithic tuff in the south-central portion of the pit but are of limited extent. Most are slightly banded and are composed almost entirely of quartz with minor zeolite. Cinnabar occurs as blebs adjacent to the veinlet walls and comprises less than 1 percent of the veinlets. Because the veinlets cut pervasively silicified rock, only minor amounts of this cinnabar have been mined as ore to date. The amount of cinnabar in the veinlets is insignificant, relative to the entire orebody.

Limonite is finely disseminated in all rock types to depths of 45 to 65 m. Corderoite ($Hg_3S_2Cl_2$), which comprises 25 percent of the ore (Roper, 1976), is very fine grained, occurring as dissemination and wispy masses with cinnabar in the zone of oxidation. The corderoite probably is an in situ supergene replacement of cinnabar (Hetherington, 1983).

Hydrothermal Alteration

Hydrothermal alteration at McDermitt is zoned relative to the present surface. At depths greater than 120 m, quartz-pyrite veinlets with narrow sericitic (?) alteration halos cut propylitized rocks. Above 120 m, propylitic alteration, characterized by fine-grained pyrite and epidote, extends within 80 to 55 m of the surface, where it grades into argillically altered rocks. Glanzman and Rytuba (1979) described the zonation of the argillic assemblages. Alunite from the Cordero mine yielded an age of 12.3 ± 0.7 m.y. (McKee, 1976).

Disseminated and replacement-type silicification is abundant in the zone of argillic alteration. Quartz is the dominant phase. The sedimentary rocks are volumetrically less silicified than the lithic tuff (Fig. 5). Partially silicified rocks retain much of their original color and texture. In thin section, thin films of quartz surround clastic grains and fill interstices. Completely silicified rocks are extremely hard, dense, and brittle, the original color is rendered darker, voids and pore spaces are filled, and, locally, clastic grains and fragments are partially to completely replaced.

Boundaries between variably silicified rocks are gradational and irregular. The upper limit of silicification is irregular and cuts stratigraphy (Fig. 5). Because silicification is most pervasive in the lithic tuff, the tuff was called opalite breccia. The irregular, knobby, upper surface of the opalite breccia that Roper (1976) inferred was evidence for thermal springs within a lake is the combined result of silicification that cuts across stratigraphy, the irregular eroded and reworked surface of the lithic tuff, folding, and selective mining of intervening zones of unsilicified rock.

Two other phases of silica occur in minor amounts. Alpha-cristobalite, identified by X-ray defraction, occurs as disseminations in the lithic tuff and overlying sediments and locally as overgrowths on quartz and cinnabar that were deposited during the main phase of mineralization. Most of the alpha-cristobalite is probably a product of devitrification. Chalcedony occurs locally as lenticular or stratiform masses in the

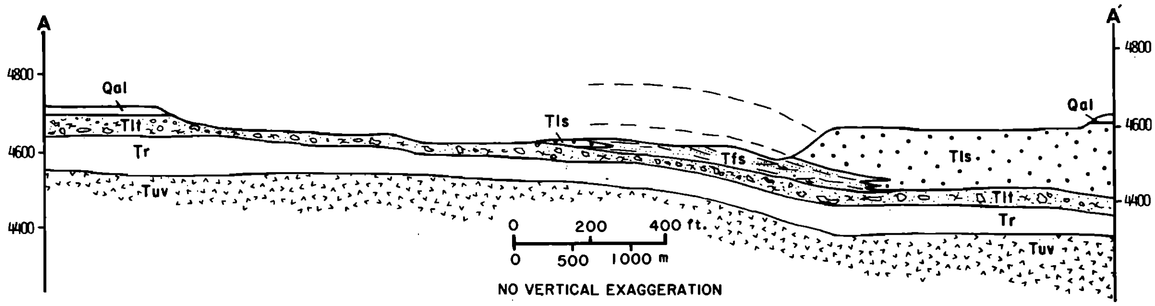

FIG. 4. Cross section of A-A′ at the McDermitt mine looking westward. See Figure 2 for location of the section line. Quaternary alluvium lies unconformably on the lithic tuff to the north.

TABLE 1. Descriptions of the Andesite and the Rhyolite

Unit	Composition	Texture and field characteristics
Andesite (Ta)	10% plagioclase; euhedral to subhedral, up to 1 mm, undulose, patchy extinction 8% mafic phenocrysts; 0.5-mm stubby and highly corroded grains with oxidized rims, partially replaced by biotite 3% opaque minerals; black, patchy, anhedral 1% quartz; subhedral phenocrysts 79% groundmass; plagioclase, quartz microcrysts	Brownish-red, porphyritic, massive, thickness unknown; well jointed and sheared; probable fault contact with rhyolite; age uncertain
Rhyolite (flow-banded member) (Tr)	65% quartz; 10% subhedral phenocrysts, rounded, undulatory extinction; 50% ragged, sutured patches in groundmass (secondary?) 20% feldspar; ragged, irregular, spherulitic with quartz intergrowths 5–10% opaque minerals; black, irregular patches 1% clinopyroxene (?); green, microcrystalline laths	Light gray, aphyric to microporphyritic to finely porphyritic; usually flow banded but locally massive; flow banding defined by variations in grain size of quartz; minimum thickness (both members) 22 m
Rhyolite (ash-flow tuff member) (Tr)	35–40% pumice; lapilli and ash 5–10% crystals; subhedral to euhedral fragments of quartz and anorthoclase up to 0.5 mm 45–55% matrix; yellow-brown ash and dust, shards locally preserved 1–5% lithic lapilli and ash; assorted compositions	Light gray, finely porphyritic massive, fragmental, nonwelded to partially welded; locally has poorly developed eutaxitic texture
Undifferentiated volcanic rocks (Tuv)	Brick-red to medium and dark gray, nonwelded to welded, andesitic to rhyolitic air-fall and ash-flow tuff	Exposed in deep drill holes; Speer (1977) correlated these rocks with the alkali rhyolite of Long Ridge of Greene (1972)

lacustrine sediments and is unrelated to the ore; it probably is diagenetic.

Discussion and Conclusions

Fluid inclusions from McDermitt have homogenization temperatures of 200°C and indicate that boiling did not occur during deposition of quartz; this corresponds to a depth of formation of at least 150 m (Rytuba, 1976). Opal and chalcedony, which are significant phases of silica in surficial hot springs (White, 1967), are minor and not pervasive at McDermitt. Advanced argillic alteration (kaolinite, illite, dickite, native sulfur, and sulfates according to White et al., 1971) typical of surficial, acidic sulfate springs cannot be documented. Instead, potassium feldspar, zeolites, montmorillonite, and quartz suggest intermediate argillic alteration, which is characteristic of geothermal systems beneath the water table (Rose and Burt, 1979).

Hypogene mineralization and alteration in the McDermitt pit apparently occurred in three stages. Outcrop-sized bodies of argillically altered rock within the zone of silicification suggest that much of the argillic alteration preceded silicification. Cinnabar

TABLE 2. Modal Analyses of the Lithic Tuff

Sample number	Percentage of rock exclusive of foreign rock fragments					Lithic fragments (% total)	Total points counted
	Matrix	Quartz	Anorthoclase	Mafic minerals	Pumice		
JH81-103	50.8	6.8	3.3	2.0	37.0	53.5	1,509
JH81-130	87.2	0	2.3	1.1	9.4	40.3	2,107
JH81-147	69.7	2.4	7.3	1.5	19.1	38.6	1,708
JH81-171	69.6	0.7	9.4	0	20.3	61.2	1,433
JH81-174	81.7	0.4	3.3	0.8	13.7	27.8	2,936
JH81-207	51.3	7.3	3.8	0.5	37.0	55.2	2,151
JH81-232	80.6	0.8	1.9	0.4	16.4	50.7	1,618
JH81-291	83.4	2.5 combined		0	14.1	56.7	2,004
JH81-297	76.4	1.5	2.6	0.08	19.4	42.8	2,069
JH81-384	88.0	3.1	1.7	0	7.2	29.8	2,068

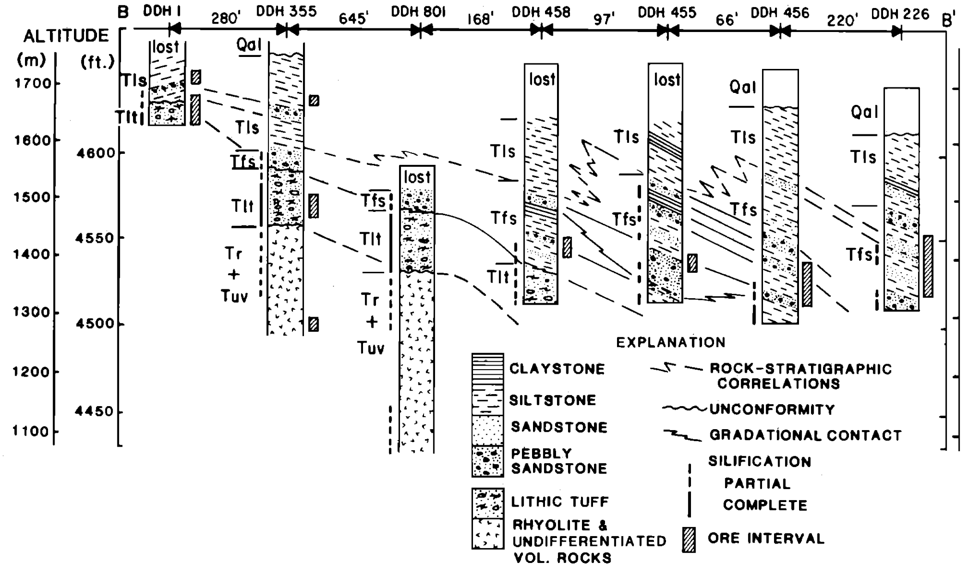

FIG. 5. Stratigraphic correlation along a north-south transect (B-B') of the McDermitt mine. See Figure 2 for location of section and drill holes. True dips are shown in the columns representing the drill holes but not between holes. Note that silicification and mineralization crosscut stratigraphy.

is disseminated in all rock types as open-space fillings. Because the textures of cinnabar in both the argillically altered and silicified rocks are similar, and because cinnabar is intergrown with euhedral quartz in vugs in silicified rocks, mineralization and silicification probably were essentially contemporaneous. Nonetheless, for some reason, mineralization extends well above silicification, which is most abundant in the lithic tuff. The late quartz veinlets with minor cinnabar in the silicified rocks are a volumetrically insignificant part of the ore.

Because mineralization and silicification extend above and below the lithic tuff (Fig. 5), the ore-forming fluids may have used this unit as an aquifer. The McDermitt mine is adjacent to the zone of ring fractures (Fig. 2). At the Cordero mine about 2.2 km to the south, mineralization is confined to fractures in rhyolite and other volcanic rocks (Curry, 1960; Fisk, 1968) stratigraphically below the lithic tuff. If these ring fractures at Cordero intersected the lithic tuff, the ore-forming fluids could have migrated laterally through this more permeable unit, forming the disseminated McDermitt deposit. However, any direct evidence for such a plumbing system has been removed by erosion of the northward-dipping lithic tuff and associated units from the vicinity of the Cordero mine.

Thus, Cordero and McDermitt may be akin to other deposits in which fluids emanated from mineralized fracture systems and caused disseminated mineralization in adjacent permeable sedimentary or volcaniclastic units. Such deposits include: (1) the base metal deposits in the Telluride Conglomerate, Silverton caldera, Colorado (Mayor and Fisher, 1972); (2) silver deposits in the Creede Formation, Creede caldera, Colorado (Steven and Eaton, 1975); (3) gold in the Klondike Mountain Formation, Republic, Washington (Full and Grantham, 1968); (4) gold in poorly welded tuffs of the Jefferson caldera, Round Mountain, Nevada (B. A. Mills, pers. commun., 1982); and (5) uranium mineralization in flow tops and other permeable units in the Aurora deposit in the McDermitt caldera (Roper and Wallace, 1981).

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