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Geologic Setting and Genesis of the Mule Canyon Low-Sulfidation Epithermal Gold-Silver Deposit, North-Central Nevada

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Abstract

The Mule Canyon mine exploited shallow, low-sulfidation, epithermal Au-Ag deposits that lie near the west side of the Northern Nevada rift in northern Lander County, Nevada. Mule Canyon consists of six small deposits that contained premining reserves of about 8.2 Mt at an average grade of 3.81 g Au/tonne. It is an uncommon mafic end member of low-sulfidation Au-Ag deposits associated with tholeiitic bimodal basalt-rhyolite magmatism. The ore is hosted by a basalt-andesite eruptive center that formed between about 16.4 to 15.8 Ma during early mafic eruptions related to regionally extensive bimodal magmatism. Hydrothermal alteration and Au-Ag ores formed at about 15.6 Ma and were tightly controlled by north-northwest- to north-striking high-angle fault and breccia zones developed during rifting, emplacement of mafic dikes, and eruption of mafic lava flows.

Hydrothermal alteration assemblages are zoned outward from fluid conduits in the sequence silica-adularia, adularia-smectite, smectite (intermediate argillic), and smectite-carbonate (propylitic). All alteration types contain abundant pyrite and/or marcasite ± arsenopyrite. Field relations indicate that silica-adularia alteration is superimposed on argillic and propylitic alteration. Little or no steam-heated acid-sulfate alteration is present, probably the result of a near-surface water table during hydrothermal alteration and ore deposition.

Two distinct ore types are present at Mule Canyon: early replacement and later open-space filling. Replacement ores consist of disseminated and vesicle-filling pyrite, marcasite, and arsenopyrite in argillically altered or weakly silicified rocks. Ore minerals consist of Au-bearing arsenopyrite and arsenian pyrite overgrowths on earlier-formed pyrite and marcasite. Open-space filling ores include narrow stockwork quartz-adularia veins, banded and crustiform opaline and chalcedonic silica-adularia veins, silica-adularia cemented breccias, and sparse carbonate-pyrite and/or marcasite veins. Ore minerals consist mostly of electrum and Ag sulfide and selenide minerals, with minor to major amounts of pyrite, marcasite, and arsenopyrite, and local stibnite. Both types of ores have similar geochemical signatures, characterized by high Au, Ag, As, Sb, and Se contents, locally high Hg, Mo, Tl, and W contents, and low Cu, Pb, and Zn contents.

Stable isotope data indicate that ore fluids consisted dominantly of meteoric water that evolved by deep circulation through Paleozoic sedimentary rocks at low water/rock ratios (about 1) and high temperatures (>200°C). Calculated isotopic compositions of ore fluids are $\delta^{18}O_{H_2O}$ = –3 to –7 per mil, δD_{H_2O} = –107 to –124 per mil, $\delta^{13}C_{CO_2}$ = 0 to –6 per mil, and $\delta^{34}S_{H_2S}$ = –3 to +8 per mil. The ore fluids obtained much of their H_2S and CO_2 and probably scavenged ore metals and trace elements from the Paleozoic sedimentary rocks. Some H_2S and CO_2 may have been derived from degassing Miocene magmas.

Mule Canyon formed at shallow depths, probably about 100 m below the paleosurface. Ore fluids were dilute, nearly neutral in pH, reduced, H_2S-rich, and CO_2-bearing. Peak temperatures in ore zones reached 230° to 265°C at nearly lithostatic pressures when some crystalline quartz ± adularia precipitated, but most ore formed at temperatures <200°C at near hydrostatic pressures and was accompanied by precipitation of opaline and chalcedonic silica ± adularia ± calcite and dolomite. Deposition of gold in As-rich overgrowths on pyrite and/or marcasite in disseminated ores occurred owing to decreasing H_2S in the ore fluids resulting from sulfidation reactions. Later electrum and Ag selenide precipitation in open spaces occurred owing to boiling, loss of H_2S to the vapor phase, and cooling.

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Mule Canyon is similar to most other low-sulfidation Au-Ag deposits associated with Miocene tholeiitic bimodal basalt-rhyolite magmatism in the Great Basin, such as Sleeper, Midas, and Buckhorn. Major differences at Mule Canyon are the high Fe sulfide contents of some ores and altered wall rocks, the paucity of silicification, and the presence of only narrow and discontinuous gold-bearing siliceous veins. These differences primarily are due to the mafic composition of the host rocks. Mule Canyon differs from low-sulfidation deposits associated with subduction-related calc-alkaline porphyry intrusions, such as the Comstock lode, in that a much smaller proportion of water, salts, and metals was derived from crystallizing magmas.