

Paragenetic and Lithogeochemical Constraints on the Hydrothermal and Supergene Evolution of the Big Mike Volcanogenic Massive Sulfide Deposit, Nevada, USA

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The Big Mike volcanogenic massive sulfide (VMS) deposit in Nevada is a small but high-grade deposit with historical production of 100,000 tons at 10.5% Cu from the massive sulfide lens. Sulfide mineralization is hosted within the Pennsylvanian to Permian Havallah sequence, which consists of chert and argillite associated with greenstones and basaltic to rhyolitic flows. This study uses whole-rock geochemical data and detailed petrographic analysis to constrain the hydrothermal and supergene evolution of the deposit and to assess its potential for critical minerals. Geochemical evidence indicates that the host rocks were deposited under reducing conditions, with early sulfide mineral precipitation from relatively low-temperature (<250°C) hydrothermal fluids. The host rock chert Post-Archean Australian Shale (PAAS)-normalized rare earth element (REE) patterns are near-flat patterns with positive Eu anomalies and negative Ce anomalies. Combined with Ce/Ce*-Pr/Pr* systematics and Y/Ho ratios (23.43-28.89), these signatures suggest precipitation from reduced hydrothermal vent fluids that interacted with oxygenated seawater. In contrast, argillites and massive sulfide mineralization have weaker negative Ce anomalies and elevated Ce/Ce* and Pr/Pr* values, reflecting a progressive shift toward more reducing conditions. This shift likely resulted from increased fluxes of reduced, higher-temperature hydrothermal fluids during the evolution of the hydrothermal system. Higher-temperature (~300°C) hydrothermal fluids promoted the precipitation of fine-grained pyrite enriched in Co, followed by main ore-stage chalcopyrite and minor sphalerite. Multiple subaerial supergene events at Big Mike also enriched the system in critical (Cu, Co) and precious metals (Au). In summary, the hydrothermal and supergene mineral assemblages at the Big Mike preserve a complex archive of physicochemical conditions involved in the formation of VMS deposits and associated critical minerals. Thus, understanding the Big Mike system provides insights that can be used for VMS exploration elsewhere within the Great Basin.