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Vein Evolution, Mineralogy, and Critical Mineral Potential of the Red Mountain Porphyry Copper System, Arizona, USA

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The Red Mountain porphyry copper system is a largely intact, upright, and well-preserved magmatic-hydrothermal system hosted in Late Cretaceous andesitic to rhyolitic volcanic rocks within the Laramide porphyry copper belt of southwestern North America. A deep (> 3,600 feet), strongly mineralized breccia pipe, with altered and mineralized clasts from the disseminated porphyry system, is cut by a late quartz-eye porphyry dike. This study integrates new detailed petrography, mineral chemistry, and whole-rock geochemistry to define the ore and alteration mineralogy, relative timing of mineralization and alteration, and reveal critical mineral deportment at Red Mountain.

The hypogene vein paragenesis follows the classic vein and alteration evolution of porphyry copper deposits. Within observed veins, early potassic alteration is characterized by thin quartz-magnetite-biotite assemblages, while late potassic alteration assemblages consist of quartz-chalcopryrite (A-veins) or quartz-molybdenite (B-veins), typically with K-feldspar halos. Thin C-veins of chalcopryrite-pyrite ($\pm$ quartz-sericite-pyrite halos) represent transitional potassic-phyllic alteration. Phyllic alteration principally consists of D-veins of quartz-pyrite with quartz-sericite-pyrite halos. Lastly, representing phyllic to advanced argillic alteration are E-veins of quartz, sulfide(s) (Cu-sulfides, galena, sphalerite, and/or fahlore), sericite, and clays.

Pyrite, galena, and fahlore exhibit significant trace-element enrichments when present in D- or E-veins (Ag, Bi, Cu, Ni, Te, and Zn) or in the mineralized breccia pipe (Co and Ag). Notably, galena within an E-vein contains, on average, 0.79 wt. % Ag and 0.93 wt. % Bi, while fahlore within that same vein averages 5.45 wt. % Bi and 0.26 wt. % Te. Within the mineralized breccia pipe, pyrite averages 1,407 ppm Co, whereas pyrite elsewhere in the system averages 131 ppm Co. These trace-element enrichments may suggest late fluids were metal-rich. Altogether, understanding the spatiotemporal distribution of ores in a well-preserved porphyry copper system, such as Red Mountain, is crucial for future exploration, mineral processing, and critical mineral recovery.