Mineral Petrography, Trace Element, and Pb Isotope Geochemistry of the Black Butte Cu-Co District, Belt Basin, Montana, USA: Constraints on Ore Genesis

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Petrographic and geochemical analyses of more than 100 samples of pyritic shale from in and around the Cu-Co deposits of the Black Butte district, Belt Basin, Montana, have revealed a complex, multi-stage pyrite paragenesis. Two main pyrite generations—one early (syn-diagenesis) and the other late (syn-hydrothermal)—are preserved across the district. Diagenetic pyrite is typified by its fine-grained, densely packed to sporadic spherical shapes. Hydrothermal pyrite is distinguished from diagenetic pyrite by its euhedral cubic forms, which commonly occur as overgrowths on diagenetic pyrite. Other types of hydrothermal pyrite also occur (e.g., colloform), hosted in either veins or brecciated shale. Diagenetic pyrite typically contains ppm-level concentrations of Co, Ni, Tl, Mn, Ag, Cu, Pb, and Bi, but below-detection levels of Se and Te. Gold has a bimodal distribution in diagenetic pyrite, in that samples above the regional Volcano Valley fault zone have below-detection levels of Au, whereas samples below the fault zone contain ppm-level Au concentrations. Hydrothermal pyrite bears a marked chemical resemblance to diagenetic pyrite, except for Co, As, and Ni, which reach values of up to 5, 3, and 1 wt. %, respectively. Furthermore, the Pb isotope compositions of diagenetic and hydrothermal pyrite enable effective discrimination between the two generations, particularly in samples below the Volcano Valley fault zone, which exhibit more radiogenic Pb compositions than those above it. The deposits of the Black Butte district represent unique examples of Mesoproterozoic sediment-hosted Cu-Co mineralization that do not fit well into any existing models for sediment-hosted Cu deposits. Furthermore, shared textural, mineralogical, and sedimentological affinities with Meso- to Paleoproterozoic sequences in northern Australia may indicate heightened potential for McArthur River analogues in the Black Butte area, which warrants further investigation.