

## **Paragenesis and Mineral Chemistry of Arsenide Five-Element Veins at Black Hawk District, Grant County, New Mexico**

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The Black Hawk district in southwestern New Mexico is one of the few arsenide Five-Element (Halls and Stumpfl, 1972; Ag-Co-Ni-Bi-As) vein deposits in the United States. These high-grade silver deposits (1000's g/T Ag) are characterized by carbonate veins that contain critical minerals, such as Ag, Ni, Co, As, Bi, U, Pb, Zn, Sb, and other elements, but are gold impoverished. Between 1881 and 1960, this district produced approximately 1,286,000 oz Ag, 3,000 lbs Cu, and 4,000 lbs Pb.

In Five-Element hydrothermal veins, nickel and cobalt generally occur as arsenides, with silver, arsenic and bismuth comprising native elements, often with a characteristic skeletal texture. This study uses whole rock geochemical analyses, optical microscopy, cathodoluminescence (CL), and microanalytical techniques including Electron Microprobe Analysis (EMPA) and Raman spectroscopy to update the mineral chemistry and paragenetic sequence for these complex ores.

Samples were collected from drill core, underground and surface exposures, fresh and altered host rocks, and mineralized veins and breccias. In total, 154 samples were prepared as mount polished and thin sections for detailed petrographic and mineralogical analysis. Ten thin sections were selected for EMPA, two for CL and six for Raman spectroscopy.

This study shows that gangue carbonates calcite, ankerite, and dolomite host inclusions of hematite, and occur in early and late paragenetic stages, with quartz and pyrite. Ore minerals, including native Ag and Ni $\gg$ Co arsenides, show complex textural relationships, suggesting a sequential deposition similar to Five Element vein ores at Cobalt, Hay River, and the Erzgebirge. Late-stage minerals include base metal sulfides and sulfosalts. Microprobe images show detailed textural relationships, compositional variation of sulfarsenides, and U enrichment often associated with nickeline. CL imaging shows complex zonation in carbonates. Multiple stages of brecciation show magmatic hydrothermal or hydrothermal origin; bladed quartz-after-calcite textures suggest boiling, consistent with earlier fluid inclusion studies (Gerwe, 1986).