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Critical mineral deportment in slag from the Kennecott Cu smelter and implications for secondary recovery

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Ore deposits are typically mined for a limited number of primary commodities but can contain other critical minerals and valuable elements at elevated concentrations relative to the unmineralized country rock. Understanding the deportment of these critical minerals among value and waste streams during ore processing provides insight into opportunities for additional resource recovery. Slag, an abundant byproduct of smelting, is one such possible secondary source. Determining the mineralogical partitioning of valuable elements in slag is essential for developing effective metallurgical approaches for their recovery. In this study, we evaluate critical mineral enrichment of a suite of Cu slag samples from the Kennecott porphyry Cu-Mo mine at Bingham Canyon in Utah using bulk geochemistry, optical and electron microscopy, X-ray diffractometry (XRD), and electron microprobe analysis.

The slags are mainly composed of the silicate and oxide phases fayalite, magnetite, clinopyroxene, powellite ($CaMoO_4$), quartz, and a Si-rich glass. They also contain immiscible blebs of chalcocite and Cu-arsenide minerals such as domeykite (Cu_3As), ranging in size from less than one µm to as large as 300 µm in diameter. Relative to the ore, the slag is enriched in Bi, Cu, Mo, Pb, Sb, and Zn. These elements are unevenly distributed among the phases. The Mo and Zn partition into the silicates and oxides. In one sample, for example, 40% by mass of Mo is found as a trace element in magnetite (~3600 ppm Mo on average), with the remainder divided mainly between the glass and the powellite. In contrast, Bi, Pb, and Sb partition into the Cu-rich blebs. Bi and Pb were detected in metallic and sulfidic µm-sized inclusions in the chalcocite and Cu arsenides, whereas Sb was observed in solid solution with the Cu arsenides.

These preliminary observations indicate that critical minerals and other commodities partition differently in the slag, with some associated with discrete Cu phases and some as trace to minor constituents in silicates and oxides. Documenting the mineralogical distribution of these elements is the first step in determining approaches to concentrate them for recovery and is therefore important for developing slag as a potential secondary source of critical minerals.