The State and Fate of Noble Metals in Bornite and Digenite

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Bornite (Cu_5FeS_4; Bn) and digenite (Cu_9-x$FexS_5$, x~0.2; Dg) are common components of a broad range of Cu-Ag-Au deposits, including skarns. At high temperature, Bn-Dg forms a solid solution (ss) with cubic symmetry (a~5.5 Å). Superstructures, defined by multiples of a, or other structural derivatives, e.g., anilite (Cu_7S_4), rhombohedral (R) Dg (Cu_9S_5), can form during cooling of Bn-Dgss. The potential of bornite and digenite as noble metal carriers is assessed using complementary micron- to nanoscale petrographic/mineralogical analysis in a case study from the world-class Ertsberg East Skarn System (EESS), Papua, Indonesia. The study aims to answer the question of whether noble metals (Au, Ag, Pd) occur in solid solution in Cu-(Fe)-sulfides, or as nanoparticles (NPs), and how this distribution changes during cooling. Results are significant for understanding precious metal enrichment mechanisms in Cu-Au skarns and analogous deposits in which bornite-digenite intergrowths are exsolution products of high-temperature solid solutions in the system Cu-Fe-S. Gold-rich bornite-digenite assemblages are analyzed from EESS magnesian skarns.

Bornite and digenite display lamellar intergrowths and form dense basket-weave textures at the nanoscale comprising host Bn2a, and exsolved Dg1a+anilite+Dg-R. (Sub)-micron inclusions of Au-Ag-Pb-Te-(Se) phases and merenskyite ($PdTe_2$) occur within lamellar bornite–digenite intergrowths, highlighting their role as important carriers of noble metals. Bornite from prograde skarn contains tens of ppm Au; nanoscale imaging confirms the generation of Au-Ag-Te NPs during phase transformation of parent digenite into lower temperature anilite. Lattice-bound Au is estimated at <10 ppm. In retrograde assemblages, a comparable redistribution of lattice-bound Au and Ag into NPs and micron-sized gold is facilitated through reworking of lamellar intergrowths. An enigmatic Cu-telluride phase identified within all Au-Ag-Te NPs may act as a catalyst for noble metal enrichment. Merenskyite inclusions in bornite contain minor Au, emphasizing the role of high-temperature bornite-digenite solid solutions in scavenging noble metals from fluids.