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Lifting the cloak of invisibility: Gold in pyrite from the Olympic Dam Cu-U-Au-Ag deposit, South Australia

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Abstract

"Invisible gold" refers to gold (Au) occurring either within the lattice of a host sulfide or as discrete nanoparticles (NPs, <100 nm diameter) within a host that are only observable when imaged at very high magnifications. Previous research has regarded the physical form of invisible gold to be partially controlled by the concentration of arsenic (As) in the host sulfide, with stability fields for lattice-bound vs. Au-NPs defined by an empirical Au-As solubility curve. We undertook micrometer- and nanoscale analysis of a representative sample of As-Co-Ni-(Au)-bearing pyrite from Cu-mineralized breccias in the deeper part of the Olympic Dam Cu-U-Au-Ag deposit (South Australia) to define the location and physical form of Au and accompanying elements. Trace element geochemistry and statistical analysis show that >50% of pyrites contain measurable Au and As, and plot below the Au-As solubility curve. Au and As are geochemically associated with Te, Bi, Pb, Ag, and Sn. Primary oscillatory zoning patterns in pyrite defined by As-Co-Ni are reshaped by processes of dissolution-reprecipitation, including new nanoscale growth and rhythmical misorientation structures. Low-angle slip dislocations, twist-wall boundaries and deformation-dipole nanostructures are associated with Te-Bi-Pb-enrichment and host Au-Ag-telluride nanoparticles (NPs). Electrum NPs occur associated with pores coated by Bi-Ag-tellurides or within chalcopyrite particles. Bi-Pb-sulfotellurides, petzite, and sylvanite were identified by atomic-scale scanning transmission electron microscopy. The data support trace element (re)mobilization during pyrite deformation at the brittle to ductile transition (0.5–1 kbar, 300–400 °C) during brecciation. Au-NP formation is decoupled from initial As incorporation in pyrite and instead fingerprints formation of strain-induced, chalcogen-enriched nanoscale structures. Pore-attached NPs suggest scavenging of Au by Bi-bearing melts with higher rates of fluid percolation. Similar scenarios are predictable for pyrite-hosted "invisible Au" in pyrite from other deposits that experienced multiple overprints. Unveiling the cloak of invisibility using contemporary micro- to nano-analytical techniques reveals new layers of complexity with respect to the trace/minor element incorporation in mineral matrices and their subsequent release during overprinting.

Keywords: Pyrite, invisible gold, Au-Ag-tellurides, Bi-Pb-(sulfo)tellurides, Olympic Dam, HAADF STEM