Occurrence of Invisible Au in Carlin-Type Au Deposits

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A key diagnostic feature of Carlin-type gold deposits is the predominance of invisible gold in arsenian pyrite, contrasting with other gold deposit types. Here, we used the focused ion beam combined with scanning electron microscope (FIB-SEM), spherical aberration-corrected transmission electron microscope (AC-TEM), and atom probe tomography (APT) to examine invisible Au and how it evolved through later geologic events. TEM analyses reveal extensive Au-enriched domains within high-grade arsenian pyrites. These domains exhibit characteristic Au-associated trace element signatures (Sb, Tl, Hg, Cu) in energy-dispersive X-ray spectroscopy (EDS), while showing no detectable metallic nanoparticles. APT data further demonstrate that invisible gold occurs in complex, oscillatory-zoned micro- to nano-scale zones, with Au distributed homogeneously at atomic scales rather than as discrete nanoclusters. Critically, AC-TEM confirms gold's structural incorporation through substitution at iron lattice sites and vacancy positions. The widespread occurrence of stacking faults and nano fluid inclusions in Au-bearing arsenian pyrite indicates rapid crystallization conditions. Curved dislocations pinned by solid inclusions further record subsequent annealing processes.

Combining nanoscale textures with geologic information, we suggest that invisible Au was initially incorporated into the crystal structure of arsenian pyrite during rapid precipitation. Subsequent post-ore thermal events initiated the annealing of the ionic Au-bearing arsenian pyrite, leading to the re-distribution of trace elements and formation of Au-bearing nanoparticles. The dominant occurrence of ionically bound Au in arsenian pyrite indicates that ore-forming fluids were undersaturated with respect to gold during pyrite crystallization. This gold deposition from Au-undersaturated, As-rich ore fluids ultimately produced the giant Carlin-type gold deposits.