The Electrochemical Flocculation of Colloidal Gold by Semiconductive P-Type Pyrite: A Novel Ore-Forming Mechanism for Gold

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A growing body of evidence suggests that bonanza-grade hydrothermal gold deposits are formed by the physical transport of gold as a colloid (i.e., a suspension of ≤10 nm, negatively-charged nanoparticles in an electrolyte solution) rather than direct deposition from dissolved, aqueous Au complexes. While there is general consensus that colloidal suspensions can explain how gold may be mobilised within hydrothermal systems at concentrations many orders of magnitude greater than those predicted by solubility models, there is little consensus over the processes by which colloidal gold suspensions aggregate (i.e., flocculate) to produce ultra-high-grade gold occurrences in hydrothermal veins. Detailed paragenetic observations at the high-grade Brucejack Au-Ag deposit, northwestern British Columbia, Canada, show that ore-stage epithermal carbonate-quartz-electrum veins commonly host bonanza gold where these veins cross-cut earlier mesothermal pyrite veins. This observation, coupled with the discovery of abundant arsenic-rich growth zones in pyrite during LA-ICP-MS and EMP-WDS trace element analyses, offers insight into how such flocculation might occur. We propose that positively charged surfaces on arsenian pyrite, which behave as a p-type semiconductor (due to As substitution in the sulphide structure), promote cationic bridging and electrochemically destabilise colloidal gold suspensions circulating in epithermal carbonate-quartz veins. This destabilisation triggers flocculation (deposition) of the colloidal gold particles and explains why, at Brucejack, many spectacular gold occurrences appear to have been triggered by the intersection of ore-stage epithermal veins with earlier pyrite veins. This genetic model offers a novel explanation for how bonanza gold may form paragenetically late in hydrothermal ore deposits, i.e., after most sulphide mineral deposition has occurred, without the need for phase separation (boiling) or the presence of steep physicochemical gradients. Moreover, it can also be used to predict the potential locations of bonanza gold occurrences from the block-modelled distribution of arsenic based on exploration and resource drill data.