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Chlorite Composition: Insights into Fluid Evolution and Gold Precipitation at the Jinshan Gold Deposit, South China

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The physicochemical controls on gold precipitation in orogenic gold deposits remain poorly constrained, with traditional fluid inclusion and isotopic studies often yielding ambiguous results due to overprinting or incomplete records. This study addresses this challenge using chlorite—a sensitive mineral proxy for fluid conditions—as a quantitative sensor in the Jinshan orogenic gold deposit (>200 t Au) of the Jiangnan orogenic belt, South China. Hosted in Neoproterozoic phyllite within NE–NNE-trending ductile–brittle shear zones, Jinshan features auriferous quartz–polymetallic sulfide veins with prominent chlorite alteration. Integrating high-resolution SEM-EPMA analyses of multi-generational chlorite with thermodynamic modeling, we reconstruct the temporal evolution of temperature, oxygen fugacity (fO_2), pH and sulfur fugacity (fS_2) during ore formation. Four paragenetic stages are identified: Stage 1 (ankerite–quartz), Stage 2 (pyrite–arsenopyrite–quartz), Stage 3 (quartz–gold–polymetallic sulfide), and Stage 4 (chlorite–carbonate–quartz). Chlorite from Stage 2 (Chl-1) formed metasomatically at low fluid/rock ratios, while Stage 3 and 4 chlorites (Chl-2 and Chl-3) precipitated directly from higher fluid/rock ratio fluids. Chlorite compositions record a critical Stage 2–3 transition involving cooling from ~ 320 °C to ~ 260 °C, reduction (log fO_2 from –33.6 to –39.7), and alkalinization, and sulfur fugacity remained stable within a narrow range (log fS_2 = –13.6 to –8.0), followed in Stage 4 by minor reheating to ~280 °C, re-acidification, and a slight rebound in oxygen fugacity. Thermodynamic simulations reveal that the destabilization of $Au(HS)_2^-$ complexes, primarily driven by the synergistic effects of cooling, pH increase, and decreasing oxygen fugacity, triggered gold precipitation during the main ore stage. Results demonstrate that abrupt cooling coupled with fluid alkalinization and reduction exerted the dominant control on gold precipitation in Jinshan, resolving long-standing debates on ore-forming mechanisms and highlighting chlorite as a robust quantitative sensor for fluid evolution.