

Tracing Hydrothermal Evolution and Exploration Targets in Early Neoproterozoic Gold Deposits (Brazil): $\delta^{65}\text{Cu}$ Isotopic Signature Gold from Serra Dourada

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Understanding the evolution of hydrothermal systems in orogenic gold deposits is an important tool for exploration and for developing new strategies to prospect ancient and deeply systems. In this context, three levels of the Serra Dourada deposit were investigated through microthermometry of hydrothermal quartz and compositional, isotopic ($\delta^{65}\text{Cu}$), paragenetic, and morphological analyses of gold. Fluid inclusions indicate an aqueous–carbonic fluid, rich in CO_2 , of low salinity, with minimum trapping temperatures of 365°C and 225°C during the early and late stages of the hydrothermal system, respectively. From the deeper to the shallower levels of the deposit, the analyzed gold defines three populations: P1=Au(100): $\delta^{65}\text{Cu}$ (+0.30‰); P2=Au(98.90–100):Ag(0–1.40):Cu(0–0.07): $\delta^{65}\text{Cu}$ (+0.10‰):(cassiterite); P3=Au(87.00–100):Ag(0–13.00):Cu(0–0.16): $\delta^{65}\text{Cu}$ (–1.45‰):(pyrite–cobaltite). These groups reveal a compositional and isotopic zoning of the deposit from deeper to shallower levels. The fluid inclusion trapping temperatures, the chemical signature of gold controlled by the thermodynamic behavior of the Au–Ag–Cu system, and mineral inclusions act as markers to trace progressive cooling and variations in the redox conditions of the hydrothermal fluid. The high purity of P1 and its positive $\delta^{65}\text{Cu}$ values reflect relatively high oxygen fugacity ($f\text{O}_2 \approx -35$) and elevated temperatures in the deeper parts of the system. In P2, the intermediate level, the increase in Ag and Cu contents, together with positive $\delta^{65}\text{Cu}$ values and cassiterite inclusions, marks stabilization of the system under moderately oxidizing conditions ($f\text{O}_2 \approx -26$) and decreasing temperature. In P3, the shallowest level, higher Ag contents in gold record cooler stages of the hydrothermal system. The negative $\delta^{65}\text{Cu}$ values indicate a shift toward more reducing conditions, supported by the pyrite–cobaltite paragenetic equilibrium suggesting $f\text{S}_2 \approx -8$ and temperatures around 220°C. These results highlight the sensitivity of Cu isotopic fractionation to variations in hydrothermal systems and its potential as a tracer for reconstructing mineralizing fluids.