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On Hydrodynamic Factors Influencing Gold Mineralization: Insights from Reactive Flow Modeling

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Gold mineralization is a product of subsurface fluid flow, heat transport, fluid-rock reaction, and related changes in physico-chemical conditions of the ore-forming fluids. Hydrodynamic factors influencing gold mineralization, however, remain unclear. Reactive fluid flow modeling was performed, for the first time, to address these factors by developing conceptualized models based on the constraints of the Jiaojia gold deposit in the Jiaodong Peninsula, China. These models include a metamorphic rock cover, dipping faults, and a granite basement that align with field observations. Our numerical modeling results indicate that ore-forming fluids flow upwards along the fault due to thermally induced buoyancy. In the absence of magnetite, biotite dissolution occurs in the fault zone and granite basement, releasing Fe^{2+} into the solution which leads to pyrite precipitation in the fault. Fluid-rock reaction causes gold precipitation and enrichment in the fault, coexisting with sericite precipitated from the solution. In the presence of magnetite, however, biotite precipitation, instead of dissolution, occurs throughout the entire model domain. In this case, Fe^{2+} released from the dissolution of magnetite causes pyrite precipitation within the fault. The presence or absence of magnetite does not appear to affect the distribution of precipitated gold and sericite. The greater the dip angle of the fault, the higher the grade of the gold ore. In step-fault zones, significant gold mineralization tends to occur in the steeper segments of the fault. The greater the fault permeability, the higher the grade of the gold ore. When the fault permeability is high up to 1.0×10^{-12} m^2, fluid circulation occurs within the fault zone, instead of unidirectional upward flow, resulting in discrete mineralization therein. A more permeable granite basement is conducive to gold mineralization, thus forming larger and higher-grade gold deposits. On the other hand, the permeability of the metamorphic cover appears to have a negligible impact. Temperature is another important factor influencing gold mineralization. Lower geothermal gradients favor the formation of large but low-grade gold deposits in deeper areas, while higher geothermal gradients favor the formation of small but high-grade deposits in shallower areas. These findings have important implications on field exploration for high-grade gold.