Alteration-Derived Volume Changes Control the Location of Iron Oxide-Cu-Au Mineralization

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Iron oxide-copper-gold (IOCG) deposits are a key source of copper crucial for the energy transition. The Ernest Henry deposit in Queensland, Australia, is the region’s largest IOCG system. Early deposit formation models emphasized hydrothermal brecciation and magnetite–chalcopyrite infill with limited overprinting, contrasting with tectonic brecciation and alteration-related mineralization models but aligning with the role of structures in focusing fluid flow and Cu deposition.

This study synthesises published data from >200 samples, including modal mineralogy, inferred magnetic fabrics, and combines them with thermodynamic modelling to evaluate alteration and porosity evolution at Ernest Henry. Alteration halos, marked by systematic changes in mineralogy, geochemistry, porosity, and petrofabric intensity, are gradational and cross lithological boundaries and structures. High-grade Cu–Au mineralization is associated with a recognizable hydrolytic alteration overprint of pre-Cu Na–Fe and syn-Cu K–Fe alteration assemblages.

The thermodynamic modelling of sequential Fe–K alteration (stage I) and hydrolytic fluid-rock interaction (stage II) involved two fluids, both approximating fluid compositions published from IOCG deposits. Stage I interaction of Na–Fe–K–S–CO_2–Cl fluids (200 ppm Cu) with albite + magnetite host rock at 300–400 °C yields, depending on the fluid/rock ratio, dominantly K-feldspar + magnetite with un- to subeconomic chalcopyrite grades. Stage II alteration by acidic, low Cl-salinity Na–Mg–SO_4 fluids (500 ppm Cu) at 225–250 °C enhances Cu deposition to the observed chalcopyrite grades, reproduces key mineral assemblages, their concentrations and distribution determined.

High-grade chalcopyrite distribution reflects mineralogical and porosity changes caused by K–Fe and hydrolytic alteration, including partial destruction of magnetite and K-feldspar. This generates porosity in ore zones, enhancing permeability, while porosity decreases in alteration halos nearby.

These findings, along with subtle changes in magnetic fabrics, show that structural preparation and alteration-induced porosity–permeability changes jointly control high-grade Cu mineralization.