

Coeval Porphyry Cu-Au-Mo and Iron-Oxide Copper Gold Mineralization in the Llahuín-El Espino District, Chile

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Porphyry and iron oxide-copper-gold (IOCG) deposits are typically viewed as distinct mineral systems due to their contrasting tectonomagmatic requirements, yet their spatial overlap in metallogenic transition zones suggests a shared geodynamic evolution. The Llahuin Cu-Au-Mo deposit displays mixed characteristics of both porphyry and IOCG systems, involving several overprinting stages where the absolute chronology and genetic relationship between pulses remain poorly constrained. We integrate multivariate magnetite trace-element chemistry with in-situ U–Pb titanite and rutile petrochronology to resolve this complex hydrothermal history and its relationship to the neighboring El Espino IOCG system. We identified a persistent porphyry-style geochemical footprint within the magnetite that was preserved despite significant textural and chemical re-equilibration. Hydrothermal titanite (88.0–85.6 Ma) and rutile (84.8 Ma) ages anchor this porphyry mineralization to a district-scale magmatic pulse coeval with the mineralization at El Espino. These results demonstrate that porphyry and IOCG mineralization can form coevally during major tectonic reorganization as magmatic-hydrothermal fluids utilize inherited structural pathways. By characterizing these systems as temporally linked facies of an evolving arc architecture, this study highlights the role of metallogenic inheritance in the concentration of copper. Recognizing the transition between IOCG and porphyry environments as a process-driven shift in the volatile and sulfur budget within shared plumbing systems provides a robust framework for exploration in transitional magmatic-hydrothermal environments globally.