

How Arcs Become Ore Factories: The Iron-to-copper Transition and the Emergence of Arc Fertility in the Andes

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Understanding why only a minority of arc magmatic systems evolve into major ore districts remains a central question in economic geology. Addressing this question requires examining arc segments where the development of ore-forming conditions can be tracked through time. The Coastal Cordillera of northern-central Chile, west of the Andean Cordillera, provides a natural laboratory to examine how arc systems progressively develop conditions for large-scale metal concentration.

The Coastal Cordillera forms part of a Mesozoic metallogenic belt extending from southern Peru to central Chile and hosts diverse deposit types, including IOA, IOCG, and porphyry Cu systems. This diversity reflects a long-term progression in magmatism and tectonics that drove a transition from Fe-rich, Cu-S-poor systems toward increasingly Cu- and S-rich ore deposits. These systems represent an early stage in the metallogenic evolution of the Andean margin that preceded the giant Cenozoic porphyry belts of the Main Cordillera.

Mineral-scale geochemical archives, particularly zircon petrochronology, provide key insights into this evolution. Early arc stages associated with IOA systems (~135–125 Ma) developed in relatively thin crust and were characterized by high-temperature magmas (~750–850 °C), near-FMQ conditions ($\Delta\text{FMQ} \approx -1$ to $+1$), and low apparent hydration (≤ 0.4 Eu/Eu*), favoring magnetite-dominant mineralization with limited Cu transport. During the IOCG stage (~125–115 Ma), increasing horizontal stress and crustal thickening produced cooler but more hydrous and oxidized magmas (~650–750 °C; ≥ 0.4 Eu/Eu*), enhancing volatile fluxes and Cu mobility. In this more evolved stage, oxidized and volatile-rich magmas ($\Delta\text{FMQ} \approx +1$ to $+2$) produced early porphyry Cu systems (~115–90 Ma), with the Atacama Fault System acting as a transcrustal conduit for magma ascent and hydrothermal fluid flow.

Construction of the Mesozoic Coastal Cordillera preconditioned the Andean margin for giant Cenozoic porphyry belts, highlighting arc fertility as an emergent property of the long-term interaction among tectonic, magmatic, and surface processes.