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Chronology and geochemical rates of supergene copper enrichment in porphyry deposits from the Coastal Cordillera, north-central Chile

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Copper (Cu) is essential for the low-carbon energy transition [1]. Many of the world's largest Cu deposits formed through a two-stage process: initial hypogene Cu-Fe sulfide mineralization, followed by supergene Cu enrichment. This enrichment occurred near the Earth's surface due to uplift and climate-driven chemical weathering, leading to a 3 to 4-fold increase in Cu grade, ensuring economic viability [2].

Supergene enrichment is key to the Chilean Andes, the world's most productive Cu province. Despite its significance, key questions remain about the origin and timing of supergene Cu enrichment in the Mesozoic Coastal Cordillera of north-central Chile. This metallogenic belt, west of the Andes, hosts porphyry Cu, IOCG, and stratiform Cu deposits of Jurassic-Cretaceous age. However, the supergene history of this older province is less understood compared to the Cenozoic belt, leaving questions about the geological controls on Cu enrichment, and its connection to Cenozoic uplift and climate.

To address these questions, we are conducting a geochemical study of supergene profiles from porphyry Cu and IOCG deposits within the belt. This includes high-precision $^{40}Ar/^{39}Ar$ dating of alunite and jarosite, coupled with stable isotope analyses (δD, $\delta^{18}O$, $\delta^{34}S$) to determine the timing and conditions of supergene Cu enrichment. These data, along with field observations and mineralogical characterization, are used to calibrate reactive transport models to numerically simulate Cu enrichment scenarios.

Supergene chronology data from porphyry Cu deposits in the Domeyko area (~28ºS) was obtained from drill core samples cross-cutting supergene profiles exceeding 100–200 m. The ages range from ~15 Ma to as young as ~1 Ma, suggesting a protracted enrichment process. Given that supergene enrichment in the Atacama region (~23ºS) peaked at ~25–15 Ma, before the onset of hyperaridity, our results suggest a comparatively younger enrichment history in the Domeyko area, with hydrological conditions favorable for Cu remobilization and reprecipitation. We expect our data to provide a framework to aid exploration strategies for new Cu resources in the belt.

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[2] Gleeson, S., Perez-Fodich, A., Reich, M. (2025) Treatise on Geochemistry, 3rd Ed. v. 2.