Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.33222

How long and under what geochemical conditions do supergene profiles form in porphyry copper deposits?

MARTIN REICH[1], ANTONIA B. CLERICUS CASTILLO[1], MIGUEL ANTUNEZ[1], FERNANDO BARRA[1], ALIDA PEREZ-FODICH[1], IRENE DEL REAL[2] AND BRIAN JICHA[3]

[1]Universidad de Chile
[2]Pontificia Universidad Católica de Chile
[3]University of Wisconsin-Madison

Supergene processes drive oxidation and leaching of primary hypogene Cu-Fe sulfide mineralization, producing a Cu-rich, vertically stratified profile capped by a leached zone dominated by Fe oxides/hydroxides and sulfate minerals [1]. These near-surface modifications are controlled by uplift and climate-driven chemical weathering, and play a key role in determining the economic potential of porphyry Cu deposits [2].

The timescales and geochemical conditions required for the development of high-grade supergene enrichment blankets under variable tectono-climatic regimes remain poorly constrained. Available geochronological data in the world-class Andean province are largely restricted to surface exposures in isolated deposits, distributed sparsely across extensive regions. With some notable exceptions [3], systematic geochronological constraints across vertical profiles remain largely absent, leaving unresolved questions about the rates of oxidation, leaching, and Cu enrichment at depth.

We conducted a geochemical study of the supergene profile at the Cretaceous Dos Amigos porphyry Cu deposit in the Coastal Cordillera of northern Chile. We took advantage of a ~250 m-long drill core that crosscuts the supergene zone and provides continuous vertical coverage through the weathered profile. Supergene alunite [$KAl_3(SO_4)_2(OH)_6$] is abundant along the profile and occurs in cm-scale veins, offering a unique opportunity to evaluate weathering processes at depth.

High-precision $^{40}Ar/^{39}Ar$ dating of alunite defines an inverse age-depth gradient, with older ages at the top (~15 Ma) and younger ages at the bottom (~1 Ma) of the profile. A linear age-elevation relationship yields a profile deepening rate of ~7 m/Ma, consistent with previously reported local denudation rates [4]. Furthermore, stable isotope data (δD, $\delta^{18}O$, $\delta^{34}S$) of alunite across the profile reflect both fluid source effects and isotopic fractionation processes driven by evolving hydrologic conditions that controlled Cu mobilization and reprecipitation. Together with ongoing reactive transport modeling, these data allow quantification of Cu upgrading mechanisms and rates during supergene enrichment.

[1] Gleeson, S., Perez-Fodich, A., Reich, M. (2025) Treatise on Geochemistry, 3rd Ed. v. 2.
[2] Reich, M., Simon, A.C. (2025) Ann. Rev. Earth Planet. Sci., v. 53.
[3] Shaw et al. (2021) G^3 22, e2021GC009759.
[4] Krone et al. (2021) Sci. Rep. 11, 1305.