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Climate Change, Groundwater Flow, and Supergene Enrichment in the Central Andes: Insights from (U-Th)/He Hematite Geochronology

Frances Cooper,[1,*] Byron Adams,[2] Jon Blundy,[1] Ken Farley,[3] Ryan McKeon,[4] and Alberto Ruggiero[5]

[1]University of Bristol, School of Earth Sciences, Bristol, United Kingdom
[2]University of Tübingen, Department of Geosciences, Tübingen, Germany
[3]California Institute of Technology, Department of Geological and Planetary Sciences, Pasadena, CA, USA
[4]Dartmouth College, Department of Earth Sciences, Hanover, NH, USA
[5]BHP Billiton, Copper Exploration, Las Condes, Santiago, Chile

*Corresponding author: e-mail, frances.cooper@bristol.ac.uk

The western margin of the Central Andes has an arid climate that is thought to have persisted since at least ~15 Ma, and yet the region also hosts a number of porphyry copper deposits with well-developed supergene enrichment blankets that must have formed when the climate was wetter (e.g., Chuquicamata, La Escondida, and Cerro Colorado). While it has been suggested that the onset of aridity at ~15 Ma was caused by the rain shadow created by uplift of the Andes in the late Oligocene, others have suggested that the arid climate could have already been established by Eocene time. Determining the precise relationship between Andean uplift, aridity, and the cessation of supergene mineralization in northern Chile is of fundamental importance for our understanding of porphyry copper enrichment and could inform future exploration strategies in the region.

In this study, we place direct constraints on the timing of climate aridification in northern Chile by tracking the downward migration of the water table in the Cerro Colorado leached cap using (U-Th)/He hematite geochronology. The hematite formed by reaction of oxygenated groundwater with ferrous-bearing minerals, such as pyrite and chalcopyrite, above the redox interface at the water table. In the reducing environment below, this process was unable to continue, and, thus, the depth of hematite precipitation as a function of time can be used to constrain the relative movement of the water table.

Nine samples collected from vertical drill holes through the ~50- to 200-m-thick leached cap yielded ages from 30.82 ± 1.54 to 2.12 ± 0.35 Ma (2σ), suggesting that hematite precipitation has been continuous at Cerro Colorado since at least ~31 Ma, and was broadly commensurate with growth of supergene alunite and jarosite until ~14 Ma. After ~14 Ma, alunite and jarosite precipitation appears to have ceased, indicating an end to supergene mineralization. This coincides with the start of a downward younging trend in our data that implies a slow and steady lowering of the water table at a rate of ~11 m/m.y. until the present day. We relate this lowering to the incision of a local canyon in response to the onset of aridity and suggest that it could be linked to the shutting off of supergene mineralization at this time.