The Role of Exhumation in Generating High-Grade Copper Deposits: Insights from the Central Andes, Northern Chile

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Copper is a vital part of the global effort to transition to a greener, low-carbon economy. Today, most copper derives from magmatic-hydrothermal porphyry copper deposits (PCDs), which are typically associated with subduction zones. However, there are two problems: (1) finding PCDs is increasingly difficult because the relatively easy surface deposits have already been discovered; and (2) they are notoriously low grade (≲1% Cu), so large volumes of rock must be removed to retrieve a tiny amount of copper. With global demand set to double by 2035, mining companies must not only seek more elusive, buried deposits, but also those that will have the least environmental impact. To achieve this means finding regions likely to host the highest-grade deposits (≳1% Cu) that require the smallest amount of extraction. Determining the exhumation history of an area could provide a critical tool to assist in this effort by significantly narrowing down potential search space.

The exhumation history of a PCD plays an important role in determining its copper grade. During the initial hypogene stage of mineralisation, rapid exhumation is required to advect heat towards the surface, allowing metal-carrying magmas and fluids to transport their cargo into the shallow crust. To achieve maximum ore grade, exhumation must then slow considerably so the deposit can linger close to the surface, where supergene enrichment by meteoric water takes place. We present an example from the Middle Eocene-Early Oligocene copper belt in northern Chile, which hosts the world-class Chucquicamata and Escondida deposits. By combining U-Pb zircon geochronology, Al-in-hornblende geobarometry, low-temperature thermochronology, and thermal-kinematic modelling, we track spatial-temporal patterns of exhumation. Our results suggest that both the rate and timing of exhumation are critical in determining the potential of an area to host high-grade PCDs and should be considered when scoping out new targets for exploration.