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Exhumation of Andean granites: Implications for porphyry copper formation and enrichment

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Porphyry copper deposits are typically thought to form only a few km beneath the Earth's surface, associated with granitic host rocks. They are subsequently exhumed to the surface, where they may undergo secondary enrichment by meteoric fluids or be completely removed by erosion. The rate at which exhumation occurs is therefore a critical factor in the potential for supergene enrichment, preservation at the surface, and possibly also for primary hypogene mineralization. Rapid exhumation during the supergene enrichment stage leaves little time for the system to interact with the water table to produce mature enrichment blankets before the ore is eroded at the surface. However, if rapid exhumation occurs during the hypogene stage it may result in telescoping of the ore, which can be of economic importance because of the potential for enrichment as the deep porphyry mineralization is overprinted by shallow epithermal precious and base metal mineralization.

We present a regional study of granite exhumation rates across northern Chile, focusing on spatial and temporal patterns of exhumation in both barren and mineralized areas along the Eocene – Oligocene metallogenic belt. Zircon U-Pb geochronology is combined with Al-in-hornblende geobarometry to pinpoint the time and depth of granite emplacement. Various thermochronology techniques are then used to track cooling through the low temperatures of the upper few kilometers of the crust. We present new LA-ICP-MS U-Pb zircon ages for granitic intrusions collected near the Collahuasi and Queen Elizabeth porphyry copper deposits, and from drill holes close to the Chile-Peru border. Plutons were found to be Eocene (39 – 51 Ma), with the exception of one pluton of Permian age (294 Ma), and two previously unrecognized plutons of Triassic age (240 Ma). Emplacement depths for eight of these intrusions were calculated using a revised version of the Al-in-hornblende geobarometer calibrated for shallow intrusions. The Eocene, Triassic, and Permian plutons all show very similar emplacement depths of 5 – 7 km, suggesting little exhumation of the older plutons between the Permian and the Eocene. However, apatite fission track results indicate that rapid exhumation of the region occurred in the late Eocene, cooling through ca. 110°C around 36 – 39 Ma. Apatite and zircon (U-Th)/He thermochronology analysis will further constrain the exhumation histories of these intrusions permitting a comprehensive spatial and temporal history of exhumation that can be integrated with the mineralization record along the Eocene – Oligocene porphyry copper belt of northern Chile.