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Petrochronology resolves the multi-Myr crustal scale magmatic evolution of an arc segment resulting in porphyry copper formation

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The crustal-scale magmatic systems of Andean-style subduction zones produce thick volcanic deposits and abundant plutons emplaced into the upper crust. They can also result in the formation of spatially- and temporally-restricted, economically-important porphyry Cu deposits. Understanding the magmatic and tectonic processes acting within an arc segment, including changes in the fractionating assemblage, subduction angle, chemistry of slab-derived melts or water content, is essential to develop and refine quantitative models for the formation of these deposits. Specific geochemical signatures (e.g. elevated Sr/Y) are associated with magmas that source the metals and volatiles to form porphyry deposits based on empirical studies. However, it is unclear whether this geochemical signature is the result of geologically rapid processes resulting in sudden shifts in magma chemistry or whether they are the result of protracted changes within the crustal-scale magmatic system over extended timescales.

In this study we examine the magmatic evolution of the Rio Blanco-Los Bronces district, ~30 km northeast of Santiago, Chile, which is host to the Earth's largest resource of Cu. Eocene to Early Miocene volcanic rocks were intruded by the Miocene San Francisco Batholith that, in turn, partially hosts intrusions related to the Late Miocene to Early Pliocene Rio Blanco-Los Bronces porphyry deposit cluster. We apply a combination of whole-rock and zircon geochemistry, isotopic tracing and LA-ICP-MS U-Pb geochronology to the intrusive rock suite of the district to provide temporally- constrained geochemical information over the entire duration of batholith assembly and ore formation.

U-Pb geochronology reveals incremental assembly of the San Francisco Batholith by individual magma batches over >13Myr (~17 – 4 Ma), with ore formation occurring in discrete pulses in the last 3 Myr before cessation of intrusive activity within the district. Temporally-resolved whole-rock major element chemistry shows that the progressively-emplaced magmas were not sourced from a common, continuously differentiating, lower crustal magma reservoir. Evolving trace element signatures over the recorded timescale indicate that magmas were sourced from progressively deeper fractional crystallisation reservoir(s) that exhibited increasing water contents. The geochemical evolution recorded over the entire investigated 13 Myr timescale could reflect

geodynamic changes linked to the ingression of the subducting Juan Fernandez ridge from the north. However, within this continuous evolution, the most prominent geochemical shifts occur over a much shorter timescale of a few Myr, directly preceding economic ore-formation, implicating an additional mechanism for controlling the metallogenic potential of the magma source.