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Petrological and zircon chemical record of arc magma evolution from long-lived batholith construction to giant porphyry copper deposit formation

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Porphyry Cu ore deposits are a rare product of arc magmatism that often form spatiotemporal clusters in magmatic arcs. The petrogenetic evolution of igneous rocks that cover the temporal window prior to and during porphyry Cu deposit formation may provide critical insights into magmatic processes that are key in generating these systems. This study documents the magmatic evolution of the Palaeocene-Eocene Yarabamba Batholith, Southern Peru, that was incrementally assembled between ~67 and ~59 Ma and hosts three, nearly contemporaneous, giant porphyry Cu-Mo deposits that formed at 57-54 Ma (Quellaveco, Toquepala and Cuajone). Whole-rock geochemistry, U-Pb geochronology and zircon trace element chemistry are reported from Yarabamba rocks that span the duration of plutonic activity, and from six porphyry intrusions at Quellaveco that bracket mineralisation. A change in whole-rock chemistry in Yarabamba intrusive rocks to high Sr/Y, high La/Yb and high Eu/Eu* is observed at ~60 Ma which is broadly coincident with a change in vector of the converging Nazca plate and the onset of regional compression and crustal thickening during the first stage of the Incaic orogeny. The geochemical changes are interpreted to reflect a deepening of the locus of lower crustal magma evolution in which amphibole ± garnet are stabilised as early and abundant fractionating phases and plagioclase is suppressed. Zircons in these rocks show a marked change towards higher Eu/Eu* (>0.3) and lower Ti (<9 ppm) compositions after ~60 Ma. Numerical modelling of melt Eu systematics and zircon-melt partitioning indicates that the time series of zircon Eu/Eu* in these rocks can be explained by a transition from shallower, plagioclase-dominated fractionation to high-pressure amphibole-dominated fractionation at deep crustal levels from ~60 Ma. Our modelling suggests that any redox effects on zircon Eu/Eu* are subordinate compared to changes in melt composition controlled by the fractionating mineral assemblage. We suggest that growth and intermittent recharge of the lower crustal magma reservoir from ~60 Ma produced a significant volume of hydrous and metallogenically fertile residual melt which ascended to the upper crust and eventually generated the three giant porphyry Cu-Mo deposits at Quellaveco, Toquepala and Cuajone from ~57 Ma. Our study highlights the importance of high-pressure magma

differentiation fostered by strongly compressive tectonic regimes in generating world-class porphyry Cu deposits.