

Porphyry Copper Formation Driven by Water-fluxed Crustal Melting During Flat-slab Subduction: Insights From the Laramide Belt, SW USA

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The prevailing view of porphyry copper formation along convergent plate boundaries involves deep crustal differentiation of metal-bearing juvenile magmas derived from the mantle wedge above a subduction zone. However, many major porphyry districts formed during periods of flat-slab subduction when the mantle wedge would have been reduced or absent, leaving the source of the ore-forming magmas unclear. A key example is the Late Cretaceous-Palaeocene Laramide Porphyry Province in Arizona, which formed during flat-slab subduction of the Farallon Plate beneath western North America between ca. 75-50 Ma. By combining geochronology, thermobarometry, and isotope geochemistry to investigate the deep crustal processes taking place during Laramide porphyry mineralisation, we show that the Laramide granitic host rocks did not derive from the mantle wedge, but instead from a Proterozoic crustal source that was potentially pre-enriched in copper. This source underwent water-fluxed melting between ~73 and 60 Ma, coincident with peak granitic magmatism (~78–50 Ma), porphyry genesis (~73–56 Ma), and flat-slab subduction (~70–40 Ma). This petrogenetic model is further supported by low Ti concentrations in zircon (>6 ppm Ti) from syn-mineral and peraluminous granites across which requires magmas to be 'super wet' (>6 wt% H₂O). Contrastingly pre-mineral intrusions and volcanics have much higher Ti concentrations in zircon due to hotter and drier (<2 wt% H₂O) magma associated with pre-cursor steep subduction. To explain this data, we propose that water-fluxed crustal melting occurred in a geodynamic 'sweet spot' located directly above the leading edge of the flat-slab at the point the subducting slab was shallowing from a steep to low angle geometry. The Central Andes show similar spatial-temporal magmatic and mineralization trends, invoking a similar flat-slab regime associated with Late Eocene–Miocene porphyry copper formation. We therefore propose flat slab regimes to be important areas for future mineral exploration targeting.