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Timescales and Processes of Au- and Cu-Fertile Magmatic-Hydrothermal Reservoir Accumulation in Continental Arcs

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Continental arc systems are loci of world-class Cu-Au porphyry and intrusion-related orogenic Au vein deposits. The subduction environment facilitates high magma and fluid fluxes, acting as a heat engine and promoting metal transport. How and when, during the lifetime of an accretionary orogen, Cu and Au fertile magmas are generated and ore-producing fluids are expelled remains elusive.

We present combined structural, geochemical, and zircon trace element, U/Pb and Lu/Hf isotope data from the Carboniferous Eastern Andean Cordillera, northern Perú. Our geochemical data demonstrate that primitive, mantle-derived calc-alkaline diorite magmas are hydrous, oxidized, and enriched in metals (Cu, Au) but lack evidence for crustal assimilation. Field relationships indicate repeated intrusion of these fertile magmas into midcrustal levels. Hornblende-dominated crystallization and fractionation led to successive batch segregation of granodiorite melt upon diorite recharge. Petrographic observations attest to hornblende textural breakdown during magmatic recharge, providing a mechanism for ore-fluid expulsion in the plutonic realm.

Zircon U-Pb dates cover the entire ~370-310 Ma evolution of the Eastern Andean Cordillera (Fig. 1). Age peaks indicate magmatic pulses of 2-5 m.y. duration, followed by 3-4 m.y. gaps that correlate with truncation of zircon internal growth structures. Concomitant to magma recharge, subsets of distinct zircon domains display trace element concentrations indicative of interaction with hydrothermal fluid.

Based on zircon Hf isotope evolution, a slightly unradiogenic source component ($\varepsilon Hf_{(i)} = -2$) at 370 Ma is inferred (Fig. 1). We interpret this signature as representing a mantle source that was already fertile at the onset of subduction-related melt generation. Source fertilization is ascribed to influx of incompatible elements and metals derived from subducted sediments. Most juvenile $\varepsilon Hf_{(i)}$ zircon values indicate that the source fertility diminished over time, with $\varepsilon Hf_{(i)}$increase to +4 until 342 Ma (Fig. 1). This may be due to (i) consumption of subducting sediments or (ii) progressive contribution of uncontaminated asthenospheric mantle. Both scenarios imply slab retreat and associated compressive stress relaxation, supported by structural data. During ~338-332 Ma emplacement of the upper crustal batholith, no juvenile magma input is detected, suggesting magma discharge from the midcrustal reservoir, corroborating subduction cessation and lithospheric relaxation, promoting magma ascent. The world-class Pataz-Parcoy gold vein system formed directly subsequent to batholith emplacement (Fig. 1).

We argue that compressive stresses in continental arcs inhibit magma discharge, allowing for incremental midcrustal fertile reservoir accumulation. Tapping of such reservoirs is triggered once the buoyancy threshold, as a function of prevailing stresses, is overcome. Episodic magmatic activity during subduction may be explained through either (i) episodic partial melt generation, (ii) intracrustal feedback processes driven by magma volume or melt segregation processes, or (iii) external slab-related tectonic events.

Fig. 1. Time chart of the Eastern Cordillera, northern Perú, highlighting episodic magmatic activity associated with incremental midcrustal, fertile reservoir accumulation, and corresponding mantle source depletion (εHf). Progressive slab retreat and lithospheric relaxation led to discharge manifested in volcanism and batholith emplacement and, in response, the formation of the world-class Pataz-Parcoy orogenic-mesothermal gold vein system.