

## **Sulfur and Chlorine in Magmatic Apatite as Tracers of Porphyry-forming Potential in Arc Systems**

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The accelerating global transition toward clean energy has driven an unprecedented surge in copper demand, an irreplaceable metal in electricity generation, transmission, and storage, as known reserves are progressively depleted. Porphyry copper deposits (PCDs), which account for more than 60% of global copper production, represent the primary exploration target to meet this demand.

Their formation is fundamentally linked to the capacity of subduction arc magmas to transport and concentrate metals in hydrothermal fluids during magmatic evolution. An increasing hypothesis holds that PCD-forming fertility of arc magmas may depend on their volatile content, mainly water, sulfur, and chlorine. This study provides a comprehensive evaluation of the chemistry of apatite crystals from barren and PCD-forming magmas to test their role in magmatic fertility and the potential for porphyry deposit targeting.

Our results indicate that apatite from PCD-forming systems systematically exhibits higher sulfur and chlorine contents, as well as more elevated Sr/Y ratios. The higher sulfur contents (up to ~3500 ppm, compared to values below detection limits in barren magmas) likely reflect a more oxidized magmatic environment, providing independent constraints on the elevated oxygen fugacity conditions characteristic of ore-forming magmas. In contrast, the chlorine contents (XCl/XF up to 1.34, relative to a median of 0.19 in barren systems) likely record the chlorine budget of their parental melts, which may facilitate more efficient copper transfer to exsolving fluids. The distinguishably higher Sr/Y ratios (up to 5.2 in ore-forming magmas, compared to 0.17 in barren systems), on the other hand, reflect the geodynamic conditions under which these magmas formed, typically associated with more hydrated systems under a thickened crust or increased compressional regime. These observations suggest that magmatic apatite chemistry is a distinguishing tool between barren and ore-forming systems, with important implications for understanding the magmatic processes underpinning PCDs.