

Copper and Molybdenum Isotope Variation Along a Vertical Transect Through the Epithermal-Porphyry Valeriano Cu-Au System, El Indio-Maricunga Belt, Northern Chile

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The Valeriano epithermal-porphyry Cu-Au system in the Miocene El Indio-Maricunga belt, Vicuña segment, has been intermittently explored for about 35 years, initially for its El Indio-style gold potential. The deep porphyry-Cu(-Au) system at a depth of ~1,000 to >1,800 m, identified in 2012, is overlain by a shallow silicic lithocap, with low-grade epithermal Au-Ag(-Cu) mineralization. A deep drill hole (VALD-D13-14) from the surface down to the porphyry system allows the systematic evaluation of Cu and Mo isotope profiles over the full vertical drill length of ~1,900 m. There is no systematic relationship between $\delta^{65}\text{Cu}$ (-6.46‰ to +2.67‰) and $\delta^{98}\text{Mo}$ (-0.32‰ to +0.27‰) isotope composition and lithology, metal (Cu, Au, Mo) content, and Cu mineral assemblages, but there are relationships between $\delta^{65}\text{Cu}$ - $\delta^{98}\text{Mo}$ and alteration mineral assemblages.

From top to bottom, copper isotopes show an increasing trend in the epithermal system (-6.48‰ to -0.54‰) characterized by dominantly advanced argillic alteration, followed by a narrow enrichment zone with Cu contents up to 2 wt % and $\delta^{65}\text{Cu}$ of -2.84 to +2.67‰, with dominantly phyllic alteration. The transition to the deep porphyry system is characterized by systematic increase in $\delta^{65}\text{Cu}$ values (-2.12‰ to +2.67‰) in phyllic altered rock. The deeper porphyry system has in general a narrow $\delta^{65}\text{Cu}$ range between -0.10‰ and 0.86‰ in mostly potassic altered rock. Propylitic alteration domains in the epithermal system and in the transitional section have heavier Cu isotope compositions, while domains with advanced argillic alteration have lighter Cu isotopes. The epithermal system is characterized by the highest $\delta^{98}\text{Mo}$ values (+0.27‰), whereas $\delta^{98}\text{Mo}$ decreases systematically in the transitional section downwards towards the deep porphyry, a behaviour which can be attributed to Rayleigh fractionation combined with boiling. Advanced argillic alteration displays heavier Mo isotope values, while propylitic alteration has the opposite effect.