

Is the primary sulfur isotope signature of a porphyry Cu-magma preserved in zircon-hosted apatite?

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The mobility of sulfur (S) during magmatic differentiation and degassing is interpreted to facilitate metal transport from silicate melt to magmatic aqueous fluids that are responsible for the formation of magmatic-hydrothermal ore deposits. However, the S budget and isotopic signature of the initial melt, together with constraints on the S sources in porphyry copper environments remain unresolved.

Inclusions of apatite in zircon are an ideal tool to fingerprint the primary volatile components (S, Cl, F, OH) of ore-forming magmas. Once encapsulated in zircon, apatite is prevented from exchanging volatile species with the crystallizing melt, thus being able to retain its early geochemical composition. Conversely, the petrogenetic information of matrix apatite is likely modified during hydrothermal processes.

We measured high precision $\delta^{34}\text{S}$ ratios in apatite via SIMS to elucidate the S isotope signature of apatite inclusions and matrix apatite from the Escondida porphyry Cu deposit, northern Chile. Both mineralised samples and ore-related intrusions were investigated to understand the physico-chemical conditions of the melt and fluid responsible for the Cu-Au mineralisation in Escondida. In mineralised samples, apatite inclusions show fairly homogeneous, positive, $\delta^{34}\text{S}$ values, irrespective of the mineralisation stage recorded in the rock sample (i.e., early porphyry, late porphyry). In contrast, matrix apatite shows a strong zoning in cathodoluminescence (CL). The dark core in CL of matrix apatite shows positive S isotope values, similar to those measured in the inclusions. The CL-lighter rims, instead, record S isotopic ratios trending toward lighter, negative values. Matrix apatite thus records a complex magmatic-hydrothermal evolution contrasting with the apatite enclosed in zircon, which likely recorded the primary melt signature. We demonstrate that sulfur isotope measurements along with detailed mineral chemistry and microtextural studies applied to apatite inclusions in zircon and matrix apatite