Tracing Granite-Hosted Mineralization via Zircon Metal Anomalies

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Granite-hosted magmatic-hydrothermal mineral deposits are major sources of Cu, Sn, Li, and W, originating via mineralizing fluids exsolved from volatile-saturated magmas. We show how trace elements in zircon sampled from the granite-hosted Zaaiplaats Tin Field, Bushveld Complex, South Africa, preserve a record of both incompatible metal enrichment during magma fractionation and that arising from magmatic-hydrothermal mineralization.

Mineralization at Zaaiplaats resulted from closed-system magma differentiation and the eventual appearance of a saline magmatic Sn-rich hydrothermal fluid, which promoted cassiterite precipitation in the central mineralized zone. We sampled across the intrusion, through the magmatic-hydrothermal paragenesis, and, on the basis of mineralogy, subdivided samples into two groups: mineralized and unmineralized.

Unmineralized samples define a fractionation trend on the basis of zircon REE and HFSE arrays. Plots of Sm and Sn versus Gd show consistent trends, where Sn is dominated by Rayleigh Fractionation. In contrast, mineralized samples show enrichment in Sn for the same Gd, attributed to the introduction of an Sn-rich mineralizing fluid resulting from volatile saturation during zircon growth, consistent with the preservation of whole-rock Sn zonation in the Zaaiplaats granites. Zircon Sn/Gd ratios from unmineralized samples define a magma fractionation trend with increasing Y at constant Sn/Gd, whereas those from the mineralized samples are displaced to high Sn/Gd ratios at similar Y, a deviation marking the onset of mineralization processes.

A metal anomaly, Sn/Sn*, is defined that describes the deviation of Sn over that expected through magma fractionation alone (Sn*), and arises from Sn mobilization due to magmatic-hydrothermal mineralization processes. Identification of metal anomalies (e.g., Sn/Sn*, Cu/Cu*) in mineral archives or at the whole-rock level provides an empirical link to the onset of mineralization processes in magmatic-hydrothermal systems and can be coupled with geochemical proxies to yield a better understanding of the conditions leading up to, and subsequent to, volatile saturation.