Garnet Geochemistry as a Tracer of Timing and Fluid Pathways in Pb-Zn Systems

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Garnet can be a powerful tracer of metamorphic and hydrothermal processes in ore systems, preserving chemical and isotopic signatures that reflect its formation conditions and evolution. We present a multi-proxy geochemical study of garnet from two contrasting Pb-Zn deposits in the Eastern Succession of the Mount Isa Inlier: A Broken Hill-type (BHT) system hosted by migmatitic gneisses and a clastic dominated Pb-Zn deposit hosted in shales.

Garnets were collected across ore zones, alteration halos, and distal host rocks, and analysed for major and trace elements (EPMA, LA-ICP-MS), oxygen isotopes (SHRIMP), and Lu-Hf geochronology on selected samples (LA-ICP-MS/MS). In both deposits, garnets near ore show elevated Mn concentrations and $\delta^{18}O$ values up to ~3‰ higher than distal garnets, consistent with metasomatic overprint by external fluids—such as metal-rich evolved basinal brines, Mn-enriched metamorphic fluids derived from dehydrating sediments, or rock-buffered fluids that equilibrated with high-$\delta^{18}O$ sediments. In addition, Zn enrichment in near-ore garnets and, in the shale-hosted system, Lu-Hf ages overlapping with the timing of mineralisation, further support a genetic link between garnet growth and ore-forming processes.

Despite these shared trends, garnets from the two systems show distinct signatures. Notably, in the BHT system, near-ore garnets are also enriched in Ca, display positive Eu anomalies and lower $\delta^{18}O$ values (up to ~11.5‰ vs. ~13.5‰ in the shale-hosted system) possibly reflecting higher-temperature conditions, interaction with Ca-rich lithologies and/or more reducing fluid conditions.

These results demonstrate that garnet Mn contents and elevated $\delta^{18}O$ can serve as reliable path finders to mineralisation. The integration of stable isotope geochemistry, trace element signatures, and in-situ geochronology of garnet provides a robust framework for reconstructing fluid evolution and timing in sediment-hosted ore systems, with garnet offering a unique, time-integrated archive of metal-bearing fluid pathways.