When Dates Lie: The Impact of Mineral Porosity on Isotopic Dating of Base Metal Deposits

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Dating economic mineral systems, such as base metal deposits, poses significant challenges due to the limited availability of conventional geochronometers in ore mineral packages (e.g. zircon, monazite) and the susceptibility of minerals to fluid-induced alteration. Therefore, integrating petrographic observations with in-situ dating is essential for accurately interpreting geochronological data.

Recent advances in laser ablation Lu-Hf and Rb-Sr geochronology offer new opportunities, but this study highlights the limitations of applying these methods to porous minerals. High porosity—a key indicator of coupled dissolution–precipitation replacement—can cause partial isotopic resetting and enhance element mobility below diffusion closure temperatures. Consequently, ages from porous minerals may reflect times between primary crystallisation and later replacement or appear younger due to post-replacement radiogenic loss.

At the Dugald River Zn-Pb-Ag deposit in the Mt Isa Inlier, northwest Queensland, the timing of mineralisation remains poorly constrained. This structurally complex, poly-deformed system has undergone extensive alteration, rendering traditional mineral separate dating ineffective. This study combines ultra-high-resolution BSE imaging with in-situ U-Pb (apatite), Rb-Sr (K-feldspar–muscovite), and Lu-Hf (calcite ± fluorite) geochronology.

Our results identify an albitisation and calcite veining event at ~1535 Ma, and a younger event (~1500–1480 Ma) possibly linked to Zn-Pb mineralisation—providing the first direct age constraints for the Dugald River deposit. These intervals coincide with a regional mineralisation phase at the end of the Isan Orogeny, underscoring its economic significance.

Although U-Pb apatite dating in ore samples was compromised by common Pb, our results suggest that mineral porosity poses an even greater challenge for reliable geochronology. The unclear significance of younger populations (~1430 Ma and ~1140 Ma) in moderately to highly porous minerals highlights this issue. Overall, this study demonstrates the utility of Lu-Hf and Rb-Sr geochronology in complex systems and emphasises the importance of microstructural screening before analysis.