Taking the pulse on garnet through high-precision Lu-Hf domain chronology

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Garnet Lu-Hf chronology is among the most reliable methods to precisely date high-pressure and -temperature metamorphism. This technique is conventionally done on bulk grains or grain populations, providing grain-averaged ages that may not inform on individual pulses of garnet growth. Domain dating —dating of single growth zones— allows such pulses to be dated but is challenging for "common-sized" grains due to sample size requirements and sample loss using conventional micro-mill sampling. To overcome these limitations, we developed a new method that combines low-loss micro-sampling by laser cutting with a refined Lu-Hf routine.

We applied this method to date multiple growth zones in a single 1.3 cm-sized garnet grain from a mica schist from the Schneeberg Complex, Austria. The garnet grain was chemically characterized by major- and trace-element mapping (EPMA, LA-ICPMS) and five compositionally distinct micro-domains were extracted using a laser mill. Each single zone was divided into multiple garnet aliquots to enable multi-point isochrons. The four inner zones, corresponding to ~ 85% of the total garnet volume, yielded identical ages with a weighted mean of 98.4 ± 0.1 Ma (2σ). The outermost zone shows a strong chemical contrast with the rest of the grain, yielding a resolvably younger age of 97.8 ± 0.3 Ma. The timing of distinct garnet-growth episodes, together with the variations in trace-element chemistry, were evaluated in terms of mineral reactions.

Our new protocol for Lu-Hf domain geochronology of "common-sized" garnet allows distinct pulses and pauses of garnet growth to be resolved within less than 1 Ma. The data show that garnet growth in metapelites may take less than 1 Myr and, within that short time, likely progresses in several pulses. Our results demonstrate that garnet growth may occur much faster than changes in P–T conditions caused by tectonic processes. This growth style constitutes a rare opportunity to investigate reaction overstepping and the rapid pushes of the system to attain equilibrium during periods of efficient matrix element transport. High-precision domain dating opens new possibilities not only for precisely determining the pace of tectonic processes but also for bringing unique insights into the causes and rates of garnet growth in metamorphic rocks.