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The petrochronologic potential of LASS-ICPMS U–Pb dating of garnet and evidence for an ultra-high closure temperature

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Garnet is the prime vehicle for *P–T* reconstructions in metamorphic rocks, and has long been targeted for solution-based radiometric dating with the aim of being established as the ideal petrochronometer. At FIERCE, we combine garnet MC-ICPMS U–Pb geochronological analyses with SC-ICPMS chemical major- and trace-element analyses using the laser-ablation split-stream (LASS) method.

As a test case, we applied the method to polymetamorphic garnet from an Antarctic granulite for which the metamorphic evolution had previously been established. Two distinct garnet zones had been identified in the sample [1]. The host rock experienced upper amphibolite-facies metamorphism (790 °C, 0.95 GPa) at a previously unknown age that produced low-Ca garnet cores. This was followed by loading to 1.45 GPa around 590 Ma, severe heating including a short episode (≤1 m.y.) of UHT metamorphism (930 °C) at 570 Ma, with subsequent decompression and cooling [1]. High-Ca garnet rims formed at the higher-pressure event. Metamorphic temperatures in excess of 800 °C prevailed from 593–550 Ma.

Major-element compositions determined by LASS-ICPMS enabled us to identify specific garnet growth zones, while trace-element contents allowed us to discriminate against analyses contaminated by inclusions. Approximately 800 analyses were completed on this sample in the course of two days, of which 2/3 were rejected for their elevated Zr, Ce, Ti, Sr, K or Rb contents. The remaining 272 garnet analyses from both growth zones show low U (0.06–95 ng/g) and Pb (2–400 ng/g) contents.

The Ca-rich rims revealed an age of 591 ±28 Ma (MSWD = 1.6), which is consistent with the published zircon age of high-*P* metamorphism. This demonstrates the accuracy of our method. The relatively large uncertainty may in part reflect the extended growth period of the Ca-rich rims during heating between 593 and 570 Ma. The low-Ca cores show an age of 654 ±7 Ma (MSWD = 1.4), which relates the upper-amphibolite facies metamorphic event to a phase of rifting in the area [2]. Most importantly, the old garnet-core ages were not reset during the subsequent 930 °C UHT-metamorphic event embedded in long-lasting (≥40 m.y.) high-grade metamorphism.

These results demonstrate that the U–Pb system in garnet has a closure temperature at UHT conditions that may only be rivaled by zircon. Consequently, garnet U–Pb ages from crustal metamorphic rocks have to be interpreted as crystallization ages. LASS-ICPMS garnet U–Pb dating thus provides accurate, precise and geologically meaningful insight into the timescales of prograde metamorphism and the *P–T–t* history of polymetamorphic terrains. This opens the door to investigating mountain-*building* processes, where most other petrochronometers only record the collapse and exhumation of orogens.

[1] Pauly et al. (2016) doi: 10.1093/petrology/egw005; [2] Jacobs et al. (2020) doi: 10.1016/j.precamres.2019.105553