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A novel approach to in-situ rutile petrochronology

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Rutile petrochronology has become an increasingly important tool for deciphering the timing and conditions of petrological processes. Rutile provides a reliable single-mineral thermometer, capable of retaining temperature information during high and ultra-high temperature metamorphism. Its HFSE contents can be used to investigate the geochemical environment in which rutile crystallized. Most importantly, rutile strongly fractionates U/Pb and enables U-Pb thermochronology in the intermediate temperature range. Here we present a novel approach to using U-Pb thermochronology of rutile by exploring the use of Pb as a diffusive species in kinetics-based thermometry. We performed high spatial and analytical resolution micro-analysis of rutile by laser ablation multi-collector ICPMS to constrain Pb diffusion profiles in rutile from high-grade metamorphic rocks of the Western Gneiss Complex (WGC), Norway. The age and thermometric results from this analysis are used to constrain a full thermal history from single grains.

Millimeter-sized single crystals of rutile from a rutile-rich phlogopitite vein in eclogite were mounted and polished to expose their geometric cores. The grains were analyzed in transects using rectangular spots (c. 15x45 μm). This ensures ablation of a significant volume while maintaining the required radial spatial resolution. The transects yielded well-defined Pb diffusion profiles, with U-Pb ages ranging from c. 415 Ma in the cores to c. 380 Ma in the outermost rims ($\pm$2%, 2σ on individual spots). Diffusion zoning length was used with well-established Pb diffusion parameters [1] to determine peak temperature conditions following the approach of [2]. The result, c. 810 $\pm$ 25 °C, is consistent with 800 $\pm$ 25 °C and c. 780 °C estimated for the same sample using conventional and Zr-in-rutile thermometry, respectively. The cooling history that is reconstructed through age zoning analysis and diffusion modeling shows remarkable consistency with that established for the WGC through decades of $^{40}Ar/^{39}Ar$ dating.

The data presented here demonstrate that in-situ rutile U-Pb analysis yields reliable and precise temperature and age information that can be combined to resolve full thermal histories from single crystals. This novel approach to the toolbox of rutile petrochronology has great potential for research into the tectonics and dynamics of the lithosphere.

References

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