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Improving in-situ rutile thermochronology by laser ablation micro-sampling

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Rutile U-Pb thermochronology provides an extremely powerful means of constraining cooling histories; rutile is a common mineral in metamorphic and sedimentary rocks and chronometric closure is relatively robustly constrained [1]. In-situ U-Pb micro-analysis by laser ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) enables resolving of cooling age profiles, which may provide time-resolved histories of cooling through 600-450 °C [1]. Although promising, this method is underused, because cooling age profiles can typically not be resolved well; trade-offs in analytical precision or spatial resolution may impede proper resolving of age heterogeneity. New approaches are needed that allow improved spatial resolution, while still maintaining the ∼2% (2 s.d.) uncertainty that rutile U-Pb dating by LA-ICPMS is capable of.

Modern laser ablation systems enable the analysis of rectangular spots, for example to precisely analyze narrow compositional zones in samples. This method is now routinely used to constrain chemical and isotope heterogeneity in various geological and biological materials. Here, we explore the use of this feature to quantitatively constrain radiogenic-Pb (Pb*) diffusion profiles in rutile. The rectangular spots ensure ablation of a significant volume while maintaining a much higher radial spatial resolution compared to round spots. Different rectangular spot dimensions of a similar area yielding 2% precision or better were ablated to investigate ablation behavior and fractionation. The optimal dimension was found to be c. 11x55 μm; narrower spots did not yield the required reproducibility. Orientation of the ablated rectangle was an important factor controlling ablation behavior. As such, rectangle orientation was kept equal for both samples and calibration standards.

To further test the spatial and analytical resolution of the method, we performed U-Pb LA-MC-ICPMS on rutile grains extracted from: 1) a granulite sample from the Saglek Block (SB), Nain Province, Labrador, Canada, which exhumed and cooled from mid-crustal levels during the Neoarchean, and 2) a rutile-bearing phlogopitite in eclogite from the UHP zone of the Western Gneiss Complex (WGC), Norway, which underwent tectonically driven exhumation during the Devonian. The material revealed age gradients over 140 Ma (SB) and 30 Ma (WGC) over a distance of 40-50 μm (SB) and 200 μm (WGC), both of which could be resolved at a precision of 1.5-2.0 % (2 s.d.) and spatial resolution of ∼15 μm. The results show that rutile U-Pb dating by rectangular ablation micro-sampling of single grains allows high time-resolution on cooling histories of high-grade rocks, even in cases where age profiles are too underdeveloped to be resolved by conventional spot-based LA-ICPMS.

[1] Zack & Kooijman (2017) Rev. Mineral. Petrol. 83, 443-468.