Rutile U-Pb age depth profiling: a continuous recorder of lithospheric thermal evolution

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Traditionally, the thermal evolution of the lithosphere is recovered by the interpolation of discrete temperature-time points, generated by assigning estimates of nominal closure temperatures to volume-averaged radiometric ages. Whilst informative, bulk thermochronology potentially fails to yield high-resolution thermal histories capable of revealing short-lived (10^2—10^5 years) thermal events associated with processes such as magmatism and orogenesis. Rather, the highest resolution thermal history information is recovered by numerical inversion of the intracrystalline daughter nuclide concentration distribution [1]. Motivated by the kinetic sensitivity of Pb, Zr, Hf, Nb and Ta diffusion in rutile [2, 3] to record mid- to lower-crustal thermal evolution, we have developed LA-ICPMS depth-profiling techniques to measure near-surface (<35 μm) diffusion gradients in $^{206}Pb/^{238}U$ age and HFSE concentrations with ~1μm depth resolution. To illustrate the potential utility and limitations of the method, we analyzed lower-crustal rutile from several tectonic settings, including the Ivrea Zone and the Canadian Shield. Notably, the presence or absence of detectable age gradients is consistent with predictions made by thermally-activated diffusion theory. Inversion of $^{206}Pb/^{238}U$ age profiles from Ivrea Zone rutile reveals a continuous cooling history from ~650°C to ~450°C following a transient thermal pulse at ca. 180—190 Ma. Constrained by the topology of Zr, Nb and Ta diffusion profiles, integrated diffusion calculations show that the reheating event occurred over <10^4 years at characteristic temperatures in excess of 1000°C. These data demonstrate the potential for rutile depth-profiling to recover otherwise inaccessible continuous thermal history information from the mid- to lower-crust.

[1] Harrison *et al* (2005) *Rev. Min. Geochem* **58**, 389-409. [2] Cherniak (2000) *Contrib. Min. Pet.***139**, 198-207. [3] Cherniak *et al* (2007). *Contrib. Min. Pet.* **261**, 267-279.