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 (102—105 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 206Pb/238U age and HFSE concentrations with ~1 µm 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 206Pb/238U 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 <104 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.