Applications and Limitations of U-Pb Thermochronology

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Geodynamic processes impart characteristic thermal signatures to the lithosphere that are recorded by the distribution of daughter nuclides in minerals with radiogenic parent elements. Mineral chronometers through which daughter nuclide diffusion is slow preserve a record of mineral growth that may be related to rock mineralogy and textural information—*petrochronology*. Mineral chronometers through which diffusion is fast preserve a record of the rock's post-growth *T(t)(-P(t))* evolution—*thermochronology*. Combined, thermochronology and petrochronology define end-members of a spectrum controlled by partial retention of daughter nuclides. Measurements of intracrystalline mineral date zonations are imperative to ensure the accurate application of a petro- or thermochronometer. As volume diffusion of Pb through apatite, rutile, and potentially titanite, is effective at temperatures characteristic of the deep crust (above 400 °C), the U-Pb system is well-suited to illustrate the limitations of petro- and thermochronometers.

Recent developments in microbeam techniques enable sampling of U/Th-Pb isotopic ratios at sub-micron spatial resolution. In petrochronology, this affords assessment of thin growth zones that are unresolvable by traditional whole-grain, or spot analysis. Examples will be shown from depth-profile analysis of zoned lower-crustal zircon from the Ivrea-Verbano Zone. In thermochronology, this affords the measurement and inversion of closure profiles for high temporal resolution thermal histories, and the assessment of Fickian-type diffusion. Examples will be shown from lower-crustal rutile from the Slave Province, northern Canada.

Assessment of published intracrystalline titanite, rutile and apatite U-Pb date profiles from lower crustal rocks shows that purely diffusive profiles are the exception to uniform, step-like or irregular profile topologies. This suggests that processes other than thermally-activated volume diffusion may control U-Pb systematics in accessory phases residing at temperatures above 500 °C. Special emphasis is placed on the importance of flux-limited boundary conditions, fast-intragranular diffusion pathways and recrystallization. This analysis demonstrates the importance of integrating microtextural observations, and trace-element concentrations, with U-Pb age data in order to discriminate between diffusive and non-diffusive Pb transport mechanisms in accessory phases, thus avoiding generation of spurious thermal histories.