Spinel (U-Th)/He chronometry: A novel approach to date mantle exhumation

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The timing of cooling and exhumation of mantle peridotites in oceanic and continental settings has been challenging to determine using traditional geo-and thermochronometric techniques. Hence, the timing of the exhumation of mantle rocks to the Earth's surface at mid-ocean ridges, rifted and passive continental margins, and within continental volcanic and orogenic systems has remained largely elusive or only loosely constrained by relative age bracketing. Magmatic spinel [$(Mg,Fe)(Al,Cr)_2O_4$] is a ubiquitous primary mineral phase in mantle peridotites and is often the only primary mineral phase to survive surface weathering and serpentinization. This work explores spinel (U–Th)/He thermochronology as a novel tool to directly date the exhumation and cooling history of spinel-bearing mantle peridotite. Spinel grains were selected based on grain size and morphology, screened for internal homogeneity using X-ray computed tomography, and air abraded to eliminate effects of alpha ejection/implantation. Three case studies yield spinel He age results that are reproducible and generally in good agreement with independent age constraints. For ODP Leg 209, a spinel He age of 1.1 ±0.3 Ma (2 SE) (n =8) is consistent with independent U–Pb and magnetic anomaly ages for the exhumation of oceanic crust by detachment faulting along this segment of the slow-spreading ridge. Spinel from the Lherz massif yield He ages from 60–70Ma (n =3), which correspond well with independent thermochronometric constraints for cooling associated with Pyrenean collisional exhumation. Spinel from a mantle xenolith within a previously undated kimberlite diatreme at Green Knobs, New Mexico, generate a reproducible mean He age of 11.7 ±1.8Ma (2 SE) (n =6) that appears to record young volcanism in the area or age resetting by post-emplacement re-heating or alteration. The combined results of these case studies demonstrate the viability for spinel He thermochronometry to resolve cooling histories of peridotite exhumed through tectonic and volcanic processes.