Thermal history recovery from zircon 4He/3He thermochronometry

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Zircon (U-Th)/He thermochronometry is a valuable tool for recovering thermal histories and reconstructing tectonic events in the upper crust. This technique relies on the determination of age based on the accumulation and diffusive loss of radiogenic 4He produced by the decay of U and Th parent isotopes. While a single (U-Th)/He total gas age can be the result of an infinite number of thermal histories, the recovery of the spatial He distribution in a grain (i.e., concentration profile) offers the ability to reconstruct a continous thermal history. This study systematically explored the 4He/3He thermochronometry of single zircon crystals for the recovery of continuous thermal histories of samples from >9 km crustal sections and fast-cooled volcanic rocks. We studied the robustness of thermal histories derived from the inversion of He diffusion profile topologies in zircon and the influence of parent nuclide zonation. Volcanic zircon (Fish Canyon Tuff), as well as zircon samples from an exhumed crustal section (Wassuk Range, NV) and from the KTB deep-continental borehole, were proton irradiated to produce a uniform spallogenic 3He distribution in order to determine 4He concentration profiles. 3He/4He profiles were created either indirectly through fractional loss step-heating experiments or by in-vacuum Excimer laser-ablation depth profiling. Additionally, step-heating permitted the simultaneous determination of He diffusion kinetics. 3He/4He fractional loss experiments were performed by detailed diode laser step-heating (>30 steps between 300-1200C) in ultra-high vacuum using a Thermo Helix SFT magnetic-sector noble gas mass-spectrometer. Direct 3He/4He profile measurements were obtained by sequential in-vacuo laser ablation depth-profiling using an AnalyteG1 excimer laser. Subsequently, zircon U and Th zonations were measured by LA-ICP-MS depth profiling. The 3He/4He data, measured either by fractional loss or depth-profiling, and the 1-D U and Th zonation data were inverted using Monte Carlo inverse modeling (HeFTy) to determine the time-temperature evolution of samples across the zircon He PRZ. Results from multiple single zircon 4He/3He step-heating experiments were obtained from 3 locations across the zircon He partial retention zones of both the Wassuk Range and the KTB crustal section. In addition, >10 4He/3He step-heating experiments were carried out on Fish Canyon Tuff zircon with variable U-Th zonations.