# LASER STEP-HEATING AND THE SIGNIFICANCE OF 4HE PARENT NUCLIDE ZONATION FOR ZIRCON 4HE/3HE THERMOCHRONOMETRY

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## ABSTRACT

The radiogenic accumulation and thermally-activated diffusive loss of 4He from accessory minerals, such as apatite and zircon, is used to constrain upper-crustal exhumation, long-term landscape evolution, and other low-temperature geologic events. A single (U-Th)/He total gas age can be the result of an infinite number of thermal histories. Thermal history reconstruction generally requires the analysis of multiple samples, multiple thermochronometers, or kinetic differences between grains within a single sample. However, the spatial distribution of 4He found in a single grain is a function of the thermal history experienced by the sample and the parent nuclide (U and Th) distribution within the grain. By normalizing 4He against a uniform field of proton-irradiation induced 3He, intragrain 4He/3He concentration profiles can be determined by fractional-loss experiments. While apatite yields reliable 4He/3He thermochronometry data, zircon often exhibits complex U and Th zonation that must be accounted for. To investigate zircon pitfalls and potential, different laser heating protocols for fractional loss step-heating were tested. Parent nuclide zonation was measured by one-dimensional LA-ICP-MS depth-profiling and two-dimensional parent zonation mapping. The methodical technique of combining both 4He/3He fractional loss experiments and detailed analysis of parent nuclide zonation allowed for numerical modeling that produced continuous thermal history constraints. The method was applied to grains from independently characterized locations – rapidly cooled volcanic samples (Fish Canyon Tuff), fault-exhumed crustal samples (Wassuk Range), and drilled crustal samples (KTB) – to determine its robustness and reliability. This novel and systematic approach illustrates both the pitfalls and the potential of zircon thermochronometry to reliably determine continuous thermal histories.

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