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Correcting for long-alpha stopping distances in (U-Th)/He dating

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Conventional (U-Th)/He dating requires a correction of measured He content for the effect of He loss by alpha particle ejection (e.g. Farley et al. 1996). Compared to typical mineral grain sizes (~100 μm), the relatively long stopping distance of alpha particles (~22 μm) results in a significant volume of lost He that systematically bias age calculations (e.g. Ketcham et al. 2011). For example, only 65% of radiogenic He ingrowth will remain within an apatite grain with a radius of 40 μm, assuming a spherical grain shape (Ft=0.65). With such a significant correction to (U-Th)/He age calculations, accurate characterization of grain shape and precise measurement of grain dimensions may often be the largest source of analytical uncertainty. Indeed, difficulty in calculating grain shape may explain at least part of commonly observed overdispersion in (U-Th)/He ages (e.g. Dobson et al. 2008; Horne et al. 2016). For example, the widely used Fish Canyon standard yields ~11% dispersion in zircon (U-Th)/He ages(e.g. Dobson et al. 2008; Horne et al. 2016), although the analytical error in He and U-Th-Sm measurement is typically ~2%.

Most laboratories measure apatite and zircon grain dimensions with a stereo microscope under ~200x magnification. Grains are often elongated and therefore measurements are often based on photomicrographs with the crystallographic c-axis parallel to the field of view. Grain dimensions measured this way cannot account for cross sectional variation perpendicular to the crystallographic c-axis, despite this assumption in commonly used analytical calculations of the Ft correction factor (e.g. Ketcham et al. 2011). Moreover, grains with morphologies not well described by frusta or pyramidal-terminated box, cylindrical or hexagonal shapes do not have simple analytical solutions for the Ft correction factor, and must be neglected from subsequent analysis. Here we introduce an advanced numerical approach to measure grain shape and calculate Ft correction factors from photomicrographs taken at multiple perspectives that include images where the crystallographic c-axis of grains perpendicular to the field of view. This approach works on grains of any shape, as the 3D grain shape is numerically approximated directly from photomicrographs. A Monte Carlo simulation is then used to calculate the Ft correction factor. Preliminary applications of this new approach suggest that it is best applied to calculate Ft correction factors of broken grains and for those grains with abnormal shapes not well described by typical shapes used in the prior derivation of analytical solutions. In the latter case Ft values can be >10% different, largely exceeding the analytical error. Future MicroCT analyses may allow for quantitative evaluation of the accuracy of the numerical and traditional measurement approaches.

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