Paper Number: 3298

# Temperature sensitivities of non-traditional (U-Th)/He thermochronometers and thermal evolution of the Phalaborwa carbonatite complex, Kaapvaal Craton, South Africa

Baughman, J.S.[1] and Flowers, R.M.[1]

[1]University of Colorado Boulder, UCB 399 Boulder, CO, 80309, jaclyn.baughman@colorado.edu

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(U-Th)/He thermochronometry is a powerful tool that can be used to reconstruct thermal histories. Apatite and zircon are relatively well-studied He thermochronometers, but there is great potential to better develop other U-Th bearing phases for (U-Th)/He work. Doing so would make additional lithologies amenable to thermochronologic analysis, expand the temperature range accessible by the (U-Th)/He technique, and enable interpretation of more detailed thermal histories. We conducted a multi-thermochronometer study on the 2.06 Ga Phalaborwa carbonatite complex of the Archean Kaapvaal Craton to better constrain the temperature sensitivities of several non-traditional He thermochronometers and unravel the thermal evolution of the eastern Kaapvaal Craton. The plethora of U-Th bearing accessory minerals in the Phalaborwa complex as well as the region's protracted thermal history, make it an excellent target for this study. Previous work has documented the strong effect of radiation damage on the He retentivity of apatite, zircon and titanite [1, 2, 3]. The differences in He diffusion kinetics between and within different He thermochronometers are amplified by protracted thermal settings, which can lead to spans of He dates correlated with effective U concentration (eU). Comparison of results for the better understood He thermochronometers in such settings with those that are less studied enables us to better assess the temperature sensitivity and utility of non-traditional He thermochronometers.

We acquired (U-Th)/He data for baddeleyite, rutile, zircon, titanite, and apatite from Phalaborwa, associated syenite plugs, and nearby Archean basement. Baddeleyite (U-Th)/He dates record Phalaborwa emplacement at ~2060 Ma. Negative correlations between He date and eU are displayed by both Phalaborwa rutile and zircon, although the date ranges (1800-800 Ma for rutile, 700-270 Ma for zircon) and eU spans (6-13 ppm for rutile, 350-770 ppm for zircon) for each mineral differ. Such negative date-eU correlations have previously been observed in zircon and titanite, and are indicative of radiation damage decreasing the mineral's He retentivity. Basement titanite He dates are 1100-700 Ma, older than the dates yielded by higher eU zircon from both the same basement sample and Phalaborwa. AHe dates are reproducible with a mean of 107 ± 7 Ma, consistent with previously published Cretaceous AHe dates in the region. The results 1) indicate that baddeleyite has the highest temperature sensitivity of the dated minerals from this area, 2) imply that rutile He retentivity is reduced by radiation damage , an effect not previously recognized in this mineral, and 3) record a protracted thermal history encompassing ~2 byr, including initial slow cooling following Phalaborwa emplacement, subsequent reburial by Karoo Basin sedimentary and volcanic rocks, and Cretaceous unroofing associated with southern African Plateau uplift.

*References:*

[1] Flowers RM et al. (2009) GCA 73: 2347-2365

[2] Guenthner WR et al. (2013) Amer. J. Sci. 313: 145-198

[3] Baughman JS et al. (in prep) to be submitted to EPSL