Intercalibration of multiple thermochronometric systems at the Little Devil’s Postpile contact aureole

David L Shuster$^1$, Peter W Reiners$^1$, Leif Karlstrom$^1$, Jennifer L Schmidt$^1$, and Peter K Zeitler$^1$


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Abstract

A fundamental assumption in thermochronology is extrapolation of kinetic parameters over geologic timescales, temperatures, and mineral compositions that often differ significantly from the laboratory conditions used to quantify them. In this study, we aim to test and intercalibrate kinetic parameters of multiple thermochronometric systems using a tractable, natural thermal perturbation associated with the emplacement of a small, young basalt intrusion into granite in the Sierra Nevada, the site of the classic study of Calk and Naeser (1973). We collected a suite of samples along a linear transect orthogonal to the contact, from which the minerals apatite, zircon, titanite, epidote, magnetite, biotite, hornblende, K-feldspar, and plagioclase were separated. Our results to date reveal that the (U-Th)/He system in apatite was completely reset within $\sim$7 m of the contact during basalt emplacement $\sim$8 Ma. At distances $>$16 m from the contact, the apatite He ages are uniformly $\sim$58 Ma, which likely represents the background (i.e., unperturbed) cooling ages of the granite. Apatite $^4$He/$^3$He thermochronometry and an observed transition from background-to rest-ages of these samples are quantitatively consistent with a higher degree of thermal perturbation nearer to the contact. As predicted by our current quantification of radiation damage accumulation influence on He diffusion kinetics (Flowers et al, 2009), we observe correlation between the “effective uranium” concentration and He ages of individual apatite crystals, particularly within this transition zone. In contrast, the (U-Th)/He system in zircon is only partially reset $\sim$7 m from the contact, and the background cooling ages at distances $>$10 m are $\sim$78 Ma, consistent with a 40 Ar/39 Ar age-spectrum from a distal K-feldspar that rises from $\sim$70 to $\sim$80 Ma; both observations are consistent with the relative, experimentally determined temperature sensitivities of these minerals. We present ongoing numerical modeling that provides a framework with which to quantitatively compare and assess these results with forthcoming 40 Ar/39 Ar and fission track results in various mineral systems. Inversion of data using these multi-material conductive models will be used to assess the sensitivity of results to assumptions about geometry (1D, 2D, 3D), duration of basalt emplacement, and pre-intrusion cooling rate.
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Summary - A fundamental assumption in thermochronology is extrapolation of kinetic parameters over geologic timescales, temperatures, and mineral compositions that often are not significant to the laboratory conditions used to quantify them. In this study, we aim to test and intercalibrate kinetic parameters of multiple thermochronometric systems using a tractable, natural thermal perturbation associated with the emplacement of a small, young basalt intrusion into granite in the Sierra Nevada, the site of the classic work by Calk and Naeser (1973). We collected a suite of samples along a linear transect orthogonal to the contact, from which the minerals apatite, zircon, titanite, epidote, magnetite, biotite, hornblende, K-feldspar, and plagioclase were separated. Our results to date reveal that the (U-Th)/He system in apatite was completely reset within ~7 m of the contact during basalt emplacement ~8 Ma. At distances >16 m from the contact, the apatite He ages are uniformly ~58 Ma, which likely represents the background (i.e., unmodified) cooling ages of the granite. Apatite He/He thermochronometry and an observed transition from background- to reset-ages of these samples are quantitatively consistent with a higher degree of thermal perturbation nearer to the contact. As predicted by our current quantification of radiation damage accumulation influence on He diffusion kinetics (Flowers et al., 2009), we observe correlation between the “effective uranium” concentration and He ages of individual apatite crystals, particularly within this transition zone. In contrast, the (U-Th)/He system in zircon is only partially reset ~7 m from the contact, and the background cooling ages at distances >10 m are ~78 Ma, consistent with a *4Ar*/Ar age-spectrum from a distal K-feldspar that rises from ~70 to ~80 Ma; both observations are consistent with the relative, experimentally determined temperature sensitivities of these minerals. We present ongoing numerical modeling that provides a framework with which to quantitatively compare and assess these results with forthcoming *4Ar*/Ar and fission track results in various mineral systems. Inversion of data using these multi-material conductive models will be used to assess the sensitivity of results to assumptions about geometry (1D, 2D, 3D), duration of basalt emplacement, and pre-intrusion cooling rate.

Located within Yosemite National Park near Tuolumne Meadows, the Little Devil’s Postpile is a 2 km-wide,esian-shaped basalt plug that intruded into the Cathedral Peak Granite batholith, a mesocratic pegmatitic granite massif. The basalt is irregularly shaped, approximately 100 m in cross-section. Previous work measured apatite fission track (AFT) ages of ~8 Ma near the contact, providing constraint on the timing of intrusion (Calk and Naeser, 1973). We collected basaltic samples granite along two transects from the contact and samples of the basalt itself. Our objective is to use the thermal perturbation associated with basalt emplacement to test lab-based kinetic parameters for different minerals, as well as different mineral chemistry systems of different minerals, both in the absolute and relative to one another.

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Citations


We use the thermal model of Ketcham et al. (2010) to infer the temperature history of the intrusion, which is consistent with the observed U-Th/He ages. However, our model predictions for the temperature history of the intrusion require further validation, and additional constraints are needed to better constrain the temperature history. In particular, additional geochronological data from the area are needed to better constrain the temperature history of the intrusion.

We use a 3D model of the intrusion to constrain the temperature history of the intrusion. This model assumes that the intrusion was intruded at ~8 Ma, and that it was intruded as a single, continuous event. The model is consistent with the observed U-Th/He ages and the observed temperature history of the intrusion. We hope to use additional geochronological data from the area to further constrain the model.

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