Assessing Thermochronometer Systematics in a Natural Geologic Setting, Little Devil's Postpile, Yosemite National Park

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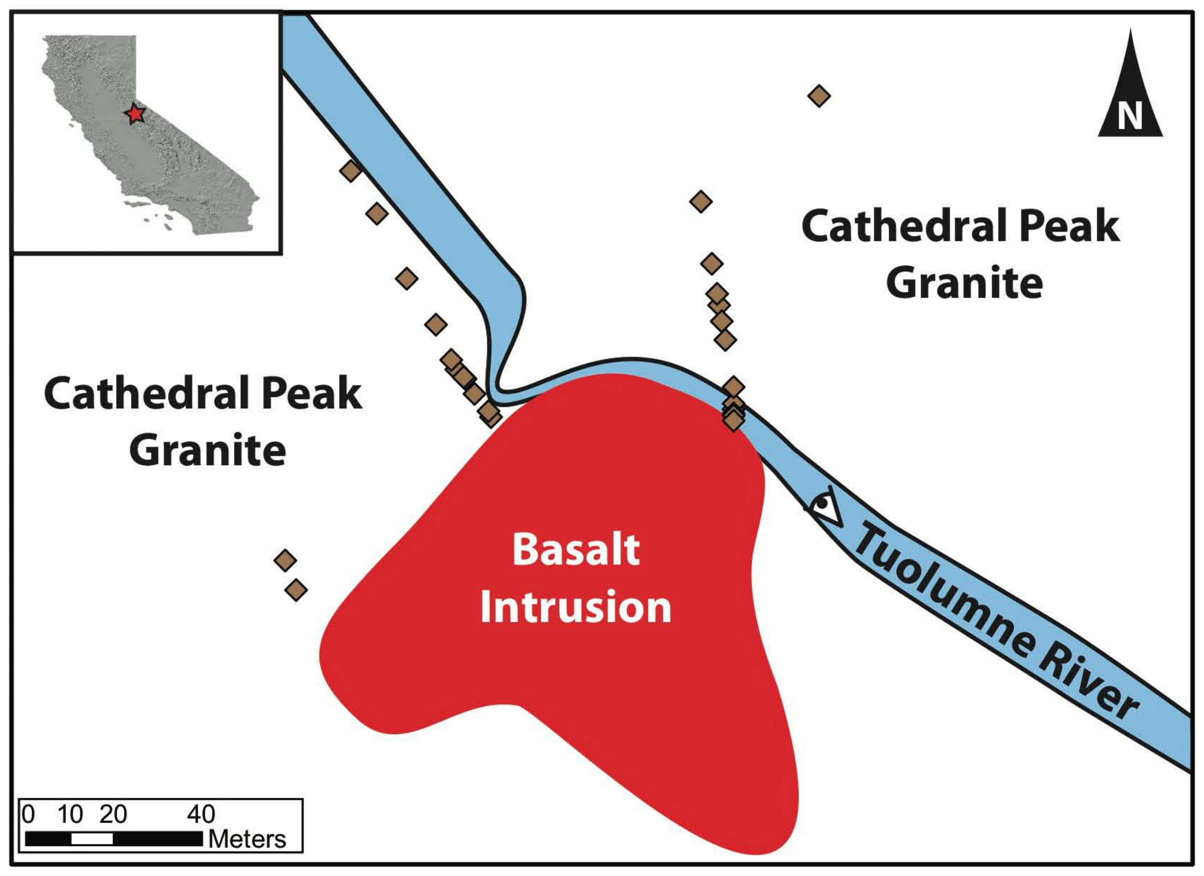
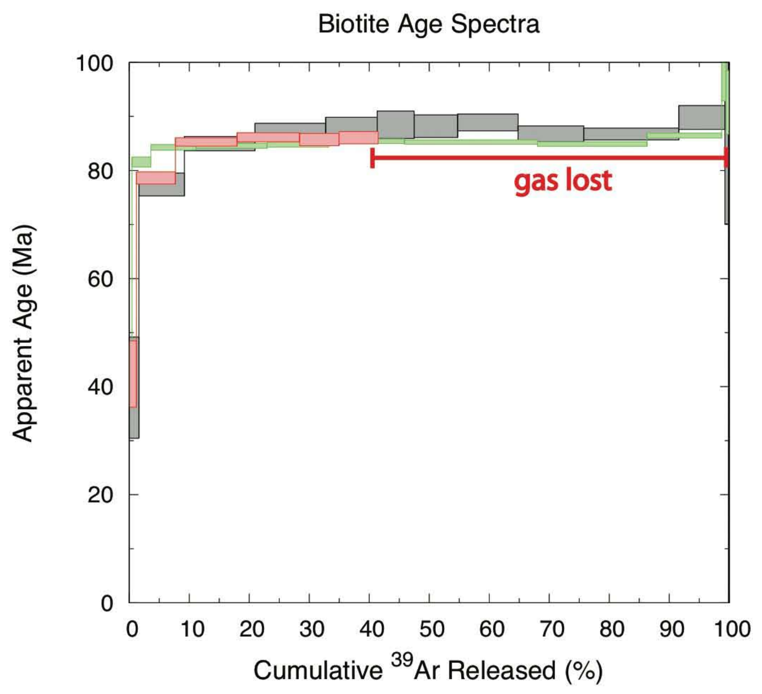
Abstract *- A better understanding of the systematics of several commonly used thermochronometers will provide the geologic community a basis to interpret thermochronologic data. To this end, this study focuses on intercalibrating several established and experimental chronometers. The Little Devil's Postpile intrusion, located within Yosemite National Park, is an ideal location for this study. This approximately 100 m diameter asymmetrical basalt plug intruded the Cathedral Peak granite (quartz monzonite), at ~8 Ma. The thermal pulse resulting from the injection of the basalt systematically reset the age of the ~80 Ma host. Little Devil's Postpile provides the opportunity to evaluate the relative performance of several thermochronometric systems in a natural geologic setting. Samples were collected along two transects within the Cathedral Peak granite to assess the resetting response of individual thermochronometers to a relatively short thermal pulse. This portion of the project focuses on analysis of $^{40}Ar/^{39}Ar$ in K-feldspar, biotite, and plagioclase. Preliminary data follow predicted behavior, where a higher closure temperature system such as biotite is affected to a lesser degree than K-feldspar at the same distance from the intrusion. $^{40}Ar/^{39}Ar$ analysis of the basalt reveals an intrusion age of 7.7 Ma. Age spectra from both proximal and distal biotites display little to no resetting. Samples closer to the contact are needed for more meaningful biotite data. Plagioclase display jagged age spectra and low temperature excess argon however proximal samples appear partially reset. MDD modeling of distal K-feldspar sample (22 m) reveals the Cathedral Peak granite cooled quickly at ~80 Ma. K-feldspar samples proximal to the intrusion contact (4.5 and 6.86 m) display partial resetting. Forward modeling of the closest sample indicates that the maximum thermal pulse experienced by this sample was approximately 420˚C, 100˚C lower than predicted by the model proposed by Calk and Naeser (1973).*

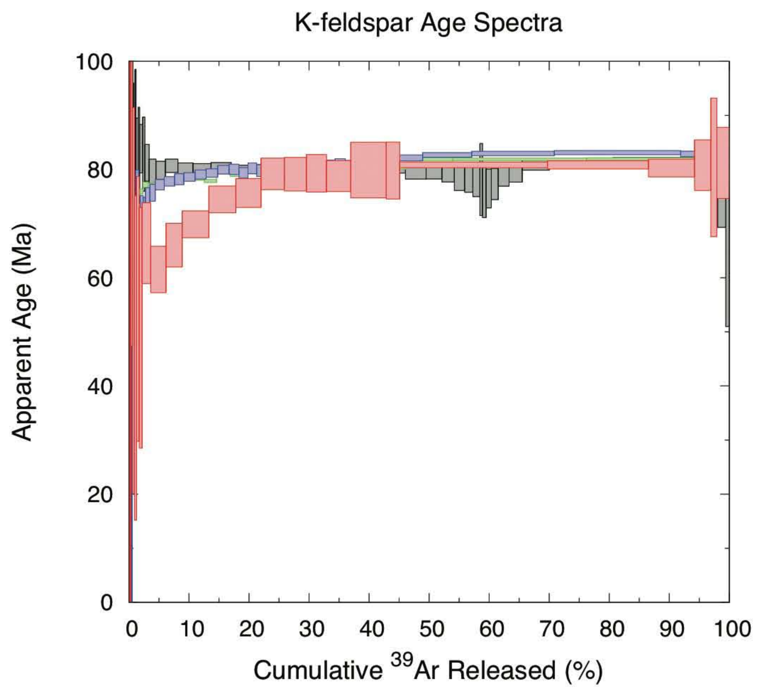
Little Devil's Postpile

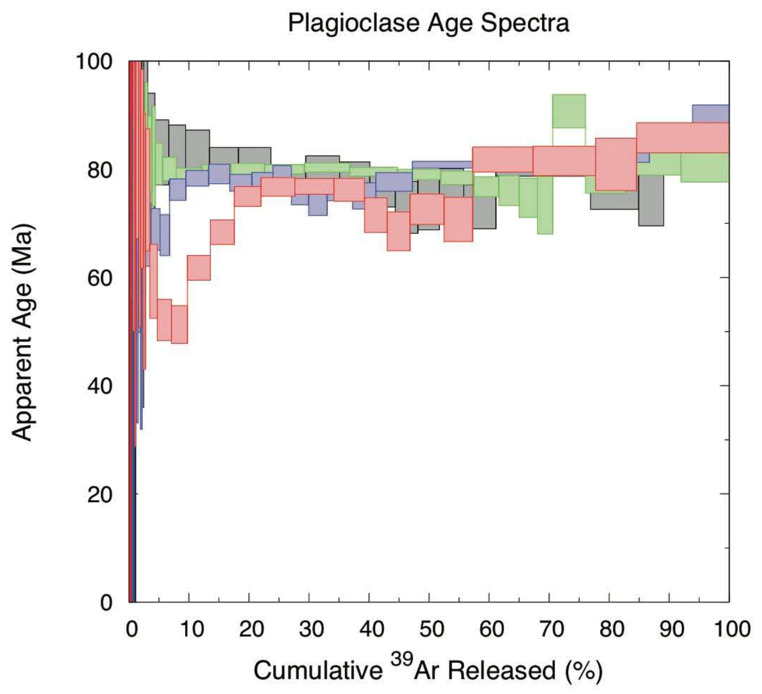


The Little Devil's Postpile is an ~8 Ma asymmetric porphyritic olivine basalt plug that intruded the Cathedral Peak Granite, an ~80 Ma quartz monzonite. To assess thermochronometer systematics, two transects were collected orthogonal to the intrusion contact within the Cathedral Peak Granite. Systems analysed in this work include $^{40}Ar/^{39}Ar$ in K-feldspar, biotite, and plagioclase.

Age Spectra



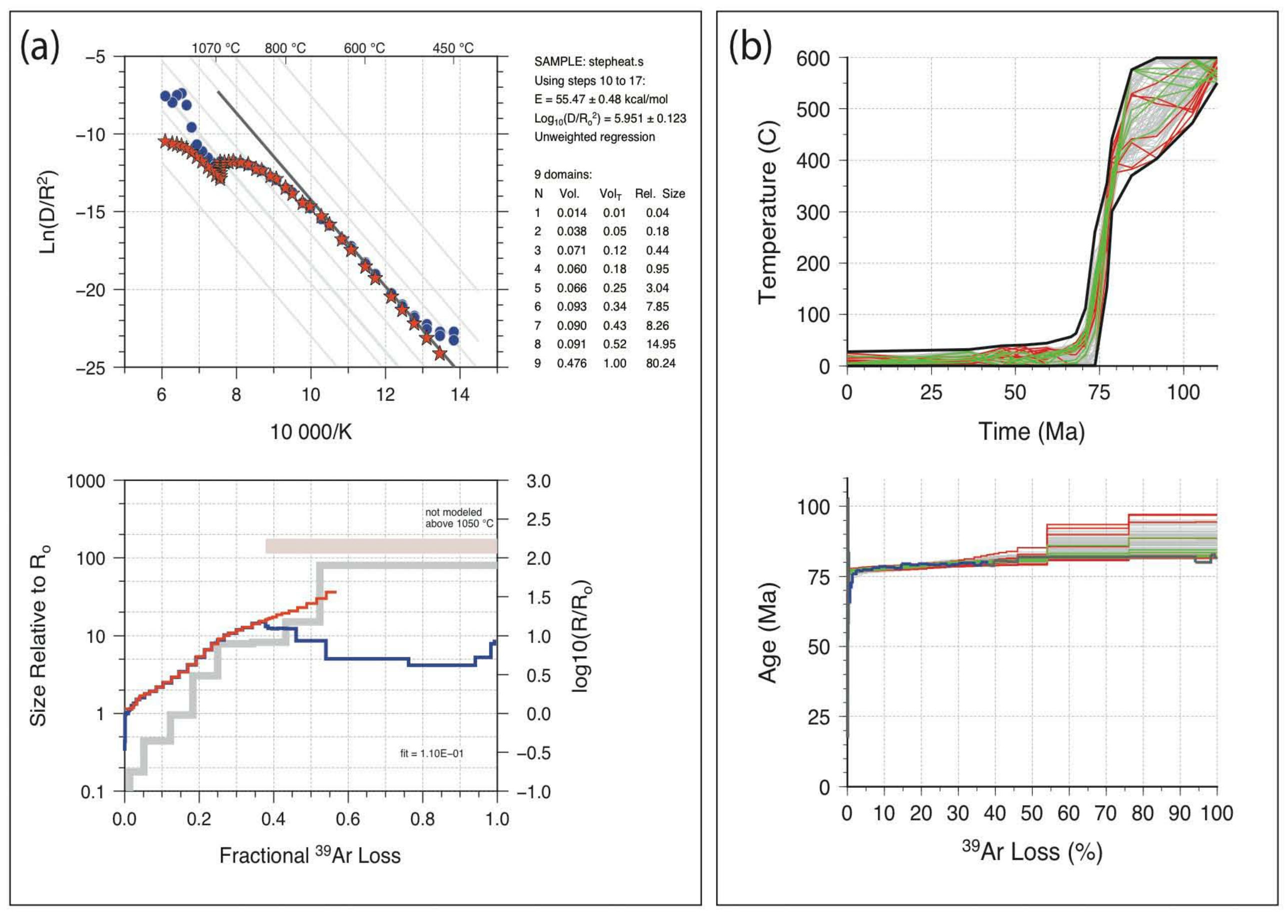




Sample Age spectra for each thermochonometric system. Systems with lower closure temperatures such as biotite display little to no resetting as close as 4.5 m from the contact. K-feldspar and plagioclase display partial resetting at distances close to the contact indicating thermal effects for moderate temperature systems to at least 22 meters from the intrusion. Plagioclase display intermediate age maxima, possibly due to high temperature recrystallization close to the contact. Black = LDP10-03 (62.8 m); Green = LDP10-01 (22 m); Purple = LDP10-10 (6.86 m); Red = LDP10-05 (4.5 m).

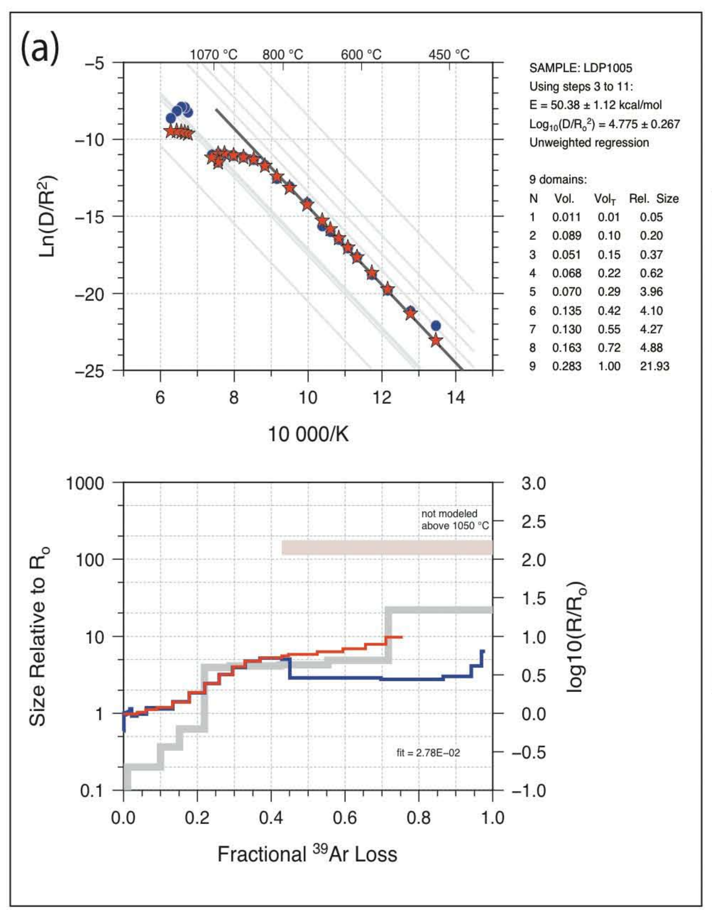
K-feldspar MDD Modeling

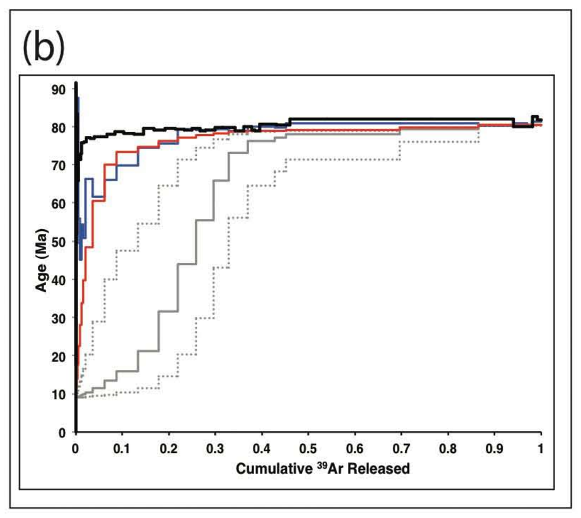
Distal Sample Kinetics and Inverse Model



Multidomain diffusion (MDD) modeling and inversion of sample LDP10-01, from 22 m away from the intrusion indicates fast cooling of Cathedral Peak Granite ~80 Ma. (a) Arrhenius plot (top), and log(R/Ro) plot (bottom) for modeling of sample LDP10-01 obtained using modified Autoarr program (Lovera et al., 1997) indicating domain structure and kinetic parameters (Ea & D/a^2). In Arrhenius plot, blue = observed data, red = model, gray = domain structure. (b) Inverse model results using Arvert 4.1 controlled randon search code (Harrison et al., 2005; Zeitler, 2004). In thermal history plot (top) and age spectrum plot (bottom) green and red lines = modeled thermal histories. In age spectrum plot blue line= modeled portion of observed age spectrum. Gray line = unmodeled portion of age spectrum.

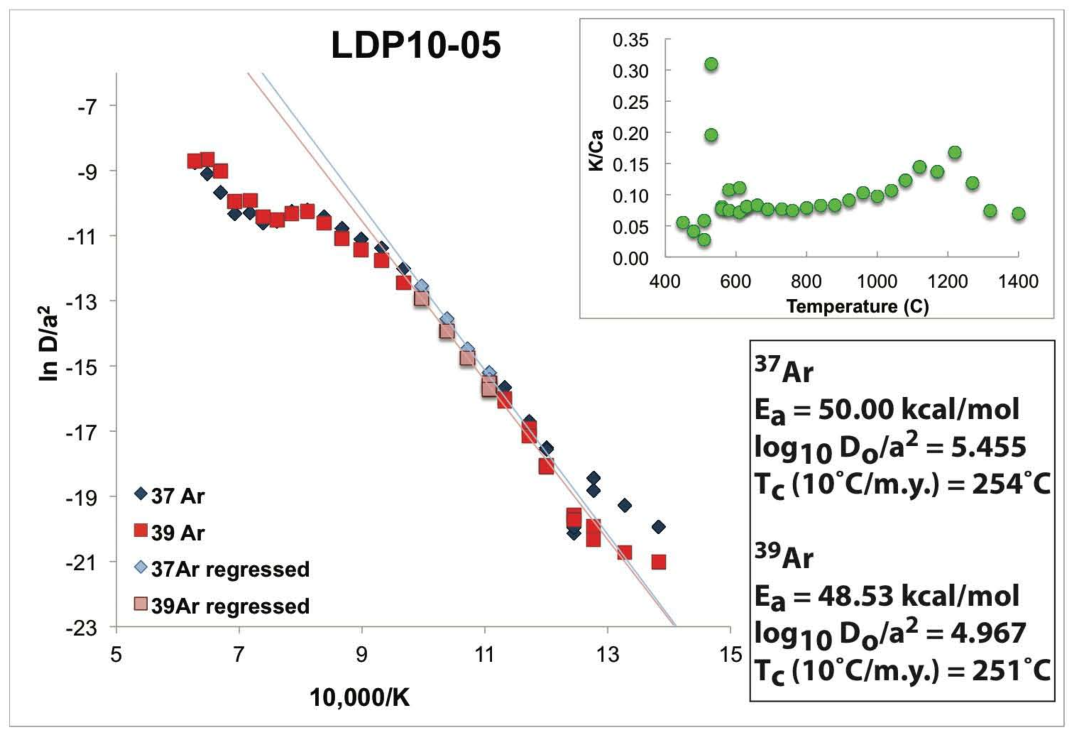
Proximal Sample Kinetics and Forward Model

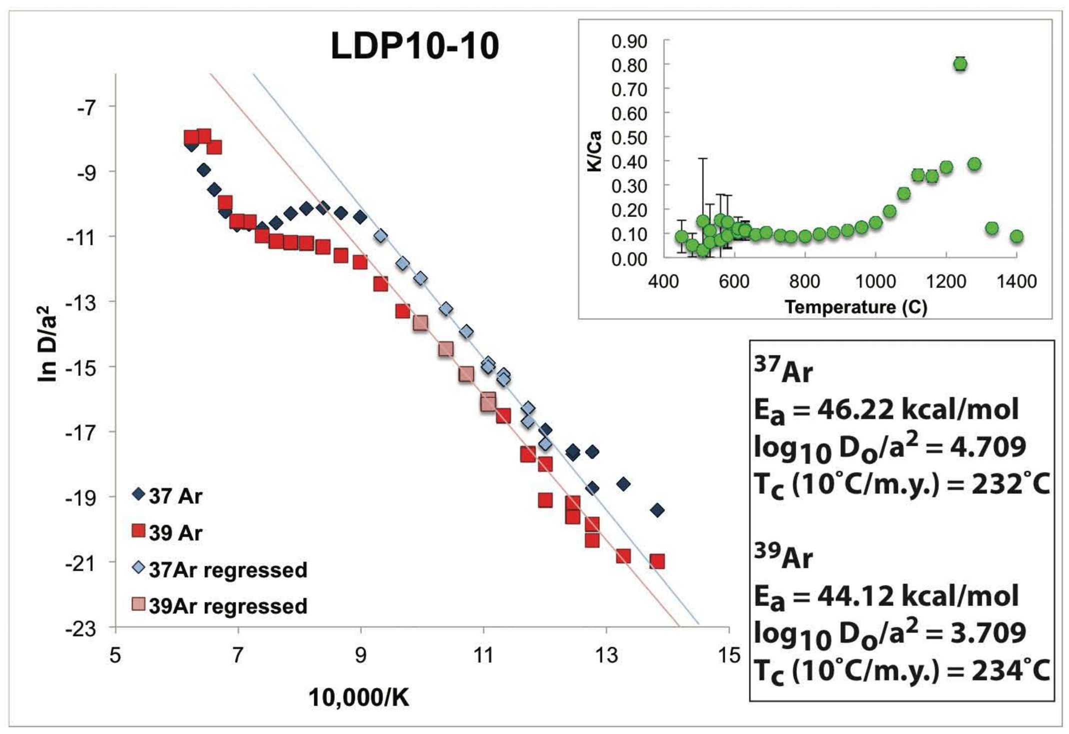


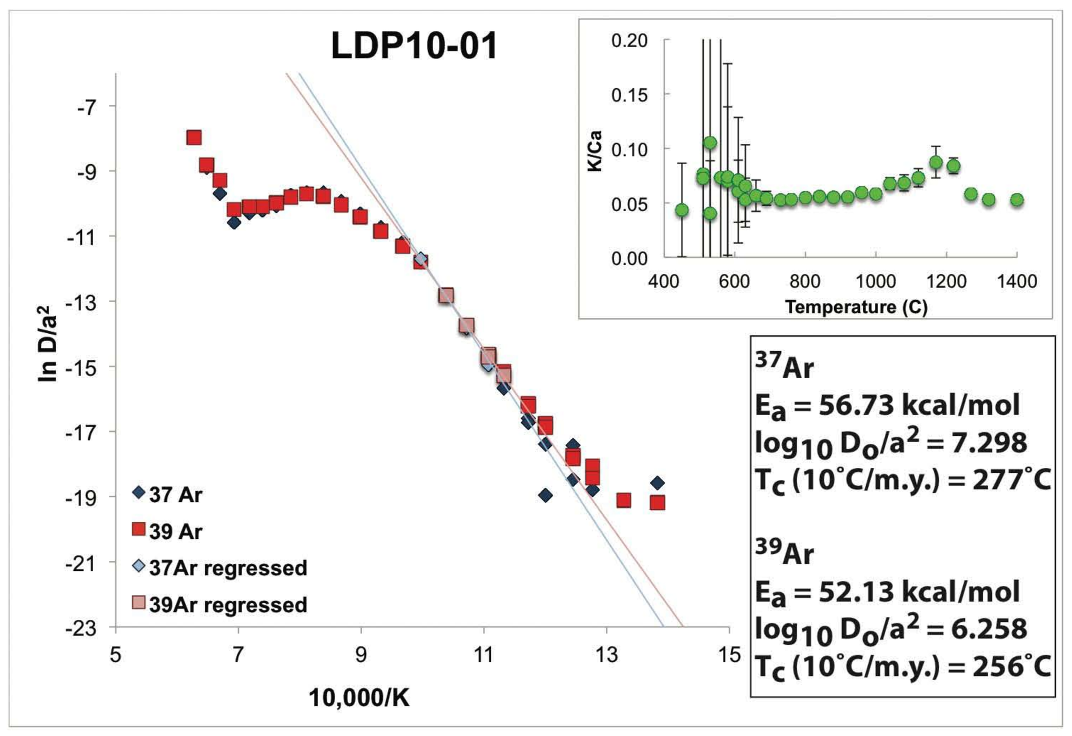


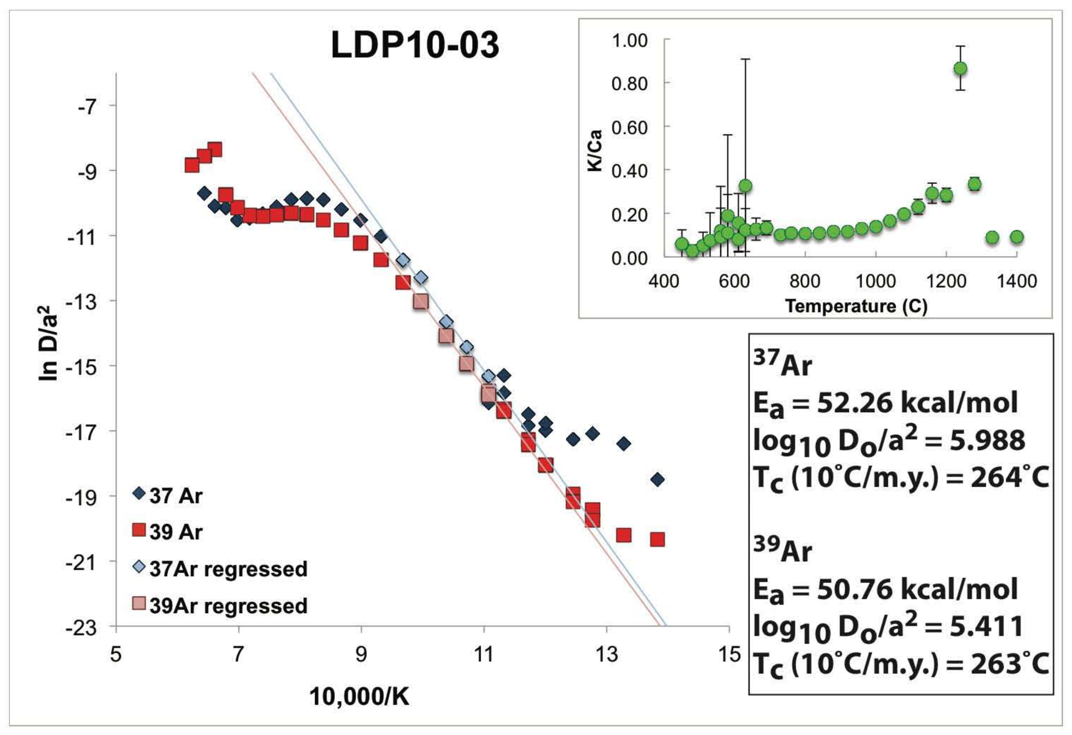
MDD modeling of sample LDP10-05, from 4.5 meters from the intrusion. (a) Arrhenius and log (R/Ro) plots and associated kinetic parameters and domain structure. (b) Age spectra resulting from forward model of LDP10-05 calculated from distal sample domain structure. Black = age spectra from distal sample LDP10-01. Blue = spectrum from proximal sample LDP10-05. Gray = predicted spectrum for thermal model of Calk and Naeser (1973) in which the magma temperature of the intrusion was assumed to be 1530 ˚C (higher than typically assumed to account for latent heat) and the maximum temperature experienced by the sample at 4.5 meters away was 521 ˚C for a duration of ~10 years. Dashed gray = predicted age spectra for thermal pulse 50˚C above and below the Calk and Naeser (1973) model. Red = predicted spectra 100˚C below the Calk and Naeser (1973) model.

Plagioclase Kinetics







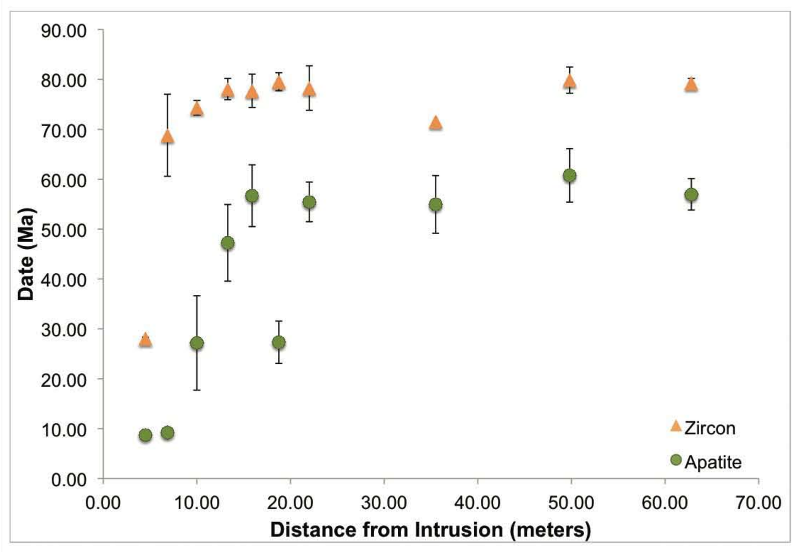


Plagioclase, an experimental thermochronometer displays promise as a useful system. ^{37}Ar and ^{39}Ar Arrhenius plots and measured K/Ca ratios for each sample displayed to left. Sample-specific kinetic parameters and closure temperatures are calculated using both ^{37}Ar and ^{39}Ar as both are reactor-produced reference isotopes. Plagioclase gives closure temperatures of ~230-280 ˚C.

Kinetic parameters calculated from release of ^{37}Ar are similar to those of ^{39}Ar, however predict slightly higher activation energies and lower log_{10} D/a^2 values.

Plagioclase display "stepped" age spectra, typical of multiple domain behavior, however Arrhenius plots do not display expected rollover outside of high temperature steps, where this effect could be due to breakdown of sample during heating. Further analyses are required to elucidate distribution of diffual domains. If single domain behavior is assumed, K/Ca ratios may reflect zoning within grains. Complex modeling of K and Ca zoning would be required if samples display multiple domain behavior. Electron microprobe profiles of major elements is needed to understand zoning in plagioclase.

Apatite & Zircon U-Th/He



Apatite and zircon U-Th/He data courtesy of P. Reiners. Data indicate resetting of these systems close to the intrusion. Apatite data display anomaously young ages at 18.75 meters and grade to a background age ~20 Ma younger than predicted by other systems. K-feldspar inverse modeling indicate fast cooling of the Cathedral Peak Granite at ~80 Ma, however apatite background ages of ~60 Ma may indicate slow cooling or far distal effects of the basalt intrusion.

References

Calk, L.C., and Naeser, C.W., 1973. Thermal effect of a basalt intrusion on fission tracks in quartz monzonite. Journal of Geology, v. 81, p. 189-198.

Harrison, T.M., Grove, M., Lovera, O.M., and Zeitler, P.K., 2005, Continuous thermal histories from inversion of closure profiles, in Low-Temperature Thermochronology: in Reiners, P.W., and T.A. Ehlers, Techniques, Interpretations, and Applications, Reviews in Mineralogy & Geochemistry: v. 58, Mineralogical Society of America, Chantilly, VA, p. 389- 409.

Lovera, O.M., Grove, M., Harrison. T.M., and Mahon, K.I., (1997) Systematic analysis of K-feldspar 40Ar/39Ar step-heating experiments I: Significance of activation energy determinations. Geochimica et Cosmochimica Acta, v. 61,p. 3171-3192.

Zeitler, P.K., 2004. Arvert 4.1. Inversion of 40Ar/39Ar age spectra. Users manual (http://www.ees.lehigh.edu/EESdocs/geochron/downloads/arvert/arvert_41_manual.pdf) (version 4.1 update 7 April, 2012).