**HeFTy Thermal Modeling**

Inverse thermal models were created for our AFT using the program HeFTy (Ketcham, 2005). HeFTy models delineate the time and temperature cooling history of a sample. The program evaluates “best-fit” cooling paths and slopes based on input age and AFT track-length constraints. We present Monte Carlo method inverse models showing acceptable and good cooling paths constrained in envelopes and weighted-mean T-t paths after 200,000 runs. Input constraints for the models include AFT data (120–60 °C) (single-grain ages, Dpar, track lengths, angle of tracks to the c-axis), and ZHe ages. We use a broad temperature window (80–40 °C) for sample average AHe ages because intra-sample grain age dispersal and overall grain age dispersal were not correlated with either grain size or effective uranium. The models include: temperature-time (*T-t*) path envelopes (good paths in purple and acceptable paths in green), weighted mean path (thick blue line), constraint boxes (explained in detail below), AFT track length distributions (red).

**Modeling details**

Modeling program: HeFTy v1.9.3

Statistical fitting criteria: Default.

GOF values >0.05 are acceptable fits. GOF values >0.5 are good fit

GOF method K-S test

Ending condition: 200000 = paths tried

**AFT Sample Details**

Annealing model: Ketcham et al., 2007

C-axis projection: Ketcham et al., 2003; model used c-axis projected lengths

Used CF irradiation: Yes

Default initial mean track length: 16.3

Length reduction in standard: 0.893

Kinetic parameter: Dpar (μm), one kinetic population

Dpar Calibration: 1.0

Length Calibration: 1.0

**AHe Sample Details**

None of the samples produced AHe aliquots that were modellable on their own or combined with the AFT data. This is not surprising given the lack of intrasample correlation between AHe single grain ages and [eU] or grain size. Hence, when AHe data was present we added a box constraint between 80 °C and 40 °C (Farley, 2002) sized to the age and stdev uncertainty of the AHe sample set.

**Additional Constraint boxes for inverse thermal modeling**

All samples were modeled with the annual present-day surface temperature (0 °C) and a 5 °C +/- uncertainty. HeFTy requires an initial constraint box at a higher temperature and older than the AFT data and AHe data (if present). If 40Ar/39Ar data (e.g. Biotite and/or KFATmin) was not available we put in a constraint box at least as twice as old as the AFT data and over 200 °C.

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