Inter-laboratory comparison of fission track confined length and etch figure measurements in apatite

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ABSTRACT

Apatite fission-track length and etch figure data are powerful tools for obtaining thermal history information, but both require human analysts making manual measurements and reproducibility is not assured. We report the results of an inter-laboratory study designed to clarify areas of congruence and divergence for these measurements and provide a basis for evaluating best practices to enhance intercompatibility of data sets. Four samples of megacrystic apatite from Durango, Mexico, with induced tracks, one unannealed and three thermally annealed by varying amounts, were distributed internationally. In all, 55 analysts in 30 laboratory groups participated in the experiment. Relative mean track lengths among the samples were consistent across all analysts, but measurements for each sample showed scatter among labs and analysts considerably in excess of statistical expectation. Normalizing measurements of annealed samples using the unannealed sample improved consistency, as did normalizing for track angle using c-axis projection. Etch figure data also showed variability beyond statistical expectation, and consistency was improved by normalizing. Based on these data we recommend rigorous analyst training for length and etch figure measurement that includes measurement of standards, and that each analyst’s data on unknowns be normalized by that analyst’s own measurements on standards when using thermal history inverse modeling as part of the interpretation process.

Keywords: Geochronology, fission-track dating, track length measurement, apatite, inter-laboratory calibration, thermal history analysis

INTRODUCTION

The key to resolving detailed thermal histories using the apatite fission-track (AFT) system comes from combining ages with track length data. Fission tracks form over time, and earlier-formed ones will experience more of a sample’s thermal history than later-formed ones. This leads to characteristic patterns in horizontal confined track length distributions that can provide unique information on thermal history (Gleadon et al. 1986). Even greater resolution is available when length data are paired with computational tools (e.g., Gallagher 1995, 2012; Green et al. 1989; Ketcham 2005) to identify the range of thermal histories that are consistent with both the length and age data and other geological constraints, using kinetic models of fission-track annealing (Crowley et al. 1991; Ketcham et al. 2007b, 1999; Laslett and Galbraith 1996; Laslett et al. 1987).

The ability to use track length data correctly and confidently hinges on the fidelity of the length measurements, and in particular their consistency with respect to the measurements underlying models of fission-track annealing (e.g., Barbarand et al. 2003a; Carlson et al. 1999; Green et al. 1986). Although the analytical procedures used in these studies can be reproduced, and we understand many of the geometric sources of bias associated with track observation (Galbraith 2005, Chapter 8; Galbraith et al. 1990; Ketcham 2003), full compatibility is not assured. In particular, because confined tracks are found and measured by a human analyst using a microscope, rather than some mechanical or automated procedure, reproducibility of length data is an important concern.

The reproducibility of confined length data has been considered at both the inter-lab and intra-lab level. Intra-lab studies are valuable because they enable better control of conditions (such as repeating measurements of the same material using the same instrumentation), and thus allow focus on variables of interest. For example Green et al. (1986) include and compare measurements by two analysts of the same mounts. Barbarand et al. (2003b) gathered a series of induced-track data aimed at examining various aspects of reproducibility in detail, including among analysts and for single analysts over time, as well as the effects of C11 irradiation and the number of measurements necessary to converge to the correct mean length. Ketcham et al. (2009) obtained data for several analysts on two samples with induced and spontaneous tracks, and assessed the effects of measurement variability on thermal history reconstruction and the potential mediating ability of normalizing for length and angle.

Inter-laboratory experiments, however, provide the information necessary to assess the fidelity of measurements across the community and thus the overall reliability of the technique as it is applied. There has only been one previous large-scale inter-laboratory experiment for length measurements (Miller et