Evaluating the effect of anisotropy on fossil fission track length distributions in apatite

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Latent Fission Tracks (FTs) are thermally unstable and with increasing temperature and time, they become progressively annealed (i.e. their etcheable length shortens due to lattice restoration). Length measurements on horizontal confined fossil FTs in apatite are therefore frequently used to reconstruct the thermal history of crystalline and sedimentary rocks. An important observation is that, for a given set of annealing conditions, the length of FTs varies with their orientation to the crystallographic c-axis of the apatite crystal. To correct for this effect, a method has been developed that converts the individual lengths to equivalent lengths parallel to the c-axis of the crystal [1, 2]. The calibration line that serves as a basis for this correction relies on length studies of induced FTs in Tioga apatite. Similar, but less anisotropic trend-lines were found in other experiments based on different apatites and using different laboratory etching conditions [3].

A careful length analysis on fossil tracks that we carried out in a number of apatite samples, originating from various geological contexts, reveals a trend that is strikingly different from the one observed for induced tracks in Tioga apatite. The fossil FT distributions are systematically less anisotropic than predicted by the Tioga calibration line [2]. This was already recognized earlier [2], but likely obscured by the effect of secondary ^{252}Cf-irradiation, used to create more etchable confined FTs. Further experiments show that the deviation is not significantly caused by the applied etching conditions as one might expect at first instance. The fitting of ellipses through a spectrum of length populations that underwent different degrees of annealing, might introduce a small bias in the anisotropy but this bias is also insufficient to explain the more isotropic trend observed for the fossil FTs.

No major difference has been observed between the anisotropic characteristics of fossil tracks and induced tracks in Durango apatite that were annealed in laboratory conditions and studied on well defined crystal faces. The problem thus probably relates to uncertainties in the precise crystallographic orientation of the observed crystal surfaces and in the c-axis determination in small sized geological (subhedral or anhedral shaped) apatite grains.

Although it is commonly applied and forms a part of the currently used AFT-thermochronology modelling software, it is clear that an invalid length correction through c-axis projection might lead to an erroneous temperature-time path. Actually any sample whose (l_A, l_C) data deviate from the Tioga line is problermatic and has to be treated with caution. Our conclusion is that each set of samples therefore needs to be tested against this line before the correction can be applied with confidence.

References

[1] Donelick R.A. (1991). Crystallographic orientation dependence of mean etchable fission track length in apatite: An empirical model and experimental observations. *American Mineralogist*, **76**, 83-91.

[2] Donelick R.A. et al. (1999). Variability of apatite fission-track annealing kinetics: II. Crystallographic orientation effects. *American Mineralogist*, **84**, 1224-1234.

[3] Ketcham R.A. et al. (2007). Improved measurement of fission-track annealing in apatite using c-axis projection. *American Mineralogist*, **92**, 789-798.