Effective Etch Times and Compositional Effects on the Etching of Fossil Fission Tracks in Geological Apatite Samples

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I. Introduction

- The fission-track method for determining ages and thermal histories of rocks is based on counting and measuring damage trails from Uranium fission

- These damage trails become visible by chemical etching, but questions remain how to relate the etched tracks to the actual damage

- A radial etch model with an apatite etch rate v_R and an along track etch rate v_T explains the geometries of etched fission tracks

- We explore how v_R and v_T scale with chemical composition, i.e. *Dpar*

- For samples with known *Dpar,* this allows to calculate effective etch times t_E of individual confined tracks from their widths and v_R; this has several practical implications (see section IV.)

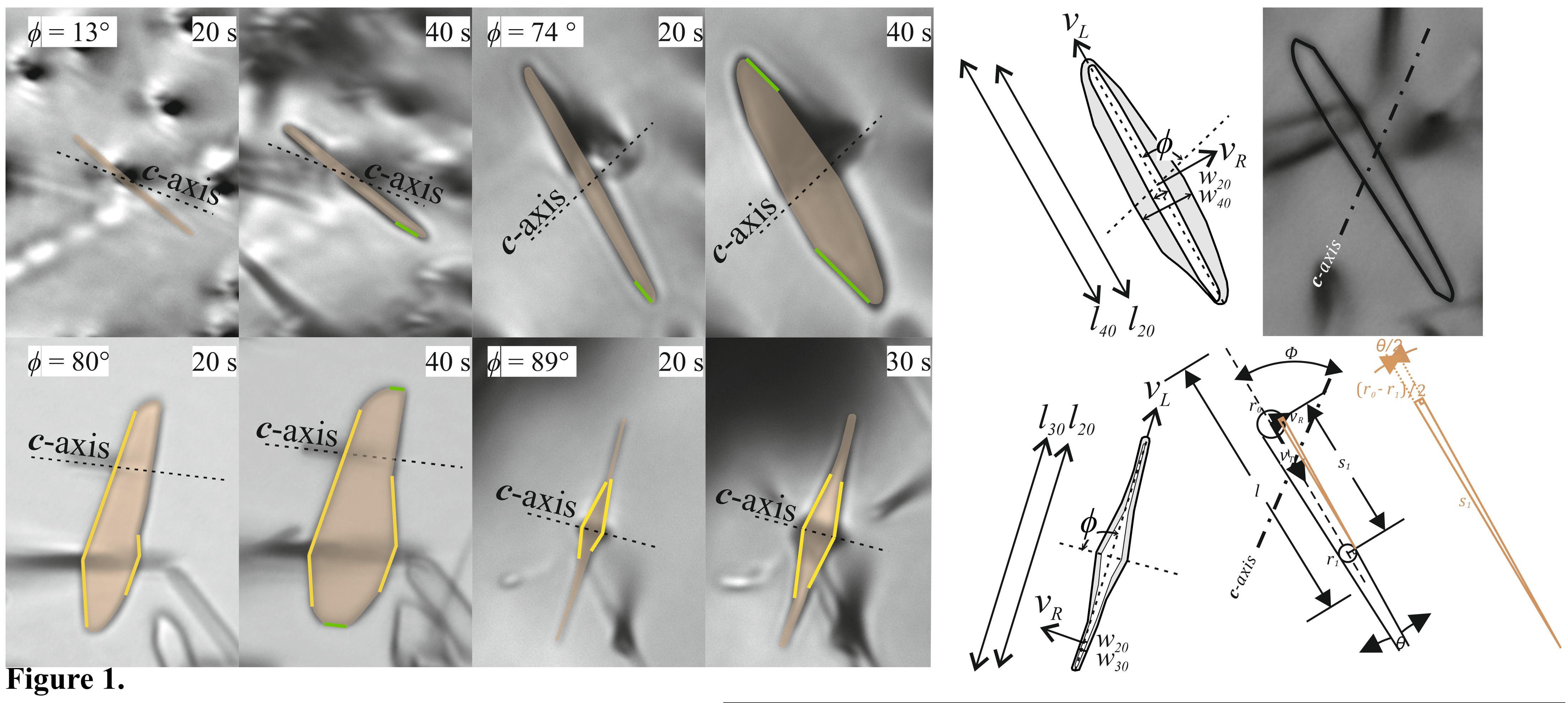

Figure 1.

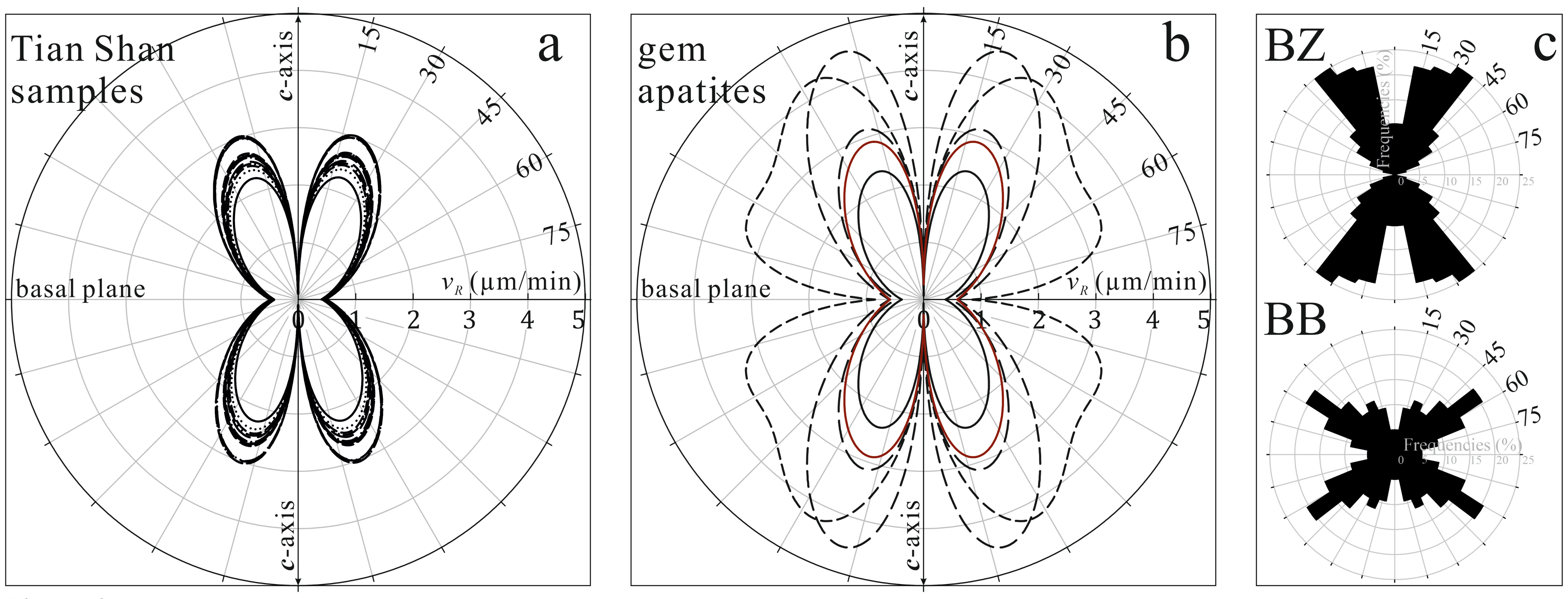

Figure 2.

II. The apatite etch rate v_R

- We conducted step-etch experiments to calculate v_R from width increases of confined tracks in prism faces of 14 samples from the southwestern Tian Shan (*Dpar* = 1.4-2.7 µm) and 4 gem apatites (*Dpar* = 1.6-4.6 µm) (Figure 1)

- v_R scales with *Dpar* for all hexagonal apatites (Figure 2a-b):

$$v_R = (0.14\,Dpar + 0.09)\,\phi'\,e^{(-0.0017\,Dpar - 0.0470)\phi'} + 0.1$$

- This allows to calculate the apatite etch rate v_R and effective etch times for natural samples with known *Dpar*

- Monoclinic apatites show a different v_R pattern (Figure 2b)

- The rate of width increase controls the frequencies of tracks in a certain orientation (Figure 2c)

III. The track etch rate v_T

- The track etch rate v_T is calculated from the angle between the facing straight track boundaries (Figure 1)

- v_T correlates with *Dpar* (Figure 3a), suggesting that v_T is under chemical control rather than determined by the lattice damage along the track

- Track etch rates vary from track to track, suggesting an imprint of the thermal history on v_T

- Fossil tracks of samples with low average track etch rates are to different degress under-etched compared to induced tracks using standard protocols (Figure 3b)

- The observations made above suggest the need to adjust immersion times for different samples (Figure 3c)

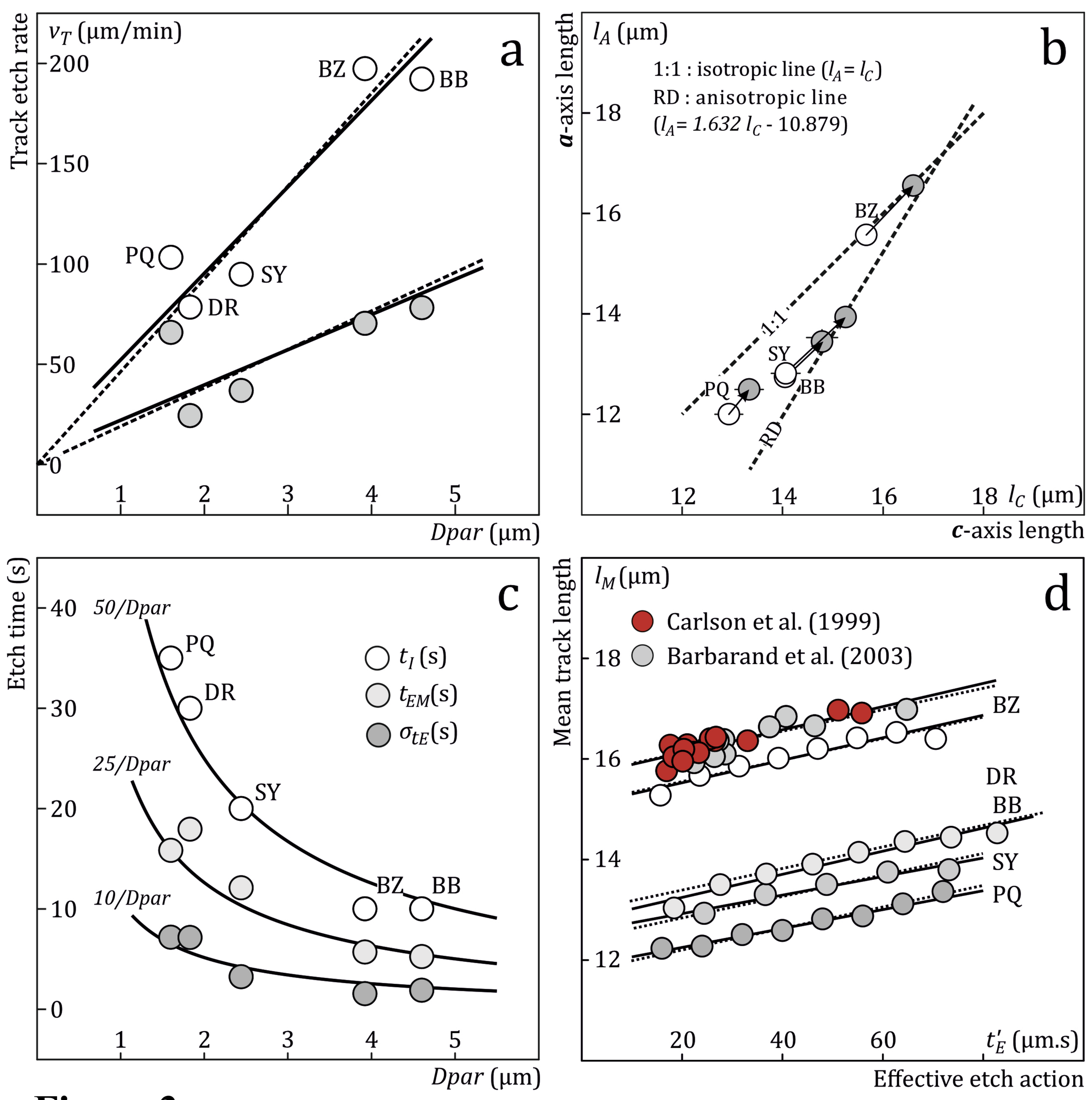

Figure 3.

IV. Implications

- Effective etch time calculations allow a quantitative selection of tracks within an etch-time window that excludes under- and over-etched tracks for T-t modelling (Figures 4 and 5)

- This approach allows to adjust the immersion time for individual samples with known Dpar:

-> Longer immersion times or pooling of consecutive etch steps can increase the number of confined tracks for young and U-poor samples

-> Plots of ***c***-axis projected length against orientation with a positive slope are a sign of under-etched fossil tracks; further etching lowers the slope and increases the agreement with induced tracks (Figure 5, left panel)

- For our samples T-t models with well-etched tracks (t_E = 15-30 s) fit better to independent AHe data than those with the conventional 20 s protocol (Figure 5, right panel)

- The initial mean length of unetched induced tracks is ~15.6 µm, independent of the apatite chemical composition (Figure 3d)

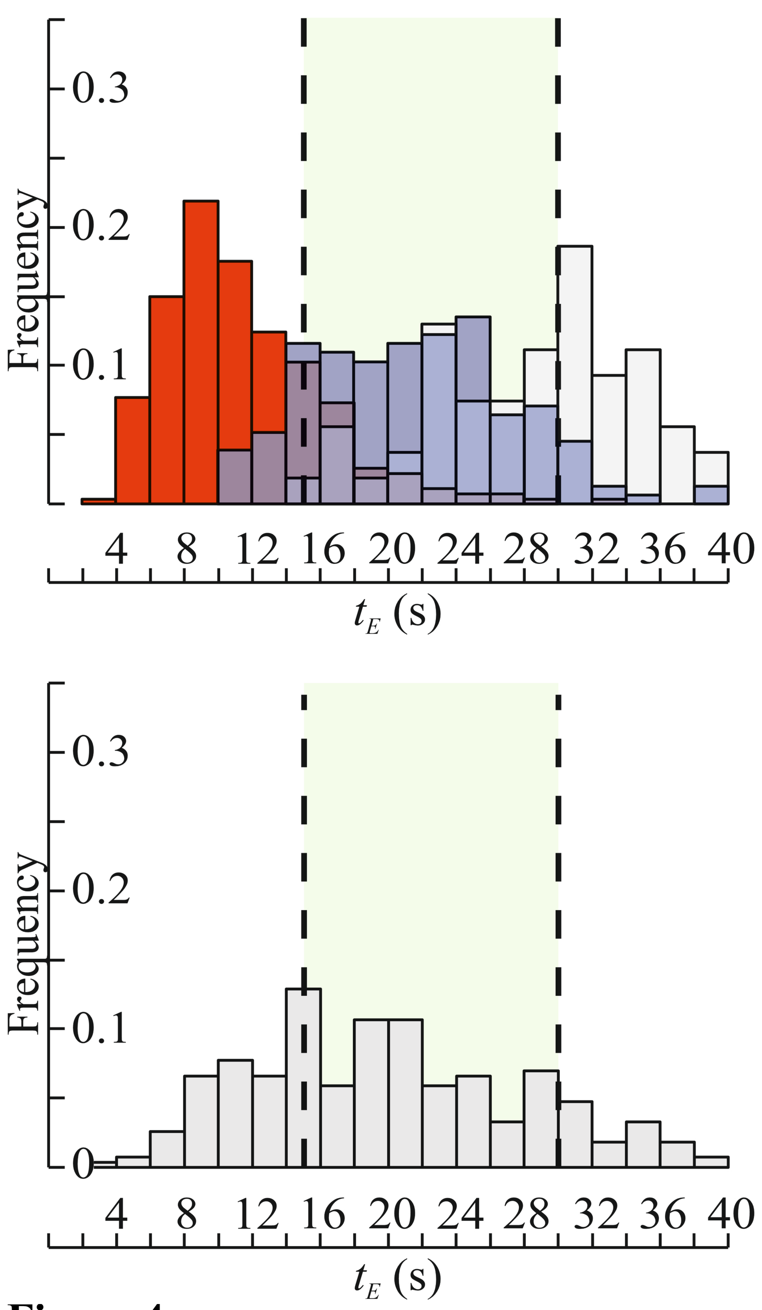

Figure 4.

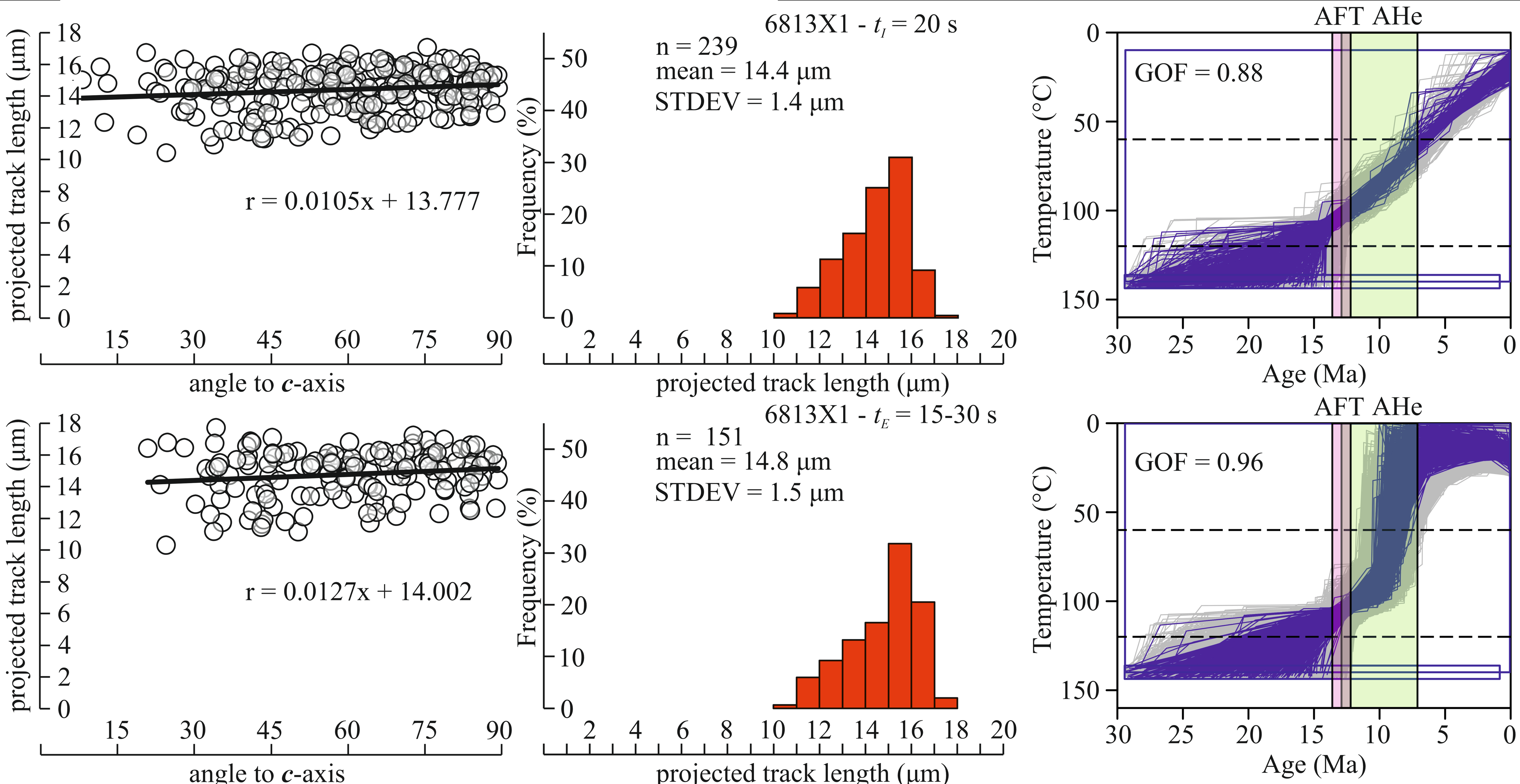

Figure 5.