

Manuscript gchron-2021-28 - Revision 1

Short communication concerning experimental factors affecting fission-track counts in apatite

Carolin Aslanian, Raymond Jonckheere, Bastian Wauschkuhn, and Lothar Ratschbacher

Replies to the reviewers' comments

Overview of substantial corrections

As explained in our detailed replies to reviewers *Drs. M. Tamer* and *H. Iwano*, we accepted almost all their comments. The few exceptions concern matters of phrasing and one Figure. Instead, we added two Figures, replaced Figure 4, and provided three more in supplement. Our main corrections are:

1. We added an image (Figure 3) of a basal section illustrating the loss and gain of tracks from different causes.
2. We corrected and added some detail to Figure 3 (becomes Figure 4). This forms the basis for a comparison of the measurement data with numerical predictions based on the etch model of Aslanian et al. (2020). The model predictions are explained in Figure 5, which replaces our previous Figure 4. The new Figure illustrates the same principle as the previous in greater quantitative detail.
3. We added significant details to Figure 6 (becomes Figure 7), which enable us to address the matter of transmitted-light vs. reflected-light counts in a more detailed and convincing fashion (see replies to Dr. *H. Iwano's* comment to Figure 5). We added Figure 8, illustrating the extended discussion.
4. We added the missing data on the sizes of the etched-track openings to the data supplement.
5. We provide reflected- and transmitted-light images illustrating the loss and gain of tracks with etch time in supplement.

The reviews of *Drs. M. Tamer* and *H. Iwano* offered us an opportunity to take a fresh look at our data. This permitted us to pull together further strands of numerical evidence, and to present a fuller interpretation and a much stronger case for our conclusions than before. We expect that the complete corrections will lengthen our text by 50%, and therefore ask the editor to consider the suggestion of one reviewer to treat our manuscript as a full article instead of a short communication.

Freiberg, 16 November 2021.

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Reviewer #1 (Dr. M. Tamer)	Replies
<p>This manuscript reports two different experiments on track counting in Durango apatite and uses a recent etch model to explain how the track counts change in different observation criteria. The first experiment is track count and etch pit measurement analysis of fossil tracks in three different sections of Durango apatite; the second one is a further counting analysis of unannealed, annealed, induced and fossil tracks in c-axis parallel section of Durango apatite.</p>	<p>We are grateful to the reviewer for emphasizing the merits of our work and supporting its publication.</p>
<p>The text is well written, the figures are clear, the tables and supplementary file contain almost all the analysis data, excluding etch pit/track opening length measurements.</p>	<p>We included the missing data in the supplement. This occasioned us to correct the calibration of our measurements of the etched-track openings in the different apatite faces. This, in turn, led us to expand our discussion and to relate the numerical values to our published etch model.</p>
<p>Analyst bias and track selection criteria have significant impact on fission track data analysis and ultimately affect the modelling results. After adding suggested figures, a new table and supplementary data for etch pit/track opening lengths and rearranging the format from short communication to regular manuscript (with more discussion and conclusion part), this work should be resubmitted as a regular manuscript. Please find the specific comments and suggestions in annotated pdf.</p>	<p>We address the reviewer's specific comments below, including those on the annotated manuscript.</p>
<p>Line 4: Institute fuer Geologie, Technische Universität, Bergakademie</p>	<p>Corrected to: Institut für Geologie</p>
<p>Line 30: Time-temperature sounds better than temperature-time, maybe I am just use to hear the first one.</p>	<p>This is a matter of preference; we believe temperature-time is more used in most geological papers.</p>
<p>Line 30: frequently?</p>	<p>Another matter of preference: "a much-used ... tool" sounds better to us.</p>
<p>Line 31: The dating method rests on counting and the modeling on length measurements.</p>	<p>It is not so straightforward; an age without lengths can be a formation, cooling, mixed or a reset age, with uncertain or no geological meaning; a modelled T,t-path without an age can</p>

	extend over any length of time. Our emphasis on " <i>counting and measuring</i> " is deliberate and, we believe, right.
Line 32: Latent?	Corrected.
Line 34: unable to be observed under optical microscope	Another matter of preference: " <i>too thin to observe with an optical microscope</i> " sounds better to us.
Line 47: and Tamer et al. 2019	Corrected; we cited the wrong reference: Ketcham and Tamer (2021) should indeed have been Tamer et al. (2019).
Line 56: Just like Figure 5 showing the images of tracks, maybe a figure can be made to show the step-etched tracks at the exact same locations for three Durango sections in three different etch times.	Corrected; transmitted and reflected-light images of the step-etched tracks in a basal, prism and intermediate face have been added in supplement, because they would overwhelm the text elsewhere.
Which light source was used for counting?	Corrected; we explain that we used both reflected and transmitted light (cfr. images in supplement).
The experimental procedure includes mounting, polishing and etching. The reader can expect that the tracks being counted are only spontaneous tracks but maybe the word spontaneous or fossil can be added in this sentence, referring the type of tracks.	Corrected: we specified "spontaneous tracks".
Figure 1: Comparisons on the 1 to 1 lines already show the increase and decrease in track counts with the step-etch experiments, however, an addition of a simple density vs time plot may help.	We do not object to adding this simple figure but would prefer not do so because we already have a lot of figures in relation to the text, and need to add others in response to the reviewers' comments. We prefer to add the more important figures rather than this not so important one.
Although it is written in the text and figure caption, maybe it would be good to include "basal face", "prism face" and "intermediate face" to the corresponding figures at top left.	Corrected; we added "basal face", "prism face" and "intermediate face" to Figure 1.
Table 1: what is TL? Transmitted light? Did you use transmitted light only for counting?	TL means transmitted light. We used reflected light for measuring the track openings and transmitted light for counting the track channels. We now explain this in the caption to Table 1, to which we have also added basic statistics related to the measurements of the track openings.
Table 1: Something unimportant: the densities reported in the table as tracks/cm ² . Maybe it would be good to use cm ² to describe the area of the field instead of μm ² .	Corrected; 3.815 10 ⁻⁴ cm ²
Line 96: in?	Corrected.

Line 102: etch

Corrected.

Line 108: A figure showing a (some) track(s) disappear in the same field with the increasing etch time can turn this proposition truth. Maybe you can add such a figure. But there is also an inevitable possibility that you may missed some tracks to count, which is part of the fission track counting. Maybe you can mention this too.

Corrected. We added a figure showing the merger and gradual loss and gain of tracks in a basal face. We also use this figure to illustrate the discontinuous track terminations in relation to experiment 2.

As the images in supplement illustrate, in step-etch experiments on Durango apatite, there is little room for accidental miscounts. Although it is not possible to exclude them (or anything else) formally, emphasizing such a hypothetical effect would detract from the results. We do not deny that accidental miscounts are real, but they are surely more important for routine counts of geological samples where neither the apatite, polishing nor etching are as in this work.

Line 131: The vast majority of the papers in fission track methodology is on the tracks parallel to c axis. A new figure that is suggested in comment #9 may visually assist the reader to understand the difference of the track openings in these 3 different samples.

Corrected. We added a figure in response to this comment, showing tracks in a basal, prism and intermediate face.

I could not see any data in the tables or in the supplementary excel file regarding the track opening measurements. How many openings were measured? Were the opening measurements executed consistently on the same openings from 10s to 30s or random openings were measured each time? What are the long axis in basal and in 30 degree section? Maybe a figure would be good.

Corrected. We included the measurements of the track openings (>18.000 in total) in the data supplement. The openings were measured in the images used for the track counts. Although overall the same tracks were re-measured after each etch step, we did not trace the individual openings from one step to the next. As the reviewer demonstrated (Tamer and Ketcham, 2020) and our etch model implies (Aslanian et al., 2020) their rate of growth is constant.

Line 158: I did not notice that there is a second experiment until here.

That is deliberate. To describe both experiments at the start and then return to each in turn for discussion would confuse the reader, as the two experiments are in part similar and in part dissimilar.

Figure 3: Visual differentiation of the shades of gray is a little narrow. Different shades can be distinguished in the histograms but it is somewhat harder for Figure 4d. Maybe using further ends of shades in the spectrum would be better.

Corrected. We improved the shading contrast in Figure 3. We also extended the discussion of the track openings, comparing them with numerical predictions based on Aslanian et al. (2020).

Line 165: Maybe the experimental details and the results can be divided, or at least the experimental details of the both experiments can be pointed out first. Both experiments include Durango apatite underwent same type of polishing and microscopy routines, same type of etchant with a little difference in etch times. The light source used in the first experiment is not pointed out. Merging the experimental details can reduce the repetition of the routine procedural descriptions, cover missing descriptions and pre-inform the reader about the number of experiments.

The problem is that we report two experiments on the same topic, stated in the title. One is a step-etch experiment and the other an annealing and counting experiment. The material and initial sample preparation are indeed similar, but that is what makes it difficult to distinguish between them. After considering the alternatives, we chose to treat the experiments in separate blocks, so that the reader does not have to switch back and forth between them. After reconsidering, we believe that it is the best solution, as the repetition amounts to a couple of lines at most. We made it clear at the start that we report two experiments in succession.

Line 185: Did you use isolate the counting only RL and only TL in the approach or did you switch the light sometimes? How about a third approach of counting by switching the light source constantly? For example, the TL and RL counts in sample 313 °C are 1450 and 7852 but if you use a mixed light approach with high switch frequency (maybe 30-40 switches per field counted, depending on the degree of annealing track density and other features), you may achieve a new number, probably close to 7852 but likely to be higher.

We separated the TL and RL track counts with the explicit intention to avoid biasing one or the other. We first performed the TL counts without use of RL and then the RL counts without use of TL. Although we did so a field at a time (instead of finishing all the TL counts before doing the RL counts), the TL count betrays next to nothing about the RL image. Conversely, with few exceptions the track channels cannot be distinguished in RL (Figure 5). A practised track counter will know from experience that it is impossible to keep in mind a previous image while counting the next. Thus, to all intents and purposes, the TL and RL counts are independent. Even if there were some inadvertent bias, that would have no effect on the rather obvious fact, illustrated in Figure 5, that there is a discrepancy between the TL and RL images. We explain this in detail in our revised manuscript.

Figure 5: Instead of not annealed, maybe unannealed or control would be better?

Another matter of preference: "*not annealed*" seems to us as good as "*unannealed*", which spelling checkers signal as incorrect.

Figure 5: maybe (t,T)?

Most co-authors have used (T,t) for years; we do not understand the need to change it now.

Figure 6: Why does this figure remind me the length vs density relationship figures in Green 88? The same dog leg pattern is visible here. Maybe Jonckheere 2003 and Green 1988 can be considered in the discussion part to point out these similarities.

We agree that the similarities between Figure 6 and those of Green (1988) and others are not coincidental, the common factor being the break-up of the tracks, which causes the TL track densities to collapse but not the RL track densities or the mean confined track lengths. We expanded our discussion and added a new Figure showing how these observations are related.

Line 201: Maybe this common knowledge shouldn't be in the discussions and conclusions?

Every manuscript contains some common knowledge. In this case, it is a single sentence introducing the topic of etching, which is the subject of our research. "*Measuring and counting fission tracks requires etching to make them accessible for microscopic examination. Track etching is ...*". The discussion would be ill-structured and difficult to follow if we had no such sentences.

Line 218: It is understandable that there is no solution for these issues but maybe some further speculation can be added in the discussion part.

This comment refers to: "*Our findings provide no solution*". This is a warning that our results refer to our experimental conditions and cannot be extended to others. In contrast, our approach, based on step-etching, measurements of the track openings, and attention to polishing and etching as contributing factors, can be useful in searching for a solution. In particular efforts to automate track counts could benefit from considering these factors. We prefer to desist from speculation other than the references to ongoing research mentioned in our manuscript.

Freiberg, 16 November 2021.

C. Aslanian
R. Jonckheere
B. Wauschkuhn
L. Ratschbacher