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Interactive comment on "Confined fission track revelation in apatite: how it works and why it matters" *by* Richard A. Ketcham and Murat T. Tamer

Edward Sobel (Referee)

edsobel@gmail.com

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General comments I have read through both the manuscript and the 3 presently existing comments and replies (no reply to RC4 at this moment). I will try not to reiterate what the other reviewers have noted. I think that they have done a good job in addressing weaknesses in the ms, although not always in a manner which makes it easy to see how to revise the text. In general, the study has the potential to be an important work examining how confined track length and termination shape evolves as a function of etch time. It is clearly not the final answer to this topic, nor do the authors claim that it is. However, it is a complicated problem which has been studied for over 35 years, so

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Discussion paper

why expect a quick solution:-) Yes, progressive steps forward are useful. In this case, technology has made it possible to track track growth in ways that previous generations could not measure - this has lead to the ability to improve our understanding. We all (try to) build upon previous work - that is the goal! I certainly learned a great deal about how and where confined tracks form and lengthen - and how few of them are actually measurable. The discussion of how track tips become more defined as they become better etched and how defining these shapes may lead to better inter-operator agreement is an important point in the study.

Specific comments In general, I concur with the other reviewers that the text is challenging to read and needs significant rewriting to make the points easier to understand. It would help if the introduction provided a better roadmap of what will be presented in the ms. Renaming the sample numbers with abbreviations matching the experimental conditions might help the reader to keep track of what is being done. E.g., SE1 could be renamed IU1 (Induced Unannealed). Transition sentences explaining what is about to be presented - such as 'observed data will be compared to numerical results' - would help the reader to follow the text. Some figures would benefit from captions that stated whether the plots depict observed or modeled data. In general, the captions are too short and do not sufficiently explain what is being shown (and why). Better labelling of figures would also help. Rather than just writing text in the caption, place information on the individual panels as well. For instance - add "randomly oriented unannealed induced tracks" and 'Cf tracks' to the individual panels in fig. 3. I agree with Gleadow's comment that a figure showing all geometries and terms is required. A table defining all terms would also help. The study of annealing of fission tracks has been advancing in fits and starts for over 55 years. A fair number of references from this evolution are included. Most fission trackers have probably not read most of these papers nor are they deeply attuned to the unresolved problems. Yes, they should be aware; however, a more robust introduction to the open problems would be useful for many readers. The text is written in a very compact form, with the authors apparently assuming that the readers are quite familiar with the topic. I encourage them to expand the text. This

is a paper which can at present only be read by a specialist. Perhaps this is true of most scientific papers, and this is not a bad thing. However, this ms requires a large amount of prior knowledge because many points are taken for granted rather than being explained. The introduction should clearly explain what tracks are and how they etch (damage 1st, then bulk etching in 3D). A sentence about how tracks form wouldn't hurt either. At the moment, I think that many non-specialist readers wouldn't even finish reading the introduction. Note that by non-specialist, I mean a fission-tracker who isn't deeply into methodology. Repeating methodologic information from the experimental paper (Tamer and Ketcham, 2020b) would be useful - how exactly was the step-etching done? This is pretty fundamental for understanding this dataset. And as many institutions do not subscribe to Elsevier journals, it is not always a 1 minute task to get this reference.

The discussion is much easier to follow than the preceding sections.

59-60 More recent work has documented enhanced but continuously diminishing etching velocity in the region along tracks beyond where most current etching protocols reach (Jonckheere et al., 2017). Could it be that as etchant travels along a longer/deeper track, that the strength of the acid and hence the etch rate decreases? This is suggested by the difference in measured track length of 20 sec etching of SE3 (3 steps, 14.89 microns) versus TK20 (1 step, 14.43 microns) and SE2 (2 steps, 20 sec, 16.19 microns) versus SE1 (1 step, 20 sec, 15.77 microns). A parallel question - does the strength of all possible etchants (e.g., 1.6 vs 5.5 mol nitric acid) have the same relationship to both bulk etching rate and track revelation rate? Or is there a difference between these rates as the acid is changed? This is relevant for both slow versus fast etch acid recipes as well as changes in acid strength as it penetrates farther into the crystal. These questions likely reveal my ignorance about the etching literature; however, answers or guesses about these questions might be helpful for improving the ms, particularly as the average reader is probably as ignorant as I am about this topic. The 2nd point is partly addressed in 413-423.

87-88 There was no clear indication of vB varying with track orientation (Tamer and Ketcham, 2020b). This was commented on by other reviewers. Please add a comment in the text about this observation, similar to the response to reviewer.

92 In cases where it was difficult to determine if an intersection truly occurred due to interfering features, we conservatively included it. Following Green's comment and your reply, it would be useful to explain your explanation of conservative here.

129-130 Variation in impingement point alone is likely responsible for some component of the observed variation in track lengths. How many tracks would one have to measure for such variability to become irrelevant. I.e., is this concern real and important for actual data collection or is this just an issue for interpreting this data set?

180-185 Adding photos of actual track tips would help to explain this useful concept. Naturally, anisotropy is quite important here, but this approach provides a way to go forward for better defining criteria about when a track can be measured. The argument that operator's track identification choice is responsible for much of the length variability observed in the inter-lab comparison is a key result of this study.

207-208 The tracks have a range of tip development (Fig. 6D), and only selecting those with vT/vB $\leq$ 12 (Fig. 6E) results in an excellent match to the measured data (Fig 6F). Excellent seems overstated. Adding text to the caption to point out what one is supposed to notice (this agreement) would help.

480 efficiency suggests that a carefully controlled preheating step could greatly increase confined track numbers, potentially without affecting lengths and thus paleothermal information Potentially is the key word in this sentence. If it did affect lengths, wouldn't this be fatal? It seems unlikely that the length reduction could be sufficiently well-constrained, particularly for detrital apatites, which are more likely to exhibit kinetic variability.

fig 2 caption - please add definition of xint in caption to help reader understand the

figure. It is not defined in the text. It appears to mean the position where the track began to etch / was intersected by a semi-track. The reader shouldn't have to interpret how a parameter is defined - it must be clearly stated. Ah - it is defined on line 159 - far too late. It is quite hard to see the difference between the 2 sets of figures; therefore, the difference should be described in the figure caption. If there isn't a real difference, then say so in the caption so that the reader doesn't get frustrated.

Fig. 8 is quite hard to understand. Write a useful caption! Fig. 9 shows 15 plots. The caption says nothing. Do you really expect the reader to look at this and understand your point? Ok, you have plotted 5 different data sets, each with the same 3 cross-plots. Conclusions? What is significant? Yes, if I have lots of time, I can try to figure out your point, and remind myself what are the differences between these 5 sets. However, if you want readers to understand your points, it would be better if you guide them. Otherwise, many people will give up and get nothing from at least this part of the paper. And ultimately, articles which demand too much patience by the reader are not yet ready to be published. Please increase your font sizes. Look at the text below the color scale on this figure. Do you really think that it can be read (including the subscript) without strong magnification?

Technical corrections 105 Only simple models justifiable at this point because our data consist of a very limited number of experiments. Add 'are' 150 Figure 3 shows examples of penetration and revelation rate. add 'calculated' 178 which will develop as a function etching velocity add 'of the' 199-200 Etching time must be greater than 3 s, after which track observability the probability of selecting a track is represented as ((L - 4.5)/5.5)3; A word or 2 are missing here 220 The merit function is reduced chi-squared () This is too brief -for instance: We used a reduced chi-squared () value for the merit function. 230 Thus, we simultaneously fit data sets SE1 and SE2, At a minimum, point to table 1, so the reader can be reminded what SE1 and SE2 are. 233-234 Similarly, we co-fit SE3 with a single-step 20s measurement of unannealed fossil tracks from Tamer and Ketcham (2020a). Please name this dataset here (TK20). 236 After several

trials, we settled on a vT/vB of 12, why? 242-244 adding commas to this sentence might help to make it understandable on the 1st reading. 270 add micron after ∼0-0.2 Table 1 notes need to define more column headers. Fig. 11 - Explain what velocity gradient means in the caption. What is the database here? Fig. 13 - What do lighter and darker bars on histogram mean? Presumably the same as a similar fig. 6. State that - don't just expect the reader to remember (or to have read the entire ms).

Edward Sobel Universitaet Potsdam, Jan. 19, 2021

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