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Interactive comment on "Thermal Annealing of Implanted ^{252}Cf Fission-1 Tracks in Monazite" *by* Sean Jones et al.

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Overview

My perspective on this manuscript is from a person who develops and applies models rather than one who does hands on laboratory work. In my opinion, this a high quality manuscript that presents new and important annealing experimental data that help to constrain a potential new ultra-low temperature thermochronometer using fission tracks in monazite. This study is a nice follow up to previous annealing study of monazite by Weise et al. (2009). The manuscript is well organized and well written and includes essential figures and tables that are required for understanding how the work was done and how the data are used to estimate monazite-annealing temperatures

through geological time. This work is exciting and interesting because these results support the notion that monazite has greater sensitivity at much lower temperatures than other widely used thermochronometers. This can lead to new applications in the earth sciences and perhaps allow for the resolution of previously undetectable thermal events. I recommend that this manuscript be published after some minor revision.

Specific comments

Although the manuscript is efficiently written and easy to follow, I believe that more details on aspects of the experimental methods could be included, probably in a supplementary appendix. The authors give many useful details on track implantation and measurement and that part is fine. We know that accurate laboratory temperatures are critical for calibrating annealing models and that extrapolation of annealing temperatures to geological time scales are particularly sensitive to uncertainties in laboratory temperatures. Therefore, it would be helpful to have some more information on laboratory procedures and conditions. For example, there is no mention of any pre-heating of samples to pre-anneal fossil tracks and eliminate any potential radiation damage. A very brief description is given for the heating apparatus and temperature uncertainties were estimated to be $\pm 2^\circ$C. How was this estimated? Any steps taken to ensure constant isothermal conditions within the heating apparatus where the grains were inserted would be worth noting. This information is important because, for example, differences in the results of fission track annealing experiments for apatite among different laboratories have been attributed to temperature uncertainties.

There is significant variation in the initial track lengths for the control apatites used in the annealing experiments which is attributed to ambient annealing following track implantation. Based on the results in Table 1, I assume there is too little compositional variability among the grains to have a significant affect, and if spontaneous tracks were pre-annealed, then any contribution from potential radiation damage related to variable Th and U concentration is unlikely as well. Ambient annealing seems like a reasonable hypothesis so it is unfortunate that there is no information on the time between track implantation and etching. It would be useful in the supplement to provide some information concerning the order of steps that were performed so that readers could get an idea of the relative time scales involved. How were the data acquired? Were the control grains etched before or after the annealing experiments and did they proceed in some specific order. Presumably, the last ones to be etched had more time for ambient annealing. Did the experiments proceed in the order of shortest heating duration to longest heating duration? Was etching done at the end of each experiment or after all experiments were finished. If this information is available, it may be helpful for a better understanding of the results.

The authors point out that the results in their Figure 6 suggest that anisotropic annealing increases the standard deviation at short mean track lengths, similar to confined tracks in apatite. However, unlike apatite, the standard deviations are also larger at long lengths and this may be attributed to ambient annealing affecting the longer tracks. The U shape distribution of points seems clear in the figure and is worth discussing. There seems to be a slight hint of this pattern in the residual plots in Figure 9.

The last paragraph in the conclusions seems to be more appropriate for the discussion section. The discussion section could be expanded to elaborate on some of the recommendations for future work and the possible influences of other factors on monazite fission track annealing. For example, in addition to using longer heating schedules, low temperature geological benchmarks would be needed to help constrain a fanning curvilinear model like the one used by Ketcham et al. (1999, 2007). That model seems to be better suited to accounting for low temperature annealing of apatite fission tracks. Given the apparent very low annealing temperatures inferred for monazite, it could be very difficult to constrain ambient annealing in a model without such data.

In general, elemental composition has been neglected in many apatite fission-track thermochronology studies and therefore the full potential of multikinetic annealing behaviour has not been utilized. My hope is that this does not happen with monazite should composition turn out to be an important factor influencing annealing. Chemically heterogeneous apatite is widespread in detrital apatite of all ages and it is common for two or three (and sometimes more) kinetic populations to be present in a sample. I have ∼200 detrital multikinetic apatite FT samples, some of which contain kinetic populations with differences in annealing temperatures that can approach 100°C, in general agreement with temperature ranges inferred from models calibrated using the results of annealing experiments (Ketcham et al., 1999, 2007). If monazite composition is important, then it may shift the annealing range to higher temperatures and allow for a better-calibrated annealing model. Otherwise, it may difficult to calibrate a model where tracks are unstable at temperatures of geological interest.

Although not stated in the manuscript, it seems that etching is nearly isotropic in monazite or, at least, far less anisotropic than apatite. In addition, in the conclusions it is stated that anisotropic annealing occurs at measurably different rates with respect to the crystallographic axes in monazite. It would be worth mentioning the degree of anisotropy with respect to a well-known mineral like apatite as a reference for readers. Elsewhere in manuscript, the degree of anisotropy is not considered to be that large and that point could be made in the conclusions as well.

Technical Corrections

A few minor technical corrections are needed.

1) Lines 64,and 65, page 3. There seems to be a paragraph break but no space between these lines. 2) Line 264, page 13. Replace “a” with “an” before unannealed. 3) Line 297, page 14. Reference should be to Figure 4, not Figure 2. 4) Line 393-394, page 19. At first, it seemed odd to be showing the double Box-Cox transform when only the single form was being used here. Later in the text, it is mentioned that both are used so it makes sense to include it. However, you might want to modify the description to say you use the term in parentheses in equation 4 when referring to the single Box-Cox transformation. 5) Line 423, page 20. A square bracket is missing at the end of equation 7. 6) Line 502, page 26. Reference should be to Figure 9, not

Figure 7. 7) Line 680, page 32. Reference to the third author should be O'Sullivan, P.B. Also, a space should come after the colon, not before it.

Reviewer: Dale Issler

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