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Interactive comment on "Resolving the effects of 2D versus 3D grain measurements on (U-Th)/ He age data and reproducibility" *by* Emily H. G. Cooperdock et al.

Anonymous Referee #2

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General comments: The manuscript "Resolving the effects of 2D versus 3D grain measurements on (U-Th)/ He age data and reproducibility" by Cooperdock et al. provide insight into the issue of accurately measuring apatite grain dimensions for ultimate use in (U-Th)/He age calculations. The manuscript is concise and well written with respect to identifying key problems with conventional 2D microscope approaches and adds to the literature beginning to assess 3D (CT scan) methods for better grain characterization.

Please refer to the attached annotated PDF for in-depth line comments; main points are highlighted below.

I found some references to the general U-Th/He method (early development and application; Zeitler et al. '87, 90s Wolf/Farley/Ehlers/Reiners work etc.) to be lacking and additionally some recent work on age dispersion/analytical approaches for assessing age reproducibility to be uncited, and even prior 3D/CT scan work was cited later in the introduction (Evans et al.; Herman et al.; Glotzbach et al. etc.) - when statements made earlier in manuscript should cite these references as well or perhaps requires reworking of this intro. section.

The authors show that when comparing 2D vs. 3D approaches for age calculations, that there is essentially no difference in the computed U-Th/He ages. While I agree that 3D-CT seemingly yields overall 'better' grain dimension(s)/morphology results, the additional time/cost put forth for CT work is not realistic for most users - i.e. the cost/benefit does not make this approach worthwhile to researchers that do not have easy CT scanner access. Page 18, Lines 20-25 best summarize this conceptually..."Overall, these data suggest that although the 3DFT can provide a more accurate FT correction and varies from 2D estimations by ~2%, it has a minimal effect on the calculated sample age (1-2%) and no effect on the reproducibility for these two samples. This is not surprising, as a ~2% error would constitute a negligible proportion of the often cited 6% dispersion derived from analyzing age standards; error propagation indicates that removing a source of 2% error would only reduce an overall 6% error to 5.7%. This points to the importance of other factors in intra-sample dispersion, such as U-Th zonation, and/or excess He from nano-inclusions or high U-Th neighbors." This passage advocates for a more proactive approach to dealing with real and greater sources of age dispersion.

Additionally, this work utilizes apatite grains that were previously known to yield highly reproducible results (and the same holds true after their new work). This was probably the best approach to assess first-order discrepancies between 2D/3D, however, what does a sample look like that yields highly scattered age data? Does 3D help with reducing (some) dispersion? As we know, it is more common for a lot of apatite He ages to be statistically over-dispersed. I think for additional communal value the authors should characterize some other 'normal' samples.

Major Line-by-line comments (see PDF for all): Page 1, Line 12: How do you quantify eU with 2D microscope or CT information? Page 1, Line 16: Arguably no one uses mass for interpreting age scatter and eU (known to be underestimated)...ESR may be problematic and could be better addressed by the 3D technique. In regards to eU/ESR-age relationships being used in a meaningful way for age scatter interpretation, see recent paper by Fox et al. 2019 G-cubed "Badly behaved detrital U-Th/He ages: problems with He diffusion models or geological models?" Page 1, Line 18: "...effectively no impact on reducing intra-sample age reproducibility" Why would it? We already know what the major causes for intra-sample grain age variation are, even though they are poorly characterized on a routine basis. Even though grain characterization 'errors' have always been a known problem, we know that 2D estimation isn't that bad, otherwise He ages would never work out correctly during FT correction. Well-behaved whole grain samples show this well and you demonstrate this here that for age calcs. it all works out. The magnitude of age dispersion due to inclusions, zoning, or especially 'anomalously sited' 4He far outweigh 2D grain measurement-derived errors for FT correction (see recent papers by Idleman et al. 2018 Chemical Geology or Mcdannell et al., 2018 Geochimica et Cosmochimica Acta –the latter more directly deals with causes of age dispersion) Page 2, Line 11: Why would someone 'assume' parent nuclide heterogeneity without any proof of it? Page 3, Line 23: Number of grains? chi-squared? % dispersion? all informative/useful...because that is a highly precise AFT age. Page 18, Line 15: If it is old compared to the rest of the grains then it must contain anomalous He content. Personally (IMHO), I don't like these types of 'catch-all' statements in papers dealing with unexpected He age data. Rather than the usual retelling of the laundry list of potential issues such as 'He implantation, mineral inclusions, fluid inclusions, U-Th zoning, etc'. - just make a general statement that the age was 'bad or unexpected' - you don't actually know why. If you don't actually have any way of quantitatively assessing the reason then speculation is not useful. By listing

the many issues it subliminally perpetuates the idea that there are so many problems that we don't know where to start or what to do to fix things. Page 19, Line 6: You should stress here that labs should not pick grains with inclusions regardless. It was just done here to illustrate that the CT scan can pick up fluid/mineral inclusions, right? This text as-is makes it seem like it is okay to date as long as they aren't U/Th-bearing inclusions (which you wouldn't know until it was too late).

Please also note the supplement to this comment:
https://www.geochronology-discuss.net/gchron-2019-3/gchron-2019-3-RC2-supplement.pdf

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