1. Comment: My main concern relates to the presentation of the methods. I found the methodology section difficult to follow because it effectively requires the reader to reproduce the modelling step-by-step while reading the manuscript. I recommend moving much of this procedural information to the Supplementary Material and instead focusing the main manuscript on the concepts, consequences, and visualization of the modelling results. A detailed user guide for OptiPit, together with instructions for using the accompanying Excel spreadsheet, would be more appropriate as supplementary material.

I attempted to run OptiPit on a workstation PC, but the estimated computation time exceeded 1000 hours. It is possible that I selected inappropriate settings; however, this highlights the need for a detailed "How-To" guide and example project files that users can load directly into OptiPit. Such documentation would greatly improve the accessibility and reproducibility of the workflow.

Answer: We thank the reviewer for his recommendations. We agree that a user guide or manual for OptiPit would have made the software much more approachable for the user, and that not including it during the original submission was an oversight from our part. As a reaction to your comment, I wrote a user manual for both OptiPit and the connected Excel file, containing screenshots and best practices, to hopefully resolve this issue.

However, we think that stripping the procedural information from the manuscript would leave out information necessary to understand our manuscript. We are aware of the difficulty of the methodology section and the immense number of concepts introduced within it. Therefore, we slowly introduce the user to the concepts by providing the procedural information first. Without these, understanding of those would be even more hampered. Thus, we would like to keep that section.

2. Comment: The manuscript should also clarify whether the proposed optimization procedure needs to be performed for every individual grain or only once for a given mineral system and analytical setup. Performing these calculations for every grain would be highly time consuming and may not be practical, especially because LA-ICP-MS analyses are typically performed using consistent pit sizes throughout an analytical session.

Answer: This is a very good point. It depends on the goal for which an OptiPit simulation is done. If the goal is to find the optimal combination of He pit and ICP pit geometries in a homogeneous grain, the simulation only needs to be carried out once. Similarly, if the aim of the user is to simulate maximum/minimum age offsets produced by a range of worst-case radionuclide zonation patterns and, from those, determine the optimal analytical set-up for an analytical session, the analysis also only needs to be carried out once.

However, if the aim of the user is to minimize individual age offsets produced by different zonation patterns by using combinations of differently-sized laser ablation pits, new OptiPit runs would need to be carried out for every new combination of the input variables. The provided excel table can facilitate this by assuming the radionuclide zonation to be symmetric around the laser ablation pit. In this case, OptiPit only needs to be run once for every He pit geometry, ICP pit depth, and decay chain. The age offset and mismatch can thereafter be easily calculated using the excel file. This procedure is illustrated in the new user guide stored alongside OptiPit within the static repository.

3. Comment: In the discussion, I believe the interpretation of the modelling results is somewhat overstated. The authors explicitly acknowledge that their modelling does not account for kinetic effects, such as those associated with radiation damage, nor for helium diffusion. Therefore, the statement that symmetric zoning does not affect age determination provided that the He and ICP pits are appropriately selected is not fully supported. Indeed, the subsequent discussion acknowledges these limitations. I recommend revising these conclusions to better reflect the assumptions and limitations of the model.

Answer: This is a good point. We consciously did not explore this question in the original submission because we wanted to highlight the, in our opinion, underexplored topic of He redistribution during alpha decay in the in-situ technique. Following this and other comments, however, we have included a new section in the discussion of the manuscript with practical implications of our findings, as mentioned in other replies. Please see our answer to Reviewer 1's Comment 5 for an overview of how diffusion affects our conclusions. Also, we have adapted this passage dealing with symmetrical zoning to clarify that the difference in diffusivities between crystal zones with variable damage prevents using such a strategy

4. Comment: An important practical aspect that should also be discussed is the difficulty of accurately measuring the volume of laser pits with low surface-area-to-volume ratios. Depending on the technique used for pit-volume determination, deep and narrow pits may not be measured accurately, introducing additional uncertainties that are difficult to quantify.

Answer: This is a good point, and we thank the reviewer for the suggestion. Regarding the analytical aspect of determining pit volume, Maier et al. (2026) argue that a pit diameter >20 µm combined with a depth of <=8 µm is optimal for the pit volume analysis. Our suggested optimal pit has the same diameter to depth ratio. We now include this point in the new section on practical implications of our contribution.

5. Comment: Another methodological consideration that is currently not addressed concerns the effect of differing ICP pit geometries between unknown samples (two overlapping cylinders) and reference materials (simple cylinder). Variations in pit geometry could potentially influence LA-ICP-MS data reduction and calibration. Although I am not aware of previous studies that have explicitly investigated this issue, it has been one of the main reasons why I prefer a nested analytical approach (corresponding to the authors' Geometry A), in which a relatively wide and shallow He pit is followed by a slightly narrower ICP pit drilled within it. Besides minimizing potential calibration differences, this approach also allows radionuclide variations with depth to be quantified. In contrast, the proposed Geometry B would more likely produce a mixed signal when compositional zoning is present.

A: We approach the first issue mentioned by the Reviewer in a pragmatical way. In order to generate similar down-hole fractionation trends in the non-He-ablated phases a pit is drilled into the reference crystals that has a size similar to that of the He pit. In this way we get consistent data and proper secondary standard cross-calibrations.

Beyond the reasoning based on the numerical results, we prefer Geometry B (deep He pit and slightly wider, deep ICP pit) because of the following reason: the optimized ICP pit of Geometry B includes more volume than the un-optimised ICP pit of Geometry A. The measured average actinide concentration in a zoned crystal consequently reflects the bulk radionuclide concentration more reliably than a small volume. The acitinide concentration of the latter can differ significantly from the true bulk concentration that generated the helium budget of the He pit.

Line by line comments:

Line 234-238: I had a quick look into the spreadsheet, looks complicated and I am somewhat lost in this part of the manuscript. Please explain in more detail what the user should do to make sure of OptiPit.

We acknowledge that the spreadsheet should have been accompanied by better documentation. The spreadsheet is now thoroughly explained in the OptiPit user guide that I uploaded into the static repository.

Line 243: You mentioned this earlier in the manuscript. It is quite obvious that your LA-ICP-MS pit must be the size of the HePit plus the maximum stopping distance to measure all area that contribute to the measured helium. Maybe you simply say somewhere that the maximum LA-ICP-MS pit size is constained by this assumption and you have tested within that constrain.

Although not strictly necessary, we think that pointing this out again increases the readability of the manuscript.

Line 277: I would not call it 'schools of thought' since there are not yet so many papers published with one or the other approach.

We modified the sentence which now reads:"Hence, the following section compares two pit geometries commonly applied in in-situ (U-Th)/He dating (Fig. 4, Table 4)."

Line 349: I thought that the radius of the He pit in geometry A is 30 microns, and that is limiting the radius of the ICP pit to <30 microns. Same for geometry B with 25 microns He pit, while the best ICP pit is also 25 microns. Maybe you say in the sentence before that you also test cases where geometry A and B will be switching to B and A.

Thank you for pointing us to that section. The cited radii refer to the ICP pit (line 348). But, as you point out, the radius stated for geometry B is off. It should be 32.5 µm, as shown in Fig. 6, 7, etc. This was wrong and it was corrected.

The radius of the optimal ICP pit is not limited by the radius of the He pit. Our model moreover shows that the geometry that only measures the parent nuclei beneath the He pit captures helium and radionuclide budgets with a strong mismatch. To reduce the mismatch to a minimum the radius of the ICP pit of geometry A (wide and shallow He pit) would have to be increased beyond the radius of the He pit. Contrary, to optimise Geometry B, the radius of the ICP pit would have to be decreased from 32.5 to 25 µm.

Line 350-351: For the geometry B both the He and ICP pit are essentially the same, therefore it is not sampling around the He pit.

Using an optimised radius of 25 µm for the ICP pit leaves a spot with a diameter about 25 µm wider than the He pit of diameter 25 µm/ radius 12.5 µm.

Line 370: Use 'larger contribution' instead of 'bigger share' if that makes sense here.

Modification done.

Line 462: Have you done additional modelling that proves your statement? I would guess that the age offsets that you mentioned previously will increase with increase radionuclide ratios of >5. In addition in the sentence before you mentioned that you have not considered diffusion and kinetic effects and therefore you cannot strictly saying that accurately dating is possible.

It is true that this approach (meaning that spots with symmetric zoning do are not affected by He redistribution during alpha decy) does not consider the effect of diffusion and differential radioactive damage and is therefore impractical for most natural samples. We now point this out in our manuscript.

Line 501-505: Mention also that the He content is also defining the size of the He pit. Grains with low radionuclide and/or age would require larger pit sizes and going deeper is also limited by the ability to measure precisely the volume of laser pits (which is more accurate in cases the laser pits are wide and flat).

The revised paragraph of the manuscript now points those facts out.

Figures

Figure 5: This figure is partly difficult to understand and does require (at least me) to read the text several times. Part a) and d) are easier to get, but b) and c) are difficult and I wonder if this is important to show and can be shown in an easier way.

While it is true that the figure is somewhat dense, we believe that it is beneficial in illustrating the mathematical definition of the variables used in our calculations, and we therefore choose to keep it in the manuscript.

Figure 8: It is not clear what exactly is shown in the left panel. My guess it is the top view of the modelling domain. I do not really understand the lower x-axis labelling and what are the half circles? Please at least add more explanation in the figure caption.

Thank you for pointing us towards that figure. We changed the figure to now include labels for the x- and y-axes to clarify that the figure shows a top-down view. Furthermore, we added a label to identify the ICP pit shells. Lastly, we modified the caption to point out that the left-hand side shows a top-down view of the laser ablation pits and linear radionuclide zonation. We applied similar changes to Fig. 9.

References

Maier, A.-K.; Glotzbach, C.; Falkowski, S. (2026): Analytical and modelling strategies for therml histories from in situ (U-Th-Sm)/He data of single apatites. In: Geochronology 8, pp. 165-189. DOI: 10.5194/gchron-8-165-2026.