

Interactive comment on “U–Pb geochronology of epidote by LA–ICP–MS as a tool for dating hydrothermal-vein formation” by Veronica Peverelli et al.

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Dear Editor,

Please find below the response on behalf of all authors to the comments posted by Elizabeth Catlos (Referee #1) on our manuscript “U–Pb geochronology of epidote by LA–ICP–MS as a tool for dating hydrothermal-vein formation” (MS id: gchron-2020-27).

The response is laid out as follows: we start by grouping comments that were raised several times into “General issues”. We then provide a “Response” to each individual “Referee comment”, indicating in brackets the manuscript lines or sections as reported

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by the referees.

We hope that you will find this response satisfactory.

Yours sincerely, Veronica Peverelli, on behalf of all authors

General issues:

1. Comments on Tara allanite as primary reference material We acknowledge the complications of allanite as a standard. Nevertheless, all allanite samples used in this work have been characterized in the cited literature. It is the conclusion of the cited studies that Tara allanite is the most isotopically homogenous among our available allanite samples and therefore the most promising reference material for U-Th-Pb dating. Moreover, regarding Tara allanite Liao et al. (2020; section 5.1) state that “the relatively low common Pb concentration ($f_{206} \sim 7\text{--}20\%$ and $f_{208} < 1\%$) and good U/Th–Pb age reproducibility demonstrate its applicability as a U–Th–Pb dating standard”. Smye et al. (2014) report the only available ID-TIMS data for Tara allanite. The fact that its reference age is a matter of debate can indeed be problematic, as pointed out by the referee in “Comment #7”. However, the fact that our allanite secondary standards yield accurate U-Pb ages indicates that the reference values from Smye et al. (2014) are accurate for Tara allanite. We therefore disagree with the referee’s concerns on the suitability of Tara allanite as primary reference material.

Referee comments by Elizabeth Catlos:

1. “It is possible to microdrill different domains of epidote, especially as it forms larger crystals and zones in the types of rocks under investigation. The authors also date one of the unknown epidote grains using solution ICP-MS, which seems at odds with this statement.” (lines 52-53) The epidote micro-separate analyzed by solution ICP-MS was in fact not dated. It was only used to inspect the consistency between LA- and solution ICP-MS data in a Tera-Wasserburg diagram. The revised text will however be edited acknowledging the possibility of micro-drilling material for in-situ TIMS and

Pb-Pb dating.

2. “Allanite has been shown to reproduce TIMS ages using SIMS as early as 2000 (Catlos et al., 2000, Am. Min.)” (lines 104-107) The suggested reference will be added.

3. “Allanite can be incredibly complex, as shown in numerous BSE images available throughout the literature. It is likely that a careful understanding of its chemistry in terms of compositional analyses could be included here. I don’t think any of the issues described above can be avoided, and the authors should be more precise in their description of problematic issues.” (lines 110-115) The compositional characterization of the used allanite samples is presented in the cited literature. The statement that none of the issues related to allanite for its use in geochronology can be avoided is at odds with what concluded in the cited literature, and we therefore disagree with the referee’s comment. It is in fact beyond the scope of this study to address the issues related to allanite geochronology, but rather to prove that it is a suitable reference material for epidote U-Pb geochronology.

4. “It is unclear if the sample numbers also correlate to samples described in these references. They should perhaps provide GPS locations if the authors do not want to make geological maps of the areas.” (lines 128-129) Samples Albula-1, Grimsel-1 and Grimsel-2 presented in this study were not characterized elsewhere, and the cited literature and figures are only intended to show the sampling locations. Sample Heyuan-1 is instead discussed in Tannock et al. (2020a; 2020b; their sample HY17-5), with the exact sampling location shown in Fig. 1 of Tannock et al. (2020a). This will be clarified in the revised text. In addition to this, GPS locations of sampling localities will be provided or it will be specified where they are reported in the cited literature.

5. “An overprint would suggest that alteration is possible. “Weak” is a relative term. It would be helpful to include particular P-T conditions.” (lines 130-131) Specific conditions will be added to the revised text.

6. “Anticipated absolute ages for the samples are not provided. It would be helpful to



indicate what they could be here or in further paragraphs.” (lines 132-133) “If the epidote ages from this area are unknown is at odds with the impression of this manuscript up until this point that the technique will reproduce epidote ages to a degree of helpful precision.” (lines 157-158) The revised text will be rephrased in a way to make it clear that there are no precise anticipated ages for the epidote samples, but that the consistency of the obtained ages can be verified thanks to the well-known tectonic history of the sampling areas.

7. “One would hope that all of the standards are homogenous in terms of U-Th-Pb isotopes, which translate to their ages. The CAP and AVC allanites are incredibly useful materials. They are compositionally heterogeneous, but they are incredibly well-characterized in terms of their ages. There is no need for qualitative judgments regarding allanite standards.” (lines 201-203) See “General issue #1”.

8. “No need to repeat the Smye reference twice in the sentence. The age and uncertainty that they obtained from the standard should be reported. [continues below] The repeated reference will be deleted, and age and uncertainty of Tara allanite obtained by Smye et al. (2014) will be added to Table 2. From my understanding, the Tara allanite age has a more considerable uncertainty compared to CAP and AVC (e.g., see Liao et al. 2020 JAAS). See also their concerns about the homogeneity of this grain and problems regarding the reproducibility of its ages. [continues below] See “General issue #1”. All of the allanite standards have ages that differ significantly from the age of the “unknowns.” It would be helpful to comment on this observation.” (lines 203-205) See “Comment #15”.

9. “This sample appears affected by secondary fluid interaction, but that was not considered problematic in terms of interpreting its solution ICP-MS result.” (lines 302-303) A few laser spots were intentionally placed on areas with veinlets, as well as across zonations, to assess whether these features would yield outliers within the dataset. We conclude that they do not based on the statistical values obtained from the Tera-Wasserburg diagrams, and consequently that sample Albula-1 could be safely ana-

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lyzed by solution ICP-MS. This will be discussed in sections 3.2 and 4.3 of the revised manuscript.

10. I am not sure what CAP superscript b is exactly. It is likely explained somewhere, but I could not find it. (line 343) Burn et al. (2017) sampled CAPb allanite from the Cima d'Asta pluton and determined ages consistent with those presented for CAP allanite by Barth et al. (1994). They therefore concluded that it is likely that CAPb and CAP are the same allanite, but could not confirm this from field relations – hence the superscript in CAPb. This will be made clearer in the revised manuscript.

11. “It would be helpful to indicate what the U-Pb ages are and reference those results.” (line 445) The U-Pb ages will be mentioned in the revised text.

12. “The approach applied is very similar to that done for apatite by others (Oldum and Stockli, 2019, Tectonics and 2020 EPSL)” (lines 512-513) The suggested literature will be cited.

13. “Table 1. Is difficult to read. Similar parameters for each session can be placed in a footnote. There is a footnote b at the last row that is not explained.” The table will be revised to improve clarity. A typo will be corrected (i.e. ablation time with 30-micron spot size is 30 sec and not 40 sec). See “Comment #10” for the footnote.

14. “Table 2. Reference data for the other standards could be provided as well. Please include the ages.” The table will be edited accordingly.

15. “Table 3. The CAP and AVC ages reported here are 10 m.y. older than their TIMS ages (Barth, 1994, also Liao et al. 2020).” TIMS ages are actually Th-Pb ages. It is in fact reported and thoroughly addressed in the cited literature that U-Pb ages of allanite tend to be older than their reference Th-Pb ages, and addressing this issue is outside the scope of this work. Since we only measure U-Pb ages, we compare U-Pb ages from allanite secondary reference materials to the available literature in order to check for reproducibility of U-Pb ages, rather than for their concordance with Th-Pb ages.

Indeed, one CAP U-Pb age that we obtained (July 2019 session) is slightly outside uncertainty of its U-Pb age reported by Gregory et al. (2007). Although we recognize that this specific age alone may raise concerns, the other secondary reference material (AVC allanite) used in the same session gave a U-Pb age consistent with its U-Pb age reported by Gregory et al. (2007). A brief statement of these points will be added to the manuscript.

16. “Table 4 and Table 5. Are difficult to read in terms of which dataset belongs to which sample. Could place the sample names in rows.” The tables will be improved in clarity in the revised manuscript.

17. “Figure 2. Are the BSE images located in the petrographic images in Figure 1? No spots are shown in panel a1, so I assume it was not also dated using LA-ICP-MS. I think the contrast can be enhanced in some of the images to enhance the zoning.” We do not show the exact location of the BSE image within the petrographic ones, but will consider adding rectangles in the latter. The BSE image of panel 1 shows an epidote grain where all described features (growth zoning, veinlets and fractures) can be seen, but this specific grain was not analyzed. Contrast and brightness were optimized upon image acquisition: the zoning in epidote grains is simply modest, and thus faint in the BSE images.

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