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Interactive comment on "Baddeleyite microtextures and U-Pb discordance: insights from the Spread Eagle Intrusive Complex and Cape St. Mary's sills, Newfoundland, Canada" *by* Johannes E. Pohlner et al.

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Review of "Baddeleyite microtextures and U-Pb discordance. . .." by Pohlner et al.

This manuscript deals with an important and interesting topic, i.e. the mechanisms causing discordance of the U-Pb system in baddeleyite. I fully agree with the authors that understanding these controls are fundamental for the interpretation of discordant U-Pb data sets, and ultimately, for accurate age interpretation. This study combines age data (ID-TIMS and SIMS) of two samples with high-resolution imaging (BSE- and

CL-imaging) of baddeleyite in rocks that are variably affected by secondary processes (metamorphism). In addition to discussing causes of discordance, the ms includes a compilation of hitherto known baddeleyite-zircon intergrowth relationships.

I regret to say that although this manuscript embraces many complexities causing discordance, it does not provide definite answers to any of these problems. In addition to a no. of "geological causes" such as diffusional Pb loss, mixing between bd/zrn of different generations, isotopic disequilibrum, etc. – there also exist analytical complications that could trigger "apparent" discordance such as matrix effects, crystal orientation effects, mass fractionation, etc. (all of variably importance depending on what technique is applied – SIMS, TIMS, LA-ICPMS). I find this study too ambitious in its aim to deal with far too many of these complexities. The ms would benefit from instead focusing on one or two, starting with careful selection of suitable samples depending on what mechanism(s) to be study. The ambition to address all these complexities of data from complex (partly metamorphosed) samples using both SIMS and ID-TIMS makes it difficult to grasp and interpretations/conclusions not convincing. Sorry to say, but the ms leaves the reader with a bunch of questions unanswered. I agree that "microscale imaging is powerful for extracting reliable age information from complex baddeleyite grains", but that is something I would say most geochronologists already would agree on.

Indeed, the topic is important and interesting, but in order to make real progress each one for these mechanisms requires to be dealt with rigorously, and preferrably "one-by-one". With such a strategy, selection of optimal samples is crucial. For instance, if one want to investigate discordance related to matrix effects of SIMS data on baddeleyite, the samples should be top-quality, "simple" baddeleyite grains with no trace of secondary affects (i.e. 2nd zircon, alteration features, etc.). If choosing high-quality grains from rocks of different age (that could include bd reference samples), such study could also address the effect of oxygen flooding depending on crystal orientation. Perhaps the authors would then be able to identify a threshold with respect to age of sample when 206Pb/238U dates are preferred over 207Pb/206Pb dates. On the other hand, if you want to deal with discordance related to metamorphism, then it would be advantageous to exactly know the age of metamorphism, and preferably work on samples with large time differences between protolith age and age of metamorphism.

The samples studied here have protolith ages of ca. 500 Ma and 440 Ma, and which have "experienced deformation and pervasive low-grade metamorphism lasting from ca. 420-360 Ma". This complicates the interpretation of lower intercepts and the reasoning about when and what mechanism(s) caused discordance. Figure 12 indeed shows the importance of choosing the right samples in this respect. If disregarding causes linked to "isotopic equilibrium" - which I personally believe are of less importance in general compared to other mechanisms – any analysis will plot in the triangular, grey area shown in Figure 12. I am sure the authors agree on that in order to evaluate the relative importance of controls causing discordance one should select samples that have significant age differences with respect to "protolith age", "metamorphic event" and "recent Pb loss". The samples chosen for this study do not fulfill these criteria.

I wish I could be more positive but I cannot recommend this manuscript for publication in its present shape. I still think there are some good "pieces" that can, and should, be saved/published. The obtained crystallization ages of these intrusions are overall robust and I would suggest the authors to considering publish these in a more regular "geological" journal. Since I cannot recommend publication of the submitted ms I have not made any detailed review of text and structure. Nevertheless there are a few issues I would like to comment on and that I hope could be helpful to the authors in future work:

1. For two samples, FP6D monzonite and S2E granophyre, the authors discuss the negative lower intercepts possibly reflecting remobilization of 222Rn. From my experience negative lower intercepts is something one see very rarely. The lower intercept of S2E is -229 +/- 370 Ma, thus within 0 Ma given the uncertainties so you cannot really state the l.i. is negative for that particular sample within stated uncertainties. The negative l.i. age of FP6D is largely controlled by fraction #11. I recalculated that sample, and if removing that analysis in the regression one still end up with a negative l.i. but then very close to "embrace" 0 Ma. You may be right, but more evidence is required.

2. Likewise I am not convinced about the interpretation of zn-bd intergrowth in one of the samples (FP12, SEIC?), i.e. zircon cores surrounded by baddeleyite are xenocrysts. From a textural viewpoint, it seems that many zn-bd intergrowths are sometimes very complex with "irregular" boundaries between bd and zn. Can you be sure this core-rim relationship is not apparent?, i.e. the result of a cutting affects and complex intergrowth? As argument you claim the zn cores are older than the rim, which truly would justify the zn cores to represent xenocrysts. Figure 10 shows one of these zn-bd grains. I agree the cores seem to have older 206Pb/238U dates, but here comes the difference between "age" and "date" into play. I doubt the zircon analyses have significantly older 207Pb/206Pb dates? Looking at the SIMS data on standard samples (SL18, Figure 9), the 206Pb/238U are not always reproducible, at least not from in-situ analyses. Possible biases related matrix-effects from these complex grains in the SEIC sample(s) should be even greater for composite grains, yielding 206Pb/238U that well could be biased towards older dates. Finally, I have problems imaging the process. Baddeleyite that forms in igneous systems (i.e. from Si-poor magmas) requires that magmas eventually reached Zr-saturation. This is why Bd is always (with rare exeptions) found in interstitial volumes representing the last % of liquid. Why and how would zircon xenocrysts remain in the final liquids without being trapped as inclusions in early feldspars and Fe-Mg phases?

3. About Section 6.4. "Approaches to obtain the most accurate baddeleyite crystallization ages"- I would like to make a general comment, since these type of discussions are often seen in publications. Typically, these discussions circle around the importance of high-resolutions techniques, understanding discordance, micro-scale imaging, etc. etc. However, if we really want to make improvements and find out what really matters for "obtaining accurate ages", then I infer that all these contributions fail to recog-

nize/address the most important approach.

I have separated baddelyite from plus 500 samples over the last decades. I dear to say, that there is an almost perfect (!) correlation between quality of samples (fresh, pristine igneous mineralogy) and quality of baddeleyite grains.... and thus, concordant data. I am confident that at least two of the co-authors of this ms would agree on that the most important "approach to obtain accurate ages" would be if we spent only a bit more time in the field to find the best, coarsest, most pristine, and the least altered sample. Careful petrographic studies on thin sections would additionally be favorable in order to identify the most suitable samples. So, if the authors in future manuscripts want to discuss "approached to improve accurate U-Pb baddeleyite ages", then do not forget to highlight that selection of sample for processing should be given highest priority.

Despite the authors may find this review "harsh", I hope they find my comments and decision justified. They are welcome to contact me directly if something is unclear or they want further inputs.

Lund 2020-03-09 Best regards, Ulf Söderlund

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