Authors' Comments

We would like to thank the editor, reviewers, and community members for their commentary on our manuscript, "Chemical abrasion: The mechanics of zircon dissolution" that will ultimately help to strengthen this contribution. We respond to each of their comments below. If given the opportunity to submit a revised version of this manuscript, some of the major changes we would make in response to feedback include:

1) Focus on the heart of the manuscript more strongly – *textural evidence* for the mechanics of zircon dissolution. Many comments reference the lack of geochemical and geochronological data. We would like to emphasize that a complimentary manuscript that focuses on the geochemical and geochronological evolution of chemically abraded samples is currently in preparation. We would shorten and refocus Sections 4.2 (Implications for ID-TIMS U-Pb Geochronology) and Section 5 (Conclusion) to emphasize that the effectiveness of any chemical abrasion protocol for ID-TIMS U-Pb geochronology will ultimately be sample-dependent and reflect a sample's radiation damage and inclusion content and distribution. We would refrain from prescribing any specific chemical abrasion protocol, since no geochronological and geochemical data are presented in the current work.
2) We would also remove Section 4.3 (Implications for radiation damage annealing models) since it is tangential to the discussion and in need of additional supporting data.
3) Streamline the writing to eliminate wordy text and shorten the manuscript length. We would add two small tables that more succinctly summarize Raman data and basic sample descriptions.

We address each reviewer's specific comments below. Reviewer comments are in black text, and our responses are in blue text.

Community Comment 1 – Charles Magee

Section 2.1 Firstly, the introduction says that the second described sample- SAM-47- is from the Corunna Downs granitoid complex. The Australian Stratigraphic Unit database describes this term as informal. See:

https://asud.ga.gov.au/search-stratigraphic-units/results/34394

It has been replaced by the Corunna Downs Granitic Complex:

https://asud.ga.gov.au/search-stratigraphic-units/results/72996

Note, however, that this term also is obsolete. As shown in the links above, Pilbara Granitic Complexes are not stratigraphic units, but are geological provinces, so neither of these descriptors is particularly informative. More importantly, the SAM-47 description is the only description that does not have any references associated with it, making it difficult to understand the geologic background of this sample, or any associated information that would allow readers to interpret the results.

Furthermore, the latitude and longitude (89°59’55.97”, 100°08’2.38”) given are in the Arctic Ocean near the north pole, and are not in the Pilbara craton.

In summary, it would be helpful if the authors could more accurately locate the sample site, and relate it to a local, named stratigraphic unit, and provide appropriate reference(s) to previous work that provides geological context.

We thank the reviewer for catching these mistakes. The correct GPS coordinates are (-21°24’29.01”, 119°46’21.03”). The sample comes from the Emu Pools Supersuite stratigraphic unit. Appropriate literature references about the region’s geological setting include:

Barley, M. and Pickard, A.: An extensive, crustally-derived, 3325 to 3310 ma silicic volcanoplutonic suite in the eastern Pilbara craton: evidence from the Kelly Belt, Mcphee Dome and Corunna Downs Batholith, Precambrian Research, 96, 41–62, 1999.

Smithies, R. H., Champion, D. C., and Cassidy, K. F.: Formation of Earth’s early Archaean continental crust: Precambrian Research, 127, 89–101, 2003.

van Kranendonk, M. J., Hugh Smithies, R., Hickman, A. H., and Champion, D.: Review: secular tectonic evolution of Archean continental crust: interplay between horizontal and vertical processes in the formation of the Pilbara Craton, Australia, Terra Nova, 19, 1–38, doi:10.1111/j.1365-3121.2006.00723.x, 2007.

Section 3.2.1. The use of a synthetic zircon (which is not described in the samples section of the methods) may not be the most appropriate measure of a full annealing natural zircon. Lattice strain can be caused by factors other than radiation damage, such as the incorporation of variably incompatible trace elements into the lattice structure. If the synthetic zircon is pure $ZrSiO4$, instead of being grown with levels of P, Y, REE, and other trace elements typical of zircons from basic to felsic host rocks, then the ability of chemical abrasion to repair lattice strain may be underestimated due to the lack compositionally related lattice strain in the chemically pure synthetic crystal.

Similarly, we can’t tell from the Raman data whether the narrower peak widths of KR18-04 and BOM2A are due to damage or composition, although the narrower peaks for the younger zircons, and excellent choice of one mafic and one felsic zircon from both the 'old' and 'young' groups does suggest irradiation is important.

We can add text to the Raman methods section describing the synthetic zircon used as a loose analog for undamaged zircon and report Raman results for it in Table S1. The reviewer is correct that synthetic and natural zircon crystals have different types of intrinsic defects, some of which are related to composition. However, composition has not been shown to significantly influence the zircon Raman spectrum (Nasdala, 1995), and synthetic zircon is used in the literature as an analog for undamaged zircon in Raman FWHM-alpha dose models (Vaczi and Nasdala, 2017), so we feel that including the synthetic zircon in Fig. 5, 6, and 7 as a visual reference point is useful and appropriate. We can update the wording to acknowledge that the slight differences in FWHM values between annealed BOM2A and KR18-04 samples and synthetic zircon could reflect either residual radiation damage in the annealed samples or other intrinsic differences between synthetic and natural samples.

On a related note, when estimating the accumulated lattice strain, a U/Th/He age or a fission track age may be more appropriate than a crystallization age, depending on the ability of moderate-to-high temperature zircon to self-anneal radiation damage over geological time. The lack of location data for SAM-47 (see above) makes estimating this difficult, but to use a well-studied East Pilbara Archean example, the Owen's Gully Diorite has a crystallization age of 3467 Ma (Stern et al. 2009), but a helium age of only about ~750 Ma (Magee et al. 2017).

The reviewer is correct that a zircon's crystallization age is not equivalent to its radiation damage accumulation interval, since radiation damage anneals at relatively low temperatures over geologic time. Depending on a sample's thermal history, a zircon (U-Th)/He age or other thermochronometric data often provides better insight into how long a sample has accumulated radiation damage. However, we do not use U-Pb crystallization ages to calculate samples' radiation damage. All equivalent alpha dose estimates cited in this study are instead based on Raman v_3 FWHM peak width measurements of accumulated damage. A second, forthcoming contribution which includes U-Pb isotopic data for three of the four zircon samples will more extensively discuss what is known about each sample's thermal history since it is pertinent to isotopic systematics. We appreciate the suggested reference, and we will include it in the forthcoming manuscript.

Figure 2. Finally, it might be worth specifically pointing out that 2b is a colour photomicrograph, as the annealing out of radiation damaged colour centres is an important but sometimes overlooked part of CA. This illustration is so dramatic that

readers might not appreciate that the second image is a colour image in which all the colour has been annealed out of the zircons, leaving them almost colourless.

We can add text to the figure caption emphasizing that Figure 2b is in color, and we will better highlight the significance of the color change.