We thank the reviewers for their time and thoughtful commentary. Their feedback will undoubtedly strengthen the manuscript. Our responses to their suggestions are recorded below in blue.

**Reviewer #2 – Fernando Corfu**

The paper reports the results of experiments on the chemical abrasion of zircon, using 3 samples of different age, and applying two different experimental protocols. The reported results include U-Pb isotopic ratios and ages, and abundances of a number of chemical element typical in zircon. The experiments evaluate the efficiency of the two different approaches in removing discordant zircon domains and isolating grains with closed isotopic systems.

The data will be interest to the geochronologists that use the U-Pb dating methods, especially the ID-TIMS community. It is not the first paper to report such experiments, but it adds some new perspectives, which will certainly be useful for a further advancement of the technique.

The paper is reasonably well prepared. There are some technical glitches, with figures inserted in the text and locally covering up portions of the text. I have put some suggestions and a number of comments directly in the annotated file.

We will address the technical glitches. Responses to specific line edits are listed below.

The tables need some work to make them more useful and accessible for the readers. (1) It would be practical to assemble them all as separate sheets in just one file. (2) It would be practical to list U abundances, since they are mentioned repeatedly in the text. At present one has to use the Th/U ratios from one table and combine them with the Th abundances in another table to get an idea of the U contents. (3) There is no explanation of what (ppt) stands for (part per trillion, or per ton?), and ppt of what? Some solution? Because of this enigma the listed numbers do not mean anything directly. Further back in the table there are then absolute abundances in ppm. Please, put those in the front, and explain all the terms used. (4) Please list the 206/204 ratios.

We will make the suggested changes to the tables. 1) We will list results for the different zircon samples in separate tabs in one U-Pb and one ICPMS file. 2) We will add U concentrations to the ICPMS file. 3) We will move the concentration of the element in zircon (ppm – parts per million) to the front of the ICPMS file. The concentration of the element in 1 mL solution (ppt – parts per trillion) is listed at the back of the ICPMS file. 4) We will add the $^{206}Pb/^{204}Pb$ ratios to the U-Pb file.

(5) The outcome of the experiments depends very strongly on the qualities and characteristics of the zircon grains used, but the tables provide no information in merit at all. One may perhaps try to link the individual data to the information in the previous associated paper by these authors. I highly recommend putting a characterization of each grain in the table. Geochronologists know that no two zircons are born alike, and they know that successful dating

is best done by a strict discrimination of the good from the bad. A lack of information on the tested grains strongly weakens the interpretations and lessons learned from the study.

We will add cathodoluminescence images (AS3 & KR18-04) and backscattered electron images (AS3 & SAM-47) of dated grains to the Supplementary Materials (SAM-47 grains were luminescent in CL). We feel this additional data will be more useful for evaluating the characteristics of dated grains than written descriptions in a table would. The general characteristics of the three zircon populations are discussed in detail in our GChrong companion paper: "Chemical abrasion: The mechanics of zircon dissolution."

The discussion comprises are section linking a-dosage and degree of discordance, and its implications for the CA-application. It is certainly true that a-dosage and the relative radioactive damage are important factors affecting discordance. But it is also very simplistic, and not realistic, to reduce the degree of discordance to a straight function of a-dosage. Clearly, the textural factors, inclusions, and alteration play a major role, often regardless of U content. Some extremely high-U zircons, which would be destroyed in no-time by CA, can provide concordant U-Pb data if they are just treated gently by air abrasion, demonstrating the relativity of these indicators. I would recommend that the authors reconsider and re-evaluate their discussion in merit.

Chemical abrasion by design leverages the fact that radiation-damaged zircon is more soluble than crystalline zircon. Establishing a relationship between radiation damage and zircon solubility is therefore fundamental to understanding how different chemical abrasion protocols affect zircon dissolution and U-Pb outcomes. Radiation-damaged zircon is also more susceptible to Pb loss and alteration than crystalline zircon. Consequently, understanding at what alpha dose zircon becomes susceptible to alteration and potential Pb loss is also a fundamental, outstanding question. The reviewer is correct that not all radiation-damaged zircon are affected by Pb-loss; the presence of fluids likely plays an important role. We will add this point in our revisions. The zircons analyzed in this study, however, are affected by Pb loss, so interrogating the threshold alpha dose at which Pb loss effects are apparent has merit. Future contributions by the U-Pb community will help determine whether the threshold alpha dose established for our samples is relevant to other zircon populations. We do not ignore the effects of textures, inclusions, and alteration on chemical abrasion or U-Pb data. In this paper and our GChron companion paper, "Chemical abrasion: The mechanics of zircon dissolution" we devote extensive discussion to the role of zonation, fractures, textures, and inclusions affect zircon dissolution on chemical abrasion and chemical and isotopic analyses – the alpha dose relationship is only one piece of chemical abrasion puzzle.

There seems to be some confusing concerning the parameters used in the various calculations for data from the literature, such as the 238/235 ratio. I suggest adding a table listing the original information, and the equivalent values calculated with the same constants as in the present paper. It would be useful for the reader, but also a reminder for the authors, avoiding comparisons of apples and oranges.

The $^{206}Pb/^{238}U$ and $^{207}Pb/^{206}Pb$ ages reported for AS3 by Schoene et al. (2006) were calculated assuming a U ratio of 137.88, whereas our ages assume a U ratio of 137.818. We will recalculate the literature data using a U ratio of 137.181 in revisions as the reviewer suggests for a more accurate comparison.

Line 30: We will make the suggested edit.

Line 32-34: We can rephrase this sentence, but we continue to conclude that this represents an important finding of this paper.

64: We will make the suggested edit.

129: We can rephrase these lines to improve clarity.

145-147: We can rephrase these lines to improve clarity.

177: We will make the suggested edit.

189-191: We will make the suggested edits.

224: Most of the Pbc in AS3 leachates is derived from inclusions and altered zones. The Pbc in the AS3 residues and 210 °C L2 & L3 leaching steps, however, is most likely derived from the blank.

264: The debate about the dome and keel structures of the Eastern Pilbara Craton is a debate over whether a stagnant lid or mobile lid tectonics regime was operating during the Archean.

274: The region likely remained at temperatures below ~460 °C based on the hornblende Ar-Ar, and apatite U-Pb (line 268).

Figure 6: WM stands for weighted mean. We will add this to the caption.

Figure 8: The error bars are smaller than the marker size. We will rephrase this.

343: The inclusions were not identified.

Figure 9: U ionization was very poor for these samples. We can add this to the text.

370: We will fix the text that the figure cut off.

373: 100 ppm U is fairly low for zircon.

378: We will fix the text that the figure cut off.

436: We agree with the interpretation of Takehara et al. (2018) that the altered zones reflect hydrothermal alteration. Low-temperature hydrothermal alteration is not uncommon. Fluids generally need to be present for alteration to occur.

465: Like the reviewer suggests, U concentration was estimated using the measured Th concentration and Th/U ratios. We can, however, include the estimated U concentration in the tables.

467: We will remove these lines as suggested.

522: We can rephrase this sentence to exclude the term frantzing.

598: We will remove the term discords.

649: We will replace “non-pattern” with “inconsistent behavior.”

804: We will remove the duplicate reference.