This contribution is about the potential of detrital zircon U-Pb dates to record geologic events that overprinted zircon and caused partial to near-complete Pb-loss, resulting in discordance. Such discordant detrital zircon data are usually discarded, whereas Reimink et al. convincingly argue that such data can reveal geologically meaningful lower concordia intercept ages. A numerical model is introduced, building on Reimink et al. (2016), and tested against a real-world data set for detrital zircon from a quartzite which was thermally overprinted in a magmatic contact aureole.

Judging from the success of Reimink et al. (2016), which was designed to extract meaningful formation ages from discordant detrital zircon data sets and is frequently cited, I find this approach promising. Interrogating detrital zircon for their potential of revealing geological episodes capable of producing Pb-loss would circumvent culling of significant amounts of data and allow gaining useful insights from zircon domains usually not targeted for high spatial resolution analysis due to their non-ideal structure (e.g., rims, cracks, etc.). The quality of the writing and the artwork are at a high level, and the scope of the work is a perfect match for GEOCHRONOLOGY.

We thank Dr. Schmitt for his robust and constructive comments. They have helped us significantly improve the manuscript.

One suggestion for improvement is adding an explanation about the lower age limit of this approach. The manuscript clearly states that older primary ages permit more precise identification of discordance, but it does not specify the lower age limits. Discordance in Phanerozoic detrital zircon ages is typically difficult to discern in LA-ICP-MS or SIMS data, and $^{207}Pb/^{206}Pb$ ages required as input in the model will have high uncertainties. I tested the model with the link provided on the Ulusoy et al. (2019) dataset, and it did not produce the expected zero-age intercept for heating during a Holocene eruption.

This is an excellent point. To address this we have conducted an additional set of sensitivity modeling and added one additional figure. This section builds on the previous modeling work except allows the maximum age of any zircon in a synthetic population to decrease to 100 Ma, all with a 30 Ma imposed discordance-inducing event. This allows us to quantify the necessary ages of zircon grains that would provide sufficient precision to any given lower intercept age calculation. This comment led us to also model an increase in maximum zircon age, well into the Archean, such that we can provide guidance on the precision capabilities of this method as a function of the primary ages of zircons in the sample database.

The results of this modeling were surprising to us, in that older grains to not universally provide more precise discordance dating ages. We have added additional discussion to this section to fully address the results of this modeling, including providing guidance on sample selection.

With regard to the Ulusoy et al dataset, the reason for the lack of a zero age intercept is straightforward. There are only a few >1 Ga discordant data points in that dataset, and several near-concordant Phanerozoic grains. This means that the older discordant grains provide likelihood along chords that intersect with many of the younger grains, producing a flat likelihood structure across much of the Phanerozoic. We have provided some discussion of the types of data necessary for reliable use of the discordance dating technique, and discussed some analytical approaches that may prove useful to interested geochronologists.

Potential mechanisms which produce Pb-loss in zircon are discussed. The authors specifically address recrystallization/overgrowth vs. fluid induced leaching for their sample data considering correlative trace element data. Although they are correct that identifying the Pb-loss mechanism is difficult and may require different tools on a case-by-case basis, it would be helpful to provide a bit more context by discussing other zircon-based dating methods targeting sediment evolution (e.g., in-situ dating of xenotime overgrowths, U-Th/He geochronology, Raman dating, or fission tracks; see additional reference list).

This is an excellent suggestion. We have added some discussion of these techniques and the suggested references to the main text.

If possible, it would be useful to quantify the thermal regime for which this new discordia-lower-intercept geochronometer/thermochronometer is sensitive, for example by calculating model closure temperatures for volume diffusion (e.g., for Pb in metamict zircon; Geisler et al., 2002) and comparing these to those of alternative methods mentioned above.

This suggestion is an interesting one. After careful consideration we have decided not to include a volume-diffusion model in this manuscript. Given the correlation in trace-element concentrations with discordance in the Tintic detrital zircons, pure diffusion of Pb is unlikely to be a dominant discordance-inducing mechanism in our sample set.

In the list of processes suspected of causing discordance (Lines 69–76), I would also include pyrometamorphic heating for completeness. Zircon in crustal volcanic xenoliths or contact rocks when sufficiently heated can also be (partially) reset; this has been utilized by (U-Th)/He dating (Cooper et al., 2011), and concomitant Pb-loss has also been documented (Ulusoy et al. 2019).

Excellent suggestion, changed as recommended.

Providing an easy-to-use portal for the numerical model is a welcome service to the community. When testing it, however, I missed an output value for the lower intercept age and its uncertainties.

We have not implemented a single procedure for outputting lower intercept age and associated uncertainty as the outputs from any given sample's discordance dating procedure will be widely varying. The output data can be downloaded and a knowledgeable chronologist who is intimately familiar with the vagaries of their particular dataset can apply peak fitting and uncertainty estimates (FWHM, etc) to that data. We do note that some datasets would be inappropriate to input to this type of data modeling procedure, and outputs such as suggested here could potentially be misleading. Thus, we prefer to provide output data and leave the interpretation, and especially uncertainty assessment, to the individual chronologist.

Some additional suggestions for improvement and minor corrections are provided point-by-point.

Line 32: Please write "U-Th-Pb" as the Schaltegger et al. (2015) also reviews U-Th disequilibrium dating.

Changed as suggested.

Line 35: Please check references for completeness; none of the three references cited here were found in the reference list.

Thank you for catching this error, it has been corrected.

Line 64: Micron = not SI; should be micrometre

Corrected

Line 75: Pyrometamorphic heating of xenocrysts/xenoliths is another process (Ulusoy et al., 2019).

Reference added

Line 98: It would be helpful to explicitly state the formula for calculating discordance here, as it was done in Reimink et al. (2016).

Changed as suggested.

Line 114: The discordance method can be seen as complementary to (U-Th)/He dating or other methods in its ability to extract thermally or fluid induced alteration of sediments. Mentioning these alternative approaches would provide valuable context.

Line 150: Something is missing here.

“are the most useful” was added here to complete the sentence.

Line 165: Here and elsewhere: ranges should be indicated by the “en dash”.

Changed as suggested.

Line 192: “and“ after 1800 Ma?

Changed as suggested

Line 150: Why 150? Please justify.

We have added a line justifying this number of samples.

Line 277: Isn’t this a logical consequence of each probability curve being normalized to an area of unity?

Yes and no. The dataset is internally normalized to the probability distribution of a given number of datapoints in a dataset. Given that all the simulations here have the same number of data points, the total area under the curves will be fixed when considering all of the U-Pb data space (0-4500 Ma, including Discordia arrays). However, we are focusing on a small area of U-Pb space here, such that the area under any of the curves in Fig. 3 (C, F, I) are not identical. The peak height is much more strongly correlated to the position of the most discordant data point, which serves to focus likelihood to a single point along a lower intercept array (both increasing peak height and sharpening the peak). We have added a line explaining this in the text. “Note that in this version of the analysis, we are focusing on a small portion of the total U-Pb Discordia space, such that the area under each individual curve in Fig. 3C, F, and I are not all uniform.”

Line 354: Space between number and unit.

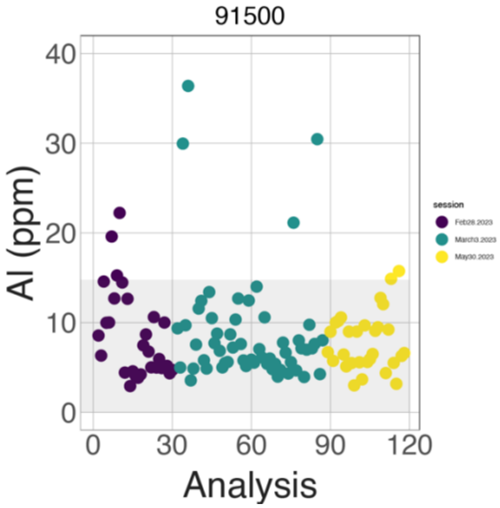
Changed as suggested

Line 398: Use official name SRM 612 (https://tsapps.nist.gov/srmext/certificates/612.pdf)

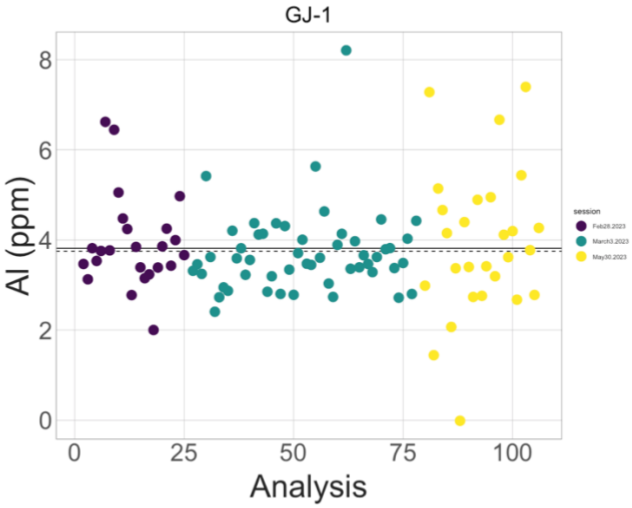
Changed as suggested

Line 398: When comparing data for the 91500 secondary reference zircon to literature values, some discrepancies are noted. Campbell et al. (2014), for example, state 11 +- 3 µg/g Al in 91500 (1se), whereas the average from the supplement is only half that value (5.7 +- 0.19 µg/g Al). Notably, there is also significant scatter in the data (MSWD = 5.1). The discrepancy is even more severe for Ca, for which literature values are 1.9 +- 0.6 µg/g (Coble et al., 2018) whereas the average for the data in the supplement is 35 µg/g (with in part very large uncertainties and even negative values). Iron in 91500 zircon, by contrast, is lower in the supplementary data compared to the literature (1.71 vs. 3.4 µg/g; Coble et al., 2018). I am suspicious about these elements being major components in NIST SRM 612 glass (except for Fe): Al and Ca are present at ~2 and ~12 wt.% (oxide) levels. How much of a matrix effect does this introduce when NIST SRM 612 is used as the trace element primary reference material for zircon? If trace element data are inaccurate for zircon, then raw ratios should be used, which would serve the same purpose. Please also remove negative values from the supplementary table and state corresponding detection limits.

Excellent questions, though much of this text will be removed based on suggestions by Dr. Ickert. However, here are some thoughts. First, 91500 has been shown to be heterogeneous in trace element composition (Caulfield et al., 2025, Chemical Geology), specifically Al which has a wide range (0-15 ppm) of concentrations. This is shown below where the grey box is the range in Al in 91500 documented by Caufield et al. (2025).

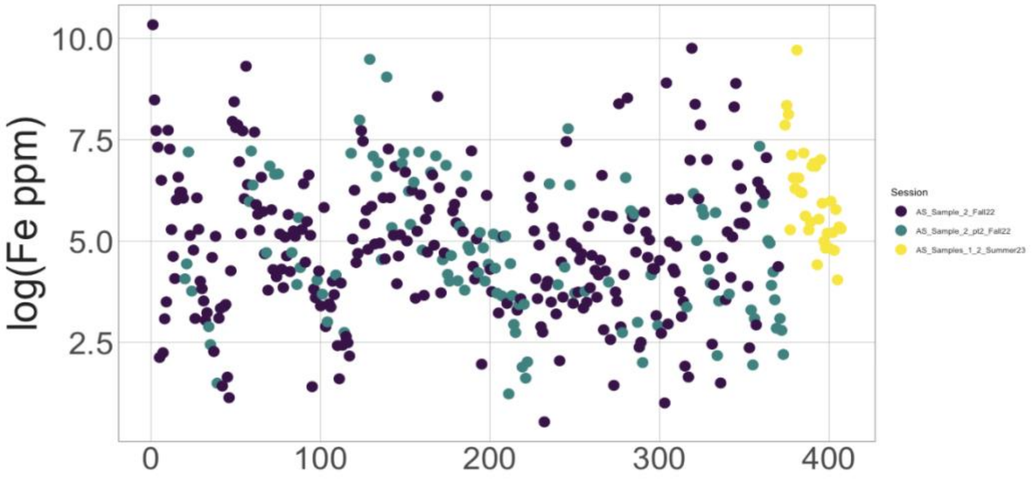


Conversely, our GJ-1 data shows clearly that the concentration of Al is accurately reproduced using NIST SRM 612 as the primary standard (mean of 3.8 compared to the accepted value of 3.75, see below). This gives us confidence that at least to a first order our trace element data using NIST SRM 612 as a primary reference material is working properly.



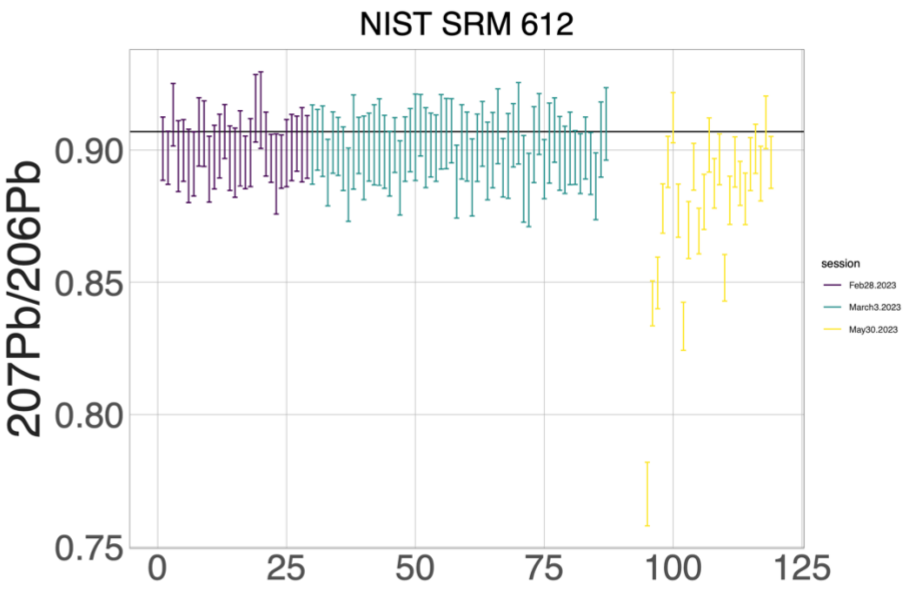
We agree with Dr. Schmitt that the accuracy of the Ca and Fe concentrations are hard to evaluate, largely due to a lack of information on zircon reference materials. However, we have chosen to keep the concentration data while adding in the raw ratios to the final reference material data table. We have kept the concentration data because the high calculated concentrations are, at least in a rough sense, indicative of the changing chemistry of altered zircon domains. We believe presenting trace element data as concentrations will be useful to the zircon geochemistry community and might help guide further work on zircon alteration mechanisms, including those causing U-Th-Pb discordance.

We also note that in our Session #3, there is excess scatter in the Ca, Fe, and other low concentration elements. This was due to a background issue during this run that affected some of the low concentration elements, yielding many negative values in the resulting concentrations. However, this does not affect high concentration elements (e.g., Yb, Hf) and does not seem to dramatically affect the interpretations of our sample data due to the high concentrations of Ca and Fe detected in the Tintic detrital zircons, as shown below.



Line 401: Please address why the ^{207}Pb/^{206}Pb values for NIST SRM 612 appear to be significantly lower than reference values reported in the literature (0.8995 vs. 0.907; Woodhead and Hergt, 2001)? Also, there are several outliers for run IDs between 500 and 531. How does this affect the robustness of the zircon ^{207}Pb/^{206}Pb results analysed under these conditions?

This difference is minor (~0.7% lower) and the NIST SRM 612 ^{207}Pb/^{206}Pb ratios are generally within uncertainty of the accepted value, despite the different matrix composition (shown below).



The beginning analyses of Run #3 do fall significantly outside of uncertainty of the accepted value. But these do not affect the samples or standards analyzed later during this session, and do not impact the trace-element data collected on the iCAP-RQ mass spectrometer. We have added text to the manuscript, and additional supplemental figures in the GitHub repo documenting this and further U-Pb data descriptions (reference in a revised version of the manuscript).

Line 403: Spelling: Peixe (here and elsewhere)

Changed

Line 449: between … and

Changed as suggested

Line 464: In Fig. 7, please state a value and an uncertainty for the discordance date.

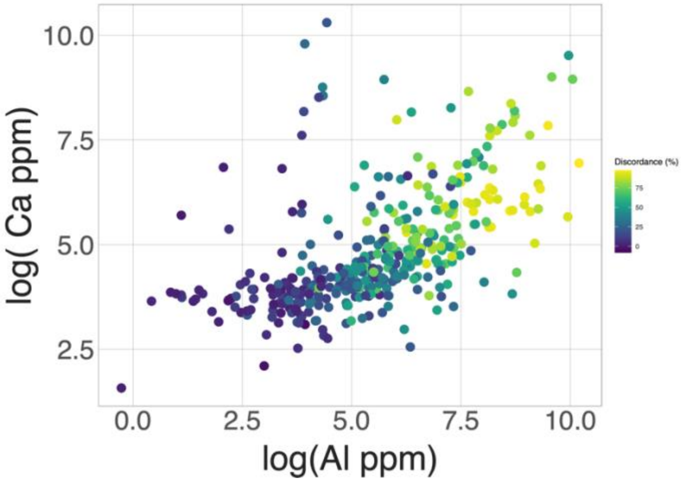
We have chosen to use the median, 5th, and 95th percentile peak positions derived in the bootstrapped resampling method to determine the uncertainty in this age. This is now reported in the caption of Fig. 7 and changed throughout the manuscript.

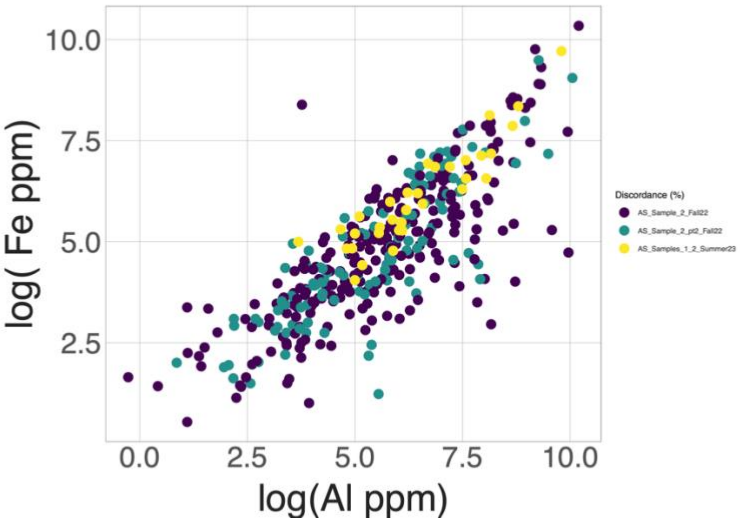
Line 523: Fig. 9 preferable μg/g instead of ppm (cosmetics: superscript in panel C).

This text is removed following Dr. Ickert’s comments.

Line 526: Al-in-zircon as a tracer for discordance is interesting, and a bit surprising as Al is comparatively fluid immobile. The dissolution-reprecipitation scenario for metamict zircon invokes amorphous phases in recrystallized zircon as sinks not only for Al, but also Ca and Fe (e.g., Geisler et al., 2007). It is hence unexpected that Ca and Fe seemingly do not share the trend for Al. In the light of the deviations of the reported values for secondary references from literature values (see comment for line 398), could you please comment if such variability could have gone undetected?

This text would be removed following Dr. Ickert's comments. However, there is a weak correlation between Fe and Al, and Ca and Al, when considering the sample data plotted in log-log space (shown below). Though far from a perfect correlation, particularly for Ca, there a general consistency of behavior between these elements, especially for Fe. This may indicate that the mechanisms suggested by Geisler et al. 2007 were operating in Alta zircons, though we are not confident enough in that assessment to substantially modify our interpretations.





Line 547: Please explain how alpha dose was calculated.

This text would be removed following Dr. Ickert's comments.

Line 582: The first column is difficult to understand; can the percentiles be separated from the classes, and be directly shown with their respective columns?

This text would be removed following Dr. Ickert's comments.

Line 632: Please add degree symbol. This would also be the place to discuss the thermal sensitivity ("closure temperature") of different chronometers applicable to zircon.

This text would be removed following Dr. Ickert's comments.

Line 641: "to use" seems superfluous

Removed as suggested

Line 668: Please use abbreviations that are consistent with the author list.

Changed as suggested

Additional references

Campbell, L. S., Compston, W., Sircombe, K. N., & Wilkinson, C. C. (2014). Zircon from the East Orebody of the Bayan Obo Fe–Nb–REE deposit, China, and SHRIMP ages for carbonatite-related magmatism and REE mineralization events. Contributions to Mineralogy and Petrology, 168, 1-23.

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Geisler, T., Schaltegger, U., & Tomaschek, F. (2007). Re-equilibration of zircon in aqueous fluids and melts. Elements, 3(1), 43-50.

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McNaughton, N. J., Rasmussen, B., & Fletcher, I. R. (1999). SHRIMP uranium-lead dating of diagenetic xenotime in siliciclastic sedimentary rocks. Science, 285(5424), 78-80.

Reiners, P. W., Campbell, I. H., Nicolescu, S., Allen, C. M., Hourigan, J. K., Garver, J. I., ... & Cowan, D. S. (2005). (U-Th)/(He-Pb) double dating of detrital zircons. American Journal of Science, 305(4), 259-311.

Woodhead, J. D., & Hergt, J. M. (2001). Strontium, neodymium and lead isotope analyses of NIST glass certified reference materials: SRM 610, 612, 614. Geostandards Newsletter, 25(2-3), 261-266.

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