We thank Dr. Ickert for the careful and substantive comments. These points have helped substantially improve the manuscript.

In this manuscript, the authors do the following:

- Present a modification (section 2.1) to an algorithm introduced in a prior publication (Reimink et al., 2016) so that "lower intercept U-Pb concordia" data can be inverted from discordant sets of U-Pb measurements. They ground-truth the algorithm using a suite of synthetic datasets (section 2.2).
- They apply this algorithm (section 3) to a suite of detrital zircon data from a Cambrian clastic rock affected by a well constrained Oligocene-Miocene (~25-23 Ma) magmatic and hydrothermal event. Inverting the highly discordant array of zircon U-Pb data recovers a ca. 25 Ma date.
- They describe trace element and imaging data collected on the zircon (section 3.3), and speculate on its utility for inferring discordance inducing processes.

The manuscript is well-written, clear, contains high quality geochemical and isotopic data, and has good figures, although in the PDF the figures are quite small and difficult to read. I assume that in a final typeset form this would be rectified. The modification to the 2016 manuscript should be useful.

Since the manuscript is so generally well written, I only have large-scale "substantive" comments.

Manuscript length

The manuscript is too lengthy and should be a "short communication" or a "technical note". The heart of it is a modest, straightforward (but useful!) modification of a technique introduced in a 2016 paper. The introduction is a suite of boilerplate "zircon is a good mineral" text, and the entirety of Section 3.3 has no bearing on the conclusions drawn in Section 3.1/3.2 and is not referenced in the abstract. The trace element/imaging data in Section 3.3 is interesting and the authors have obviously put a lot of thought into it but unfortunately -as they make clear – the results provide no real insights. If the authors would like to infer process from trace element data from discordant zircon, I would like to read that, but it should be a different manuscript. I strongly recommend cutting section 3.3 (the rest of the manuscript would read the same with no editing, including the abstract, introduction, and conclusion), and compressing the introductory material (it's just a list with no literature synthesis) and if needed, moving some or all of section 2.2 and 3.2 to a supplement.

This is a worthwhile suggestion to consider. We appreciate that the trace element discussion (formerly 3.2) is not conclusive and have removed that discussion. We have also reduced the length of the discussion of sensitivity modeling, though not completely removed it as this discussion highlights important interpretative limits on the discordance dating tool presented in this work.

As far as transitioning the manuscript to a Technical Note, we would prefer to not make this change. The guidance for the length of a Technical Note in GChron is provided as "a few pages only", which would require us to cut most of the text in this manuscript, including the sections on sensitivity testing as well as prevent us from adding in new discussion requested by comments made by all three reviewers. In our view, the modeling and sensitivity testing is a valuable component to our efforts as it shows the statistical limits of the method proposed here. We would, therefore, be hesitant to remove all the text and figures that discusses the limits of our method as required by the length of a Technical Note.

As an alternative, we have kept this manuscript a research article, while removing Section 3.3 (trace element discussion) and shortening the introduction (the specifics of which are outlined below in response to a comment by Dr. Kirkland), and the text of Section 2.2. This has removed much of the text highlighted as unnecessary by Drs. Kirkland and Ickert, while keeping the text that is germane to the discordance dating procedure specifically. This also allowed us to add additional text required to address some of the points made by Dr. Schmitt (regarding uncertainty) and Dr. Kirkland (regarding other methods of discordant data treatment).

We believe that including the modeling discussion, while still having several figures to fully visualize the value of discordance dating makes the manuscript more readable for the user. However, we would ultimately defer to the editor's recommendation on this decision.

Singular discordance events

The passage on line 108-113 describes a critical assumption for this technique:

"…one useful assumption can safely be applied: after the deposition of the sediment, all the zircon grains have a shared thermal and geological history. In this study we leverage this assumption that post depositional U-Pb isotopic discordance may affect all zircon grains within a given sediment at the same time, in order to use discordant detrital zircon U-Pb data to investigate post-depositional geologic events."

This is clearly a safe assumption for the Alta example here, where there is overwhelming geological, geochemical, and geochronological evidence for a massive ca. 25 Ma event. It's unclear to me that this might be equally true for sample suites with different histories, including and especially those without such a strong, singular event. The key assumption here is that each individual measured chronometer responds in the same way to the shared geological history, and it's one that I suspect is not correct. Individual grains, particularly detrital grains, will have different sizes, alpha-parent concentrations, alpha-dose histories, and annealing histories and will each have different susceptibility to geological events.

We may not understand this comment precisely, but we do not assume that each grain responds to the shared geological history the same way. In fact, the variable response is what allows for discordance dating to be useful. Our phrasing in this section was indeed confusing and did not clarify our understanding correctly, thus we can easily modify this text to add the clause "However, importantly, each grain will respond to these geologic events differently due to the unique crystallization, radiation damage, and previous thermal/annealing history of that particular grain. This shared history, but variable response, can be utilized to estimate ages of lower-temperature events than are typically recorded in zircon U-Pb ages"

For example, fluid flow is likely to be highly protracted, and different grains are likely to respond differently, or not at all, in a manner corresponding to their local environment and history. One grain might record an event at one point because it is associated with a vein and fluid flow, then it might seal, and millions (or 10s of millions etc.) of years later a different event occurs to a different grain. Protracted uranium uptake is well documented in for example, in the literature of U-daughter product geochronology of low temperature phosphate and carbonates (a good example is some of the U-Pb data in the supplement to Fassett et al. 2011 https://doi.org/10.1130/G31466.1).

This is not to say this isn't a useful technique, but the authors are presenting, in my opinion, an inadvertently misleading characterization of the applicability of the assumption listed on lines 108-113.

We think that the correction mentioned above would adequately address this comment by Dr. Ickert, but this latter statement is also true – discordance dating is not likely to be as precise of a tool as typical U-Pb zircon geochronology due to both the varied response as well uncertainties in the likelihood distribution (as modeled in Section 2.2 and now 2.3).

Decay Constants

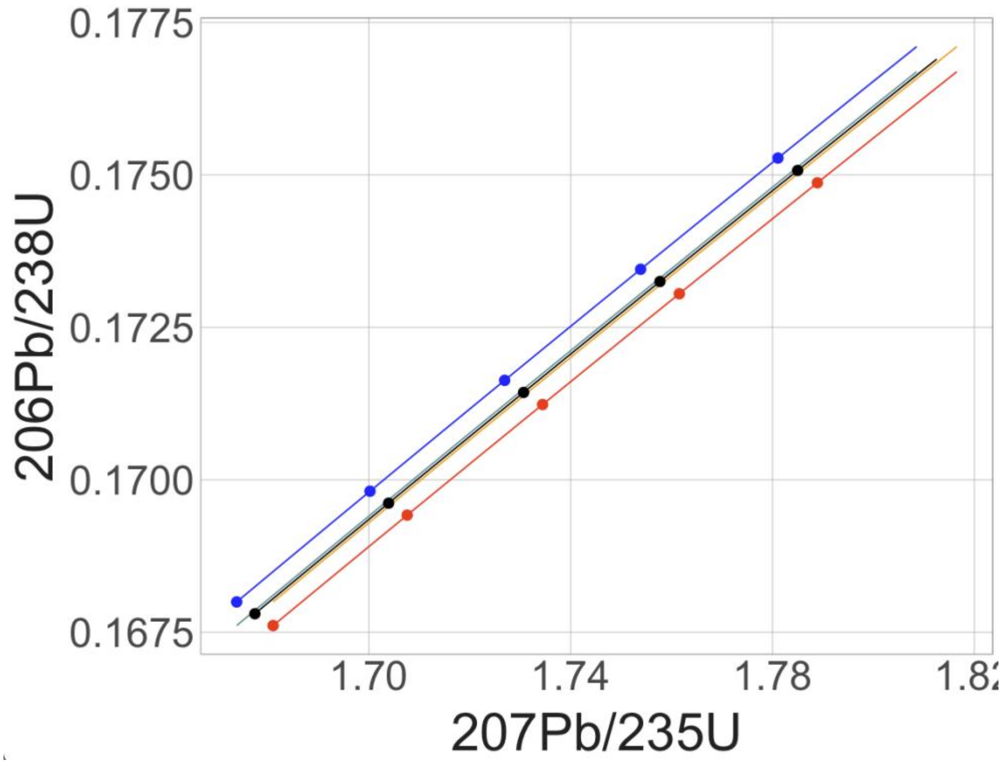
There is a subtle but important issue here, having to do with decay-constant uncertainties.

When single decay constants are used, and used in the same manner (for example comparing two 206/238 dates from concordant analyses) the decay constant uncertainties are very highly correlated and are typically negligible. This is the basis for ignoring such so-called “systematic” uncertainties when comparing dates from the same isotopic system. However, when mixing decay constants, and using them in what are effectively different proportions, they can no longer be neglected, and when looking at concordia “chords”, can be surprisingly large.

To frame the issue differently, if you compare a 206/238 date to another 206/238 date, you almost certainly can neglect decay-constant uncertainties on the difference between the two dates. If you compare a 207/235 date to a 206/238 date, you cannot neglect them. If you compare a 206/238 to a 207/206 date, you cannot neglect the decay constant uncertainties, but they are not independent because they both use the 238U decay rate. Upper and lower intercept concordia dates each have a unique “mixture” of both decay rates and so cannot be neglected except when comparing them with very similar (e.g., subparallel) chords.

In the dataset presented here, because of the young age of the lower intercept and the old age of most of the grains, the decay constant uncertainties are negligible. But since this is meant to be a useful technique for future work, this may actually matter a great deal, particularly with early paleozoic and older, lower intercepts, where decay constant uncertainties when compared to say, 206/238 dates, can be 10s of Ma.

This is an excellent point, and one we had not originally modeled the implications of. To clarify this point, we plot below various ‘concordia’ lines in 207Pb/235U vs 206Pb/238U space (Wetherill concordia). The black curve is the concordia line position using the mean decay constants while colored curves move the decay constants to the extremes of the uncertainty in the decay constant values (0.137% in the 235U decay constant, and 0.107% uncertainty in the 238U decay constant; Jaffey et al., 1971). Note that these uncertainties likely overrepresent the problem because they ignore any empirical refinement of the relationship between the decay constants (e.g., Schoene et al., 2006; Mattinson et al., 2010) The dots represent 1000 Ma, 1010Ma, 1020Ma, 1030Ma, and 1040Ma.



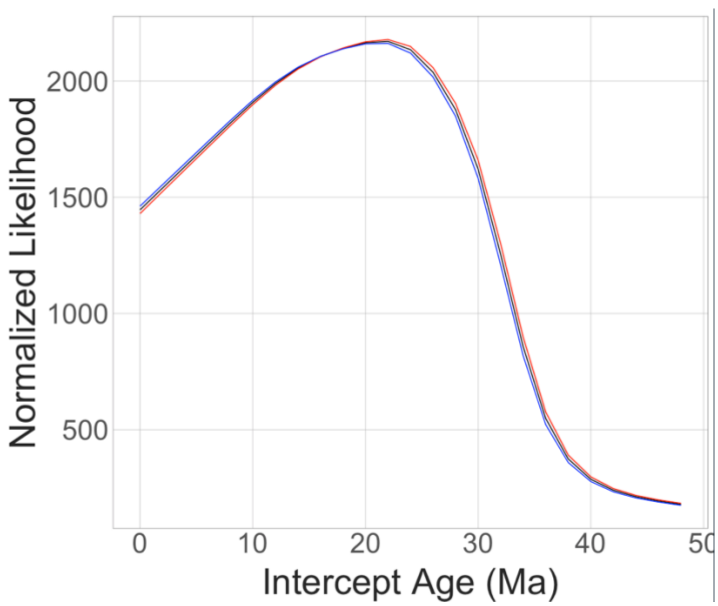
We plot the range of variability that could be produced by systematic uncertainty in the decay constants. There are four additional lines plotted, where we varied the U235 and U238 decay constants by their two sigma error estimates, and recalculated the position of the equal-age line (Concordia) given the isotope ratios measured. Covariation in these values (i.e., high U235 lambda + high U238 lambda) produce very little change in the position of the concordia line in Wetherill concordia space. However, anti-variance, where we calculate the equal-age line with a U235 lambda value 2sigma low, and a U238 lambda value 2sigma high (or vice versa) produces concordia lines that are significantly different from the mean line – blue and red curves and dots in the above image.

Geometrically, it's easy to see when this will matter – as the slope of the chord near the intercept (lower or upper) becomes more parallel, the date will "smear" more within the uncertainty band around the concordia. Having folks use this tool without a method to address this potentially significant source of uncertainty would be dangerous.

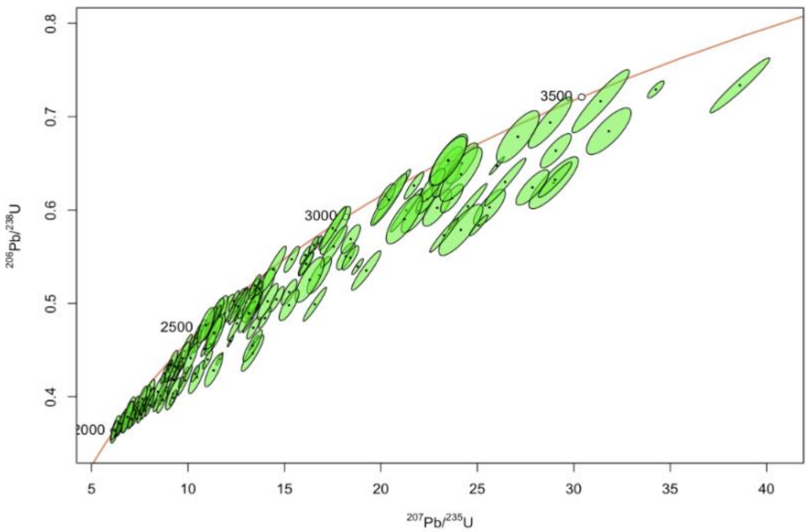
Unfortunately, it can be a bit complicated to address because it depends on the date you want to compare it to. The decay constant uncertainty in the difference between a lower intercept and a 206/238 date is different than when comparing it to a 207/235 date (or a 207/206 date, or an intercept with a different slope etc.). However, the calculation is straightforward to do numerically and could easily be incorporated into the code.

To address this issue in the most conservative way, we have modified our code to allow users to rerun the discordance dating model using anti-correlated decay constant values – in effect shifting the concordia line to the blue or red lines shown above, and re-running the modeling procedure.

As our model fundamentally operates using the Pb/U ratios and maps out probability distributions in ratio space, changing the decay constants requires simply using a different model concordia curve.
To highlight the potential effect of these systematic uncertainties, we re-ran the modeling on the Tintic detrital zircon dataset discussed in this manuscript. The lower intercept likelihood results are shown below. There is no significant (within uncertainty) change in the peak position (no change within the 1 Ma node spacing used here), and little change in the slope of the curve across the lower intercept likelihood space.

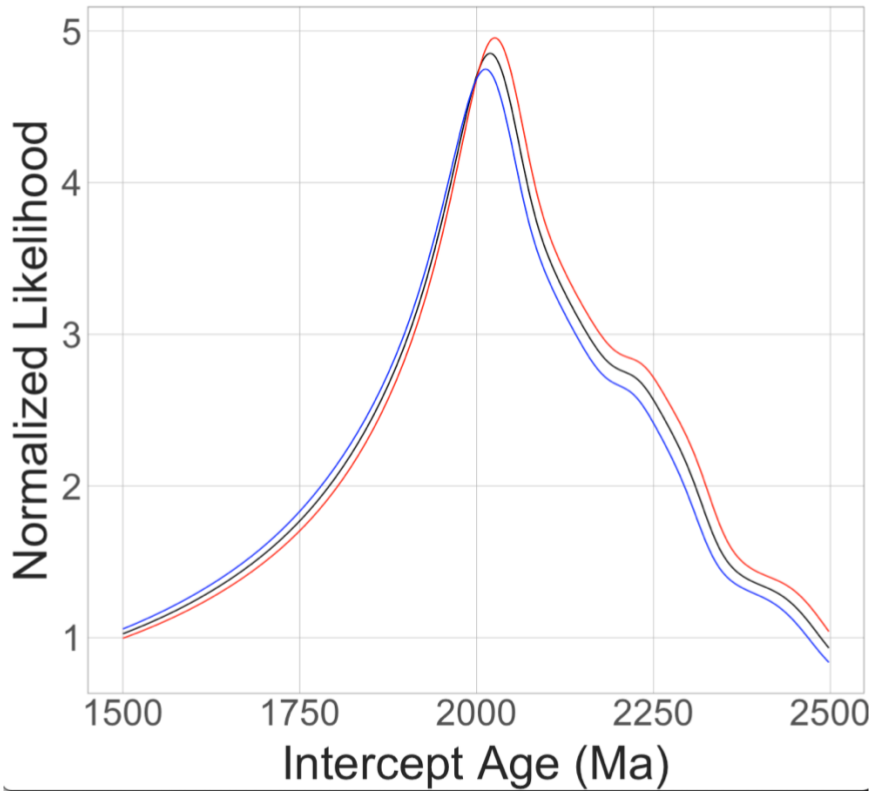


As noted by Dr. Ickert, the magnitude of this change will vary across geologic time, depending on the vagaries of a particular discordant U-Pb dataset. To highlight this, and document the potential effect, we generated a synthetic dataset with upper intercepts ranging from 2.5 Ga to 4.0 Ga, and induced discordance at 2.0 Ga.



We then re-ran the discordance modeling procedure three times using the range of possible concordia line positions (by changing the decay constants) to show the range of possible variation in discordance dating outputs produced solely by varying the decay constants. The outputs are shown below, and as expected there is more variation given the relatively large uncertainty in the U235 decay constant, and the relative importance of the 235U-207Pb system further back in time. However, the discordance dating peak shifts by 14 Ma (0.7% of the age). We again note that this is likely an overestimate of the shift as this simplistic approach to evaluating decay constant uncertainty does not account for

empirical recalibrations of the decay constants.



We have modified out code to allow users to perform this same uncertainty analysis and provided instructions on how to accomplish this. We have also added in a paragraph into the text describing the above uncertainty estimate.