Response to Reviewer #3's comments on manuscript egusphere-2023-1293

"An expanded workflow for detrital rutile provenance studies: An application from the Neotethys Orogen in Anatolia"

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November 15, 2023

We appreciate the thoughtful reviews of the 3 referees. First, we summarize the broad themes from the three reviews before responding in detail to Reviewer #3 below. The reviews critiqued (1) the novelty of the study, (2) the number of U-Pb analyses discarded during data reduction, (3) the potential bias of discarding data and the validity of interpreting discordant U-Pb analyses, and (4) the apparent lack of novelty and complexity in geochemical data interpretations. Regarding these points, the goal of the manuscript was to provide a transparent workflow for detrital rutile geochronology using new data from sedimentary basins in Anatolia. We acknowledge that it was confusing or misleading to present this work as a revised workflow. We intended to emphasize that we found a paucity of methods papers that provide a straightforward approach. Although we did not claim to present new workflows with the geochemical data, this was perhaps unintentionally implied with the title. We have presented as much information as we could squeeze out of our particular geochemical dataset. The revised manuscript will scale back statements on new workflows and instead refocus the title and introduction on suture zone settings and Anatolian geology while maintaining the broad overview of detrital rutile provenance and the details of our methods.

We also acknowledge that it is surprising to see the number of data discarded during data reduction. However, we contend that this is a common practice with detrital U-Pb geochronology in common Pb-bearing minerals. We are not the first to discard a significant number of analyses; we have found this practice in many published detrital rutile datasets, although it is not discussed much in the literature. We further expand on this point in our detailed reply and will add this context to the revised manuscript. This manuscript gives precedence for papers to be transparent in data reporting—including the number of grains analyzed and criteria for rejection—as well as examination of the full dataset in Tera-Wasserburg diagrams. Our manuscript provides an opportunity to show the consequence and potential value of the full dataset, which is relevant to others working with this type of data. While the use of common Pb-bearing minerals is common in some labs and geographic settings, the application of these tools is still far behind detrital zircon geochronology, for which there is a well-established global framework. We have encountered many detrital geochronology users who want to add detrital rutile to their toolkits but are still uncertain in how to collect and interpret these data. Here, we present a complicated detrital rutile U-Pb dataset that can serve as an example for how to treat and interpret complex, yet potentially meaningful, discordant data.

Reviewer #3 provided a thoughtful review of our manuscript that highlighted several ways to improve the manuscript that include scaling back statements on 'new workflows' and altering the framing of the manuscript, clarifying the U-Pb data reduction and rejection of U-Pb analyses, and expanding the analysis of the detrital rutile trace element geochemistry. The review includes several main suggestions for improvement that we will implement in the revised manuscript. Reviewer #3 included many in-text typographic and citation comments that will be incorporated into the revised manuscript.

Reviewer #3 provided comments in the review and line-by-line comments in the text. We address the comments below by theme. Reviewer #3's comments are included below in black text. Our response is in purple text and the specific changes we will implement are highlighted in ***bold, italic purple text***.

1. **Comments regarding the framing of the manuscript**

- My suggestion, if you will, is that you make a full twist and turn of your manuscript. Place the focus on using detrital rutile in reconstructing convergent margin evolution, using Anatolia and your sample set. I recommend you acquire more data (more grains) to overcome the reduced number of dates you have from each individual sample. Focus first on your case study, then move on into the rutile dating challenges affecting provenance, and how your approach can enhance the level of information we obtain from U-Pb rutile dating and from convergent settings. This requires major rewriting, but you can reuse most of your very nice figures. Unfortunately, I do not recommend publication in its current form, but you should feel encouraged to a re-submission.
- Title: After reading the manuscript a few times, I have my doubts about the suitability of this title. You have explored a couple things in your geochronology that improve using rutile ages in provenance studies.
- Line 25: I think that the main focus should be this one, and rutile data treatment would be a second-level objective.

The goal of the manuscript was to provide a transparent workflow for detrital rutile geochronology using new data from sedimentary basins in Anatolia. We acknowledge that it was confusing or misleading to present this work as a revised workflow. We intended to emphasize that we found a paucity of methods papers that provide a straightforward approach. ***The revised manuscript will scale back statements on new workflows and instead refocus the title and introduction on suture zone settings and Anatolian geology while maintaining the broad overview of detrital rutile provenance and the details of our methods.***

Following the comments of Reviewers #1 and #3, we will move away from phrases like 'new workflow.' The revised manuscript will have an updated title and introduction that is oriented toward Türkiye and suture zone settings. We will emphasize how detrital rutile is a useful complement to detrital zircon in accretionary collisional settings like Anatolia, where many sediment sources are obducted ophiolites and metamorphic terranes. Additionally, we will emphasize how detrital rutile can disentangle signatures of sediment recycling. This was not discussed much in the manuscript but can be expanded in the revision with the more nuanced geologic setting. We will keep the discussion of Pb corrections and uranium concentration.

2. **Comments regarding U-Pb analytical protocol, data reduction, and rejection of data**

- My main concern related to U-Pb data acquisition/treatment came from the rather large number of discarded rutile grains, due to inclusions, lamellae, etc. In the end, they discarded many rutile grains. How did it affect or biased the final dataset? In these circumstances, how robust is it to average all samples and plot them together, especially in a dynamic sedimentary environment? What about source variability through time weighted on each of your sample populations (n)? Figure A3 is clear in illustrating the issue here.
    - Figure A3: very few grains per sample. Can we really average all these data into one KDE? You showed they have very differing ages... I am afraid that you have a major issue here and you need a bit more data. Another challenge in detrital rutile geochronology...

Reviewers #2 and #3 raised concerns about the number of analyses discarded during data reduction. The workflow that we present includes the analyses of all detrital rutile grains in a sample. *"Rutile grains were handpicked; all rutile grains were picked from most samples, except for samples 16SKY26, 16SKY42 and 17OZK05 for which 260–320 grains were selected"* (lines 238-239). Part of the

reason that provenance interpretation is not possible at the sample level is because of the low rutile yield in some samples. For example, sample 18DMN01 only had 5 rutile grains, all of which were analyzed and 4 satisfactory dates were obtained. First, we suspect that this could be a feature of local geology (i.e., metamorphic sources were not exposed at the surface at the time the sample was deposited), however, in the future we will collect larger samples to try to increase heavy mineral yield. Second, low yield could be due to the exclusion of analyses during data reduction, for reasons including poor signal intensity and large uncertainty in the $^{207/206}$Pb ratio. Anomalous signal intensity was likely due to a combination of very low uranium concentrations, "*elemental heterogeneity from ablating into small inclusions and/or lamellae, and inhomogeneities due to micro-cracks with different element/isotope composition"* (lines 257-258).

The exclusion of analyses during data reduction is not unique to this study but represents a larger problem with large-*n* detrital rutile provenance work. Many published studies discuss analyzing a larger number of grains than are presented—discarding analyses—due to low U and/or low radiogenic Pb content (e.g., Bracciali et al., 2013; Caracciolo et al., 2021). For example, Shaanan et al. (2020) discard 60% of their detrital rutile U-Pb data due to discordance. Similarly, Reviewer #1 points to the study by Caracciolo and co-authors (2021) that analyzes 712 detrital rutile grains without a U-filter, yet, after discordance filtering, only 347 grains remained (48%) (from what we can tell as the data is not available online). Additionally, Caracciolo et al. (2021) did not have enough rutile ages per sample to discuss sample-by-sample provenance interpretations, which we also experienced with our dataset. This points to a larger problem in trying to scale up detrital rutile to large-*n* provenance applications. For this reason, we wanted to confidently include as many U-Pb analyses as possible in our interpretations, which led to the exploration of U-Pb discordance.

To address this comment, ***the revised manuscript will emphasize that the rejection of analyses during data reduction is not a unique limitation of this study, but typical of many detrital rutile studies. We will clarify that this seems to be common in studies that have attempted large-n detrital rutile U-Pb. The original text emphasized the role of inclusions and lamellae in potentially contributing to poor signal intensity patterns and did not clearly emphasize that, in addition, low signal intensity could be from low U and/or low radiogenic Pb contents. The revised manuscript will also include low U and low Pb as a potential cause of poor raw signal intensity. As discussed below, we will also include a data treatment section of the Appendix that includes a figure with examples of signal intensity patterns in the unknowns.***

- Line 235: we assume from the non-magnetic fraction of the heaviest fraction, but you should detail it here, please.
    - Line 235: random HM minerals? Did you also hand-picked for those or you just decided you wouldn't pick for these two? Why?
    - Line 240: if you hand-picked rutile grains except for three samples, did you do this for all samples? Or did you image all your grains to analyse their textures, the occurrence of inclusions and double check their mineral id? It would be appropriate to include your SEM imaging conditions as well, as you would do for LA-ICPMS or EPMA.

The samples analyzed were previously processed for detrital zircon U-Pb and Hf analysis (Mueller et al., 2019, 2022; Campbell et al., 2023). In order to extract detrital rutile, all heavy mineral fractions from post-water table separation steps were recombined and reprocessed in the following manner. Samples were first separated in methylene iodide to collect the dense fraction. The Frantz magnetic separator was set to 20° side slope and 20° forward slope such that rutile grains were separated into the 0.3 to 0.7 amp. fraction (Rosenblum and Brownfield, 2000). Rutile grains were handpicked with a Leica M205C binocular microscope using transmitted and polarized light. Rutile grains are red-brown-yellow colored in reflected light, red to opaque in plane polarized light, and displayed a resinous to vitreous luster; grains are well rounded to euhedral and many display twinning characteristic of rutile's

tetragonal crystal system and striations parallel to the long axis. Three samples—16SKY26, 16SKY42 and 17OZK05—yielded hundreds of rutile grains and we handpicked 260–320 rutile grains from each sample. For samples with a small quantity of heavy mineral grains, rutile was picked from all 0.3 to >1.5 amp. magnetic fractions. The low yield of rutile partially contributes to the low-*n* of the samples. Then, the grains were mounted in epoxy, polished and imaged in the SEM. We used EDS to confirm that the grains that were handpicked were in fact TiO_2. ***We will clarify this methodology in the revised manuscript.***

- Line 245: I find this rather harsh, when you have a fine laser. This will increase your DHF. Why not being more gentle, ablating at a lower frequency? You also went too depth unnecessarily

This comment is regarding the 10 Hz rep rate. The laser system used has a fast washout: 4-5 magnitudes of signal in <1 second. Using a lower frequency would result in a sawtooth signal pattern and lead to aliasing problems. We decided against signal smoothing and lower frequency to avoid "smearing" out the effect of inclusions or exacerbating the potential effect of surface common Pb. For the relatively large spot used, the pit depth is moderate, also due to the moderate laser energy used. 10 Hz frequency has been widely used for U-Pb geochronology of accessory minerals, including rutile (e.g., Kooijman et al. 2010; Zack et al. 2011). The conditions were chosen to allow analyses of relatively low U and Pb rutile, as anticipated for relatively young rutile received from low to medium grade metamorphic rocks with a high likelihood of mafic protolith.

- Line 245: I understand why, but in most detrital rutile samples this may be a very large spot, where you most likely will hit micro-inclusions. For a better workflow, in my pov, we should aim for 35-40 um, even though we lose signal. This should be discussed, perhaps not here, but in the discussion section

Yes, a larger spot size gives a higher signal, which is better for grains with potentially low U or low Pb concentrations. The tradeoff is potentially hitting more inclusions, we are aware of this. See previous comment, we aimed to optimize for relatively young, low U and Pb rutile, because it was obvious that many source rocks would be ophiolite units with largely mafic rock types. In areas with higher input of older or higher grade metamorphic rocks conditions may be chosen differently.

- Line 250: include the published or accepted ages for all these RM here. Also, you need to state if you used a sample bracketing approach, and of how many unknowns interspersed with how many primary and secondary RM.

The revised manuscript will include the published ages for the reference materials: R10 (1091.6 ± 3.5 Ma by TIMS, 2s abs.; Luvizotto et al., 2009), Wodgina (2845.8 ± 7.8 Ma by TIMS; Ewing, 2011), Kragerø (1085.7 ± 7.9 Ma by TIMS; Kellett et al., 2018), 9826J (381.9 ± 1.1 Ma by TIMS; Kylander-Clark, 2008), and LJ04-08 (498 ± 3 Ma by LA-ICP-MS; Apen et al., 2020). ***The revised manuscript will clarify our sample-standard bracketing approach. This is stated briefly in Table A2 but will be expanded.*** For U-Pb analyses, the analysis of 5-8 unknowns was followed by 2 standards, the primary standard R10 and one of the secondary standards. For trace element analysis, the analysis of 5-10 unknowns was followed by analysis of 2 standards, the primary standard GSD-1G and one of the secondary standards.

- Line 250: what splines did your use?

For the drift correction, we used iolite's SplineSmooth5 for all analytical sessions. However, in response to Reviewer #2's comments regarding standard reproducibility, we compared the effects of weighted linear fit, SplineSmooth5 and SplineSmooth9 curves for drift correction. The choice of spline had little effect on the final age of the reference materials but impacted the MSWD. We prefer the weighted linear fit as this curve reproduces the secondary standard ages and brings the MSWD closest to 1 for each standard. ***The revised manuscript will include the results that were reduced using the weighted linear fit drift correction. All figures and tables in the main text and supplement will be***

updated. We do not anticipate that this change will produce significant changes to the results or interpretations.

- Line 255: it is not clear how it changed from the previous one, as you don't highlight it.

We will remove this statement and only focus on the protocols used here.

- Line 255: which signal? in all channels? It is natural for rutile to have small mineral inclusions. For how long, in s, did those spikes affected your signals? The entire ablation duration? At the start, end? We all discard a few analyses every now and again, but I was a bit surprised with these numbers. I think that this deserves further consideration, so you should include a "data treatment" section in the appendix, where you show print screens of your signals and give examples of analyses you excluded due to these spikes…

The U-Pb data reduction was performed in *iolite* (Paton et al., 2011). We monitored signal intensity by examining ^{206}Pb, ^{207}Pb, ^{238}U, ^{232}Th, 206/238 and 207/206 ratio channels. It was easy to spot inclusions by monitoring these channels. In some instances, the signal of an inclusion was short enough that the integration window could be shortened to exclude the inclusion. In other cases, the non-inclusion signal could not be isolated and the entire analysis was discarded. Some grains were excluded due to too low U or Pb signal. Anomalous patterns in 207/206 ratio resulted in either shortening the integration window or excluding the analysis. ***The revised manuscript will include an appendix section that details the data treatment. We will follow Reviewer #3's suggestion to include a figure with a few examples of good and bad signals.***

- Line 270: which one was used as primary and which ones as QC ? You should provide Ti concentration of your primary material
    - Line 270: how did your secondary rm behaved as QC? Which elements are within 10% error and which ones fall out?

For trace element analysis, GSD-1G was used as the primary standard. Figure R1 displays the trace element results of the three reference materials for the four analytical sessions. The trace element results are within 10% for all of the main elements discussed in the paper: Cr, Nb, and Zr. For the secondary standard GSC-1G, all elements are within 10% of the published values except for Sn and Ga. The R10 rutile reference material displayed internal heterogeneity in trace element composition, which we noticed when comparing the trace element results with the laser ablation spot coordinates. This is also reflected in the range of trace element compositions reported for R10 in the GeoReM database (http://georem.mpch-mainz.gwdg.de/). The R10 results are within 10% for many elements but the offset is much higher for some elements. We note that all of the R10 results are within the range of reported values from the GeoReM database. ***The revised manuscript will clarify the primary and secondary reference materials and include a discussion of reproducibility in the main text and appendix.***

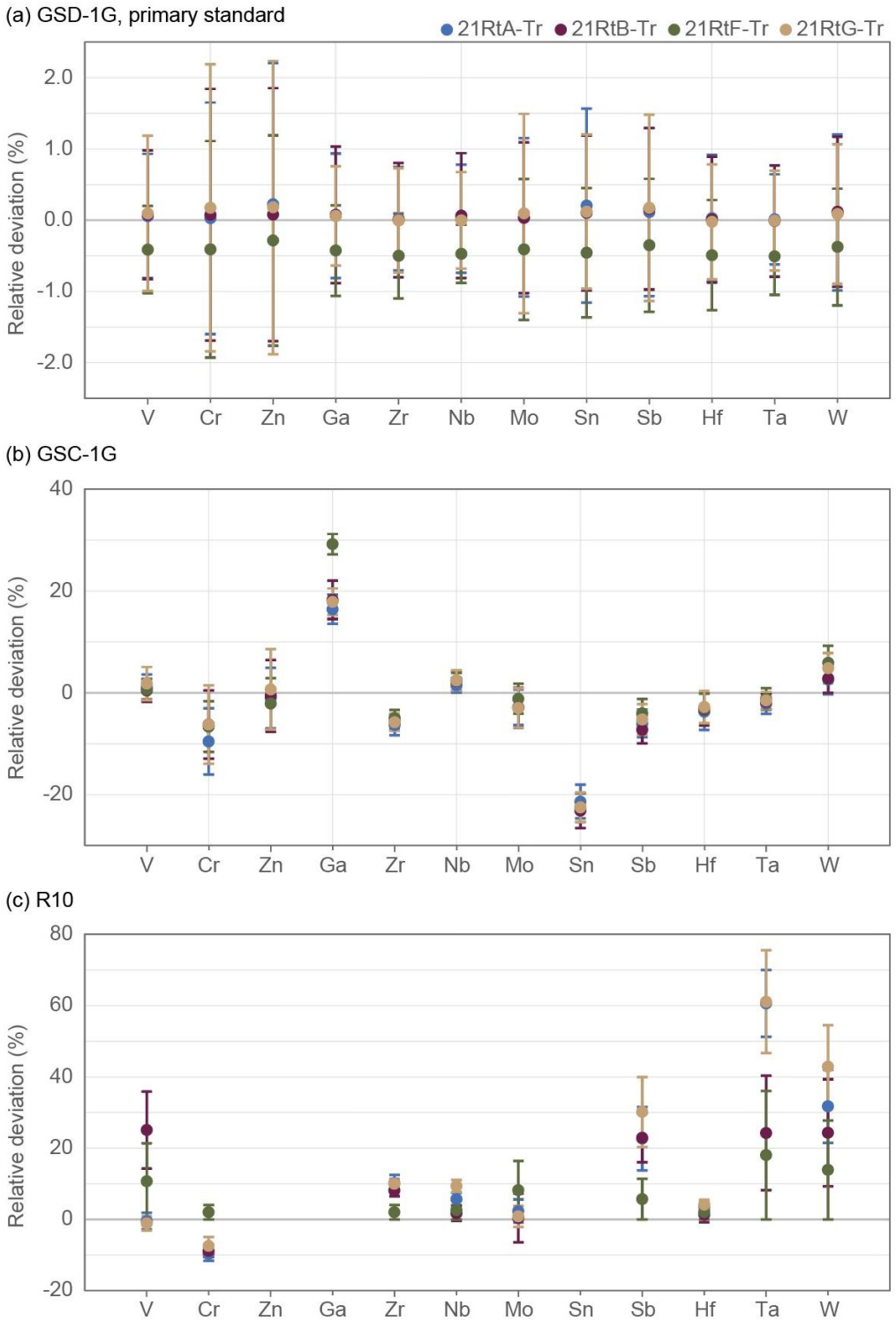

Figure R1. Plots of percent deviation of the trace elements for reference materials GSD-1G, GSC-1G and R10. The data were calibrated using GSD-1G and Ti as an internal standard element. Error bars show the standard deviation.

3. Comments regarding the trace element dataset

- The geochemistry is used, but PCA is not really adding anything new or rather interesting. I do not see the purpose of keeping it in its current form. I am afraid that by stating strongly very early on that you would be "expanding the workflow" of rutile in provenance studies, but then not combining it well with TE systematics is misleading.
- Section 2.1. Provenance: Don't place all the focus on Nb-Cr and Zr thermometry. You can be more concise in your sentences and ideas, and then you could highlight how other more recent tools can be effectively used in provenance studies (see my comments in the pdf). I also find that this subsection's title is not suitable. You should re-think better how 2.1 related to the other subsection under section 2 and propose an improved structure and matching headings. You have provenance in 2, and then a "synopsis", followed by "challenges" that actually just relate to U-Pb. So, in my view you are emphasising the application of detrital rutile geochronology as a provenance tool. This is fine, but the subheadings need to clarify this.
- Section 6.2. Careful with rushing into conclusions. While it may be true that in your dataset your U<4ppm is vastly metamafic, this does not necessarily imply lower T. For a robust assessment of lower Ts, you need to rely on your metapelitic detrital grains. Rephrase.
- Line 355: hmmm if they are metamafic, you increase the probabibility of not having the boundary conditions to effectively use Zr as a thermometer. So lower Zr in a mafic rutile does not equal lower T...
- Section 6.3 If you are not exploring your data further, I would remove it, as it is not bringing anything really new, and it does not add to any relevant information to your main objective. Since they are detrital grains, I would have difficulty to saying much more.
    - If you decide to follow my suggestion of major rewriting, you could do a bit more work on detrital rutile trace element geochemistry, try to interpret their chemistries a bit more, and then it would be fine to use the PCA as a starting point of such a subsection.

As stated above, although we did not claim to present new workflows with the geochemical data, this was perhaps unintentionally implied with the title. We have presented as much information as we could squeeze out of our particular geochemical dataset.

Reviewers #1 and #3 raised points about the use of our geochemical dataset. We used the detrital rutile trace element dataset in several ways. We confirmed that analyzed grains were rutile using Cr, V and Zr (Appendix A). The Cr and Nb concentrations are used to discriminate mafic and pelitic protoliths and Zr concentration is used to determine Zr-in-rutile temperatures, with the caveat that this assumes the necessary buffering assemblage. The aforementioned applications only use 1 or 2 elements each. To evaluate the suite of trace elements, we used principal component analysis. Dimensionality reduction methods like PCA and tSNE are useful for evaluating clustering in large, multivariate datasets (we did not discuss tSNE in the manuscript as the results were similar to PCA). We hoped that these methods would help distinguish detrital populations. However, the PCA results show that *"the variance between [grains] can largely be explained by Hf, Zr, Sn, Cr, V, Nb and Ta. Because Cr, Nb and Ta are protolith dependent (PC 2) and Hf and Zr are temperature dependent (PC 1), the variance in detrital rutile trace element chemistry is best explained by both protolith and metamorphic grade, allowing us to track these two properties of source rocks." (Lines 376-379)*. This is valuable information, since we are not aware of other publications trying this approach. The PCA results show that the protolith and Zr-in-rutile sections are already exploring the most salient aspects of the trace element dataset. ***The revised manuscript will clarify the most salient points of the PCA results. We will emphasize that the protolith and temperature sections capture the most important components of the trace element results. Additionally, we will***

revisit the trace element data to evaluate trends in samples and/or age populations and consider adding spider plots, bar plots, and/or other clustering algorithms as relevant. The revised manuscript will include updated text, figures and supporting information to support any new findings.

Regarding the Zr-in-rutile temperatures of metamafic grains, we show that the majority of mafic-classified grains have lower temperatures, around 400-500 °C (Figure 9). We did not mean to imply that all metamafic grains have low Zr-in-rutile temperatures. ***We will clarify the text.*** On the comments about Zr-in-rutile temperatures in mafic grains that point to the requirement for zircon, quartz and rutile to be in equilibrium to use the Zr-in-rutile thermometer, we are aware that this assumption may not hold in mafic rocks. In the absence of zircon and/or quartz, the concentration of Zr is not buffered by the reaction and the calculated temperature is not reliable. In their review, Pereira and Storey (2023) discuss how inclusions in rutile can be used to determine whether rutile grew in equilibrium. We suspect that only a workflow of automated mineralogy with a very small spot size would be able to systematically study all inclusions in a high-*n* detrital study. ***We can add a statement in Section 2.1 about the requirement that zircon, quartz and rutile are in equilibrium, which may not hold and is hard to determine in a detrital context.***

4. Additional line by line comments, excluding typographic comments

- Sections 2.3.1 and 2.3.2: You should provide at least a short review on the ^{204}Pb-based correction of common Pb. You can discuss why it is sometimes very difficult to apply it, but omitting it is not satisfactory in a paper meant to cover common Pb corrections.
    - Line 150: what about 204Pb correction? Even if you do not include a section, I think you should add a sentence to explain how it can be done.

Reviewers #1 and #3 both inquired why the ^{204}Pb correction was not discussed. This was not initially included because (a) ^{204}(Pb+Hg) and ^{202}Hg were not measured (high Hg in UHP He gas in the midcontinent US), so we did not perform a ^{204}Pb correction, and (b) it is reviewed in other publications. Although we will not be able to explore the ^{204}Pb correction in our dataset, it is a goal of future work, ***the revised manuscript will include a short overview of this correction and its application in rutile.***

- Sections 2.3.1 and 2.3.2: I suggest you include a figure with two panels, in one showing a common Pb-bearing analysis and the corresponding corrected age using the ^{208}Pb correction and in the second the 207. These can the theoretical if you will, but you can add arrows and annotations illustrating the assumptions.
    - Line 190 / Figure 1: actually, it would be beneficial to see the lines of 2s +/- regressing the age in TW space from 6/7 ratios. equally relevant is the impact of these choices in the resulting date.

Following the comments of Reviewer #2, the revised manuscript will modify the discussion of the ^{207}Pb correction. We will use an iterative approach to the ^{207}Pb correction and will include the equations for how to do so in the revised manuscript. This eliminates the original purpose of Figure 1, which shows how to graphically perform a ^{207}Pb correction and how to calculate discordance. It might make sense to keep Figure 1 in the revised manuscript to demonstrate the effect of common Pb incorporation in pulling an analysis from concordia toward the Pbc composition. We will consider this point in the revised manuscript.

- Line 70: I think this is a very simplistic sentence for the complexity about the age significance. Since this is partly the focus of your work, why not elaborate a bit more? In recent papers you find discussion about rutile ages all over.

Reviewers #2 and #3 commented on the statement, *"With a U-Pb closure temperature of 490–640°C (Kooijman et al., 2010), rutile U-Pb dates correspond to cooling from the most recent medium to*

high-temperature metamorphic event that exceeded the closure temperature (Zack et al., 2004b; Zack and Kooijman, 2017)" (line 72-74). ***The revised manuscript will expand on this statement to better reflect the meaning of a rutile U-Pb date. The revised manuscript will clarify that the U-Pb age is a function of grain size, diffusion kinetics, and cooling rate, and potentially of fluid presence. High peak temperature and/or slow cooling rates can produce U-Pb dates significantly younger than the timing of metamorphism (e.g., Möller et al. 2000). This is relevant to our dataset as rutile U-Pb dates around 190 Ma are 10-25 Myr younger than estimates of peak metamorphism in the Karakaya Complex. We will mention this in the discussion.***

- Section 2.1: I think that the work by Hart et al., 2016 should be acknowledged here as well, with a brief outlook detailed in Pereira and Storey 2023, on the applications of such an approach in rutile provenance studies.

We will add mention of these papers in our revised Section 2.1 overview of detrital rutile.

- Line 95: Potentially you could add potential use of rutile TE to constrain oxygen fugacity (using V and H).

We will add mention of this application of rutile trace elements to the overview.

- Section 2.2: In all truth, while many of us have been saying that this can generate a bias, no systematic study has been done to actually quantify and test the effect of screening for high U rutile only. I think that you may want to strengthen this point in a few parts of the manuscript, including here.

We will strengthen the point that our dataset clearly shows the bias of screening out rutile with low uranium concentrations.

- Line 135-140: in my opinion, this is irrelevant here. Focus on rutile, people reading should know about U-Pb geochronology or should go somewhere else to learn the fundamentals.

We will consider shortening or removing this overview of U-Pb geochronology of rutile. We originally included these few lines because we have encountered many detrital geochronology users who want to add detrital rutile to their toolkits but are still uncertain in how to collect and interpret these data. We have seen detrital rutile papers that treat the data like detrital zircon in how they treat discordant data (i.e., applying a very strict discordance filter). It is important to emphasize to the detrital geochronology community the differences in why zircon versus common Pb-bearing minerals are discordant and how to treat these datasets.

- Line 190: what do you consider to be a stricter filter?

We will change the language of this sentence. Here we define discordance following the "Stacey-Kramers discordance filter" from Vermeesch (2021). At any discordance threshold, this filter includes more young dates than old (> 1000 Ma) dates due to the change in concordia slope around 1000 Ma.

- Section 5: This is a bit odd. Usually you would have a separate Results section and then you discriminate each type of result as a separate subsection...

We will reconsider the organization of the Results section in the revised manuscript.

- Line 350: since this is a results section, you need to explain this data a bit further. Which pressure have you used for these calculations and why? It is not clear if you followed what you reviewed earlier, as no uncertainties in your Ts were reported.
    - Figure 9: calculated for what P?

We calculated Zr-in-rutile temperatures with an average pressure of 13 kbar and an uncertainty of 5 kbar (i.e., 8 kbar to 18 kbar). The uncertainty is calculated as the difference between the Zr-in-rutile

temperature at 13 kbar versus 8 kbar or 18 kbar. This calculated uncertainty is already included in the supplementary file spreadsheet. ***We will clarify this in the methods section.***

- Line 350: arghhh you will find plenty of provenance studies or detrital rutile studies where no such strategy is employed... missing some literature here…

Reviewers #1 and #3 commented on whether 'low-U filtering' is prevalent in the literature. We agree that most labs that analyze detrital rutile do not apply a U-threshold filter. While not a global problem, this is a regional problem. There are 4 published detrital rutile U-Pb datasets from Türkiye (including this study), and 2 of them (Okay et al., 2011; Şengün et al., 2020) only analyze U-Pb on grains with uranium concentrations above ca. 4-5 ppm. This is a regional problem and imparts a bias, which we wanted to address in this manuscript as detrital rutile is still uncommon in Anatolia. The 2 studies that do not use a U-threshold filter but instead analyze all detrital rutile grains (Shaanan et al., 2020; this study) have to discard data due to very low uranium signals (below LOD) and must implement a protocol for evaluating discordance because of common Pb incorporation. For example, Shaanan et al. (2020) discard 60% of their detrital rutile U-Pb data due to discordance. Similarly, Reviewer #1 points to the study by Caracciolo and co-authors (2021) that analyzes 712 detrital rutile grains without a U-filter, yet, after discordance filtering, only 347 grains remained (48%) (from what we can tell as the data is not available online). Additionally, there were not enough rutile ages per sample to discuss sample-by-sample provenance interpretations, which we experienced with our dataset. This points to a larger problem in trying to scale up detrital rutile to large-*n* provenance applications. For this reason, we wanted to confidently include as many U-Pb analyses as possible in our interpretations, which led to the exploration of U-Pb discordance. To address this concern, ***we will change the text to reduce the discussion of U-threshold filtering. The revised manuscript will clarify that U-threshold filtering is currently not a common practice but is used regionally in Anatolia.***

- Line 415: are there KDEs from these units that you could use to compare them with?

Yes, the detrital zircon results are displayed alongside the detrital rutile results as KDEs in Figure 12. ***We will refer the reader to Figure 12 in this sentence.***

- Figure 7: in terms of age, you data actually seems to support that no significant differences are perceptible between populations. In your 190-200 population you may have a higher proportion of lower U grains, so that is nice, but it seems that there are no missing ages when you compare it with the > 4ppm U grains.

We agree that for our dataset there is not a significant difference in age modes between the U-threshold and concordance filtered data. It would be interesting to see if this holds in other datasets. We want to alert readers to the possibility and encourage them to test this. We addressed this in the text: *"The [U-threshold and concordance] filtering methods produce date spectra with the same dominant modes, yet the amplitude of peaks varies between methods. For example, the 190 Ma mode is more prominent with the concordance filter than with the U-threshold filter. Furthermore, the predominant date modes contain rutile of both metapelitic and metamafic origin (cf. next section and Figure 8). Even though the two filters do not yield different provenance interpretations in this case, most mafic-classified grains have U contents below 4 ppm and are in the 190 Ma population. Hence, the U-threshold filter is likely biasing results toward pelitic sources."* (lines 330-335).

- Figure 7: not statically robust to say much about the data points here...

We agree and have not made any statements or interpretations on the U-Pb dates > 1000 Ma.

- Figure 7: in the green and pink you should state here in the legend no U concentration filtering

We will update the figure caption and/or legend.

- Figure 8: include the 2se as error lines or just plot the data as ellipses

- Figure 10: include the 2se as error lines or, even better, as ellipses

We chose not to include the ellipses or error bars in these figures in order to simplify. The U-Pb data is shown with 2s error in Figure 4. ***We will consider updating this in the revised manuscript.***

- Figure 8: you have different dashed lines, so you should clearly attribute each to an author

We included the citations in the figure caption, but acknowledge it is unclear in the figure. ***We will change this in the revised manuscript.***

- Figure 12: to help the reader, you could add bars or arrows to known events in the area. This would simplify our work as we try to interpret the plot and follow your discussion\

This is a good suggestion, and we will update the figure in the revised manuscript to show the main orogenic events that correspond to the main age populations, Variscan, Cimmerian and Alpine.

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