Reviewer RC2: Stephanie Walker

This manuscript presents an important contribution by comparing in situ monazite Lu-Hf and U-Pb geochronology in a complex metamorphic terrane. Although the specific technique has already been outlined in a previous paper, this study is well-structured, methodologically rigorous, and effectively demonstrates the utility of Lu-Hf dating as an independent chronometer for validating U-Pb age interpretations. The authors provide a strong dataset with comprehensive analytical procedures. However, I have some concerns about the handling of the uncertainties which require further clarification.

General comments

Data processing: The matrix correction for Lu-Hf dating is based on apatite reference materials. While the justification is reasonable, the authors should explicitly state whether monazite-specific correction factors were tested and how any uncertainties from matrix mismatches were handled.

Apatite RMs yielded correction factors (CFs) of 4.40 ± 0.04 % and 4.71 ± 0.05 % for sessions 1 and 2, respectively. While monazite-corrected data are not presented here, the two monazite reference materials (RMs) yield correction factors of the same order as those from apatite RMs. We will expand this section to state the exact CF values for both RW-1 and TS-Mnz across both sessions, however, since the monazite correction factors

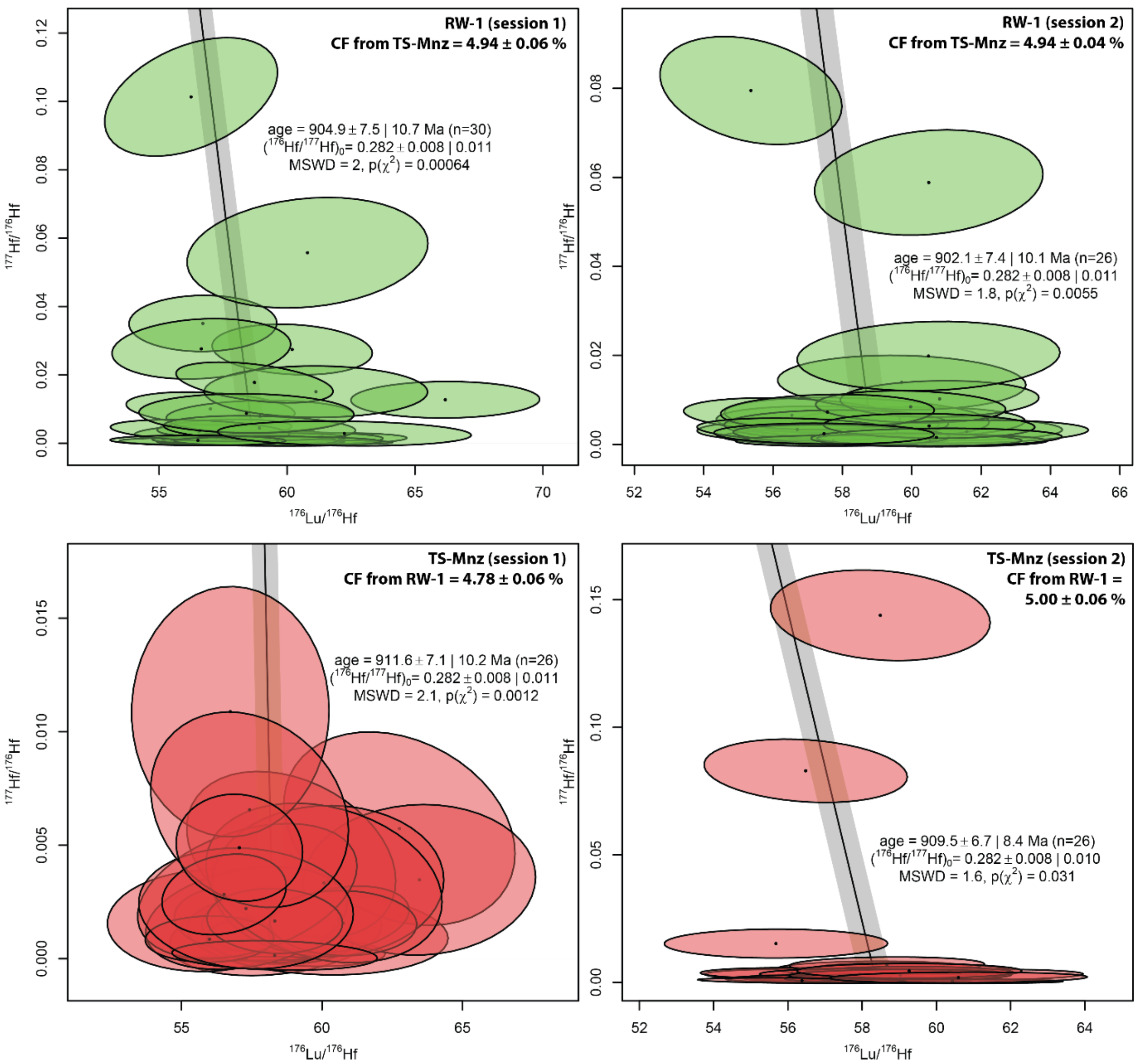

Figure RC2-1: Inverse isochron plots for samples RW-1 (top panels) and TS-Mnz (bottom panels) demonstrating the use of monazite-based matrix fractionation correction factors (CF).

are similar to those attained from apatite (i.e., deviating from the apatite derived CFs by < 1 %), we do not feel it necessary to present an additional dataset demonstrating their use. In Figure RC2-1, we present data from RW-1 and TS-Mnz which have had matrix fractionation corrections performed using CF values from monazite RMs (TS-Mnz used to correct RW-1, and RW-1 used to correct TS-Mnz). Although the calculated inverse isochron dates are within uncertainty of those corrected to apatite RMs, they provide slightly better accuracy in reproducing the published ID-TIMS ages of these RMs.

Matrix correction factors were not initially propagated onto the final inverse isochron/weighted mean dates (apologies for this oversight). This will be updated, and the propagated uncertainty values will be updated in the text and on Figures 1, 2, and 6.

Uncertainty propagation: Error propagation was undertaken involving quadratic addition of uncertainties from various sources (eg analytical session, reference material age, decay constant etc). However, there is no discussion of how systematic errors (instrumental drift and long-term reproducibility) were assessed.

Instrument drift was corrected for using LADR. Output uncertainties from LADR factor in intra-session instrument drift by fitting an 8^{th} order polynomial spline (default fit in LADR) to NIST-610 SRM analyses which bracket the unknown analyses throughout the time-series data. The misfit of this calibration curve is accounted for in the exported uncertainties. For our comments on the long-term reproducibility of this method, we refer to the discussion on this topic in our response to RC1.

I'm guessing that the reference materials were processed in the same way as the unknowns? How do they compare over multiple sessions?

Yes, RMs are always processed in the same way as unknowns. Although two different apatite RMs were used between sessions 1 and 2 (Bamble-1 and OD-306, respectively), we refer to Glorie et al. (2024a) who present multi-session data for these RMs, demonstrating no meaningful variance across multiple sessions. We will also incorporate data from in-house secondary apatite standard HR-1 (long-term Lu–Hf age of 344 ± 2 Ma; Glorie et al., 2024a) to further appraise apatite corrections. HR-1 yielded corrected isochron ages of 348 ± 4 Ma (n = 15, MSWD = 1.30, p = 0.17) and 342 ± 3 Ma (n = 26, MSWD = 0.96, p = 0.52) for sessions 1 and 2, respectively.

Statistical handling of isochrons:

The study appropriately employs IsoplotR for isochron calculations, but the discussion lacks sufficient depth on the selection of anchored vs. unanchored regressions.

Unanchored isochrons give poor age results when Lu–Hf ratios are highly radiogenic (as in this study). The terrestrial variation in initial Hf ratios is miniscule on the scale of the isochron plot. However, anchoring the isochron to the terrestrial initial ratio, with an uncertainty that covers the entire range of terrestrial variation, prevents obtaining isochron results with impossible initial ratios. The choice of anchor, within the initial range makes no difference to the final isochron age (see discussion below). Some additional discussion around this point will be added to the main text.

The authors use a fixed initial $^{177}Hf/^{176}Hf$ of 3.55 ± 0.05 for isochron regressions. While this may be appropriate, it introduces a level of model dependence that should be discussed in more detail. Were alternative initial ratios tested?

Because $^{177}Hf/^{176}Hf$ of all terrestrial sources covers only a very small range (encompassed by the uncertainty on 3.55 ± 0.05), we believe that anchoring the data within this range is a valid approach. Free regressions on data which exhibit little spread along the isochron can lead to spurious upper intercepts yielding geologically implausible initial Hf values (Vermeesch, 2024). This is particularly pertinent to monazite data, as monazite should contain no inherited Hf (nominally). As such, one would expect the data to be clustered around extremely radiogenic values, impeding the ability to fit a precise isochron via free regression. This is supported by the data we present from our analysis of various RM/SRM monazites, where there is significant clustering of analyses from samples towards radiogenic values. In Figure RC2-2, we demonstrate that anchoring the isochron to values of $^{177}Hf/^{176}Hf = 3.5$ or $^{177}Hf/^{176}Hf = 3.6$ (upper and lower limits of the range we allowed our regressions to intercept) makes no statistical difference to the resultant dates (i.e., they are all within uncertainty).

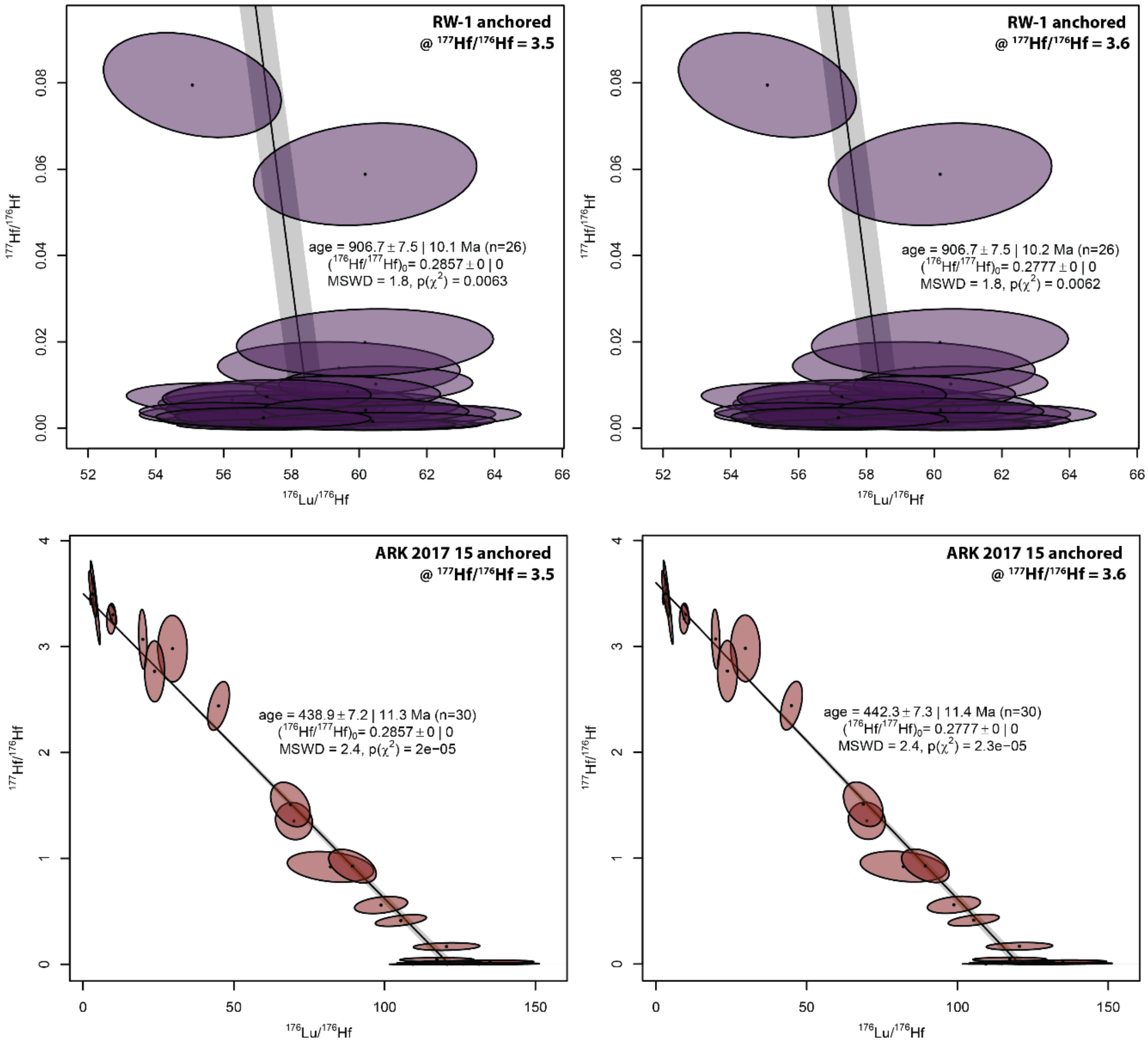

Figure RC2-2: Inverse isochron plots for samples RW-1 (top panels) and ARK 2017 15 (bottom panels) anchored at values of $^{177}Hf/^{176}Hf = 3.5$ (left panels) and $^{177}Hf/^{176}Hf = 3.6$ (right panels).

Some of the inverse isochrons have MSWD values greater than 2. The manuscript states that this suggests prolonged fluid-rock interaction, but alternative explanations (e.g. analytical scatter, common Hf incorporation) should also be considered.

We agree that some discussion about alternative explanations for the observed excess scatter is warranted. Although we believe that the scatter is likely due to fluid-rock interaction (supported by the U–Pb dataset), we cannot unequivocally rule out other options. We will add additional text to the manuscript discussing this.

Minor comments

Figures: The figures are clear and well-labelled, but the colour scheme in Fig 4 for the different microstructural domains could be more distinct to improve readability.

The format of Figure 4 will be modified to improve visibility.

References: These are comprehensive, but there are some inconsistencies in the formatting such as missing DOIs for some references.

DOIs will be added to all references (where available).

Supplementary data: Why are there such an absurd number of decimal places for the ratios? Obviously this depends on the precision of the values, but I imagine no more than two or three are actually significant.

The number of decimal places will be reduced.

Recommendation

While the manuscript presents valuable and well-executed research, improvements in uncertainty handling and statistical interpretation are required prior to publication. Once the above comments are addressed, I am confident that this will be a robust foundation for future monazite studies.

References cited in this response

Glorie, S., Hand, M., Mulder, J., Simpson, A., Emo, R. B., Kamber, B., Fernie, N., Nixon, A., and Gilbert, S.: Robust laser ablation Lu–Hf dating of apatite: an empirical evaluation, Geological Society, London, Special Publications, 537, 165–184, https://doi.org/10.1144/SP537-2022-205, 2024a.

Vermeesch, P.: Errorchrons and anchored isochrons in IsoplotR, Geochronology, 6, 397–407, https://doi.org/10.5194/gchron-6-397-2024, 2024.