

Dating circulations of hydrothermal fluids in the crystalline basements of unconformity-related metallic deposits using in situ Rb/Sr geochronology : proof of concept

Pont-by-point reply to editor and reviewer comments:

Dear Noah M. McLean,

We sincerely thank you for your careful assessment of our manuscript and for your constructive and encouraging comments. We greatly appreciate your positive evaluation of the quality of the measurements, the robustness of the geological interpretations, and the thoroughness of both the manuscript and our responses to the reviewers. We have carefully considered all of your suggestions and have revised the manuscript accordingly. **Our responses are in bold.**

Associate editor: Noah M. McLean

Overall, the highly constructive and detailed referee comments agree that this contribution is of broad interest, presents high-quality measurements, and that its geological interpretations are appropriate and defensible. I agree with both reviewers that the submitted manuscript is thoughtfully and thoroughly referenced, and its detailed methods and results are sufficient to judge its conclusions. Author responses to the reviewers are also thoughtful and thorough. In particular:

The authors' proposed clarification to the propagation of uncertainty related to the reproducibility of the La Posta secondary standard and its communication in the manuscript is excellent. I'm not sure what the "weighted mean statistics, along with their dispersion" means precisely, but the ~1.3% (1σ) magnitude they report in 'AC1' looks about right. I look forward to reading the details in the Methods section of the revised manuscript. As the authors indicate, adding the analytical uncertainty (in quadrature) to the reproducibility of the secondary reference material ensures that the reported uncertainty best reflects the total uncertainty in these analyses.

Thank you for this positive assessment. We agree that the previous description was insufficiently explicit. The Methods section has been expanded to provide a detailed explanation of the procedure used to assess long-term reproducibility from repeated analyses of the La Posta secondary reference material over a three-year period. We now specify that for each analytical session, an isochron age was calculated independently. The resulting session ages were then combined using a weighted mean, in which each session age was weighted by the inverse square of its internal uncertainty. The dispersion of individual session ages around this weighted mean, quantified as the standard deviation of the weighted residuals, was used to estimate an external reproducibility of approximately 1.6% (2σ). We also clarify that final age uncertainties incorporate both internal analytical uncertainty and external reproducibility through quadrature propagation ($\sigma_{\text{total}} = \sqrt{(\sigma_{\text{internal}}^2 + \sigma_{\text{reproducibility}}^2)}$), ensuring that the reported uncertainties reflect the total analytical uncertainty of the method.

Adding detailed concentration calculations to the revised Methods section would be a welcome addition, considering that they differ from standard practice.

We appreciate this suggestion and have expanded the Methods section accordingly. A dedicated paragraph now describes in detail the procedure used to calculate ^{87}Rb , ^{86}Sr , and ^{87}Sr concentrations from LA-ICP-MS/MS isotopic measurements. The revised text explains each calculation step, including the correction for natural isotopic abundances, derivation of Sr concentrations from measured isotopic ratios, and application of the matrix correction factor. For clarity and reproducibility, the corresponding equations have been added to the manuscript.

I appreciate the discussion in the reviewer comments and replies about where and how to address the apparent low initial $^{87}\text{Sr}/^{86}\text{Sr}$ isochron intercepts. The proposed changes, in response to Reviewers 1 and 2, appear adequate to address these concerns. I echoed Reviewer 1's surprise at the ± 1.7 Myr and ± 1.2 Myr uncertainties on the high-MSWD fits for altered muscovite in figure 7C-D. The text makes it clear that you do not interpret these uncertainties as geologically meaningful. I recommend eliding the last decimal places and the uncertainty on these high-MSWD fits to help others better understand your interpretation; for instance, reporting both as "ca. 1635 Ma".

Thank you for this helpful recommendation. We agree that reporting highly precise internal uncertainties for regressions characterized by elevated MSWD values may inadvertently imply a level of geological significance that is not warranted. Accordingly, the manuscript has been revised to report these regressions as ca. 1635 Ma and ca. 1636 Ma respectively, consistent with our interpretation that the regressions define a broad age cluster rather than precise geological ages. We have also retained the discussion explaining that the elevated MSWD values indicate substantial excess scatter and limit the geological significance of the formal regression uncertainties.

Attaching the proviso about BIC-selected Gaussian mixture models to the revised manuscript is prudent and sufficient in this context. I agree that more sophisticated statistical treatments are beyond the scope of this paper. I look forward to seeing the proposed KDE plots for the uncertainty-binned data.

Thank you for your assessment. The manuscript now explicitly includes the caveat regarding the limitations of BIC-selected Gaussian mixture models and emphasizes that the resulting age populations should be regarded as exploratory statistical groupings rather than uniquely defined geological events. In addition, the KDE plots for uncertainty-binned datasets have been added to the revised manuscript.

The authors' responses to Reviewer 2's alternative regression considerations and suggestions are all reasonable. I appreciate the constructive back-and-forth on this topic from the authors and the reviewer.

We thank you for this positive evaluation. We found the discussion with Reviewer 2 highly constructive and have incorporated the agreed clarifications and explanations into the revised manuscript where appropriate.

The authors proposed changes to typographic errors and color schemes, as suggested by both reviewers, are all excellent.

We appreciate this comment. All typographic corrections identified by the reviewers have been implemented. In addition, the color schemes of the relevant figures have been revised to improve readability and visual consistency throughout the manuscript.

In addition to the reviewer comments: I appreciated the clarity and detail in Figure 9. Both reviewers commented that this contribution is “somewhat dense,” and I’d echo this sentiment. However, the text is not duplicative, and the sections are well-organized. Before resubmission, I’d recommend reading through the text once more to identify long paragraphs that might be divided into two, with the new paragraph getting a summative topic sentence. This revision helps readers navigate longer, more technical prose. I believe there is a place for detail-oriented science writing as you’ve provided here, but I think the easier you can make it to read, the more your article will be read and cited.

Thank you for this thoughtful suggestion and for your positive assessment of the manuscript structure and Figure 9. We carefully reread the manuscript with readability in mind and revised several of the longer paragraphs, particularly within sections 5.2 and 5.3 of the Discussion. Where appropriate, lengthy paragraphs were divided into shorter thematic units, and additional topic sentences were introduced to improve logical flow and guide the reader through the more technical sections of the text. These modifications were implemented without reducing the scientific detail of the discussion.

Overall, I suggest only minor edits, as outlined by the authors and discussed above, are required for publication of this manuscript in *Geochronology*.

Best wishes,

Noah McLean, AE

We sincerely thank you for your constructive comments and for the time and effort devoted to evaluating our manuscript. We believe that the revisions have significantly improved the clarity, transparency, and readability of the manuscript, and we hope that the revised version is now suitable for publication in *Geochronology*.

Yours sincerely,

Quentin Boulogne and co-authors