Reviewer 2

The reviewer's comments are in black, and our responses in blue.

I enjoyed reading the manuscript because it attempts to address one of the long-standing difficulties in the application of amino acid racemization reactions to the dating of Quaternary successions. The challenge has been to try to reliably convert the extent of racemization to a numeric age. The vagaries of diagenetic temperature, as well as the preservation state of fossils has commonly rendered this a challenging task. This study is interesting because it incorporates samples that have experienced variable diagenetic temperatures due the effects of geothermal gradients, which appear not to be uniform within the Pannonia Basin, Hungary.

Some more specific comments appear below.

1. Line 65 it would be nice to see here, and explanation of why a linear model was selected.

This is outlined in Section 2.2, where the original model assumes an exponential relationship between the extent of IcPD, time, and temperature. This assumption was made because the rate of racemisation is known to increase exponentially with temperature (Miller, 2000). Log-transforming the model enabled linear regression, allowing all necessary calculations to be performed analytically (Aitchison and Dunsmore, 1975). We will expand this explanation in Section 2.2 and briefly summarize the rationale in the introduction where the model is first introduced to avoid repetition.

Miller, Gifford H., C. P. Hart, E. B. Roark, and B. J. Johnson. 'Isoleucine Epimerization in Eggshells of the Flightless Australian Birds Genyornis and Dromaius.' In Perspectives in Amino Acid and Protein Geochemistry, edited by G. A. Goodfriend, Mathew J. Collins, M. L. Fogel, S. A. Macko, and J. F. Wehmiller. Oxford University Press, 2000.

Aitchison, J., and I. R. Dunsmore. Statistical Prediction Analysis. 1st edn. Cambridge University Press, 1975. https://doi.org/10.1017/CBO9780511569647.

2. I am not sure if this is possible, but can an outline of the margin of the Pannonian Basin be shown in Figure 1?

We thank the reviewer for the suggestion. An outline of the Pannonian Basin can be added to the map based on the boundaries described by the geological maps of the area.

3. Line 103 Can the validity of this assumption be stated here?

The assumption of near-continuous sedimentation stems from the work of Püspöki and colleagues on the Quaternary deposits within this basin (see Cooke et al., 1979; Püspöki 2016; 2020; 2021a; 2021b; 2023). This assumption is supported by high-resolution magnetic stratigraphy record within sediments from the Körös Basin, and correlations between sub-basins through cyclo- and amino acid stratigraphy. We will explicitly cite and summarise this evidence in the revised text to justify our assumption.

4. Line 118 The Püspöki age model needs to be briefly described.

This age model is described in section 2.1.2, so we will refer to this section in the text here.

5. Line 127 Alanine is a Fast racemizing acid.

In *Bithynia* opercula alanine racemises slower than the faster racemising amino acids (aspartic acid/asparagine, serine) but faster than valine and glutamic acid/glutamine. It is for this reason that this amino acid has been described as a moderate-rate racemising amino acid here. In Nelson et al. (2024), the extent of racemisation for different amino acids vs. age was presented. To provide more clarity on the selection of alanine for this model, we can include in 2.1.3 an overview of the time ranges each amino acid was able to provide age discrimination for, to support assumption 3 for the linear regression model.

6. Line 137 What is the basis for the c. 49 ka age reported by Nelson (2024)?

The shallowest/youngest opercula analysed in Nelson et al. (2024) was from the Deváványa sediment core at 5.38-5.54 m. Through the Püspöki age model this level was assigned to 49 ka. This will be clarified in the text.

7. Figure 2 - Is there any merit in producing three graphs - one for each amino acid? It might improve the clarity of the information and make it easier to see the structure of the data.

We thank the reviewer for this suggestion and agree that presenting the fit for each amino acid does make it easier to see the structure of the data. We will therefore change this figure to where the model fit for each amino acid is presented in individual subplots.

8. Line 152 '... time has passed since ...'

This will be corrected in the revised version of the manuscript.

9. Line 159 Please keep spelling consistent within the document - racemization or racemisation.

In the revised version of the manuscript we will ensure the British English spelling on racemisation will be used consistently throughout.

10. Line 159 Please adopt in all instances 'compared with' throughout the text.

This will be corrected in the revised version of the manuscript.

11. Line 186 D/L values

This will be corrected in the revised version of the manuscript.

12. So, can you calculate some numeric ages and compare with the likely ages of the basin fill based on independent evidence?

In Figure 4, we present four examples of predictive age distributions generated by our model; the blue point on each subplot represents age estimates from the Püspöki age model. These examples demonstrate that numerical ages estimated by the model currently carry high levels of uncertainty, meaning its accuracy must be improved age estimates produced by the LRM can be compared against independent chronological evidence.

Furthermore, Quaternary sediments in the deepest part of the basin overlie Pliocene deposits (e.g., Püspöki et al., 2023), which exceed the chronological limit of IcPD. Consequently, even if the model's precision is improved to provide numerical age estimates, extrapolating the IcPD data would still be necessary to estimate the overall age of the basin fill.

Püspöki, Zoltán, Philip L. Gibbard, László Ferenc Kiss, et al. 'Obliquity-Driven Mountain Permafrost-Related Fluvial Magnetic Susceptibility Cycles in the Quaternary Mid-Latitude Long-Term (2.5 Ma) Fluvial Maros Fan in the Pannonian Basin'. Boreas 52, no. 3 (2023): 402–26. https://doi.org/10.1111/bor.12618.