Constraining the depth of the lithosphere-asthenosphere boundary in tectonically complex regions using locally adjusted lithological forward models and seismic velocities

by N. Liptai, D. Kalmár and I. J. Kovács

Reply to Reviewer 2

Dear Reviewer,

Thank you very much for your detailed and constructive comments. We have modified the manuscript based on your suggestions and we believe that it has significantly improved. Please find below our reply to your comments point by point, highlighted in blue italic.

Sincerely,
Nóra Liptai, Dániel Kalmár, István J. Kovács

Comments

The introduction presents a clear aim to apply 1D migration of S-to-P receiver functions within an interdisciplinary framework to improve constraints on lithosphere-asthenosphere boundary depth. However, Section 3 Methods remains partly brief and general, and would benefit from further elaboration.

• The used RF methodology could be described in more detail. While it is understandable that the authors follow the procedure of Kalmar et al. (2023), the details of parameter setting would be good to mention.

• The authors mention the use of data from 41 seismic stations in the region, but provide no information about the data itself (parameters of selection, preprocessing, etc.).

• Also, information about the resulting Receiver functions, such as the number of RFs, back-azimuth coverage, and the quality of the RFs, is missing. Only the sums of S-to-P receiver functions are presented in Figure S3 (supplement). Further comments on Figure S3 are below.

• Additionally, the migration method would be good to describe slightly in this paper (even though it is already described in Kalmar et al. (2023)).

Thank you very much for this valuable suggestion. Based on your comment, we have rewritten Section 3 to make the workflow, data usage, and methodological choices clearer. We believe that the revised text now addresses all of the raised questions and concerns related to the description. The new version of the paragraph reads as follows:

"The S-to-P receiver functions (RFs) used in this study were computed previously by Kalmár et al. (2023), and here we directly used this existing RF dataset for the seismic forward modelling. In this way, information on the LAB depth was obtained from two independent approaches: (1) the seismologically derived RF-based 1D migration and (2) the geochemistry-based forward modelling applied beneath the same stations.

The data selection criteria, preprocessing steps, parameter settings (including deconvolution parameters), and the characteristics of the RF dataset (number of RFs, back-azimuthal coverage, and overall quality) are identical to those described in detail in Kalmár et al.

(2023) for the same 41 seismic stations, and are not repeated here. A brief summary of the main steps is nevertheless provided for clarity.
Raw S-to-P receiver functions were computed using the iterative time-domain deconvolution method (Ligorría & Ammon, 1999) with 300 iterations following Kalmár et al. (2023), and three independent quality control procedures (Hetényi et al., 2018b; Kalmár et al., 2021; Colavitti et al., 2022). The resulting stack S-to-P receiver functions from the all back-azimuthal direction (Figure S3) were then converted from time to depth by a 1D migration method (Kalmár et al., 2023), using a velocity model defined beneath each seismic station. The median value of the negative S-to-P phase (SpN) was accepted as the representative depth for the 1D migration, which was applied at all 41 investigated stations to estimate the negative phase depth (interpreted as the presence of the LAB) within the lithosphere. For the migration, the velocity models were implemented at a vertical resolution of 5 km, down to a maximum depth of 120 km."

• At line 105, the right parenthesis is missing.

Thank you, we corrected.

• At line 106, the AdriaArray initiative is mentioned. Please cite the paper Kolínský et al., 2025. AdriaArray – a Passive Seismic Experiment to Study Structure, Geodynamics and Geohazards of the Adriatic Plate. Ann. Geophys. 2025, 68 (5), DM555. https://doi.org/10.4401/ag-9284

We have added this reference.

• At lines 125-127: The statement about the complexity of the structures is vague, there is no clear indication of what the authors compare those structures to, and there is no example of what exactly is meant by good agreement.

We modified the sentence, adding that we mean 'more complex' in petrological sense, as opposed to the applied simplified model.

By good agreement we mean that the calculated seismic velocities are in a similar range as those provided by Kalmár et al. (2021). For example, S-wave velocities at LTVH station go from ~3.5 km/s at the top of the upper crust to ~4.2 km/s at the bottom of the lower crust (see figs 13 and 15 in Kalmár et al., 2021, and tab 2 of Table S2 in this manuscript. We used this as a confirmation that our calculations for the crustal part of the model are valid, however we do not think this warrants a separate figure as it does not represent a significant finding.

Besides, it is not clear which data were calculated newly (during the work on this paper) and which were already published. In case that some figures have already been published, it should be mentioned (e.g., the stack of LTVH station – compare with Figure 5 in Kalmar et al., 2023). Regarding Figure S3, it would be good to specify whether the stacks are from all back azimuths or a specific azimuthal sector only, and describe the content more precisely. For readers unfamiliar with the S-to-P receiver functions, it is unclear what is presented.

Thank you for your suggestions, we enhanced the caption of Fig. S3 and added clarifications in the main text (the last part of Section 3), see our reply to the first group of comments.

In Figure 2c, it would be helpful to reverse the y-axis to agree with fig. 2a and 2b. In Section 5.2, the authors mention that at six stations (A265A, A272A, HU04A, HU21A, HU22A, JOS), receiver-function data were insufficient to produce an acceptable LAB depth. This would be beneficial to include at least as an explanation in Figure S3 (e.g., by showing the accepted peaks).

Thank you very much for this observation. All values related to the LAB depth are presented in Table S1, while in Figure S3 the stacked SRFs of the stations clearly show, in a visual way, the reasons why certain results were not accepted. For the sake of clarity, we added the following sentence to the manuscript:
“. In this case, neither the positive nor the negative peak appeared on the SRF, because the data quality was poor or the station operated only for a short period and therefore could not record a sufficient amount of data.”

In Figure 7, it would be helpful to know which symbol belongs to which station, not only to which group (Alcapa or Tisza and thick or no (thin) sediment). Also, keeping the uniform axis scales at subfigures a – d would make the comparison clearer.

While we agree that it would be useful to know which symbol belongs to which station, due to the large number of data points we think it would be unfeasible to label each station. Nevertheless, all the data presented on this figure are contained in Table S1 for all stations.

References to the seismic networks are missing:
• AlpArray Seismic Network (2015). AlpArray Seismic Network (AASN) temporary component, AlpArray Working Group, doi:10.12686/alparray/z3_2015
• Hetényi, G., Plomerová, J., Bielik, M., Bokelmann, G., Csicsay, K., Czuba, W., Meier, T., Środa, P., Wéber, Z., Wesztergom, V., Žlebčíková, H. (2019). Pannonian-Carpathian-Alpine Seismic Experiment [Data set]. International Federation of Digital Seismograph Networks. https://doi.org/10.7914/SN/ZJ_2019
• Kövesligethy Radó Seismological Observatory (Geodetic And Geophysical Institute, Research Centre For Astronomy And Earth Sciences, Hungarian Academy Of Sciences (MTA CSFK GGI KRSZO)). (1992). Hungarian National Seismological Network [Data set]. GFZ Data Services, doi:10.14470/UH028726

We added these references.

line 466: Babuska → Babuška

Thank you, we corrected.

Seismic stations are sometimes mentioned as seismic stations, and sometimes as seismological stations (e.g., lines 12, 86, 96, 102, 358, 412). Unification using the phrase „seismic stations“ would be good. Similarly, seismological discontinuity (l. 49) and seismological data (l. 50); low velocity zone → lowvelocity zone (l. 36, 39, 54, 205, 331).

It would be beneficial to review the text for grammatical accuracy.

We have unified these expressions that appeared in different versions in the manuscript text.

I hope the suggestions mentioned above will help to improve the manuscript.