Shear wave velocity structure of the transition zone between the Eastern Alps and the Pannonian Basin from ambient noise tomography

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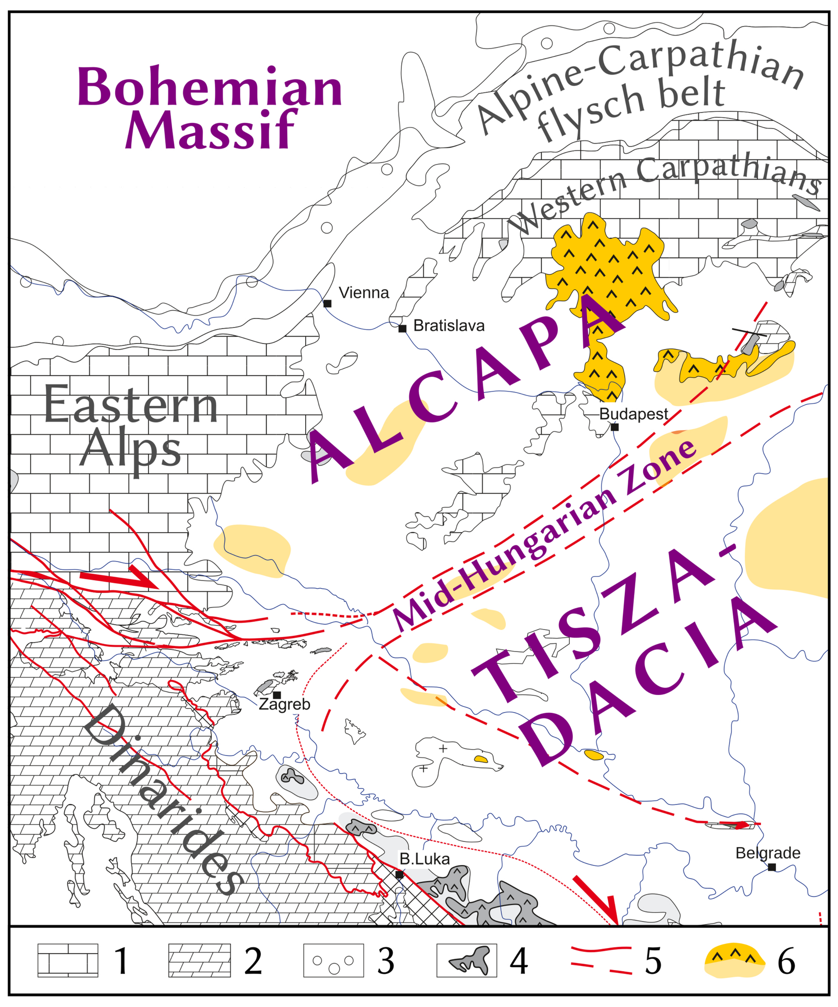
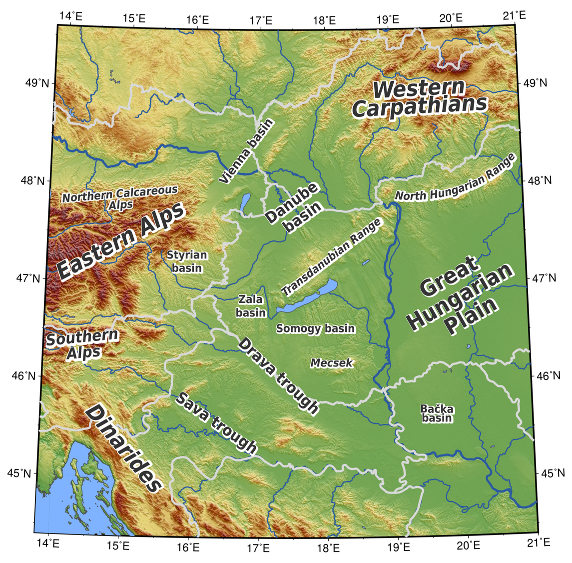
Study area

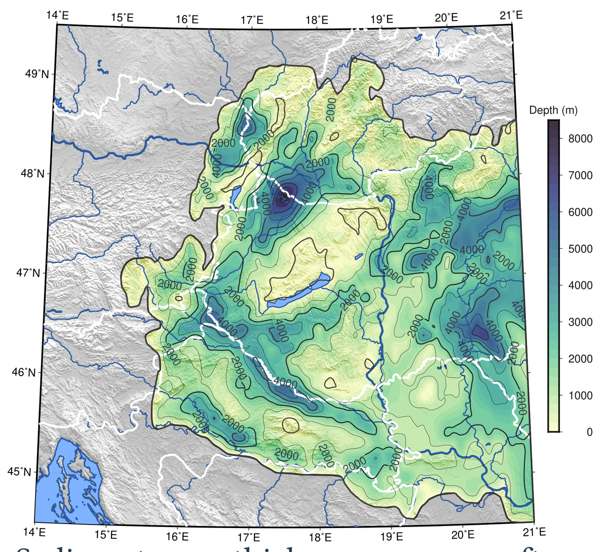


The Pannonian basin is an extensional back-arc basin in the convergence zone between Adria and the stable European Platform, surrounded by the Alps, the Carpathians and the Dinarides. The basin includes several smaller subbasins separated by elevated basement topography and filled with several kilometres thick young sediments. The pre-Tertiary basement consists of two main structural domains: 1) the ALCAPA micro-terrain in the northwest, 2) the Tisza-Dacia micro-terrain in the southeast separated by the Mid-Hungarian Zone.

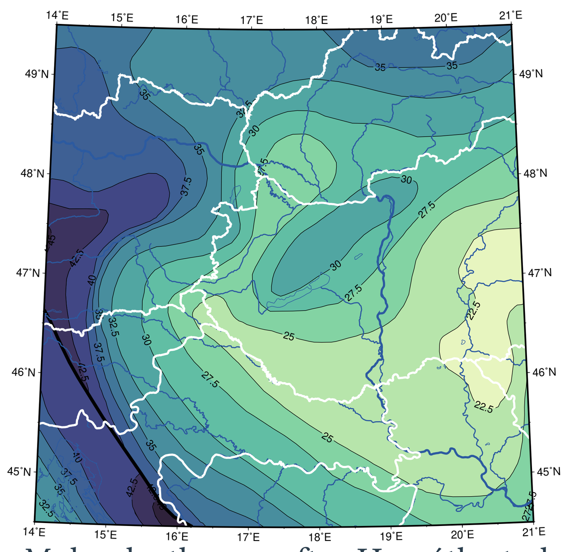


Topographic map of the study region with the names of the geographical units.

1) outcrops of the ALCAPA unit; 2) Southern Alpine, Dinaric, Adriatic unit; 3) Alpine-Carpathian foredeep; 4) Mélange and ophiolites; 5) Main faults exposed/subcrop; 6) Middle-Miocene–subrecent magmatic rocks exposed/subcrop



Sedimentary thickness map after Kilényi and Šefara (1989).

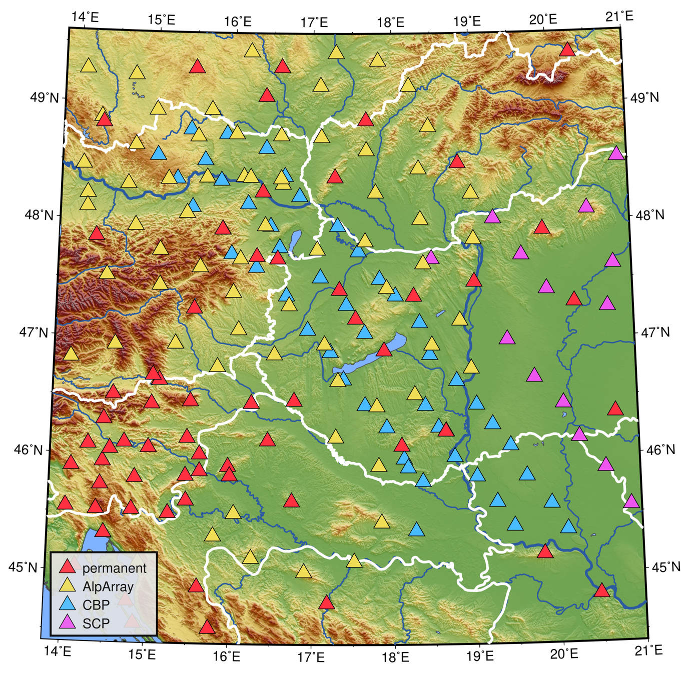


Moho depth map after Horváth et al. (2015).

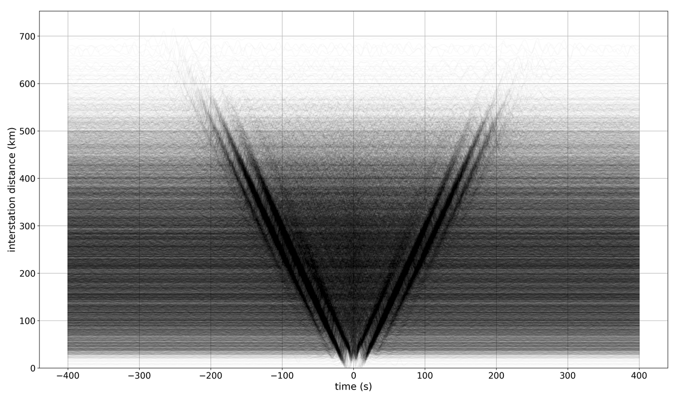
Objectives

We aim at outlining the large scale sedimentary and tectonic features of the crust by using ambient noise tomography and a direct inversion method of dispersion curves.

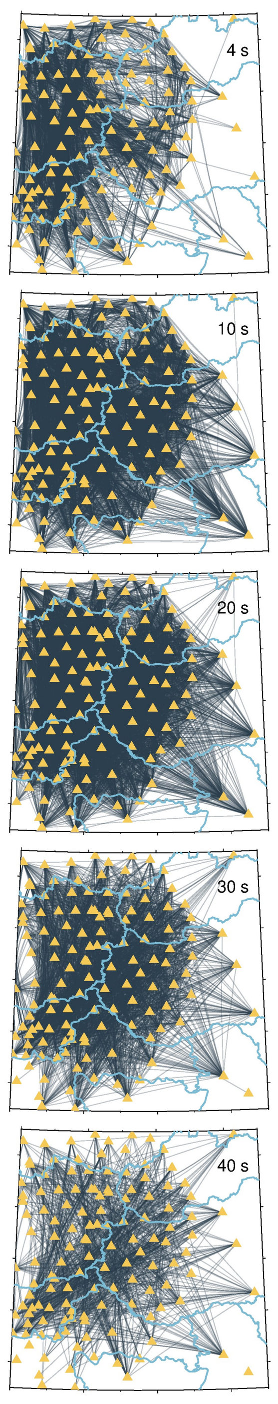
Data & Method



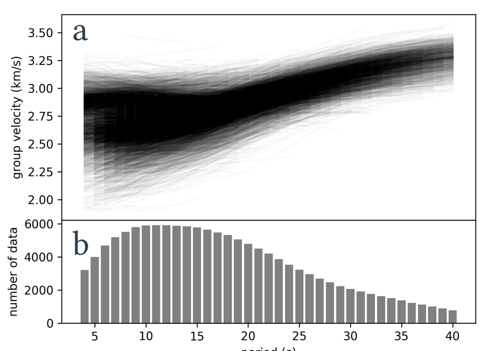
Stations used for cross-correlation function calculations. CBP: Carpathian Basin Project (2005-2007); SCP: South Carpathian Project (2009-2011).



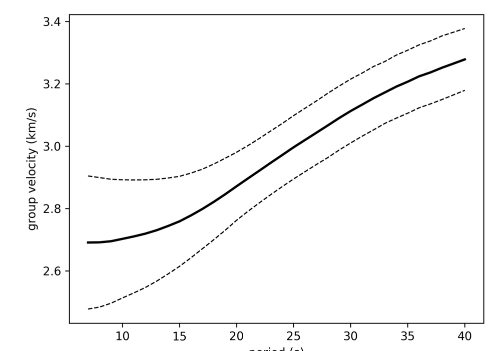
Cross-correlation functions (CCFs) have been calculated following the method described by Goutorbe et al., (2015). Rayleigh wave group velocity dispersion curves were measured by automatic frequency-time analysis of CCFs.



Path coverage at different periods.

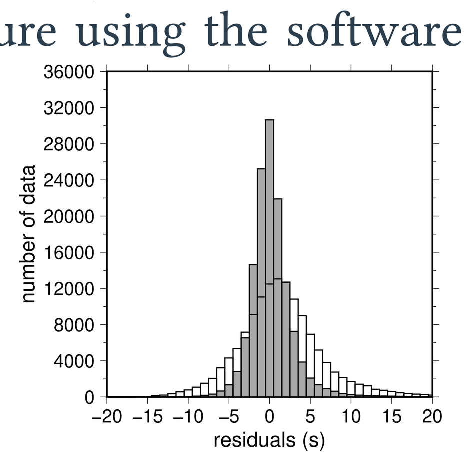


a) Selected dispersion curves.
b) The number of group velocity values at each period.



Average group velocity curve, which was inverted in order to get an initial 1D velocity profile for 3D inversion. The dashed lines indicate standard deviations.

Dispersion curves were directly inverted for 3D shear wave velocity structure using the software DSurfTomo, that realizes a wavelet-based sparsity-constrained tomography method described in Fang et al. (2015). Its ray tracing method also accounts for curved ray paths.



Traveltime residuals before (white) and after (gray) inversion.

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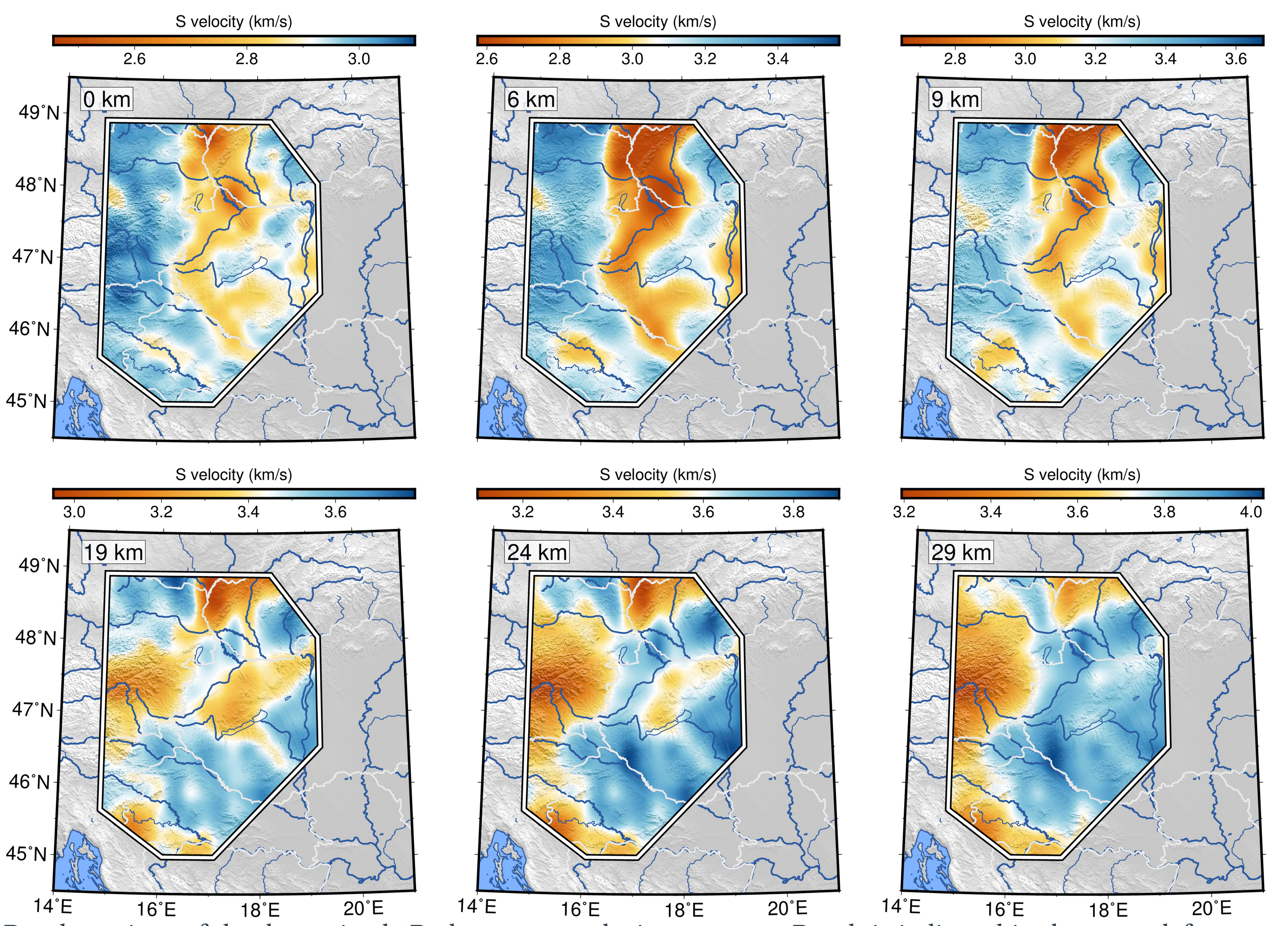
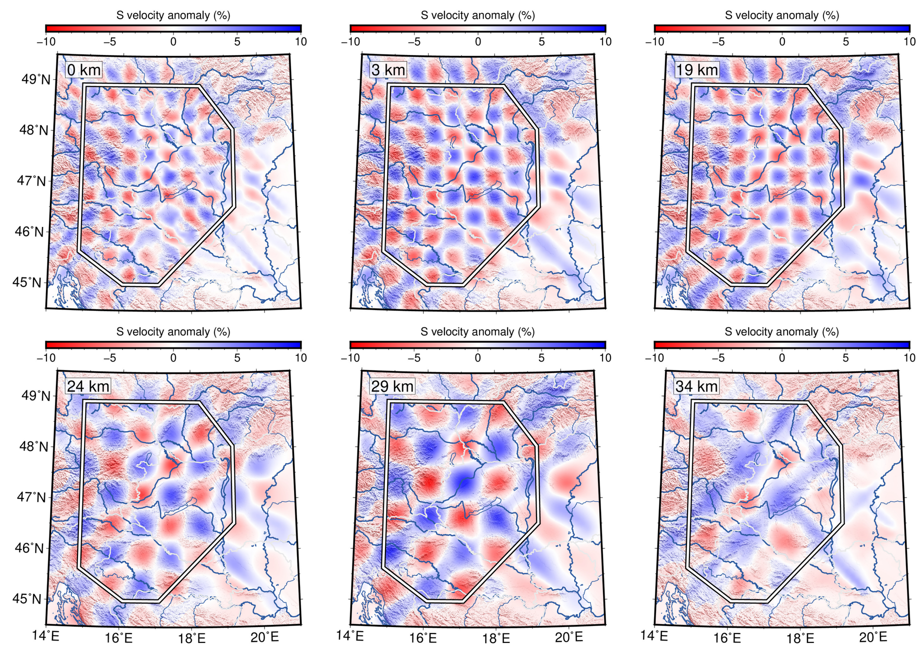
Results

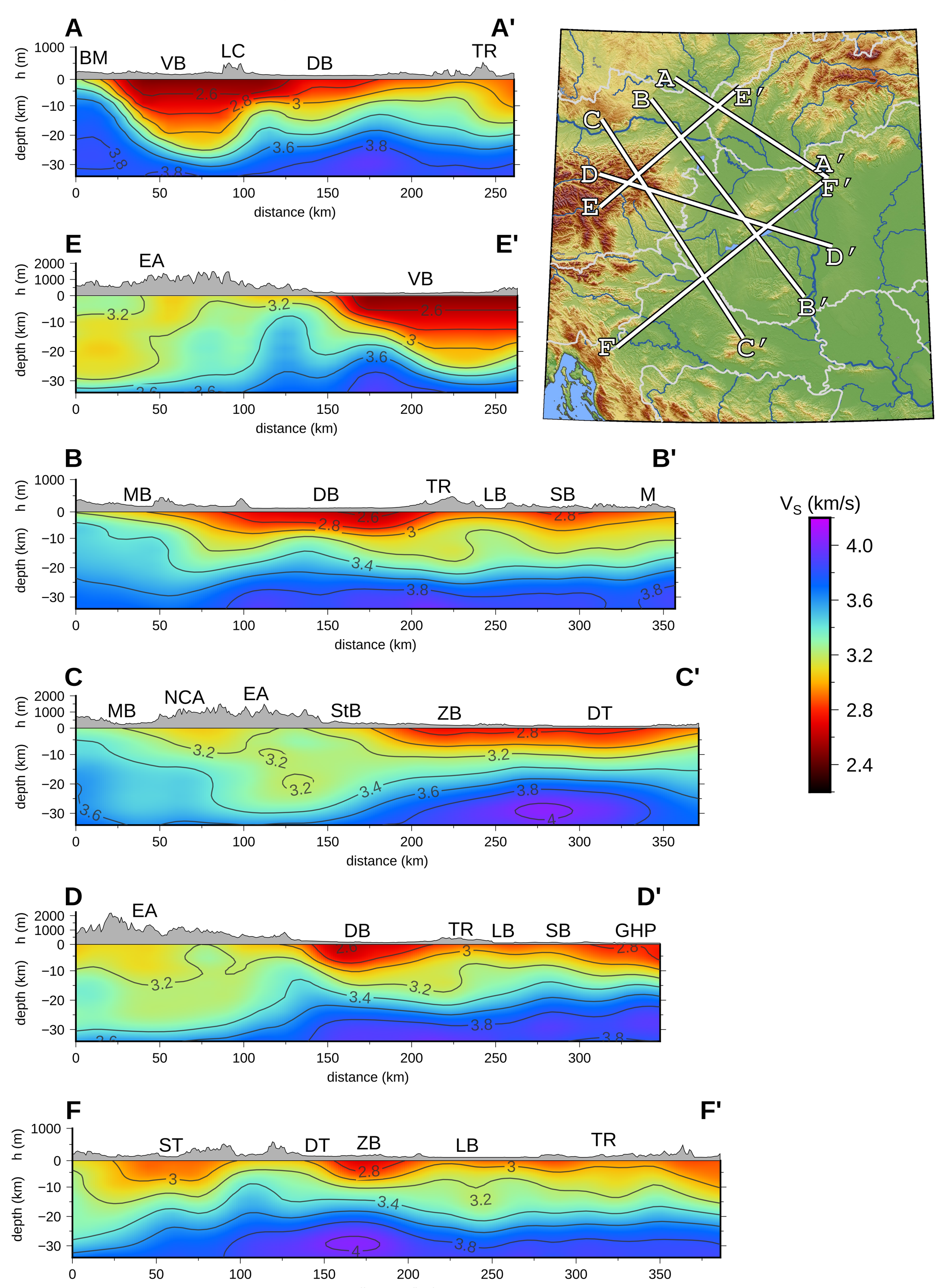


Depth sections of the determined 3D shear wave velocity structure. Depth is indicated in the upper left corner. Note the different velocity scale for each figure. White color always shows the mean shear velocity of the depth section. Results are only shown for the areas with good resolution.



To estimate the spatial resolution of the inverted shear wave velocity model, we conducted checkerboard tests with increasing anomaly sizes from 20 km to 80 km in 10 km steps. Anomalies larger than 20 km can be mapped with our dataset in the upper and middle crust, however the amplitude of the velocity anomaly is often slightly underestimated. In the lower crust, anomalies of 30-40 km in diameter can be well resolved, while below 30 km, an anomaly of 50 km size can be recovered.

The figure shows the recovered checkerboard patterns at different depths. The well recovered area is marked by white line.



Cross-sections of the S wave velocity structure along selected profiles. BM – Bohemian Massif, DB – Danube basin, DT – Drava trough, EA – Eastern Alps, GHP – Great Hungarian Plain, LB – Lake Balaton, LC – Little Carpathians, M – Mecsek, MB – Molasse basin, NCA – Northern Calcareous Alps, SB – Somogy basin, ST – Sava trough, StB – Styrian basin, TR – Transdanubian Range, VB – Vienna basin, ZB – Zala basin

Discussion

The computed velocity distribution at shallow depths is consistent with upper crustal geological features; low shear velocities can be observed in the local sedimentary basins and higher velocities characterize the hills and mountain ranges due to the general slower propagation of shear waves in unconsolidated sediments than in crystalline rocks. At greater depths, the highest observable velocities correspond mainly to the sedimentary basin areas, which may be associated with the presence of a shallow Moho. In contrary, low velocities can be observed beneath the Eastern Alps and the Transdanubian Range, indicating the crustal root of the mountains.

It should be noted, that the Bohemian Massif presents itself with high shear velocities in the entire crust.

A peculiar feature of the depth sections is a strong negative velocity anomaly at the junction of the Austrian, Slovak and Czech border, that extends from the surface down to approx. 24 km but still visible at 29 km. This anomaly is also associated with negative Bouguer anomaly (Schippkus et al., 2018), higher electric conductivity, positive magnetic anomaly (Behm et al., 2016; Hrubcová and Środa, 2015), lower surface heat flow (Lenkey et al., 2002) and high gradient in the integrated lithospheric strength (Bada et al., 2007). We raise the possibility here, that in this region the rocks are strongly tectonised and fractured in the entire crust which may account for all the above-mentioned anomalies. The heavily tectonised nature of this part of the crust may be explained by the fact that this is the focus of deformation where the Bohemian Massif collides with the Outer Carpathian units, and also this area is close to the rotation pole of the ALCAPA unit (Csontos and Nagymarosy, 1998) where significant stress could have been accumulated.

Acknowledgement

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