Seismic anisotropy beneath western Hungary

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Introduction

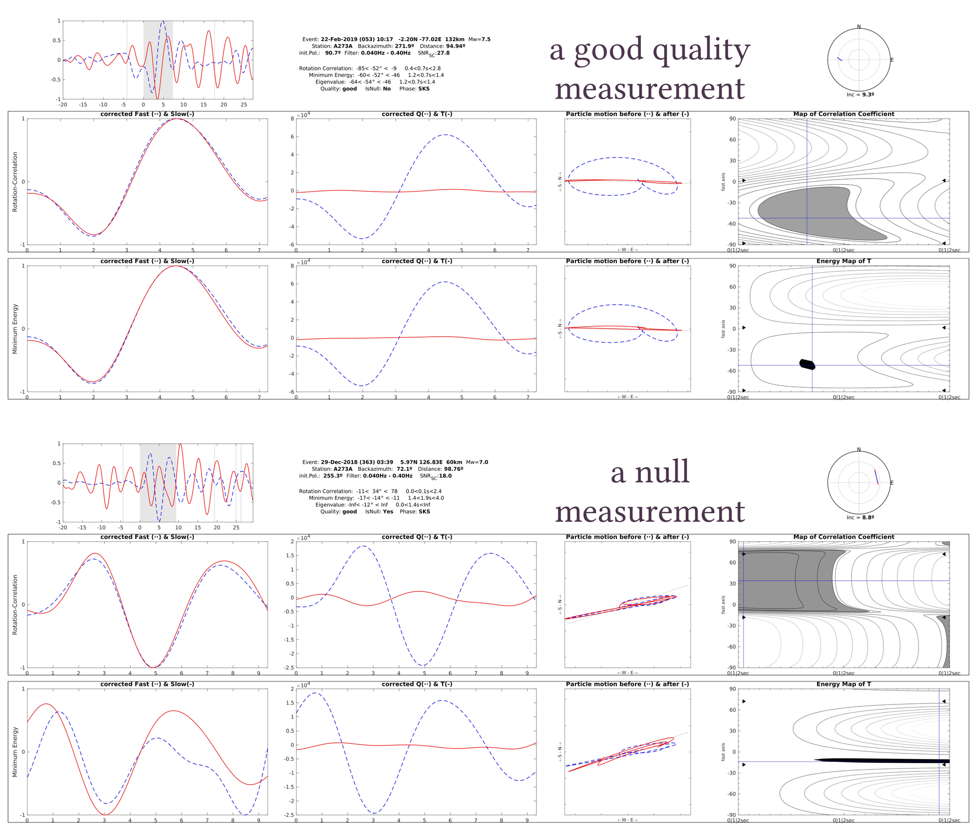
Shear waves passing through an anisotropic medium experience splitting into two orthogonally polarized waves. Examining the waves converted P-to-S at the core-mantle boundary allows studying upper mantle anisotropy. The delay time between the split phases and the direction of fast wave polarization are important proxies to describe the stress and strain regime of the upper mantle.

Shear wave splitting analysis has been carried out previously by Qorbani et al. (2016) for western Hungary publishing the results of 84 splitting measurements.

The aim of this study is to increase the number of available splitting data and to describe the anisotropy beneath the transition zone between the Eastern Alps and the Pannonian basin in more detail.

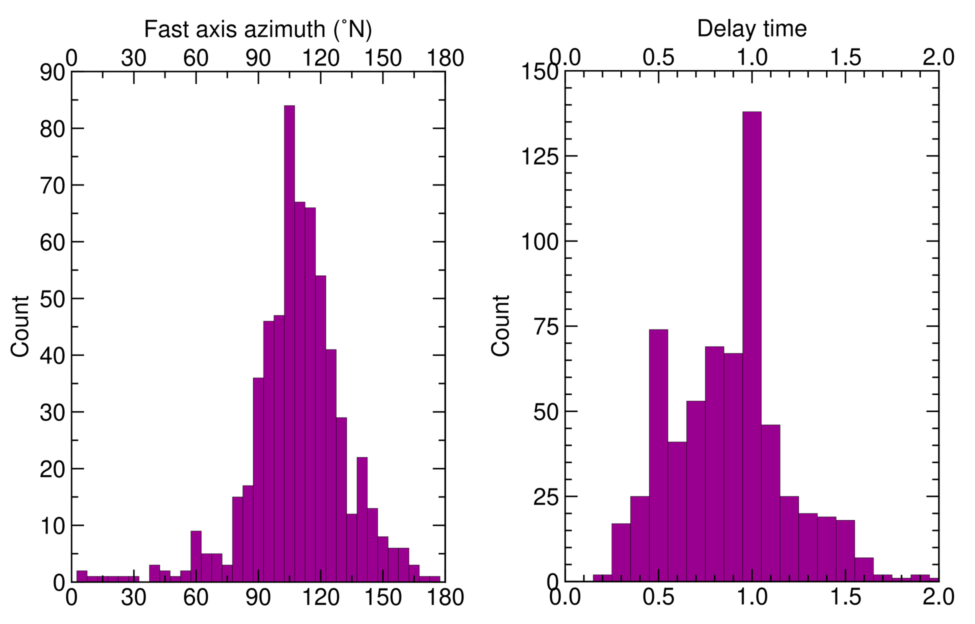
Method

The method and software of Wüstefeld el al. (2008) was used for the XKS measurements. Optimal splitting parameters were calculated by minimizing the XKS energy on the corrected transverse component.



Quality control was based on the following criteria:

- XKS arrival clearly visible on the original radial and transverse component
- almost perfect energy removal on the corrected T component
- similarity of the corrected fast and slow waves
- the original particle motion is elliptical and the corrected one is linear
- well defined minimum on the contour map
- stability of the measurement
- similarity between splitting parameters defined by transverse minimization and rotation correlation method

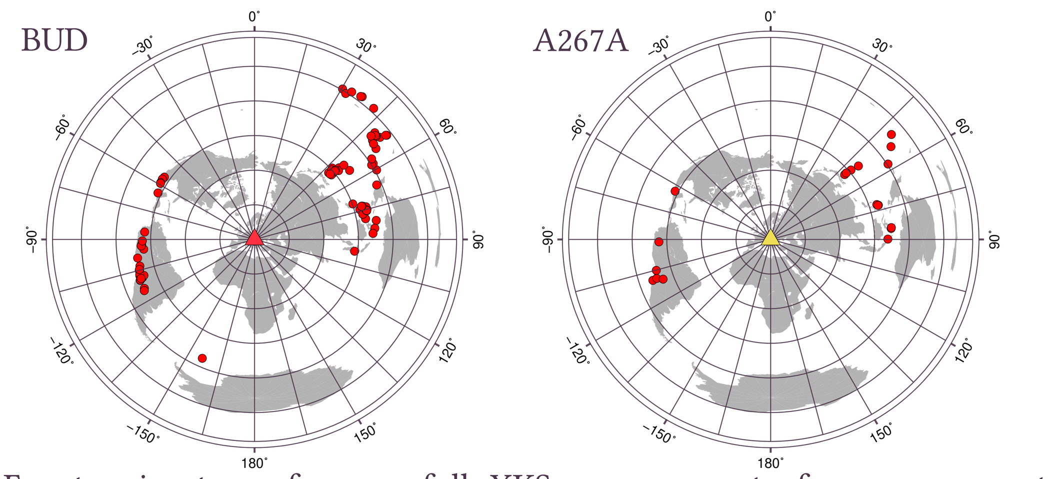


Histograms of the observed fast directions and delay times. Fast axis directions cluster around 105°. Delay times show two most common values: 0.5 s and 1.0 s.

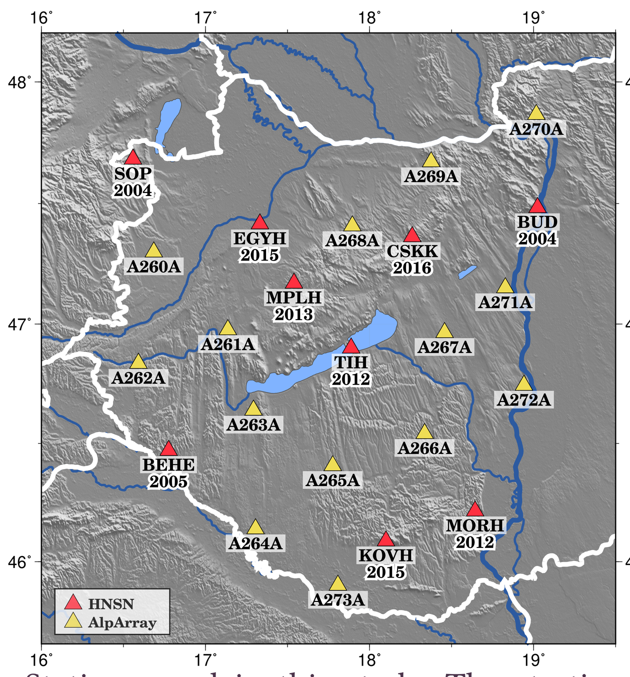
Data

In the presented study, we analysed PKS, SKS, SKKS and even a few SKiKS wave phases (which will be collectively called XKS) recorded by the currently operating permanent and temporary broadband stations in western Hungary.

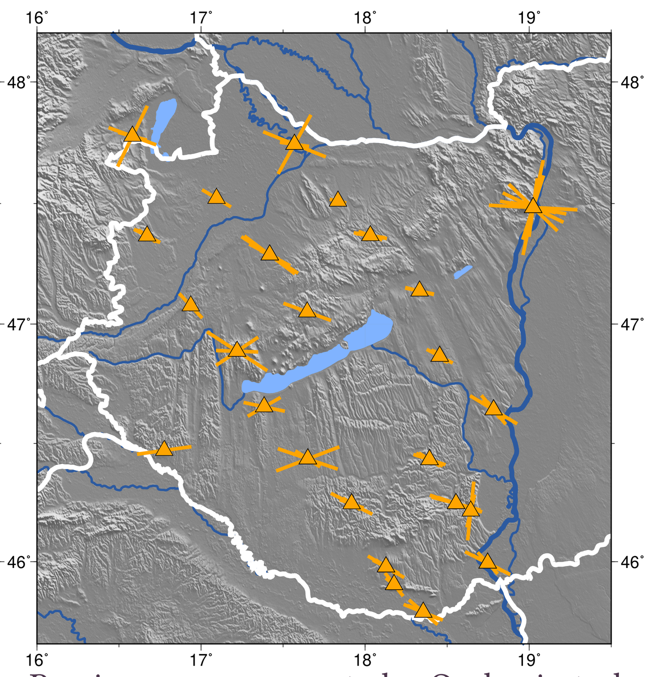
The Hungarian seismological stations have been deployed using a magnetic compass until 2019. In 2018, we had the opportunity to use a gyrocompass in order to measure orientation for existing stations all over the country. Their misorientation varied between -14.6° and 18.9°.



Event epicentres of successful XKS measurements for a permanent station operating since 2004 and an AlpArray station. We inspected all earthquakes of M>5.7 in a distance window between 85° and 180°.



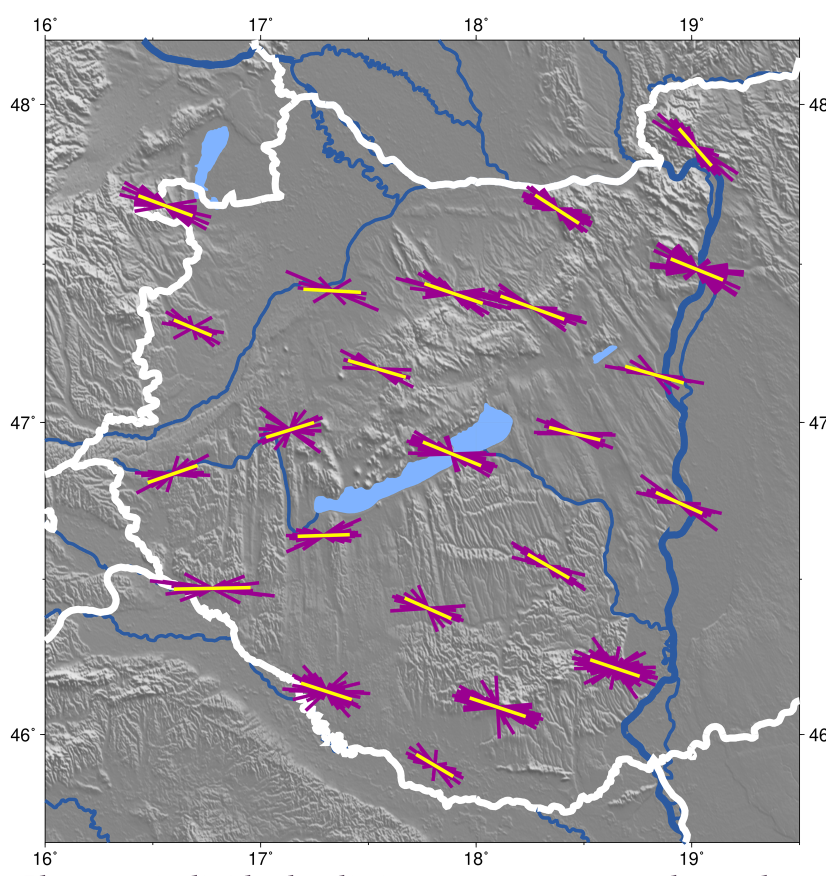
Stations used in this study. The starting year of the operation is indicated for the permanent stations.



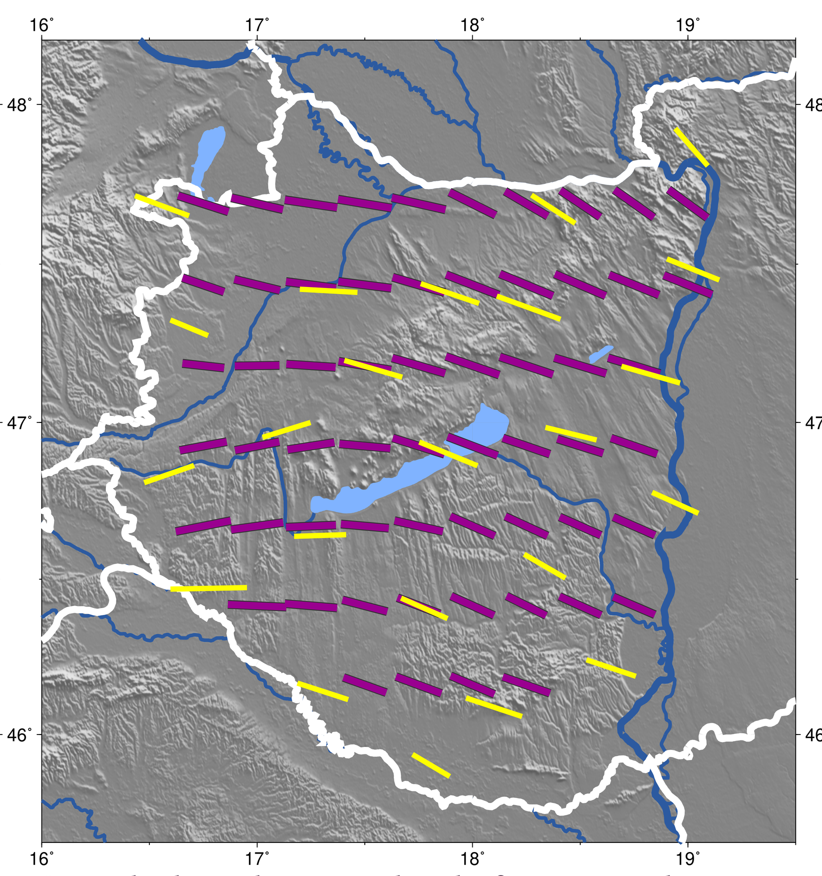
Previous measurements by Qorbani et al. (2016) for the stations of the Carpathian Basin Project (2006-2007) and co-existing permanent stations.

The Hungarian National Seismological Network (HNSN) is constantly expanding, several temporary and permanent stations have been deployed in the past years, which gave us the opportunity to significantly increase the number of splitting measurements, while the orientation data allowed us to refine the fast axis of anisotropy.

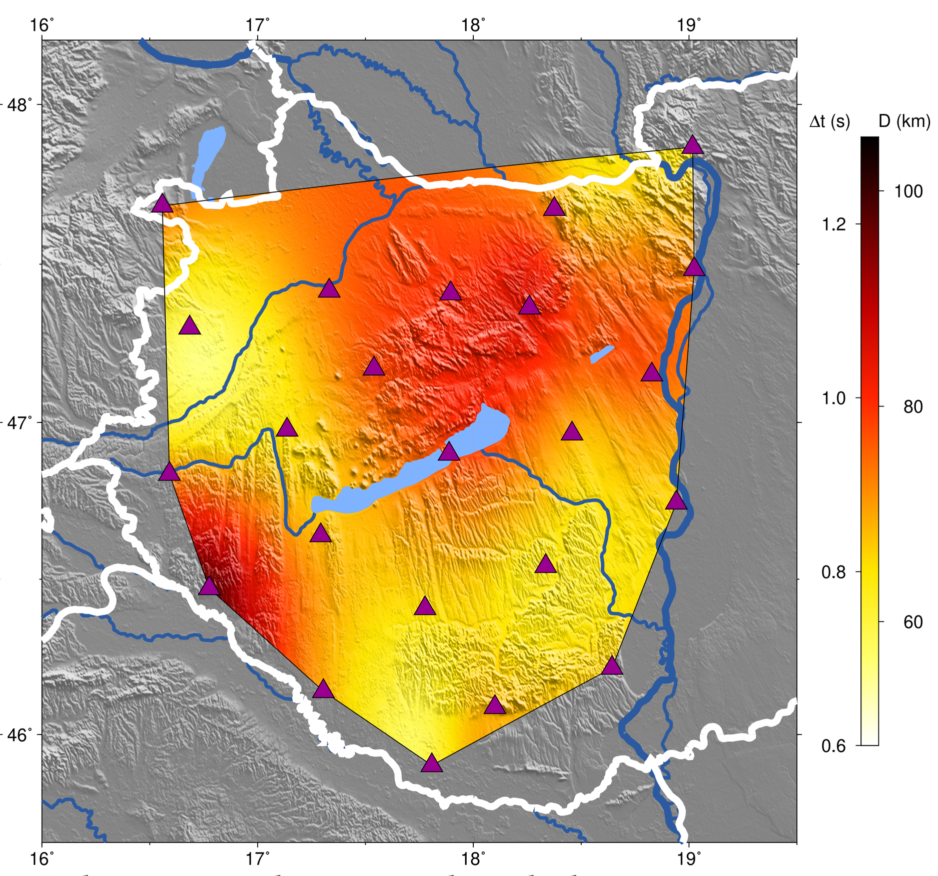
Results



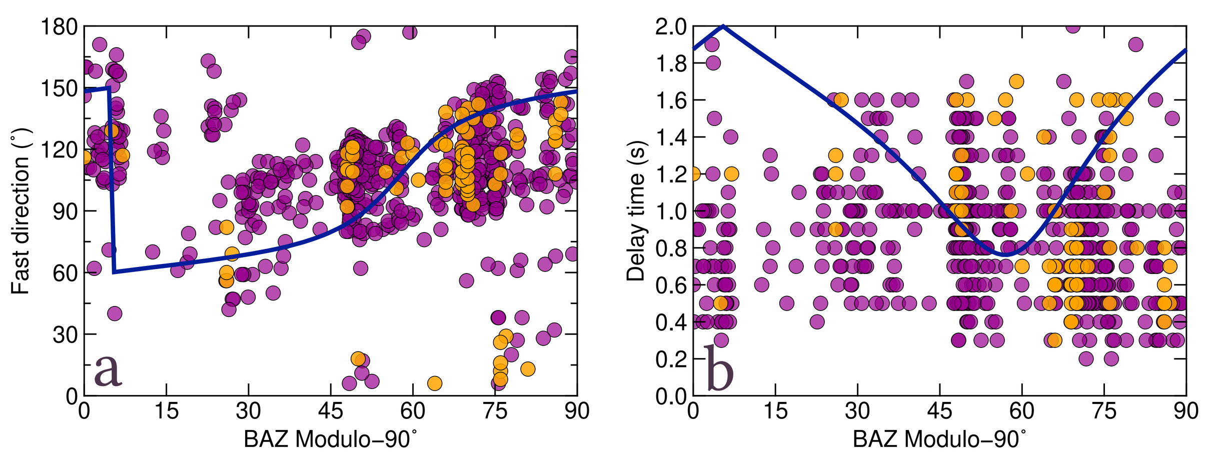
The new individual splitting parameters are shown by purple lines, their circular means are plotted with yellow bars.



Smoothed and interpolated fast axis directions (purple) plotted with the circular mean at each station (yellow).



Delay times and corresponding thickness assuming a single, horizontal anisotropic layer, 6% anisotropy and 4.85 km/s average S velocity.



We have plotted the fast directions (a) and delay times (b) as a function of backazimuth. Purple circles represent the 627 new measurements and orange circles show the 84 splitting parameters published in Qorbani et al. (2016). The two datasets are in good agreement.

The observed delay times (b) show a great variation, mean values for each station vary between 0.65 and 1.2 s, suggesting significant lateral thickness variation of the anisotropic layer.

Fast axis directions (a) exhibit a strong backazimuth dependence, indicating the occurence of complex anisotropy beneath western Hungary. A tentative estimate assuming a two layered model, results in a lower layer of 165° fast axis and 1.2 s delay time, while the upper layer has 140° fast axis and 1.4 s delay time. Blue lines indicate theoretical apparent fast axis directions and delay times for the above described two-layer model.

Conclusions

In general, the fast polarization directions beneath western Hungary are roughly ENE–WSW and E–W trending. The delay times vary greatly, between 0.65 and 1.2 s. These observations match very well, in general, the results of Qorbani et al. (2016), nevertheless, provide a better areal coverage and more splitting determinations. These results could be interpreted by vertical foliation and horizontal lineation in the upper mantle parallel to the fast polarization direction assuming a single layer model (Kovács et al., 2012; Qorbani et al., 2016). The variation of the fast direction with backazimuth, however, refers to a complex anisotropy pattern involving multiple layers. One possible interpretation is that two layers with similar degree of anisotropy can explain the observed anisotropy: a deeper with 165° and a shallower one with 140° fast direction. Further work is warranted, however, in this regard as upper mantle xenoliths from the area show weaker anisotropy for the shallower and stronger for the lower layer. The most plausible explanation for the origin of the fast direction is the roughly ENE-WSW compression between the Adriatic indenter and the stable European platform (Bada et al., 2007; Qorbani et al., 2016). This compression creates perpendicular foliation and lineation in the upper mantle, most prominently in the less viscous asthenosphere.

References

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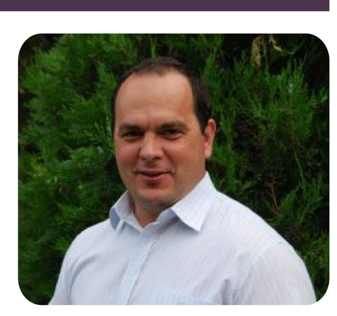

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