Layered anisotropy and mantle flow beneath AlpArray from shear-wave splitting

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DOI: http://dx.doi.org/10.17169/refubium-41079

Seismic anisotropy provides a unique link between directly observable surface structures and the more elusive dynamic processes in the mantle below. The ability to infer the vertically- and laterally-varying anisotropic structures is of great significance for the geodynamic interpretation of surface-recorded waveform effects. In the first part of this presentation, we assess the capabilities of different observables for the inversion of XKS phases to uniquely resolve the anisotropic structure of the upper mantle (Rümpker et al., 2023). For this purpose, we perform full-waveform calculations for relatively simple models of upper-mantle anisotropy. In addition to waveforms, we consider the effects on apparent splitting parameters and splitting intensity. The results show that it is not generally possible to fully constrain the anisotropic parameters of a given model, even if complete waveforms are considered. However, inversions of both waveforms and apparent splitting parameters lead to similar models that exhibit systematic variations of anisotropic parameters. These characteristics may be exploited to better constrain the inversions. The results also show that splitting intensity has some significant drawbacks: First, even from measurements over a wide range of back-azimuth, there is no characteristic signature that would indicate depth variations of anisotropy. Secondly, identical azimuthal variations of splitting intensity for different anisotropic structures do not imply that the corresponding split waveforms are also similar. Thus, fitting of observed and calculated splitting intensities could lead to anisotropic models that are incompatible with the observed waveforms. In the second half, we present the first comprehensive analysis of layered anisotropy for the complete Alpine range based on apparent splitting parameters determined at 591 seismic stations of the AlpArray experiment (Link & Rümpker, 2023). Our findings suggest a combination of asthenospheric and distinct lithospheric contributions to the splitting observations, which can be seen as a refinement of previously reported models of single-layer anisotropy. The enhanced vertical resolution exposes the impact of successive Mediterranean tectonic episodes, such as the opening of the Provencal-Ligurian and Tyrrhenian Basins alongside the Adriatic slab retreat, as well as the Pannonian Basin opening and the Aegean slab retreat, resulting in deformation of the lithosphere and flow in the asthenospheric mantle. The dominant role of the larger scale Mediterranean subduction systems on mantle dynamics becomes evident. The observations provide supporting evidence that the European slab has broken off at its boundaries and that the resulting gaps channel flow from the mantle beneath the Eurasian plate to the Adriatic and Aegean subduction systems. The results provide important constraints on geodynamic processes involved in forming the European Alps, as previous and ongoing tectonic episodes can be inferred from the anisotropic fabric of the lithosphere-asthenosphere system.

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