Simultaneous Inversion for 3D Crustal and Lithospheric Structure and Regional Hypocenters beneath Germany in the Presence of an Anisotropic Upper Mantle

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Starting with the pioneering refraction seismic studies of Bamford [1973] and Fuchs [1977] on 1D Pn-velocity anisotropy underneath southern Germany, numerous subsequent investigations have provided further ample evidence that large sections of the upper mantle underneath Europe and Germany, in particular, are anisotropic. In fact, using regional earthquake travel times, Schlittenhardt [1999] showed that the corresponding Pn-residuals display an azimuthal pattern matching the anisotropy in the region. This phenomenon was further investigated by Song et al. [2001] and Song et al. [2004] by means of a 1D time-term analysis and a full 2D Pn anisotropic inversion, respectively. Whereas in the first of these studies the authors showed that an anisotropic velocity ellipse with the “fast” axis in the direction of ~N25°E and an anisotropy level of ~3.5% reduces significantly the data variance, the second study did indicate that geologically meaningful upper mantle Pn-velocity perturbations could only be obtained if the named anisotropy ellipse was included in the inversion process.

Employing a modified version of the method of simultaneous inversion for structure and hypocenters (SSH) of Koch [1993], including a priori known upper mantle anisotropy, the analyses of Song et al. [2001, 2004] are extended here to a full simultaneous inversion for 3D crustal and upper mantle structure and regional hypocenters underneath Germany. Regional travel times from local earthquakes occurring between 1975-2003 are included in the study. After application of several selection criteria ~1300 events with a total of ~30000 P- and S-phases were obtained for the SSH inversion procedure.

In spite of the huge number of events and phases, many of the recorded events appear to suffer from relatively poor hypocentral depth locations which makes a full SSH analysis an intricate undertaking. To alleviate the problem the SSH procedure is carried out in several incremental steps of increasing complexity. First of all improved vertically inhomogeneous velocity (1D) models are derived assuming an isotropic as well as an anisotropic upper mantle. In addition of a slightly better model fit for the anisotropic than for the isotropic model, the latter gives also a somewhat too low Pn-velocity of ~7.90 km/s, compared with ~8.0 km/s for the former. This indicates that inclusion of upper mantle anisotropy into the model is required to obtain physically reasonable Pn-velocities. The results for the P-velocity in the lower crustal layer of the model are less clear, as there appears to be some trade-off in the velocity of that layer and that of the upper mantle.

Significant improvements for both the isotropic and anisotropic upper mantle cases are obtained for full 3D SSH inversion models. Similar to the 1D Pn-velocity models there are remarkable differences in the lateral Pn-velocities, depending whether the lithosphere is corrected for anisotropy or not. Namely, for an anisotropic upper mantle the median ellipse velocities are generally higher, laterally smoother and behave also more stably throughout the
inversion than those obtained when the upper mantle is considered isotropic. Interesting enough, these differences in the Pn-velocity structure do not project into the inverted lateral P-wave velocity structure of the crust indicating that the regional travel time data provide for an independent resolution of the crust and upper mantle over most of the study region. Nevertheless, whereas the upper crust is rather well resolved, large sections of the lower crust show poor lateral resolution, due to a paucity of earthquakes and, consequently, seismic phases there.

Finally the manifold of structural seismological results obtained from the SSH-inversion for both crust and upper mantle will be interpreted in terms of the present-day knowledge on the geology and the tectonics of the central European Variscides.