The Deep Structure of the Upper Rhine Graben: Constraints from Teleseismic Measurements and Geodynamic Implications

J.R.R. Ritter, S. Kirschner, M. Wagner & B. Wawerzinek
Geophysical Institute, Universität Karlsruhe (TH), Germany
joachim.ritter@gpi.uni-karlsruhe.de

The Upper Rhine Graben (URG) is an intracontinental rift and branch of the European Cenozoic Rift System (ECRIS), located in Southwest Germany and bordering to France and Switzerland. The URG has a SSW-NNE strike, a length of about 320 km and an average width of about 40-50 km. Its estimated crustal extension is just 3-5 km which occurred mainly in the Eocene and Oligocene. The structure of the lithosphere-asthenosphere system below the URG is still poorly known. One seismic refraction study indicates that the crust is possibly thinned in the southern part. Three deep seismic reflection lines indicate an asymmetric detachment in the upper crust, but its continuation into the lower lithosphere is unknown. The results of a previous teleseismic experiment across the southern URG indicate that there is no hot upper mantle or anomalous asthenospheric cushion below the southern URG as proposed earlier (a model that is still sometimes used today …). However, compared to other rifts, there is relatively few data-based knowledge on the subcrustal structure of the URG.
During the TIMO project (TIefenstruktur des Mittleren Oberrheingrabens) the Geophysical Institute of the Universität Karlsruhe (TH) operated the KArlsruhe BroadBand Array (KABBA) with 32 mobile seismic broadband stations from December 2004 until May 2006. Global and local seismicity was recorded continuously, and we could also use recordings from 5 permanent broadband stations and several short-period stations. These waveforms are analysed to study the subcrustal structure as well as the local seismicity.
Using SKS splitting measurements at 64 stations (TIMO, Eifel Plume Project and permanent stations) in Southwest Germany and adjacent regions, it is possible to determine mantle anisotropy with high spatial resolution. The results provide the delay time *dt* between the fast and slow shear waves and the angle *phi* which points into the direction of fast wave propagation relative to north. The determined direction of *phi* in Southwest Germany indicates a smooth spatial variation mainly towards NE-SW. This smooth pattern prevails, although four different tectonic regimes are covered (Saxothuringian and Moldaunubian lithospheric terranes, the Neogene URG and the eastern range of the active Eifel plume). This smooth variation in *phi* is interpreted to result from recent orientation of minerals in the asthenosphere due to flow-induced shearing. Fossil mineral alignment in the lithospheric mantle may be also present, but it seems to be of lower importance in our SKS splitting observations. Especially there is no distinct anomaly related to the URG, and thus we cannot find hints for significant deformation of the mantle lithosphere.
The arrival times of teleseismic P-waves were determined manually with high precision (~0.05 s) at 0.5-2.0 Hz from a wide range of backazimuths. To eliminate travel time perturbations due to the crustal structure, especially the rift sediments, crustal seismic velocity models were determined for each station site using all available information from geology and geophysics. Furthermore the slowness and backazimuth of the P-wavefronts were determined using array techniques to search for anomalies. As result we find no measurable seismic P-wave velocity anomaly related to the upper mantle underneath the URG.
The SKS-splitting, traveltime and array analyses with the TIMO dataset indicate that there is no anomaly in the upper mantle that is related to the URG. Our current conclusion is that the rifting processes left no measurable signature at subcrustal level. Thus the rupture of the lithosphere did not penetratively alter the lithospheric structure. The P-wave data show no indication for lithospheric thinning. However, this needs to be confirmed by S-wave receiver function analysis which is more sensitive to the lithosphere-asthenosphere boundary.