Reflection of mantle flow in the tectonics of Europe: stress, strain, and induced seismic anisotropy.

Alexey Petrunin[1]

1. Deutsches GeoForschungsZentrum GFZ, Potsdam, Germany

DOI: http://dx.doi.org/10.17169/refubium-41071

Mantle flow is one of the key factors influencing the lithosphere's loading, including both normal and tensile basal tractions. This flow dominantly controls the dynamics of the lithosphere and the distribution of stress within continental plates. To account for both far-field stresses, e.g. caused by ocean spreading, and the influence of plumes, the computation of regional patterns of mantle flow requires the development of a global convection model that is consistent with GPS measurements and local stress field data. To achieve this goal, we first developed a refined density-temperature model for the lithosphere. This model is based on the latest findings from tomographic, gravity, and crustal structure data, which have been used for the joint density inversion. This approach allows us to significantly reduce uncertainties due to the influence of the crust and to refine the primary tomographic inversion results for the density structure of the upper mantle and lithosphere.

As a result, we have derived a density distribution map beneath the Alpine region and its surroundings for the lithosphere and upper mantle. Figure 1(left) demonstrates the refined density anomaly map for the depth of 100 km.

Using our spectral code ProSpher 3D (Petrunin et al., 2013) and the results of the density model, we computed mantle flow patterns, stresses, and estimates of seismic anisotropy at 1x1 degree resolution. The most revealing result, demonstrating the reliability of our model, is the map of calculated maximum principal stress directions, Figure 1 (right). It shows good agreement with observations of SKS splitting (red dashes). We also calculate the tectonic regimes of the lithosphere (compression-tension) for the study area.

One of the causes of seismic velocity anisotropy is the finite strain accumulated in the lithosphere and/or upper mantle. This parameter is not calculated in our snapshot model. However, since the direction of the main forces in the lithosphere has not changed significantly since at least 10-15 Ma, we assumed that the directions of the principal axes of the finite strain tensor should correlate with those of the stress tensor.

In order to identify the main factors controlling the mantle flow beneath the European lithosphere and induced by the flow stresses, we constructed a three-dimensional model of the flow lines in the mantle. According to this model, we can assume that the main factors are the Island, Canary Islands, and Azores plumes and they interplay with the subduction of the African plate under Europe. Thus, our model provides a 3D map of density, viscosity, stress, and seismic anisotropy distribution for the European lithosphere and upper mantle down to depths of 400 km, taking into account both local body forces and traction forces as well as far-field stresses.

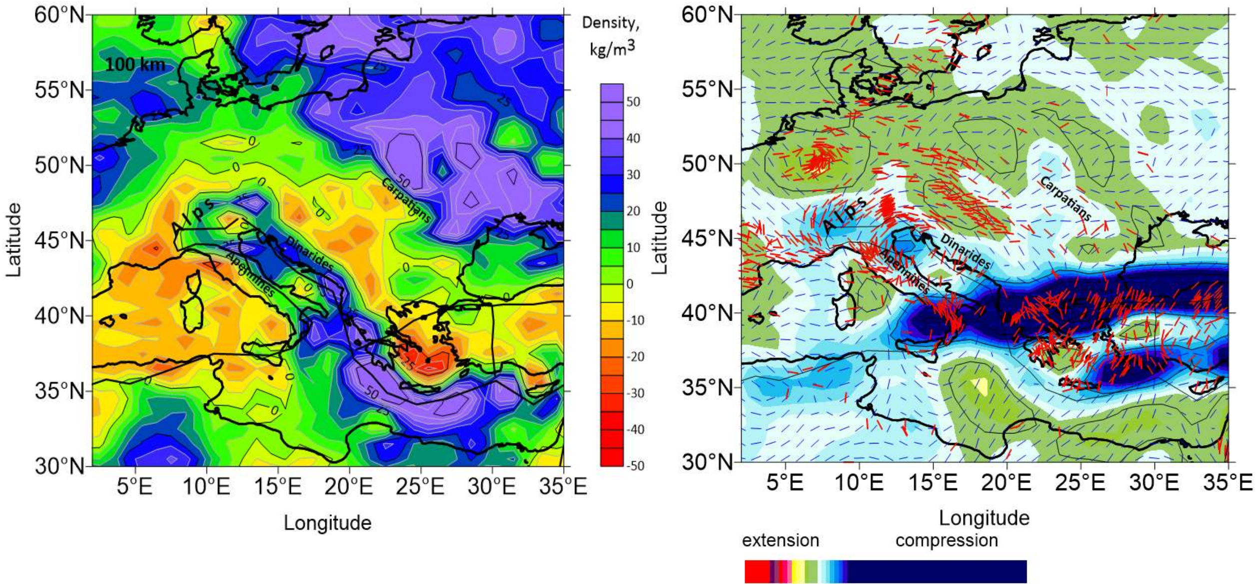

Figure 1: The new map of density anomaly (left) and maximum principal stress directions for the depth of 100-150 km (blue dashes). The red dashes indicate the SKS splitting observations and show the fast seismic velocity azimuth averaged by co-located stations (Wüstefeld et al., 2009, Becker et al., 2012). Colors denote tectonic settings from the modeling.

Becker, T.W., Lebedev, S. and Long, M.D., 2012. On the relationship between azimuthal anisotropy from shear wave splitting and surface wave tomography. Journal of Geophysical Research: Solid Earth, 117(B1).

Petrunin, A.G., Kaban, M.K., Rogozhina, I. and Trubitsyn, V., 2013. Revising the spectral method as applied to modeling mantle dynamics. Geochemistry, Geophysics, Geosystems, 14(9), pp.3691-3702.

Wüstefeld, A., Bokelmann, G., Barruol, G., & Montagner, J.P., 2009. Identifying global seismic anisotropy patterns by correlating shear-wave splitting and surface-wave data. Physics of the Earth and Planetary Interiors, 176(3-4), 198-212.