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Isostatic adjustment of the continental lithosphere at long timescales: constraints from 3-D gravity modelling

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In geodynamic studies it is important to have knowledge about distribution of density and mechanical properties of the continental lithosphere. On local and regional scales (up to hundreds of kilometres), gravity anomalies over continents are caused by variations in surface elevation and density distribution in the lithosphere; that is why the latter can be obtained using modeling and inversion of gravity data. The density distribution, in turn, can be used to estimate at what depth isostatic compensation of different lithospheric loads occurs and to make conclusion about distribution of mechanically weak and strong layers in the lithosphere. In our study we use this approach to evaluate density and rheological structure of the lithosphere of selected regions within the young Phanerozoic and old Precambrian lithosphere of Europe. For this we utilized 3-D velocity models compiled from high-resolution seismic models of the crust and upper mantle from recent controlled-source seismic experiments in the area adjoining the Trans European Suture Zone in Poland and in the area of Palaeoproterozoic Lapland-Kola Orogen in Fennoscandia. The velocity models were transformed into the 3-D density models of the lithosphere using both forward modeling and inversion of gravity data. The density models were used to estimate depth of compensation of various lithospheric loads (namely, elevation, sediments and density heterogeneities in the crust and lithospheric mantle). Our study revealed significant diversity in the depth of compensation of these loads in tectonic units of different tectonothermal age and showed that different loads and mass deficiencies are compensated at different levels of the lithosphere. In particular, isostatic compensation of shallow loads (topography, sediments) occurs in the shallowest mechanically weak layer, while compensation of large-scale differences in crustal thickness and lateral mantle density heterogeneities is achieved in the mantle. This implies that mechanically weak (low viscosity) layers are present (or were present at the stage of the lithosphere stabilization) both in the crust and in the lithospheric mantle. The diversity in the depth of compensation of various loads in tectonic units of different age indicates also diversity in rheological structure of the lithosphere.