THE DENSITY STRUCTURE AND ISOSTATIC STATE OF THE EASTERN ALPS

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Abstract: The results of 3D density modelling of the Eastern Alpine lithosphere show the strong influence of near surface structures in addition to the crustal root in the related gravity fields. This coincides with the results of Airy isostatic investigations. Investigations of flexural models, which include surface and subsurface loading taken from the density model, point to a, in general, low flexural rigidity of the alpine lithosphere.

Key words: Gravity, isostasy, flexural rigidity, Eastern Alps

Recent results of the seismic profile TRANSALP (TRANSALP Working Group, 2001) initiated new investigations of the lithospheric density structure in the Eastern Alpine area. By combining seismic results with geological models, tomographic studies and other available information the 3D density structure were modeled according to the Bouguer anomaly field and geoidal undulations. Especially the upper crustal structures (< 10 km depth), which can easily connected to surface tectonics, are extremely well constrained. These structures give an amount of up to 30 % of the connected Bouguer anomaly (Ebbing et al., 2001).
Major problems in the modeling process concerned the question of defining a common crust-mantle boundary in gravity and seismic/tomographic studies. The seismic crust-mantle interface shows a depth of some 40 km in the Adriatic area, leading to a lower crustal thickness of around 10 km, while the “gravity Moho” points to a depth of around 30 km. A 40 km thick crust would require high densities in the Adriatic crust (3100 kg/m^3 for the lowest structures) to fit the model to the observed gravity fields. These values are unusual for crustal domains. A probable answer to this problem is crustal underplating/doubling or a detached Moho interface. In the northern European foreland both models show a crustal thickness of around 30 km.

This density structure modeling provides information of the isostatic behavior of the Eastern Alps, which are probably not in isostatic equilibrium and show great isostatic anomalies in the sense of Airy isostasy (Götze et al., 1991, Lillie et al., 1994). The shape of the isostatic residual and the good correlation between the first and the surface tectonics, points to the upper crustal structures as a reason of the not balanced isostatic state. This buried masses affect the isostatic state and have to be considered in further analysis like regional isostatic models (Vening-Meinesz isostasy).

The model of a flexed “thin elastic plate” (e.g. Banks et al., 1977) is such a regional model, for what the significance in mountainous areas was shown in numerous studies (e.g. Watts, 2001, p. 251).

This model considers the calculation of the flexural rigidity D or, equivalently, the effective elastic thickness Te. This D is connected to the topographic and crustal, internal loads and their distribution. The modeled density structures can now be used to derive this internal, subsurface loading, which is essential for a calculation of the flexural rigidity (Banks et al., 2001). The density model indicates that the subsurface loads of the Alpine crust are as important as the topographic loading.

The analysis of flexural rigidity was done by the convolution method, which is a new approach to calculate D and overcomes some analytical problems of previous used methods (Braitenberg et al., 2002). One of the major advantages of this method is that the flexural rigidity can be calculated with a spatial resolution of around 100 km. Therefore different regions of D can be distinguished.

The T_e values are generally low within the study area. Highest values are found in the NE , while the main body of the Alpine range has values around 1-3 km. The residuals between the Moho by the 3D density model and the Moho by flexure analysis are altogether low, in the order of 2-3 km, except in the southern part, in correspondence of the Vicenza gravity high and in the area where the Moho interface reaches its deepest values (area East and Northwest of the town of Bolzano).

The low value of Te in the central part of the alpine range shows that here the crustal thickening conforms to that of a thin plate with low rigidity, near to an Airy-type local isostatic compensation. This could be also an indication of the presence of a plate brake, that can be approximated as a continuous plate with a zone of low Te-values (Watts, 2001).

The high values of curvature of the Moho surface to the south of the alpine crust below the Periadriatic lineament cannot be modeled by the simple flexure model, and require a more sophisticated 3D mechanical model. In this area the differences between the Moho undulations according to the flexure model and to those according to the model based on the deep seismic results (forward gravity model) are quite high, and locally reach 10 km.

Another reason for the disagreement could be that horizontal and vertical tectonic forces linked to the collision process of the European and Adriatic plate, which must be taken into account,: a task that can be only fulfilled in a complete 3D mechanical model.

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