MULTIDISCIPLINARY GEOPHYSICAL AND GEOLOGICAL STUDY OF THE STRUCTURE AND DYNAMICS OF THE LITHOSPHERE IN THE WESTERN CARPATHIANS AND THE BOHEMIAN MASSIF JUNCTION

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Abstract: This paper is about regional research of a deep geological structure and dynamics of the lithosphere of the contact zone of the Western Carpathians and the Bohemian Massif. The research is based on multidisciplinary geophysical and geological study. The complete interpretation of gravity, seismic, magnetic, magnetotelluric and heat flow data was made along two transects, 3T and 6HR. The deep structure of the contact zone is characterized by small 2-3 km deepening of the Moho discontinuity. The deep contact of both colliding plates is very steep, almost vertical. Because the border lithosphere-asthenosphere in the contact zone is evidently rising from the depth from 130 km to depth 70 km, we assume that the subducted lithospheric plate is detachment and submerged to deeper asthenosphere.

Key words: Moho, lithosphere, gravity modelling, reflection seismic transect, Western Carpathians,

Introduction

Lately there was published many works based on complex geological-geophysical study of geological structure and dynamics of the Western Carpathians (Bucha and Blížkovský 1994; Šefara et al. 1987; Bielik et al. 1998; Kováč 1999; Vozár and Šantavý 1999; Plašienka et al. 1997; Bezák et al. 1997; Kováč et al. 1997). The main goal of this work is regional research of the deep geological structure and dynamics of the lithosphere of the contact zone between the Western Carpathians and the Bohemian Massif with use of multidisciplinary geophysical and geological interpretation. The paper presents complex interpretation of the lithospheric structure and geodynamics along two transects 3T and 6HR. Its main effort is an integration of so fare existing geophysical and geological knowledge about lithosphere on the base of 2D density modelling based mainly on reflection seismic measurements.

The input geophysical and geological data

The presented geophysical-geological lithospheric models are based on synthesis of the results obtained mainly by deep refraction and reflection seismic profiling, seismology, gravimetry, magnetometry, magnetotellurics and geothermics.

The basic seismic data and knowledge were obtained from newly published work "Atlas of the deep reflection seismic profiles of the Western Carpathians and their interpretation" (Vozár and Šantavý, 1999). Primary knowledge about the density inhomogeneities were obtained on the base of works by Šefara et al. (1987); Bielik (1998); Vozár et al. (1998); Bezák et al. (1997). The seismological studies based on interpretation of seismic delay time (Babuška et al., 1987, 1988) and magnetoteluric measurements (Ádám et al., 1990; Červ et al., 1984) provided data about thickness of the lithosphere. Information about magnetic properties of the Western Carpathians rocks were obtained mainly from the map of magnetic anomalies of the local vector intensity of the geomagnetic field of Slovakia (Gnojek in Vozár and Šantavý, 1999; Filo and Kubeš, 1994). Also geothermal data and interpretations were used in the synthesis of the geophysical data. They were published, for example, in works by Čermák and Hurtig, 1979; Majcin, 1993; Zeyen and Bielik, 2000; Král, 1995).

Density lithospheric modeling

Comparison of the calculated isostatic lithospheric columns of the Pannonian basin region and the Eastern Alps region with typical continental lithosphere (characterized with mean values of topography, densities and thicknesses of sediments, crust and lower lithosphere) released that asthenosphere is characterized with density contrast +270 kgm^{-3} against the mean density of the lower crust, i.e. -30 kgm^{-3} against mean density of the lower lithosphere (Lillie et al. 1994). This density parameter was subsequently applied in calculations of the local isostatic models of the Pannonian basin as well as of the Eastern Alps. In the Pannonian basin it was proved, that the main compensation for the significant gravity effect of the shallow Moho ($V_Z = +100*10^{-5}$ ms^{-2}) originates in significant elevation of the asthenosphere, which gravity effect was approximately $-60*10^{-5}$ ms^{-2}. The gravity effect of the topography and Neogene sediments was only $-40*10^{-5}$ ms^{-2}. Lillie et al. (1994) notice that the gravity effect of the lithosphere-asthenosphere boundary must be considered in modelling of gravity anomalies with large wavelength in the Eastern Alpine region.

Geophysical - geological interpretation of the deep geological structure and geodynamics of the lithosphere.

We made re-interpretation of the gravity profiles calculated along the deep seismic transects 3T and 6HR (Šantavy in Vozár et al. 1999). The re-interpretation is based on considering the lithosphere-asthenosphere boundary as density one. As thickness of the lithosphere was taken the mean depth of the lithosphere-asthenosphere boundary published by Babuška et al. (1988) and Horváth (1993).

Westhern part of the transect 3T is characterized by significant gravity depression reaching value almost -40×10^{-5} ms^{-2}. Low-density Neogene sediments of the Vienna basin reaching thickness up to 6.5 km and flysh belt are the most substantial source of this anomaly. However, we note that also other deep geological structures have certain portion on this negative gravity anomaly. Gravity effect of upper crust of the Bohemian Massif bending under the Western Carpathians units (Tomek et al. 1987) and 2-3 km deepening of Moho discontinuity (or partial thickening of the Earth's crust in the contact zone of both tectonic units) should be included among them. The dominating feature of the collision zone between the underthrusting Bohemian Massif plate and the upper Carpathian-Pannonian plate there is seismically determined flower sturcture, that in depth itself joints into one sinistral deep-seated fault - Záhorie fault (in Austria the Mur–Mürz–Leitha fault is continuation of this fault). Along this zone the Malé Karpaty Mts. are lifted by almost 3 km. The Malé Karpaty Mts. are important gravity high and their contact with the Vienna and Danube basins is accompanied with significant horizontal gravity gradients. The western outlining of the Malé Karpaty Mts. is faulty, however, the seismic reflectors of their southeastern side dip continuously and concavely into area of the Danube basin. The Danube basin is characterized by gravitational depression spreading between two gravitational highs caused by the Malé Karpaty Mts. and high-density Kolarovo anomaly body. It is clear from the multidisciplinary approach of the interpretation of the gravity field, that its course is strongly influenced by the deep geological structure of the Danube basin. The measured gravitaty field is influenced mainly by gravitaty effect of the Moho discontinuity and upper-lower crust boundary. On the contrary, its positive influence is suppressed by negative effect of the sedimentary filling of the basin. Under this basin can be observed reflection elements with inclination angle (about 45º) which dips towards ESE. Such organizing of the reflection elements was interpreted as manifestation of extension that can be observed in the central part of the Western Carpathians and subsequent updoming of the lower reflectors of Tatricum. The crust thickness has clear decreasing character from the area of the Bohemian Massif towards the Danube basin. The crust thickness under the Bohemian Massif changes from 32 km to 30 km. In the Western Carpathian part the depth of the Moho is about from 30 km to 28 km. Beneath the Danube basin the interpreted elevation of Moho (26-28 km), which is result of the Neogene extension processes that take place in this area. In the contact zone of the two colliding plates, i.e. the European platform and the Carpathian - Pannonian plate, there was interpreted 2-3 km deepening of the Moho discontinuity. The lithosphere-asthenosphere boundary rise from the depth 130 km to depth 70 km in direction from the Bohemian Massif toward Danube basin.

Graduate growth in direction from the Bohemian Massif toward the Western Carpathians is characteristic feature for the gravity field along the profile 6HR. The values of the total Bouguer anomaly increase from $-22x10^{-5}$ ms^{-2} up to $+25x10^{-5}$ ms^{-2}. The gravity effect of the rising Moho, which rise from the depth about 33 km to 30 km (Szalaiová and Šantavý in Vozár et al., 1998), is the reason of this increase. In order to reach sufficient accord between measured and calculated gravity field the crust thickness was interpreted as 35-36 km. The jump on the Moho was about 2-4 km. The lithosphere-asthenosphere boundary is characterized by significant lifting on relatively small horizontal distance. In the profile section from 10 km to 70 km this boundary rise from depth 120 up to depth 80 km. From all surface structures are two the most important: region of the outer Western Carpathian flysch belt and region of the Bánovce basin and the Rišňovce depression. Both cases are significant gravity lows. The first negative gravity anomaly is invited mainly by large thickness of relatively low-density flysch units with density changing from about 2400 to 2650 kgm^{-3}. The thickness of the flysch units increases in direction toward the Klippen belt. It is part of the western segment of the Western Carpathian gravity minimum, in sense of Tomek et al. (1979). Crust thickening interpreted in the area under outer flysch belt has its partial share on the gravity minimum. The total gravity minimum is then superposition of the gravity effects of the flysch belt and thickened crust in this area. Worth of mention is also a body interpreted on bases of seismic as well as gravity measurements. This body is located directly under the flysch units. Low-density Neogene sediments of the Bánovce basin and the Rišňava depression (2200 kgm^{-3}) are a source of the second negative gravity anomaly (km 45-75). In the increasing tendency of the regional gravity field two gravity highs can be observed. The first (km 30-50) is a joint manifestation of the Mesozoic nappe units in the valley of the river Váh, envelope sequence and also Tertiary crystalline rocks in the area of the Považský Inovec Mts. It is emphasized also by assumed elevation of the lower crust. Mostly sub-horizontal reflection zones that confirm a rangy platen structure of Tatricum (Vozár and Šantavý, 1999) are characteristic for Tatricum of the Považský Inovec Mts. Basing on the works by Plašienku et al. (1997) and analyses of seismic reflection profiles 6HR and 2T (Tomek et al., 1989) the Peninicum (?) or lower crust of the Tatricum unit itself was interpreted under Tatricum. The second gravity high is invoked by surface as well as by deep geological structure of the Tríbeč Mts.

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