Preliminary map of the lithospheric thickness in the Pannonian-Carpathian basin region obtained by means of 2D integrated modelling

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Abstract: A unique method of 2D integrated modelling that combines interpretation of surface heat flow, gravity and topography (local isostasy) was used for the calculation of the lithospheric thickness along nine geotransects passing through the Pannonian-Carpathian basin region. Based on the obtained results, a new map of lithospheric thickness has been created for the area. The map indicates a new phenomenon of the lithosphere thickness in the studied area. In central and eastern part of the Western Carpathians, a lithospheric root (up to 150 km) can be observed. This feature is not observed beneath the western segment of the Western Carpathians (transitional zone with the Bohemian Massif). Strong lithospheric thickening (up to 240 km) can be observed along the whole Eastern Carpathians, whereas the maximum thickness (260 km) was modeled for the seismic zone Vrancea. The thickening of the lithosphere in these areas has not been suggested in the former interpretations. The new results coincide better with the newest ideas of the structure and tectonic development of the Carpathian-Pannonian basin region.

Key words: integrated modelling, gravity, heat flow, topography, Carpathians, Pannonian basin, lithospheric thickness

1. Introduction

Zeyen et al. (2002) has calculated thermal lithospheric structure along five geotransects crossing the Western Carpathians and the Pannonian basin,

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using the method of integrated interpretation of surface heat flow data, gravity data and topography. *Dérerová and Bielik (2003)* have determined lithospheric thickness along the Vrancea geotransect, using the same method. Now, three new geotransects passing through the European platform and the Eastern Carpathians have been added (Fig. 1). The aim of the paper is to construct a new map of the lithospheric thickness based on the results obtained for all nine profiles and the results obtained by seismic modelling *Babuška et al., 1987; Babuška et al., 1988)*, magnetotelluric soundings *(Ádám et al., 1990; Ádám et al., 1996; Horváth, 1993)* and geothermal modelling *(Lenkey, 1999)*.

2. Method

A method of 2D integrated modelling, which combines joint interpretation of geothermal data, gravity data and topography (local isostasy) has been used for determination of lithospheric thickness along nine geotransects in the Pannonian-Carpathian basin region. A detailed description of the method and its fundaments is given by *Zeyen and Fernàndez (1994)* or can be found in *Zeyen et al. (2002)* and *Dérerová and Bielik (2003)*.

3. Geotransects

Profiles I and II start in the Bohemian Massif, pass through the Western Carpathian orogen in SE direction. Both profiles continue then through the Danube basin and finish in the Pannonian basin. Transects III, IV and V start in the European platform, continue across the Western Carpathians and terminate in the Neogene sediments of the Pannonian basin. Profiles VI, VII and VIII start in the European platform and pass through the Eastern Carpathians. Profile VI continues across the Transcarpathian basin and finish in the Pannonian basin. Transects VII and VIII go through the Transylvanian basin, Apuseni and finish in the Békés basin (BB). Profile IX (Vrancea) starts in the westernmost part of the Black Sea, continues across the Eastern and Southern Carpathian junction, the Transylvanian basin, Apuseni and ends in the Békés basin.

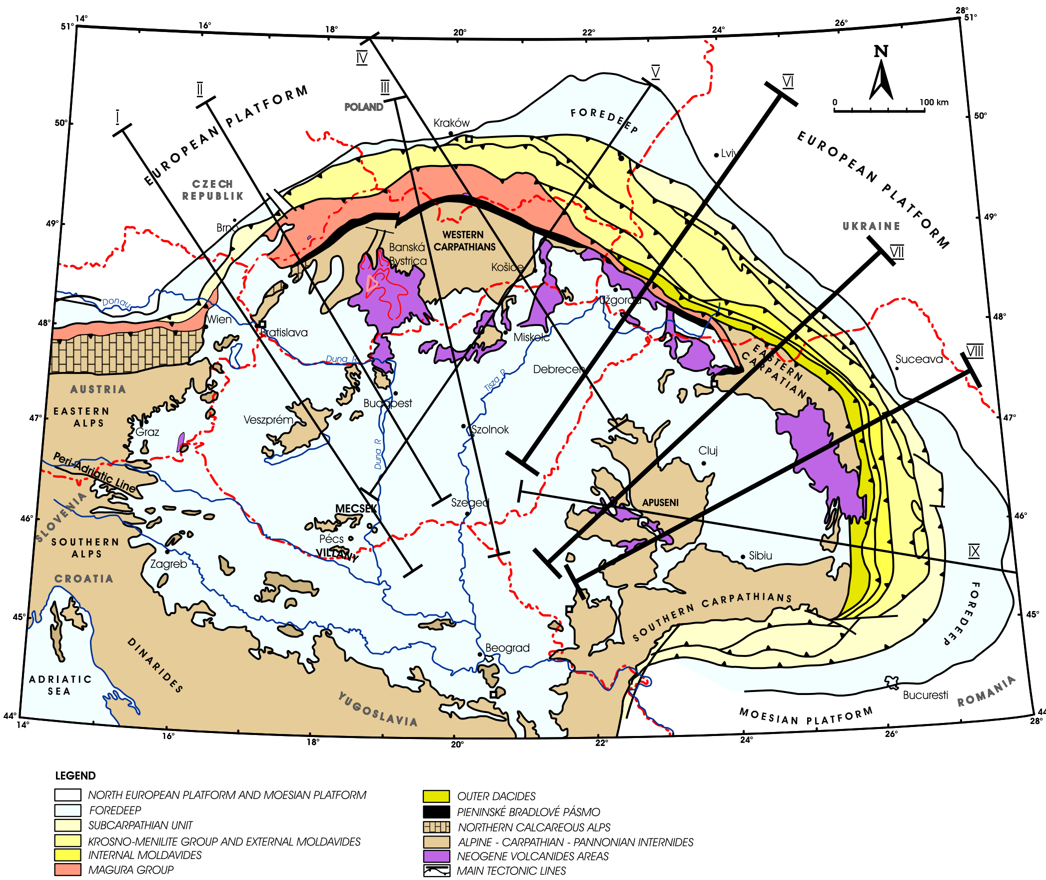

Fig. 1. Schematic tectonic map of the Carpathian-Pannonian basin region together with locations of the modeled geotransects I-IX (modified after *Lillie et al., 1994*). The bold lines represent new geotransects.

4. Input geophysical data

The topography has been taken from the GTOPO30 database *(Gesch et al., 1999)*. The free air gravity anomalies were taken from the TOPEX 2-min gravity dataset (ftp://topex.ucsd.edu/pub). The heat flow density data were compiled from the worldwide dataset of *Pollack et al. (1993)*.

The thickness of the Western Carpathian molasse foredeep sediments (Fig. 1, Legend No. 2) was taken from data published by *Tomek et al. (1987, 1989); Poprawa and Nemčok (1989); Krejčí and Jurová (1997); Kováč (2000); Matenco (1997)* and *Cornea et al. (1981)*. The thickness of the flysh sediments of the Outer Carpathians (Fig. 1, Legend No. 3–7) was compiled using data published by *Krejčí and Jurová (1997); Poprawa and Nemčok (1989); Mocanu and Radulescu (1994); Matenco (1997); Kováč (2000); Sandulescu (1994)* and *Stefanescu (1988)*. The thickness of the Neogene sediments in the Pannonian basin was taken from data by *Bielik (1988)* and *Kilényi and Šefara (1989)*.

The depth of the boundary between upper and lower crust was taken from *Bielik et al. (1990)* and *Bielik (1995)*. The depth of the Moho boundary was taken from *Mayerová et al. (1994); Šefara et al. (1996); Horváth (1993); Lenkey (1999); Guterch et al. (1986a)* and *Lazarescu et al. (1983)*. The depth of the lithosphere-astenosphere boundary was taken from *Babuška et al. (1988); Horváth (1993); Šefara et al. (1996)* and *Mocanu and Radulescu (1994)*.

5. Results

Integrated modelling was carried out along nine geotransects. The resultant profile of integrated geophysical modelling along profile VI is shown in Fig. 2. Thermal and density properties of particular tectonic units for all profiles are in Tab. 1.

Based on the results of the integrated modelling of the lithospheric structure in the Pannonian-Carpathian basin region, the existing models of the lithospheric thickness in the area *(Babuška et al., 1987; Horváth, 1993; Šefara et al., 1996; Lenkey, 1999)* were modified. The results are shown in Fig. 3. In our modification we concentrated mainly on the area of the

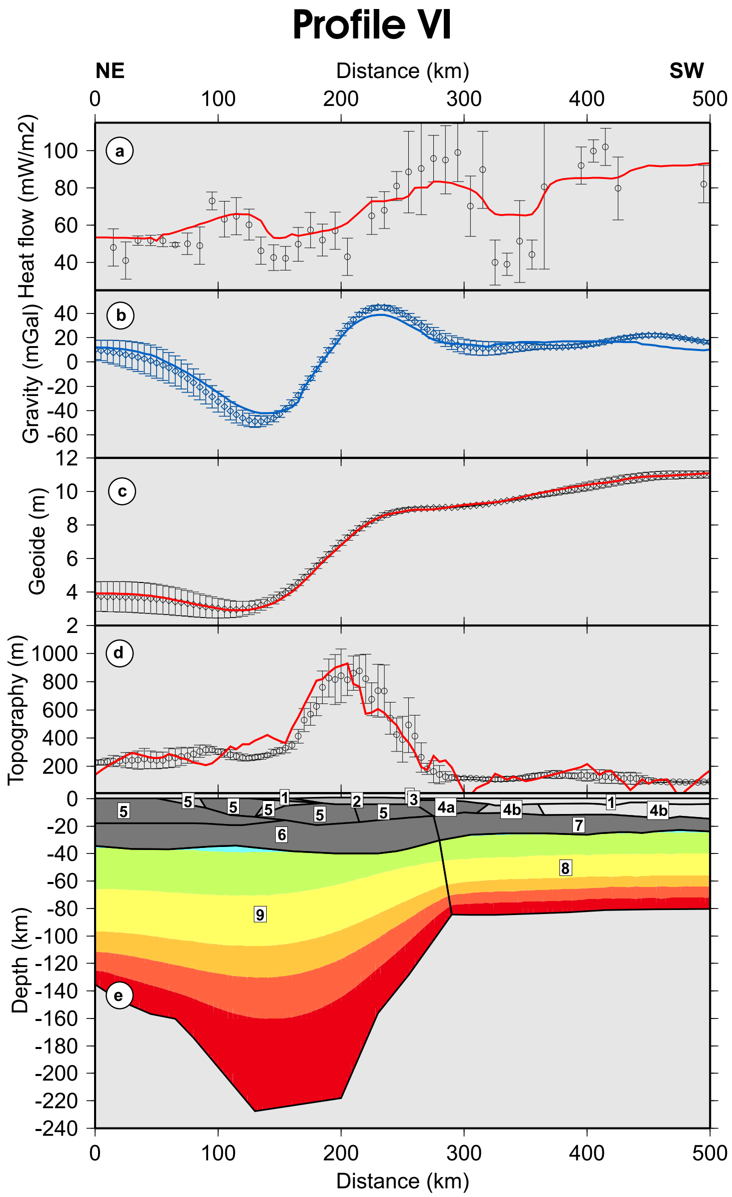

Fig. 2. Lithospheric model along geotransect 6. (a) surface heat flow, (b) free air gravity anomaly, (c) geoid, (d) topography with dots corresponding to measured data with uncertainty bars and solid lines to calculated values. Numbers in (d) correspond to material number in Tab. 1.

Tab. 1. Densities and thermal properties of different bodies used in the models VI

Nr.	Geological unit	HP	TC	ρ_0
1	Neogene sediments	3.0-3.5	2.0-2.5	2400-2550
2	Flysh	2.0-2.5	2.0–2.5	2550-2650
3	Volcanics	2.0-3.5	2.5-3.0	2600-2800
4a	Carpathian upper crust	3.5	3.0	2750
4b	Pannonian upper crust	1.0-3.5	2.0-3.0	2740-2750
4c	Apuseni upper crust	2.0-2.5	2.5-3.00	2740
4d	Eastern Carpathian upper crust	2.0-2.5	2.5-3.0	2700-2760
4e	Transylvanian upper crust	2.0	2.0-3.0	2750
5	European upper crust	1.5-2.5	2.0-2.5	2650-2820
6	European lower crust	0.2	2.0	2950-2980
7	Carpathian and Pannonian lower crust	0.2	2.0	2930
8	Carpathian and Pannonian lower (mantle) lithosphere	0.05	3.40	3200+
9	European lower (mantle) lithosphere	0.05	3.40	3200+

Nr: reference number of bodies in the models VI-VIII;
HP: heat production ($\mu W/m^3$);
TC: thermal conductivity ($W/(m\cdot K)$);
ρ_0: density at room temperature (kg/m^3).

Carpathian arc and its foreland. We did not modify the isolines of the thickness in the Pannonian basin. They were taken from the map of the lithospheric thickness published by *Lenkey (1999).* They are based on the interpretation of the results of magnetotelluric sounding carried out by Hungarian geophysicists *(Ádám et al., 1996).*

The area of the Eastern Alps and the Southern Carpathians was also taken from the map published by *Babuška et al. (1987).* Isolines of lithospheric thickness in the Bohemian Massif were modified only partially, because it is a marginal part (transects I and II) of the study area.

If we summarize, it can be told that the resultant map of the lithospheric thickness in the Carpathian-Pannonian basin region is a combination of results obtained with our integrated modelling and results of seismic modelling *(Babuška et al., 1987)* and magnetotelluric sounding *(Ádám et al., 1990, 1996; Horváth, 1993; Lenkey, 1999).*

6. Conclusions

Integrated modelling of surface heat flow, gravity data and topography, together with using geological and seismic data, make it possible to con-

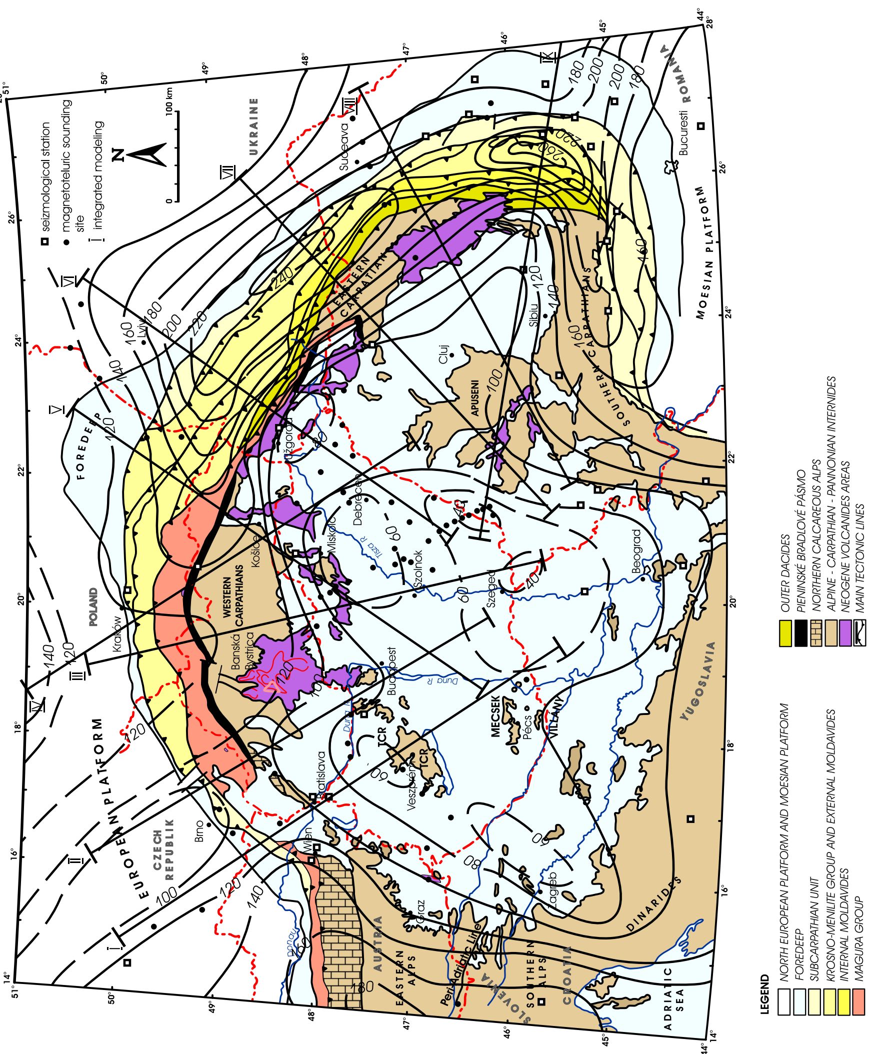

Fig. 3. Modified map of the lithospheric thickness in the Carpathian-Pannonian basin region.

struct a new model of the lithospheric structure in the Carpathian-Pannonian basin region.

Taking into account the results along all nine geotransects in the study area, a new map of the lithospheric thickness for the Carpathian-Pannonian region has been created (Fig. 3).

This map clearly shows changes in the lithospheric thickness not only across, but also along the Carpathian arc. The thickness of the lithosphere increases along the Carpathian arc from the Western Carpathians to the Eastern Carpathians. It is a new phenomenon of this study. In central and eastern parts of the Western Carpathians, a lithospheric root (up to 150 km) can be observed. This feature is not observed beneath the western segment of the Western Carpathians (transitional zone with the Bohemian Massif). Strong lithospheric thickening (up to 240 km) can be observed along the whole Eastern Carpathians, whereas the maximum thickness (260 km) was modeled for the seismic zone Vrancea.

The thickening of the lithosphere in these areas had not been suggested in the former interpretations. The new results coincide better with the newest ideas and suggestions on the structure and tectonic development of the Carpathian-Pannonian basin region *(Kováč, 2000).*

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