

NEW APPROACH FOR DETERMINATION OF THE WESTERN CARPATHIAN LITHOSPHERIC THERMAL STRUCTURE

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Abstract: We continued in applying of a new interpretation approach represented by integrated lithospheric multi-method modelling for determination of the continental lithospheric thermal structure. The study was performed along two transects II and V crossing the Western Carpathians. A thick lithosphere (up to 130-150 km) is indicated underneath the central segment of the Western Carpathians. This structure is interpreted as a remnant of a subducted slab of the European plate. In contrast, no lithospheric root shows up in our models of the westernmost segment of the Western Carpathians.

Key words: geophysics, integrated modelling, lithosphere, Western Carpathians

Introduction

The analysis of the differences and problems related to interpretation of the lithosphere thickness by means of different geophysical data (Babuška et al. 1987, 1988; Praus et al. 1990; Horváth 1993; Ádám et al. 1996; Čermák 1994; Majcin et al. 1998) led us to the application of integrated lithospheric modelling. In this paper, we present the results obtained by means of 2-D numerical models based on a combined interpretation of heat flow, absolute topographic elevation and gravity data. We intend with this method to determine the 2D thermal structure of the lithosphere based not only on surface heat flow data but taking into account the dependence of density on temperature through the coefficient of thermal expansion. The main aim of this study is to calculate models of the lithosphere thickness and the actual temperature distribution along further two transects crossing the Western Carpathians and to supplement our former study (Dérerová et al. 2001).

Method

A detailed description of the method and its fundamentals is given by Zeyen and Fernandez (1994). A finite element algorithm is used to calculate the 2D temperature distribution in the lithosphere, given its thickness (here defined as the 1300°C isotherm) and the distribution of heat production and thermal conductivity solving the steady state heat conduction. Once the temperatures are calculated at every node, densities are evaluated at the same nodes, depending on temperature and pressure and based on predefined densities at room conditions. In our calculations, we assumed a thermal expansion coefficient of $3 \times 10^{-5} \text{K}^{-1}$. With this density distribution, we are able to calculate the gravity (Bouguer or free air) anomalies along the transects (Talwani et al. 1959) and the topography under the assumption of local isostatic equilibrium.

The Western Carpathian Geotransects

The integrated modelling algorithm has been applied to next two geotransects II and V crossing the Western Carpathians (Fig. 1). Transect I starts in the Bohemian Massif, crossing the orogen between the Alps and the Western Carpathian mountains in southeastern direction. The profile passes through the Danube basin and finishes in the Pannonian Basin. Transect V starts in the Tornquist-Teisseyre Zone, continue across the Outer Western Carpathian molasse foredeep, the Outer Western Carpathian flysch and the Pienniny Klippen belt. Then it goes on through the Slovenské Rudohorie Mts. and finishes in the Pannonian Basin.

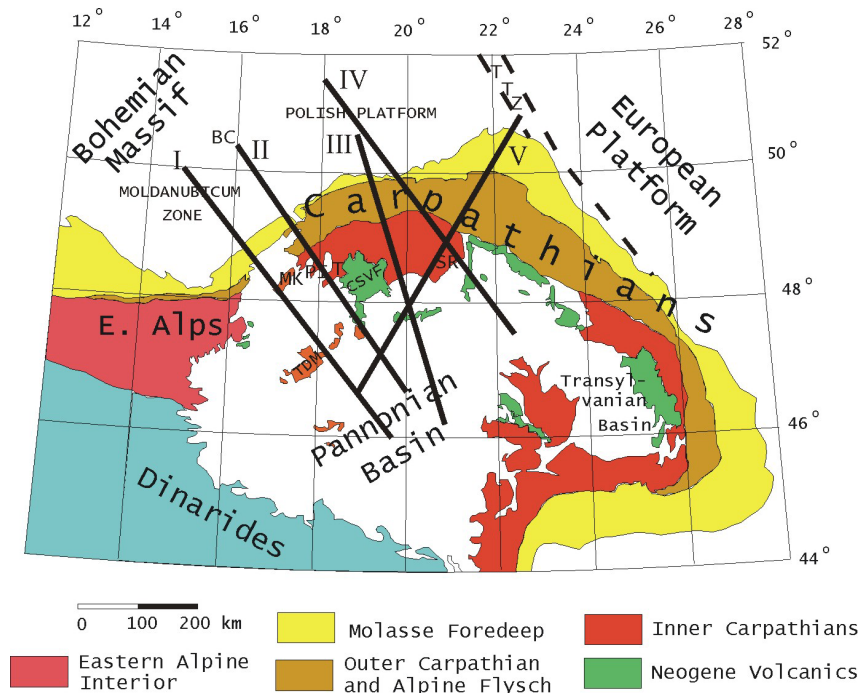


Fig. 1. Schematic tectonic map of the Carpathian-Pannonian region with location of the modelled transects (modified after Lillie et al., 1994). Keys: MK – Malé Karpaty Mts., PI – Považský Inovec Mts., CSVF – Central Slovak Neovolcanic field, SR – Slovenské Rudohorie Mts., TDM – Transdanubian mountains, TTZ – Tornquist-Teisseyre Zone.

Modelling Results

We constructed an initial density model based on the results obtained by former density modelling (e.g. Pospíšil and Filo 1980; Bielik 1995, 1998; Lillie et al. 1994; Šefara et al. 1996; Szafián et al. 1997) and geothermal modelling (Čermák 1994; Majcin et al. 1998) in the study region. An initial lithosphere thickness was taken from Horváth (1993) and Šefara et al. (1996) maps.

The lithospheric thickness underneath the Bohemian Massif (transect II) is nearly flat and varies in our model only from 90 to 100 km (Fig. 2a-b). A high-density body at the base of the crust was modelled in this area for transect V in the vicinity of the TTZ (km 0 – 120) indicating an affiliation to the East European Platform.

The most interesting feature, however, is seen underneath the Western Carpathians. The integrated modelling shows clear a lithosphere thickening from about 110 km to about 145 km depth. This feature was not modelled in the western segment of the Western Carpathians. Note that the thickening of the lithosphere in the central and eastern segments of these mountains is accompanied by crustal thickening. The lithosphere thickening is interpreted as a small remnant of a subducted slab. Taking into account these results we suggest that tectonic evolution of the continental collision along the Western Carpathian orogen has changed in time and space.

Beneath the Pannonian basin, the lithosphere thickness ranges in our models from about 75 to 95 km, which is more than usually assumed. Therefore, part of the surface heat flow has to be explained by an increase in radioactive heat production in the Pannonian upper crust and sediments. The used values are, however, not higher than those used in other young western European areas (e.g. Sobolev et al. 1997).

Conclusions

Joint modelling of surface heat flow, gravimetric and topographic data, using geological and crustal seismic data as constraints, allowed us to establish a new model of the lithospheric structure of the Western Carpathians and parts of their surrounding tectonic units: The Bohemian Massif, the Polish platform and the Pannonian Basin. The thickness of the lithosphere under the European platform and the Outer Western Carpathians varies from about 110 to 120 km. Under the Pannonian Basin it attains about 75 to 95 km. These values differ somewhat from earlier models, which gave often larger values for the European platform and a thinner lithosphere underneath the Pannonian Basin.

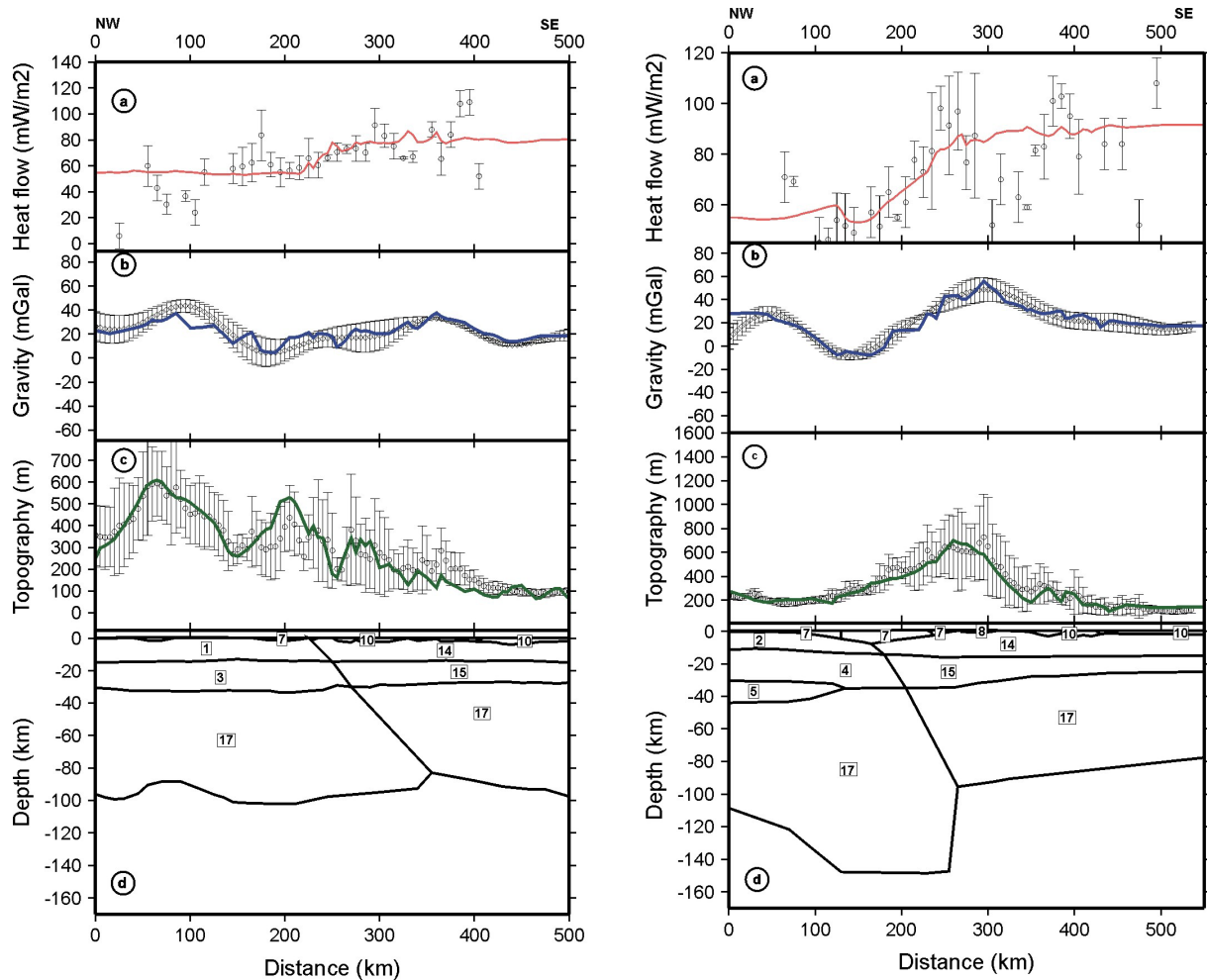


Fig. 2. Lithosphere models along transects II and V. (a) - surface density of heat flow, (b) Free-air gravity anomaly, (c) topography. Dots correspond to measured data with uncertainty bars and solid lines to calculated values. Keys: 1–Bohemian Massif upper crust, 2–European upper crust, 3– Bohemian Massif lower crust, 4–European lower crust, 5–Anomaly body within the European plate, 7–Outer Western Carpathian sediments, 8–Inner Western Carpathian sediments, 10–Pannonian basin sediments, 14–Carpathain-Pannonian upper crust, 15–Carpathain-Pannonian lower crust, 17–Lower (mantle) lithosphere.

Underneath the Outer Western Carpathian orogen, the thickness of the lithosphere shows important variations, across the chain as well as along-strike. In the central and eastern segments of the Western Carpathians, the lithosphere seems to be thickened to depths of up to 150 km. This thickening is interpreted as remnants of a former slab, which broke off in late Miocene. It may indicate a continuation of the convergence movement during a few Ma after the break-off.

Under the western segment, in the transition zone to the Eastern Alps, the data are not compatible with a thickening of the lithosphere underneath the Carpathians. We interpret this as an indication that no clearly visible slab evolved in the Tertiary. Since the direction of the plate boundary was strongly oblique to parallel to the direction of relative movement, sinistral strike-slip movements should have dominated during the entire period of convergence.

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