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Lithospheric structure in Central Europe: Integrated geophysical modelling

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ABSTRACT

We present four new 2D lithosphere-scale transects crossing central Europe from the West European Platform in the North to the Aegean Sea in the South and from the Adriatic Sea in the West to the East European Platform in the East. Modelling is based on the joint interpretation of gravity, geoid, topography and surface heat flow data with temperature-dependent density. Wherever possible, crustal structure is constrained by seismic data. The thickness of the lithosphere decreases from the older and colder platforms to the younger and hotter Pannonian Basin with a maximum thickness under the Eastern and Southern Carpathians. Similar to earlier studies, the thickness of the Carpathian arc lithosphere varies between 150 km in the North (the Western Carpathians) and about 300 km in the Vrancea zone (the Eastern and Southern Carpathian junction). In the Platform areas it is between 120 and 150 km and in the Pannonian Basin it is about 70 km. The lithosphere thickens strongly underneath the Transylvanian Basin reaching locally values of nearly 200 km which is thicker than in earlier studies. New results are given for the Southern Carpathians and the Moesian Platform. The models show that the Moesian Platform is overthrust from the North by the Southern Carpathians and from the South by the Balkanides and characterised by bending of this platform. In all transects, the thickest crust is found underneath the Carpathian Mountains or, as in the case of the Vrancea area, under their immediate foreland. The thickest crust outside the orogens is modelled for the Moesian Platform with Moho depths of up to 45 km. The thinnest crust is located under the Pannonian Basin with about 26–27 km.

1. Introduction

The Carpatho-Pannonian region is a complicated puzzle of platforms, basins and orogens formed during the Alpine orogeny by the amalgamation of different terranes (Fig. 1). The Carpathian Mountains form a nearly 270° arc that is still seismically active in its SE corner, the Vrancea zone. They separate the Pannonian Basin inside the arc from the Precambrian East European Platform in the E, the Paleozoic West European Platform in the NW and the Paleozoic Moesian Platform in the SE. Although most authors agree that this setting was created by the eastward extrusion of two microplates during the Alpine collision, the ALCAPA microplate, forming nowadays the northern part of the Pannonian Basin and the TISZA-DACIA microplate forming its southern part, the detailed tectonic evolution is still debated (e.g. Schmid et al., 2008; Vozár et al., 2010). The tectonics of the area is further complicated by the eastward subduction of the Adria microplate forming the Dinaride Mountains limiting the Pannonian Basin to the West.

Geophysical imaging of the lithosphere structure of the whole area may help to shed light on the tectonic evolution. In recent years, an important amount of work has been published concerning the Pannonian Basin, the Western Carpathians and the transition to the West and East European Platforms. Deep seismic refraction and wide-angle reflection images of the crust and uppermost mantle were obtained during the CELEBRATION-2000 project (e.g. Grad et al., 2006; Janik et al., 2011; Środa et al., 2006), SUDETES 2003 project (e.g. Hrubcová et al., 2010) and two-dimensional (2D) (Dérerová et al., 2006; Zeyen et al., 2002) as well as three-dimensional (3D) (Bielik et al., 2005; Tašárová et al., 2009; Tašárová Alasonati et al., 2008) potential field interpretations gave insights in the lithosphere structure of the northern part of the Pannonian Basin, the Western Carpathians and the southern part of East European Platform. In the Eastern Carpathians, Dérerová et al. (2006) published 2D potential field images along some profiles and a detailed teleseismic tomography study was carried out in the Vrancea zone (Fan et al., 1998; Koulakov et al., 2010; Weidle et al., 2005; Wenzel et al., 2002). Only little work has been done in the Southern Carpathians and surrounding areas. Only crustal-scale gravity (Szafián et al., 1997) and seismic images (Fan et al., 1998) have been published. The transition from the Adriatic Sea to the Pannonian Basin has been investigated at crustal scale using

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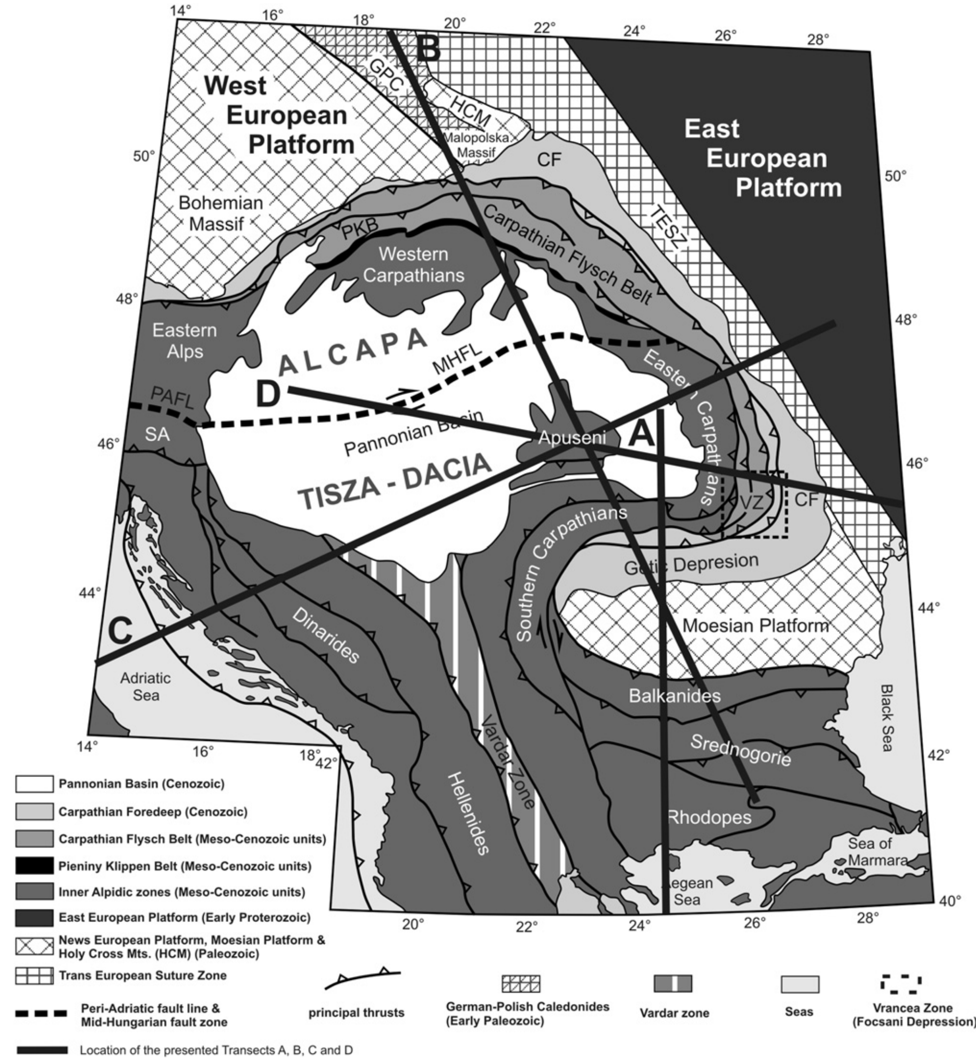

Fig. 1. Simplified tectonic map of the Central Europe with the four modelled transects (modified after Mahel', 1973; Artemieva et al., 2006). Keys: HCM, Holy Cross Mts.; GPC, German-Polish Caledonides; SA, Southern Alps; VZ, Vrancea zone; PAFL, Periadriatic fault line; MHFL, Mid-Hungarian fault line.

seismic and gravity profiles of the ALP-2002 project (Šumanovac, 2010; Šumanovac et al., 2009). The area as a whole has only been imaged by regional-scale seismic tomography (Raykova and Panza, 2006; Wortel and Spakman, 2000) and one regional crustal gravity profile has been published by Szafián et al. (1997).

The aim of this paper is therefore to present new lithosphere-scale transects based on the joint interpretation of gravity, geoid, topography and surface heat flow data, crossing the whole area from the West European Platform in the North to the Aegean Sea in the South and from the Adriatic Sea in the West to the East European Platform in the East. We modelled four transects (Figs. 1 and 2). Transect A starts in the N in the Transylvanian Basin, crosses the Southern Carpathians, the Moesian Platform, the Balkanides and the Rhodopes and finishes in the northern Aegean Sea. Transect B starts on the West European Platform and crosses in SSW direction the Western Carpathians, the Pannonian Basin, the Apuseni Mountains, the Southern Carpathians, the Moesian Platform and the Balkanides. Transect C starts in the Adriatic Sea and crosses towards the NE the Dinarides, Pannonian Basin, Apuseni Mountains, the Transylvanian Basin and the Eastern Carpathians, finishing on the East European Platform. Finally, Transect D starts in the western Pannonian Basin and crosses in easterly direction the Apuseni Mountains, the Vrancea zone and the East European Platform and finishes in the Black Sea.

2. Geology

The study area includes a series of strongly variable lithospheric blocks that have been amalgamated during the major European orogeneses from the Cadomian to the Alpine ones (Fig. 1). The northern part of the study area is formed by the North-European Platform (NEP) which is separated by the Trans-European Suture Zone (TESZ – e.g. Pharaoh, 1999) into the Precambrian East European Platform (EEP) in the East and the Paleozoic West European Platform (WEP) in the West. The WEP consists of a collage of Gondwana-related Precambrian and/or Cadomian terranes amalgamated during pre-Variscan tectonic events and then covered by thick sedimentary deposits. In the area described, these terranes also include the Malopolska Massif and the Bohemian Massif surrounding the German-Polish Caledonides.

During the Alpine orogeny, the terranes of ALCAPA and TISZA-DACIA docked to the older ones, forming the immense East Alpine-Carpathian Arc. Southwards, the Carpathian Arc turns around the Moesian Platform and continues into wide orogenic zones of the Balkanides. The southern branch of the Alpine orogen includes the Southern Alps that are linked to the Dinarides, Albanides and Hellenides towards the Southeast. All these Alpine mountain belts are wrapping around the large Pannonian Basin rimmed by volcanic chains, which were formed by back-arc