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# Lithosphere model of the Pannonian–Adriatic overthrusting

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ABSTRACT

A gravity model has been established at the contact of the southern part of the Pannonian basin and central Dinarides. Two-dimensional gravity modelling was carried out by means of the calibrated density set, defined at the Alp07 profile (Šumanovac, 2010), which significantly improved the resolution of the method. Gravity attraction caused by the structure in the upper mantle was analyzed in detail, which enabled construction of complete lithosphere model at the contact of the Dinarides, as a part of the Adriatic microplate, and the Pannonian basin as a segment of the Eurasian plate.

Geophysical models demonstrate that overthrusting structures need to be considered in the present geological model; notably, the thrusting of the Adriatic microplate under the European plate. However, overthrusting processes cannot provide a complete explanation of the processes in the Pannonian basin. Considering that the Pannonian basin area is in fact a large geothermal anomaly, it is necessary to introduce the asthenosphere upwelling into the model. The presence of this structure is confirmed by a change in densities and seismic velocities in the uppermost mantle. This process has led to a significant thinning of the crust in the Tisia block and to the homogenization of properties as a result of the rising of the asthenosphere, and the crust can therefore be considered as a single layer. The combined effect of the push exerted by the African plate, and the rising of the asthenosphere and the thinning of the crust in the Pannonian basin caused the underthrusting of the Adriatic microplate below the Pannonian segment, thickening of the crust and steeply sinking of the Adriatic upper mantle below the Dinarides. Seismicity of the area and earthquake hypocenters enable the construction of active faults, which correlate well with the main faults at the surface and boundaries of density blocks in the crust.



## 1. Introduction

The subduction model at the contact of the Dinarides and the Pannonian basin has been considered for some time (Herak, 1986; Moretti and Royden, 1988) as a contact of the Adriatic microplate and the Pannonian segment of the Eurasian plate. In such a model, the most common evidence is taken to be the geological development and the magmatic activity in the area. Initial subduction processes initiated in the Late Jurassic–Early Cretaceous, accompanied by ophiolite obduction (Tari and Pamić, 1998). Strong compression deformation occurred at the end of the Eocene and at the beginning of the Oligocene, and it resulted in the final rising of the Dinarides and the termination of the subduction processes. The final stage of subduction is documented by sedimentary, magmatic and metamorphic formations of northern Bosnian mountains (Prosara, Motajica), but also Serbian mountains (Cer and Bukulja), Pamić (1993). Nevertheless, the subduction of the Adriatic microplate, i.e. Apulia as the upper part of the African plate, is still often discussed. In its real meaning, subduction should denote active processes of one plate thrusting under another plate, and the sinking of a plate and associated processes, primarily magmatism and earthquakes. Nowadays, it seems that typical subduction processes are no longer active, and that it is more accurate to speak about the overthrusting and underthrusting of plates or their segments. However, such overthrusts and the positions of overthrust contacts have not been precisely and reliably defined yet.

The present front of the Adriatic underthrusting is defined by Doglioni and Carminati (2002) at the island belt of the Croatian Adriatic Sea, namely, at the extension of the Ćićarija fault. Therefore, several geophysical scientific and research projects have been conducted recently in order to define more completely the recent relationships at the contact between the Adriatic microplate and the Pannonian segment of the Eurasian plate.

The basic data were obtained within the ALP 2002 deep refraction experiment (Brückl et al., 2003, 2007), within which the Alp07 profile, crossing the contact of the Dinarides and the Pannonian basin, was defined (Šumanovac et al., 2009). Since the Alp07 profile is located at the edge of the contact, gravity data were used in order to conduct a more detailed investigation of the contact in a wider area, i.e. along a larger part of the contact. The investigation area was thus expanded to cover Croatia and Bosnia and Herzegovina, as well as the marginal parts of the neighboring countries (Šumanovac, 2010) (Fig. 1). A new contribution to the definition of these relationships was also made by the application of passive seismic measurements within the ALLPASS

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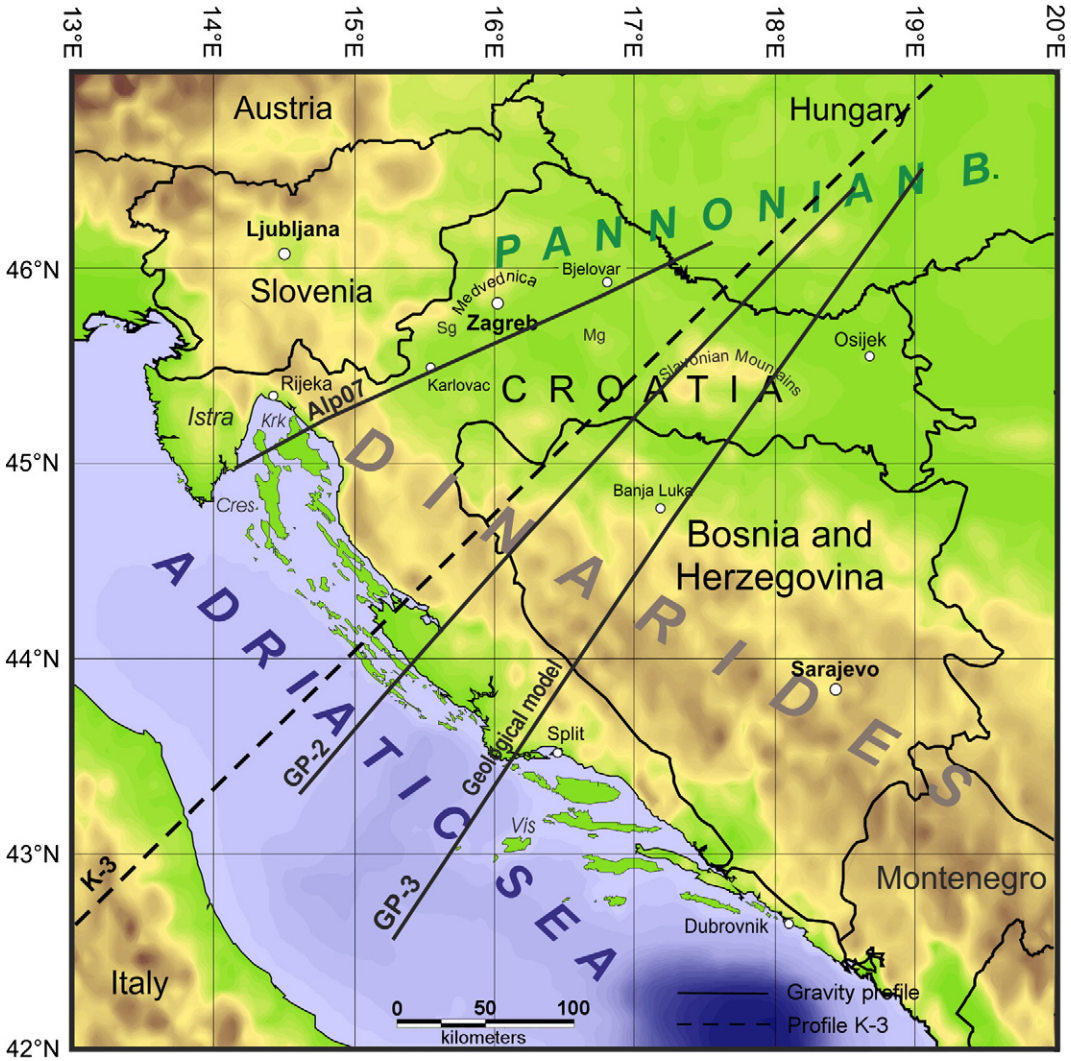


**Fig. 1.** Positions of profiles used for gravity modelling at the contact of the Dinarides and Pannonian basin (Šumanovac, 2010) and tomography profile K-3 after Koulakov et al. (2009). The geological model was constructed along the profile GP-3 (Sg-Samoborsko gorje, Mg-Moslavačka gora).

(Mitterbauer et al., 2011) and ALPASS-DIPS project Orešković et al., 2009, 2011).

The purpose of this paper is to propose a more reliable definition of the present lithosphere model at the contact of the Dinarides and the Pannonian basin based on the gravity model. The initial gravity model was constructed by means of the geophysical data and geophysical models obtained within the most recent seismic and gravity investigations in the survey area. The goal is to obtain a more complete image of the structural and tectonic relationships that are caused by the contact between the Adriatic microplate and the Pannonian segment, and which can help to explain some processes that occurred during the course of geological history.

## 2. Regional and geological setting

The study area covers the southern part of the Pannonian basin and central Dinarides, and engages the area of Croatia, Bosnia and Herzegovina and edge portions of Hungary (Fig. 1). In a geological sense, two main areas can be distinguished in the study area: the Dinarides and the Pannonian basin. The Dinarides, which stretches about 700 km, merges with the Southern Alps in the northwest and the Hellenides in the southeast. Mesozoic carbonates (limestones, dolomites, carbonate breccias, etc.) are dominant in the Dinarides. Smaller slices of Paleozoic and older rocks can be found in this area. Paleogene rocks (carbonates, clastics and flysch layers) can also be found, especially in Istra and the coastal part of Croatia, but also in some inland karst fields (Geologic Map of SFR Yugoslavia, 1970). There is a large tectonostratigraphic unit of the central Dinarides called the "Bosnian Flysch" ("flysch bosniaque"), Aobouin et al. (1970), between Sarajevo and Banja Luka in Bosnia and Herzegovina, which is a passive continental margin carbonate-clastic unit. This unit consists of Jurassic to Late Cretaceous sequences, up to 4000–5000 m thick, which were deposited at the continental slope of the Adriatic–Dinaridic carbonate platform (Pamić et al., 1998).

There are two significant reverse faults in the External Dinarides: the Ćićarija fault and the Velebit fault. The Ćićarija fault is at the edge of the External Dinarides (CF in Fig. 2). Its location at the mainland is very well defined, but in the Adriatic Sea, its direction is not accurately defined. The other significant reverse fault is the Velebit fault (VF in Fig. 2). These faults are part of a zone of reverse and thrust faulting southeast of Trieste that lies along the Adriatic coast and is considered by some authors as the main discontinuity between the External Dinarides and the Adriatic microplate (Aljinović et al., 1984).

The southern marginal fault of the Pannonian basin (Fella-Sava-Karlovac; SMF in Fig. 2) is considered to be the boundary between the Dinarides and the Pannonian basin (Prelogović et al., 1998).

Neogene and Quaternary sediments are predominant in the southwest part of the Pannonian basin. There are depressions filled with