The contact of the Bohemian Massif, Western Carpathians and Eastern Alps: Density modelling

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Abstract: The Vienna Basin is situated at the contact of the Bohemian Massif, Western Carpathians, and Eastern Alps. Deep boreholes data and existing seismic profile were used in density modelling of the pre-Neogene basement in the Slovak part of the Vienna Basin. Density modelling was carried out along profiles oriented in NW–SE direction, across expected contacts of main geological structures. From bottom to top, the four structural floors have been defined. Bohemian Massif crystalline basement with the autochthonous Mesozoic sedimentary cover sequence. The accretionary sedimentary wedge of the Flysch Belt above the Bohemian Massif rocks sequences. The Mesozoic sediments considered to be part of the Carpathian Klippen Belt together with Mesozoic cover nappes of the Alpine and Carpathians provenance are thrust over the Flysch Belt creating the third structural floor. The Neogene sediments form the highest structural floor overlying tectonic contacts of the Flysch sediments and Klippen Belt as well as the Klippen Belt and the Alpine/Carpathians nappe structures.

Geological background

Surface geological structure of the investigated area contains the Tatricum, Fatricum and Hronicum tectonic units of the Internal Western Carpathians (IWC). The Pieniny Klippen Belt (PKB) represents the frontal part of the IWC composed mainly of Jurassic and Cretaceous sediments which underwent several phases of folding and faulting during the Late Cretaceous to Miocene (Hók et al. 2016). The Upper Cretaceous to Palaeogene sediments (Gosau Group) are present a top of the Hronicum and PKB tectonic units. The tectonic units of the Northern Calcareous Alps (NCA) are interpreted in pre-Cenozoic basement of the Vienna Basin (Fusán et al. 1987; Wessely 1992a).

The Bohemian Massif (BM) rock complexes below the External Western Carpathians (EWC) sediments are represented mainly by crystalline rocks (Picha et al. 2006). On the other hand, Wessely (1992b) suggested the occurrence of the autochthonous Mesozoic sediments of the BM in the deep substratum of the Vienna Basin. The EWC (Flysch Belt) are in the investigated territory represented by the Magura nappes system characterized by the Palaeogene and Upper Cretaceous flysch sediments on the surface (Biely et al. 1996).

Density modelling

Input data

The 2D density model was created in GM-SYS software (GM-SYS User's Guide for version 4.9, 2004). It is an interactive software for calculating the gravity field from the geologic models. 2D model is composed of closed polygons with representative density. The calculations of the gravitational effects of the geological bodies are based on the formulae of Talwani et al. (1959), with Won & Bevis's algorithm (GM-SYS User's Guide 4.9, 2004).

The gravity data were obtained from the Bouguer anomaly map with the grid of 200 x 200 m (Pašteka et al. 2017). The topography data were taken from the Topographic Institute (2012). The 2D quantitative interpretation depends on geometry of the modelled polygons that approximate geological bodies and the knowledge of the rock densities.

The surface and subsurface structure of the individual tectonic units was constrained using the geological map, structural data and deep boreholes (lithology, tectonic affiliation and sediment thickness).

The Moho depth (crustal thickness) along the profile is consistent with the Moho depth imaged in the papers of Alasonati Tašárová et al. (2016) and Bielik et al. (2018).

The lithosphere–asthenosphere boundary (lithospheric thickness) has been taken from the papers Dérerová et al. (2006) and Alasonati Tašárová et al. (2016).

The sediment densities were constrained using data summarized in paper of Šamajová & Hók (2018). The natural densities of the tectonic units which built the upper part of the upper crust were taken from the map of the tectonic units of the Western Carpathians (Šamajová & Hók 2018). Input average densities of the lower part of the upper crust, lower crust, mantle lithosphere and asthenosphere were determined by analysis of the results of Bielik (1995); Šimonová & Bielik (2016).

To make the resultant models display a good resolution of the deep and subsurface structures, while the lithosphere–asthenosphere boundary and Moho discontinuity is not shown on final model.

Profile PF-1

Profile PF-1 passes from the Vienna Basin through the Malé Karpaty Mts. into the Danube Basin (Fig. 1). This profile was constructed parallel to seismic profile 8HR (see Vozár et al. 1999; Bielik et al. 2004). Surface geology is interpreted according to geological maps (Geological map of Slovakia 2013). The calculated gravity of the resultant model consists of the several local anomalies. The density model suggests that the EWC Magura and Krosno nappe systems are overthrust onto the BM. The PKB is interpreted as shallow structure thrust together with Mesozoic cover nappes sediments over the EWC sediments.

The affiliation to the Alpine or Carpathians tectonic provenance of the Mesozoic cover nappes was determined according to the presence or absence of anhydrite-rich strata (Opponitz Fm. the Reichenhall Fm., Haselgebirge Fm.).

The density model indicates of the fault contacts of the Malé Karpaty Mts with the Vienna and Danube Basins Deep contact of the Tatricum tectonic unit outcropping in the Malé Karpaty Mts is slightly shifted over the Bohemian Massif.

The boundary between the upper and lower crust was modelled in a depths of about 17.5 and 19 km. The deep contact between the EWC nappes and the Bohemian Massif is characterized by a small inclination.

Profile PF-2

Profile PF-2 (Fig. 1) was constructed across the documented boreholes (Biela 1978; Michalík et al. 1992). The surface geology is interpreted according to geological maps (Geological map of Slovakia 2013) and the structural research. Mainly normal faults with a negligible oblique component of movement disrupt the Brezovské Karpaty elevation structure. The Gosau Group sediments are preserved in the zone continuing from the Vienna Basin area to the Myjavská pahorkatina

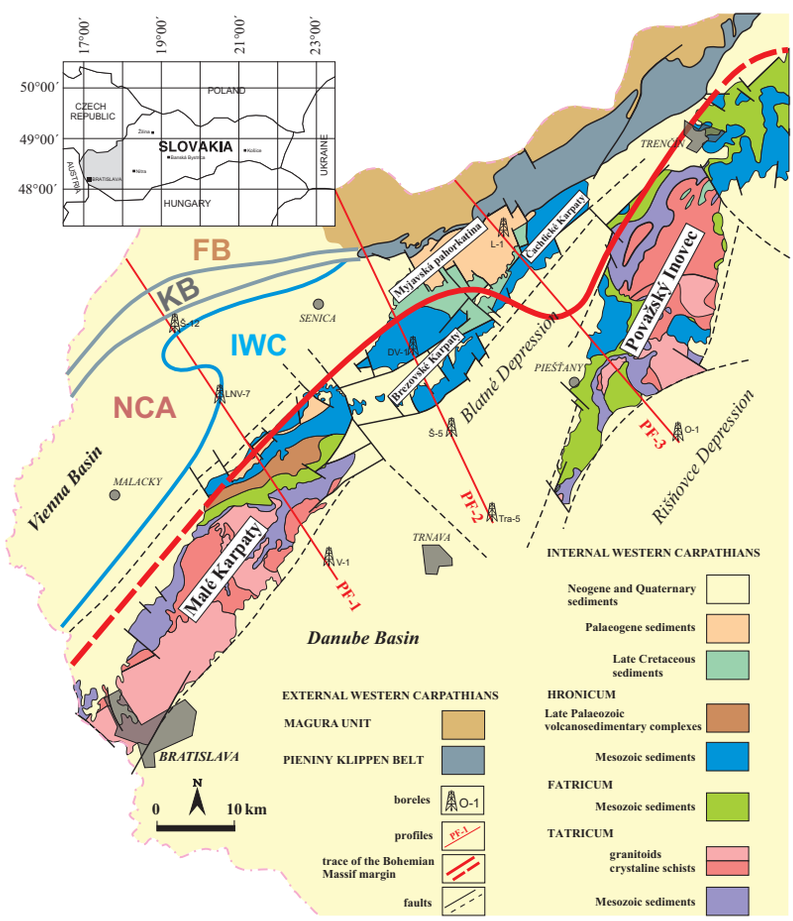

Fig. 1. Simplified geological map with the position of the Alpine and Carpathians nappe systems. FB — Flysch Belt; KB — Klippen Belt; NCA — North Calcareous Alps; IWC — Internal Western Carpathians (map based on Šamajová et al. 2018).

Upland. The calculated gravity includes two gravity lows and one gravity high located between them. A significant gravity high is caused by the structure of the Brezovské Karpaty Mts., which are split by a system of faults with a horizontal gravity gradient of 2.66 mGal/km. The high gravity anomaly of the Brezovské Karpaty Mts. is the result of superposition of gravity effects related to the Mesozoic sediments, the Tatric crystalline basement and the upper/lower crustal boundary, which are in an elevated position. A tectonic contact between the Brezovské Karpaty Mts. and Blatné Depression is confirmed again by the sharp gravity gradient (3.5 mGal/km). Neogene and Quaternary sediments of the Blatné Depression are the cause of a significant gravity low. The shape of the gravity profile in a NW direction from the Brezovské Karpaty Mts. reflects the huge thickness of the Magura nappe system flysch sediments, which are characterized by lower density. The deep contact between the BM and EWC with the IWC along this profile is similar to the situation on profile PF-1. The difference lies in the elevated position of the BM lower crust (0 –18 km of the profile). The contact area between the EWC and IWC is very steep (Šamajová et al. 2018).

Profile PF-3

Profile PF-3 (Fig. 1) is constructed between deep boreholes Lubina-1 (Leško et al. 1982) and Obdokovce-1 (Biela 1978). The geological structures were taken from geological maps (Geological map of Slovakia 2013) and original geological and structural data including geological and structural mapping. The Eocene sediments of the EWC are underthrust below the flat-lying PKB and the Palaeogene sediments (Gosau Group) in borehole Lubina-1 (Leško et al. 1982). From this point of view the PKB is a detached structure thrust above the EWC sediments in the western part of Slovakia during the post-Eocene time. The borehole Obdokovce-1 (O-1) reached the Mesozoic sediments

of the Tatricum cover only (Biela 1978). The resultant density model is characterized by two alternating local gravity highs and gravity lows. The gravity high situated on the NW side of the profile is related to a gravity effect of the Mesozoic sediments belonging to the Hronicum. The elevation of the BM basement contributes to this anomaly, too. Both gravity lows reflect the presence of the Blatné and Rišňovce Depressions. A significant gravity high between them is caused by a horst structure of the Považský Inovec Mts. The top of the BM basement creates an elevation with a minimum depth of ~8 km beneath the Čachtické Karpaty Mts. Towards to the SE, BM dips sharply under the IWC (Šamajová et al. 2018).

Conclusion

Geophysical and geological modelling and interpretations along the gravimetric profiles brought new results on the structures of the Western Carpathians, Northern Calcareous Alps and Bohemian Massif (Fig. 1). The gravimetric profile was constructed in the NW–SE direction along deep boreholes and expected tectonic contacts. The data from deep boreholes, especially from Lakšárska Nová Ves-7 (LNV-7) and Šaštín-12 (Š-12), have been reviewed from the point of view of the current lithostratigraphy knowledge of the Mesozoic rock sequences. The obtained results can be summarized as follows:

- The Bohemian Massif (BM) margin is situated internally/southeast from the surface occurrences of the Pieniny Klippen Belt (PKB).
- The accretionary prism of the External Western Carpathians (EWC) is formed by (from the bottom up) the Krosno (Waschberg-Ždánice-Pouzdřany Unit) and Magura units / nappe system thrust over rock sequences of the BM.
- The PKB does not represent topographical manifestation nor geological contact with BM.
- The PKB represents shallow (max. 5 km deep) contact between the EWC and the IWC thin-skinned tectonic units i.e. has not as structural and tectonic importance as has been so far attributed to it.
- The trace of BM margin is apparently bent inward the IWC.
- The deep contact between BM/EWC and IWC propagates as the transtension zone towards the surface.
- The contact between Alpine and Carpathians provenance of Mesozoic sequences is verified by borehole data. The decisive argument for determining the tectonic identity of the cover nappes is the presence or absence of anhydrite-rich strata.

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