Interpretation of the Tribeč Mts. deep geological structure based on results of geophysical, mainly magnetotelluric modelling

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Abstract: Magnetotelluric measurements (MT) in the southeast (SE) part of MT–15 profile in the frame of CELEBRATION 2000 project identified a subhorizontal zone with higher conductivity in the depth of cca 2–6 km below the Tribeč Mts. surface. This zone is interpreted as a complex of metamorphic rocks under the tectonically overlaying granites. The original presuppositions collected through other geophysical methods on the existence of such a complex are thereby confirmed. Apart from this finding, the MT measurements identified other conductive zones in the Tribeč mountain range and its surroundings. Those are close to the surface and belong to sedimentary rocks and volcanites. The steep, narrow and deeply penetrating conductive zone at the north-western edge of Tribeč Mts. can be interpreted as a deep Neogene shear zone. Subhorizontal conductive zone in SE part of the cross-section under the volcanic complexes is interpreted as the older mylonitized zone. This zone may be saturated by fluids, and is possibly of carbon origin and mineralized, connected with volcanic activity.

Key words: Western Carpathians, Tribeč Mts., geological structure, geophysical data, magnetotelluric modelling

1. Introduction

The Tribeč Mts. belongs to the southernmost core mountains of the Western Carpathians mountain range. The Tribeč Mts. has a rather complicated geological composition and it has been interpreted in a very dubious way in the geological maps (see *Biely, 1975; Ivanička et al., 1998*). The introduction of a new General geological map of Slovak Republic 1:200 000 *(Bezák*

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et al., 2008) is a certain compromise in this situation. The mountain range consists of Tatricum crystalline complexes, its Permian – Mesozoic cover and nappe units mainly. The ridge is the Neogene horst encircled by Neogene sediments in the grabens and by neovolcanic elements. South of the range, the Čertovica line is expected, which makes us believe in the presence of larger Veporic complexes in the tectonic structure.

What is also interesting is the deep tectonic structure of this mountain range and its surroundings. It was some time ago that the presence of heavier and more magnetic masses under the lighter granite body was signaled in the geophysical results (e.g *Šefara et al., 1987; Kubeš et al., 2001; Lanc et al., 1995*). This issue has, however, not been settled satisfactorily. The aim of the present work is to use the newest MT measurements in the MT–15 profile within the project CELEBRATION 2000 *(Vozár, 2004)* to decode the tectonic structures in the mountain range and compare them with the tectonic concepts and results from other geophysical methods.

2. Geological setting

The Tribeč Mts. represents the Neogene horst. It belongs to the tectonic blocks at the southernmost extreme of the Western Carpathians that were directly affected by the Neogene displacements and tectonics of the neighboring Danube Basin (e.g. *Csontos et al., 1992*). This means that besides vertical displacements, the formation of this block was also affected by horizontal displacements in the shear zones, which encircle the range from both sides – NW and SE. The area is also significant because in the close proximity of the south-eastern section of the horst there is a Čertovica line that we believe to be a deep overthrust Paleoalpine Cretaceous fault zone where the Veporicum was slid onto the Tatric block (e.g. *Plašienka et al., 1997*). The Fatricum units are positioned directly on the surface of the horst; they were detached from this zone and transferred on top of the Tatricum. Both units are imbricated in the interface zone. The Cretaceous fault zone was reactivated in the Neogene and covered by other displacements on the system of Mojmírovce fault zone (e.g. *Bezák et al., 2004*).

The block itself and its continuation under the grabens on both sides has its internal structure. Paleoalpine units of the Tatricum – crystalline basement and its cover units - represent its basic building blocks (Fig. 1). These

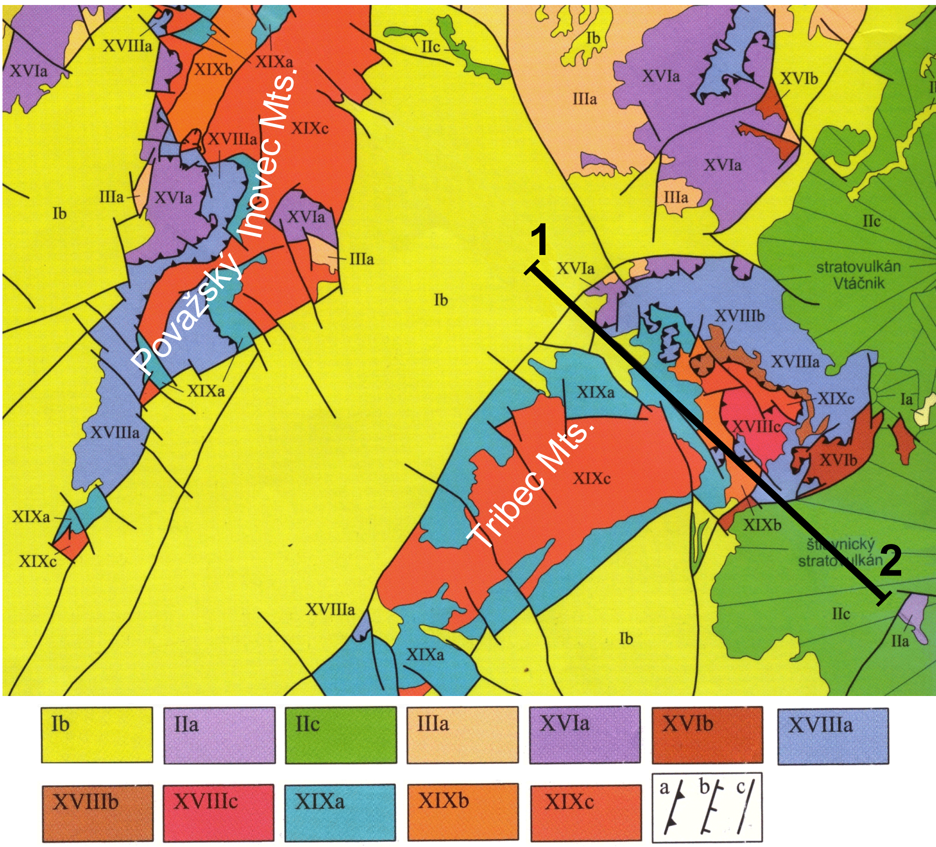

Fig. 1. Position of tectonic units in the surrounding of Tribeč Mts. (after *Elečko et al., 2004*) and position of interpreted magnetotelluric cross-section.
Explanations: Ib Neogene sediments, IIa,c Neogene volcanics, IIIa Paleogene sediments, XVI Hronicum: a – Mesozoic formations, b – Upper Paleozoic formations, XVIII Fatricum: a – Mesozoic formations, b – Upper Paleozoic formations, c – crystalline complexes, XIX Tatricum: a – Mesozoic formations, b – Upper Paleozoic formations, c – crystalline complexes. Tectonic boundaries: a - main Paleoalpine nappes, b – other overthrust lines, c – unspecified faults.

are covered with superficial Fatricum and Hronicum units on the eastern edge. The north-eastern side is covered by Neogene volcanic complexes. The crystalline basement is the basic building block of the crust and it has its internal older – Hercynian structure generally defined as a set of middle crust lithotectonic units *(Bezák et al., 1997)*.

3. Geophysical input data

The magnetotelluric sounding provides information about distribution of resistivity/conductivity properties within the Earth. The magnetotelluric 2D profile measurements of the seismic profiles within the CELEBRATION 2000 project (e.g. *Guterch et al., 2003*) were performed by the company ELGI Budapest to the depth of 50–60 km and by the Geophysical Institute of the Slovak Academy of Sciences to the depth of 120 km *(Vozár, 2004; 2005)*. In this work we interpret the part of MT profile MT–15 which crosses the Tribeč Mts. (Fig. 1). The measured 2D data were processed to impedance transfer function *(Semenov and Kaikkonen, 1986)* and inverted by 2D inverse algorithm *Nowożyński and Pushkarev, 2001)* to 2D geoelectrical models. When interpreting the geoelectrical models, it was discovered that the near-surface rock complexes in the Tribeč mountain range generate a quite high measured resistance of 1000–1800 Ωm. At the depth of 2–6 km, a subhorizontal layer with a low measured resistance of 100–800 Ωm was identified (Fig. 2). These data are in accord with the results from gravimetry and refraction seismic measurements *(Vozár et al., 1999; Grad et al., 2006)*. It seems that the crystalline massif of the Tribeč mountain range is composed of a couple of physically different lithological environments with notable differences between the individual resistance values.

In the profile through the Razdiel section of the Tribeč Mts. a relatively negative gravimetric anomaly is manifested as a result of the effects of the Neogene sediments stretching towards south-east *(Szalaiová et al., 2005)*. Even the late Paleozoic and Mesozoic complexes are represented in the relatively shallow layer. The curve of the complete Bouger anomalies shows remarkably positive values in the massif, limited on both sides by major weight gradients. When interpreting the weight effects it was identified that the rock protruding into the surface structure cannot cause such an intensive positive anomaly due to its volume and density parameters. This is why it was necessary to compensate this gravity effect with another type of crystalline material in the bedrock (e.g. metasediments of mica-schists character). The properties of the magnetic field *(Kubeš et al., 2008)* also support the existence of such a complex in the bedrock. The presence of such heavy rocks in the bedrock of the massif is also expected by *Šefara et al. (1987)*. A zone characteristic of the alternations of positive and negative weight heavy rocks in the bedrock of the massif is located on the south-eastern side of the Tribeč mountain range at the contact with neovolcanic complexes.

Apart from regional mapping and geophysical evaluation *(Lanc et al., 1995)*, the complex inner structure of Tribeč Mts. was examined also for the purpose of mineralization and radioactive waste storage location.

4. Interpretation of MT measurements

Several of conductive zones (A–F in the Fig. 2) can be identified in the interpretation of the SE part of MT–15 section, which traverses Tribeč Mts. at the interface of its Zobor and Razdiel parts. These zones are interpreted in Fig. 3.

The Zones A–C are superficial (up to 1 km). Zone A represents a Tertiary sediments - the filling of the Hornonitrianska kotlina basin and underlying Mesozoic sequences. Zone B is interpreted as tectonically disrupted granitoids in the massif. In Zone C, mainly the volcanic complexes and sediments underneath are conductive.

The deep conductive zones are either subvertical (Zone D) or subhorizontal (Zones E and F). The subvertical Zone D runs very deep and it is interpreted as a deep, young shear zone along which the Tribeč block moved to the north-east in the Neogene. Tectonically disrupted rocks in this zone are an ideal environment for the migration of fluids and CO_2, which can result in the creation of carbon surfaces causing high conductivity. It is a crushing zone for crystalline rocks and an open path for fluids, and the creation of graphite by CO_2 condensation. The relatively thick subhorizontal Zone E, located under the granitoid body, is interpreted as a set of metamorphic rocks (metasediments of gneiss or mica schist character), which is also asserted in the results collected by other geophysical methods, mainly gravimetry. A tectonic position where granitoids are located above metamorphites is typical for the Hercynian orogene - the upper Hercynian

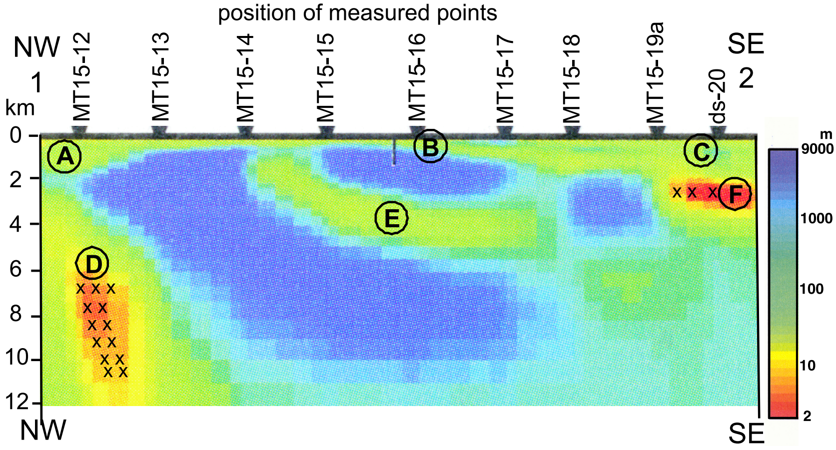

Fig. 2. Interpreted part (1–2) of magnetotelluric cross-section MT–15 with conductive zones (A–F).

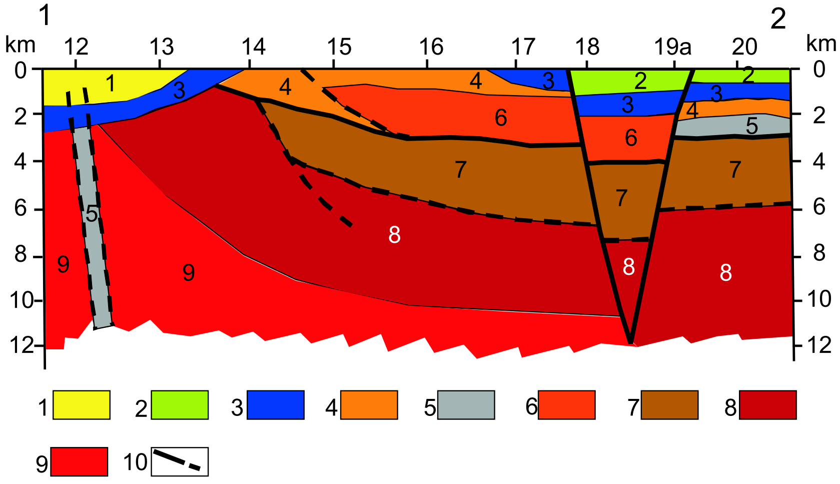

Fig. 3. Geological interpretation of the part (1–2) of magnetotelluric cross-section MT–15. Explanations: 1 – Neogene and Paleogene sediments, 2 – Neogene volcanics, 3 – Upper Paleozoic and Mesozoic complexes, 4 – fractured granitoids of the Tribeč Mts., 5 – high conductive shear zones, 6 – compact granitoids, 7 – complex of metamorphic rocks, 8 – higher resistive granitized crystalline complexes, 9 – crystalline complexes with lower resistivity (with higher content of metamorphic rocks and basic rocks), 10 – faults.

unit in the sense of *Bezák et al. (1997)* vs. middle unit, and/or middle vs. lower unit. These tectonic units generally converge in the south and they are inclined to the north. The shape of the conductive body better corresponds to the Paleoalpine tectonic structures, which is quite logical in the proximity of a major tectonic suture. It is commonly known that the Hercynian tectonic structures were often transformed into the newer Alpine ones. The question of which part of the Hercynian tectonic unit was transformed in this area, i.e. whether the granitoids contacted its metamorphic cower or the middle unit contacted the lower one, remains open. At this stage, we tend to support the former claim: we expect the standard West-Carpathian crystalline structures under the conductive metamorphics other body mainly with granite composition and not the Cadomian basement, which should theoretically appear underneath the lower unit. This issue will be studied in a greater detail in the future.

What still stands out is the interpretation of the subhorizontal layer in the conductive Zone F in the area under the volcanic complexes. Based on the depth layering data and other geological indications, this zone is already part of the crystalline units. It is probably a rejuvenated, older Hercynian mylonitized zone on a tectonic interface area between the granitoids and metamorphites. This area is also crossed by various veins and subvolcanic bodies which could have been the sources of fluids, carbon and mineralization saturating this crushed mylotized zone, thereby increasing its conductive properties.

Our interpretations are in accord with the results from previous geophysical measurements, mainly the gravimetric and magnetic ones.

5. Conclusion

Geophysical measurements have been carried out in the Tribeč mountain range for the purpose of extracting mineral resources and constructing a storage location for radioactive waste. Gravimetric, magnetometric and geoelectric methods were applied. Zones with disrupted granitoids, granitoid pockets with higher magnetic values (basic differentiates) and a couple of fracture zones were identified. The results in all the above methods conclude that underneath the granitoid body, which takes up most of the mountain range, there has to be a heavier body with higher magnetic values. This assumption was put forward in *Šefara et al. (1987).* All hitherto interpretations concluded that this body probably consists of metamorphic rocks of mica schist character. The top edge of the body was expected to lie 2–3.5 km deep.

In the CELEBRATION 2000 project, the range also includes a seismic section where MT measurements were performed. These were interpreted in the section and confirmed the existence of a subhorizontal zone with higher conductivity with a slight south-east inclination in the depth of 2 to 6 km under the granitoids. This zone may correspond to the above mentioned conductive complex of metamorphic rocks. This tectonic position of the unit with metamorphic rocks in between the granitoids and/or granitized rocks is in harmony with the tectonic structure of the Hercynian crystalline even though its current position is affected by Alpine tectonic processes.

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