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GEODETIC AND GEOPHYSICAL ANALYSES OF DIENDORF–ČEBÍN TECTONIC ZONE

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ABSTRACT
In the contribution the results of repeated precise levelling and GPS measurements at the central part of the Diendorf-Čebín tectonic zone (DCTZ) are presented. This morphologically very expressive tectonic system that belongs to a typical type of transcurrent tectonic system, with activity from Protherozoic up to recent period in separate parts is considered to be a seismoactive fault, too. Preliminary results at two measured profiles across central part of eastern marginal fault of the Boskovice Furrow confirmed expected vertical movement tendencies. It is evident that all tectonic system is seismoactive not only in the Lower Austria district but also in its northern continuation.

KEYWORDS: Diendorf fault, Boskovice Furrow, levelling, GPS, gravity, geodynamics

INTRODUCTION

Recent studies of lithosphere of Central Europe, mainly based on the complex analysis of geological, geochemical, structural and geophysical data (especially gravity, magnetic, seismic and magnetotelluric data), enabled to develop the appropriate model of the genesis in the area of the Alps, the Carpathians and the Pannonian Basin for the period from the Lower Miocene to the Recent.

More complicated situation arises in surveying of the geodynamic conditions for this period in the area of the Bohemian Massif and the boundary areas of the East European Platform.

In the contribution we deal with the possibility of usage of the comprehensive geological-geophysical knowledge for determination of movement tendencies in the one of critical areas - Area III – Diendorf-Čebín tectonic zone, that might (from the geodynamic and mainly seismotectonic point of view) represent major tectonic risks for the eastern part of the Bohemian Massif (Fig. 1).

DIENDORF – ČEBÍN TECTONIC ZONE (DCTZ)

In the Bohemian Massif territory, in addition to mentioned recently geodynamical active regions of the Western Bohemian, Sudetes, etc., our attention is concentrated on structurally and tectonically complicated the Boskovice Furrow. This Variscan structure of the first order, filled by perm-carboniferous sediments, in prolongation to Austrian part suggests connection with recently seismoactive zone of the Diendorf fault system. The aim of a forthcoming geodetic-geophysical surveys is to verify and prove connection and common activity of these two large structural and tectonic elements.

The proposed surveys will be focused on the geodetic, remote sensing and geophysical mapping and investigation along the whole tectonic zone, specially at the area where the connection of the Diendorf fault with the Boskovice Furrow is covered by relatively thick sediments of Neogene.

The Diendorf fault represents intensive seismotectonic system described in detail at first by Figdor and Scheidegger (1977 – Fig. 2). After the data on seismic intensities, zone of decreased density, the shape, size and depth of the anomalous low- density mass they indicate the shift of the two sides of fault to be approximately 40 km (Fig. 2).

Furthermore, measurements of the orientations of joints and structural data confirm long time activity of this tectonic zone (Figdor and Scheidegger, 1977; Behr et al., 1984; Brandmayr et al., 1995; Jelínek at al., 2003 – Fig. 2A).

In satellite images and air orthophotos these faults appear to be geomorphologically very steep edges, with facets. In recent times it can be considered as active tectonic boundary. Preliminary research works have revealed new information about historical seismic events in this territory near Znojmo town. The crackled band, crumbled town wall etc. on 1581, July 21, near a midnight had been described in the chronicle of Znojmo town (Vrbka, 1902).

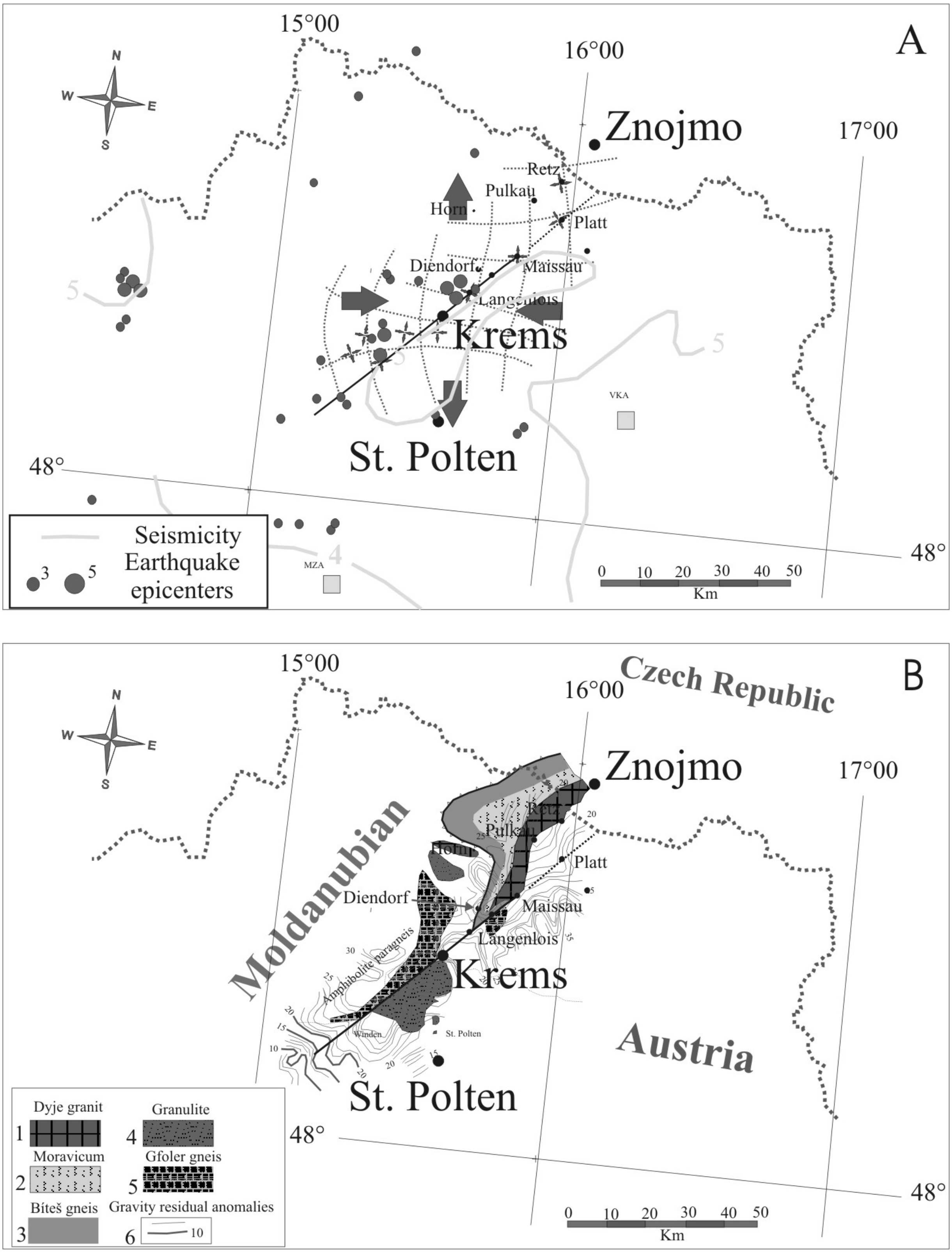

Fig. 2 The anomalous structural and geophysical data interpreted by Figdor and Scheidegger (1977) modified by the authors on the southern segment of tectonic system. Explanations: B - 1 - Dyje granit, 2 – Moravicum, 3 – Býteš gneiss, 4 – Granulites, 5 – Gföler gneiss, 6 – Gravity residual anomalies.

The Diendorf – Čebín tectonic zone is composed of two different tectonic parts – the Boskovice Furrow and Diendorf fault system. Each part has been influenced in Tertiary by quite different processes and in recent image characterizes quite different tectonic predisposition.

The Boskovice Furrow (BF) is an elongated asymmetrical basin oriented in the SSW-NNE direction filled with Permian - Carboniferous sediments, especially sandstones and conglomerates. Present width of the basin is only 5-12 km and the length is about 90 km, but the original extent was larger. The basin has been formed along the major SSW-NNE trending marginal fault (the main fault of the BF) that can be considered as the continuations of the Diendorf fault in Austria. The first mention about transcurrent character of the fault is described by Cloos (1948). The whole length of the fault extends 200 km. Tectonic subsidence driven by this fault was important factor that controlled the deposition and depositional processes in the basin. The first stage of formation of the basin was the extensional period, during which the Permian - Carboniferous sediments were formed. The extensional period was accompanied by intermediate to acid volcanism. This period was followed by a compressional stage which deformed the sedimentary fill composed of the Carboniferous and Permian deposits. It also led to thrusting of the Brunnia Massif and locally also Devonian and Lower Carboniferous rocks over the eastern margin of the basin. Internal part of the basin was overthrust to the west forming a few duplexes.

The basin is also transversally segmented by a number of NW-SE trending faults/elevations. The existence of several sub-basins within the BF with partly different sedimentation history was predetermined by these structures. The Tišnov – Kuřim Ridge is the northern margin of interest area.

The deposition in the basin started in its southern part (Rosice – Oslavany area) during Stephanian with coarse-grained red conglomerates and breccias and spread towards the N and NE. The sedimentation ceased at different time in various parts of the basin, however, the deposition in the major part of the basin finished during Lower/Middle Autunian (Jelínek et al., 2003).

Strongly asymmetric distribution of sedimentary facies and depositional environments is typical for the BF. The deposition commenced with breccias and conglomerates within the whole basin, however, two different facies successions developed afterwards in the opposite (E – W) parts/ limbs of the basin.

The Diendorf fault (DF) characterizes the mylonitic fabrics developed within conjugate wrench ductile shear and fault systems in the Southern Bohemian Massif that display sinistral (NE-SW-trending systems) shear senses. Brittle deformation dominated in the Diendorf shear zones. Brittle deformation within the shear zones was probably associated with maintenance of very high fluid pressure during the Variscan deformation (Brandmayr et al., 1995).

The Miocene tectonics and Miocene shortening was compensated by a combination of north-directed thrusting over the European basement, shortening of the upper plate by crustal-scale folding and the lateral extrusion of wedges out of the collision zone (Nemčok et al., 2006). The fault pattern in the Eastern Alps is dominated by Miocene thrusts and strike-slip faults, which formed in N-S to NW-SE compressive paleostress field (Decker et al., 2002). The paleostress directions obtained for the Miocene are roughly comparable to recent NNW- to NW-directed compression derived from focal solutions and in-situ stress measurements.

The preferred strike direction of 10 groups of outcrops in the vicinity of Diendorf fault were determined by Figdor and Scheidegger (1977); they show a basic similarity, except for a deviation by about 30° at the entrance of Wachau in the direction of the break-through of the Danube. The principal directions calculated from the joints form an essentially E-W and N-S system for the entire region what coincides with the latest results. Damaged areas may indicate a zone of tectonic activity along a line in the vicinity of the Diendorf fault.

METHODOLOGY

Methodology of investigation is based on combination of three independent geodetic and geophysical methods – repeated levelling, GPS and gravity measurements (the beginning is expected in 2009). The geodetic measurements – precise levelling started in 2008 year at two profiles. This period we considered a preliminary stage. During this period the possible activities have been checked along central part of DCTZ. Within the following period, between the years 2009 –2010, the measurements will be realized at additional 3 to 6 profiles located in area between the towns Brno and Znojmo (Fig. 3). The period of repeated measurements has been different, from 2 to 6 months. The measurements were supplied with analyses and interpretation of complex geophysical data, specially the gravity, magnetic and gammaspectometric maps, with utilization of archive data and remote sensing studies concentrated on the exogenic dynamic analyses.

At each profile 6 – 10 measured points are stabilized in dependence on available network of control levelling points in the area. Length of the profiles is planned to be between 2 and 5 km maximally. For future period the repeated measurements will be realized in 3 months or half years intervals.

REPEATED PRECISE LEVELLING

The Precise Levelling (PL) method is being used as a basic method for vertical changes detection. In the course of data processing all the relevant corrections are introduced (i.e. staff comparation correction, gravimetric correction, astronomical correction). Calibrated modern electronic levels are used for the profiles measurements, which ensure reaching of sufficient vertical accuracy with observation times reductions.

GPS MEASUREMENTS

Results of GPS surveying are used for determination of eventual horizontal displacements of the profile points and also for the independent rough checking of the vertical changes detected by levelling. The reduced observing scheme proposed for GPS surveying as an alternative to long static observations is based on combination of shorter sessions with optimized separation intervals. It is convenient to combine two (dyad), or better three (triplet) static sessions of 60-90 minutes duration, measured in separation of six to eight hours after each other - see e.g. (Kostelecký et al, 2002; 2004; Švábenský and Weigel, 2004). The session duration is comparatively short, therefore the importance of reliable ambiguity resolution is emphasized, and the detection and mitigation of multipath and diffraction effects is desirable. Appropriate modelling of the local (quasi) geoid is important for GPS absolute heights determination.

REMOTE SENSING, GEOPHYSICAL AND EXODYNAMIC DATA ANALYSES

The geodetic research and measurements are combined with an analysis of the Remote Sensing, gravity, magnetic and gamma-spectrometric data, covering the complete area of BF (Fig 4). Special volume of works is aimed to exodynamic analyses of the area, too. For these purposes the Institute of Geodesy has gained a set of images (Landsat ETM, QB, classic B/W air photos for stereoscopic analyses and orthophotos). The Complete analyses and processing of mentioned data are processed by tools of GIS technology tools (ArcInfo, Geomedia Professional, PCI, ER Mapper SWs are available). The aim of this analysis is to engage in possible inaccuracy during monitoring of the movement tendencies sequent to existence of many landslides and former mines in this area. Their slumping in character can provoke much larger movements than actual dynamic deformation of the fault system.

The measurements of the research will be supplied with permanent works combined with assignment of PhD a Diploma theses in the range of 5 years. These works and results could serve for supplement of additional information and methodology actualisation during running project.

The samples of geological and geophysical maps are presented in Figure 4. Very surprising results are observable at magnetic map, where DCTZ plays role of separating boundary between the Brunnia Massif outcrop (right) and its separated parts hidden bellow Moldanubian complexes at western side of the fault system. Special transformation of magnetic data much better emphasizes a linear feature in comparing e.g. with gravity data.

PRELIMINARY RESULTS

Two profiles going across the geotectonic fault near Rosice, about 20 km westward from Brno, were realized in period 2008 -2009. The first of them is localized near Tetčice village, the second one is placed near Neslovice village (Fig. 5). Each profile consists of 10 points stabilized in 5 groups of two nearby benchmarks. The profiles were repeatedly measured by precise geometrical levelling – preliminary results are shown in Figures 6 and 7.

At profile 1 – in Tetčice village the movement variations can be considered at points Nos. 101 to 104. The points Nos. 107 to 110 subside permanently. The largest changes of vertical movements can be indicated between point Nos. 105 and 107. The movement at points Nos.101 to 104 can be influenced by higher level of ground water at the end of winter period, or by oblique and perpendicular faults mapped in this zone. Many fissures at walls of several houses speak in favour of such explanation.

In case of points Nos. 107 to 110 we can present two ways of interpretation: the first one could be that the measurement is influenced by earlier mining activities in region, the second one, which we consider to be more relevant at this moment, may lie in the fact of larger changes of ground water reservoir for Rosice town and surroundings located just near this point No.107. Next period of observation we shall concentrate on this problem in greater detail. New network will be built for both levelling and GPS measuring in this locality.

The observations at profile 2 – in Neslovice village have proved possible subsidence at points Nos. 201 and 203. Position of eastern master fault of BF is coincided with point No. 203. At points Nos. 204 to 210, the relative uplift has been monitored.

On the base of comparing of both measured profiles it is evident, that geological resemble condition of tectonic building have different movement tendencies near the fault zone. Near by Tetčice village much more effects influencing the measurements have to be expected than supposed. Evidently at least three phenomena can be considered as complication feature – undermining, ground water and perpendicular and oblique tectonics.

By comparing the repeated levelling results with gravity images of this tectonic zone, discrepancy between geological position of fault and gravity gradient arises. The gravity gradient is very shallow and extends more to central part of BF (Fig. 8).

One of many explanations we suppose a model where the Brunnia blocks reaches much far bellow of Boskovice Furrow. The gravity effect of sedimentary

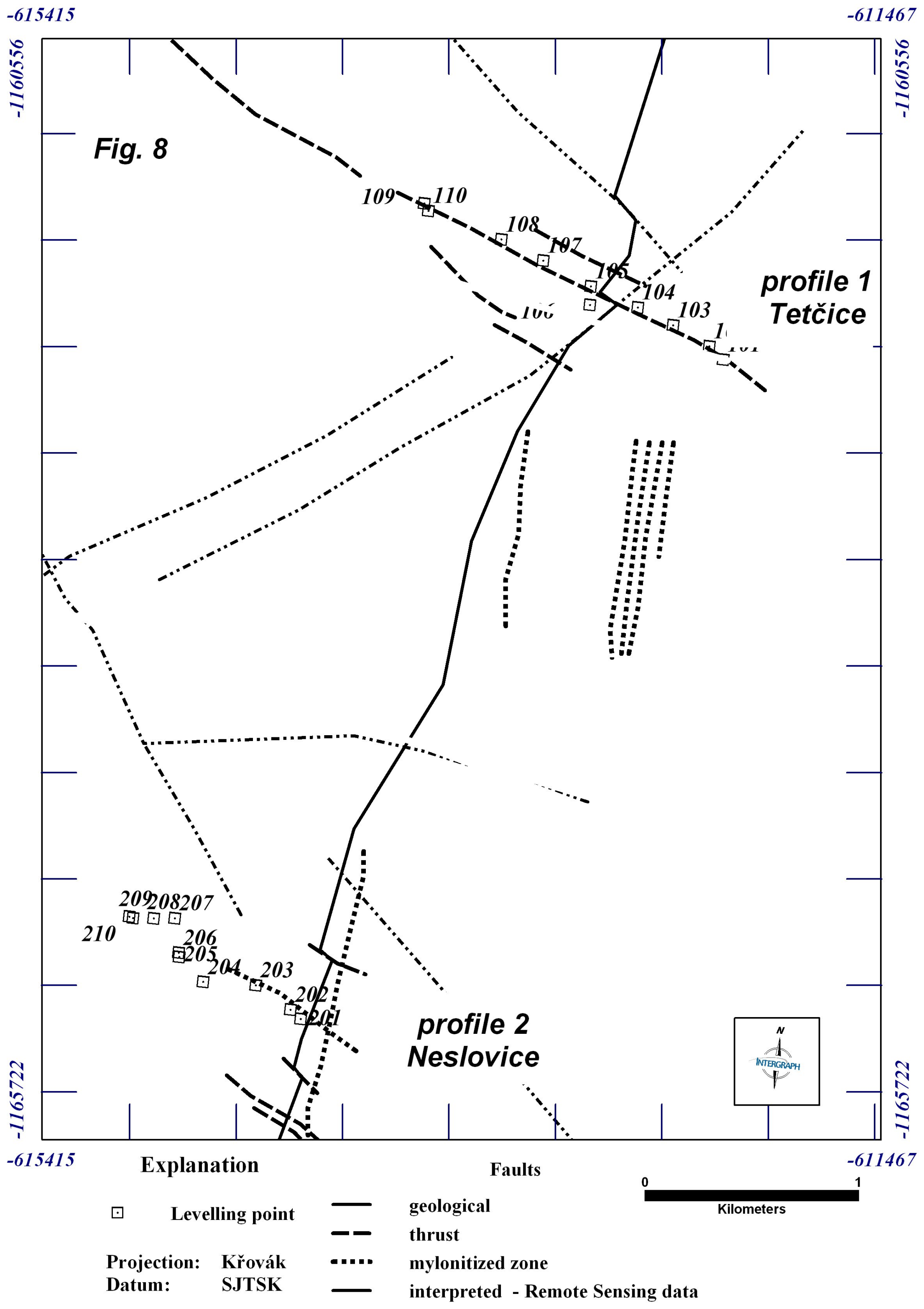

Fig. 5 The location of measured profiles supplied by simplified tectonic scheme. Explanation: triangles – measured points, black lines – known geological faults, doted line – mylonitized zone, dashed line – trust and hidden faults.

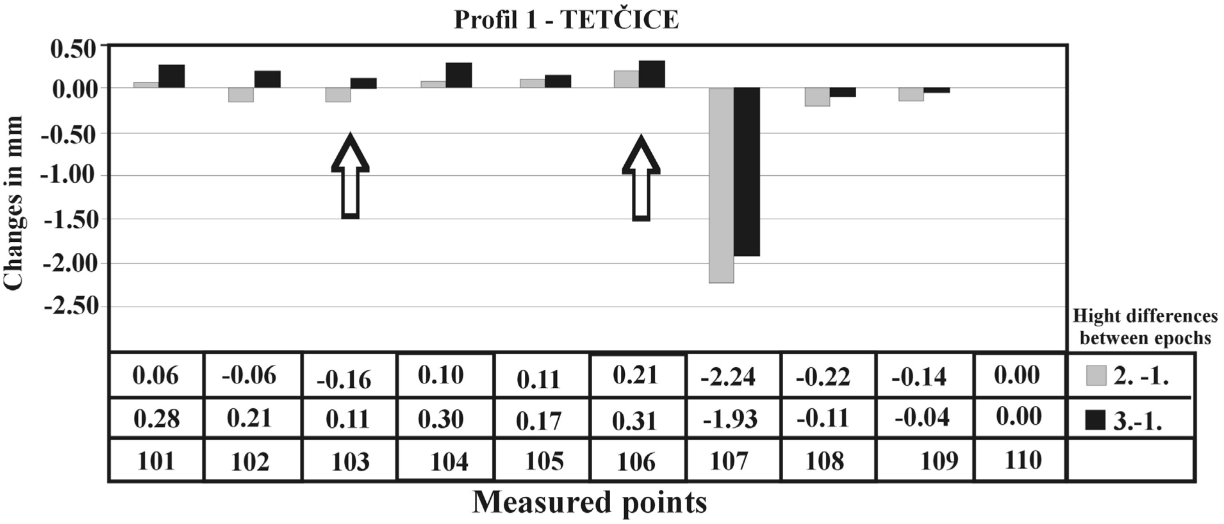

Fig. 6 The result of the vertical movements along Tetčice profile. Marginal fault of DCTZ is located near point No. 106 (arrow). The fault identified on the base of remote sensing and geophysical data crosses the profile between benchmark Nos. 103 and 104 (Fig. 5). Explanation: Gray column - the high differences between the 2nd and the 1st epochs of measuring, black column - the hight differences between the 3rd and the 1st epochs of measurements.

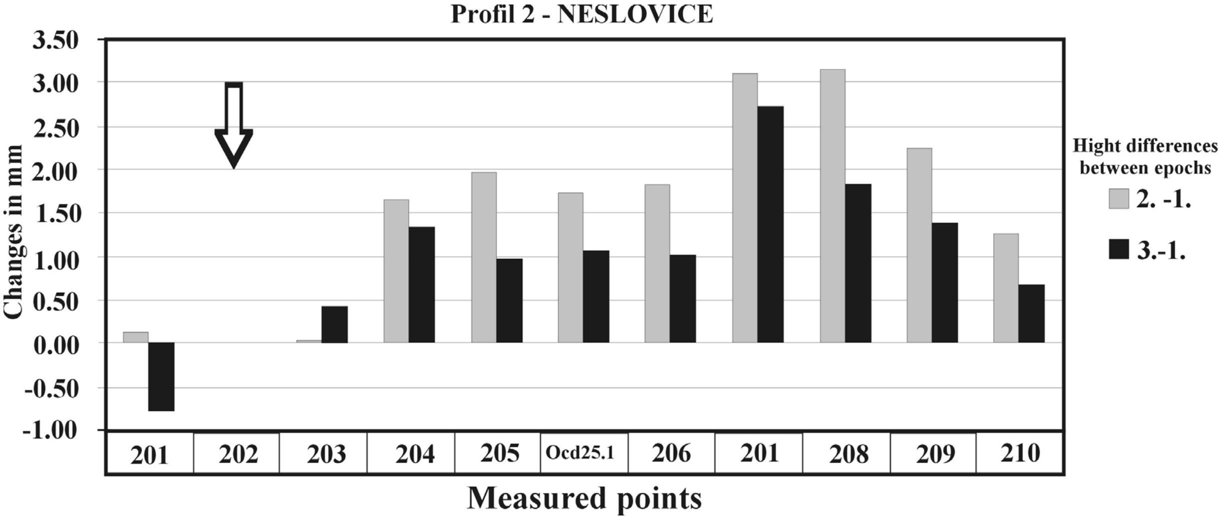

Fig. 7 The result of the vertical movements along Neslovice profile. Marginal fault of DCTZ is located between points No. 202 and 203 (arrow). For explanation see Figure 6.

filling (Permian - Carboniferous) self over complexes of Brunnia block shows minimal contrast. Density difference of sediments over crystalline rocks is 0.025kgdm^{-3} (if we consider 2 km thickness of sedimentary layer approximated by thin prism). It could mean no obstacle for application of repeated gravity measurements in next campaigns in combination with levelling and GPS. The measuring of gravity will be influenced mainly by changes and movements of ground water and tectonics.

ANALYSES OF GPS RESULTS

Six points in each profile were observed by static GPS method. Measuring procedure followed the triplet pattern – see above. For evaluation and testing purposes the virtual reference station (VRS) data were generated within the CZEPOS (Multipurpose GPS Positioning System for the Czech Republic - http://czepos.cuzk.cz/) in three selected positions. The first VRS (denoted as V) was placed between the both profiles with average distances to profile points about 2 km. The second and the third VRS (denoted as V1,

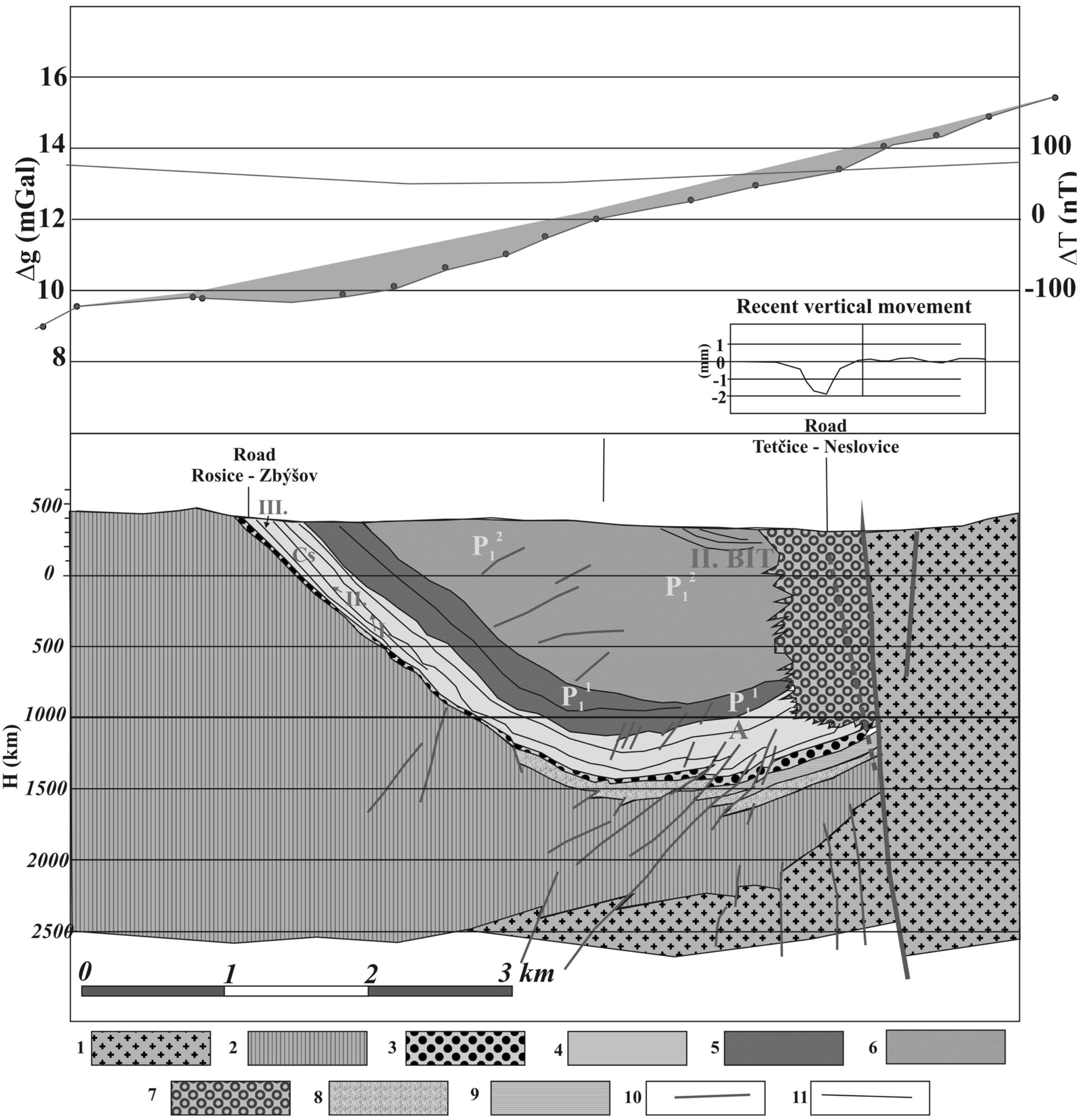

Fig. 8 Geological profile Babice – Tetčice (Malý, 1993), modified on the base of geophysical and geological data. Explanation: 1 - granodiorites of the Brunnia Massif with crystalline mantle relicts; 2 - Biteš orthogneisses; 3 - Balinka conglomerates; 4 - Lower gray formation in the roof of the seam with the lover Autunian coal development (A); 5 - Middle red - and upper gray formation with first horizon of bituminous marlites (p_1^1); 6 - formation of feldspathic sandstones, arkoses and conglomerates of the Oslava facies and the upper red formation with the second horizon of bituminous marlites (p_1^2); 7 - Rokytná conglomerates; 8 - Phyllite series; 9 - Culm, Stephanian; 10 -Tectonic lines, 11 - Coal horizont.

V2) were situated near centre of each respective profile with average distance to profile points under 1 km. In triplet observation pattern each of the profile points had been measured three times within 24 hours (8 hours spacing).

In the following Table 1 the accuracy of GPS triplet derived height differences is presented in respect to PL results (rms of triplet and PL solution differences) for the three VRS mentioned above, and for two real reference stations (RS) TUBO and CMOK which are included in the CZEPOS permanent network. The results show again almost equal accuracy level for all near VRS used, similar also for both more distant real reference stations.

Table 1 Accuracy of GPS static height differences – RS and VRS performance.

Tetčice	reference	**TUBO**	**CMOK**	**V**	**V1**	**V2**
from - to	distance	14 km	15 km	2 km	0.5 km	3.7 km
101-102	rms [m]	0.0122	0.0085	0.0118	0.0123	0.0120
105-106	rms [m]	0.0125	0.0120	0.0084	0.0074	0.0085
109-110	rms [m]	0.0042	0.0009	0.0005	0.0017	0.0011
	av. rms [m]	**0.0097**	**0.0071**	**0.0069**	**0.0071**	**0.0072**
Neslovice	reference	**TUBO**	**CMOK**	**V**	**V1**	**V2**
from - to	distance	17 km	12 km	2 km	3.5 km	0.3 km
202-201	rms [m]	0.0144	0.0038	0.0061	0.0074	0.0062
206-205	rms [m]	0.0045	0.0029	0.0016	0.0066	0.0028
210-209	rms [m]	0.0037	0.0058	0.0029	0.0023	0.0029
	av. rms [m]	**0.0075**	**0.0042**	**0.0035**	**0.0055**	**0.0039**

Table 2 GPS baseline changes in respect to V (transversal).

Tetčice point	**Dist. (E1)** [m]	**Dist. (E2)** [m]	**Diff.1-2** [m]	**Neslovice** point	**Dist (E1)** [m]	**Dist. (E2)** [m]	**Diff.1-2** [m]
101	1947.5756	1947.5904	0.0148	201	1898.5909	1898.5979	0.0070
102	1940.3798	1940.3812	0.0014	202	1870.1208	1870.1150	-0.0058
105	1824.8048	1824.8023	-0.0025	205	1878.1305	1878.1260	-0.0045
106	1746.5334	1746.5303	-0.0031	206	1863.5812	1863.5741	-0.0071
109	2002.5665	2002.5656	-0.0009	209	1874.6886	1874.6902	0.0016
110	1968.9683	1968.9580	-0.0103	210	1881.6426	1881.6467	0.0041

Table 3 GPS baseline changes in respect to V1, V2 (longitudinal).

Tetčice point	**Dist. (E1)** [m]	**Dist. (E2)** [m]	**Diff.1-2** [m]	**Neslovice** point	**Dist (E1)** [m]	**Dist. (E2)** [m]	**Diff.1-2** [m]
101	772.9098	772.9146	0.0048	201	480.7444	480.7466	0.0022
102	686.6449	686.6494	0.0045	202	418.2668	418.2714	0.0046
105	65.5551	65.5539	-0.0012	205	160.2615	160.2609	-0.0006
106	114.5800	114.5809	0.0009	206	172.3546	172.3608	0.0062
109	811.8188	811.8121	-0.0067	209	440.7560	440.7575	0.0015
110	778.6669	778.6630	-0.0039	210	458.8801	458.8775	-0.0028

In Tables 2 and 3 the horizontal positional differences of points of both profiles between measuring epochs 1 and 2 are presented. In Table 2 the baseline distance differences in respect to the central virtual reference station V (that is in profile transversal direction) is presented, and in Table 3 the baseline distance differences in respect to the central reference station of each profile V1, V2 (that is in profile longitudinal direction) is shown. The differences are under 12 mm (what is the 2 sigma threshold) for all the profile points, with exception of transversal shift of point 101 in Tetčice profile. Even for this point the suspected horizontal displacement needs corroboration over a longer time span. The results have to be taken as preliminary.

Table 5 Baseline epoch height differences PL – GPS.

Tetčice	epoch height differences PL – GPS [mm]			
baseline	E0	E1	E3	height difference rms
101-102	-1.0	3.2	3.5	**2.5**
105-106	1.6	-0.2	3.4	**1.8**
109-110	-1.0	0.6	-3.1	**2.1**
Neslovice	epoch height differences PL – GPS [mm]			
baseline	E0	E1	E3	height difference rms
201-202	14.2	3.4	5.6	**5.7**
205-206	-2.5	-2.7	-9.1	**3.8**
209-210	-0.8	-0.7	-6.7	**3.4**
epoch rms	**6.3**	**2.4**	**6.2**	**average rms 5.0 mm**

In the Table 4 the baseline epoch vertical component differences between precise levelling (PL) and GPS results are shown, together with epoch and baseline accuracy estimates (rms). It follows that in Tetčice profile the conditions are more favourable for GPS surveys than in Neslovice profile, where two maximum values occurred. Nevertheless, the average rms of a GPS height difference in respect to PL was 5 mm.

CONCLUSIONS

The study confirms that the recent activity of the same areas is much larger than could be supposed. DCTZ belongs between one of these localities. Monitoring of two chosen profiles demonstrate recently very important movement tendency anomalies at eastern margin of the Boskovice Furrow. Preliminary results show the complicated movements and offer data for follow up research of complicated transition zone between the Diendorf fault and the Boskovice Furrow.

We expect to use methodology in details modified in future period and supplied with repeated gravity measurements and combined with structural and morphological researches.

The results led to the acquisition of more knowledge not only for seismotectonic research of the Boskovice Furrow or wide surrounding of the Brno agglomeration but also for urbanite decision concerning utilization of the Boskovice Furrow as strategic transport corridor in future periods. Any movement activities in the narrow tectonic zone of the Boskovice Furrow have to be considered as negative and complicating feature in urban planning of the area.

On the bases of geo-data, the DCTZ itself can be ranked among one of the most complicated and risk area of the Bohemian Massif.

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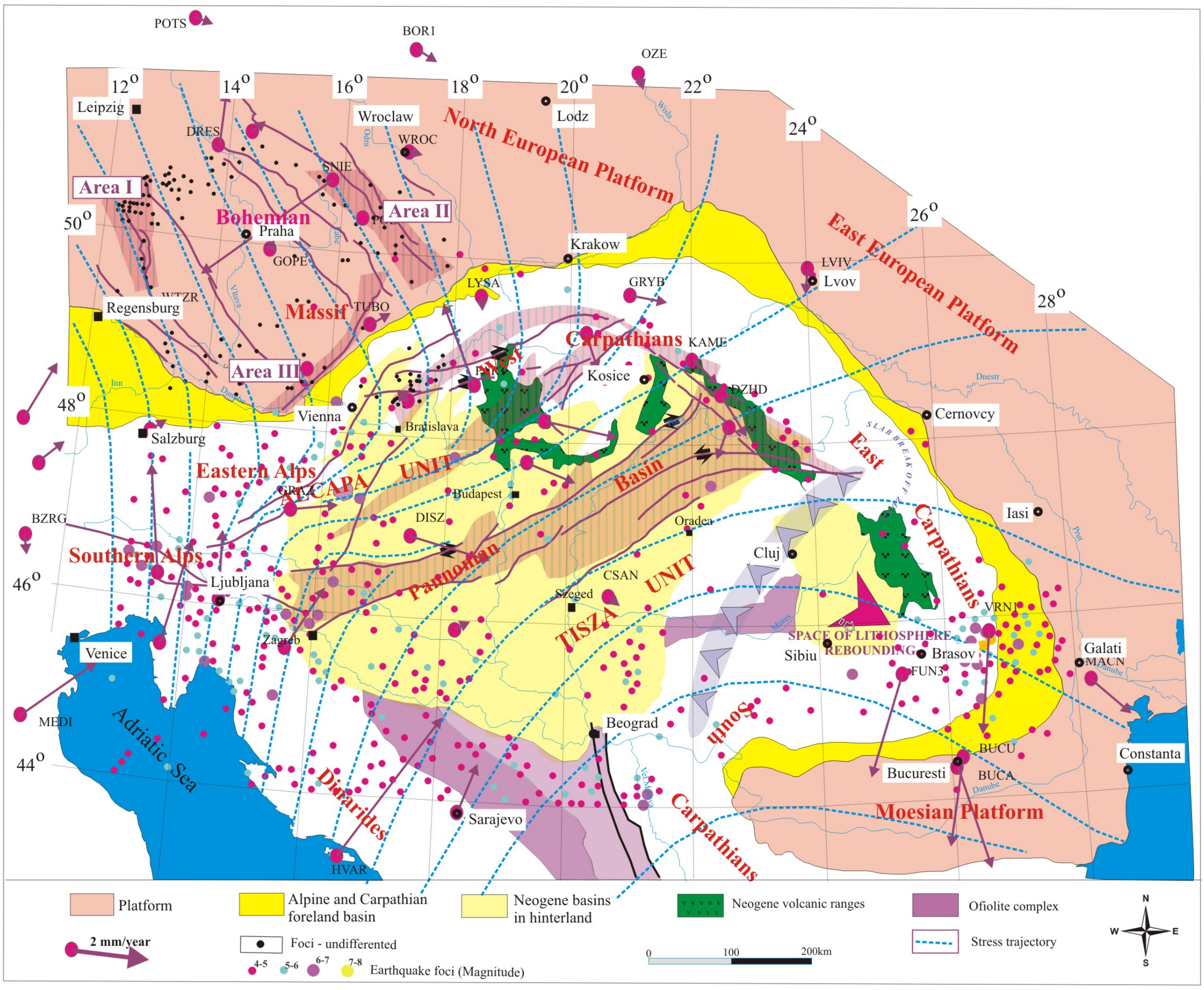

Fig. 1 The map of Central Europe with drowned risk areas in the Bohemian Massif and the West Carpathians. Red points - earthquake foci (Zsiros, 2000; Pospíšil et al., 2006). Horizontal movement tendencies (GPS measurements) and stress trajectories are modified after Hefty and Gerhátová (2006) and Szabo et al. (2004). Area I - Western part of the Bohemian Massif (Saxothuringian and the Teplá-Barrandian contact zone). Area II – the Sudetic area and Area III – the Diendorf fault – the Boskovice Furrow at eastern margin of the Bohemian Massif.

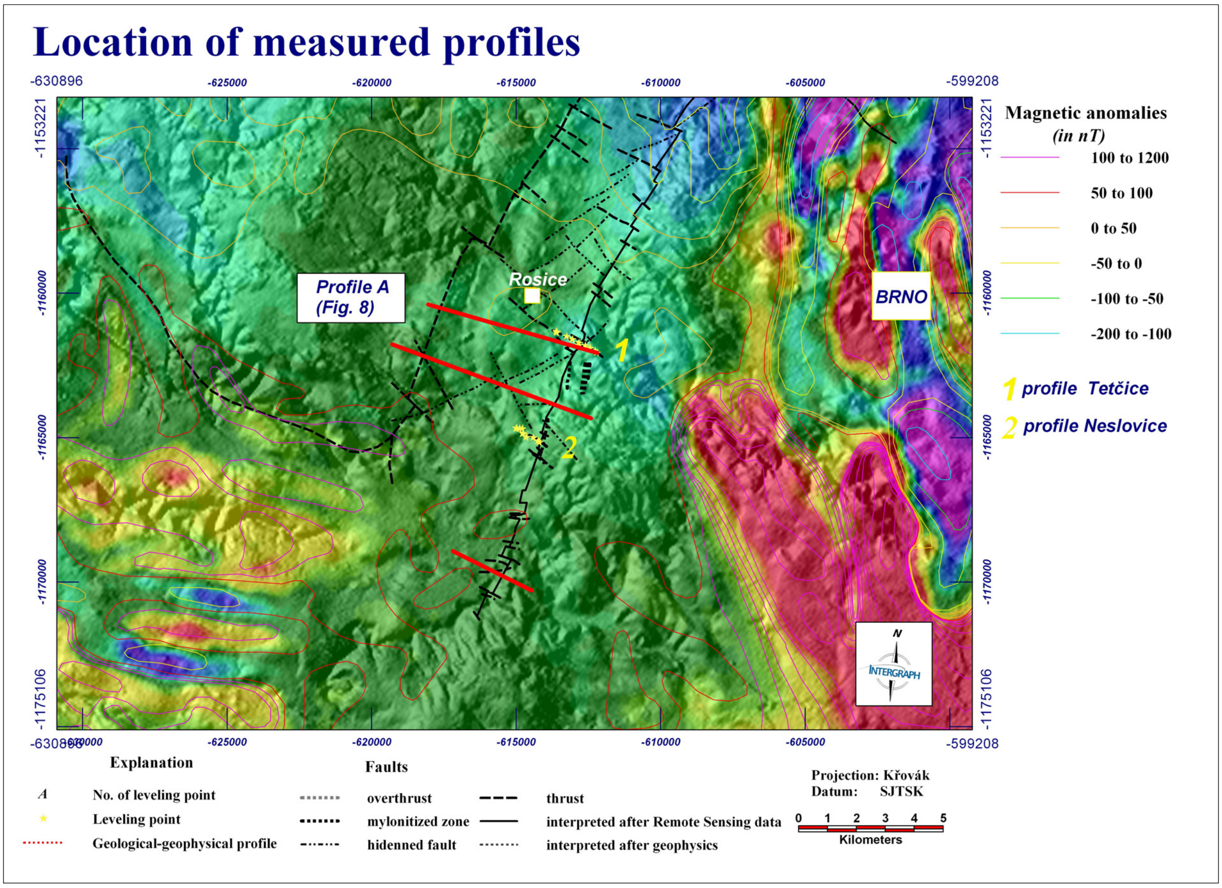

Fig. 3 Situation of the area of interest with location of measured levelling profiles (yellow stars) and supplied by magnetic map combined with radar relief. Red line – geological-geophysical profiles (see Fig. 8).

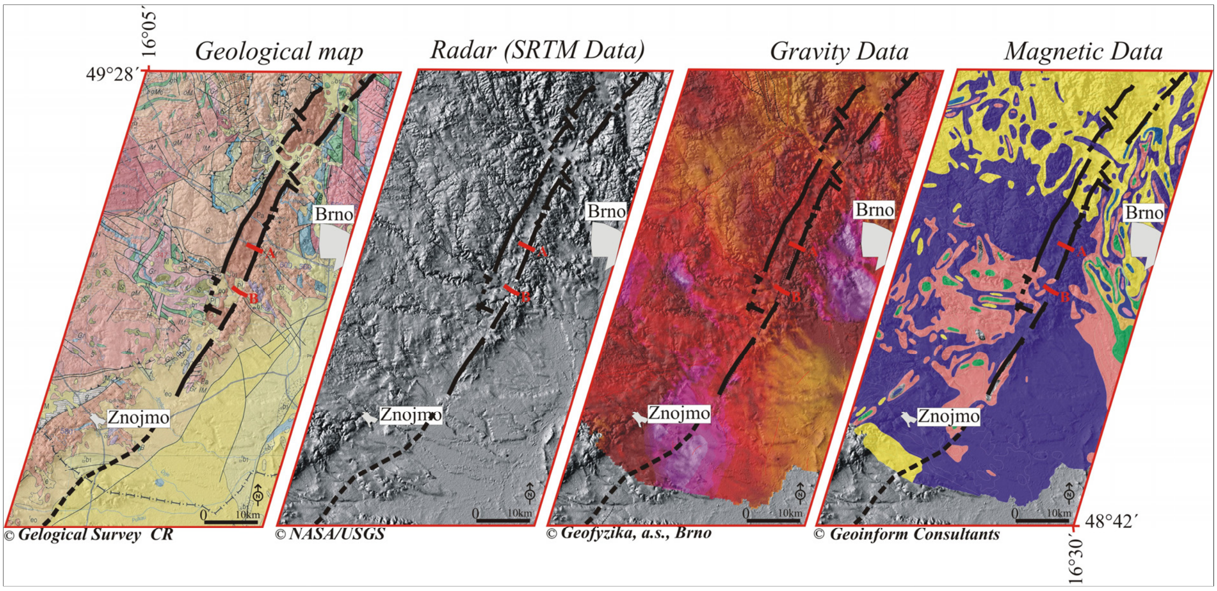

Fig. 4 Example of unified geological and geophysical data along the Diendorf-Čebín tectonic zone. From the left to right – Geological map (ČGS Praha), Radar relief (NASA/USGS), Gravity map (Geofyzika a.s., Brno), Magnetic map – (Geoinform Consultants). White lines represent the measured geodetic profiles at locality Tetčice (A) and Neslovice villages (B).