ACTIVE TECTONICS IN THE EASTERN MARGIN OF THE BOHEMIAN MASSIF – BASED ON THE GEOPHYSICAL, GEOMORPHOLOGICAL AND GPS DATA

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ABSTRACT
One of the leaved out fault active systems at Southern Moravian can be considered the so called Diendorf - Čebín tectonic zone (DCTZ), that is seismically active in its southern segment (in Austrian). The Waitzendorf fault is a part of the DCTZ, with intensive morphological signs .
The terrain recognizance along the eastern margin of the Dyje Dome confirmed many indications showing evidence of geodynamic activity. The facets, old land slides and rock falls indicate recent activity in the environs of Znojmo area. The paper offers interpretation of the geodetic results (GPS) using morphological and geophysical data from all area of the DCTZ .

KEYWORDS: active tectonics, geophysics, GPS, morphology, movement tendencies, Waitzendorf and Diendorf faults

INTRODUCTION

Preliminary GPS positioning results obtained in the territory of South Moravia (Švábenský et al., 2011) have shown relatively intensive movement tendencies between the Bohemian Massif and tectonic units of the Western Carpathians. Particularly tectonic zones the Diendorf-Čebín tectonic zone (DCTZ) and the Bulhary fault play dominant role (Švábenský et al., 2011). It has been the reason for another GPS monitoring at the Znojmo polygon, where the results have confirmed more detailed changes of movements influenced by the tectonic conditions along the Waitzendorf and Diendorf faults. From the morphological and seismotectonic points of view the two faults are among the most important tectonic zones in this territory (Lenhardt et al., 2007) .

For the preliminary analysis the movement tendencies the GPS results have been confronted with geomorphological and geophysical data. On the basis of gained results it is possible to suggest the new more detailed GPS measurements and look for a new tectonic model of the area located on the border of the three main tectonic units – The Moldanubian, Moravian and Brunnovistulian units.

GEOLOGICAL CHARACTERISTICS

The tectonic development of the eastern margin of the Bohemian Massif is rather complicated. The DCTZ creates a active tectonic zone formed during of the Variscan orogeny, later influenced by Alpine processes.

In South Moravian the Bohemian Massif is made up of three basic units – the Moldanubian, Moravian and Brunnovistulian. All units have specific relationship to the DCTZ.

The Moravicum of the Dyje Dome (Dyje Dome) is described as a transitional zone between the Moldanubian Proterozoic and the Proterozoic of the Brunovistulicum. The Moldanubian Proterozoic was completely folded and faulted during the Variscan orogeny, whereas in the Brunovistulian Proterozoic such Variscan overprint could not be observed.

The Brunovistulicum and the Moravo-Silesian Zone (BMSZ) represent Precambrian tectonic unit at the eastern termination of Central European Variscides along the eastern margin of the Moldanubian Zone and the Lugicum (Finger et al., 2000). According to Dudek (1980) three principal structural blocks are subdivided into subunits along major faults: the South Moravian Block, the Central Moravian Block and the North Moravian Block. The southern part of the Central Moravian Block and the predominant prevailing part of the Southern Moravian Block are formed predominantly by granitic plutonites.

According to Klomínský et al. (2010), the Brunovistulicum consists of the Slavkov Terrane (the island arc crust), the Brno-Břeclav Terrane (a late Proterozoic back arc basin) and the Dyje Terrane (an older continental crust). The extraordinary abundance of plutonic basement rocks of Cadomian age represents one of the most specific lithological features of the BMSZ (Finger et al., 2000). Mainly amphibolite facies crystalline schists were formed by metamorphism of monotonous metasediments with minor amounts of volcano-sedimentary series containing metabasites.

During the Variscan orogeny, the western part of the Brunovistulicum was folded and trusted and incorporated into the structure of the Variscan fold

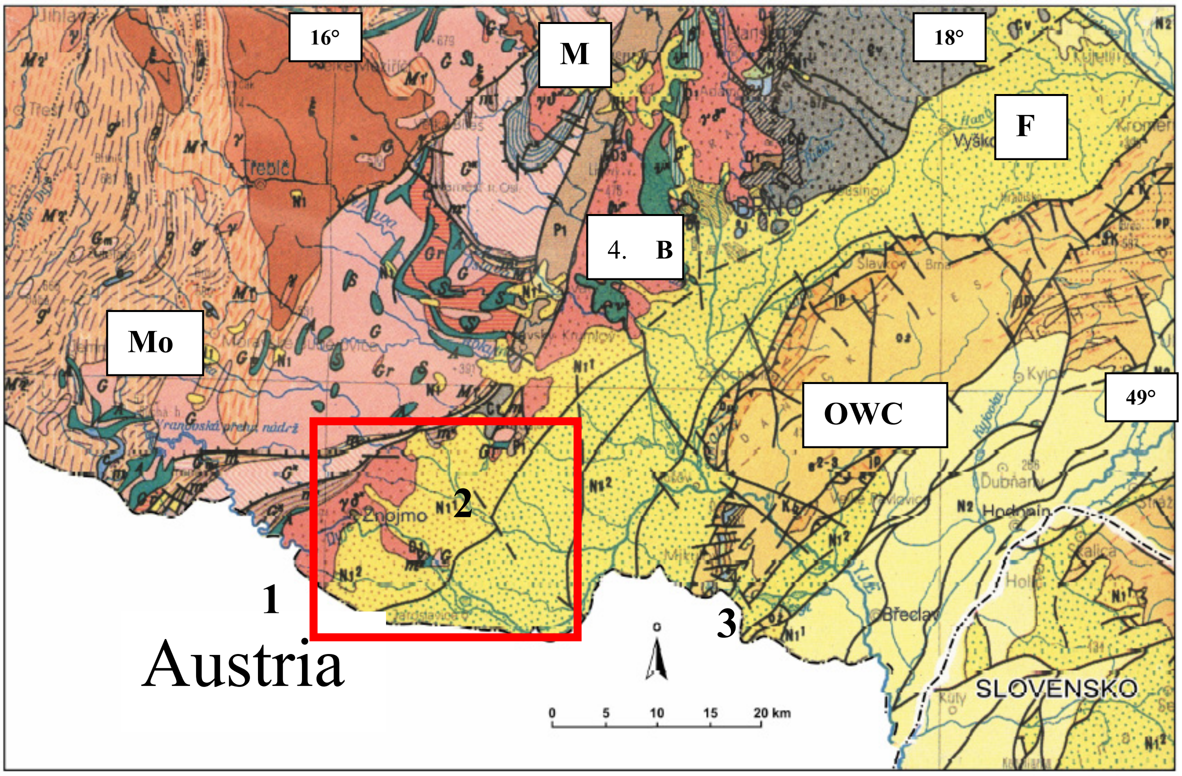

Fig. 1 Situation of the GPS measured area. Geological units: Mo-Moldanubian, BV-Brunovistulian, M-Moravian, F-Carpathian Foredeep, OWC-Outer Western Carpathians, Faults: 1- Waitzendorf, 2- Diendorf, 3- Bulhary.

belt. It is covered mainly by nappes of the outer Western Carpathians and the Foredeep (over 4,000 m thick at the Těšany borehole) as well as by overthrusted tectonic slices of the Variscides (Jiříček, 1991). Formation and consolidation of the Brunovistulicum prior to the Variscan orogeny is documented by transgression of Cambrian and Middle to Upper Devonian sediments. Most of the Brunovistulian granitoids were formed during a major tectonothermal event at approx. 580–600 Ma (Finger et al., 2000). The large batholitic terrain in the south-western half of the Moravo-Silesian basement consists of two separate domains, the smaller Dyje (Dyje) Dome and the larger Brno Composite Batholith. Both these domains are now separated from each other by a major post-Variscan sinistral fault system DCTZ. Although only to a minor part directly exposed at the surface, the plutonites are known from drillings and geophysical research to occupy at least one third of the entire basement.

The BMSZ comprises aseries of mostly Cadomian magmatic intrusions which are intruded and/or tectonically emplaced into all above mentioned terranes. They are represented by the Brno Composite Pluton, Slavkov, Ždánice, Lubná, Mikulov, Nikolčice, Svratka Massifs, Jablunkov, Dyje Composite Massif, Pleissing, Bíteš, Olomouc, Kepník, Rusava, Strzelin and the Desná blocks built by orthogneiss rocks and Vlkoš Stock (Klomínský et al., 2010). These magmatites show a high compositional variation and a variable degree of deformation and much younger regional (Variscan) metamorphism. Only three rather small Variscan (Upper-Carboniferous) granitic massifs (the Žulová-Strzelin Composite Massif, Šumperk Massif and the Rudná Stock) are cropping out at the boundary between the Desná and Keprník Domes.

DIENDORF-ČEBÍN TECTONIC ZONE (DCTZ)

One of the most important discontinuities of the DCTZ are the Diendorf and Waitzendorf faults (Roštinský, 2003, 2004; Roštínský and Roetzel, 2005; Pospíšil et al., 2009, 2010).

Their prolongation to the north is generally combined with the Boskovice Furrow. From the town of Melk in Austria up to Mohelnice in the eastern margin of the Bohemian Massif they stretch to the north over a distance of more than 200 km. Its length and course is terminated by the fault zone of Haná (trending NW-SE) in the north, its continuation beneath the units of the Eastern Alps is assumed in the south (Jaroš and Mísař, 1976). Dislocations, formed by steep normal faults and locally thrust faults, forms the boundary between the Brunovistulicum and western segments of the Moravian crystalline at a number of places. This dislocation is formed by two major segments: the main boundary fault of the Boskovice Furrow in the north, and the Diendorf and

Waitzendorf faults which gradually turns to the NE-SW direction in the south. Both tectonic structures link directly east of Znojmo and together with a number of minor subsidiary faults they create a complex but relatively compact fault system. With regard to the spatial position and limitation of the studied area (near Čebín), this tectonic structure will be referred to as the Diendorf – Čebín tectonic zone (Pospíšil et al., 2009, 2010).

On the basis of structural data, evolution of the Moravo-Silesian tectonic zone may be dated as the Lower Paleozoic at least. The DCTZ seems to be younger, but even its primary evolution may be dated to the lower Paleozoic, too – it is indicated by the mode of deposition of Devonian rocks (Jaroš and Mísař, 1976). During the further development of the DCTZ, frequent changes of tectonic regime occurred, which had a significant influence on both the forms of newly developed deformations of older crystalline units, and on the nature of newly developed sedimentary formations formed namely during the Paleozoic but also even later during Alpine movements in Mesozoic and Cenozoic periods. Stages of compression, tension and horizontal shifts both along the main fault and along genetically associated dislocations are well documented (Jaroš and Mísař, 1967, 1976; Malý, 1993). It is the length of the Diendorf fault and its accompanying dislocations particularly, as well as the duration, poly-phase character and changing orientation of movements which are generally considered as characteristic features of fault structures and regional synsedimentary deep-seated faults (Jaroš and Mísař, 1976).

The existence of several N-S trending faults forming systems which link the Diendorf fault under a sharp angle and divide the eastern (Brunovistulicum) side of this dislocation into several particular wedge-like blocks with specific lithological composition (Roštinský, 2003, 2004, Roštínský and Roetzel, 2005) is one of characteristic features. The Miroslav fault forms an eastern border of a complicated complex of crystalline and Paleozoic sedimentary rocks referred to the Miroslav horst, the fault of Falkenstein east of Langenlois (Austria) bounds minor relics of Permian-Carboniferous rocks at Zöbing, and a fault of the same direction referred to the Hadersberg fault probably forms the eastern boundary of the Krhovice crystalline east of Znojmo. A similar orientation and tectonic setting is displayed by the metabasite zone separating the eastern and the western granodiorite parts of the massif of Brno (Jaroš and Mísař, 1976). Structural functions, age and tectonic relations of above stated subsidiary fault lines towards the major dislocation are not clarified yet. Nevertheless, based on the present knowledge, their great importance in the process of setting the western part of Brunovistulicum is indisputable.

GEODETICAL DATA

The systematic continuation of velocitiy monitoring in the area of the DCTZ has been conducted in the transitional part, where the Diendorf and Weitzendorf faults are hidden bellow the Neogene sedimentary cover. At the eight GPS stabilized points surrounding the Načeratice Hill the first repeated GPS measurements were carry out during 2010. Even they are only preliminary the results suggest interesting movements near above discussed faults. Moreover, there is a good agreement with the results gained at the Morava network (Švábenský et al., 2011).

POLYGON ZNOJMO

The geodynamic Znojmo polygon was established in 2009 (Witiska, 2011; Pospíšil et al., 2010; Švábenský et al., 2011) with the purpose of displacement monitoring in southern part of DCTZ, with the covering area of about 3 x 15 km on both sides of the Dyje river valley between Znojmo and Slup.

The distribution of the Znojmo polygon points covers both the NE-SW oriented faults – Waitzendorf and Diendorf - in E-W direction. The NAHO point (Načeratice Hill – GPS point of the MORAVA network) has been chosen as the reference point (Figs. 2 and 3).

Two measuring campaigns including GNSS static observations at all points of the Znojmo polygon (Table 1) up to present day been carried out.

The initial (zero) campaign E0 was conducted in October 2009. The Leica SR520 and Leica GX1230 receivers together with Leica AT504GG, AX1202GG and AT502 antennas were used. The measuring scheme included GPS static observations of longer duration (up to 20 hours) at points HRAD and VALT, and the data of permanent station TUBO were utilized. Resting points measurements (UNEMO, TASO, KRHO, MICM, DERF, VDJM) were performed in the triplet pattern, which included shorter observations (2 hours) repeated three times in time lag from 6 to 7 hours (Figs. 2 and 3; Švábenský and Weigel, 2006).

The following (first) campaign E1 was carried out in October 2010 using the same instrumentation and the same observing scheme as in the previous E0 campaign.

The data acquired in both campaigns 2009 and 2010 were processed using BSW 5.0 (longer intervals), and LGO 8.1 (shorter triplet intervals). Precise ephemerides from CODE and antenna type phase center absolute calibrations were used in processing.

In Tables 2 and 3 the horizontal baseline component differences between epochs are shown for longer observation intervals and for triplets, computed by baseline rectangular coordinate differences dX, dY, dZ transformation to the local horizontal system.

Table 1 ITRF Coordinates of the Znojmo Geodynamic Network.

Points		ITRF 2000 coordinates (2010.0)		
Number/Location	**Name**	**X [m]**	**Y [m]**	**Z [m]**
73-Načeratice Hill	NAHO	4042236.9	1166561.3	4778124.6
001-Tasovice	TASO	4040297.3	1170333.1	4778743.1
002-Vodojem	VDJM	4042688.1	1166189.3	4777790.0
003-Hradiště	HRAD	4041041.0	1161680.6	4780324.0
004-U nemocnice	UNEM	4039478.7	1162241.5	4781524.7
005-Krhovice	KRHO	4041516.2	1171926.9	4777329.9
006-Derflice	DERF	4042578.1	1170237.9	4776869.7
007-Micmanice	MICM	4043357.9	1173138.2	4775461.9
008-Valtrovice	VALT	40422688.5	1175616.3	4775416.3

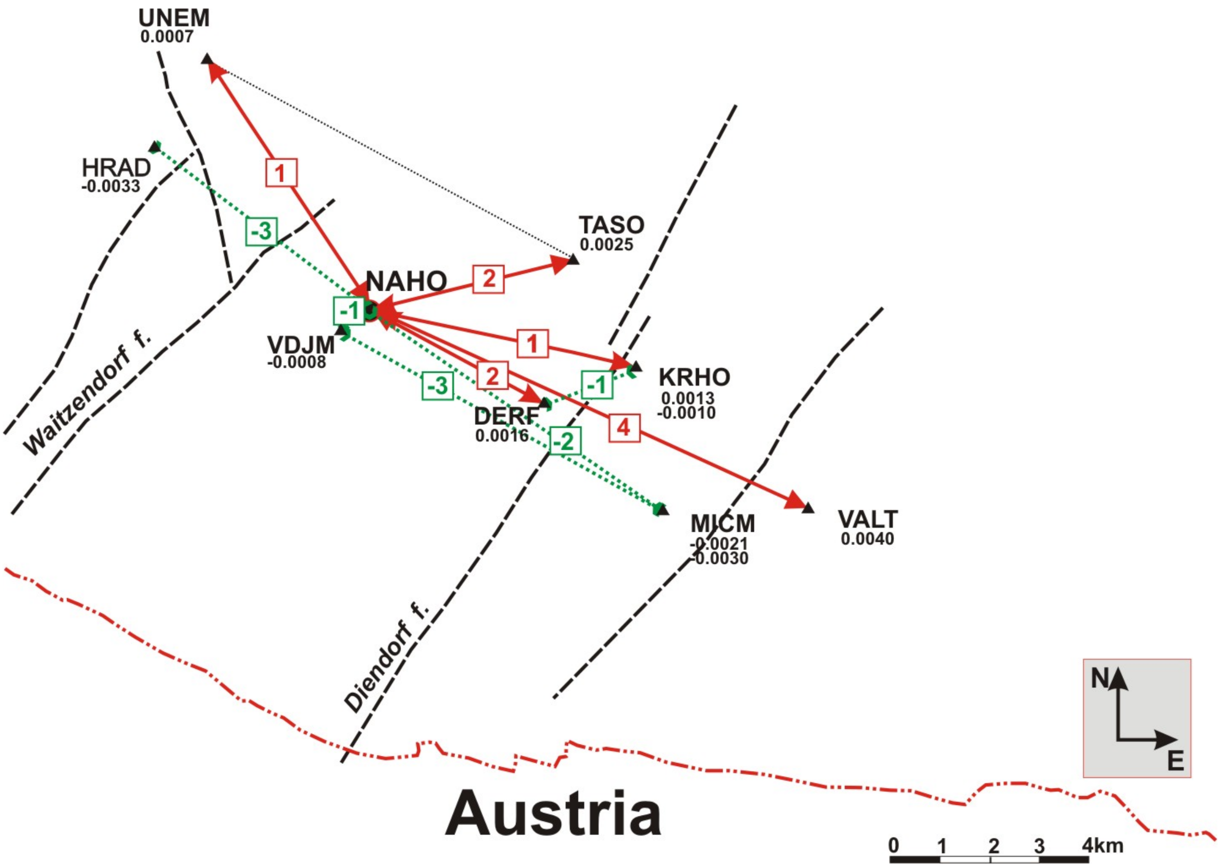

Fig. 2 The results of the first stage of repeated measurements at Znojmo polygon. The horizontal distance differences were gained on the basis of measurements in shorter intervals of triplets (LGO 8.1). The HRAD a UNEM GPS points are located at granites of Dyje Dome. The NAHO a VDJM points are situated int granites of Načeratice Hill. The dotted and heavy lines represent compression or extension between GPS points, respectively. The values between points DERF and KRHO, where the Diendorf fault is located, indicate the dextral movement tendency, while between points MICM and VALT sinistral movement has been identified.

Table 4 shows the triplet observation pattern on example of October 2010 campaign. Here the times for receiver relocations (10 – 15 min) are not shown.

Expected baseline standard deviations are under 2 mm for longer observation sessions, and under 4 mm for triplets. Adjustment results show actual accuracy as expected (see Table 5).

GEOMORPHOLOGICAL ANALYSES

For future evaluation of the GPS measurements in the DCTZ, the detailed geomorphological and geophysical analyses have been performed. In this contribution, only the main morpho-tectonic data will be mentioned.

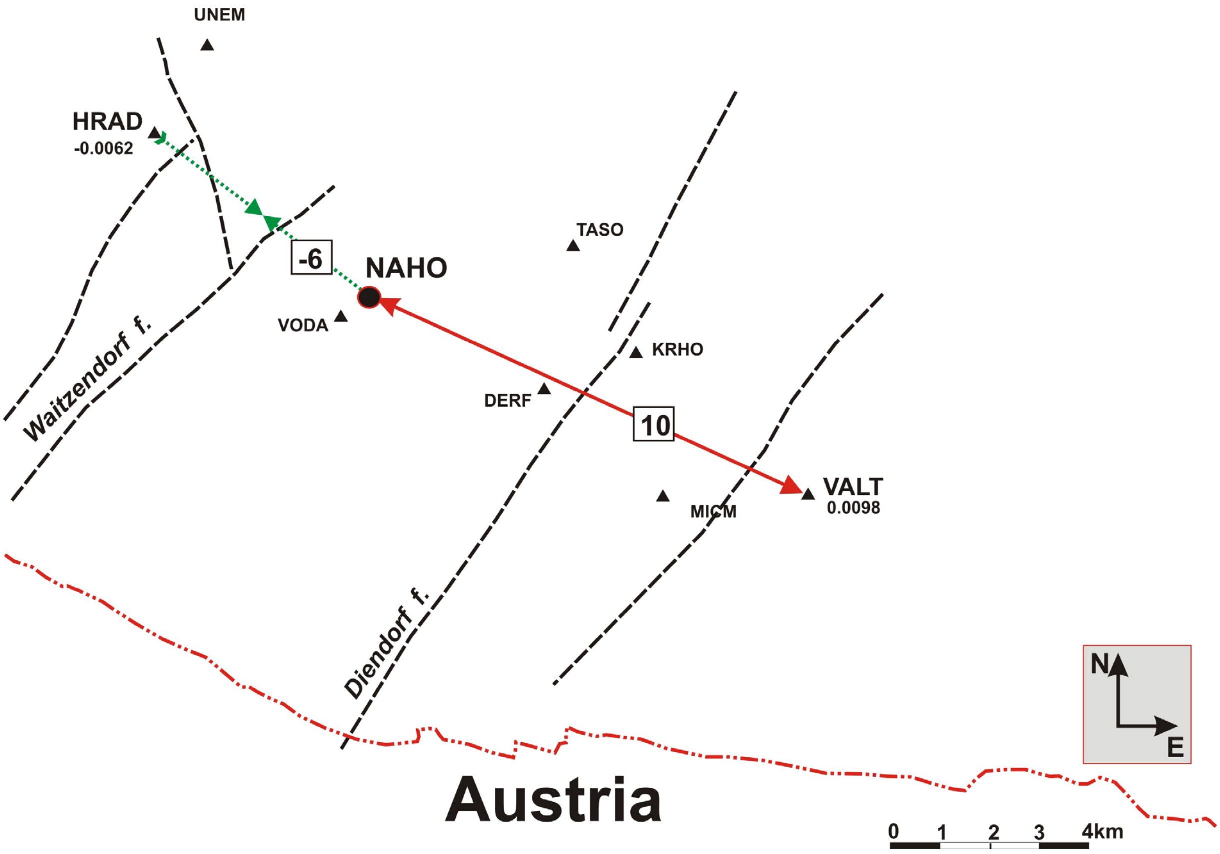

Fig. 3 The horizontal distance differences between HRAD, NAHO and VALT points were confirmed on the basis of measurements with longer intervals (BSW 5.0). The sense of movements and higher velocities between HRAD, NAHO and VALT points are surprising and will be analyzed and check by next measuring GPS campaign.

The delimited morpholineaments are plotted in Figure 4 (Roštinský, 2003, 2004, Roštínský et al., in press). Well apparent is the distribution of elements into two major systems. The first, more distinct, one, comprises the Boskovice Furrow and its southern continuation in the marginal area of the Bohemian Highlands. The prevailing directions are NE-SW, NNE-SSW and N-S. The second, a more complicated system, is composed of a series of partial tectonic zones of NNW-SSE, NW-SE, WNW-ESE to W-E direction with a relatively lower relief in this area. Horizontally it intersects the major regional structure – the Bohemian–Moravian Highland margin, Boskovice Furrow and Brno Highland (some zones investigated e.g. by Hrádek 1993, 1995). Four major and seven minor zones several kilometres wide were distinguished. Elements of NW–SE to W–E directions dominate, N–S is also abundant, however, the rest orientations are even more present. Some zone parts serve as valley sections of major regional streams (Svratka R., Bobrava R., Jihlava R., Oslava R., Rokytná R., Skalička R., Miroslavka R., Jevišovka R, Dyje R., Daníž R. – Fig. 4).

Lithological category of the morpholineaments relates, among others, to their position within major topographical segments. Elements evolved in consolidated basement rocks are dominantly situated in central parts of elevations of the Bohemian–Moravian and Brno Highlands (summit parts, some transversal zones) and in northern section of the Boskovice Furrow. Morpholineaments of combined type flank marginal parts of the Bohemian–Moravian and Brno Highlands toward surrounding depressions, are frequent in southern section of the Boskovice Furrow and its transitional zone (TZ – zone between end of BF and outcrop of Diendorf fault) to Diendorf fault and, especially, in many transversal zones within all major topographical segments. Morpholineaments developed only in the Neogene sediments were found out mainly on marginal parts of the Dyje –Svratka Graben toward the Brno Highland, in its elevated area in the S and in a lower frequency even in some transversal zones within other units in the NW.

The elements disturbing Quaternary fluvial deposits (mostly together with Neogene underbed) occur in largest extent in the Dyje –Svratka Graben

Table 2 Horizontal distance differences – longer intervals (BSW 5.0).

baseline	24.10.2009			8.-9.10.2010			dHD(0-1) [m]
	n(E0) [m]	e(E0) [m]	HD(E0) [m]	n(E1) [m]	e(E1) [m]	HD(E1) [m]	
NAHO HRAD	3331.5283	-4357.7882	5485.3804	3331.5263	-4357.7818	5485.3742	-0.0062
NAHO VALT	-3999.4792	8574.7417	9461.6082	-3999.4868	8574.7490	9461.6180	0.0098

Table 3 Horizontal distance differences – triplets (LGO 8.1).

baseline	HD(E0) [m]	HD(E1) [m]	dHD(0-1) [m]
UNEM TASO	8594.8892	8594.8892	0.0000
KRHO DERF	2047.3892	2047.3882	-0.0010
MICM VDJM	7358.8703	7358.8672	-0.0030

Table 4 Triplet observing scheme (October 2010).

station	Time interval (UTC) 8.10.2010						9.10.2010		
	12:00 14:00	14:00 16:00	16:00 18:00	18:00 20:00	20:00 22:00	22:00 24:00	00:00 02:00	02:00 04:00	04:00 06:00
NAHO	continuous								
HRAD	continuous								
VALT	continuous								
UNEM	2 hours			2 hours			2 hours		
TASO	2 hours			2 hours			2 hours		
KRHO		2 hours			2 hours			2 hours	
DERF		2 hours			2 hours			2 hours	
MICM			2 hours			2 hours			2 hours
VDJM			2 hours			2 hours			2 hours

Table 5 Estimated triplet accuracies (October 2010).

baseline from to	baseline length [m]	height difference [m]	residuals v1 [mm]	v2 [mm]	v3 [mm]	accuracy σi [mm]	σ [mm]
UNEM TASO	8595	-100.5	-3.4	4.0	-2.6	4.2	2.4
KRHO DERF	2047	15.8	-2.8	-1.3	3.8	3.5	2.0
MICM VDJM	7359	56.2	-1.7	-2.3	5.4	4.3	2.5

where they limits in a scarp landforms from several sides the remnants of two major terrace levels (Fig. 4). The higher older one is locally composed of two superposed sedimentary complexes (lowermost Pleistocene and spatially dominating Lower Pleistocene) deposited mainly by Jihlava R. and Dyje R. The lower younger one inludes two complexes of Middle Pleistocene age. It was formed by activity of other major streams (Zeman, 1974; Musil, 1993) and thus documents significant young fluvial network reorganization. Some morpholineaments of the last type are created even along streams in transversal tectonic zones within other topographical segments in the NW.

The demarcated slopes with faceted planes of triangular or trapezoidal shape include larger straight-lined superficial landforms with mean inclination of 10–30°, rarely greater (comp. Badura et al., 2007). They reach relative heights from several tens of metres to 200 m (Svratka R. valey in the N), max. length toward its dip of 100–1300 m and max. width from cca 0,5 km at many small blocks to 6 km in case of slopes in the crystallic and Neogene rocks and 12 km at slopes in the Quaternary fluvial deposits of the Dyje–Svratka Graben (higher terrace scarp especially). The rate of their areal proportion within the whole slope and degree of facets preservation is very various within the study region what could be caused, in addition to bedrock lithology, closely with original slope age and thus a scale of its remodellation under sub-aerial geomorphological processes. The long sections build-up in crystalline are the most concentrated on both sides of the Boskovice Furrow toward surrounding uplands. Remnants of faceted planes are there frequently mutually separated, excepting of solitary gap valleys, through small headwater depressions of short periodic valleys. Further, the faceted slopes are abundant within identified tectonic zones with intensely segmented topography and dense block structure (TZ, transversal structures). Particularly, they rim the steep margins of partial horsts and grabens there. Moreover, they occur in a contact area of the Brno Highland and Dyje – Svratka Graben.

General summit surface of numerous asymmetrical landforms (mostly tilted blocks – Hrádek 1995, 1998) toward E and SE totally dominate in the area. Prevailing orientations of their major slopes toward W, NW, eventually N are corresponding.

The three existing valley types of fluvial system (partly obvious in Figure 4) correlate by specific way with topographical, and thus even geological structures. The sections sharply deepened at the bases, i.e. the valleys with steep slopes and narrow bottoms (V-shaped cross profile) occur mainly within higher topographical segments in the Bohemian–Moravian Highland, in major stream valleys in its lower segments and within headwater parts of smaller streams in higher areas of the Brno Highland. Graben-type sections, i.e. valleys with steep slopes and widened flat bottoms (tub-shaped cross profile) or sections at flat bottoms of more extensive tectonic basins, are situated most frequently at major streams, almost exclusively within areas of transversal tectonic zones with relatively depressed topography, constituting often dominant type there. They are presented in all major topographic. The shallow, slopely asymmetrical or wide isometric valleys (widened U-shaped cross section) occur at upper reaches of smaller streams in summit areas of lower part of the Bohemian–Moravian Highland, abundantly in the Boskovice Furrow and TZ and prevail in the Dyje –Svratka Graben.

All the major deflections from dominant SE drainage trend are distributed within the Boskovice Furrow and TZ (DCTZ area), including valley sections oriented reversely toward NW (8 cases). The affected streams are sharply right-angledly bended into the NE or SW direction toward transversal tectonic zones.

Uplifted areas include higher parts of the Bohemian–Moravian Highland, relatively elevated parts of the Boskovice Furrow and TZ, higher parts of the Brno Highland and some elevated segments of the Dyje–Svratka Graben (surfaces of higher terrace level and uplifted blocks in the S). Subsided areas comprise most of the Boskovice Furrow and TZ, lower parts of the Dyje –Svratka Graben including central one and numerous surfaces within transversal zones crossing all major topographical units (Fig. 4).

Mostly flat bottoms of basin forms are evolved in the largest areal extent within indicated tectonic zones (Boskovice Furrow and TZ, system of NW-SE transversal zones, central parts of the Dyje – Svratka Graben). It documents significant role of neotectonic movements during their genesis, despite they are flown through with greater streams, and create together with adjacent slope surfaces within the study area a very various spectrum of landforms. The largest ones have developed in the Neogene and Quaternary sediments. In parts of the area composed of other rock types are sporadic or only their smaller forms occur. The primary neotectonic origin of these major basin forms is, furthermore, supported by their frequent lateral limitation through slope morpholineaments. A number of the marginal slope forms show, moreover, a repeating topographical occurrence in en echelon style.

Detected en echelon structures possess a very variable spatial forms, however, locally show a high grade of mutual shape similarity. Very most of them relate to subsided areas and their margins toward uplifted regions. From defined types, repeated offset slopes, parallel lower topographical steps and valley network forms (sections of several streams or in the same sence arranged mutually interconnected abrupt, mostly right-angled valley deflections of one stream) dominate. Selected cases had been presented by Roštínský and Roetzel (2005) and Roštínský (2004, 2009).

Recent or actual tectonic activity of the Diendorf–Čebín system is especially documented by following geomorphological findings.

1. Occurrence of numerous morpholineaments or slopes with faceted planes of various neotectonic ages trending NE–SW to N–S in the Boskovice Furrow and interconnected transitional zone in the south.
2. Typology and configuration of the fluvial system in the DCTZ area. The Boskovice Furrow and TZ is characterized by evidently higher ratio of shallow valley sections to sharply deepened ones compared to adjacent parts of the Bohemian–Moravian and Brno Highlands (mostly areas outside the transversal structures).
3. Distribution of relatively depressed partial topographical segments with related geomorphological features (flat-bottom basins, en echelon landforms).

GEOPHYSICAL DATA

Comparison of geophysical and geomorphological data shows striking agreements in the following areas, while a little more marked correlations were found in magnetic and gravity fields.

In its western and southwestern margin the positive gravity anomaly in the central part of Brno massif (surroundings of Brno) relatively well corresponds with the tectonic zone of the Boskovice Furrow (system Diendorf-Čebín, its eastern topographic part) with the transverse zone which intensively fragmented block structure along the rivers Jihlava and Oslava and the zone southeast of the river Bobrava defined by dense complexes of morpholineaments in rocks of various ages and by arrangement and typology of appropriate segments of the valley network. On the eastern flank of the anomaly there is an apparent agreement between the opening structure along the river Ponávka of the NNW-SSE direction (the northern part of the Nesvačilka graben).

The tectonic zones of the NW-SE direction are in good agreement with minor linear relatively negative areas dividing the structure into partial segments – a zone along the rivers Bobrava, Svratka, and less apparently the southeastern continuation of an important tectonic structure along the river Loučka in the north. On the contrary, the zone in the southeastern continuation of the important tectonic structure along the river Svratka is not manifested in the gravimetric representation of the Brno Massif. The gravity anomaly in the southwest of the area (environs of Znojmo, the Dyje Massif – Figure 5) is bordered by less dense systems of morpholineaments of prevailing N-S and NE-SW direction in the west.

However, the gravity picture corresponds relatively well with the position and expansion of the major units in the Neogene basement. Monitoring of the vaults formed by the granite complex Brunnia deserves more detailed investigation. The gravity field reflects very well a number of N-S gradients in the direction from the Miroslav horst to Znojmo, but also in the Austrian part. The gradients are connected with outcrops and distribution of partial crystalline blocks (Roštínský and Roetzel, 2005).

These elements can be more easily observed in the magnetic map (Figs. 6 and 7). A detailed section of the magnetic map of the Czech Republic (Šalanský, 1995) shows agreements in both morpholineaments (Fig. 4) and elements of the valley network. The sharp western termination of a positive magnetic anomaly or its intrusions stretching from the north across Brno to the south – SSW corresponds with the northern part of the system Diendorf-Čebín, including the Boskovice Furrow and the western part of Brno Massif (Pospíšil et al., 2010).

An agreement between the direction of several morpholineaments and the southeastern sharp margin flank of a minor positive anomaly was found in the NE-SW direction NW of Znojmo. In the magnetic map, several transverse tectonic zones can be observed. In case of the Znojmo anomaly, correlation of its southwestern termination boundary with the tectonic zones along the river Dyje (only indications) and mainly Daníž. A certain agreement can be observed between the two major anomalies in the Dyje-Svratka valley and the eastern part of the zone along the river Miroslavka where this structure follows straight boundary.

The territory of the assumed connection of the Diendorf fault to the Boskovice Furrow faults was subjected to geophysical measurements, gravity and aeromagnetic, and also aeroradiometric on the scale 1 :25 000. Gravity measurements on the scale 1:25000 were conducted by Geofyzika n.p., Brno, in the period 1977-1978. Technical documentation and gravity field interpretation are contained in the report by Krus and Šustr (1978). The measurement yielded a detailed information on the course of Δg and delimited NNE-SSW trending linear structures. In the cited work O. Friáková offered fundamental data on the density of magmatite crystalline rocks. The Dyje Massif granitoids prevail, with densities of 2650 kg/m^3. Densities of diorites attain 2940 kg/m^3 and conglomerates of Dyje Dome Moravicum exhibit values of 2710 kg/m^3. A streak of Bíteš orthogneiss, with density of 2660 kg/m^3 reaches the north-western tip of the area. Densities differences, also in comparison with shallow subsurface and surface mass, are big enough to produce measurable effects.

The data about density parameters are presented in Eliáš and Uhmann (1968) and Matolín (1970).

A dominant structure in the gravity field is a range of gravity gradients stretching across the whole area in parallel with the Waitzendorf fault. The gradients reflect the presence of a more extensive gravity depression due to accumulation of light granitoid rocks of the Dyje Massif in the west of the territory. The gravity gradient subdivides the territory into a positively disturbed area, where abundant occurrences of basic magmatities can be expected in deeper and subsurface levels (Šalanský in (Čtyřooký and Batík (1983)). The basics form two parallel belts. In can be assumed that in the eastern belt they form the direct basement of the Neogene filling. On the contrary, the gravity depression within the Dyje Dome, west of the regional gradient line, obviously marks the axis of occurrences of acid granitoids of the Dyje Massif, and in regard to the magnitude of the effect and plunging into a considerable depth, on the steep dislocation on the boundary with Moravicum. The boundary is localized on the gradient line NW of Znojmo town.

The gravity field east of the Waitzendorf fault is rather diversified. In the east of the Dyje Dome SE of Znojmo a gravity elevation indicates an extensive accumulation of basic volcanic rocks at deeper levels. Another local gravity elevation intrudes the SE part, in this case, however, it is due to a complex of crystalline rocks under a shallow Neogene cover. It is presumably a continuation of the intrusion of Krhovice crystalline rocks to the SSW. This gravity

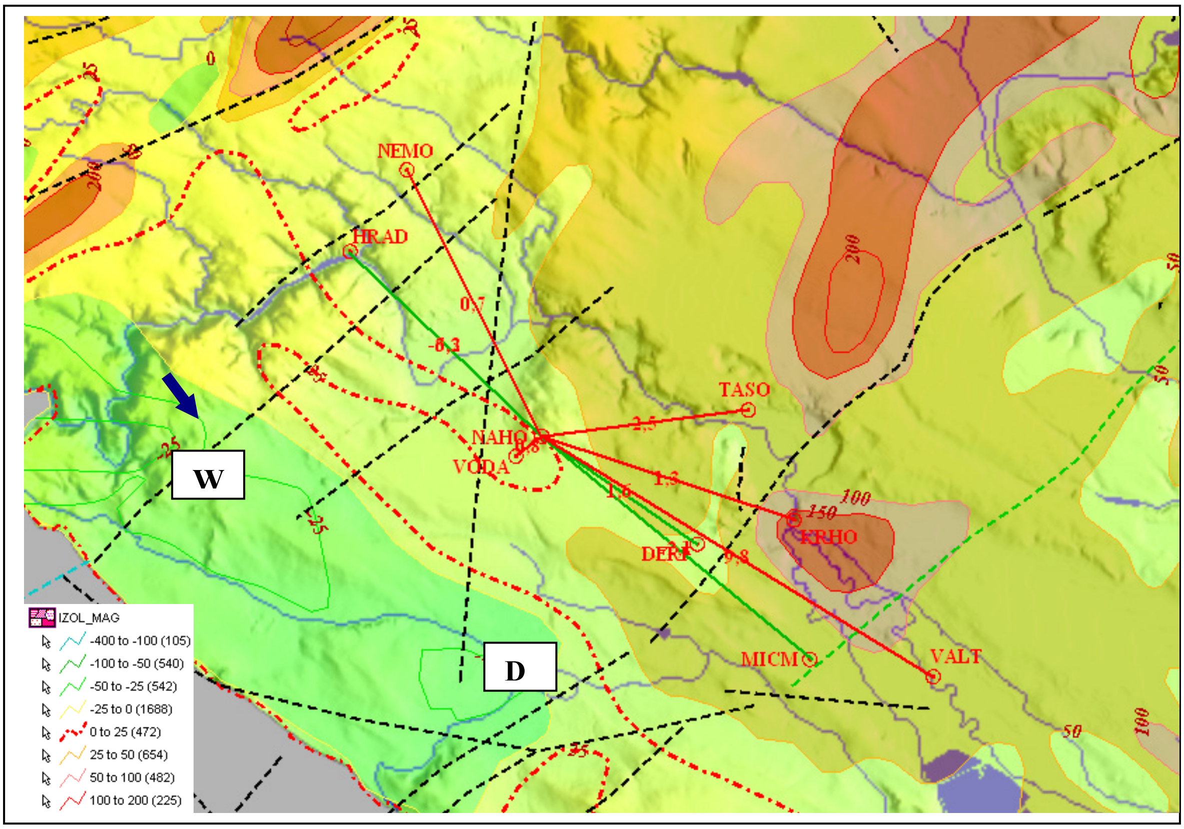

Fig. 6 Comparison of the known tectonics with magnetic anomalies shows unambiguous conclusions. Faults: W- Waitzendorf, D- Diendorf. The relatively good correlation of faults with magnetic anomalies is in better agreement with basement structures than with recent ones. The North of the Waitzendorf fault can be interpreted next fault boundary that follows Dyje valley. The arrow identifies the Waitzendorf fault.

structure was mentioned in the study on the gravity field of Moldanubicum and adjacent units (Mísař et al., 1983).

The magnetic field is monotonous. With the exception of an only anomaly SW of TASO GPS point, the local anomalies do not exceed the values of first tens of nT. It holds not only for the area of the Dyje Massif granitoids, but also in places where bodies of more basic rocks have been geologically mapped (SE of Znojmo). Minor linear anomalies comparable at a length of 2.5 km, mostly N-S trending, occur within the Neogene cover.

The major anomaly is the area of Krhovice (KRHO point) and SE of it, under the Neogene cover. Contours of basement magnetized rocks can be drawn there, forming a belt stretching to the NE and joining the exposed crystalline basement near Krhovice. The western termination of this crystalline units presumably follows the tectonic line that belongs to the Diendorf fault system.

Several partial gravity depressions in the area of the Dyje Massif delimit local density changes caused by the presence of more acid facies in granotoids. A weak gravity picture of the Moravian crystalline basement is presumably due to the degree of compensation of the effect of heavier volcanic-sedimentary rocks by the light Bíteš orthogneiss. Simultaneously, this indicates the short continuation of the Moravian crystalline basement in depth. The shallow Neogene cover does not influence the gravity picture.

A better view of the tectonic situation is offered by the results of geophysical mapping (magnetometry and radiometry). In the integrated magnetometric and radiometric picture several significant zones of magnetic anomalies can be distinguished, and local anomalies of various magnitudes can be identified. Generally, the level of ΔT anomalies increases to the NW from 25 nT in the southwestern tip of the territory to 100 nT in the northeastern part. This regional increase is due to deep geological effects, mostly acting further to the NE outside the area encompassed by the polygon Znojmo. Exceptional among anomalies due to surface and shallow subsurface sources is the area of stretching along the Moldanubian overthrust of Moravicum onto Brunovistulicum, having significance of a regional magnetic zone. The area is characterized by high amplitudes (up to 700 nT NW of Přímětice) and a field diversified into partial elevations within a 1.5 km wide magnetic elevation. Besides the primary differences in contents of ferrimagnetic accessories, the morphology of anomalies is probably affected by fault tectonics, as it is indicated in Figure 7. There are surface sources covered by a thin layer of Quaternary soils. Magnetized rocks are difficult to find.

The continuous magnetized zone is tectonically divided into partial magnetic blocks between Únanov and Plaveč. The western more branch continues into the area between Plaveč and Hluboké Mašůvky and delimits the subsurface continuation of volcanic-sedimentary rocks of the Moravicum at depths of several hundreds of meters. From Únanov, after the splitting of the zone, the branch continues as a separate anomaly farther to the ENE, outside the area. Occasional fragments of actinolitic schists exhibited susceptibility values of 24 000 - 47 500.10^{-6} SI at the maximum of 300 nT. The remanent magnetization is lower (Q is <0.4).

The zone of slightly increased values with local amplitudes of about 50 nT belongs to a number of minor anomalies in the Dyje Massif in the eastern part of the map section. They may be due to relics of an assimilated mantle in granitoids, with a certain share of ferrimagnetic accessories.

On the whole territory west of Znojmo the NE-SW direction of anomaly axes prevails. They follow the major foliation in metamorphites identical with original layering, and directions of basic rock bodies in the Dyje Massif granitoids. Derived from the magnetic picture in the area of major anomalies were also transverse discontinuities (Šalanský in Čtyřooký and Batík, 1983) indicating faults. For example, the transverse tectonic fault passes through Plavčí and joins the occurrences of serpentinite in the NW near Cernín (outside the area). GPS measurements show that there is a partial movement also between points HRAD and UNEM, which might connect with a fault of the same direction (Fig. 2).

EVALUATION OF RESULTS

The obtained preliminary results of GPS measurements were evaluated on regional scale, and a map of sources of magnetic anomalies (Šalanský, 1995) and earthquake epicentres (Lenhardt et al., 2007; Schenková et al., 1979) was added and correlated with morphological indicators and tectonic map. The preliminary results were complemented with processed recent data from permanent stations (Hefty, 2007; Hefty et al., 2009), and results from networks MORAVA (Švábenský et al., 2011) and Kralický Sněžnik (Švábenský et al., 2012). Taking into account the distribution of GPS points on the outcrops of crystalline basement in places where low thickness Tertiary units occur, movements at the basement level can be assumed, Brunovistulicum and adjacent Moravo-Silesian and Moldanubian units in this case.

The most significant movement in South Moravia was recorded between the points NAHO and VRSA (Vršava near Koryčany) – over 2 mm/year (Švábenský et al., 2011 – Figure 7). As the movement tendencies between the points NAHO and TUBO and NAHO – VYHL (Vyhlídka – network Kralický Sněžník) are negligible, it can be assumed the entire allochthonous cover (mainly Outer Carpathian Flysch nappes) of Brunovistulian block tends to depart from the Moldanubicum. Whether this movement is also on the level of Brunovistulian basement it is difficult to proof. Minimally, on the base of results between point VYHL and BISK we could consider with such interpretation. Such conclusions are confirmed by results from the Kralický Sněžník network where tension movements between points VYHL – BISK (Biskupská hora) and ZYWI (Zywiec in Poland) are significant. On the other hand, movements between the same points (NAHO, TUBO, VYHL) and points in the Bohemian Massif - GOPE (observatory Pecný) and DUKO (Dukovany – network Morava) are compression in nature (Fig. 7).

So far overlooked have been previous results regarding recent vertical movements (Vyskočil, 1996; Vyskočil and Pospíšil, 2009), well complementing the present studies on horizontal movements (Fig. 8). There is a good correlation of uplifted and sunken areas with positions of interpreted boundaries with horizontal shifts.

It would be beneficial to re-evaluate geophysical data and tectonics within southern Brunovistulicum. Good correlation of gravity and magnetic anomalies with rock complexes gives chances to obtain new findings related to this extraordinary tectonic unit.

CONCLUSION

Preliminary results from the GPS polygon Znojmo repeatedly confirm the significant movement tendencies in the area of the Waitzendorf and Diendorf faults and surrounding. The maximal velocities of –0.6 mm/year between the stabilized Dyje Dome block and the shifted Načeratice Hill block and the velocity of 10mm/year measured between points NAHO and KRHO well correspond with measured results at MORAVA network (Švábenský et al., 2011) and should receive increased attention in future investigations. It is apparent that the seismoactive zones in Austria are closely connected with the activity and dynamics along SW-NE trending faults stretching onto the territory of South Bohemia and Moravia.

Apparent in more detailed studies of component of movements on individual faults is an opposite movement. Dextral sense of movement can be interpreted along the Waitzendorf and Diendorf faults, points NAHO and DUKO depart while DUKO and TUBO approximate draw nearer. A major sinistral movement can be interpreted between points STOH and VRSA, as well as between NAHO and VRSAV (Figures 7 and 8). A possible explanation is that this recent movement is connected with the tectonic zone where a number of normal and overthrust boundaries

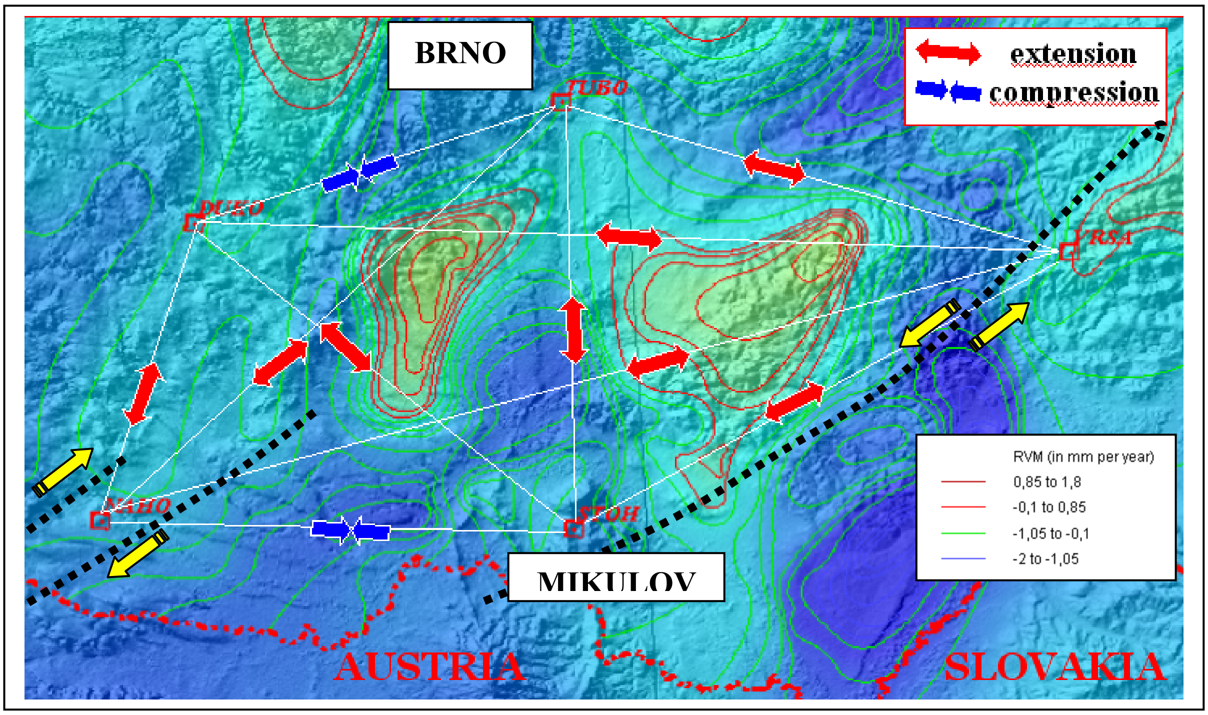

Fig. 8 Schematic map of movement tendencies in the South Moravian area. The polygon of horizontal velocities is supplied by vertical velocities (Vyskočil and Pospíšil, 2009). Tension zones in the central zone of the polygon correlate with uplifted zones, while compression zones are combined with decreases of vertical velocities. Dotted lines and yellow arrows show position and movement character at the fault systems – Waitzendorf, Diendorf and Bulhary (named from W to E).

occur (Ciprys and Thon, 1990; Němec, 1973) and could be characterized like "flower structure" based in the pre-Mesozoic basement. Moreover, this zone is connected with the formation of the Vienna Basin and most faults reach the crystalline basement formed by Brunovistulicum (Dudek, 1980).

Recently a movement has been observed in the vicinity of the Waitzendorf fault, near its northern termination. Preliminary results proved significant movement tendencies within this transitional DCTZ zone. Measurements will be repeated at two-year intervals. It would be really beneficial for the whole project to expand measurements farther to the south to the Austrian part of the DCTZ.

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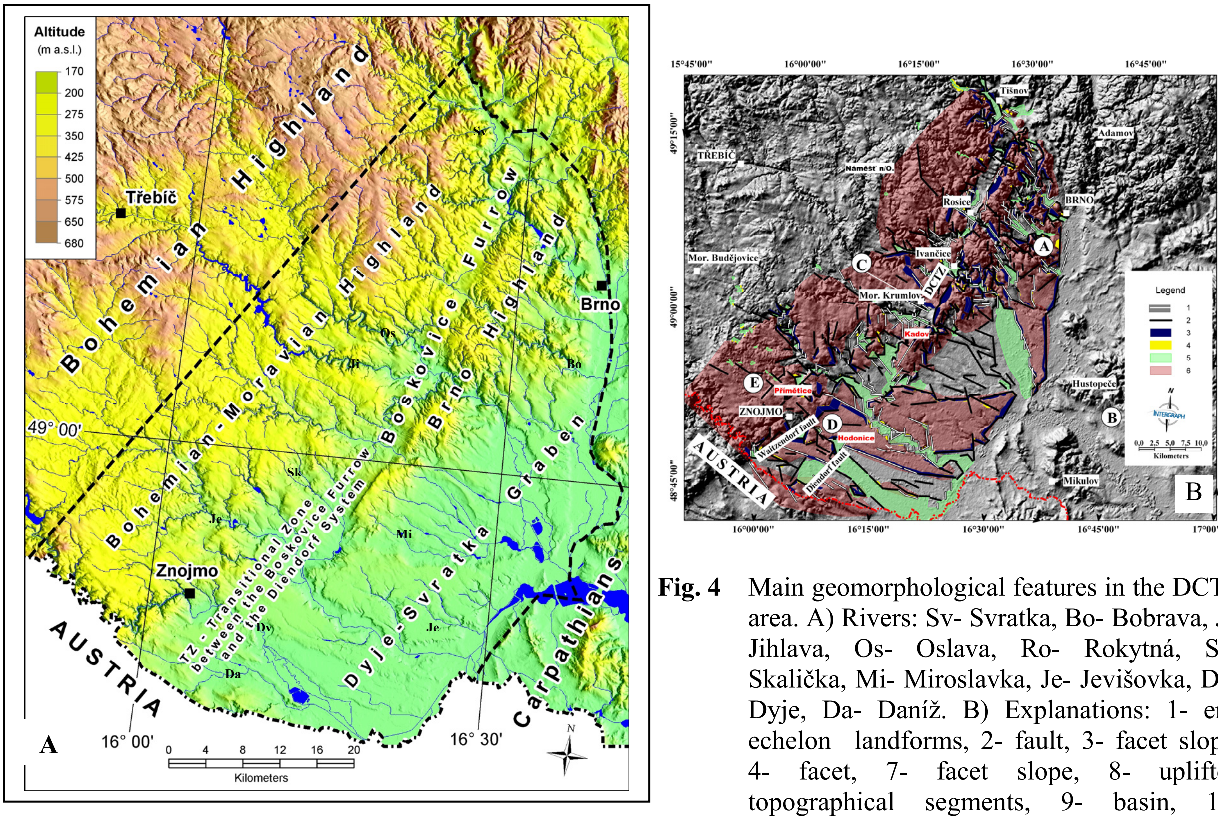

Fig. 4 Main geomorphological features in the DCTZ area. A) Rivers: Sv- Svratka, Bo- Bobrava, Ji- Jihlava, Os- Oslava, Ro- Rokytná, Sk- Skalička, Mi- Miroslavka, Je- Jevišovka, Dy- Dyje, Da- Daníž. B) Explanations: 1- en_ echelon landforms, 2- fault, 3- facet slope, 4- facet, 7- facet slope, 8- uplifted topographical segments, 9- basin, 10- neotectonically subsided topo

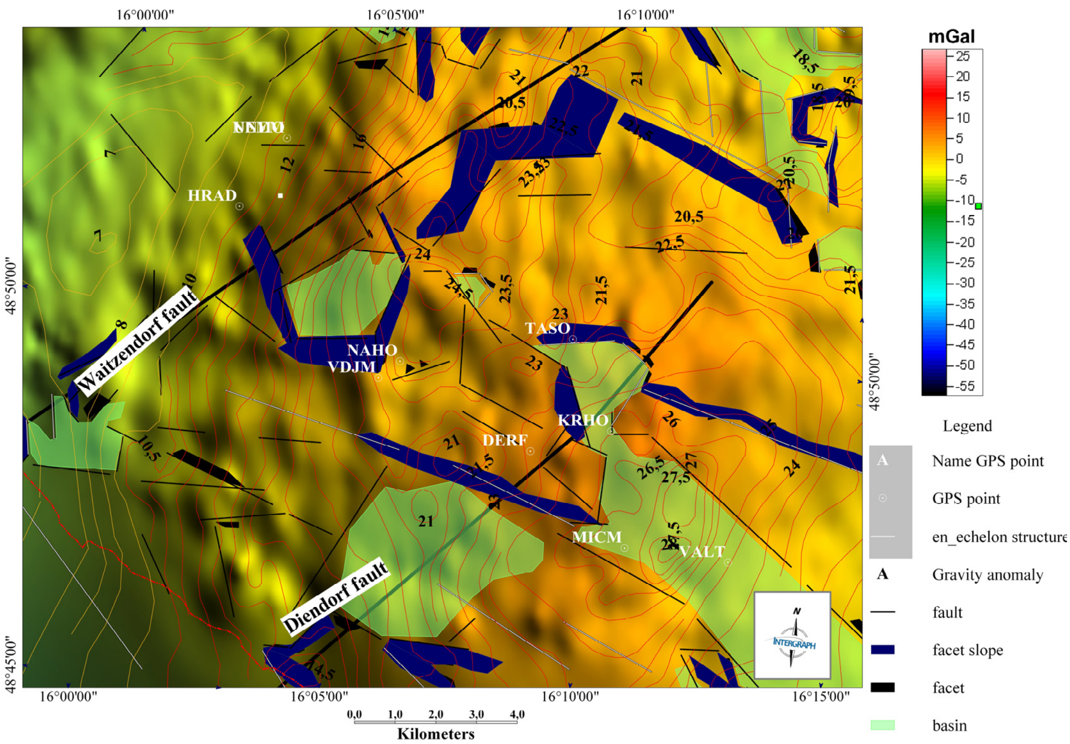

Fig. 5 Gravity anomaly map with main morphological elements can be used to analyze the role of basement structures in generation of recent tectonics. Explanation: 1- Gravity value (in mGal), 2- Gravity isoline, 3- Number of GPS point, 4- position of GPS point, 5- en_echelon structure, 6- Quaternary fault, 7- fault dissecting crystalline basement, 8- fault in sedimentary basement, 9- fault in sedimentary filling, 10- facet slope, 11- facet, 12- sedimentary of the basin.

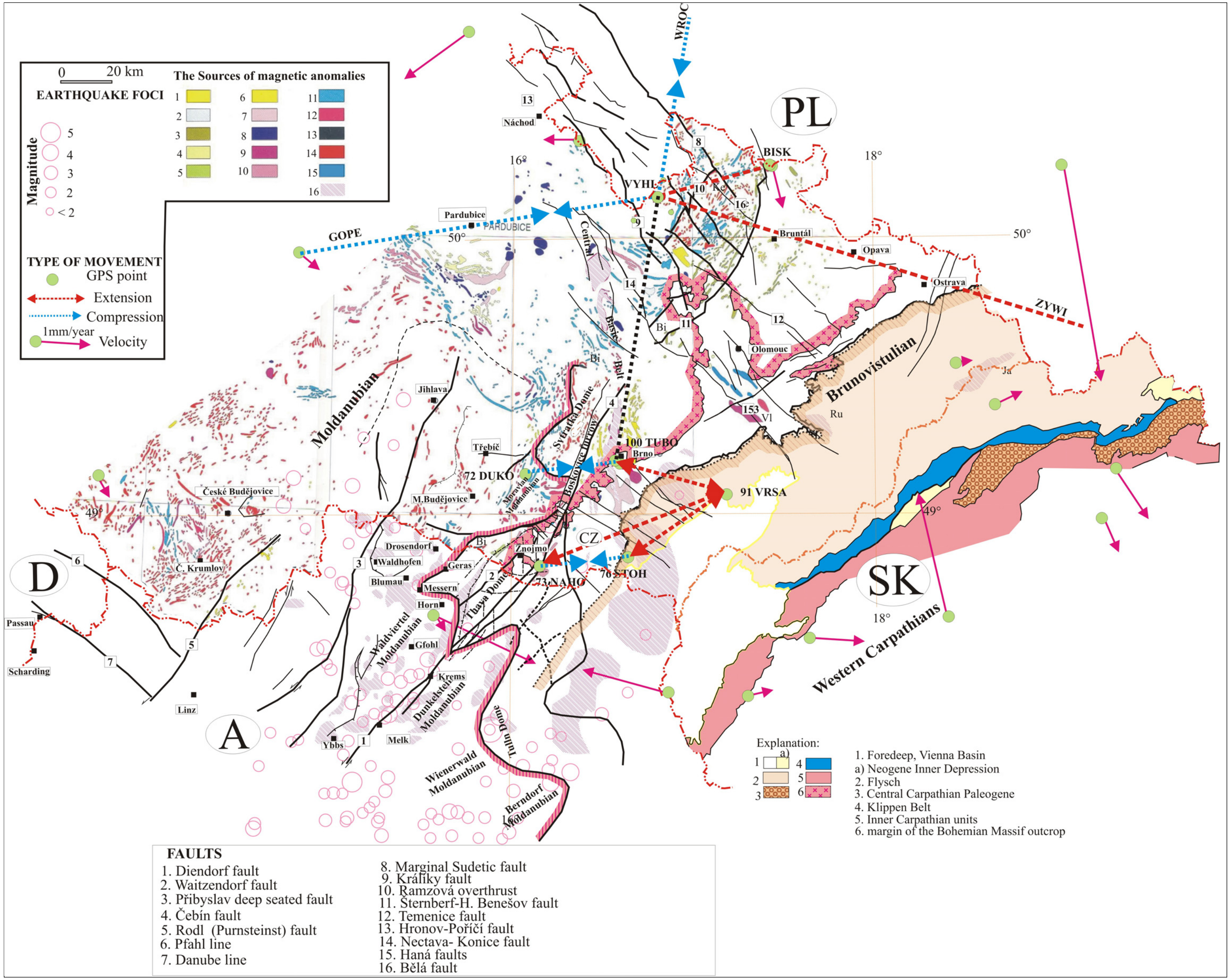

Fig. 7
Correlation of the morphotectonic and geophysical data with the results of GPS measurements. Geological explanation after Finger et al., 2000). Sources of magnetic anomalies are processed after K. Šalanský (1995): Explanation: 1 – neovolcanites, 2- paleovolcanites – Upper Paleozoic, 3- paleovolcanites – Lower Paleozoic, 4- paleovolcanites – Upper Proterozoic - Lower Paleozoic, 5- paleovolcanites – Upper Proterozoic, 6- granitoids, 7- granitoids with mafic bodies, 8- mafic intrusive rocks, 9- mafic and ultramafic intrusive rocks, 10- metamorphic volcano-sedimentary complex, 11- amphibolites, 12- serpentinites, 13- skarns, eclogites, calc-silicate rocks, 14- metamorphic rocks, 15- volcano-plutonic complex, 16- undifferentiated. Epicenters of earthquakes for the period from 8.5.1267 to 31.3.2004 (after Lenhardt et al., 2007). The sizes of pink circles are scaled proportionally to the local magnitudes of individual earthquakes.