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GEOLOGICAL CONSTRAINTS ON THE GPS AND PRECICE LEVELLING MEASUREMENTS ALONG THE DIENDORF–ČEBÍN TECTONIC ZONE

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ABSTRACT

In the contribution geological structure and geophysical data along the northern part of the Diendorf-Čebín tectonic zone (DCTZ) is analyzed in relation to the position of the measured GPS test areas and precise levelling profiles. For this purposes the former geophysical data have been reambulated and analyzed, too. Revision of geological knowledge and sources has been done in places of the proposed polygons. The results of reinterpretation of the Grav/Mag data and selected seismic reflection profiles suggest new possibilities and variety of structural interpretations of this tectonic zone. It is evident that the whole tectonic system has undergone complicated tectonic development during the Paleogene and Neogene. Therefore the recent mapping and analyses by GPS and precise levelling have to be realized in places where the geological structural ambiguity has to be eliminated.

KEYWORDS: Diendorf fault, Boskovice Furrow, levelling, GPS, Moldanubian, Moravian, Brunnia units, geodynamics, geophysics

INTRODUCTION

Recent studies of the eastern margin of the Bohemian Massif based on the complex analysis of geological, geochemical, structural and geophysical data (especially gravity, magnetic, seismic and magnetotelluric data – e.g. Dudek, 1980; Jiříček, 1991; Lenhardt et al., 2007; Schenkova et al., 2007; Pospíšil et al., 2009), enabled to develop the appropriate model of the genesis of Moldanubian, Moravian and Brunnovistulian contact. Problem opened may create explanation of the role of Diendorf tectonic system during recent and Tertiary period.

In the contribution we deal with the geological condition of the areas chosen for the mapping of the movement and kinematic tendencies, especially related to DCTZ. Particularly we concentrate on the summarizing of the most problematic geological interpretation, which can influence a selection of the convenient locality for geodetic monitoring (Pospíšil et al., 2009).

The results of the geological and geophysical evaluation of selection led to construction of two stable GPS test areas - Tetčice and Znojmo, where first measurements have been done in 2008 and 2009 respectively.

GEO- RESEARCH

Within the construction of the GPS test areas and geodetic measuring in combination of GPS and precise levelling the wide research of geological and geophysical archives has been done. We have particularly concentrated on revision of interpretation of seismic reflection profile, gravity and magnetic data analyses and collection of terrain documentation of outcrops and important structural localities in South Moravia and Austria. The one of the most problematic structure is so called Diendorf-Čebín tectonic zone (DCTZ - Pospíšil et al., 2009), which is divided into two parts – the Diendorf and Weizendorf fault zone and the southern part of the Boskovice furrow (Fig. 1).

The Diendorf fault represents intensive seismotectonic system described in detail first by Figdor and Scheidegger (1977). The data on seismic intensities of the zone of decreased density, shape, size and depth of the anomalous low - density mass indicate the offset of the two sides of fault to be approximately 40 km. Its seismicity is very problematic. The distribution of earthquakes is not concentrated to the Diendorf fault only, but to much wider zone, spreading far to the Moldanubian area.

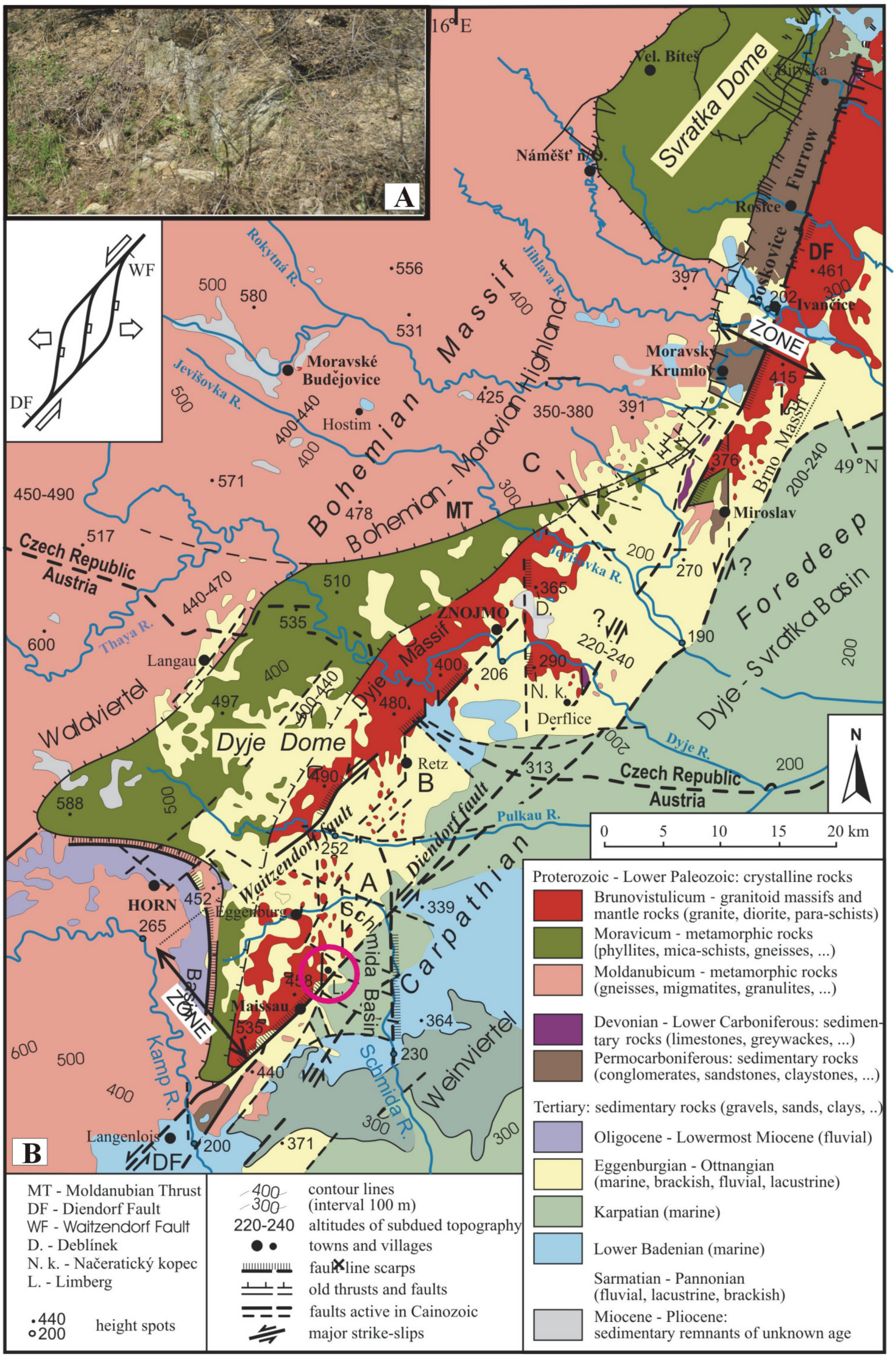

Fig. 1 The Position of the Diendorf and Weizendorf faults in Upper Austria area (After Roštínský and Rötzel, 2005 modified by authors). Red circle locate the outcrop of the Diendorf fault in Oberdünbach village (top right). The Extension on sinistral strike slip fault system (DF and WF) explains the Oligocene-Early Neogene of segmentation of area during period (Roštínský, 2003, 2004), and the actual altitudial contrast between the higer elevated crystalline terrain of the Massif and the lower sedimentary relief of the Foredeep created during the Late Miocene-Quaternary period (Roštínský and Rötzel, 2005).

Two models can be taken into account: first combined with itself active strike-slip Diendorf – Weizendorf zone, the second one with complete thrusted marginal system of the Moldanubian (Pospíšil et al., 2009).

OPENED GEOLOGICAL QUESTIONS AND PROBLEMS OF THE MOLDANUBIAN - MORAVICUM - BRUNNOVISTULICUM CONTACT ZONE

The Variscides on the SE margin of the Bohemian Massif belong to the most complicated structures in the whole Europe. This complexity is caused not only by the composition of orogene, which went through complicated evolution during the last 300 Ma, but also by its overlay by younger sediments, too. Part of Variscides is hidden under autochtonous Permo-Carboniferous deposits and Cretaceous sediments, or can be dropped on the SE slopes of the Bohemian Massif under Jurassic and Tertiary complexes. Complications arise by virtue of the overlapping of Variscides arc of Bohemian Massif by the Carpathian arc of Alpine Orogen. The Variscan units, shifted to the northeast to the Brunno-Vistulian foreland, are overlaid by Alpine-Carpathian nappes, that have been shifted in the in the opposite, western to north-western direction. Complexes of Brunnia and Vistulian recognized in the basement are generally connected into one unit – Brunnovistulicum (e.g. Dudek, 1980).

All these complications implicate, that the trace of the Variscides under the sediments and young nappes is uncertain and can be interpreted from borehole and geophysical documentation only (Dudek, 1980; Batík, 1999; Jiříček, 1991; Adámek, 2005; Schulman et al., 2005; Wessely, 2006). All these studies resulted in several theories about the structure of the hidden part of the Variscides towards the remaining, uncovered part of the Bohemian Massif. Unfortunately, the opinions vary. In addition, considerable difficulties arise in segregation of Variscan nappes and faults, which gave way to more universal concept of Variscan units (belts and blocks). The one who drew attention to their uncertainty, unrealistic and hazy definitions, which cannot be sufficient for investigation of hydrocarbons, was for example Jiříček (1991). On the opposite side the last models and interpretation of the Variscan structure, based on dating, paleomagnetic, structural and seismic data (Schulman et al., 2005; Finger et al, 2000; Edel et al., 2003; Oncken, 1997; Aric et al., 1997, and other), gave chance to better understanding of their deeper parts and origin.

The results of geophysical interpretation can provide us, in terms of in-depth deposition, more objective perspective on this problem.

F.E. Suess, (1912, 1926) divided the Variscides radially from the inside out at the Moldanubian, Saxothuringian, Lugian and Moravosilesian. On the NW side Kossmat (1927) modified these zones into following sequence chain: the Moldanubicum, Saxothuringicum, Mid-German Crystalline Rise (MGCR), Rhenohercynicum and Sub-Variscan Molasse, which have been adopted as a basis for the whole Northern Variscides. In the area of Bohemian Massif, the Variscides are divided into many structural zones and opinions about their tectonic correlations diverge. The Elbe zone, as the most problematic in BM, can significantly influence and evoke the rupture of Variscan zone. Instead of such result the MGCR is expanding through Poland to Moravia only in the form of the outer Rhenohercynian and Sub-Variscan molasse, overthrust on the Bruno-Vistulian foreland (Havlena, 1976; Dudek, 1980). Remobilised part of this foreland is described as Moravosilesian. Aother study, however, does not exclude that he Moravian and eventually part of Brunnia unit belong to the MGCR (Stille, 1951; Ellenberger and Tamain, 1980).

For correlation and interpretation of geophysical data it is very misleading and troublesome. The results of the last decade (e.g. Vrána and Štědrá, Eds., 1997) can offer us additional possibilities of solutions, which must be discussed and analyzed using geophysical data to avoid creation of popular hypotheses and models. From the point of view of this paper and specification of observed polygons we concentrate on the questions of the Moravian zone, which is parallelly flanking the whole DCTZ (Fig. 2).

For solving of the DCTZ phenomena the geophysical data can play a significant role, mainly well chosen reflex-seismic profiles. We can imagine the DCTZ as a tectonical system, which was in recent form created in Tertiary, but its origin and its main role was taken in the end of Variscan orogeny and in the Mesozoic period. Unfortunatelly, this activity is not possible to be confirmed in the recent.

From the geological point of view it is convincible, that ductile to brittle ductile moldanubian overthrust representing the sutury created by the collision of two microcontinents, we can describe on base of the structural and geochemical data.

But the brittle fault system is wholly different (including the eastern marginal fault of Boskovice Furrow and the Diendorf fault), created during younger variscides and repeately reactivated after-variscan period, which is yet generated as the most of transcurrent faults in the detachment level of some "undermoldanubian" unit (Moravicum, Brunnia unit).

Both structures mentioned are still spatially coinciding at present time, in the geophysical fields we can find out many typical signs and symptoms, but they have a whole different genesis. For the perception of function and importance of DCTZ such possibilities of interpretation must be taken into consideration, which are in accordance with the 8HR profile (Fig. 3) in the space under the foredeep and flysh structures of the Western Carpathians. There, in the depth from 5 to 7 km, the significant reflexes are detected, typical for the sedimentary complexes, which are interpreted as possible devonian complex shifted by the brunnia unit or its part (Pospíšil et al., 2004; F. Hubatka – oral comunication).

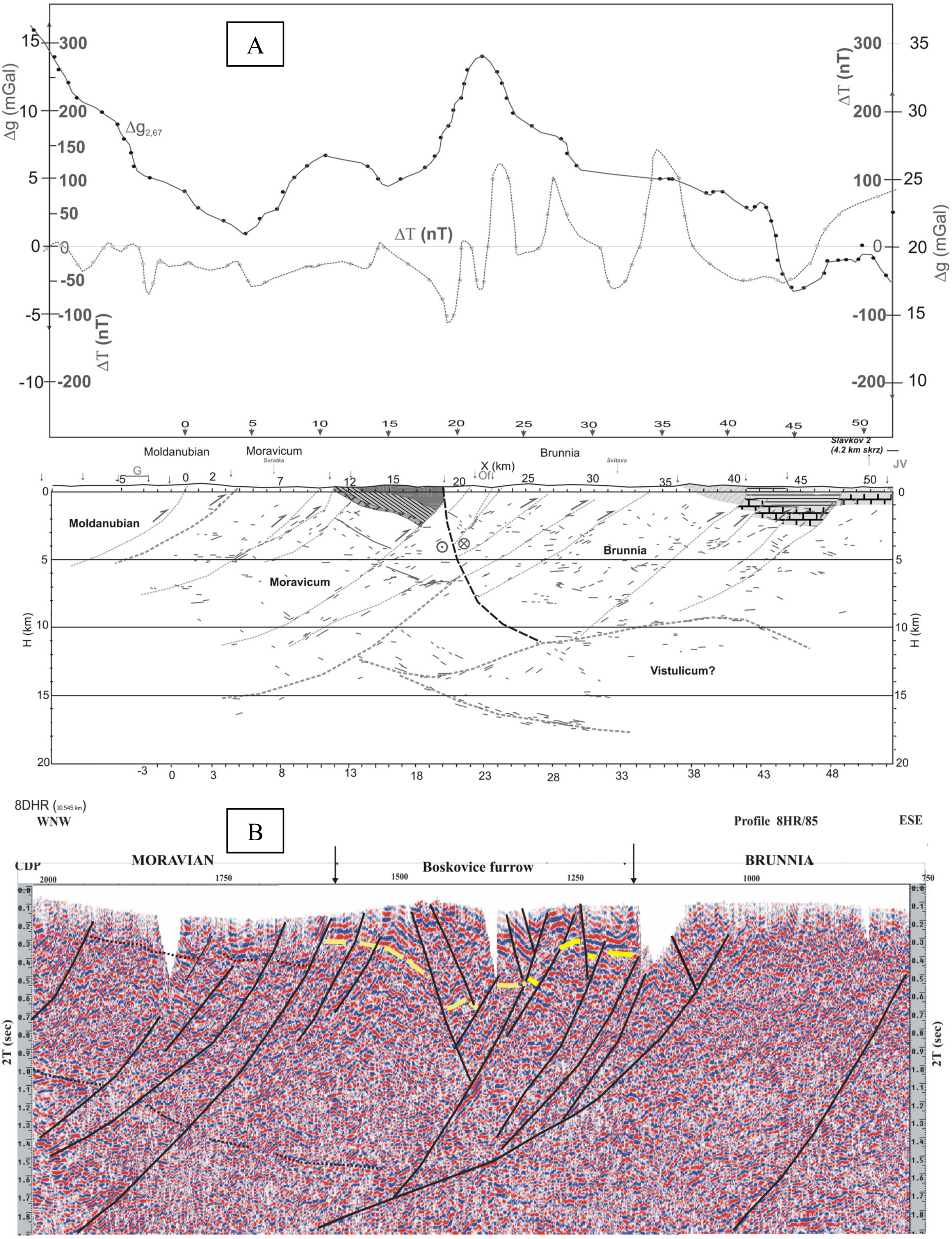

Fig. 3 **A)** Modified original interpretation of seismic section 8HR (Geofyzika n.p. Brno, 1988), with handly migrated reflections, is supplyied by gravity and magnetic data. The comparing gravity effect above Boskovice furrow (BF) with models presented by Pospíšil et al. (2009) suggests larger negative anomaly even though the thicknes of Permo-Carboniferous sediments is lower. The detail interpretation on **Fig. 3B**, shows BF as typical half graben, strongly deformed by younger tectonics. The former interpreted thrust fault is not observable in section. **Fig. 3B)** Detail interpretation of half-graben structure.

From the geophysical data, based on the knowledge of physical features of rocks and its demonstration in the magnetic and gravity field, we are able to speak about another versions of solution connected to domatic uprise of Moravicum and Brunnia unit in its domes (Dyje, Tulln, Svratka), but this really exceed the scope of this paper.

That is why we concetrate in the next part on the summary of opinions on moravicum and brunnovistullicum and from it arising questionable interpretation.

Moravo-Silesian zone – F. E. Suess, (1912) defined Moravosilesicum as a zone including folded Proterozoic a Devonian rocks, shifted from the west by the influence of Lugodanubian unit (Moldanubicum and Lugicum). This definition is generally accepted, even when it encounters some problems, mainly Květnice and Závist nappes in the Svratka Dome, which close the same Devonian sediments as parautochtonous scales of Brunnia, but completely differing from the upper complex of "outer and inner phyllites" (Jiříček, 1991).

Eastward from this synclinorium the crystalline complex has a bit different character and the Devonian sediments cover it similarly to parautochton of Brunnia. Because the narrowing of Silesian unit can lead to many misunderstandings. Jiříček (1991) considers keeping the existing range of Moravosilesian according to Suess (1912), but with the annex, that it represents the zone of detached folded nappes from the western side of Brunnia. The same Brunnia ridge represents granitoids, locally with crystalline cover, which they are sinking with in Upper Moravian Graben on north side under Silesian unit.

The Moravosilesicum in this concept represents tectonic unit, which is shifted from the west due to Moldanubian and Lugian on the Moravo-Silesian dislocation (Mísař, 1979) and on east it is contoured against the Brunnia ridge by the fault of the Boskovice furrow. The Narrow zone of Moravosilesian takes up the SSW-NNE direction, deflecting to the NNW in Poland, and to S in Austria near Krems. Southern line belongs to Moravicum, the northern one to Silesicum, with frontier at the Upper Moravian Graben. The whole unit can be characterized by the arch belt, which is by many geologists wrongly considered to be a Variscan structure. The Svratka Dome, where to the Moravian unit some authors put only outer and inner phyllites with Bíteš gneiss provide a good example. Other authors move this border even under the Květnice and Závist nappes of Tišnov Brunnian and other ones describe Moravicum unit as an arch with its granite bedrock.

Moravicum – Moravicum was described by Suess (1912) as a short narrow zone between the Moldanubian nappe and Brunnia Massif. Its inner structure can be recognized through some tectonic windows and leaks. Svinov-Vranov leak is very narrowly elongated in the SW-NE direction. Nectava izometric window is situated in its extension, slightly deflected to the south. Both geomorphological phenomena are situated in northern part of Drahany Highlands eastward from the Boskovice furrow; westward lies the Svratka Dome, characterized by eliptical shape and choked centre. The Dyje Dome has an undulate to folded triangle form and is elongated in SW-NE direction, in between Langenlois (Krems) and Moravský Krumlov. Both Domes are divides by the Moldanubian foreland. The Tulln Dome has a rounded triangle shape, stretched in N-S direction between Absdorf and Mödling near Vienna. It lies with its northern part below Neogene foredeep and eastern part below Wienerwald flysch in Lower Austria. The Dunkelsteiner Moldanubian foreland separates it from the Dyje Dome

Higher nappes of Moravicum – include a metamorphosed complex of "the inner and outer phyllites", detached by the Biteš gneiss (Batík, 1984). It is full-developed only in Moldanubian foreland in form of two flatly overlapping nappes, Bíteš nappe and Pliessing nappe.

The Bíteš nappe is the highest rear nappe of the Moravian unit. On its basis there are evolved Biteš gneiss structures, “outer phyllites” lie higher and at top we can find mica schists. This nappe is overthrusted by Moldanubian and self-overthursting on the lower situated Pliessing nappe, belonging to the Moravian unit.

Both nappe areas are connected with problems (Jiříček, 1991). Lower frontier of nappe was determined in Dyje Dome (Thiele, 1984). Here it is connected with clear thrust dislocation, where the Bíteš gneiss structures in brachyantiklinal western closure sit on top limestone horizonts of Lukov unit, but in NE direction are cut by the Bíteš gneiss and placed on phyllites of Lukov unit basement.

The same model, many authors have been interpreted in the Svratka Dome, where its existence is, however, disclaimed by Mísař et al. (1983). Jiříček (1991) excludes the possibility, that it can have other but only stratigraphic character on such short distance.

The problem is connected with the Upper Moldanubian overthrust on Moravian. Austrian geologists, represented by Fuchs, (1976), Thiele (1984) or Tollmann (1982), place the borderline of Moldanubicum under the mica-schist zone, which already Suess, (1912) supposed to be emerged by retrograde methamorphosis. In some cases, the border is considered on the surface of Biteš gneiss. Czech geologists, represented by e.g Zoubek (1976), Mísař et al. (1983), Suk et al. (1984) and Dudek (1980), place the mica-schist zone to the top of upper Moravicum, because mica schists are not pure, but graphitical quartzites, limestones or amphibolites occur inside, which do not indicate retrograde methamorphosis. Jiříček (1991) pointed out the fact that the mica schist zone lines the whole Moldanubicum along the Dyje Dome. However, in western part it gets in contact with the "outer phyllites", whereas in eastern as far as to the Biteš gneiss. This is significant demonstration of tectonic discoordination. The fact, why it occurs only in the southern part of Dyje Dome, where the Moldanubicum is situated and the boundary-line with Svratka and Letovice crystalline complexes is missing, speaks together in favour to belonging mica schist zone to the Moldanubicum (Jiříček, 1991).

Bíteš gneiss composes the nappe base, which expands from Olešnice near Letovice to Langenlois near Krems. All sorts of biotite, ruby-biotite, muscovite, amfibolitic, abound here, but at most the ones with the mesh structure. In Svratka Dome there is a middle belt between of the outer and inner phyllites. Tectonical impact of Svratka Dome is expected in NW under Moldanubicum and obviously in NE under Letovice crystalline complex. In southern direction it is sinking under Moravian Moldanubicum foreland and rising again in Dyje Dome as a wide zone. The whole length of the western and south-western side as far up as Vranov n/D. is lined by the zone of outer phyllites, but further in NE direction only by the mica schists zone of Moldanubicum. Also here Bíteš gneiss is most thick by the periphery, where it is nipped denudationaly and in NW under Moldanubikum tectonically from. The outer phyllites zone is rising in superincumbent bed of Bíteš gneiss and is closing in the lower part the ruby - mica shists and gneisses, graphitical phyllites, amphibolites, crystalline limestones, and dolomitic limestones and ruby-paragneisses. In the Svratka Dome this zone is matured in very narrow belt with 100 to 200 meters width at the periphery, sometimes it is disappearing, and only in north its width is growing to more than 500 meters. On the outer side it is sinking below the mica schists zone of Moldanubicum, Svratka and Letovice crystalline complexes with expected tectonical nip. In the east it ends on Boskovice furrow fault. To the dome center crystalline nips in relicts over the Bíteš gneiss. Outer phyllites represent Olešnice group, which is sinking below the Moravian moldanubicum and rising in western half of the Dyje Dome as the Vranov group.

The Pleissing nappe is lower tectonical unit in Moravian group. It is shifted by Bíteš nappe from superincumbent bed and is overriding on the lower Moravian nappes of the Brunnian in the Svratka Dome or lies directly on crystalline cover of the Brunnia in the Dyje Dome. Overthrust area of the Bíteš nappe has been dicussed, but the problems appear at the border against the Dyje Dome, too. Here the whole zone between the Bíteš gneiss and granitoides is usually placed to the inner phyllites of the Lukov unit. In fact, the base of the nappe represents Pleissing (Weitersfeld) gneiss, napped on phyllites and amphibolites, in the granitoides cover (Thiele, 1984). Reason is that in Znojmo to Želešice group the Devonian sediments spread only to granitoids and their cover, not to inner phyllites (Batík, 1984, 1999). By the replacement of similar rocks from both units the nappe of the Moravicum on the Dyje granitoids after Devonian is negated. In the Svratka Dome the nappe is connected with surely known the Dřínov nappe over the Devonian sediments in basement (Jaroš and Mísař, 1976).

In the Svratka Dome there is the Pleissing nappe connected with the overthrust of the inner phyllites zone on the Tišnov Brunnia nappe. Nappe nips on the denudation line to the top of the Dome, where under its Moravian units rise. It sits on it with the phyllites part, which does not exclude that towards periphery, where it sinks under the Bíteš nappe, the Pleissing gneiss can be placed, too. Tectonical nip can be observed under the Strážkov, Moravian and Waldviertel Moldanubicum, probably behind the nip of the Bíteš unit. The border between the frontal phyllites a rear Pleissing gneiss can lead along the connection of west margin of the Svratka Dome with the middle part of Dyje Dome in the SSW-NNE direction, parallel with the eastern margin of the Boskovice Furrow.

Lower nappes of Moravicum – including the Devonian sediments and the basement crystalline complex, ruptured from the western Brunnia ridge into the Květnice and Závist nappe. Sediment Devonian age determination was proved by the discovery of amphipores by Svoboda and Prantl (1951). Květnice nappe is higher and placed in the Svratka Dome between pleissingial inner phyllites and Závist unit. It is composed of gneiss and mica schists, higher from mica schists and phyllites, in both cases with localization of aplitic granitoides, cataklastic granites and ampihibolites, with isolated erlans. All of them represent the Deblín unit, covered by Devonian massive and laminated limestones and corniferous limestones, sporadically on quartzite basis (Mísař et al., 1983). The whole complex rises to the surface in small elliptical window SW from Tišnov (Jiříček, 1991). On the western side the methamorphites of Deblín group are matured, sinking under higher Moravicum. On the eastern margin the zone of Devonian limestones is placed, falling into the Tišnov Brunnides. The Závist nappe is the lowest unit, placed in the basement of Květnice nappe and in the top of autochtonous cover of the Brunnia.

Lower nappes of Moravicum are edged away to the eastern margin of Boskovice furrow and are missing in the Dyje Dome. Its continuity to the NW considers Jiříček (1991) as problematic.

With the Nectava-Svinov Moravicum also some other problems are connected (Jiříček, 1991). From the NW the complex is overthrusted by the Zábřeh cyrstalline complex on the Vacenín nappe (Kodym and Svoboda, 1948). However, this overthrust is Culmian and not post-Devonian age as the one by the Tišnov Brunnia unit (Jiříček, 1991).

On the eastern part of Bohemian Massif, K. Schulman et al. (2005) have presented a few different models basesed on the geochemical and geochronological data. They consider complete area, limited by the Brunnia and the Elbe fault zone, as transition zone with NE-SW trending orogenic fabric adjacent to the Brunnia foreland a NW-SE parallel with the Elbe fault zone. The zonation of units has been divided according to litological content and metaporphic conditions and its relation to crustal levels existing during maximum thickening of the orogenic root (Schulman et al., 2005).

Para-Moravicum – is key for understanding of tectonic connection between the Boskovice furrow with the Diendorf fault system. Under this unit R. Jiříček (1991) describes the most problematic unit, placed between Dyje and Brno Massif. This interpretation, that is not at all generally accepted, has many indices in geophysical data. From the first one it is separated by the Diendorf fault, from the second one by the Miroslav fault. The Hollabrunn, Krhovice and Miroslav crystalline complexes represent it there. In its deep basement there is evolved the Brunnia unit, which granitoides rise to the surface under Wienerwald flysch in the Tulln Dome and in Dyje Dome (second one Jiříček does not consider!?). Its cover was detected in the northern part of Miroslav horst, too. The Moldanubian to the south from the Dyje Dome, lines wide zone, elongated in the N-S direction in more than 100 km. In the common view the Hollabrunn unit represents deep crystalline synclinorium between Dyje and Brno granitoides. Diendorf fault runs in the geological chart to the NE to Langelois, dividing the Krhovice foreland and limiting from west the Miroslav crystalline complex. Behind, we can observe its connection to the eastern fault of Boskovice furrow.

Because the Permo-Carboniferous sediments are the lower situated block against the Brno Massif, many authors with the subsidence and strike-slip tectonics connect the Diendorf fault. Analogical situation is placed in the eastern direction with the Miroslav fault; on its depressed western block are permocarboniferous and crystalline complex, and granitoids on the higher Brno block. After Jiříček (1991), this fact gives to the Miroslav crystalline complex rather depressed structure than the horst character. The fact, that on the depressed Dyje block we can find granitoids, which occur on the Miroslav or Krhovice upper block under the methamorphites, there have been long discussed question about the connection of the Diendorf fault with the horizontal displacements, steep overthrusts of Hollabrunn crystalline complex or Dyje Massif in opposite vergency. Jiříček, (1991) supposes simpler composition, if the methamorphite complexes are placed on the block of Hollabrunn unit with the inclination to SE. By this way, they could get in contact with the Dyje Massif from north to the south with higher and higher crystalline unit. On the northern part of the Miroslav horst are placed the mylonites of Brunnia, on its southern part and in the Krhovice foreland Moravicum and on the south Dunkelsteiner Moldanubicum. Hollabrunn unit represents the methamorphites of Moravicum (Jiříček, 1991), which are geographically divided into cental ortho-gneiss zone, lined by the western, with and eastern phyllite zone.

Zone between Eggenburg and Znojmo is influenced by next important fault system - Weitzendorf fault (Fig.1). This fault is crossing the Thaya Dome, cuts mainly complexes of Brunnia, only on the SW margin of Dome crosses Moravian unit. In the zone between Diendorf and Weitzendorf faults there exist many subsidiary parallel and oblique, N-S-orientated dislocations (Roštínský and Rötzel, 2005). This tectonic "double" of faults strongly influenced segmentation of area during the Oligocene-Early Neogene period (Roštínský, 2003), while the actual altitudial contrast between the higer elevated crystalline terrain of the Massif and the lower sedimentary relief of the Foredeep is likely of the Late Miocene-Quaternary age (Roštínský, 2003).

The presented opinions on the geological structure of the DCTZ open several problems, which have to be considered before location of GPS test areas and starting of measurement. With support of geophysical data the following questions could be answered:

- How far is the Brunnia unit covering Moravian units?
- Can we consider the magnetic anomaly above Moravicum unit as a reflection of the presence of buried Brunnia unit in deep horizon? (Gnojek and Heinz, 1993)
- What role-plays in the deep basement the so called " High conductivity zone", that in central part crosses N-S oriented DCTZ (Červ et al., 2001)?
- Is it possible to divide the Brunnovistulicum and consider it as two genetically different units? (Finger et al., 2000)
- Is it really practicable to consider the DCTZ as a transcurrent system with activity until recent? (Roštínský and Rötzel, 2005)

Summary overview of the geological opinions and data can provisionally answer a number of questions on the basis of geophysical data and interpretations, but only to the last one, it is necessary to find out the current answer using geodetic and geophysical measurements in situ.

Two test areas were selected for the GPS measurements in localities where the ground structure is very complicated and where the biggest geodynamical processes and deformations occurred. In these places, it is concurrently expected to solve the overall geological structure using the geophysical and other measuring techniques.

GEOPHYSICAL INTERPRETATION

The geophysical investigation along the whole DCTZ has brought much valuable detail information about tectonic condition of interest area. Especially at the areas where the connection of the Diendorf fault with the Boskovice Furrow is covered by relatively thick sediments of Neogene. Two seismic sections 287A/84 and 8HR (composed from two parts - 8HR/85 and 8DHR/86) were procured for analyses of the areas where the tectonic zones are influenced by perpendicular or oblique faults. Both profiles are located between block with Moldanubian and Moravian crystalline outcrops on W and Moravian and Brunnia unit on E (Fig. 3).

Profile 287A is crossing one of the most problematic areas, where all known geological units are in contact and create combined complicated structure of overthrust/strike slip system.

Characteristic of seismic data

Several years ago we prolonged one Carpathian fore-deep seismic line (287A/84) to the West and passed the Miroslav horst (Fig. 3). The field technique employed to obtain the seismic reflection data examined at Geofyzika Brno was standard Vibroseis practices used for oil exploration. The compressional wave source in this survey consisted of three vibrators operating synchronously and transmitting a sweep signal with the frequency varying linearly from 15 to 60 Hz. The duration of each sweep was 11 s with the total recording time of 14 s, resulting in 3 s of correlated reflection data. The last and very convincing interpretation has beeen done by Tomek (1990).

The last reprocessed migrated version of profile 8HR/85 (Geofyzika, a.s., MŽP ČR, 2000), with record to 6 s (orig. to 12 s) belongs to the so-called deep reflection seismic section crossing all area between the Moldanubian to the Danube basin in the Western Carpathians. The field technique has been also Vibroseis in version slalom-line. A 48 channel recording system with the 50 metre station spacing and VBP interval of 50m was used.

Geophysical interpretation

General interpretation of geophysical data (seismic, gravity, magnetic) provided new premises and confirmed some previously expected ones.

The most impressive geophysical structure in the region between Rosice and Brno towns is the methabasite zone of Brunnia Massif. In the gravity and magnetic field this zone shows intensive anomalies.

The methabasite zone (Central Basic Belt after Finger et al., 2000) constitutes two or three parts, which correspond approximately to the geologically defined methadiorite and methadiabasite subzones (Sedlák et al., 1986; Rejl and Sedlák, 1988; Pospíšil et al., 2009). Western part of methadiabasite subzone in the geophysical data does not display itself completely, or possibly coincides with the methadiorite subzone.

Remarkable geophysical limitation of both W and E methadiabasite subzone margins, presence of predominantly tectonically coupled blocks of basal clastics on its margin and significant tectonic disturbances may refer to the significant tectonic mobility of this subzone.

Geophysical boundary in NW-SE direction often follows the primary foliation of granodiorites and does not have to reflect always only disjunctive tectonics, but the dislocations in the W-E direction seem to be faulted (Sedlák et al., 1986).

As very positive result we consider common map of tectonic units defined by Jiříček (1991) with magnetic map of Czech Republic (Pospíšil et al., 2009 – Fig. 2). All above discussed geological problems can be followed in this map. For next period draft is prepared to analyze and check depth of sources of magnetic anomalies and comparison with result of Šalanský (1995).

The southwestern margin of the belt is characterized in the SW from Brno by numerous superposed anomalies of surface or near-surface sources of the Moldanubian and Moravian units. The generalized picture of this complicated structure of anomalies is derived from magnetic maps (Fig. 2), strongly supports the conclusion of Finger et al. (2000) about hypotheses that at least parts of the Central Basic Belt formed at a time which corresponds to the main period of ophiolite and island arc formation has origin in the Panafrican orogens.

8 HR profile

The presented findings based on surface data are consistent both with the earlier published results of reflex-seismical profile 8HR (Tomek et al. 1988), and with the reambulated formerly interpreted data (Geofyzika n. p., Brno - Fig. 3). Profile 8HR, which runs from Moldanubicum, intersects the whole Svratka Dome structure, including Boskovice furrow and methabasite zone and continues to the Western Carpathian flysch belt, shows the eastern marginal fault of Boskovice furrow as a shear zone, combined with the Brunnia overthrust. (Fig. 3).

Profile 287A The section displayed (Figs. 2, 4) is not migrated, and so dipping reflections on the time sections are not in their true positions. A final geologic section (Fig. 4) is interpreted on the background of migrated time section. As was mentioned above, the Moravicum of the Dyje Dome is considered as a foreland of the Variscan orogen, from which it is separated in the north by the Moravo-Silesian fracture zone, and in the west by a system of

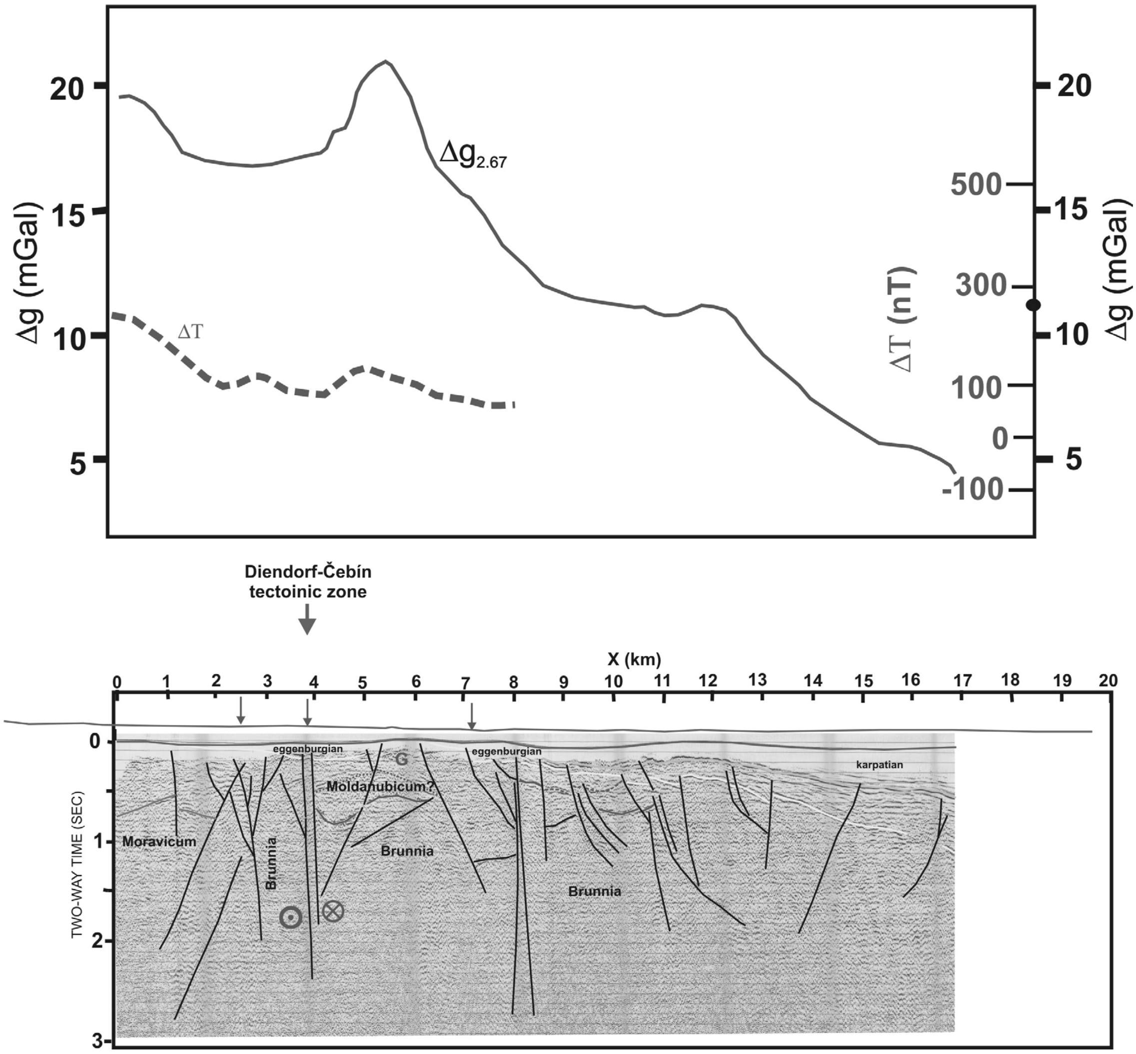

Fig. 4 Interpreted reflection seismic section 287A/84 with main tectonic structures. G – Outcrop of supposed and interpreted Moldanubian complexes with amphibolites, serpentinites, and granulites.

interrupted tectonic discontinuities. In the east it is separated from the main part of the Brunovistulicum by the Diendorf fracture zone.

The profile enabled us also to observe that reflections changed direction and character near the steeply built the Diendorf and Miroslav faults. These faults were active probably during the post-collisional Late Carboniferous — Early Permian times (probably up to the Tertiary) as left lateral strike-slip faults bringing southern blocks to the north.

The Brunnia is interpreted as a steep structure, also W of DCTZ, in tectonic contact with the Moravian unit. Unclear is the complex above, where the Paleozoic complexes and relicts of Moldanubian nappe can be expected.

In Figure 4 we can see reflections strongly inclined to the western front of DCTZ. We consider that thrust faults as features of the Moldanubian overthrust fault. These duplexes are typical for deformed Brunnia rocks elsewhere in the Brno Massif because south of the horst the Culm rocks have been drilled (Batík and Skoček, 1981) and mostly deformed together with the Brunnia rocks.

In the upper part of the section we interpret the approximately horizontal reflections G as Moldanubian overthrust over the Brunnia complex. This hypothesis is supported by not only the seismic data, but by gravity and magnetic interpretation, and mainly by structural geologic observations, too.

The final isoclinal structure of the Moravicum is given by a system of slices with steep an eastern vergency which is most intensive in the northern closure of the Dyje Dome to the north of the Čížov fault and mainly along the Moravosilesian fracture zone (Batík, 1999). However, these tectonic deformations were not strong enough to destroy a Proterozoic brachyanticlinal domal structure.

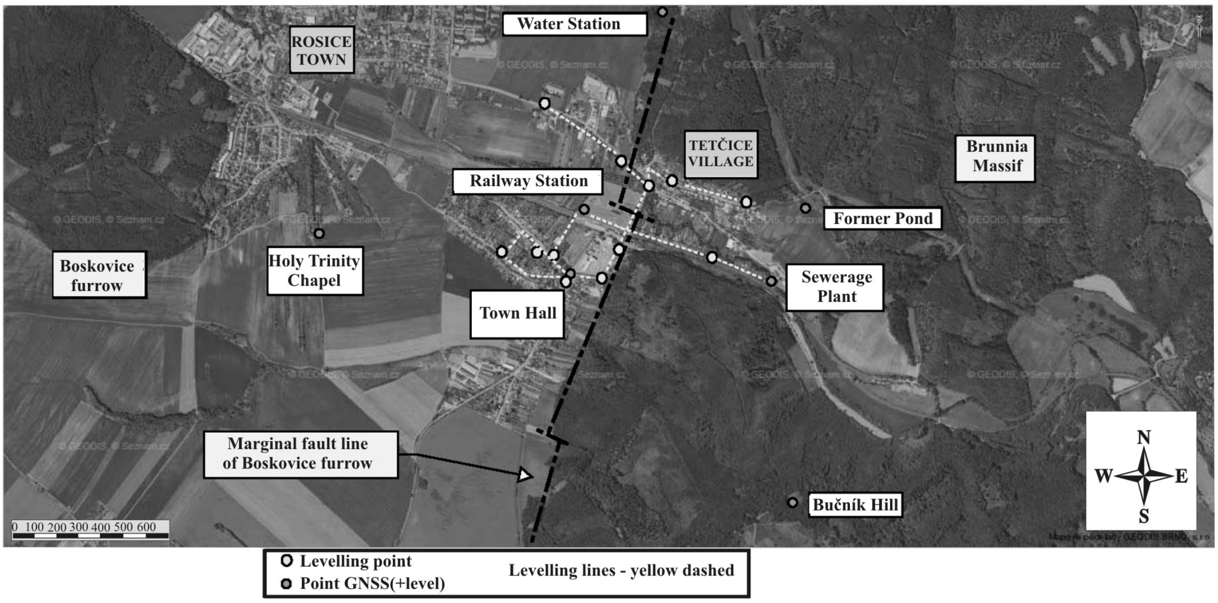

Fig. 5 GPS test area Tetčice - Network diagram and location of the measured GPS and levelling points.

The horizontal reflections between DCTZ and Miroslav fault, at points 4 and 6 km, we consider as remnant of Moldanubian complex, which can be combined with effect magnetic anomalies provoked by amphibolites, serpentinites with granulite complexes, known at front of the Moldanubian overthrusting (Fig. 2).

The final simple tectonic section (Fig. 4) illustrates and emphasizes this zone (red line with letter G). Amphibolite and granulite bodies have been interpreted from the magnetic and gravity data on surface and between point 4 and 6 km. Beneath the Moldanubian overthrust, the Brunnia (with Devonian and Culm sediments) rocks are strongly sheared and tectonized, and form typical duplexes mapped geologically in other places (Tomek, 1990). The western and eastern segments west and east of the Diendorf and Miroslav faults are similar. The Brunnia is here interpreted as steep structure W of DCTZ in tectonic contact with Moravian unit. Unclear is complex above where the Moravian and Paleozoic complexes are known (Roštínský, 2003) and remnant of the Moldanubian nappe can be expected.

Fig. 6 Deeply stabilized GPS point at Tetčice locality near railway station

GPS AND LEVELLING TEST AREAS

With respect to the complicated geological composition of DCTZ and mainly after experimental measurements near Tetčice and Neslovice village (Pospíšil et al., 2009) the results indicated, that for reliable and objective recognition of motion tendencies on boundary faults of Boskovice Furrow and northern end of Diendorf and Waitzendorf faults it needs to be established at least 2 GPS test areas, which will be supplemented with selected repeated PL profiles. With regard to this consideration 2 GPS profiles with test area were established in the locality of Tetčice village – Rosice Town (Figs. 5, 6) and Znojmo test area between Znojmo town and Valtrovice village (Fig. 7).

Methodology

For mapping of the movement tendencies along the DCTZ, 3 ground localities have been chosen. First

Fig. 8 Geodetic stabilization of GPS point NAHO – Načeratická hora (1993 – ČVUT), part of former geodynamical network Morava. Measured during campaign in October 2009.

Fig. 9 Types of stabilization of selected GPS points from the Znojmo test area, from left side Micmanice (Řapík – Light Fortification object), Krhovice and Tasovice (geodetic points).

couple, Tetčice village in the middle of Boskovice Furrow and Znojmo in the south, is established to provide the data about local movement trends. The last one, regional network, built of former Morava geodynamic network, including points Dukovany – DUKO, Stolová hora u Mikulova – STOH, VUT Brno – TUBO and Načeratická hora – NAHO (Načeratice hill – Fig. 8), have been designed to bind the local networks together and describe regional character of expected crustal movements.

In the Znojmo local network, only the GPS method for determining horizontal and vertical motions is used, because of long distances between points (up to 6-7 km) the levelling method was disclaimed for its high complicacy on long distances and mainly time costs. GPS points are observed repeatedly in triplets (3 times a day) in an interval of 6 hours, points NAHO (Fig. 8), 7 (Valtrovice) and 3 (Hradiště) are observed continually (up to 19 hours). Another method, especially the repeated gravimetry, is planned in case of acquirement of additional funds.

At Tetčice-Rosice site, the both primary methods are used. Repeated GPS measurements were used mainly for determining horizontal movements in form of reoccupation method in triplets in the same interval as in Znojmo network. Points Sv. Trojice, Bučín and

Tables 1 and 2 - identified an annual rate of measured points between the different stages reduced at the same time scale.

	1. - 0. in [mm/a]	2. - 0. in [mm/a]	3. - 0. in [mm/a]	Velocity [mm/a]	RMS [mm]
101	-5.82	-0.90	10.23	1.17	6.09
102	-10.51	-2.57	1.02	-4.02	4.35
103	-14.80	-4.81	7.86	-3.92	8.06
104	-4.42	-0.29	11.07	2.12	6.05
105	-3.81	-3.49	1.67	-1.88	2.58
106	0	0	0	0	0
107	-97.85	-53.75	-24.52	-58.71	26.45
108	-16.88	-10.05	-3.76	-10.23	4.64
109	-13.87	-8.52	-2.64	-8.34	3.98
110	-8.23	-7.51	-6.46	-7.40	0.64

	1. - 0. in [mm/a]	2. - 0. in [mm/a]	3. - 0. in [mm/a]	Velocity [mm/a]	RMS [mm]
201	-6.42	-4.40	-5.61	-5.48	1.18
202	-6.93	-2.53	-4.90	-4.79	2.50
203	-6.80	-1.48	-3.18	-3.82	2.79
204	-0.30	0.65	-0.88	-0.18	0.90
205	0.93	-0.19	-1.34	-0.20	0.80
Ocd25.1	0	0	0	0	0
206	0.43	-0.12	-1.19	-0.29	0.60
207	5.51	4.01	1.02	3.51	1.67
208	5.67	1.88	0.54	2.70	2.01
209	2.05	0.78	-0.35	0.83	0.85
210	-1.90	-0.95	-1.74	-1.53	0.62

Vodárna were observed continually (up to 24 hours). The second method, focused on vertical movements, is the precise levelling (PL). Using callibrated optical (Zeiss Ni005A) and electronical (Leica NA3003, DNA03) levels with calibrated equipment it is expected to get not only quality results in vertical direction, but also the comparison between GPS and precise levelling repeatedly for scientific and development purposes. The distances between points are shorter, mostly up to 1 km.

For the points DUKO and STOH the 24 hour static measurement is applied together with the GPS EPN station TUBO placed on the roof of Faculty Civil Engineering (BUT), included also in the permanent state satellite network CZEPOS. With the NAHO point, it is possible to determine the regional character of horizontal motions in the south-western Moravia thanks to getting sufficient information from former Morava geodynamic network, to which these points belong. Now, the measurements were repeated after 16 years afterwards, which can provide essential information about recent movement tendencies surrounding the DCTZ.

Geodynamic GPS network Morava

This satellite network, established in 1993, was designed in cooperation of ČVUT in Prague and VŠB in Ostrava (Kabeláč and Ratiborský, 1999). Main idea was the description of recent crustal movements using modern satellite techniques on large area of Morava Region with repeatedly observed points, well stabilized on representing moravian geological units, with some additional more distant points, located for example in Modra piesok (MOPI) in Slovakia. Because of lack of GPS receivers, private and scientific institutions (including Brno University of Technology - BUT, Czech University of Technology - ČVUT, Mining University -VŠB) cooperated on this project. Till the end of the measurements in 1995, the Morava network was measured 3 times in 1-year period. One of the important outputs was for example schematic chart of compresion/extension areas in Moravia. Nowadays, these data can made an important basement for determining crustal motions along Boskovice furrow in the SW part of former Morava network with an exclusive offset of 16 years.

In future the conection on the point of HIGHLANDS and GEONAS networks (Schenková et al., 2007; Schenk et al., 2010) is considered, too.

OVERVIEW OF SOME GEODETIC RESULTS

Levelling measurements at Tetčice locality

Estimated measurement accuracy in the vertical direction (PL method using Zeiss equipment Ni005A) was approximately 0.5 mm to 1 km bidirectionally measured leveling in all 4 stages. The resulting values serve for monitoring of the trend and description of annual rates of movement (Tables 1 and 2).

Points 106 and Ocd25.1 were chosen as a reference for height measurements in all stages. In Tetčice it can be noted that while the eastern branch of the profile is not moving, in the west side the shift can be shown at points 108, 109 and 110 in the area of Boskovice Furrow, this triplet of points may be affected by tectonic activity, or even subsidences made by mining activities in the former Rosice-Oslavany coal district. In Neslovice the results show a subsidence in section of point 201 and similar trends at the points 202 and 203 on the Brunovistulian, while other points show rather insignificant changes, except section 207.

GPS measurements at Tečice test area

Sequential GPS measurements were carried out in response to levelling. The technology of measurement was set to 8 hours interval and hourly

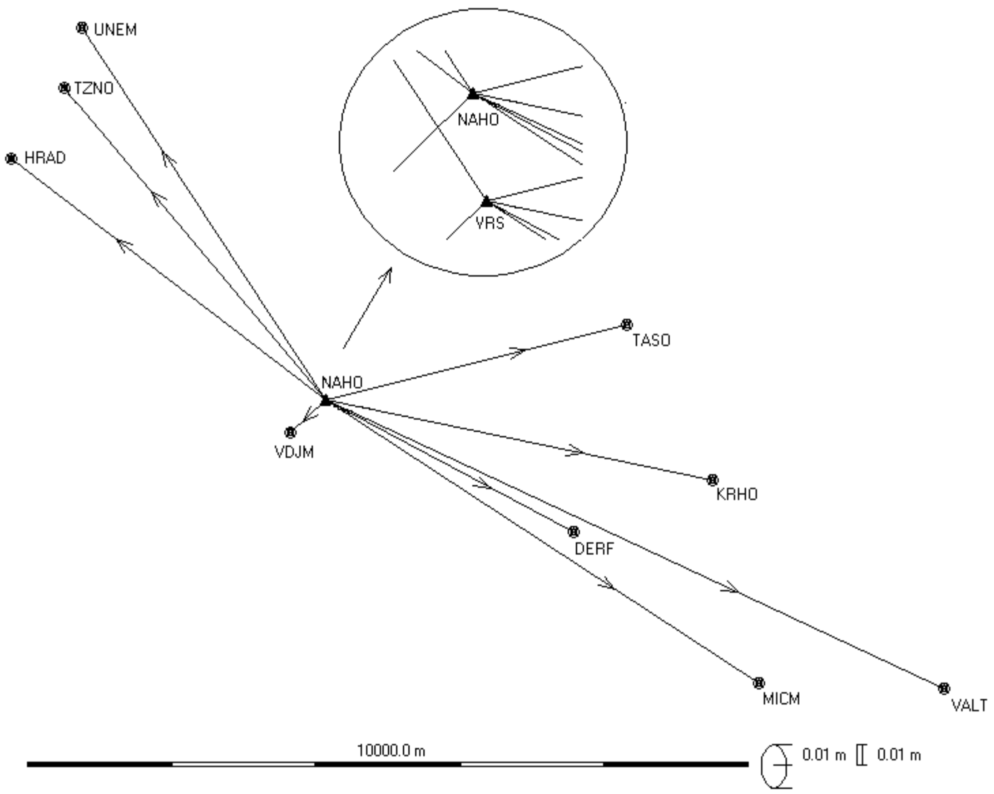

Fig. 10 Output created in LGO – scheme of geodynamic network in the vicinity Znojmo town.

observation with a recording frequency of 10 sec. It was possible to achieve (in case of no obstacles close to the horizon) relative accuracy 4 mm in N- and 3 mm in E- and 5 mm in U-component, but the results significantly depend on the distance to each reference station. Calculations with respect to 15 km distant stations TUBO and CMOK showed approx. 3 times worse accuracy characteristics. Two nearby points, so called double-points with the same expected movement were used. Processing of the results was carried out in the program SkiPro 3.0 and adjustment module MOVE3.

GPS measurements at Znojmo test area

In 2009 a local geodynamic network was built in the vicinity of Znojmo. The network covers an area approximately 15 x 3 km on both sides of the valley of the river Dyje, and should be used to monitor the expected shifts in southern part of DCTZ. Meassured points (8) are stabilized with metal pins installed in rocky outcrops or in massive objects; observation is taken from a tripod (Fig. 9).

In October 2009, first GPS campaign was carried out with equipment of two Leica SR520 and two Leica GX1230, lasting 20 hours. At six points the measurement was divided into three hourly observational intervals with spacing from 6 to 7 hours, at 2 points the observation was continuous (Švábenský and Weigel, 2005; Švábenský et al., 2006). Local reference station was established at the point Načeratická hora (at the top), which is a part of former Geodynamic Network MORAVA. Data recording interval was set to 10 sec. Network configuration and diagram of the evaluation is shown in Figure 10. Alternative reference point was at the station of permanent network TOPNET located in Znojmo (TZNO).

Virtual reference station (VRS) has been experimentally used with data generated within the CZEPOS network for the position close to the point at the top (at a distance of 6 m). Simulation studies and preliminary results of the first stage of the evaluation showed that the designed configuration and the selected observation scheme can provide the relative accuracy in the horizontal position of 1 to 2 mm, the accuracy of the vertical component of 2 to 4 mm at all points of the network. When using the VRS, the performance was found in the horizontal accuracy of about 2 times lower and the vertical accuracy of 3 times lower, and therefore VRS-data will be next used for corroborative purposes only. In the Znojmo network it will be possible to use data from the newly established permanent CZEPOS station in Znojmo (CZNO) in next stages.

CONCLUSION

This contribution summarizes basic geological and geophysical questions of ground composition interpretation along the DCTZ. Complicated tectonic evolution and ground composition impose requirements on the selection of polygon areas and their measurement. Therefore an expert team almost two years implemented verification GPS and PL measurements on Tetčice locality. The results of measurements, the assessment of sites in terms of geological structure and expected dynamics give a presumption of the successful capture of motion trends at DCTZ. Only the involvement of a wide range of experts (geomorphologists, geologists and geophysicists), can bring the expected effect in the use of geodetic measurements and their results.

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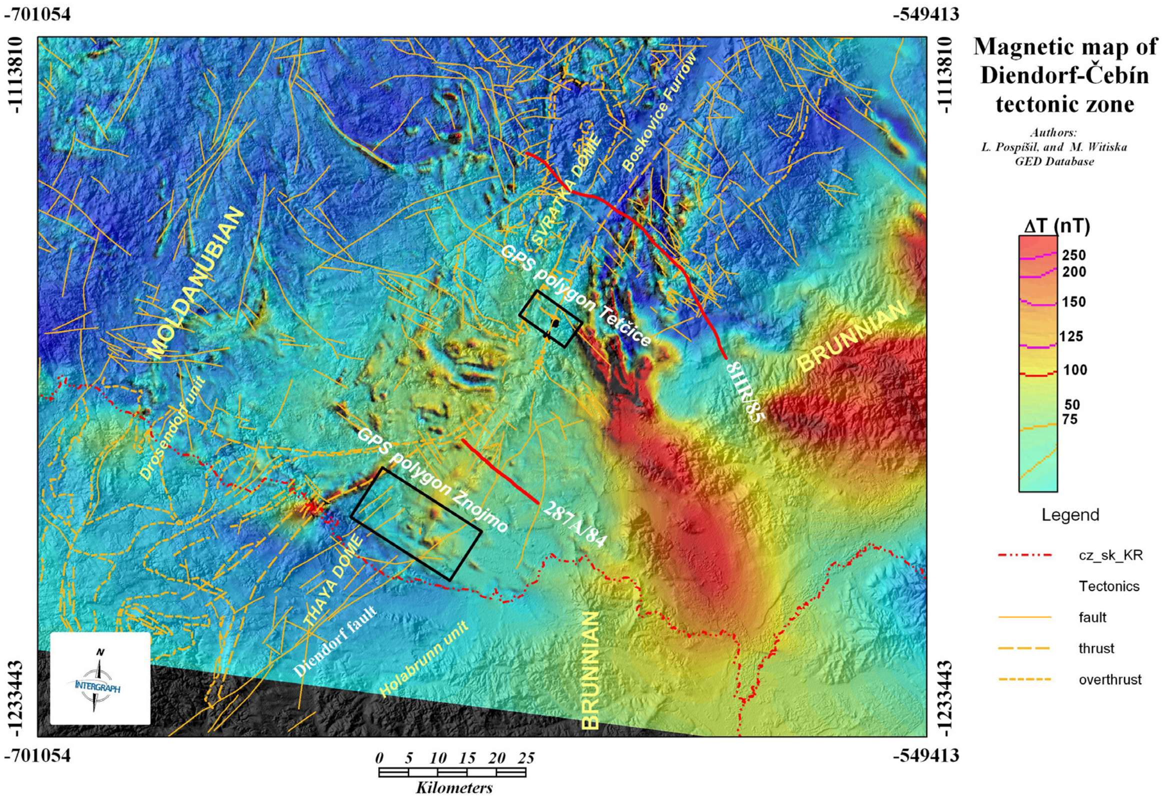

Fig. 2 The tectonic scheme and distribution of the main geological units show very strong correlation with the magnetic chart. The different intensity and form of magnetic anomalies in space of Brunnia and Moldanubian units emphasize the role of DCTZ. Red lines – location of interpreted seismic sections Nos. 8HR/85 and 287A/84. The black rectangles determinate GPS test areas - Znojmo (south) and Tetčice (north).

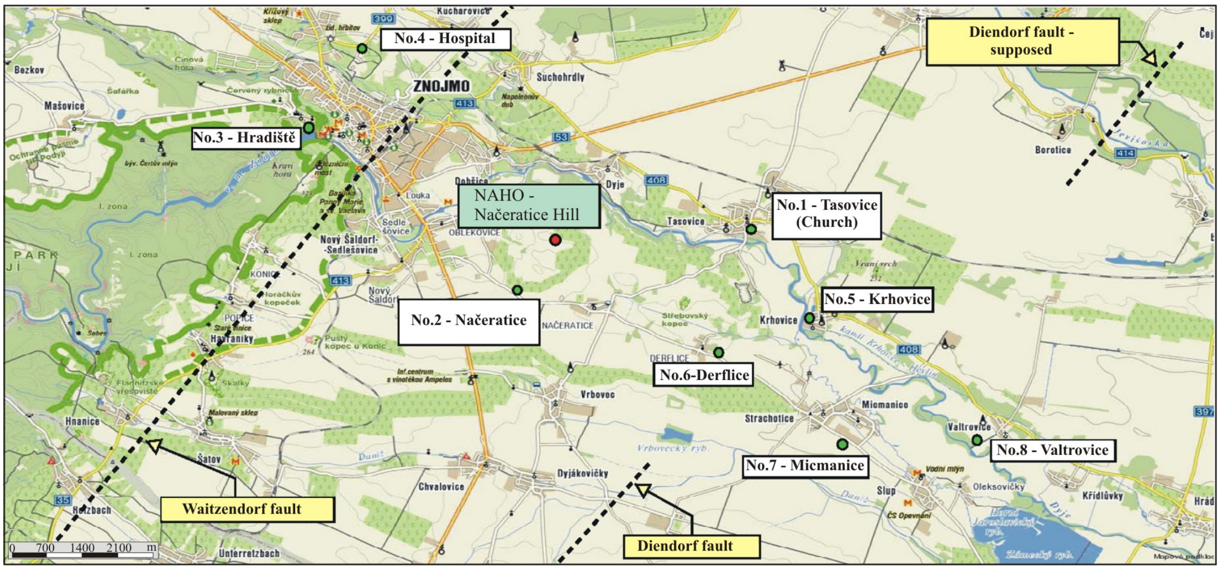

Fig. 7 GPS test area Znojmo - Network diagram and location of the measured GPS and levelling points. Weitzendorf and Diendorf faults – black dashed line.