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ORIGINAL PAPER

RESULTS OF REPEATED MEASUREMENTS AT THE ŽELEZNÉ HORY-TIŠNOV FAULT SYSTEM SURROUNDINGS

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ABSTRACT

The article deals with the possibility of usage of the comprehensive geodetic, geological, and geophysical knowledge for mapping of the critical areas surrounding of the Železné hory – Tišnov tectonic zone (ZHTTZ) that might from recent point of view (geodynamical and partly seismotectonic) represent next major kinematical boundaries for the area of the Moravia. On the Moravia territory we shortly demonstrate results of the GPS and quantitative geophysical analyses, that enable to evaluate preliminary movement tendencies in the area. The information can be in future period used for prognostication of localities with possible higher seismic hazards.

1. INTRODUCTION

The Morava network was founded in 1994 as one of the first GPS geodynamic projects in Czech Republic with aim to determine the deformations at border zone between the Bohemian Massif and the Carpathians. Three GPS campaigns were carried out in period 1994 – 1996, but the measurements were not continued.

In 2010 the Institute of Geodesy of BUT Brno seized the opportunity to carry out new measurements in southern part of the Morava network including five stations, and in 2013 another seven points have been re-measured in central and northern parts. The paper presents a comparison of results of previous and contemporary (after time lag of more than 15 years) epoch GPS measurements. Last results confirm the movement tendencies at the Bohemian Massif and the Western Carpathians border, indicating recent tectonic activity at different parts of the Moravia territory (Fig . 1).

2. TECTONIC PATTERN

Description of the Tertiary to recent tectonic pattern in the Moravia territory is presented from the N to S (Fig. 1). East of the Velké Vrbno Dome, the important Ramzová tectonic line is situated with the Branná Group of probably Devonian age (Middle Paleozoic, around 380 million years) behind it, which covers only a small, south-eastern section in the map. The crystalline series of the Sniežnik metamorphic unit in the west are separated from the Cretaceous sediments (Upper Cenomanian, around 95 Ma old) of the Nysa-Kłodzka Trough by a fault structure which locally has the character of a reverse fault. At the end we have to mention the environs of Lądek-Zdrój and Bruntál, where basaltic lavas poured out on the gravels deposited at the Tertiary-Quaternary boundary (Birkenmayer et al., 2002).

Central part of the Bohemia dominates the Železné hory – Tišnov tectonic zone (ZHTTZ – Mísař et al., 1983). This fault limits the Železné hory from the south. With this tectonic system the next significant dislocations are combined. In the Kutná Hora crystalline complex it is the Hlinsko tectonic zone which separates the above mentioned crystalline from Svratka crystalline complex. Next two zones, the Křídlo and the Vír faults, are located in Svratka crystalline. Apart from this dislocations in this area there exist group of partial faults and mylonite zone (usually with clay filling), that considerably weakened rock massifs. The weakened zone are also bound on the mica schist. The Železné hory fault itself imagines dislocation tilted to NE, along it the movements were repeated also in post-Variscan epochs (so called Saxonian tectonics).

At the south, in the NNW-SSE direction, a significant Cretaceous depression follows the ZHTTZ. Thickness of Cretaceous sediments reaches up to 90 m. In contact places with ZHTTZ this depression changes its direction to NW-SE, narrows and partly plays out.

The tectonic connection between the Boskovice furrow and the Diendorf fault system is the key for understanding of Tertiary to recent tectonic processes in area between the Moldanubian, the Saxothuringian and the Brunnovistulian units. With this zone next problems are combined, e.g existence of Moravicum. Under this naming Jiříček (1991) describes the most problematic unit, placed between the Dyje and the 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, by the Miroslav fault, from the second one it is continuation of the Diendorf-Čebín Tectonic Zone (DCTZ) through Central basic belt.

At first place, the Hollabrunn, Krhovice and Miroslav crystalline complexes represent it there. In its deep basement the Brunnia unit (Mísař et al., 1983) is evolved, its granitoides rise to the surface under Wienerwald flysch in the Tulln Dome and in the Dyje Dome (second one Jiříček (1991) does not consider!?). Its cover was detected in the northern part of the Miroslav horst, too Roštínský (2003). 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 granitoids belonging to the Bruno-vistulicum. The Diendorf fault runs in the geological map from Melk to the NE to Langelois town, dividing the Krhovice foreland. Continuation of the fault to the west of the Miroslav crystalline complex is still open to argumentation. We can also observe its connection to the eastern fault of the Boskovice furrow. Because the Permo-Carboniferous sediments of Boskovice furrow are the lower situated block against the Brno Massif, many authors connect the Diendorf fault with the subsidence and strike-slip tectonics (Fig. 1).

Analogical situation is placed in the eastern direction with the Miroslav fault; on its depressed western block are Permo-Carboniferous 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 as is generally accepted. Considering the fact, that on the depressed Dyje block we can find granitoids, which occur on the Miroslav or the Krhovice upper block under the metamorphites, there have been long discussed question about the connection of the Diendorf fault with the horizontal displacements, steep overthrust of the Hollabrunn crystalline complex or the Dyje Massif in opposite direction of the fault.

Zone between Geras and Znojmo is influenced by next important fault system – the Waitzendorf fault. This fault is crossing the Dyje Dome, cuts mainly complexes of Brunnia, only on the SW margin of the Dome crosses the Moravian unit. In the zone between Diendorf and Waitzendorf 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 altitudinal contrast between the higher elevated crystalline terrain of the Massif and the lower sedimentary relief of the Foredeep is likely of the Late Miocene-Quaternary age (Roštínský, 2003).

Concerning the recent geodynamical activity, unclear situation is in the Moldanubian unit, where the earthquake foci were also registered along the main faults.

During Alpine orogeny, the Bohemian Massif comprised a northern tectonic foreland of the Alps and the Carpathians. An Alpine stress field must have been established which was probably very similar to that maintained in the Hercynian orogeny. As a result, Variscan shear zones likely were locally reactivated at higher crustal levels. The graben of České Budějovice (Fig. 1) contains Cretaceous to Miocene sedimentary rocks and is bordered by faults which have NW-SE and NE-SW to NNE-SSW orientations; therefore, Alpine faulting is suggested for this graben (Fuchs and Matura, 1976). Reactivation of the shear zones supports interpretation of a pattern of shear deformation extending into Middle Europe and explained by Alpine N-S striking convergence (Stackebrandt and Franzke, 1989).

3. GEOPHYSICAL DATA AND REMOTE SENSING DATA

Although the analysis of Remote Sensing data has not been the subject of a project, analysis of selected parts of the Bohemian Massif showed that the majority of fractures, which focus on GPS campaigns (Sudetic Marginal fault, Diendorf-Čebín tectonic zone, Waitzendorf fault, Bulhary fault etc.), have a number of morphological characters and elements that are pointing to recent dynamics of these interfaces.

Therefore, for purposes of analysis and interpretation of physical tendencies a set of geophysical maps were compiled. These maps were also used to verify the interpretation of results. In addition, this interface was often traceable on aerial or satellite images.

From these data, we then proceeded to compile a simplified map of faults with recent activity. We are aware that in the future it will be necessary to unify the methodology of velocity estimation from different sources for detail research of the Bohemian Massif.

4. GPS DATA

Regional velocity field resulting from complex analysis based on reprocessed homogenized long-term GPS measurements provided by permanent and epoch-wise GPS stations located on the territory of Czech Republic, Slovakia and adjacent territories was published in (Hefty, 2007) and (Hefty et al., 2010). The analyzed data stemmed from more than 110 GPS

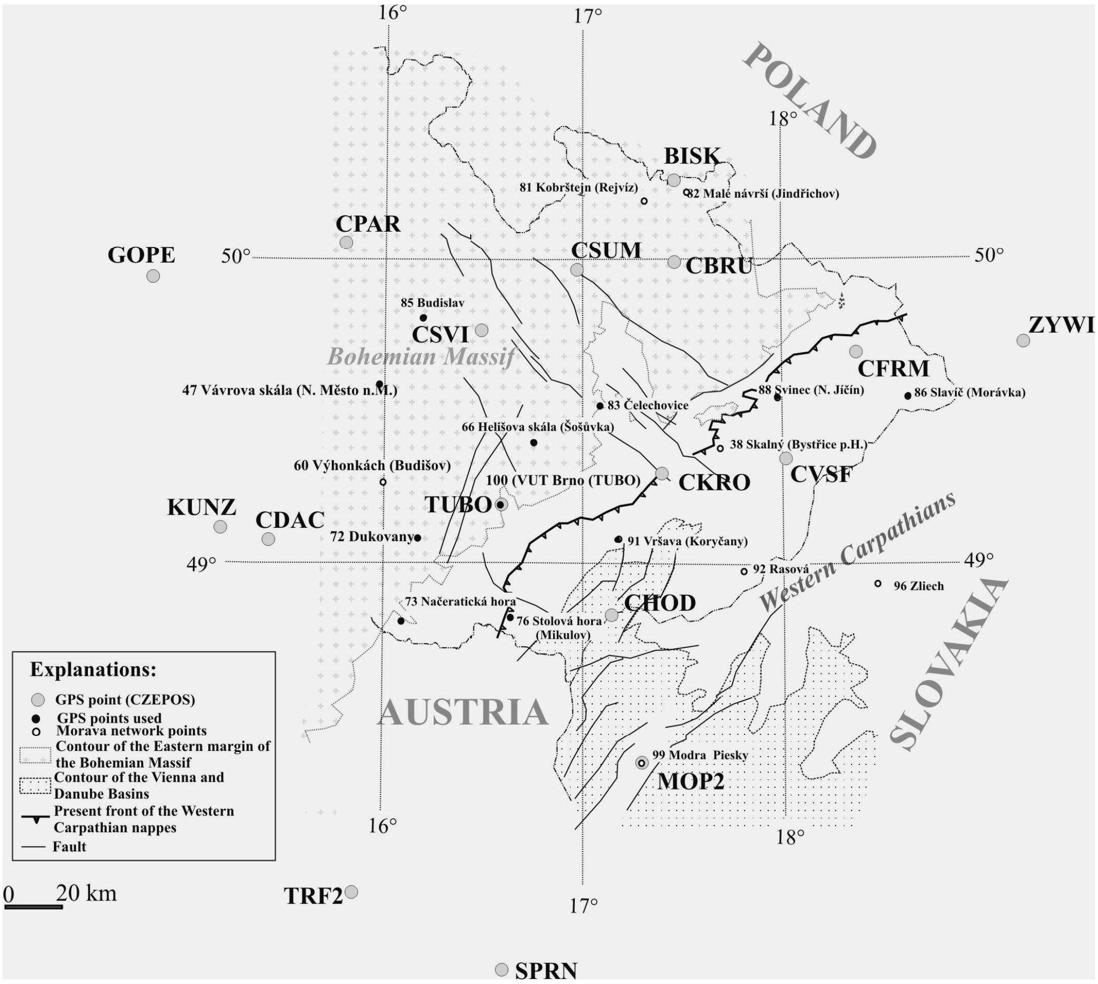

Fig. 2 Location of the Morava and CZEPOS network points.

stations, belonging to one permanent and four epoch-wise GPS networks. The data are covering reasonable time span to estimate the geo-kinematical behavior of the monitored areas. The regional velocity field we used as the comparable frame for estimation of more detailed kinematic trends and movement tendencies in Moravia region (corresponding velocity vectors are shown in Fig. 1).

Several GPS networks have established on territory of Moravia since 1992. In 1992 measurements in the Czech-Polish Local Geodynamic Network Sněžník started. First larger geodynamic project was the Morava network established in 1994. From 1996 the activities of the Institute of Rock Structure and Mechanics in Prague followed – the Eastern Sudetes and other networks, permanent station BISK and others. In 2005 the CZEPOS permanent network started to operate, with several stations located at Moravia territory. The increasing number of permanent and epoch stations enable the preliminary estimation of movement trends on base of long-term GPS data series evaluation. Locations of the Morava and CZEPOS network points are shown in Figure 2.

4.1. MORAVA LOCAL GEODYNAMIC NETWORK

The GPS geodynamic Morava network was established in 1994 for the purpose of monitoring the supra-crustal blocks motions at the Bohemian Massif and the Alpine-Carpathian Arc border. It includes 19 points covering the area stretching from eastern part of the Bohemian Massif to western part of the Carpathians. Most of the points are monumented directly on rock outcrops, two points have markers welded to casing of deep boreholes.

Measuring campaigns within the original project were carried out in period 1994 – 1996. Testing campaign had been carried out in December 1994, with only 8 observed points, the stations MOPI and TUBO were also observed. Observation time was 8 hours. First measuring campaign had been realized in October 1995, in three successive 10 hours night sessions. Total number of the observed points was 19. The second campaign had been carried out in June 1996, in time of the EXTENDED SAGET campaign. The observing time was 4 to 5 days continually, with the same instrumentation like in previous campaign. Again the total number of observed points was 19, but

Table 1 Morava network - baseline length changes.

Baseline	1995 [m]	2010 [m]	2013 [m]	Differences 1995-2010/2013 [m]	Annual velocities [mm/year]
TUBO-NAHO	55609.6905	55609.6948		0.0043	0.3
TUBO-DUKO	32967.0045	32967.0015		-0.0030	-0.2
TUBO-STOH	40694.2764	40694.2862		0.0098	0.7
TUBO-VRSA	45081.2146	45081.2291		0.0145	1.0
NAHO-DUKO	29388.5003	29388.5046		0.0043	0.3
NAHO-STOH	39775.6470	39775.6456		-0.0014	-0.1
NAHO-VRSA	85424.5644	85424.5878		0.0234	1.6
STOH-DUKO	43172.8455	43172.8464		0.0009	0.1
STOH-VRSA	49374.6791	49374.7074		0.0283	1.9
DUKO-VRSA	73671.7331	73671.7474		0.0143	1.0
TUBO-BUDI	73004.7922		73004.7870	-0.0052	-0.3
TUBO-HELI	25947.4996		25947.4871	-0.0125	-0.7
TUBO-VAVR	55325.8208		55325.8260	0.0052	0.3
TUBO-CELE	51001.7844		51001.7803	-0.0041	-0.2
TUBO-SVIN	108476.7260		108476.7234	-0.0026	-0.1
TUBO-SLAV	152368.5084		152368.5012	-0.0072	-0.4
SVIN-SLAV	46293.9120		46293.9040	-0.0080	-0.4
BUDI-SVIN	133321.9737		133321.9808	0.0071	0.4
CELE-VAVR	71387.4306		71387.4298	-0.0008	0.0
CELE-HELI	27243.6724		27243.6728	0.0004	0.0
VAVR-HELI	51267.8067		51267.8200	0.0133	0.8
BUDI-VAVR	24318.1101		24318.0957	-0.0144	-0.8
BUDI-HELI	60696.2749		60696.2869	0.0120	0.7
CELE-BUDI	72666.6893		72666.6928	0.0035	0.2
Session times	3 x 10 hours	24 hours	24 hours		

the published results covered only 10 points. In all the three campaigns the Leica instrumentation (SR299 and SR399 receivers) had been used (Foldyna et al., 1997). After 1996 the measurements were not continued because lack of support.

In 2010 the Institute of Geodesy of Brno University of Technology (BUT) seized the opportunity to realize new measurements in part of the Morava geodynamic network. Five points at Southern Moravia (DUKO, NAHO, STOH, VRSA and TUBO) were selected for re-measurement. At all the points it had been possible to identify uniquely the original position of the centering markers. Again solely the Leica instrumentation had been used (SR520/530 and GX1230GG receivers with LEIAT502, LEIAX1202GG a LEIAT504/504GG antennas). Observing intervals were 24 hours (Švábenský et al., 2011). In 2013 another seven points were re-measured in Central and Northern Moravia (BUDI, HELI, VAVR, CELE, SVIN, SLAV and TUBO). The above mentioned Leica instruments were used along with two Topcon HiPER Plus receivers

The data of campaigns 2010 and 2013 were processed by means of BSW 5.0 (Dach et al., 2007). Processing parameters were: elevation mask 10º, IGS precise orbits and Earth rotation parameters, absolute antenna phase center offsets and variations, QIF or narrow lane strategy of ambiguity solution, troposphere parameters estimated in 1 hour intervals. The final solution was computed using ionosphere-free frequency combination.

Table 1 shows the corrected baseline lengths between the Morava network points from the first campaign 1995 (Foldyna et al., 1997) and from the re-measurement 2010 and 2013, as well as the differences between the results of previous and new measurements together with the estimation of annual velocities (Fig. 3). The 1995 campaign was selected as reference for the comparison because this campaign is the most complete and includes all the points concerned.

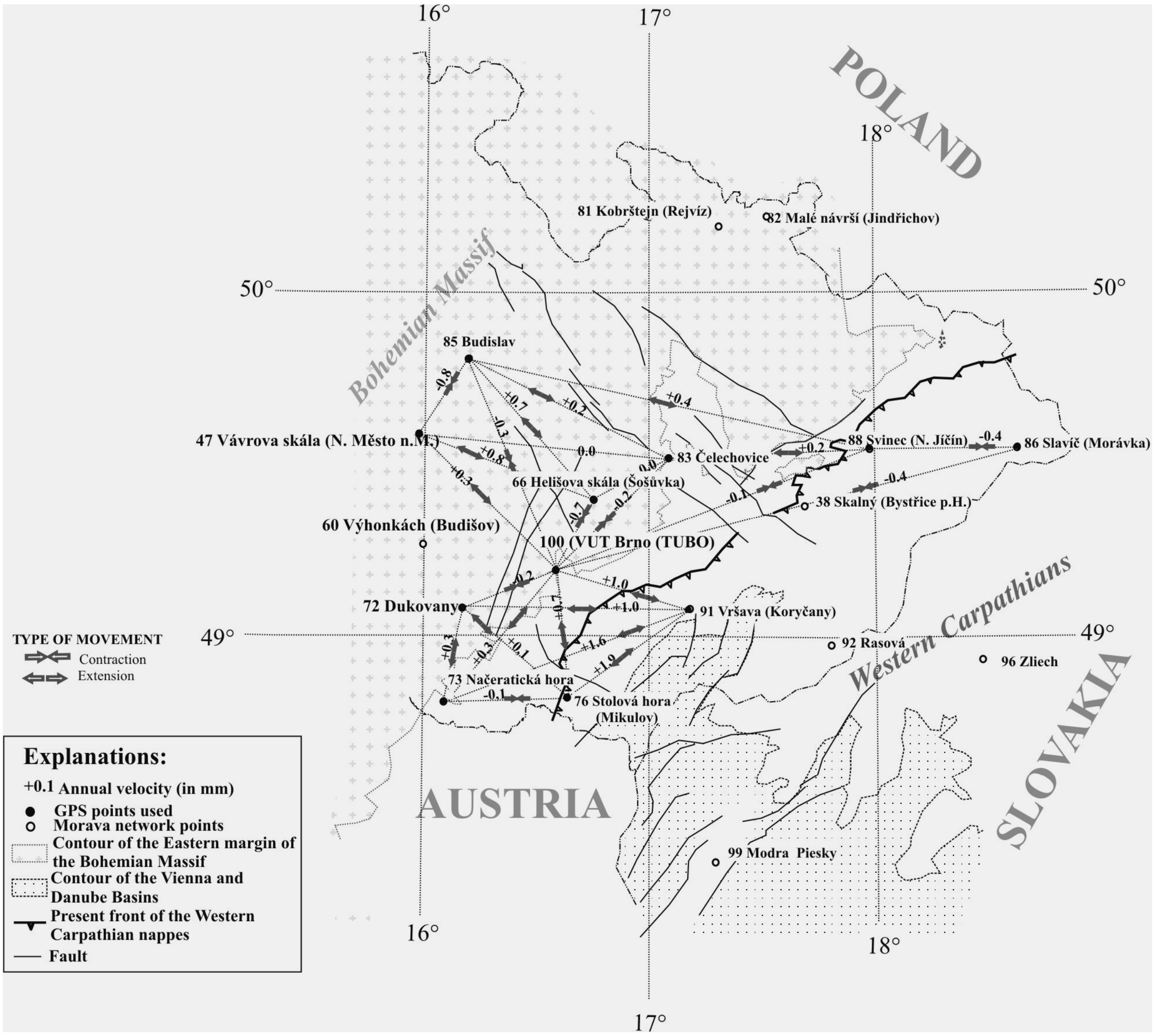

Fig. 3 Preliminary annual velocities in Morava network.

To check the consistency of previous and new processing results the original data from campaigns 1995 and 1996 were reprocessed. The above presented results are preliminary in sense that only baseline lengths were computed with reference station TUBO positions constrained to ITRF coordinates (EUREF solution) for each particular epoch.

4.2. CZEPOS NETWORK

The national permanent GNSS CZEPOS network started to operate since May 2005. To get another preliminary information about possible movement tendencies over the Moravia territory the long-term data from selected stations of CZEPOS network were evaluated. The data from stations CDAC, CPAR, CFRM, CSVI, CSUM, CBRU, CVSE, CKRO, CHOD, together with data from selected surrounding EPN stations BISK, GOPE, WROC, TUBO, ZYWI, MOP2, KUNZ (Figs. 2 and 4). The data of two 48 hours epochs per year - first in Spring (May), second in Autumn (September, October) - over the period 2005 – 2012 were processed using the Bernese software ver. 5.0, employing comparable processing strategy as in MORAVA network.

The CZEPOS stations quality in respect to displacement monitoring is not very convincing because the antennas are mounted on building roofs. On the other hand, advantageous is the identical instrumentation and the same antenna type at all stations, as well as the same processing pattern in all epochs. Evaluation period had to be shortened to 2005 – 2011 in some cases due to significant jumps in the time series caused by antenna change in complete CZEPOS network in first half of 2012 together with receivers upgrade (Pospíšil et al., 2013).

First information about velocities of the baseline changes between the permanent network stations was gained by simple superposing of linear trend upon the

Table 2 CZEPOS and EPN networks - baseline length changes.

Baseline	Annual velocities [mm/year]	Baseline	Annual velocities [mm/year]	Baseline	Annual velocities [mm/year]
TUBO-GOPE	0.2	TUBO-CSVI	0.2	CHOD-CKRO	-0.5
TUBO-WROC	-0.3	TUBO-CSUM	0.0	CHOD-CVSE	-0.4
TUBO-ZYWI	0.9	TUBO-CHOD	-0.1	CKRO-CBRU	-0.1
TUBO-MOP2	0.8	TUBO-CDAC	-0.3	CPAR-CSUM	-0.6
TUBO-TRF2	-0.5	TUBO-CKRO	-0.1	CPAR-VYHL	-0,3
TUBO-KUNZ	-0.7	CPAR-GOPE	-0.2	CSUM-CSVI	-0.5
TUBO-SPRN	-0.7	CPAR-CSVI	-0.6	CDAC-CSVI	-1.4
TUBO-CPAR	0.0	CPAR-CDAC	-1.2	VYHL-BISK	0.8
TUBO-CFRM	-0.4	CFRM-BISK	-2.2	VYHL-ZYWI	0.7
TUBO-CBRU	0.2	CFRM-ZYWI	0.6	VYHL-WROC	-0.2
TUBO-CVSE	0.1	CFRM-CVSE	-0.2	TUBO-VYHL	-0.1

single baseline time series over the period analyzed. The results evaluated are presented in the following table.

Table 2 shows the corrected estimated preliminary velocities evaluated on base of single baseline processing between the stations of CZEPOS and EPN networks. Overall accuracy of the velocity estimation is 0.2 to 0.3 mm/year. The resulting velocity values enabled to form first ideas about the main movement tendencies within the Moravia territory indicated in Figure 4.

5. RESULTS

Geodetic analysis - the results of GPS measurements in the Morava and CZEPOS networks (Fig. 4 - Švábenský et al., 2011) are based on comparison of movement tendencies with the results gained at the CEGRN network (Hefty, 2007, Hefty et al., 2010) which was used as an overall velocity frame. All geodetic information about horizontal movement tendencies has been confronted with geomorphological and geophysical data available. A distinct tectonic pattern constructed on the geodetic results indicates good correlation with geophysical anomalies (magnetic, gravity anomalies, earthquake foci etc.).

Preliminary GPS positioning results obtained on 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 (Švábenský et al., 2011). Particularly 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.

The movement tendencies, obtained on the basis of GPS results and repeated levelling measurement (Vyskočil, 1996), are confronted with geomorphological and geophysical data through GIS (Fig. 6).

The contact area of the Bohemia Massif and the Carpathians is characterized by rather intensive vertical movement activity reaching relative values up to 5 mm/year (Vyskočil a Zeman, 1980; Vyskočil, 1996). In the area of our interest the vertical movements are of maximal values from -2.0 to +2.4 mm/year and are bound to the ZHTTZ zone. Although the territory of Moravia is rather differentiated as to the vertical deformations, the relative movements reach maximal values 3 mm/year only in Southern Moravia area.

Maximal horizontal deformations occur between points BUDI and VAVR of the MORAVA network, with contraction character (-0.8 mm/year – Fig. 3), while between the both points mentioned and the point HELI an extension character of deformations is displayed (+0.8 mm/year).

Quite a large compression field at the area of Central and Northern Moravia (Fig. 4) could indicate the influence of the Carpathian Arc, what is supported also by uplifts in the Beskydy and the Jeseníky Mts. (Vyskočil, 1991), or rather the action of the Moldanubian part of the Bohemia Massif on Brunovistulian belt, what is supported by preliminary results of GPS measurements at South Moravia

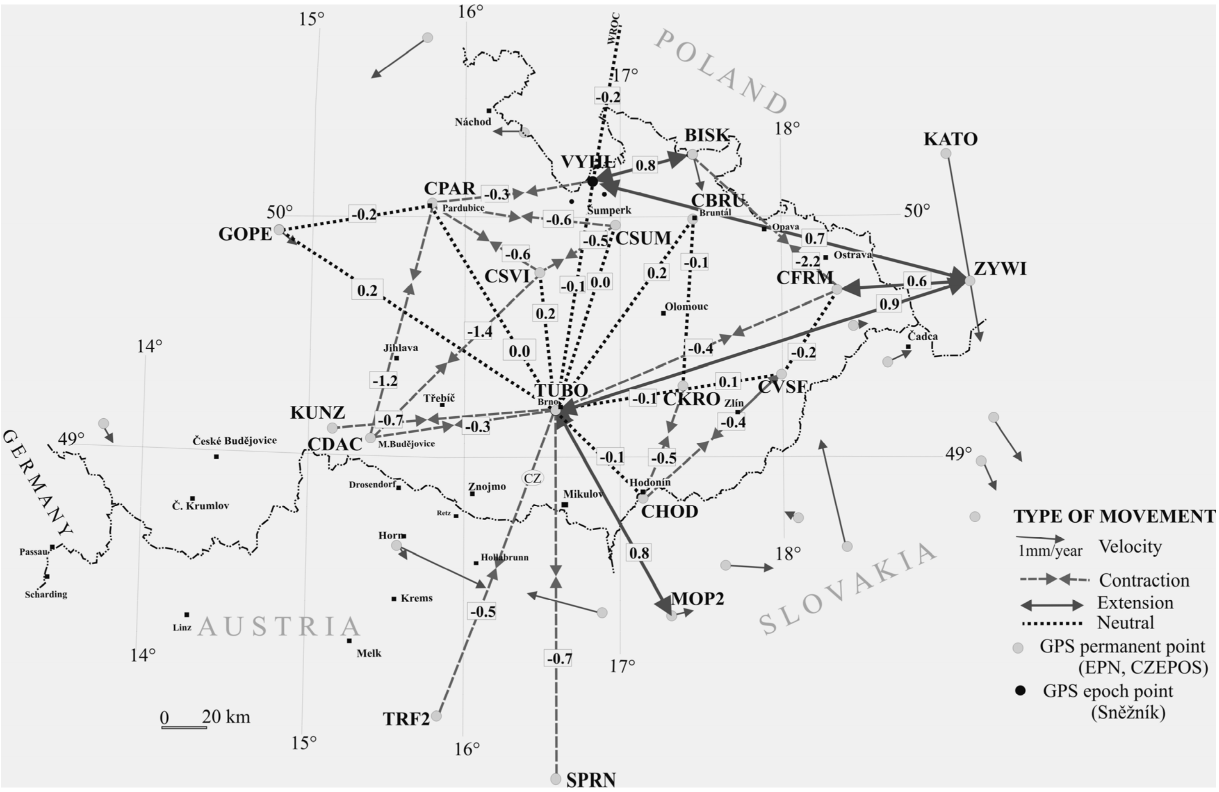

Fig. 4 Images of the major movement tendencies among selected GPS points in Moravian part of the CZEPOS network. The regional character of movements can be observed from data Hefty, 2007; Hefty et al., 2010 (arrows).

(Pospíšil et al., 2010; Švábenský et al., 2011 and Roštínský et al., 2013). Schenková et al. (2009) report even the regional movements 1 – 2 mm/year on faults at southern parts of the Boskovice furrow, interpreted as sinistral at southern part and dextral in northern part.

Seismological activities - Manifestations of feeble natural seismic activity were registered at eastern margin of the Bohemia Massif. The reasons were recently studied by several specialists (e.g. Skácelová and Havíř, 1999; Špaček et al., 2006, 2008; Lenhardt et al., 2007).

For the study we have used foci from USGS and ASCR Earthquake databases (Fig. 5). Nearby and surrounding the Boskovice town there is a dense cluster of earthquake foci with magnitudes from 1 to 2M, but their real tectonic origin is problematic. According published information (Špaček et al., 2006, 2008; Lenhardt et al., 2007) the most of them belong to so call "fake-earthquakes". In area only rarely appear foci which depths interval is between 5 km to 10 and 20 km. Similar hypocenter depths (between 7 and 19 km) were reported in northern part of Moravia (Špaček et al., 2008).

Geomorphological analyses - Various neotectonic features were distinguished in geomorphology of the area of interest, based on contour and hydrographic data from the National Geographic Database of the Czech Republic (Základní báze geografických dat České republiky, 2009). Fault-line scarps were primarily highlighted, then distinct topographic steps, elongated summit ridges and smaller intramontane basins (Fig. 7). The fault-line scarps are commonly accompanied by linear ridges. Several topographic steps used also to be linearly arranged. In the SE near Tišnov, the intramontane basins have a graben-like character.

Significant properties of the regional fluvial system were added in the respective figure, including a demarcation of main valley landforms together with an indication of their remarkable graben-like, straight and vertically asymmetric sections, places of abrupt valley deflections in their courses and locations of important drainage divides.

The general analysis pointed to two significant, roughly NW–SE trending elongated areas of zone character, manifesting themselves by a higher spatial concentrations of neotectonic features and frequently delimiting in between relatively higher surfaces of the Železné hory Highland, Žďárské vrchy Highland and Hornosvratecká hornatina Highland to the Bohemian Plateau (Czech Cretaceous Basin) and adjacent parts of the crystalline Bohemian-Moravian Highland (Demek and Mackovčin, 2006).

The major one in the center of the study area (Zone 1) extends roughly from Týnec nad Labem across Nové Město na Moravě to Tišnov, the less pronounced second one in the NE (Zone 2) from the western surroundings of Vysoké Mýto across Polička to Kunštát. Some neotectonic elements have also developed on the NE margin of the Železné hory Highland, at the N–S directed asymmetric cretaceous ridge east of Svitavy, in the N part of flat ridge west of Chotěboř, west of Velké Meziříčí, in the deep Svratka River valley NNW of Tišnov and on the SE margin of the Upper Svratka Highland to the Boskovice Furrow.

In the NW segment at a boundary of the Železné hory Highland to the Doubrava Basin, the major Zone 1 is mainly characterized by up to 150 m high NW–SE fault-line scarp (Dudíková-Schulmannová, 2008) together with related high sub-parallel ridges, locally separating intramontane basin landforms occurring behind them. The elongated drainage areas of the Doubrava River and upper Chrudimka River are also trending in the same direction; the Chrudimka River abruptly changes its course towards NE in its lower reach. The middle and SE segments of the zone area display a little different topographic image. It is especially featured by an array of NW–SE to N–S oriented crystalline summit ridges, in some cases with distinct western marginal topographic steps, and by a similar arrangement of elongated drainage areas of the Svratka River right-handed tributaries; the entire regularly directed belt is up to more than 15 km wide. By contrast, the regions of the Bohemian-Moravian Highland both SW of the introduced zone and SE of the deep Svratka River valley NNE of Tišnov are typical by a directionally irregular river network. In Žďár nad Sázavou town the upper Sázava River within its markedly asymmetric drainage area abruptly deflects its course from the S trend towards W.

In the NW, the most characteristic landforms of the second Zone 2 represent the 50–100 m high NNW–SSE fault-line scarp of the Bohemian-Moravian Highland to the SE part of the Czech Cretaceous Basin (Čech, 2009) accompanied by low sub-parallel ridges separated from this slope by asymmetric valleys. Towards N, several related distinct elongated topographic steps evolved. In the SE zone segment, the pronounced fault margin is changed for NW–SE trending crystalline summit ridges together with sub-parallel asymmetric valleys running along their NE sides. By contrast to the major zone, the consistent directional arrangement of the fluvial system is thus developed in this secondary zone in a much narrower belt only up to more than 5 km wide. Towards SW, the valley trends relate to the N–S Svratka River, towards NE to depression landforms within the Czech Cretaceous Basin; in the N on the tilted margin of this basin, an orthogonal rigorously parallel valley system in the upper Loučná River drainage area has largely evolved.

New knowledge obtained allows not only to complement and specify the permanent database and the results, but whenever refined to include more interdisciplinary interpretations. For these purposes the pilot kinematic model for the Moravian region has been constructed (Pospíšil et al., 2013). The obtained preliminary results indicate the area located approximately between the Kralický Sněžník Massif and the south Dyje Dome as passive block with pushing of a Moldanubian block from the west. The area of the Flysch Carpathians in the east tends to move in the southern part of the NE in the northern part of the contrast to NW (Ptáček et al., 2012; Jarosiński, 2005).

These conclusions are based on more than 15 year time span of repeated measurements. It is expected that in the coming years, the results will be continuously improved.

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 Brunovistulian units.

6. CONCLUSIONS

New GPS results proved existence of kinematic activity at ZHTTZ. Its display can be followed in geodetic, geological, and geophysical data, and also in seismological data (at the crossing with the Boskovice furrow), which unambiguously prove recent activity. Mapping of the critical areas surrounding of the ZHTTZ might from recent point of view (Remote Sensing, geodynamical and mainly GPS measurements) represent another major kinematical boundary for the area of the Moravia.

Joint results of studies of dynamics of the Bohemian Massif crust based on geodetic and geophysical data confirm recent activity of some parts of the Moravian territory. Recommendations submitted for further refinement of knowledge concerning the recent activity of these areas may help e.g. in the process of selection or evaluation of chosen areas for building Deep Geological Repository, which is currently a task of high priority.

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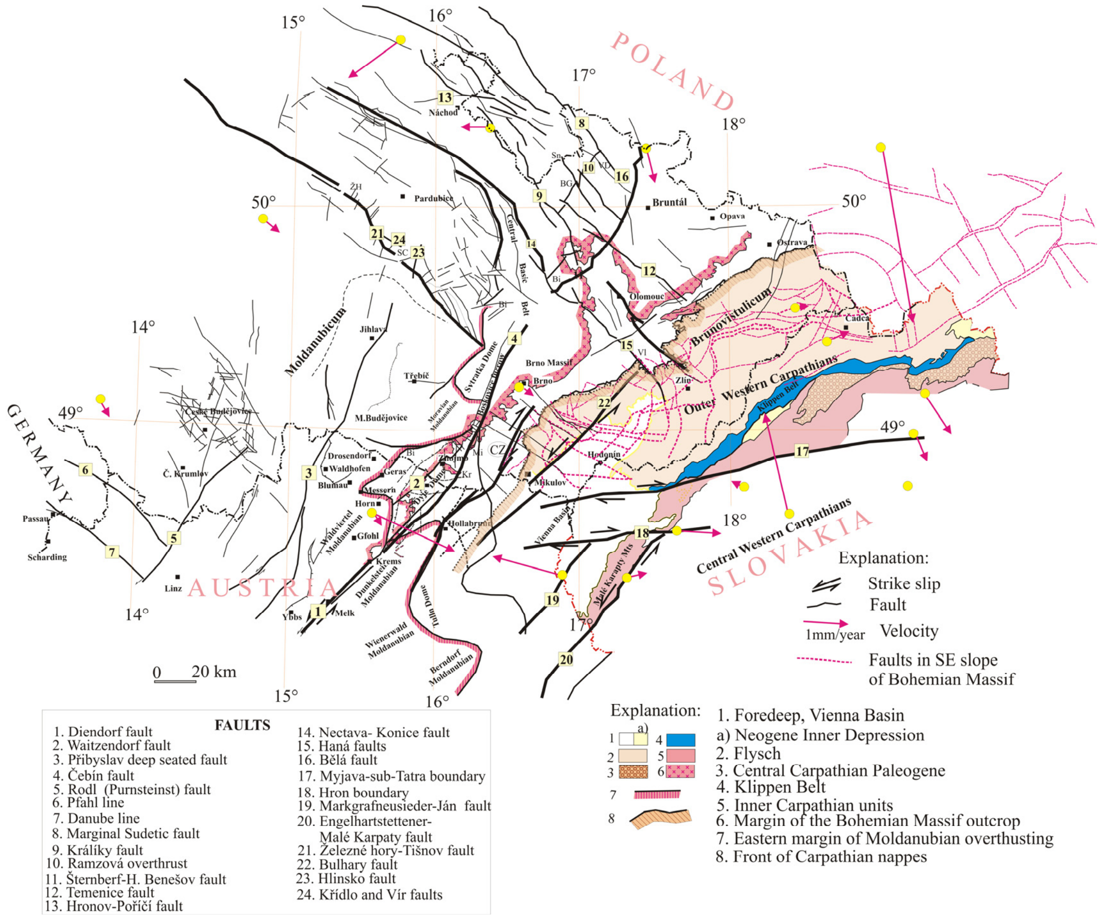

Fig. 1 Location of main faults in Moravia and surrounding. Heavy lines represent the main tectonic zones interpreted also on the base of Remote Sensing and geophysical data. It is considered to be active during Tertiary to Recent and played main role in kinematics of tectonic pattern (Malkovský , 1979; Pospíšil et al., 2010, 2012). The map supplies intraplate velocities obtained from combination of regional and local velocity fields (Hefty, 2007, Hefty et al., 2010). Explanations: Kr- Krhovice crystalline, Mi- Miroslav crystalline, SC- Svratka crystalline, ŽH- Železné hory crystalline, Sn- Snieznik Massif, BG- Branna Group,VD- Vrbno Dome.

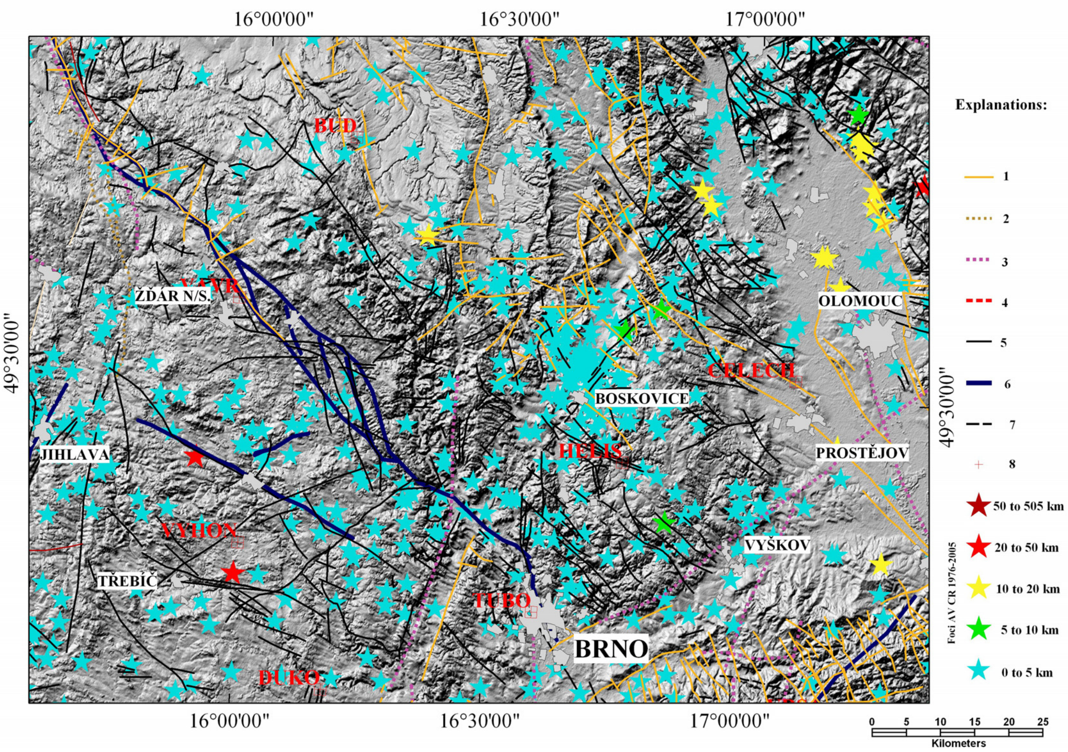

Fig. 4 Location of the Železné hory – Tišnov tectonic zone – heavy blue line with the Earthquake foci. Explanation: 1- geological fault, 2 – mylonitized zone, 3 – boundary active in RVM map, 4 – boundary after - according Remote Sensing Data, 5 - boundary after geophysics, 6 – recently active fault – after morphological and seismological data, 7 – supposed fault, 8 – GPS station. The blue earthquake foci (0-5 km) are provoked by quarry detonation ("fake-earthquakes").

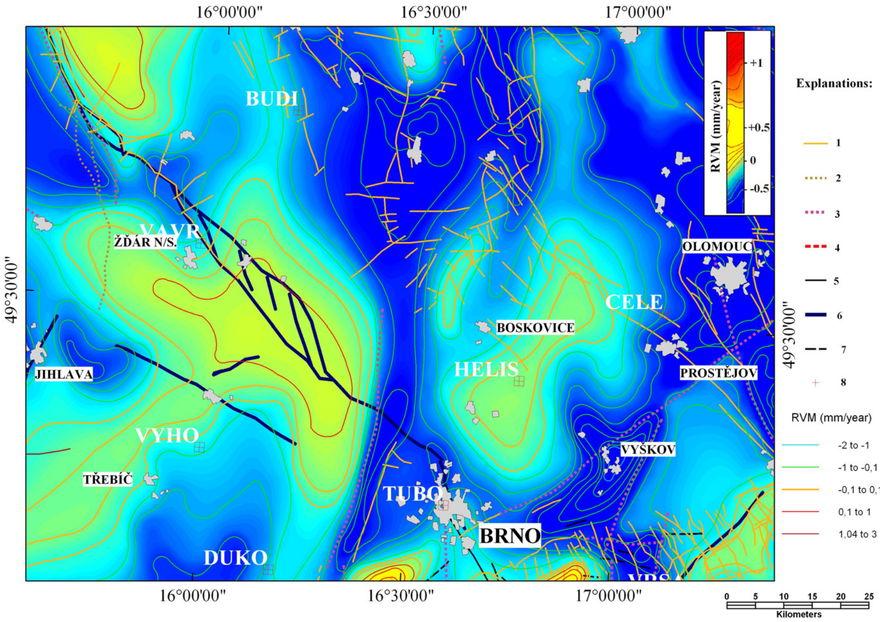

Fig. 6 Location of the Železné hory – Tišnov tectonic zone with recent vertical velocities. Explanation the same as in Figure 5.

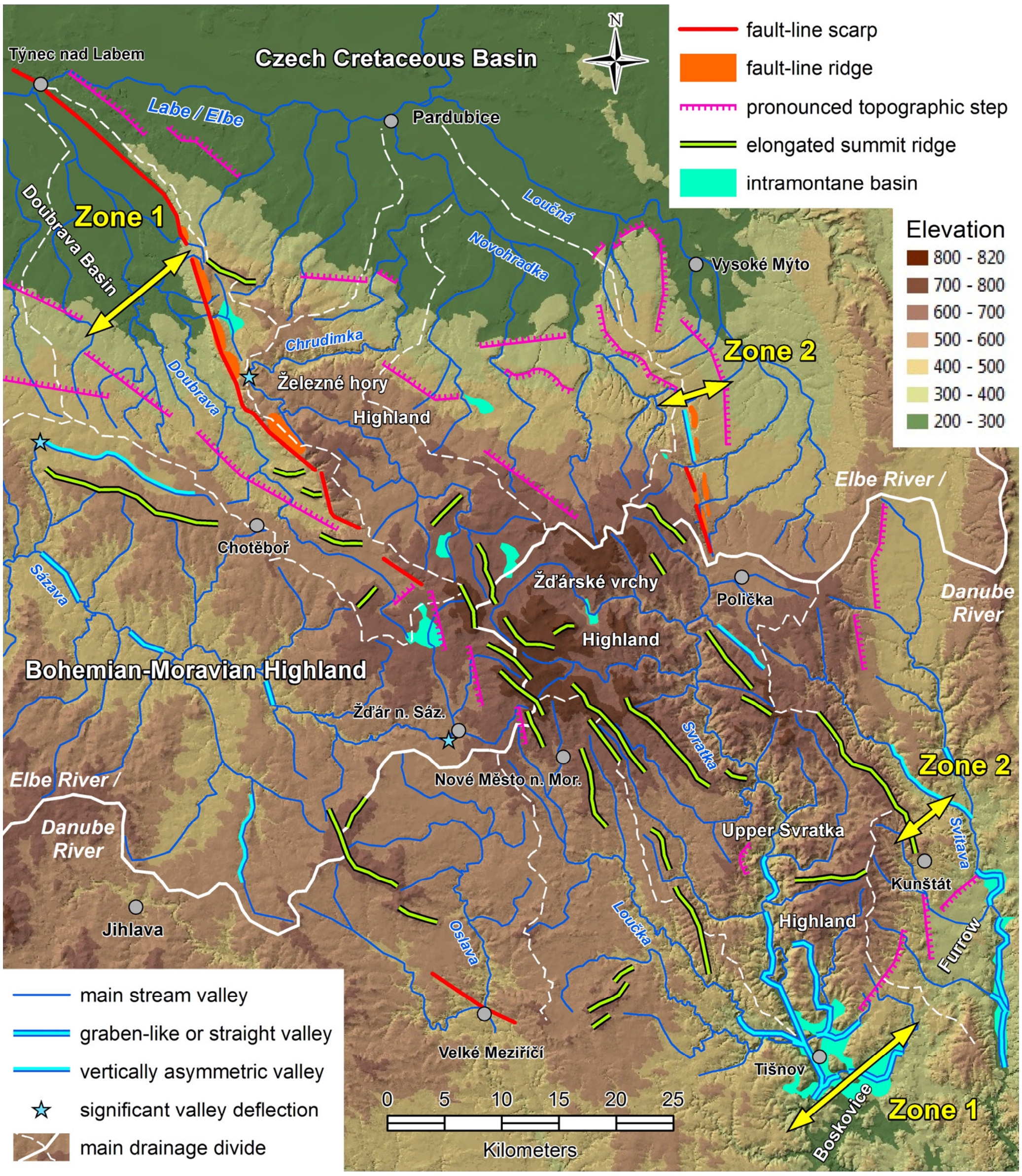

Fig. 7 Basic geomorphological features of the north-eastern part of the Bohemian-Moravian Highland. Based on: Fundamental geographic database of Czech Republic, 2009. Remark: Intramontane basin is fulfilled by Quaternary sediments.