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FUNDAMENTAL MOBILITY TRENDS IN THE NORTHERN PART OF THE MORAVO-SILESIAN ZONE (THE BOHEMIAN MASSIF) – A COMPLEX GEODYNAMIC ANALYSIS

Grant project of the Grant Agency of the Czech Republic No. 205/01/0480

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ABSTRACT

The geodynamic joint Czech-Polish GPS network East Sudeten was established in 1997. Since 1997 seven epoch GPS measurements have been realised. GPS satellite signals were monitored by the Ashtech receivers and antennas that were situated practically whenever at the same network sites and obtained GPS data were processed with the software Bernese 4.2. RMS values in the horizontal movement velocities determination have not exceeded 1 millimetres and in the vertical movements 2-3 millimetres. Seven epoch measurements already realized allowed annual movement trends to be determined and geodynamical terranes to be identified in the northern part of the Moravo-Silesian region. Monitoring of regional seismic activity alternately even by four seismic stations delineated several seismogenic zones in the area under study. The stations registered local seismic events and mining induced seismic events up to $M_L \approx 0$. In the Moravo-Silesian region nine local earthquakes were recorded in the 2001-2003 period. Geological structure-tectonic mapping of brittle deformations was correlated with data of the digital elevation model. Paleostress analyses of the Moravo-Silesian area display the NNW-SSE compression and strike-slip regime the ENE-WSW. The systems of Lusatian (WNW-ESE) and Sudetic (NW-SE) faults are in a pseudo-conjunction with the Moravo-Silesian (NNE-SSW) and Orlice (NNW-SSE) faults.

KEYWORDS: geodynamics, GPS measurements, monitoring of local earthquakes, brittle tectonics, the Sudeten, the Bohemian Massif

1. INTRODUCTION

This project was directly linked to the previously realized project of the Grant Agency of the Czech Republic (205/97/0679) that aimed at an identification of recent geodynamic movements in the northern part of the Moravo-Silesian unit of the Bohemian Massif. Mobility trends were found out directly in the field using three approaches (Schenk et al., 2000a, b, c):

(a) a measurement of GPS signals at sites of newly established geodynamic network
(b) a monitoring of local earthquake activity at newly built up seismic stations
(c) a measurement of brittle tectonic and structural mapping focusing to rejuvenated Variscian deformations.

A regional geodynamic network SILESIA was established by IRSM AS CR and local seismic stations HRMC, ZLHC and ZARC were built and operated by IGN AS CR in the northern part of the Moravo-Silesian zone (Schenk et al., 2000c). In 1997 in the frame of the Czech-Polish cooperation this network SILESIA together with seven sites of the Polish network GEOSUD formed the geodynamic network EAST SUDETEN consisting of 17 sites. In 1999 the network was extended for the site KAPR built near Potštejn (Schenk et al., 2000c). Its length is roughly 150 kilometres in the NW-SE direction and about 80 kilometres in the direction perpendicular on it. Since 1997 annual 48 hours GPS epoch measurements have been realized.

Three years period (1997-1999) of the grant project solution showed that the correlation of these three approaches bring not only new knowledge on geodynamic mobility trend evidences but also allow supposed geodynamic model to be verified. From the viewpoint of obtained results and expended funds it was beneficial to prolong the project in order to obtain more reliable evidences on mobility trends in the northern part of Moravo-Silesian unit of the Bohemian Massif. The 4th GPS was supported by IRSM AS CR budget in 2000.

2. PROJECT OBJECTIVES AND APPROACHES

The grant project of the Grant Agency of the Czech Republic (205/01/0480) was a continuation of the project the main goal of which was the establishment of the EAST SUDETEN geodynamic network for monitoring GPS satellite signals and local seismic events in the northern part of the Moravo-Silesian zone to identify recent movements of individual geological blocks. The aim of this project was (a) to continue in annual GPS epoch measurements and seismic monitoring of the area, (b) to extend the geodynamic network to new measuring points, (c) to develop identification criteria for the identification of natural and induced seismic events and (d) to analyse neotectonic motions rejuvenated by the recent geodynamic activity of Alpine units.

The analysis of seismic activity, GPS data, microstructure and geomorphologic investigations, the digital model of the Earth surface allowed a realistic neotectonic mobility pattern of the northern part of the Moravo-Silesian zone of the Bohemian Massif to be obtained. The activities above mentioned were connected with introducing many improvements.

3. GEODYNAMIC GPS NETWORK EAST SUDETEN

3.1. GPS EPOCH MEASUREMENTS IN 2001 - 2003 PERIOD

The Czech part of the regional geodynamic network EAST SUDETEN was built with respect of the assumption that the Sudetic faults of the NW-SE directions (e.g. the Main Sudetic, the Marginal Sudetic, the Bělá and Klepáčov faults, etc.) are active. Besides some mobility evidences on the Sudetic fault system there have been also some these evidences found on a few faults of the E-W direction, e.g. on the Opavice shear zone. The Czech part of geodynamic network EAST SUDETEN (Fig. 1), which consisted of ten sites in 1997, was extended for the site KAPR (hill Kapraď near Potštejn) in 1999 and for the site VRES (Vřesová studánka in the Protected Landscape Area of Jeseníky) in 2000. Simultaneously in the Polish part additional sites were built in 1998 and 2000 (Schenk et al., 2002b). Monitoring of GPS satellite signals on the geodynamic network EAST SUDETEN has been performed mostly with the Ashtech receivers equipped by geodetic and marine antennas and one

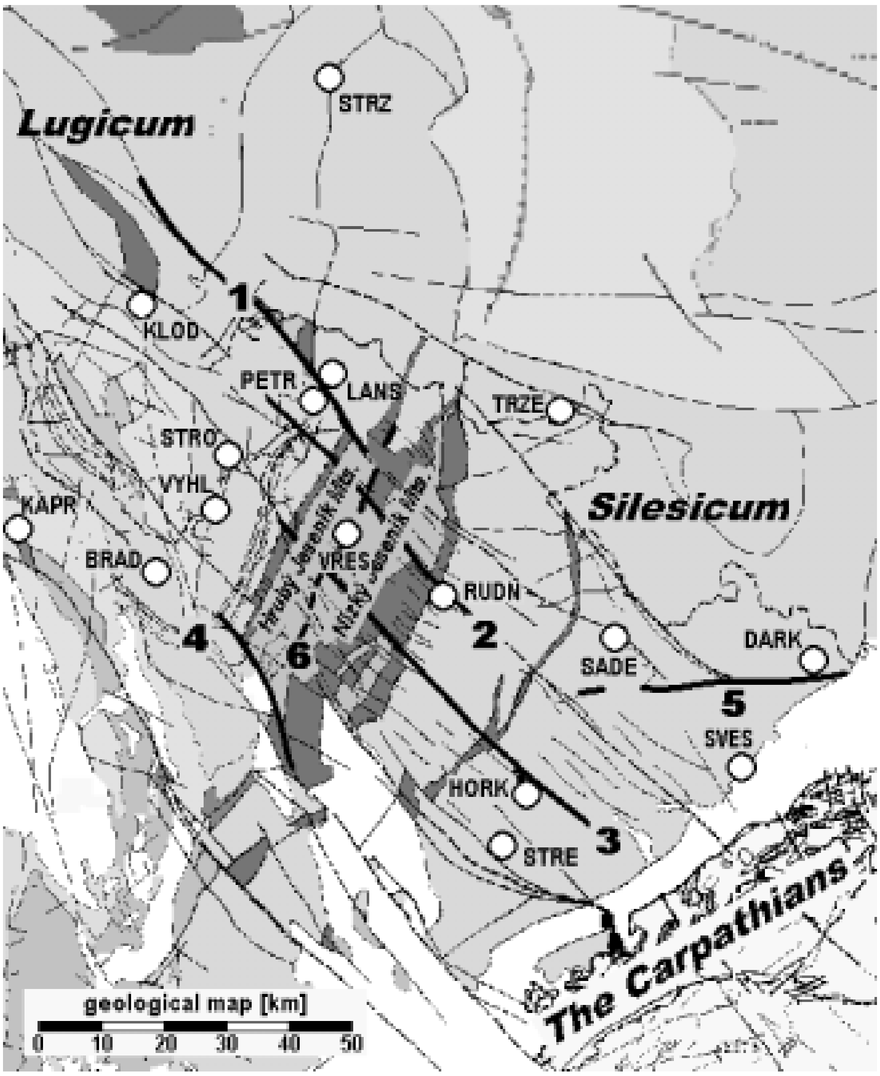

Fig. 1 The joint Czech-Polish geodynamic network EAST SUDETEN

choke-ring antenna in two full day sessions (48 hours) and a sampling rate of 30 seconds. To ensure a high standard of the GPS observations and to guarantee the maximum possible quality of data processing, a quality assurance program for geodynamic studies was assembled (Schenk et al., 2002b). Inside this regional geodynamic network the permanent GPS observatory BISK (Schenk et al., 2004) was built on the Biskupská kupa Mt. near Zlaté Hory.

During the period 2000–2003 the following four epoch measurements at the GPS geodynamic network EAST SUDETEN were organized:

- 4th campaign: September 2 – 4, 2000,
- 5th campaign: September 8 – 10, 2001,
- 6th campaign: September 14 – 16, 2002, and
- 7th campaign: September 6 – 8, 2003.

3.2. GPS DATA PROCESSING

Monitored GPS campaign data 1997–2003 at the geodynamical network East Sudeten were processed with Bernese 4.2 software by researches of the Department of Geodesy and Fotogrammetry, Agricultural University of Wroclaw and IRSM (Schenk et al., 2000b, 2001a, c, 2002a, 2002d, 2003d). Preliminary GPS data processing consisted of a carrier-phase observation processing of independent vectors of triple differences. In that process different linear combinations of the carrier-frequencies L1 and L2 were tested. The main aim was to find out and eliminate cycle slips. If they cannot be eliminated, then this part of data was rejected from observation file or new ambiguity was introduced (Hugentobler et al., 2001). Coordinates and RMS errors were generated for individual sites of the network East Sudeten by connecting the daily solutions to the ADDNEQ program (Brockmann, 1996, Hugentobler et al., 2001). Since 1998 the RMS values have been reduced by improvements of the field GPS observation technology.

The trend analyses applied to individual network sites evaluated their RMS errors in the coordinate and movement velocity determinations. The RMS errors in longitude and latitude coordinate determinations reached generally 2 to 4 mm (extremely 7 mm) and in height determination 6 to 9 mm (in one case extremely 23 mm), When the RMS errors of movement velocities were evaluated, the values for the horizontal directions exceeded hardly 1 mm and for the vertical directions 2-3 mm. One can conclude that the horizontal movement velocities had been verified and representative enough to start with their reasonable geodynamic interpretation and correlation with all available geological materials and geophysical data (Schenk, 2002, Schenk et al., 2000a, 2002c, 2002e, 2003a, 2003b, 2003c, 2003e).

For calculation of kinematic solution of movement velocity vectors by the software Bernese 4.2 the modul ADDNEQ2 was used under the following conditions:

- all GPS epoch data were fixed to the Polish permanent GPS station Borowiec (BOR1)
- the reference frame ITRF2000 was applied
- calculated values of movement velocity vectors were corrected on plate velocities resulting from the NUVEL1A-NNR model (DeMets et al., 1994)
- the EPN stations Pecný (GOPE), Penc (PENC) and Wettzell (WTRZ) were introduced to the calculation as additional reference stations

3.3. GEODYNAMIC INTERPRETATIONS

Time series of site coordinate changes with respect of the north and the east directions (Fig. 2) allowed annual movement velocities for Czech sites of the geodynamic network EAST SUDETEN to be determined. Movement velocity vectors were displayed for 14 sites of the Czech-Polish EAST SUDETEN network into a schematic geological map of the Sudeten area (Fig. 3). Annual movement velocities reached on seven network sites (KLOD, LANS, RUDN, STRE, STRZ, TRZE AND WROC) values of 4 – 6 mm. When we take into account a fact that rock masses of Central Europe are under permanent pushing to the north towards the bulky East European Platform, a relatively huge and stable body of crystalline rocks, then movement velocities round 5 mm/year are acceptable.

The eastern part of the Bohemian Massif has been geologically and geophysically investigated by many authors. Buday et al. (1995) summarized and analyzed regional motions of geological structures mainly along the Sudetic fault zones and found for them one common feature: if a structural block has an uplifting tendency with respect to its neighbouring blocks, then its relative motion with respect to these blocks heads to south-east. Similarly, if a structural block has a subsiding tendency with respect to neighbouring ones, its motion with respect to these blocks heads to north-west. To compare and verify the GPS movement vectors with the geological conclusions mentioned above, the GPS horizontal vectors (Fig. 3a) were resolved into vector components of two fault systems: the Sudetic and the Moravo-Silesian ones. In the former system mainly strike-slip movements occur and in the later, because of normal and reverse faults, the uplifted and subsided trends are activated. The fact that individual movement vector components faithfully correspond to structural block motions gives clear evidence on a high accuracy of the GPS realized in all epoch measurements on the geodynamic network EAST SUDETEN. Values of the GPS vertical vectors (Fig. 3b) should be still assumed as preliminary ones, nevertheless they display up-lifting trends for the western part of the area under study (Lugicum) and subsiding tendencies for the central part of the area (Moravo-Silesicum).

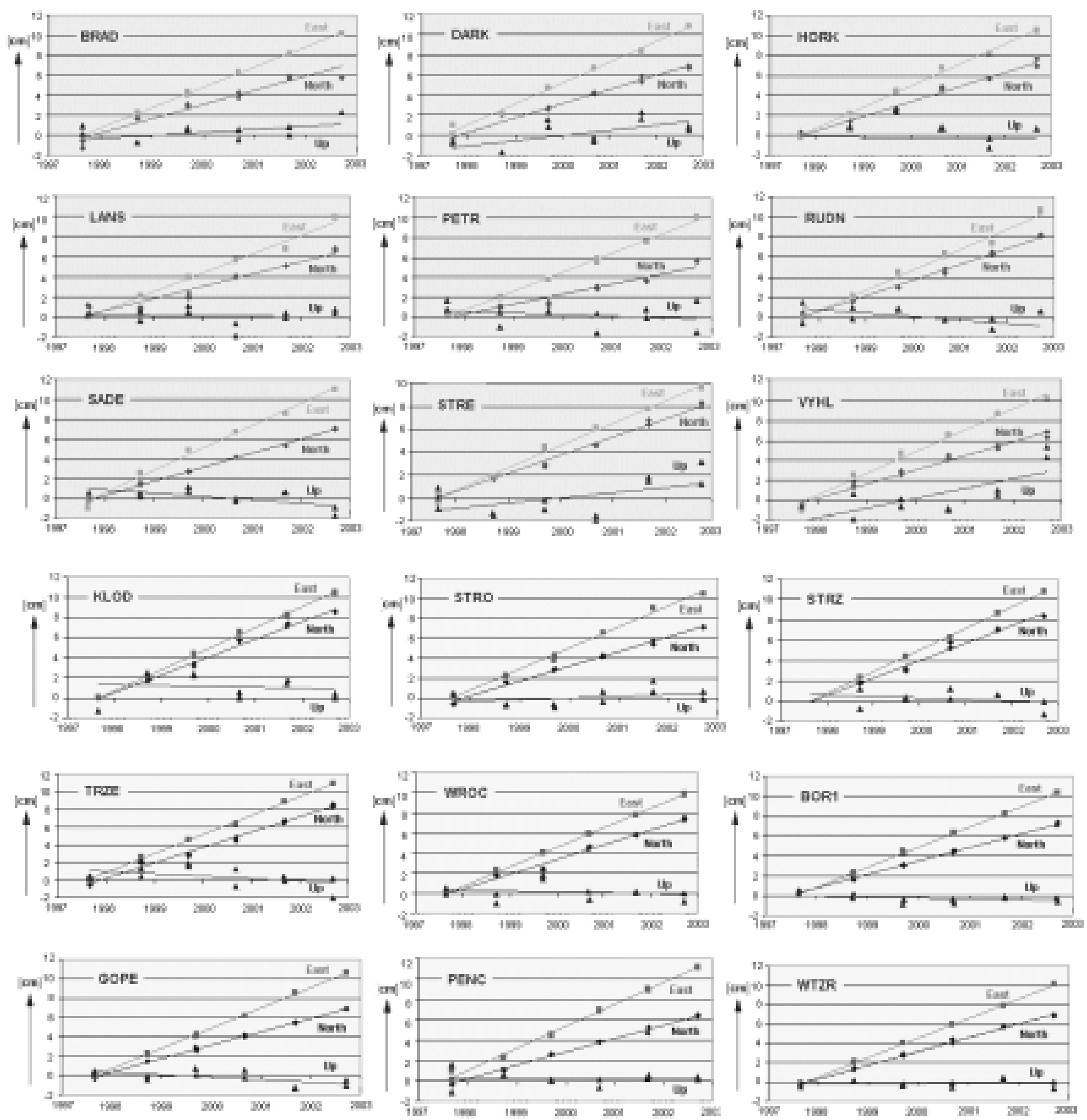

Fig. 2 Time series of co-ordinate changes (1997-2002) in the north and in the east directions of the individual Czech and Polish sites of the EAST SUDETEN geodynamic network and four EPN stations located close to the network

The preliminary stress and strain fields were investigated (Schenk et al., 2003d) on the basis of all available geological and geophysical materials. Two anomalous features were identified:

(a) The existence of a zone that affects contrariwise to the surrounding regional movement trends (geodynamic terrane B, Fig. 4). With the highest probability its mobility resistance is caused by its deep seating (its MOHO is round 5 km deeper than that of the neighbouring blocks) and by the types of regional structures (thrusting tectonic faults). In the past the western blocks (Lugicum) thrusted over the eastern blocks (Moravo-Silesicum) along these fault zones and, thus, the eastern blocks moved deeper to the upper mantle and pushed the MOHO to greater depth..

(b) The movement analysis of the network sites, located in its eastern part indicated that velocity azimuths turned to the NE, and a small decrease of velocity rates. In the positive case it could divide structural movements in the east part of the Bohemian Massif into two main directions: to the north and northwest, and to northeast.

Movement velocity vectors determined for selected sites of the geodynamic network EAST SUDETEN allowed a more detailed delineation of

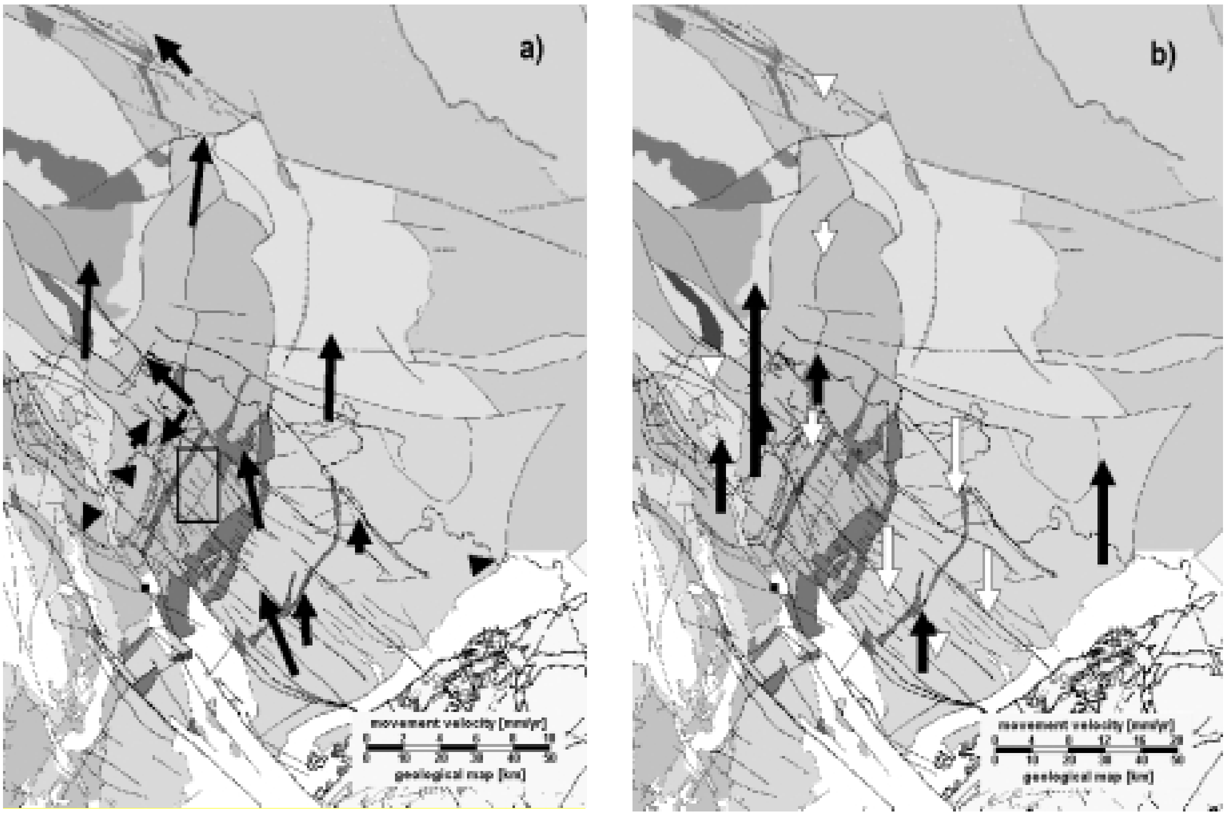

Fig. 3 Movement velocity vectors determined for the GPS network sites: a) horizontal and b) vertical components

possible geodynamic terrane of the Sudetic structural blocks to be carried out (Fig. 4, Schenk et al., 2001b, 2003b, 2003c, 2003d). Five terranes were delineated.

4. MONITORING OF LOCAL EARTHQUAKE EVENTS AND REGIONAL SEISMOLOGICAL INVESTIGATION

The Moravo-Silesian region (49.5°N – 50.5°N, 17°E – 19°E approximately) has geological and tectonic settings of the Cadomian, Variscan and Alpine ages (e.g., Kumpera and Suk, 1985). The present seismic activity of the northern part of the area under study is weak but should be pointed out that in the region more intensive earthquakes took place in the past (e.g. Kárník et al., 1984). Last earthquake swarm with the macroseismic intensity up to $I_0 = V^o$ occurred in the Opava area in the period 1992 – 1993.

Seismological monitoring supported by the Grant Agency of the Czech Republic (205/97/0679) started in 1997 (Schenk et al., 2000c). Main aims were concentrated on construction of new local seismic stations to document occurrence of weak natural seismic events. Seismic stations of IGN (Institute of Geonics, AS CR) were situated in buildings without any construction of seismic pillars for seismometers. Using this installation of sensors there was a possibility to obtain quick information from selected points without investment costs. During the project duration (1997-1999), in February 1999, three earthquakes with local magnitude up to 0.8 were recorded in the area of Opava. Recorded seismic events at the stations Zlaté Hory, Žáry, Hradec above Moravice and Poruba with triggered regime during this period (Kaláb and Knejzlík, 2000) were divided into three following groups:

- *local seismic events* – local earthquakes, quarry blasts in the surrounding of the stations, so far unidentified local seismic events that could belong to local earthquakes or man-made activities (Schenk et. al., 2000c),
- *mining induced seismic events* occurring in the Karviná part and the Polish part of the Upper Silesian Coal Basin and in the cooper mine in the Lubin area,
- *teleseismic events*, usually unidentified parts of wave patterns were recorded

Main activities of the IGN in the frame of this second project were aimed at modernizing of recorded apparatuses including GSM telemetry transmission to have a possibility to decrease apparatus noise and to check via a GSM network functions of the apparatus, to set trigger parameters, to start continuous data recordings for a given time interval and mostly to transmit recorded data. For instance, the seismic station Zlaté Hory has recently a LSB value equal to

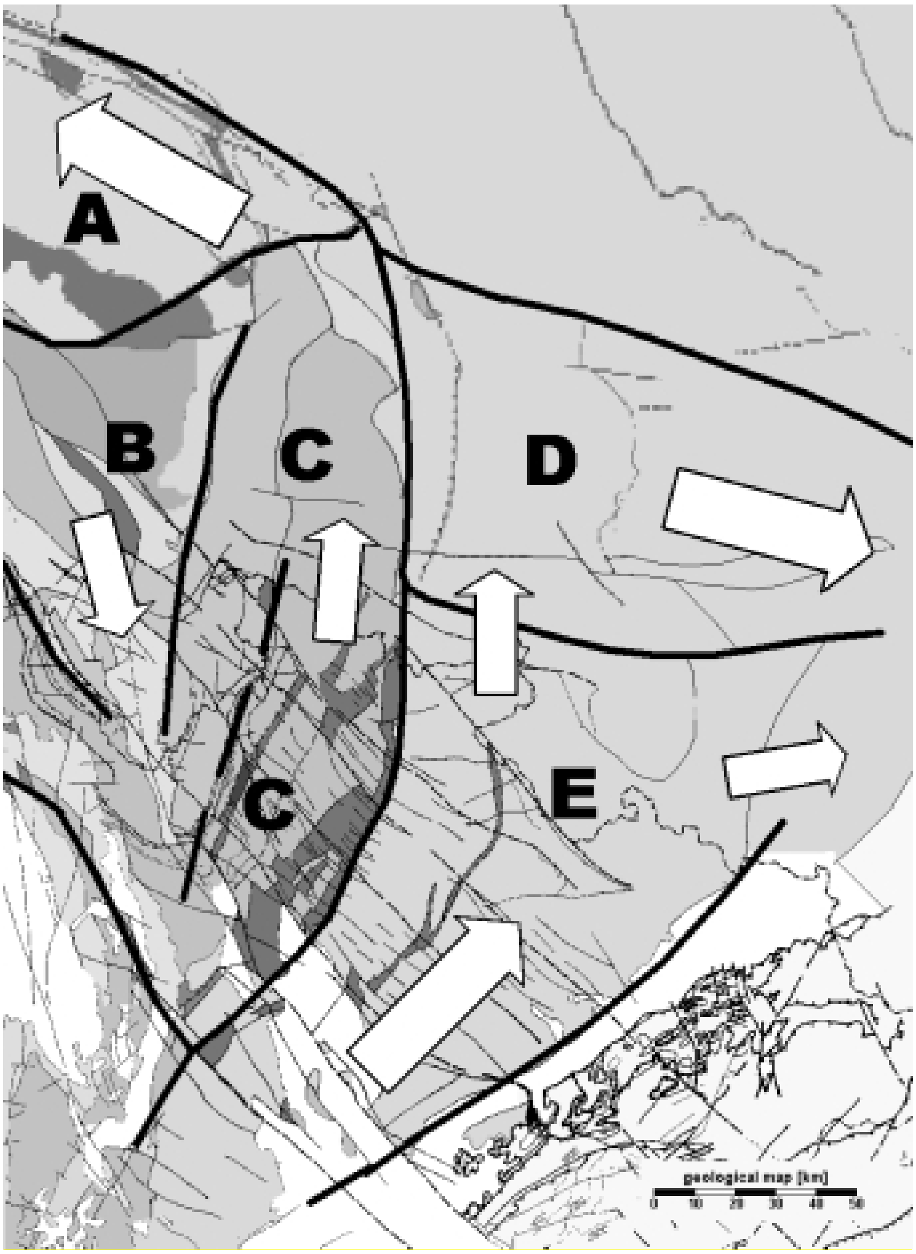

Fig. 4 The geodynamic terranes detected on the network EAST SUDETEN: A - Moravo-Devonian terrane, B - the thrusting zone terrane, C - Lower Silesian-Opole terrane, D - Lower Sudeten terrane and E - the Kłodsko furrow.

$1.9\text{x}10^{-9}$ m.s^{-1}. More than 20 new places with low value of anthropogenic noise were looked for and tested to more optimal conditions for an establishment of seismic stations were found in the northern part of the investigated area, where no seismic station has operated. Its south part is monitored by the Institute of Physics of the Earth, Masaryk University Brno (Sýkorová et al., 2004). The seismic noise at new place in Zlaté Hory has not usually exceeded $5\text{x}10^{-9}$ m.s^{-1}. The former place in Javorník had noise up to $5\text{x}10^{-7}$ m.s^{-1} and in many cases staff steps and/or building vibrations due to strong wind were recorded. Local seismic records were interpreted and man-made induced events were verified.

Seismic stations equipped with modernized digital seismic recorder PCM3-EPC (Knejzlík and Kaláb, 2002, 2004) were installed on three places operating up to now – Raduň near Opava, Slezská Harta and Zlaté Hory. However, closed seismic stations Jánský Vrch in Javorník (apparatus was removed to new place in Zlaté Hory) and Janov (place for testing of developed part of HW) were operated during the whole project duration (Table 1). All seismic stations operated under triggered regime and were remote controlled through a data transmission via a GSM network (e.g. Knejzlík and Kaláb, 2002).

Calculation of sensitivity of seismic stations using LSB values, trigger levels and results of wave

Table 1 Seismic stations (without tested places) operated by IGN in the period 2001-2003

station	Location	Coordinates	Operation
RADC	Raduň near Opava	49° 53´ 35.20” N 17° 56´ 28.50“ E	since March 8, 2001
SHAC	Slezská Harta	49° 53´20.98“ N 17° 35´01.96“ E	since June 25, 2002
ZLHC	Zlaté Hory	50° 13´23.40“ N 17° 24´22.68“ E	since Sept. 12, 2003
SMEC	Staré Město	50° 09´46.09“ N 16° 56´48.62“ E	May 16 – Aug. 8, 2001
JNVC	Janov near Jindřichov	50° 14´51.39“ N 17° 28´57.68“ E	June 22, 2001-May 8, 2002
JVR1C	Červený důl near Javorník	50° 21´08.77“ N 16° 59´32.13“ E	July 23 – Oct.17, 2001
JVRC	Jánský vrch in Javorník	50° 23´17.71“ N 17° 00´02.62“ E	Oct. 17, 2001-Nov. 12, 2003
OKC	Ostrava – Krásné Pole	49° 50´15.30“ N 18° 08´50.25“ E	permanent station of national network

Table 2 Number of all records and seismic events recorded in the period 2001-2003 at individual IGN seismic stations

Station	Operation	Number of all records			Number of seismic events		
		2001	2002	2003	2001	2002	2003
RADC	June – Dec. 2000 and since March 2001	1118	671	604	377	338	400
SMEC	May 2001 – Aug. 2001	107			6		
JNVC	June 2001 – May 2002	488	167		31	17	
JVR1C	July 2001 – Oct. 2001	607			2		
JVRC	Oct. 2001 – Nov. 2003	33	1698	806	38	164	154
SHAC	since June 2002		236	550		113	209
ZLHC	since Sept. 2003			343			118
Summary		2353	2772	2303	454	632	881

pattern analyses concluded (Kaláb and Knejzlík, 2003) that:

- the investigated area is too large and the number of mutually „very far“ seismic stations in places with high noise level (especially for weak earthquakes with $M_L<0$) is small,
- a detectibility of seismic stations placed in the structures is significantly influenced even if seismometers are on seismic pillars or not.

Seismic observations by the IGN have been taken in the Moravo-Silesian region since 1997. Annually, about 500 or more seismic events were recorded. A number of all records (triggered regime with crossing the pre-set level) and a number of seismic events records at individual seismic stations in the period 2001-2003 are presented in Table 2. Seismic events were divided into three groups (local seismic, mining induced seismic and teleseismic events). The distribution in percentages of seismic events registered in 2003 is documented in Table 3. The map with seismically active regions detected by IGN stations is presented in Figure 5. Digital data are archived in IGN and they are at disposal for research works.

Nine seismic events recorded in 2001 - 2003 were included in the group of local earthquakes (Table 4). Due to their low size they were recorded by one

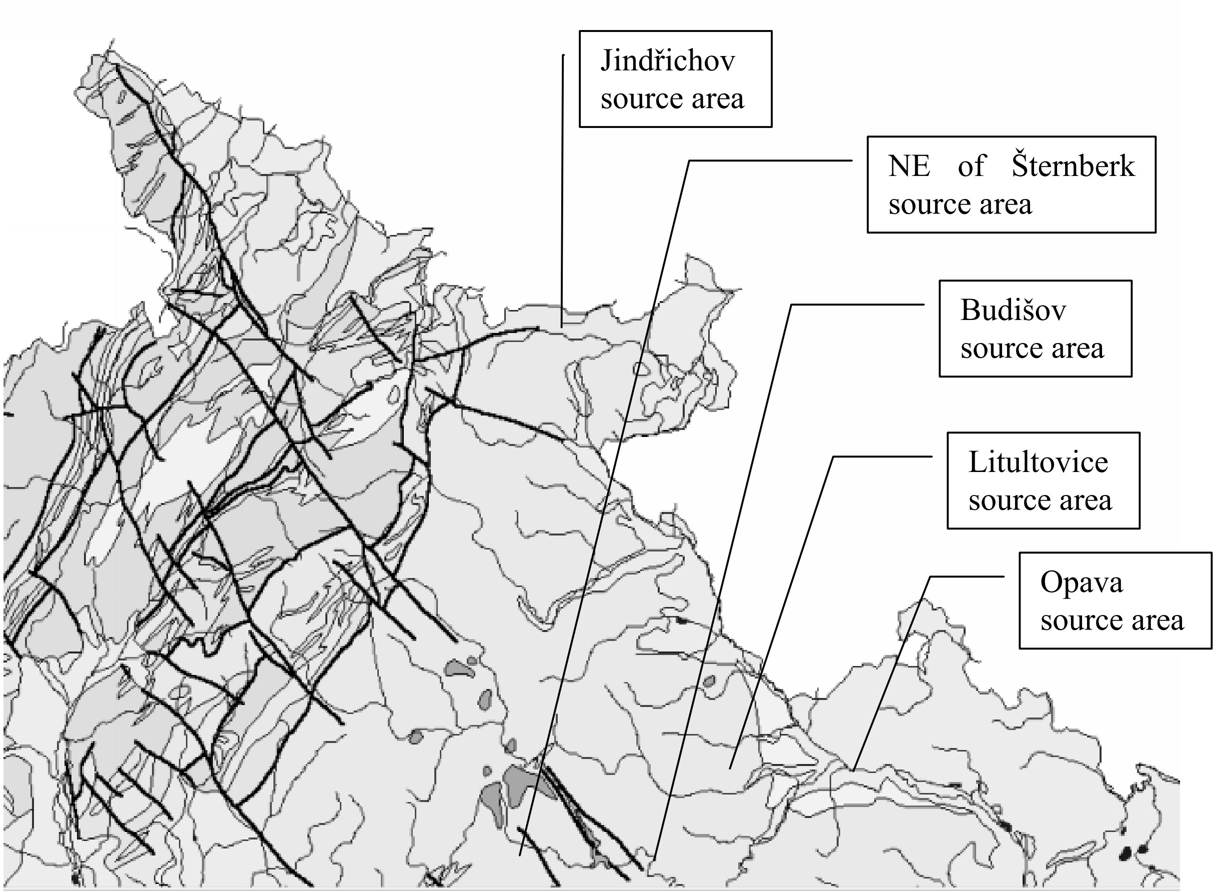

Fig. 5 Sketch of tectonic map (GEOCR 500, 1998) with source areas (black ellipses) of natural earthquakes in the Moravo-Silesian region in the period 1997-2003, data from IGN solitary stations (black triangles)

Table 3 Distribution of seismic events recorded at IGN seismic stations in 2003 given in percentages; 1– local earthquakes, 2 – local quarry blasts, 3 – mining induced seismic events from Karviná part of the Upper Silesian Basin, 4 – mining induced seismic events from Polish part of the Upper Silesian Basin, 5 – mining induced seismic events from Lubin cooper area, 6 – unidentified parts of teleseismic events

Station	Local seismic events		Mining induced seismic events			Teleseismic events
	1	2	3	4	5	6
SHAC	1	23	8	23	20	25
RADC	2	22	18	18	11	29
JVRC (I-XI)	2	4	4	45	32	13

seismic station only. Therefore, no serious seismological studies (source parameters, FPS) of the detected seismic activity could be done. The locations of these seismic events were mostly estimated from the differential S-P time and polarization analysis of the initial wave group input. The following seismic model of region elaborated by Holub and Rušajová (2002) from data of the international experiments CELEBRATION and SLICE was used:

Pn ($km.s^{-1}$)	Pg ($km.s^{-1}$)	S^*_1 ($km.s^{-1}$)	Sg ($km.s^{-1}$)
7.64	5.67	3.83	3.33

Table 4 Local earthquakes recorded at IGN seismic stations in the period 2001-2003

Date	Local time	Station	Localization	Magnitude
Jan. 27, 2001	09:15	RADC	Near Litultovice	< 0.0
May 5, 2002	04:56	RADC	Near Litultovice	< 0.0
May 5, 2002	04:57	RADC	Near Litultovice	< 0.0
May 5, 2002	04:57	RADC	Near Litultovice	< 0.0
March 11, 2003	16:06	RADC	?	
June 28, 2003	18:51	JVRC	Poland?	~ 1.0
July 16, 2003	03:01	SHAC	NE of Šternberk	~ 0.5
Oct. 4, 2003	05:30	SHAC	?	
Sept. 30, 2003	11:58	ZLHC	Near Jindřichov	

However, several seismic events (since 2003 no more than 10) have not been identified. These events correspond either to local earthquakes or to unknown anthropogenic activities. Classification of these events was based on their correlation to recorded events given in seismic bulletins of the Czech national network and/or other seismic centres, in database of mining induced seismic events from the Ostrava–Karviná Coal Basin and from adjacent Polish areas. Information about blasts was taken from the Regional Mining Bureau, local authorities and authorities of quarries.

5. TECTONIC INVESTIGATION OF THE AREA

5.1. *STRUCTURE, PALEOSTRESS AND MORPHOTECTONIC ANALYSIS*

The Moravo-Silesian zone of the Bohemian Massif, where our structure, paleostress a morphotectonic analysis were performed, is appropriate area for solving specific problems of structural-tectonic relations and regional deformation development due to fact, that area represents superposition of three structural levels, corresponding to three orogeny cycles. Lower most Pan-African (Cadomian) Brunovistulicum foreland terrane conditioned and influenced complex geological and among other deformation development of Variscan accretion wedge represented by volcano-sedimentary formations of Rheno-Hercynian Foredeep and Subvariscan foreland coal-bearing basin (molasse). Finally sequences of the West Carpathian foredeep and the Outer West Carpathian nappes formed youngest Alpine accretion wedge. Brunovistulicum as the oldest crustal segment (terrane, microcontinent – Grygar and Vavro, 1995) represents a foreland of both accretionary wedges: the older Variscan one with generally top-to-NE kinematics and younger Alpine wedge with top-to-NW up to N thrusting. The frontlines of both orogenies seem to run almost subparallel in the region of Moravia and Silesia, but in fact they are distinctly oblique. Structural framework and kinematics of Alpine nappes of the Outer Carpathians were significantly influenced by inherited epi-Variscan structures on the southeastern boundary of the Bohemian Massif with tectonically incorporated Brunovistulicum.

Except for classical structure analysis our morphotectonic analysis is based on 3D visualization and interpretation of digital elevation models (DEM) of above-mentioned structural levels (Pan-African, Variscan and Alpine). Analyzed digital models have been compiled on basis of data from drilling and mining activities and data from geophysical seismic survey, especially however from detailed digitalization of topographic map of 1: 25000 and 1: 50000 scale. The models were compiled and subsequently analyzed using software Surfer 8.0 and mainly by ArcInfo GIS 8.3 visualization capability (Grygar and Jelínek, 2000, 2001, 2003). The results of DEM analysis were compared with structure and paleostress analysis (brittle faults paleodynamic analysis – e.g. Angelier and Goguel, 1979).

5.2. *BRITTLE FAULT SYSTEM STRUCTURE AND MORPHOTECTONIC ANALYSIS*

The neotectonic activity of the Moravo-Silesian and adjacent areas is dominantly linked to kinematics and dynamic evolution on WNW-ESE and NW-SE striking fault zones usually named the Sudetic faults system. The main faults are: the Sudetic boundary fault, the Intra-Sudetic fault, the Elbe fault zone, the Bělá fault, the Opavice fault zone, the Bušín fault, the Temenice fault and the Nectava-Konice fault system etc. However wide population of faults and ductile-brittle shear zones (varying from position of strike, origin, genesis and kinematic history) are usually integrated under a term the "Sudetic fault system". The main and genetically control fault zones that belong to the Sudetic fault system are the Elbe fault zone and the Sudetic boundary fault. These major fault structures, together with the Lusatia fault, located more west (as a part of the Elbe zone), corresponds to

WNW-ESE striking faults and brittle shear zones system demarcates the Sudety Mts. (horst-like mountain system). Together with the Železné Hory fault zone, it defined the overlapping zone of strike-slip deformation that led to formation of Cretaceous strike-slip sub-basins (Uličný, 2001). These deep-seated fault zones belong to the oldest faults of Central Europe and define the Elbe zone as interpreted by Arthaud and Matte, 1977, Matte et al., 1990 and other authors. Their origin as ductile shear zones can be traced at least into the Devonian. Long-term dextral wrenching movements and/or dextral tangential (transtensional/transpresional) stress field state on above mentioned fault systems since Late-Variscan tectogenesis up to recent neotectonics is well know (e.g. Grygar et al. 1993, Alexandrowski et al., 1997, Uličný, 2001, Cacoń, 2001).

The next fault population, also ordinarily included under term Sudetic fault system, corresponds to faults striking generally NW-SE. The representatives of this system are above all Sudetic boundary fault together with Odra fault, also Temenice fault, Bělá fault, Opavice fault zone and many others of second order scale. The Sudetic boundary fault was traditionally considered an important structural boundary during the Palaezoic evolution of the Sudets. In its present shape the fault is, however, a Cenozoic, mostly dip-slip (normal fault) feature (Krzyszkowski et al., 1995), probably reactivated an older, Variscan fracture (Alexandrowski et al., 1997). In the geological map and digital elevation models the Sudetic boundary fault does not produce any significant displacement on the geological boundaries in the pre-Permian basement and no ductile shearing related to this fault has been reported from the crystalline units it crosses. Since it merges with the Intra-Sudetic fault zone at low angel (20°), it can be assumed that it may have originated as a Riedel-type brittle shear plane and/or T-type fracture with little or no strike-slip displacement component, accompanying the dextral motion on the Intra-Sudetic fault, and was later re-activated as a normal fault in Tertiary and Quaternary times (see also Krzyszkowski et al., 1995, Alexandrowski et al., 1997).

The last population of fault and fracture zones striking NNW-SSE, most common in the northeast part of the Bohemian Massif, is represented by the Orlice Mts. fracture zone (Grygar and Jelínek, 2003) and also by other faults that demarcate half-horst structures of so called Litice and Potštejn "anticlines" in the eastern part of the Bohemian Cretaceous basin. The last but not least tectonic structures belong to the Orlice Mts. fault system are the Blansko and the Mohelnice grabens.

Characteristic feature of Sudetic fault system is en echelon pattern of fault network. Releasing sidesteps or jogs superimposed individual faults produce typical rhombic-shaped pull-apart basins; the Nysa pull-apart graben and the Upper Morava pull-apart graben. Also the Mohelnice pull-apart graben (from the geomorphology viewpoint it corresponds to the Mohelnice furrow) belongs to this system (Grygar and Jelínek, 2003).

The Nysa pull-apart graben is genetically related to offset (overlapping) in-between Intra-Sudetic fault zone and Bušín fault. The development of graben was related to transtension stresses inside central domain of Orlice-Sněžník crystalline unit and it represents conspicuous asymmetrical (half-graben) and hinge-like structure (with pivot hinge near Štíty town in the area of its southern termination), with Turonian-Santonian sedimentary filling (e.g. Don, 1996, Wojewoda, 1997). The cumulative thickness of Cretaceous sediments in the graben achieved about 1100 m and almost three times exceeded the thickness of Cenomanian-Turonian deposits of the Intra-Sudetic basin (Don, 1996). The maximum subsidence culminates in NE part of graben near Idzików. According to Wojewoda (1997) the Nysa trough appears as a strongly asymmetric graben that is interpreted as a "rollover-related structure" caused by deep listric down faulting on a fault that now separates the Nysa trough from the Sněžník Massif. This principal fault of the Nysa pull-apart graben corresponds to high-angel normal fault of N-S strike. Significant post-sedimentary (post-Santonian) movement on this fault is documented by upturned strata due to flexural deformation that relates to a drag folding. The dip-slip component on this fault exceeds 660 to 740 m (Don, 1996). The westward flank of the Nysa pull-apart graben corresponds to system of small vertical component faults, separating monocline western limb of graben to system of half-horst of the Duszniki and the Bystrzyca Mts. structures. According to Don (1996) the second stage of the Nysa graben evolution took place in a compression regime. Mostly NW-SE trending faults were reactivated as reverse faults and/or new reverse faults were formed. This stage most probably corresponds to overthrusting in the Lusatia thrust zone in the pre-Miocene compression (Coubal, 1990, Adamovič and Coubal, 1999) and also corresponds to global Alpine orogeny compression stress regime with N to NE oriented compression tensor in the Eastern Alps (e.g. Decker and Peresson, 1996, Fodor et al., 1999) for Early to Middle Miocene.

The Nysa pull-apart graben still remains tectonically active, as indicated by the present-day topography showing system of hanging river valleys and terraces.

The Upper Morava pull-apart graben represents good example of complex pull-apart basin not only based on its perfect rhombic-shaped outline geometry (Grygar and Jelínek, 2003). Tectonically induced subsidence of the graben started in Lower Badenian and could be related to offset of the Bušín-Temenice fault zone and the Nectava-Konice fault zone. It was also synchronized with Alpine-Carpathian orogeny parallel stretching, which impact its foreland represented by the Moravo-Silesian area of the

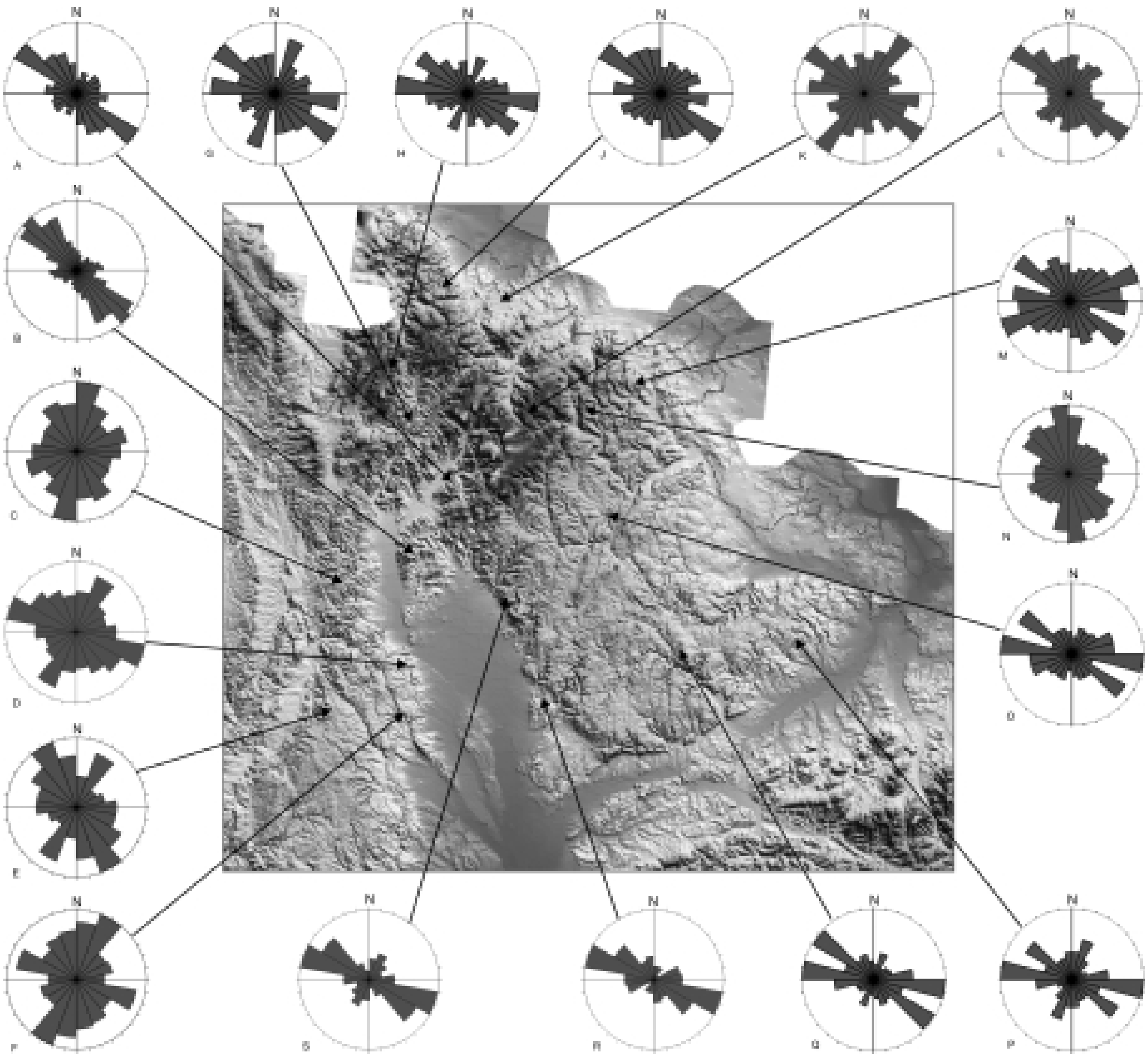

Fig. 6 The DEM (shaded relief) of the area under study and segment rose diagrams representing brittle structures (joints, fractures and small scale brittle fault).

Bohemian Massif. The Bušín fault itself represents typical concave fault geometry in the accommodation domain of the Nysa pull-apart graben and the Upper Morava pull-apart graben relays (in a sense of e.g. Le Calvez and Vendeville, 2002). The domain of the overlapping of the Bušín-Temenice fault zone and the Nectava-Konice fault zone corresponds from position point of view to ESE-ward elongation of the Elbe tectonic zone. Its elongation is possible to trace NE-ward up to tectonically buried part (with the Outer Carpathian nappes) of the Brunovistulian basement and its Palaeozoic cover. The wide Elbe tectonic zone separates the Variscan flysh area to the Nízký Jeseník upland and the Drahan upland and is distinct on geophysical maps (Grygar and Jelínek, 2003) too. The Alpine-West Carpathian orogeny parallel stretching that also affected this foreland area, initiated and subsequently forced dip-slip block tilting along principal faults inside the Upper Morava pull-apart graben. This is very well visible on compiled digital elevation models so as on implemented slope aspect analysis method.

5.3. PALEOSTRESS FIELDS AND RECENT KINEMATICS ON MAIN FAULT SYSTEMS

One of the most significant tasks of our study was field analysis of brittle structures (joints and faults) and paleostress analysis (see Fig. 6). The aim was to correlate fracture anisotropy altogether with morphotectonic analysis based on digital elevation model (DEM). On the base of this synthesis we endeavour to determine main faults as potential recently dynamically active zones. The synthesis is based on extensive field brittle structures analysis carried out on localities of area under study an above all on complex statistical evaluation of huge dataset

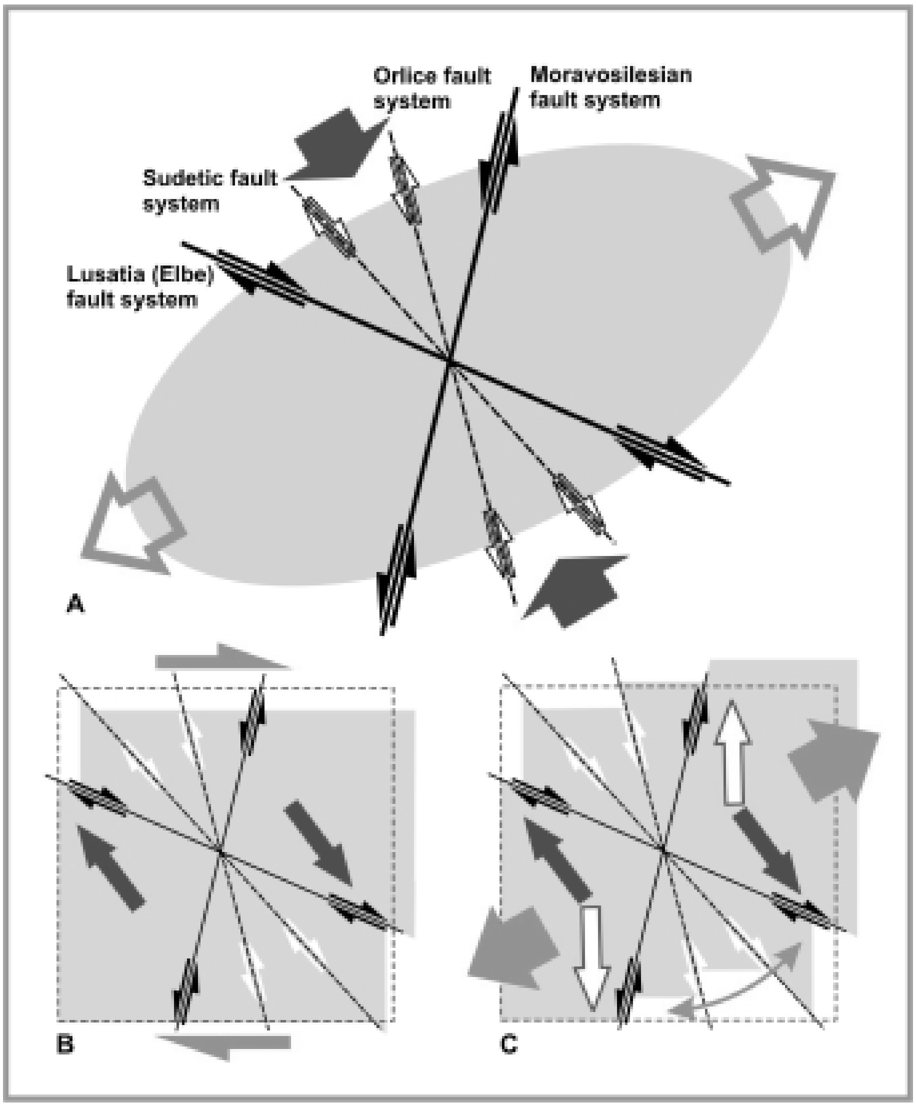

Fig. 7 Scheme strain ellipse representing dynamic conditions valid for recent stress state of Moravo-Silesian and adjacent areas. Diagram B - earlier late- and post-Cretaceous (Miocene) stage of dextral strike-slip shearing on Sudetic and Lusatian fault systems, diagram C - sinistral strike-slip shearing along pseudo-conjugate Moravo-Silesian and Orlice faults.

collected on Institute of Geological Engineering during last two decades.

Paleostress analyses of the Moravo-Silesian and adjacent areas (Grygar and Jelínek, 2003, Jelínek and Grygar, 2002) prove the NNW-SSE compression (also referred by Decker and Peresson, 1996, Fodor et al., 1999 for the last 6 Ma years - Pliocene - Quaternary) on the base of paleostress analysis in the Eastern Alps and Pannonian basin system. The recent geodynamic relation on main fault systems, represented by the NNW-SSE compression, is supported also by in situ stress measurement (Staš et al., 1996, Reinecker et al., 2003) and also by strain of the shafts ruff dug into the West Carpathian foreland – the Upper Silesian coal basin (Dopita et al., 1997). In strike-slip dynamic regime the ENE-WSW oriented extension (orogeny parallel stretching) is linked to above mentioned compression tensor. In relation to the proved regional stress fields we can interpret kinematics on main faults systems as follow: The systems of Lusatian (WNW-ESE) and Sudetic (NW-SE) faults are in a pseudo-conjunction with the Moravo-Silesian (NNE-SSW) and Orlice (NNW-SSE) faults (Fig. 7). In the case of above mentioned stress tensors fields we can assume the dextral strike slip component on the first one couple and the sinistral on second one, which was also proved by field paleostress and morphotectonic analysis (Grygar and Jelínek, 2003) and also by computed focal mechanism data (Havíř and Špaček, 2004).

Based on morphotectonic analysis of GTOPO30 USGS DEM we interpreted also progressive fanlike opening of the sub-triangular crust segment (Grygar and Jelínek, 2003), limited by above mentioned fault systems, corresponding to more intense sinistral rotation of the Western Carpathian plate in relation to the Eastern Alps (Fodor et al., 1999). The opening started in Turonian (Nysa graben) and continues SE-ward in Lower Badenian up-to Recent (Upper Morava graben). The best example of fanlike architecture of horst and grabens we can see on the DEM in the boundary area between Danube and Pannonian basins (Bakony upland and Balaton area in Hungary (Grygar and Jelínek opus cit.).

6. CONCLUSION

The satellite GPS signals monitored in the Moravo-Silesian region at the geodynamic EAST SUDETEN network in the period 1997-2003 were processed with Bernese 4.2 software to assess annual movement rates and to delineate geodynamic terranes. The RMS values of movement velocity determinations for very most network sites have not exceeded in the horizontal components 1 millimetre and for the vertical component 2-3 millimetres. Different horizontal mobility trends for the Nízký Jeseník Mts. and the Drahanská vrchovina highland (the Moravo-Devonian geodynamic terrane) and for the Hrubý Jeseník Mts. (the thrusting zone terrane of the Hrubý Jeseník Mts. and Rychlebské hory Mts.-Kralický Sněžník) were detected. They have sinistral character and differ mutually round 5 mm in the NNE to N directions. The vertical movements display for the Moravo-Devonian geodynamical terrane subsiding trends contrary to the thrusting zone terrane of the Hrubý Jeseník Mts. and Rychlebské hory Mts.-Kralický Sněžník. Even if seven annual GPS epoch measurements were realized and movement trends for individual sites of the geodynamic network EAST SUDETEN were more or less defined, still some open questions exist. In the near future the problem of the thrusting zone effects (terrane B) on regional geodynamic field has to be explained. If the geodynamic network will be extended eastward to the Beskydy Mts. in the future, then motion effects between the Carpathian nappes (upper units) and the Bohemian Massif structures (lower units) could be assessed. Such activities will clarify a question if any geodynamic *motionshed* exists in the area under study.

Monitoring of the seismic activity in the Moravo-Silesian region was limited by a number of seismic stations, maximally 4 stations. Calculation of sensitivity of seismic stations using LSB values, trigger levels and wave pattern analyses concluded that the area is too large and that the number of far seismic stations with high noise levels is insufficient for monitoring of weak earthquakes with $M_L<0$. Nevertheless, nine local seismic events were detected during the period of 2001-2003.

Geological structure-tectonic mapping of brittle deformations and regional tectonics were focused on rejuvenated Variscan deformations by the Alpine orogeny. Paleostress analyses of the Moravo-Silesian area display the NNW-SSE compression and strike-slip regime the ENE-WSW. The systems of Lusatian (WNW-ESE) and Sudetic (NW-SE) faults are in a pseudo-conjunction with the Moravo-Silesian (NNE-SSW) and Orlice (NNW-SSE) faults. Morphotectonic analysis interpreted a fanlike opening of the sub-triangular crust segment corresponding to a sinistral rotation of the Western Carpathians to the Eastern Alps. The opening started in Turonian, continued in Lower Badenian up-to Recent.

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REFERENCES

Adamovič, J. and Coubal, M.: 1999, Intrusive geometries and Cenozoic stress history of the northern part of the Bohemian Massif. Geolines, 9, 5-14.

Alexandrowski, P., Kryza, R., Mazur, S. and Żaba, J.: 1997, Kinematic data on major Variscan strike-slip faults and shear zones in the Polish Sudetes, Northeast Bohemian Massif. Geol. Mag., 134, 727-739.

Angelier, J. and Goguel, J.: 1979, Sur une méthode simple de détermination des axes principaux des contraintes pour une population de failles. C. R. Acad. Sci. Paris, 288, 307-310.

Arthaud, F. and Matte, P.: 1977, Late Paleozoic strike-slip faulting in Southern Europe and Northern Africa, result of a rightlateral shear zone between the Appalachians and the Urals. Geol. Soc. Amer. Bull., 88, 1305-1320.

Brockmann, E.: 1996, Combination of solutions for geodetic and geodynamic applications of the Global Positioning System (GPS) PhD. dissertation, Astronomical Institute, University of Berne, Berne, Switzerland.

Buday, T., Ďurica, D., Opletal, M. and Šebesta, J.: 1995, Significance of the Bělá and Klepáčov fault system and its extension to the Carpathians (in Czech). Uhlí - Rudy - Geologický průzkum, 9, 275-281.

Cacoń, S.: 2001, Recent Earth crust movements in the Sudety Mts. – GEOSUD project. Proc. 10th FIG International Symposium on Deformation Measurements, 19-22 March 2001, Orange, California, USA, 20-30.

Coubal, M.: 1990, Compression along faults: example from the Bohemian Cretaceous basin. Miner.Slovaca, 22, 139-144.

Decker, K. and Peresson, H.: 1996, Tertiary kinematics in the Alpine-Carpathian-Pannonian system: links between thrusting, transform faulting and crustal extension. In: G. Wessely and W. Liebl (Editors), Oil and Gas in Alpidic Thrustbelt and Basins of Central and Eastern Europe, EAGE Special Publication No.5, 69-77.

DeMets, C., Gordon, R. G., Argus, D. F. and Stein, S.: 1994, Effect on recent revision of the geomagnetic reversal timescale on estimates of current plate motions. Geophys. Res. Lett., 21, 2191-2194.

Don, J.: 1996, The Late Cretaceous Nysa graben: implication for Mesozoic-Cenozoic fault-block tectonics of the Sudetes. Z. geol. Wiss., 24, 317-324.

Dopita, M. et al.: 1997, Geologogie české části hornoslezské pánve, MŽP ČR Praha, p.278.

Fodor, L., Csontos, L., Bada, G., Györfi, I. and Benkovics, L.: 1999, Tertiary tectonics evolution of the Pannonian Basin system and neibouring orogens: a new synthesis of paleostress data. In: B. Furane, L. Jolivet, F. Horváth and M. Séranne (eds) The Mediterranean Basis: Tertiary Extension within the Alpine Orogen., Geological Society, London, Special Publications, 156, 295-334.

GEOCR 500: 1998, Map Atlas of the Czech Republic. Czech Geological Institute, Prague.

Grygar, R. and Jelínek, J.: 2000, Sudetic faults framework in West and East Sudetes and its recent geodynamic significance. Comparative structure and geomorphologic studies. Reports on Geodesy No. 7(53), Warsaw University of Technology, 77-79.

Grygar, R. and Jelínek, J.: 2001, Alpine rejuvenation of Epi-Hercynian foreland – the complex morphostructural and tectonic analysis (Moravosilesian region, Bohemian Massif). Proceed. 6th Meet. Czech Tectonic Group Donovaly – Nízké Tatry, May 3-6, 2001, Geolines, 13, 60-61.

Grygar, R. and Jelínek, J.: 2003, The Upper Morava and Nysa pull-apart grabens - The evidence of neotectonic dextral transtension on the Sudetic faults systém. Acta Montana, Ser. A No. 24 (131), 51-59.

Grygar, R. and Vavro, M.: 1995, Evolution of Lugosilesian Orocline (North-eastern periphery of the Bohemian Massif): Kinematics of Variscan deformation. J. Czech Geol. Soc., 40, 1-2, 65-90.

Grygar, R., Vavro, M. and Kreml, P.: 1993, Kinematika krkonošské střižné zóny ve vztahu k regionální deformaci krkonošského krystalinika. Sb. věd. prací VŠB v Ostravě, 34, 85-96.

Havíř, J. and Špaček, P.: 2004, Recent tectonic activity and orientations of the principal stress in the Jeseníky region. Geolines, 17, 38-39.

Holub, K. and Rušajová, J.: 2002, Seismological observations during the experiment CELEBRATION 2000 and their preliminary evaluation. In: Kaláb, Z. (ed.): Laboratory and Field Observations in Seismology and Enginnering Geophysics. Proceedings, Institute of Geonics of the AS CR, Ostrava, 92-104, in Czech.

Hugentobler, U., Sacher, S. and Fridez, P.: 2001, Bernese GPS software - version 4.2, Astronomical Institute, University of Berne, 515 pp.

Jelínek, J. and Grygar, R: 2002, Interaction between Alpine and Variscan orogeny on the basis of study digital elevation models – Moravosilesian area. Acta Montana, Ser. A No. 20 (124), 51-55.

Kaláb, Z. and Knejzlík, J.: 2000, Weak natural earthquakes in the Opava area in period 1997-1999. Reports on Geodesy, No.7 (53), Warsaw University of Technology, 125-130.

Kaláb, Z. and Knejzlík, J.: 2002, The monitoring of seismic events in the East Sudety Mts. in period 2000-2001. Acta Montana, Ser. A, No. 20 (124), 105-110.

Kaláb, Z. and Knejzlík, J.: 2003, Seismicity of the East Sudeten as recorded by solitary triggered stations of UGN. Acta Montana, Ser. A, No. 24(131), 73-79.

Kaláb, Z. and Knejzlík, J.: 2004, Seismological measurement in the Moravo-Silesian region in 2003. Acta geodyn. geometer. 1, No. 3(135), 145-153.

Kárník, V., Schenková, Z. and Schenk, V.:1984, Earthquake activity in the Bohemian Massif and in the Western Carpathians. Travaux Géophysiques, XXIX (1981), 9-33.

Knejzlík, J. and Kaláb, Z.: 2002, Seismic recording apparatus PCM3-EPC. Publs. Inst. Geophys. Pol. Acad. Sc., M-24 (340), 187-194.

Krzyszkowski, D., Migoń, P. and Sroka, W.: 1995, Neotectonic Quarternary history of the Sudetic Marginal fault, SW Poland, In: W. Zuchiewics (ed.), Neotectonics of Poland: Some New Achivements, Folia Quaternaria, 66, 73-98.

Kumpera, O. and Suk, M.: 1985, Some problems of development and structure of the Bohemian Massif. Krystalinikum, 18, Prague, 53-74.

Le Calvez, J. H. and Vendeville, B. C.: 2002, Experimental designs to model along-strike fault interaction. In: W. P. Schellart and C. Passchier (eds.), Analogue modelling of large-scale tectonic processes. Journal of the Virtual Explorer, 7, 7-23.

Matte, P., Maluski, H., Rajlich, P. and Franke, W.: 1990, Terrane boundaries in the Bohemian Massif: Result of large-scale Variscan shearing. Tectonophysics, 177, 151-170.

Reinecker, J., Heidbach, O. and Mueller, B.: 2003, The 2003 release of the World Stress Map (available online at www.world-stress-map.org)

Schenk, V.: 2002, Geodynamics of Central Europe based on observations of the GPS EUREF stations. Geophysical Research Abstracts, 4, CD-ROM.

Schenk, V., Cacoń, S., Bosy, J., Kontny, B., Kottnauer, P. and Schenková, Z.: 2000a, GPS crustal movement monitoring and regional seismicity – A case study for the Sudety Mts. Book of Abstracts and Papers, XXVII General Assembly of the European Seismological Commission, Lisbon University, Lisbon, 10-15 September 2000, 46.

Schenk, V., Cacoń, S., Bosy, J., Kontny, B., Kottnauer, P. and Schenková, Z.: 2002a, The GPS network "SUDETEN" – five annual campaigns (1997-2001). Data processing and results. Geophysical Research Abstracts, 4, CD-ROM.

Schenk, V., Cacoń, S., Bosy, J., Kontny, B., Kottnauer, P. and Schenková, Z.: 2002b, The GPS geodynamic network EAST SUDETEN – Five annual campaigns (1997-2001). Data processing and results. Acta Montana, Ser. A, No. 20(124), 13-23.

Schenk, V., Cacoń, S., Bosy, J., Kontny, B., Schenková, Z. and Kottnauer, P.: 2000b, GPS network "SUDETEN" – Preliminary results of the campaigns 1997-1999. Reports on Geodesy No. 9(39), Warsaw University of Technology, 25-33.

Schenk, V., Cacoń, S., Bosy, J., Kontny, B., Schenková, Z. and Kottnauer, P.: 2001a, GPS network "SUDETEN" – Results of the campaigns 1997-2000. Geophysical Research Abstracts, 3, CD-ROM.

Schenk, V., Cacoń, S., Kontny, B., Schenková, Z. Bosy, J and Kottnauer, P.: 2003a, GPS geodynamic movements of the East Sudeten area in connection to regional geological structures. Geophysical Research Abstracts, 5, CD-ROM.

Schenk, V. and Grygar, R., Schenková, Z. and Kottnauer, P.: 2002c, Pohybové trendy severní části moravsko-slezské zóny Českého masívu – komplexní analýza. In: P. Rapant: Družicové polohové systémy, VŠB – TU Ostrava, 127-131.

Schenk, V., Jechumtálová, Z., Schenková, Z. and Kottnauer, P.: 2003b, Geodynamic movements and deformations of the Sudetic structural unit of the Bohemian Massif. Geophysical Research Abstracts, 5, CD-ROM.

Schenk, V., Jechumtálová, Z., Schenková, Z. and Kottnauer, P.: 2003c, Geodynamics and deformations of the Sudetic geological structural blocks. Proceedings of the 11th International symposium on Deformation Masurements, Santorini (Thera), Greece, 25-28 May, 2003, S. C. Stiros and S. Pytharouli (eds.). Patras University, Publication No. 2, 91-97.

Schenk, V., Kaláb, Z., Grygar, R., Holub, K., Jelínek, J., Knejzlík, J., Kottnauer, P. and Schenková, Z.: 2000c, Mobility of tectonic zones in the northern part of the Moravo-Silesian region and their earthquake activity. Acta Montana, Ser. AB, No. 8(115), 47-60.

Schenk, V., Kontny, B., Borkowski, A., Bosy, J., Kottnauer, P. and Schenková, Z.: 2002d, Geodynamic movements of the Sudeten area. Geophysical Research Abstracts, 4, CD-ROM.

Schenk, V., Kottnauer, P., Schenková, Z. and Hájek, P.: 2004, Czech permanent GPS observatories for geodynamic investigations of the Bohemian Massif operated by the Institute of Rock Structure and Mechanics, Prague. Acta geodynamica et geomaterialia, 1, 3(135), 111-114.

Schenk, V., Schenková, Z., Cacoń, S., Kontny, B., Bosy, J. and Kottnauer, P.: 2003d, To geodynamic interpretations of GPS data monitored on the East SUDETEN network. Acta Montana, Ser. A, No. 24(131), 87-97.

Schenk, V., Schenková, Z. and Kottnauer, P.: 2001b, Geodynamic terrains of the Moravo-Silesian area, the Bohemian Massif. Abstract Book, The Stephan Müller Topical Conference of the European Geophysical Society „Quantitative Neotectonics and Seismic Hazard Assessment: New Integrated Approaches for Environmental Management", Balatonfüred, Sept. 22-26, 2001, Malév Air Tours, 56.

Schenk, V., Schenková, Z. and Kottnauer, P.: 2001c, Několik poznámek k hodnocení dat GPS regionální sítě SUDETY ve vztahu ke stanicím EUREF. Proceedings of regional conference with international participation"Seismology and Engineering Geophysics", IGN AS CR, Ostrava, 166-176.

Schenk, V., Schenková, Z. and Kottnauer, P.: 2002e, Geodynamic movements detected by the GPS technology and supported by the earthquake occurrences, remote sensing and other phenomena. A study case for the Moravo-Silesia part of the Bohemian Massif. Book of Abstracts, 50th Anniversary of the European Seismological Commission, XXVII General Assembly, Genoa, 1-6 September 2002. University of Genoa, 208-209.

Schenk, V., Schenková, Z. and Kottnauer, P.: 2003e, Monitorování geodynamických pohybů na strukturách Českého masívu metodou GPS a jejich geologická interpretace. Sborník "Dynamická a evoluční geomorfologie", Z. Engel a J. Kalvoda (eds.), Přírodovědecká fakulta UK, 20-22.

Staš, L., Rakovski, Z. and Hortvík, K.: 1996, Some results of horizontál measurements by hydrofracturing methods in underground mine of Karviná part of „OKR". Acta Montana, Ser. A., 9, 237-243.

Sýkorová, Z., Špaček, P., Pazdírková, J. and Švancara, J.: 2004, Seismological monitoring of the Dlouhé Stráně pumped-storage power plant. Transactions of the VSB-TU of Ostrava, 3, No. 2, 247-251, in Czech.

Uličný, D.: 2001, Depositional systems and sequece stratigraphy of coarse-grained deltas in shallow-marine, strike-slip setting: the Bohemian Cretaceous Basin, Czech Republic. Sedimentology, 48, 599-628.

Wojewoda, J.: 1997, Upper Cretaceous littoral-toshelf succession in the Intrasudetic basin and Nysa trough, Sudety Mts. In: J. Wojewoda (ed.), Obszary Zródlowe: Zapis w Osadach, WIND, Wroclaw, 1, 81-96.

ZÁKLADNÍ POHYBOVÉ TRENDY SEVERNÍ ČÁSTI MORAVSKO-SLEZSKÉ ZÓNY ČESKÉHO MASÍVU – KOMPLEXNÍ GEODYNAMICKÁ ANALÝZA

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ABSTRAKT:

Společná česko-polská geodynamická síť VÝCHODNÍ SUDETY byla vybudována v roce 1997. Od tohoto roku bylo realizováno sedm epochových GPS měření. Satelitární GPS signály byly monitorovány přijímači a anténami Aschtech. Jednotlivé body sítě byly osazeny převážně při všech měřeních stejnými přijímači a stejnými anténami. Naměřená data byla zpracovávána softwarem Bernese 4.2. Chyba v určení přesnosti horizontálního pohybu jednotlivých bodů sítě nepřesáhla 1 mm a chyba v určení přesnosti vertikálního pohybu 2-3 mm. Sedm epochových měření umožnilo v severní části moravsko-slezské zónu určit roční pohybové trendy a vymezit geodynamické terány. Regionální seismická aktivita byla monitorována až čtyřmi seismickými stanicemi. Bylo vyděleno několik seismogenních zón. Seismické stanice registrovaly lokální seismické jevy a důlní indukované seismické jevy až do magnituda $M_L \approx 0$. Za periodu 2001-2003 bylo zaznamenáno devět lokálních zemětřesení. Geologické strukturně tektonické mapování křehkých deformací bylo korelováno s digitálním modelem terénu. Paleonapěťové analýzy moravsko-slezské oblasti vykázaly SSZ-JJV kompresi a stranové pohyby VSV-ZJZ. Systémy lužických (ZSZ-VJV) a sudetských zlomů jsou v pseudo-spojení s moravsko-slezskými (SSV-JJZ) a orlickými (SSZ-JJV) zlomy.