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INVESTIGATION OF THE RECENT CRUSTAL MOVEMENTS OF THE EASTERN PART OF THE BOHEMIAN MASSIF USING GPS TECHNOLOGY

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Main investigator: Zdeňka Schenková (2006-2008) *, Pavel Kottnauer † (2005)

Scientific collaborators: Vladimír Schenk, Milada Cajthamlová-Grácová, František Mantlík (2006-2007) and Roman Kujal (2008)

Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic, v.v.i., V Holešovičkách 41, 182 09 Praha 8
*Corresponding author's e-mail:zdschenk@irsm.cas.cz

ABSTRACT

To investigate recent crustal movements among geological structures of the eastern part of the Bohemian Massif and to find a relation between the recent mobility of geological structures of the Moravo-Silesian region and the eastern part of the Moldanubicum the regional geodynamic network HIGHLANDS was established. Seven sites were built with respect of geological and geophysical materials in the southern part of the Českomoravská vysočina Highlands. Within 2005-2008 four epoch 48 hours GPS measurements were performed on them and on selected sites of the neighbouring regional geodynamic EAST and WEST SUDETEN networks. GPS epoch data and GPS data of permanent stations situated in the Českomoravská vysočina Highlands were processed by the Bernese software v. 5.0. The detection of sinistral movements of 1÷2 mm/year along faults of the Boskovice Furrow situated between the Moldanubian and Moravian parts of the Bohemian Massif verified previous results obtained for the northern part of the Moravo-Silesian structural blocks. Two zones with extension trends were identified. Regional movements along the Boskovice Furrow in its south part were evaluated as sinistral and its northern part as dextral. Two further extreme movements were detected in the Lugicum unit: along the Marginal Sudetic Fault the distinct sinistral movements and partly opposite sinistral movements on the Kynšperk and Semanice faults. During 2007 and 2008 epoch gravity measurements on sites of geodynamic network HIGHLANDS and fundamental gravity sites of the Czech Gravity Reference network were realized. Preliminary time changes in gravity differences among sites were determined.

KEYWORDS: GPS measurements, gravity measurements, geodynamics, Českomoravská vysočina Highlands, the Bohemian Massif

1. INTRODUCTION

The Bohemian Massif is a Precambrian cratonic terrane composed mostly of highly metamorphosed rocks intruded by a series of granitoids. During its existence the Massif had been affected by several orogeneses that formed its tectonic pattern. Recent crustal movements that exist between the Bohemian Massif and the West Carpathians depend on regional NNW-SSE compression field originated by the Alpine orogene. Its existence has been detected by in-situ monitoring of stress tensor and by deformations of mining works. To detect the recent geodynamic motions going on fundamental geological structures of the Bohemian Massif, geodetic satellite measurements have been applied in the last years, especially GPS measurements.

For this reason the Institute of Rock Structure and Mechanics AS CR, v.v.i., has established regional geodynamic networks EAST SUDETEN (operated since 1997, Schenk et al. 2002, 2003), WEST SUDETEN (since 2001, Schenk et al., 2006) and WEST BOHEMIA (since 2007) for epoch measurements and one countrywide Geodynamic Network of the Academy of Sciences (GEONAS) for permanent observations (GEONAS, 2009; Mantlík et al., 2007; Grácová et al., 2008) – see Fig. 1. Detected movements extended significantly knowledge on the regional geodynamics of the Bohemian Massif. Main interests were directed to a few selected areas where possible recent tectonic movements could be expected (Schenk and Schenková, 2008; Schenk et al., 2009e). Special attention was devoted to mobility trends along the Marginal Sudetic fault, the Hronov-Poříčí and Jílovice fault zones, the Železné hory Mts. fault zone, the Boskovice Furrow and in the West Bohemia swarm area (Schenk et al., 2009c, d).

The presented project was closely linked to projects of the Czech Science Foundation 205/97/0679 and 205/01/0480 and the Ministry of Education, Youth and Sports of the CR LN 00A005, LC506 and 1P05ME781 that investigated recent geodynamic motions between Lugicum and Moravo-

Silesian structures by GPS technology. The aim of the project was to extend the EAST SUDETEN network to the Českomoravská vysočina Highlands and to realize annual epoch GPS measurements regional and local movements among geological structures of the eastern part of the Bohemian Massif to be detected and a relation between the recent mobility of geological structures of the Moravo-Silesian region and the eastern part of the Moldanubicum to be found. GPS monitoring ought to be complemented by gravity measurements.

2. GEODYNAMIC NETWORK HIGHLANDS

The regional geodynamic HIGHLANDS network was established in 2005 to investigate recent crustal movements between northern and southern parts of the Moravo-Silesian region of the Bohemian Massif and to find their relation to movements of structural blocks of Moldanubicum. Seven GPS observation sites were built in the Moldanubicum (Peklůvko – PEKL and Pavlov - PAVL), in the Svratka anticline (Osiky - OSIK and Zábludov - ZABL), in the Třebíč Massif (Benetice - BENE), in the Brno Massif (Hořice - HORI), and in southern part of the Moravian-Silesian Palaeozoics (Nové Sady - NOSA); see Figures 1 - 3 (Schenková et al., 2007). The sites were chosen with respect to known geological materials and geophysical data. The construction of GPS sites of the HIGHLANDS geodynamic network is the same like for the EAST and WEST SUDETEN geodynamic network: a concrete rectangular block with a base of 40x40 cm and a height from 60 to 100 cm and on its top a steel plate with a screw thread for GPS antenna. Every block has a firm anchored contact with bedrock.

3. GPS MONITORING AND PROCESSING

The permanent GPS stations of the network GEONAS were equipped with Ashtech Z-18 or TOPCON GB-1000 receivers and antennas that allowed satellite signals of the American NAVSTAR and the Russian GLONASS positioning systems to be monitored. The epoch GPS measurements were provided by Ashtech Z-12, Ashtech Z-12 surveyor and Ashtech Z-12 X-treme receivers equipped by geodetic, marine and choke-ring antennas powered by 12V/165Ah batteries. Signals were recorded with sampling rate of 30 seconds.

Four epoch GPS measurements were realized on all seven sites of the HIGHLANDS network and on selected sites of the EAST and WEST networks (Schenková et al., 2007, 2008) in two full day sessions (48 hours) on

10 – 12 September 2005
16 – 18 September 2006
08 - 10 September 2007
19 – 21 September 2008.

Both permanent and epoch GPS measurements were processed by the Bernese GPS software version 5.0 (Hugentobler et al., 2005). The epoch network solutions for each GPS day were constrained to the following EPN stations, BOR1, PENC and ZIMM, and a few EPN stations were included to the solutions (e.g. GOPE). The Bernese software was used under these assumptions: (a) precise satellite orbits, satellite clock data and the precession of the Earth´s rotation parameters were taken from the Centre for Orbit Determination in Europe (CODE), Bern, (b) geocentric and geographic coordinates were computed in ITRF2000 reference frame, (c) the stochastic ionosphere model GLOBAL was applied for ionosphere correction estimation, (d) baselines were fixed for each GPS day, (e) linear combinations of observations L3 was used, (f) the Quasi Ionosphere Free strategy for ambiguity resolution was applied, and (g) the atmosphere DRY NIELL model was used for troposphere correction estimation. Finally, the daily solutions were combined altogether by the ADDNEQ2 program.

4. GEODYNAMIC INTERPRETATIONS

GPS measurements detected the sinistral movements on the NW-SE faults in the NE part of the Bohemian Massif, especially along the Marginal Sudetic fault. In the NE part of the Massif area, besides the sinistral movements on the Sudetic faults, also sinistral movements on the NNE-SSW faults of the Moravo-Silesian tectonic system have been observed. Because of an intersection of both tectonic systems nobody can exclude also an existence of dextral movements in this area. Generally, the preliminary analysis of movements displayed that eastern part of the Bohemian Massif could be under “slight extending” trends. The detection of sinistral movements of 1÷2 mm/year along the faults situated between the Moldanubian and Moravian parts of the Bohemian Massif (area of the Boskovice Furrow) verified the previous results obtained for the northern part of Moravo-Silesian structural block. It is evident that these preliminary detected movements (Schenková et al., 2009; Schenk et al., 2009b) have to be verified by other additional annual GPS measurements.

After four annual GPS campaigns in period 2005–2008 there were detected two zones with extension trends (Fig. 3c, dashed lines; Schenková et al., 2009):

i) the first zone along the direction of the Central granite Massif of the Moldanubian unit and
ii) the second one across the central part of the Boskovice Furrow.

Regional sinistral movements along the south part of the Boskovice Furrow were identified while in the northern part of the Furrow the dextral movements were evaluated.

Evaluation of GPS data from the HIGHLANDS network partly confirms original assumption (Schenk

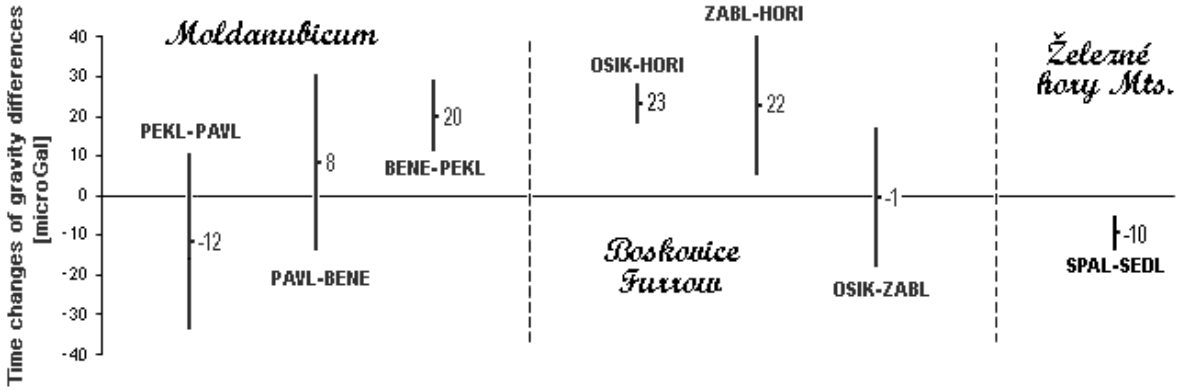

Fig. 5 Time changes of gravity differences [in microGal] for the period of 2007-2008 for site couples (with error bars).

et al. 2002, 2003) that Moravo-Silesian structures moves quicker in the NNE direction than the Moladnubian ones. The detection of sinistral movements of 1÷2 mm/year along the Boskovice Furrow faults situated between the Moldanubian and Moravian parts of the Bohemian Massif verified the previous results from the northern part of the Moravo-Silesian structural block. Detailed investigations of mutual structure movements identified extension trends in areas of the Tišnov fault and its continuation, the Nesvačily fault. Orientation of this extension (Figs. 3c and 4) is closely identical to direction of the Lower-Moravian Depression in direction of the Nectava faults. Besides it, a slight extension trend can be observed also near the eastern branch of the Central Moldanubian Pluton in direction of the Přibyslav fault.

When the site movements obtained for the HIGHLANDS network were joined in the site movements for the EAST SUDETEN network under the condition of the fixed HORI site, then a dominant movement NE direction can be observed. Besides the extension movement trends crossing the central part of the Boskovice Furrow two further extreme movements were detected in the Lugicum unit (Fig. 4; Schenková et al., 2009; Schenk et al., 2009b):

i) along the Marginal Sudetic Fault the distinct sinistral movements (marked by C letter) and
ii) partly opposite sinistral movements on the Kynšperk and Semanice faults (marked by D letter).

Both these extremes seem to have additional movements of the Lugicum unit to the NW direction. These movements along so called Sudetic tectonics have been already detected in this area.

5. GRAVITY EPOCH MEASUREMENTS.

During 2007 and 2008 there were also realized gravity measurements using the relative gravimeter Scintrex CG-05 on sites of geodynamic network HIGHLANDS, selected sites geodynamic network WEST SUDETEN and fundamental gravity sites of the Czech Gravity Reference Network (Kujal et al., 2009). The gravity measurements were concentrated on monitoring the long-term trends of gravity acceleration among individual measurement sites.

Preliminary determined time changes of gravity differences in microGal with error bars for site couples are given in Figure 5. For the Železné Hory Mts. Area the gravity differences did not show pronounced changes. In the Moldanubian area a decline of gravity differences with increasing time was observed. This trend could be correlated with the observed extensional trends of horizontal movements that were detected by GPS technology (Schenková et. al., 2009). For the Boskovice Furrow area there were almost no changes in gravity differences for sites situated in the same side of the Furrow and rather significant differences were observed between sites located on different sides. This fact indicates an existence of vertical and horizontal movements existing along and across the Boskovice Furrow (Schenková et. al., 2009).

6. CONCLUSION

Generally it can be concluded a relative good coexistence of detected site movements in the whole investigated area of the north-eastern part of the Bohemian Massif among the Moldanubian, Moravo-Silesian and Lugicum units. Nevertheless, after these preliminary regional geodynamics results additional local trends have to be investigated in the future. It is clear that further GPS epoch monitoring is needed to increase reliability of approximations of the horizontal and/or vertical movements. The research team showed that six or more annual epochs (Schenk et al., 2009a) allow reasonable horizontal motions with 1 mm accuracy and vertical ones with 2 or 3 mm accuracy to be detected.

Even if the goals of the project belong to a basic research programme, its results can contribute to urban and land planning projects. Knowledge of

geological structure stability plays a significant role in land planning and in principle, should be taken into account at the every larger technical intervention to the landscape (e.g. Schenk et al., 2007).

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SLEDOVÁNÍ RECENTNÍCH POHYBŮ ZEMSKÉ KŮRY VÝCHODNÍ ČÁSTI ČESKÉHO MASÍVU POMOCÍ GPS

Zdeňka Schenková, Pavel Kottnauer †, Vladimír Schenk, Milada Cajthamlová-Grácová, František Mantlík a Roman Kujal

ABSTRAKT:

Regionální geodynamická síť VYSOČINA byla vybudována za účelem sledování recentních pohybů geologických struktur východní části Českého masívu a jejich vztahu k recentní pohyblivostí struktur moravsko-slezské oblasti a východní částí moldanubika. Výběr sedmi stanovišť sítě byl proveden dle všech dostupných geologických materiálů a geofyzikálních dat. V letech 2005-2008 byla na těchto stanovištích a dalších vybraných stanovištích regionálních geodynamických sítí VÝCHODNÍ a ZÁPADNÍ SUDETY realizována čtyři 48 hodinová GPS měření. Epochová GPS data a GPS data permanentních stanic nalézajících se na Českomoravské vysočině byla zpracována softwarem Bernese v. 5. Regionální pohyby 1÷2 mm/rok na zlomech jižní části boskovické brázdy byly vyhodnoceny jako levostranné a pohyby v severní části jako pravostranné. Pohyby detekované v severní části brázdy na zlomech mezi strukturami moldanubika a moravika Českého masívu potvrdily již dříve nalezené pohyby. Ve sledované oblasti byly identifikovány dvě zóny s extenzními trendy. Další extrémní pohyby byly detekovány v jednotce lugika: levostranné pohyby podél okrajového sudetského zlomu a na kynšperském a semanickém zlomu. V letech 2007 a 2008 byla realizována měření zemské tíže na stanovištích geodynamické sítě VYSOČINA a na blízkých tíhových bodech základní sítě ČR. Předběžně byly detekovány časové změny v hodnotách tíže mezi stanovišti.

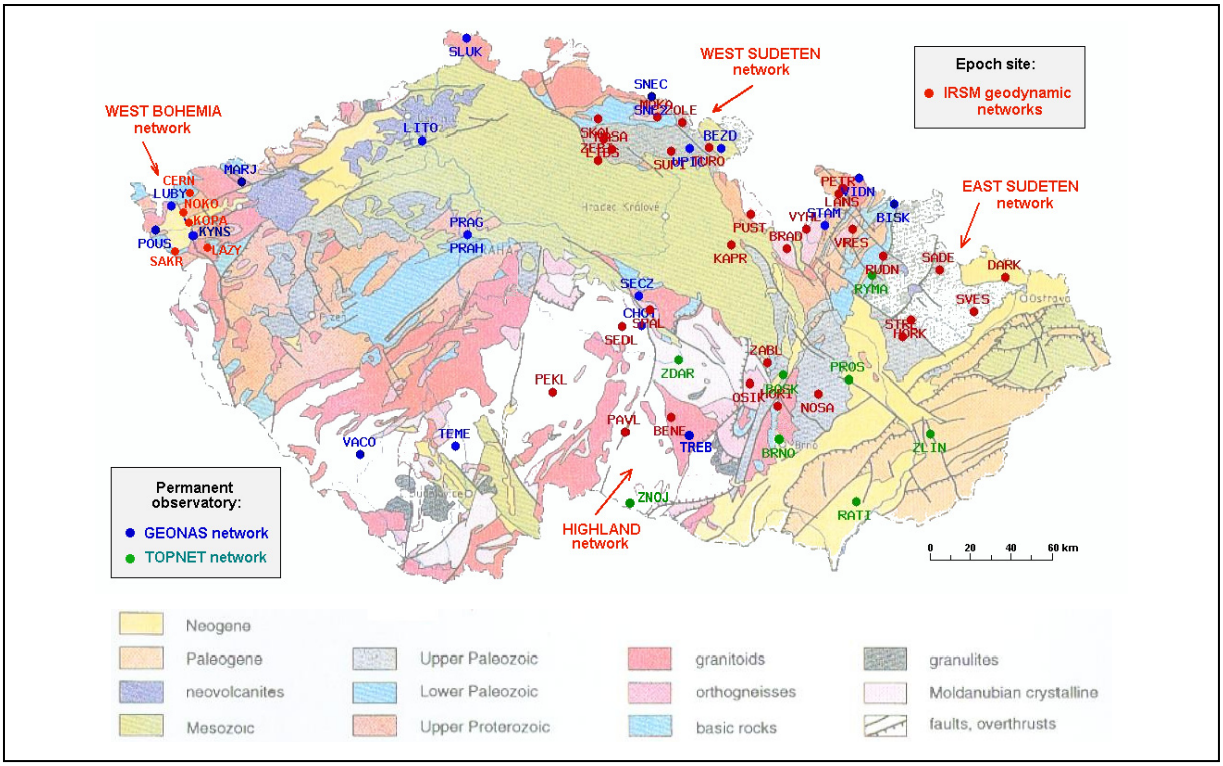

Fig. 1 Permanent and epoch GPS networks used for investigations of recent geodynamic processes in the Bohemian Massif; 35 sites (red dots) of 4 networks for epoch measurements, 18 permanent stations of the GEONAS network (blue dots) and 8 permanent stations of the TOPNET network (green dots; operated by the Geodis Lts., Brno); geological background by the Czech Geological Survey.

Benetice **Hořice** **Osiky** **Peklůvko** **construction scheme**

Fig. 2 Construction scheme of GPS site monument and photos of four GPS sites of the HIGHLANDS geodynamic network.

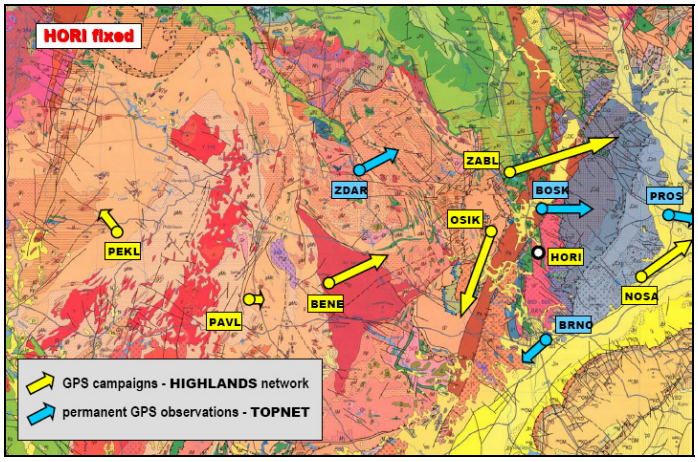

Fig. 3a Total horizontál movements of the HIGHLANDS network sites (yellow arrows) and the permanent stations of TOPNET network (blue arrows); a reference site HORI.

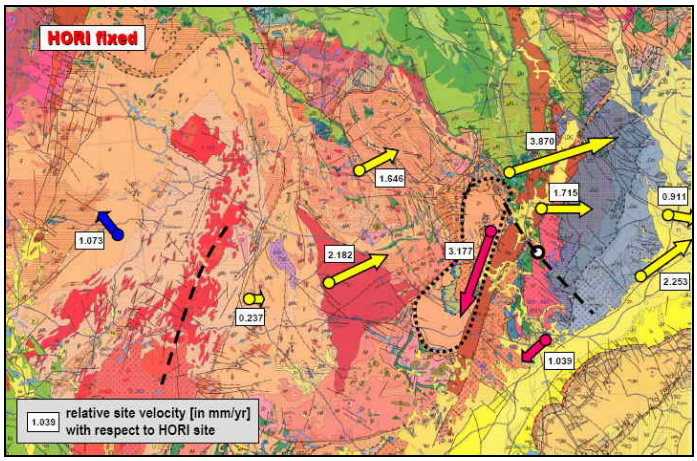

Fig. 3b Detected total horizontal movement values on the HIGHLANDS network sites; a reference site HORI; dashed lines mark extension zones.

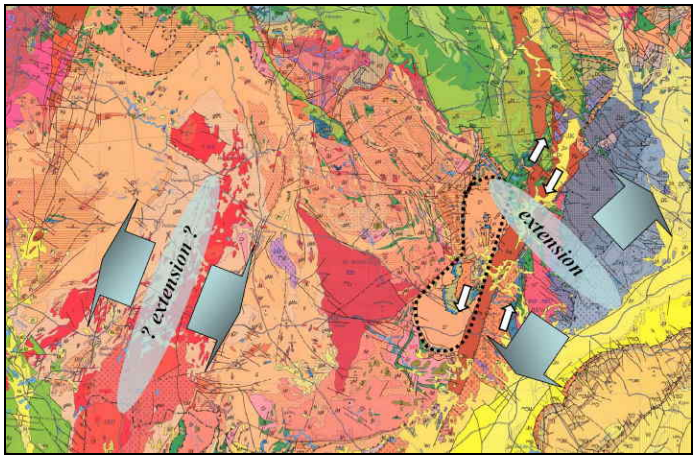

Fig. 3c Positions of detected extension zones and trends of movements along the Boskovice Furrow.

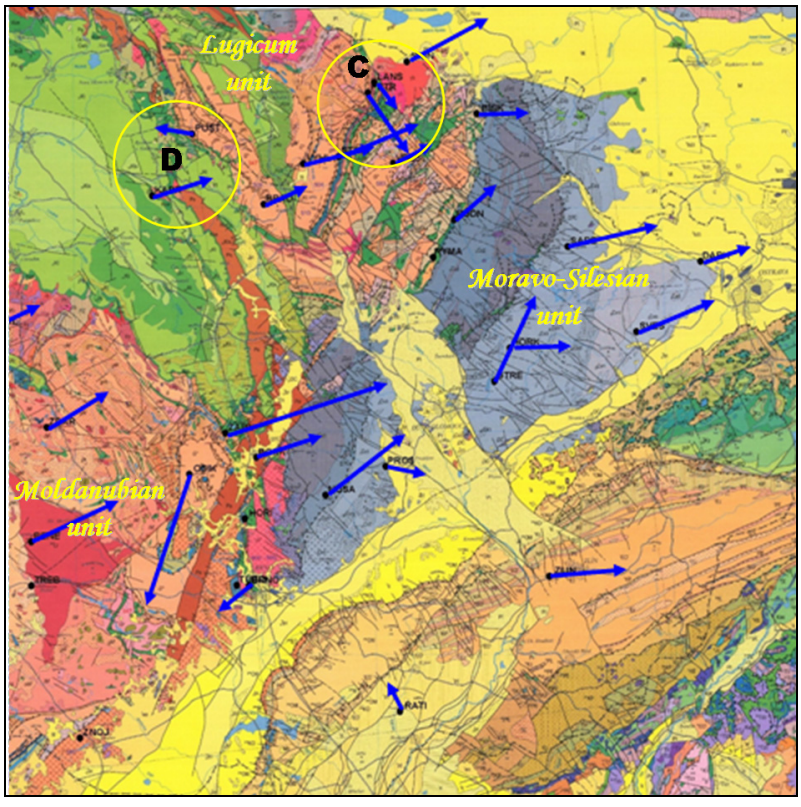

Fig. 4 Joint processing of movements monitored on the HIGHLANDS and EAST SUDETEN network sites; a reference site HORI. The NE direction is a dominant movement direction. In Lugicum units pronounced sinistral movements exist along the Marginal Sudetic fault (C) and the Kynšperk and Semanice fault (D), where they are combined with a compression trend.