PRELIMINARY SITE MOVEMENTS IN THE GPS WEST SUDETEN NETWORK

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ABSTRACT

The WEST SUDETEN geodynamic network consists of 11 sites on that five annual GPS epoch measurements in period of 2001-2005 were carried out. The 48-hour epoch data linked to 4 permanent EPN station observations created reasonable GPS data base for a preliminary evaluation of site movement velocities. General movement pattern over the network has been obtained and some regional and local movement relations among network sites were observed and discussed. The whole region under study displays three areas with relatively different movement trends. The northern area, i.e. the Krkonoše Mts. structural block, displays pronounce motion to the NW with respect to the central area that involves the Permian piedmont of the Krkonoše Mts. covered in its southern part by the Cretaceous sediments. Besides, conspicuous dextral movement along the Železné hory Mts. fault zone was detected too.

KEYWORDS: epoch GPS observations, geodynamics, the Sudeten area, the Bohemian Massif

1. INTRODUCTION

The regional GPS geodynamic network WEST SUDETEN was established by the Institute of Rock Structure and Mechanics Academy of Sciences of the Czech Republic in 2001 in the north-eastern part of the Bohemian Massif with the aim to identify recent mobile zones and to explain their movement relations in the frame of the Moldanubian structures (Schenk et. al., 2002b). It covers a large area including the Železné hory Mts. Its eleven GPS sites were selected after detailed geological, geophysical and geodetic analyses. The GPS sites are formed by concrete blocks built in the rectangular shape with a base of 40 x 40 cm and a height from 40 up to 80 cm (Schenk et al., 2002b).

Eight sites of the network (MOKA, ZOLE, TURO, SUPI, SKAL, LIBS, NASA and ZEBI) are situated in the Krkonoše Mts. and in their piedmont to monitor recent mobility trends along the Hronov-Poříčí and Jílovice fault zones (Schenk et al., 1986 and 1989). The EPN permanent observatory SNEC (before its including to the EPN network as SNEZ) situated on the top of the Sněžka Mt. has been integrated to the WEST SUDETEN network (Schenk et al., 2002c; Caco\u0144 et al., 2004, Mantlík et al., 2006a, 2006b).

The site PUST is placed in the Orlické hory Mts. opposite to the site KAPR in order to detect any possible movements along the Kyšperk and the Semanín fault zones. These zones connect the WEST SUDETEN and the EAST SUDETEN regional networks; the second one operated since 1997 (Schenk et al., 2002a, 2003).

The other two sites, SPAL in the Železné hory Mts. unit and SEDL in the Moldanubian unit, were established to detect movements between these two structural units.

2. GPS DATA PROCESSING

Five 48-hour epoch GPS measurements at eleven sites of the WEST SUDETEN network were realized in 2001-2005 (Table 1). Only Ashtech receivers equipped with geodetic, marine and one choke-ring antennas were used. The monitored GPS data sampled in 30 sec intervals were processed jointly with data of the permanent observatories of the GEONAS network (Mantlík et al. 2005, 2006a, 2006b). To obtain preliminary site movement velocities the GPS data were constrained to GPS observations of four permanent EPN stations (BOR1, GRAZ, POTS and WTZR). The Bernese GPS Software version 5.0 (Hugentobler et al., 2005) was used.

Table 1 List of epoch GPS measurements.

No of epoch	Date
1	2001, Sep 1-2
2	2002, Aug 24-25
3	2003, Aug 23-24
4	2004, Aug 21-22
5	2005, Aug 27-28

2.1. PREPARATION OF DATA AND THEIR PREPROCESSING

Raw data monitored by GPS receivers were transferred into the RINEX format. Great attention was paid to assemble correct receiver and antenna types into RINEX headers and to ensure proper antenna heights for each annual epoch at any given site.

To determine a-priori coordinates with sufficient precision for each site, the Precise Point Positioning (PPP) procedure was applied.

Earth rotation parameters, precise satellite orbits and satellite clock data were collected for each GPS day from the regional centre CODE enjoying the advantage of availability of the GLONASS GNSS system ephemeredes because our permanent GEONAS observatories assembled GLONASS satellite tracking phase and code data too.

The last steps of the data preprocessing was a conversion of the RINEX data into the Bernese format, a baseline definition and a computation of single difference baseline data files. The baselines were selected automatically in the Bernese software using Maximum-Observations (MAX-OBS) strategy, which is recommended for networks of the size similar to the WEST SUDETEN network.

2.2. CONSTRAINED NETWORK DAILY SOLUTIONS

The constrained network solution for each observation GPS day was computed using four fiducial EUREF permanent observatories to stabilize the network solution – WTZR, GRAZ, BOR1 and POTS. The standard RNX2SNX procedure was used with several modifications and options described later.

At the beginning of the computation of the daily solution data outliers were detected and deleted from the registered data by the use of the MAUPRP program. Then, the cleaned data were applied as the input for further processing.

In the next step the ambiguities for each satellite-tracking path were resolved using GPSEST program for each baseline. On average approximately 80 % of all ambiguities were resolved as integers. After the resolving of every possible ambiguity the final constrained solution was computed by means of the final run of the GPSEST program. The solution obtained was verified by the use of the Helmert transformation so that the a-priori coordinates of four fiducial sites coincide with the computed solution.

The ADDNEQ2 module run was performed as the final step of the daily solution to prepare the normal equations for later velocity computations excluding the troposphere parameters from the previously calculated daily solution. The troposphere parameters are not compulsory for the velocity estimation. When the daily-constrained solutions for each observation GPS day had been gained then the final combinations of daily solutions were computed by means of the ADDNEQ2 program.

3. MOVEMENT VELOCITIES

All possible two-, three-, four- and five-year combinations of the GPS daily-constrained solutions were analyzed to ensure reliability of site movement velocities determination. Final velocities in the north V_N and the east V_E directions and their standard deviations σ_N and σ_E were computed from the solutions mentioned above (Table 2). Time series of six selected sites are displayed in Figure 1.

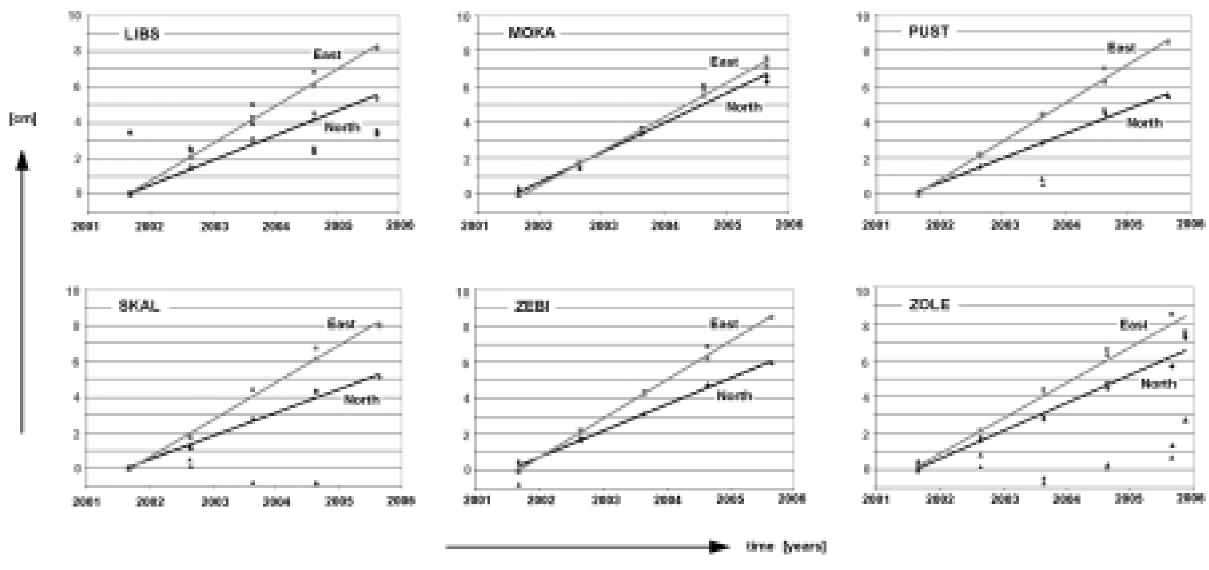

Fig. 1 Example of time series of the positions of six sites of the regional geodynamic WEST SUDETEN network in the north (♦)and the east (■) directions drawn from five annual GPS epochs (2001-2005); because the vertical (▲) positions display so far excessive scatter, none approximations of vertical movements have been done.

Table 2 Site movement velocities [mm/year].

Site	V_N	σ_N	V_E	σ_E
KAPR	13.29	1.59	20.88	1.50
LIBS	13.66	0.96	20.09	0.51
MOKA	17.17	1.98	18.46	1.22
NASA	13.83	1.27	20.41	0.80
PUST	13.92	0.66	20.74	0.67
SEDL	13.18	2.19	20.41	1.09
SKAL	13.43	0.96	20.09	0.82
SNEC	17.31	2.30	17.42	1.17
SPAL	11.73	2.23	21.32	1.93
SUPI	14.53	0.11	19.86	0.39
TURO	13.52	0.67	19.48	0.83
ZEBI	14.38	0.13	20.60	0.75
ZOLE	13.92	0.35	20.62	0.73

As evident from Figure 1, the linear approximations of the horizontal movements can already be assessed as reliable, while any reliable "linear" fittings of vertical movements due to a great scatter of so far obtained movements cannot be attain and for this reason further GPS epoch monitoring are needed.

Because of the great similarity of the movement vectors of three epoch sites LIBS, NASA and SKAL (Table 2) and their nearness each other the average movement vectors of these three sites were determined. To help us to find differences between the movements of individual network sites the average vectors were subtracted from the movement vectors of all sites. Figure 2 shows the movement differences of the horizontal velocity components displayed on the geological map.

Distinct differences in movement trends divide our area under study into three sub-areas:

- the northern area that could be identified with the Krkonoše Mts. structural unit involving the Krkonoše-Jizera granitic Massif and its adjoining high-metamorphic rock-coat,
- the central area including the Permian piedmont unit of the Krkonoše Mts. which continues southwards and partly creates a basement of the Cretaceous basin, and
- the southern area relating to the Železné hory Mts.

It is evident that velocity movement vectors of the northern and southern parts of the WEST SUDETEN network display relatively greater velocities than the central part.

4. DISCUSSION

Annual velocity movements of MOKA and SNEC sites in the northern part of the WEST SUDETEN network show pronounced differences in movement velocities, a few millimetres per year to NW (Fig. 2). Both sites are placed in the Krkonoše-Jizera granitic Massif and its high-metamorphic rock-coat roots which due to the anatexis origin of the Massif may reach deep parts of the lower lithosphere. Thus, like the structure movements of deep seated blocks in the regional geodynamic EAST SUDETEN network (Schenk et al. 2002a, 2003), we can expect that also in this area of the Bohemian Massif the lower parts of lithosphere proves leading motion trends to the NW. To verify this conclusion a joint interpretation of our and Polish GPS epoch data monitored on the KARKONOSZE network should be done (Kontny, B., 2004; Kontny et al., 2004).

The anomalous behaviour of the Sněžka Mt. was mentioned by Hefty and Gerhártová (2006). They summarized the long-term epoch GPS observations and movements evaluated on the Central European GPS geodynamic network CEGRN in the following way: *The only station in the region, which has different behaviour, is SNIE with its south-west oriented velocity with 4 mm/year magnitude. It is very probable that this is local phenomenon*.

The SNIE station is the GPS site located on the Polish side of the Sněžka Mt. (Cacoń et al., 2004). The orientation and magnitude of the SNIE site movement velocity depends on the solution performed for all GEGRN stations. Nevertheless, it can be concluded that the central part of the Krkonoše Mts. structural unit exhibits the anomalous movement trend with respect to neighbouring structures.

As to the central area, several movement trends can be identified and discussed. From geological and tectonic viewpoint this area consists of several blocks elongated in NW-SE directions. Buday et al. (1995) described their mutual uplifted and subsided motions in the late Cenozoics period. Even if no distinct vertical motions have been detected, existing mutual zig-zag horizontal trends could be explained just by local changes in dipping and/or uplifting motions among individual structural blocks at existed normal and reverse fault planes. Nevertheless, a better explanation can be expected later when additional GPS epoch measurements will be realized.

A notice has to be directed also to the KAPR and PUST sites placed on opposite wings of the Kyšperk fault zone. This zone with the Semanín fault zone are attributed as structural north-western extensions of the Boskovice Furrow. If the eastward movements assigned for both sites KAPR and PUST (Fig. 2) are detached, as a consequence of the analysis of site movement differences, a final dilative movement trend observed between both sites can give evidence that possible dilatations on these tectonic zones could be expected.

Finally, remarkable mutual movements between the Železné hory Mts. and Moldanubian units were detected. Figure 3 presents the time series of SEDL and SPAL sites each of them located on one of the

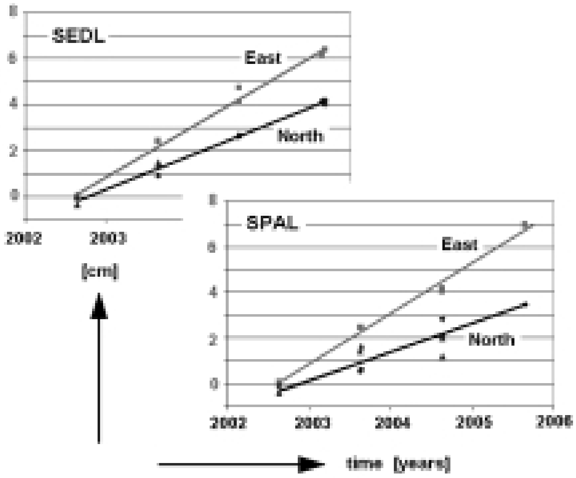

Fig. 3 Time series of positions of two network sites SEDL and SPAL situated on both wings of the Železné hory Mts. fault zone assessed from four annual GPS epoch measurements (2002-2005).

units. Their relative motions (Fig. 4) exhibit distinct annual dextral movement of 1½ mm between the Železné hory Mts. and Moldanubian units. Its origin could be most probably explained by a recent pressure of the East Alpine structures towards the Bohemian Massif the origin of which is the consequence of the northward action of the Adria plate to the Alps.

5. CONCLUSION

Preliminary velocity movements among the sites of the regional geodynamic WEST SUDETEN network were assessed and discussed. Pronounced motion trends of the Krkonoše-Jizera granitic Massif and its high-metamorphic rock-coat to the NW direction and also obvious motion between the Železné hory Mts. and Moldanubian units were detected. Some opening and contractive trends can be expected for the central area of the WEST SUDETEN network. Their geological and/or tectonic explanations could be done later when further GPS epoch measurements are performed.

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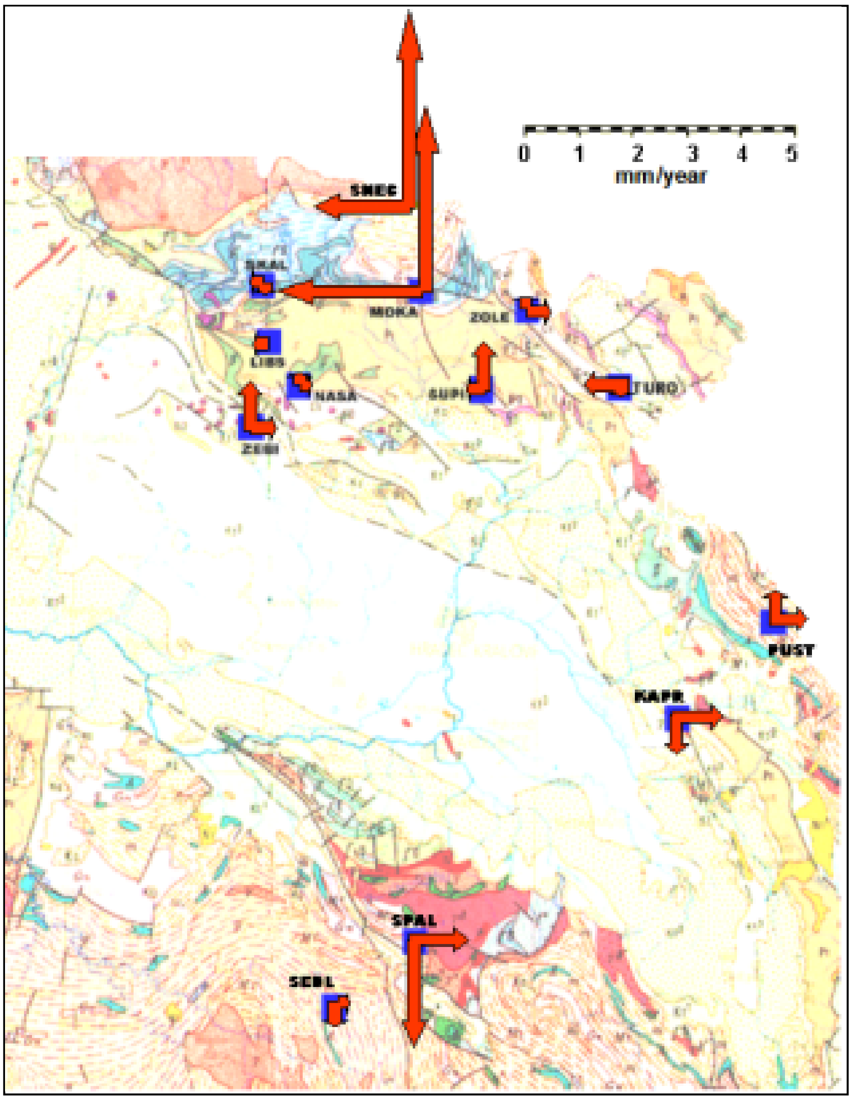

Fig. 2 Annual GPS velocity movements for the individual sites of the WEST SUDETEN regional geodynamic network determined from 5 epoch measurements carried out in the period of 2001 – 2005; blue squares – the network sites, red arrows – site movement directions

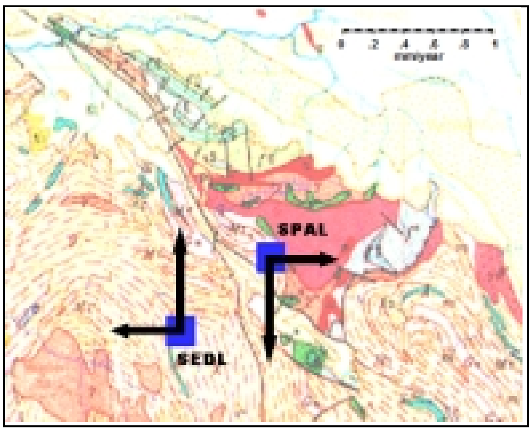

Fig. 4 Annual GPS comparative velocity movements along the Železné hory Mts. fault zone assessed between Spálava (SPAL) and Sedletín (SEDL) sites