

TECTONIC MOVEMENTS MONITORING OF SUDETIC MARGINAL FAULT USING SHORT GPS BASELINES

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Abstract

In work the concept of short baselines GPS measurements treated as relative has been presented. Such examinations have been used for detection of rock-mass displacements in local researches of the Earth's crust movements. It has been drawn the methodology of determination of reciprocal tectonic blocks motions by analysing co-ordinates changes of vectors connecting the both fault's sides. The advantages of short GPS baselines measurements have been portrayed as suitable for such investigations. The preliminary results of the short GPS baselines methods used for tectonic movements determination of the Sudetic Marginal Fault (Uskok Sudecki Brzezny) - the south-western Poland in the time's period of 1997-2000 have been presented.

1. Introduction

Geodetic investigations of contemporary local tectonic activity of aseismic areas have been conducted by using methods different from those, which were performed, in the high-seismic terrain. There is no economical reason for setting GPS permanent stations as the "SCIGN", California, USA or the "GSI" in Japan. Nowadays, regional and local investigations are based on recurrent GPS measurements of special research networks. Monitoring of singular tectonic faults can be realised by using the recurrent geodetic methods (distances and angles, precise levelling as well as the GPS) along directions perpendicular to the fault. Such methodology has been used during the monitoring of the Sudetic Marginal Fault in south-western Poland.

Comprehensive geodynamical researches in the Middle and Eastern Sudety Mts. as well as in the Fore-Sudetic Block (Blok Przedsudecki) started in 1996 as the GEOSUD project (financed by Polish Committee of Scientific Researches) - (Cacon, Kontny, Bosy, 1998). In 1997 as the co-operation with Institute of Rock Structure and Mechanics, Czech Academy of Sciences in Prague, the existing local networks were connected into the one research network "SUDETY" observed during common measuring sessions (Schenk et al, 1999). The results obtained from first campaigns (1997-1998) have been presented in particular works (Schenk et al, 1999, 2000; Cacon, Kontny, Bosy, 1998; Kontny, Bosy, Cacon, 2000).

The localisation of points of the extended network "SUDETY" has been presented on figure 1. GPS satellite measurements were annually realised in the same period (September) in two-day sessions (2 x 24 h). Results have been worked out by using the Bernese Software ver. 4.0 and 4.2 with assistance of special strategy (Bosy, Kontny, 1998).

Geodetic researches of crustal movements performed on local research networks are occupied by following assumptions of the control-measuring system, consisting of three segments: main spatial reference network, precision geodetic micro-networks and the apparatus for relative measurements (Cacon, Kontny, 1994). One of the basic assumptions of the system is to determine the deformation parameters of excluded blocks on the basis of geodetic measurements as well as relative observations performed by instruments such as extensometers, inclinometers and feeler-gauges (Cacon, Kontny, 1993). GPS measurements of independent short vectors situated transversal to the line of tectonic fault could have been treated as peculiar relative observations. In the work it has been presented the concept of using short GPS baselines for determination of relative tectonic block's movement parameters at the both sides of the fault.

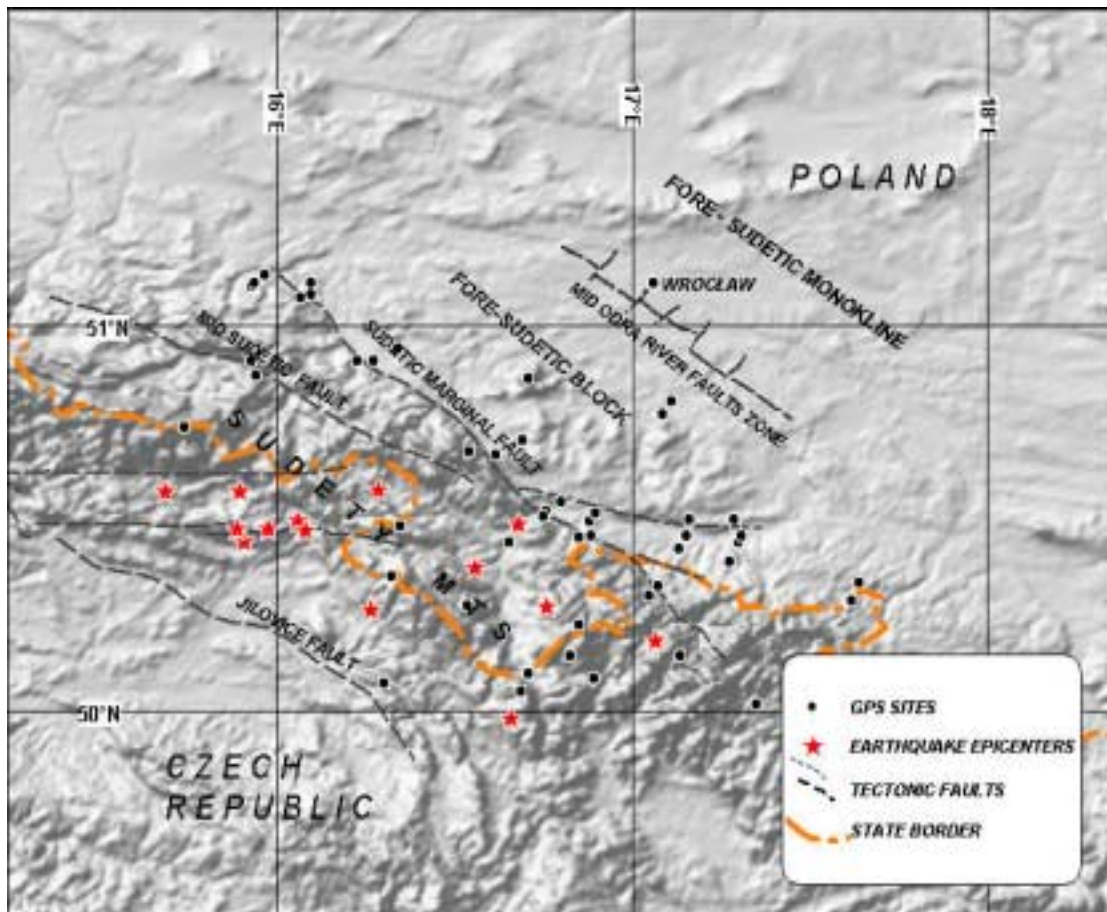


Figure No. 1 Location of GPS sites in Sudety Mts and Fore-Sudetic Block
- tectonics and earthquake epicentres location from Schenk et al.(1986)

2. Definition of relative tectonic blocks movement parameters on the basis of the GPS vector's change

Vector d taken from relative motion of two tectonic blocks treated as solids may be factorised into shearing components –horizontal d_p and vertical d_r and dilatative component d_q (fig. 2) which have the first-rated meaning for interpretation of phenomena.

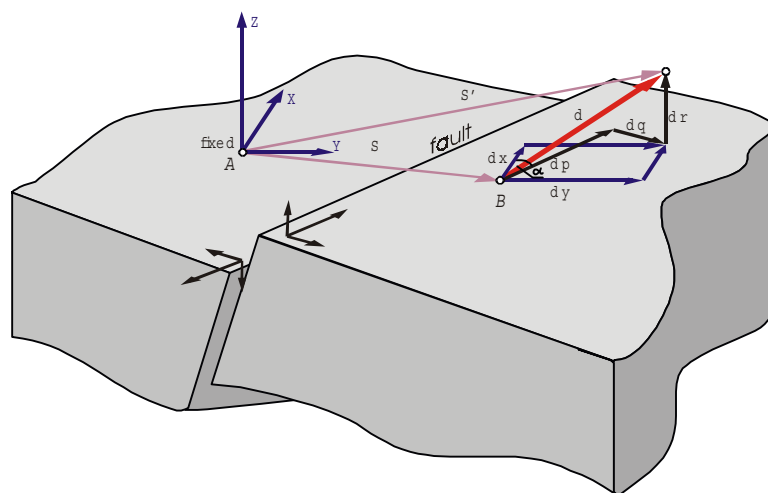


Figure No. 2 Components of difference vector of short baseline AB

The components d_p , d_q , d_r can be determined on the basis of difference vector d_B of measured GPS vectors S and S' between the points A and B (considering point A as fixed) using very simple formulas:

$$\vec{d}_B = \vec{S}'_{AB} - \vec{S}_{AB} \quad (1)$$

$$\begin{bmatrix} dx_B \\ dy_B \\ dz_B \end{bmatrix} = \begin{bmatrix} \Delta X'_{AB} - \Delta X_{AB} \\ \Delta Y'_{AB} - \Delta Y_{AB} \\ \Delta Z'_{AB} - \Delta Z_{AB} \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} dp \\ dq \\ dr \end{bmatrix} = \begin{bmatrix} \cos\alpha & \sin\alpha & 0 \\ -\sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} dx_B \\ dy_B \\ dz_B \end{bmatrix} \quad (3)$$

Where: α is the horizontal angle of fault's orientation in the topocentric co-ordinate system X,Y,Z.

Short GPS baselines measurements may have been treated as relative (a specific "crack-gauge") in the control-measuring system. It permits using such measurements for estimation of homogeneous deformation of tectonic blocs (translation, rotation and homogeneous deformations) following the rules described in (Cacon, Kontny, 1993).

3. Short baselines GPS advantages and disadvantages in relation to tectonic movements monitoring

Bock (1996) has defined a concept of short GPS baselines as the base with distances where total site and receiver specific errors (receiver noise, multipath, antenna phase center errors) are bigger than the residual tropospheric and ionospheric refraction effects and residual orbital errors. Goad (1996) emphasises that during the period of high solar activity the ionospheric influences cause difficulty in ambiguity solution even considering distances off from 10 kilometres. Authors of the Bernese GPS Software have also taken into account the distances of 10 km as the limit for used parameters and procedures dedicated for short bases (Rothacher, Mervart, 1996). Practically the distances between points situated at both sides of tectonic fault hardly exceed some kilometres.

The main advantage of short baselines use is the minimisation of atmospheric influence (ionosphere, troposphere) into the double-differences measurements and specially into the ambiguity resolution on singular frequencies L1 and L2. The use of particular single frequencies significantly reduces a noise but causes a necessity of applying a local model of ionosphere to assure a proper scale (Rothacher, Mervart, (Eds), 1996). The application during the following recurrent measurements of the same equipment set (receivers and antennas) additionally allows reducing the influence caused by the instrumental errors on determined differences. According to Goad (1996), it is possible to achieve the accuracy of short GPS baselines on the level of 1 mm.

To illustrate the influence of established strategy of ionosphere and troposphere modelling the testing calculations of the LANS-PETR vector (moreless 3.5 km) have been performed. The raw data obtained from four campaigns (1997-2000) have been calculated by using the Bernese 4.2 Software in two modes. First, it has been used the global (CODE) and local (estimated) stochastic ionosphere model as well as the total: deterministic (Sastamoinen) and stochastic (site-specific) model of troposphere parameters for individual station. In the second one it has been used only a global ionosphere model and also a local (one for both points) model of troposphere delay.

The calculated changes of vector components coming from following years and presented relatively to the very first measurement have been shown on the diagram (fig.3).

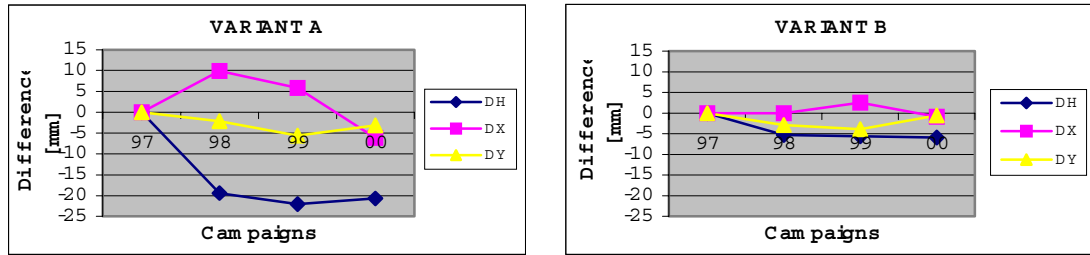


Figure No.3 The calculated changes of LANS-PETR vector components

The presented diagrams shows that differences between successive measurements calculated in the first variant are almost double bigger than coming from the second one. Such as situation took place although the *a posteriori* RMS of unit weight (single difference observation converted to L1) calculated in the second variant (average about 3 mm) was two times worse than in the first one (average about 1.5 mm). This result seems to be the confirmation of fact that in the recurrent measurements calculated differences between particular surveys can in most cases reduce systematic errors.

4. Tectonic movements of Sudety Marginal Fault – preliminary results of 1996 – 2000 measurement campaigns

Planning, systematic short baselines GPS measurements in the profiles transverse to the Sudetic Marginal Fault have been started last year as the part of GEOSUD II project (Cacon, Dyjor, 2000). However, in measure campaigns of 1996-1998, which were realised as the previous project GEOSUD (Cacon, Kontny, Bosy 1998), some points situated on both fault's sides were observed simultaneously. Short baselines between points 0303-0304, 0118-0406 on the Polish side and LANS-PETR on the Czech side (Fig.4) were selected for preliminary study.

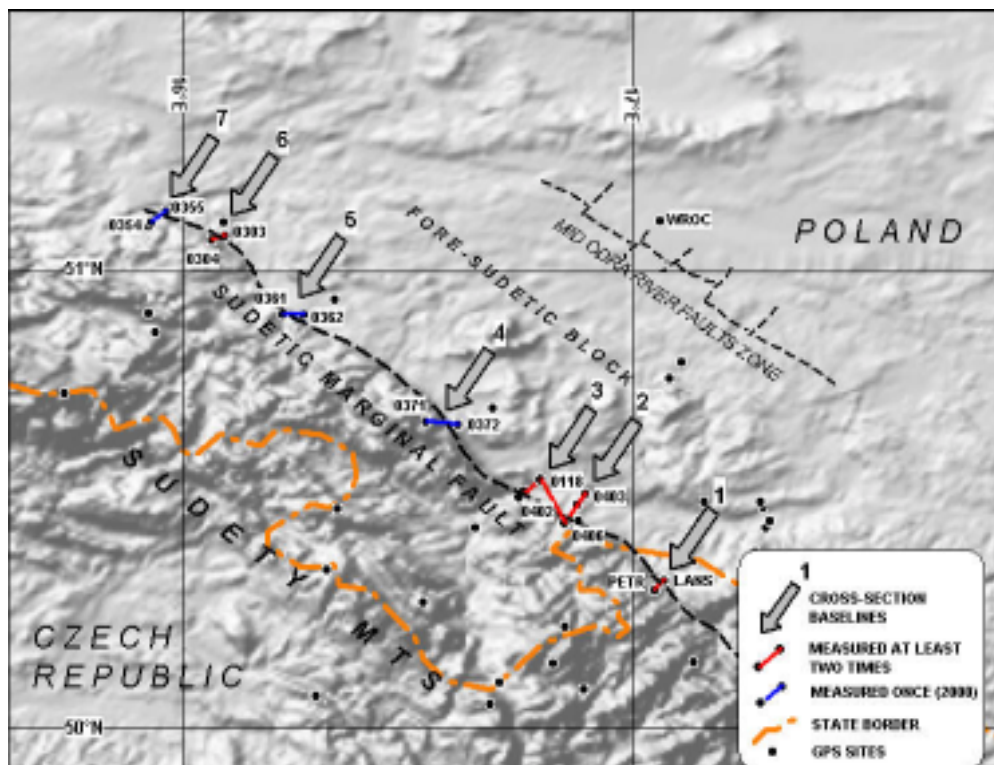


Figure No. 4 Cross-section short GPS baselines on Sudetic Marginal Fault

The raw data was calculated again as independent GPS vectors and on the basis of their differences the parameters of relative both fault's sides movement were established for the period 1997-2000. The results have been shown in the fig.5.

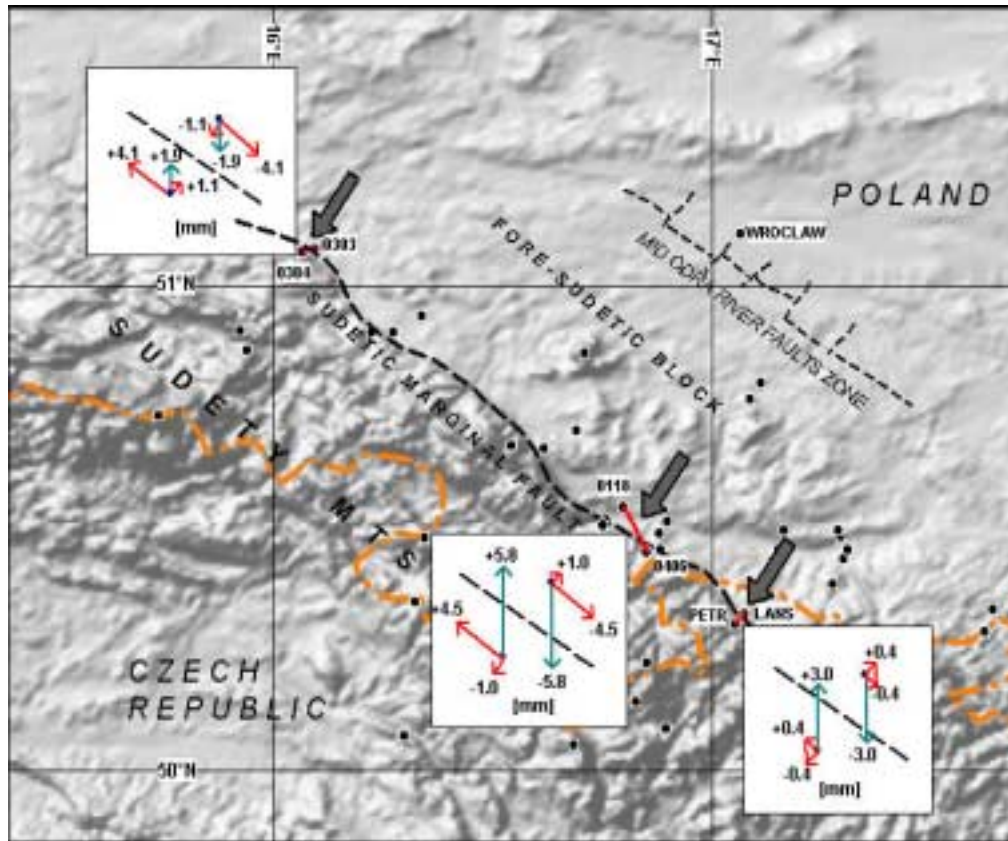


Figure No. 5 Values of the difference vector's components of selected cross-section GPS baselines (1997-2000)

The relative movement vectors components, computed for three selected cross-sections, were characterized by the same tendency but different values. The accuracy (mean error) of this values, computed on the base of RMS values of GPS vectors components (estimated by Bernese 4.2 software) was on the level of ± 1.5 mm for horizontal and ± 2.0 mm for vertical components. Hence dilatational components and vertical shearing components (except baselines 0406-0118) have been treated as non-significant. Horizontal shearing components in the cross-section 0304-0303 and 0406-0118 have seemed to be significant although horizontal relative movement velocities about 2 mm/year have been unexpected.

5. Summary

The above presented concept of relative movement's parameters in the Sudetic Marginal Fault is only the completion of complex researches of local Earth's crust movements realised in the Sudety and Fore-Sudetic Area. The Polish Committee of Scientific Researches has financed all these scientific projects.

Taking into account that the period of time seems to be very short in relation to contemporary tectonic movements in Central Europe, specially advanced conclusions may not be constructed yet.

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