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GEODYNAMICAL INVESTIGATIONS IN THE LOCAL NETWORK ŚNIEŻNIK KŁODZKI

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ABSTRACT
Metamorphic phenomena formed geological and tectonical structure of the Śnieżnik Kłodzki Massif, Kłodzko Valley, SW Poland. In 1992 twenty seven points of local geodynamical network were founded for determination the Śnieżnik Massif crust activity. Points of this network were located in Czech and Polish sides of the Massif. Researches were provided by repeated periodic satellite GPS measurements, total station, gravimetric, clinometric and crack gauges observations and precise levelling technique. Śnieżnik Massif is crossed by the section of tectonic faults zone in direction NW-SE. Several transverse faults are located near the major tectonic zone. Long term research material (data) allows to interpretation and evaluation of the object surface deformation.

KEYWORDS: deformation analysis, geodynamics, GPS, gravimetry, Śnieżnik Massif

1. INTRODUCTION

Śnieżnik Kłodzki as a part of Eastern Sudety is a place of watershed the Baltic Sea, Black Sea and North Sea (Trójmorski Wierch Mt.). Most complicated tectonics and geological formations as well as tectonic movements and recent seismic events were a background of founding Śnieżnik Kłodzki network. This project started in 1992. The research of crust activity is continuation the Bear's Cave in Kletno rock massif stability monitoring, which has been leading since 1984. Network was established in the Polish (16 points) and Czech (11 points) sides of the Massif as a result of partnership collaborations of Department of Geodesy and Photogrammetry at the Agricultural University of Wrocław and Institute of Geodesy at Brno University of Technology. All observations were provided in epoch campaignes by 4-segment measurement and control system described by Cacoń and Kontny (1994). The system has allowed to integration of satellite GPS technique, precise gravimetric measurements as well as geodetic observations (total station and precise levelling) and relative observations (clinometer and crack gauges).

2. DESCRIPTION OF THE INVESTIGATIONS AREA

Deposits in the Polish Part of the Śnieżnik Kłodzki Massif are mostly associated with metamorphic rocks. This area is characterised by heterogeneous geological composition with predominance of elongated in the southern direction outcrops of Strońska series mica schists accompanied by Śnieżnik gneisses. The distinct boundary of these geological formations runs from the Kleśnica river valley through the Stroma Mt. and Śnieżnik Mt. towards the Morava Valley in the Czech Republic. Crystalline limestone pockets can be found in the schists. Formation of limestone in the Kłodzko Valley, is dated approx 570 millions years ago – turn of Wend and Cambrian (Don, Opletal, 1996; Ciężkowski, 2006). In those geological history most of the Central Europe areas was covered by sea. Sedimentation of the lime deposits might have been running 515 million years. It was interrupted by the old Caledonian folding. As a result the marbles were formed due to metamorphic processes (Don, Opletal, 1996). During the Caledonian orogenesis volcanic events appeared under water and plenty of granite magma intrusions penetrated the upper folded formations. It was recognized that karst voids at middle level of a Bear's Cave in Kletno (near Stronie Śląskie) originated at the beginning of Pliocene (5-4 million years ago). A dense network of varied age faults running both longitudinally and latitudinally divide the structures being discussed here into smaller blocks shifting in different directions and with various intensities. These geological and tectonically structures with a scheme of photolineaments were presented in Figure 1. Described area is a reserve of nature with interesting topography and intensive forestation.

The Śnieżnik Massif network is made up of 27 points arranged on an area of approx. 100 km sq. – on the Polish (16) and Czech (11) sides of the massif (Cacoń et al., 1996). The points have been fixed with reinforced concrete pillars fitted with mounts for forced centring of measurement instruments. The

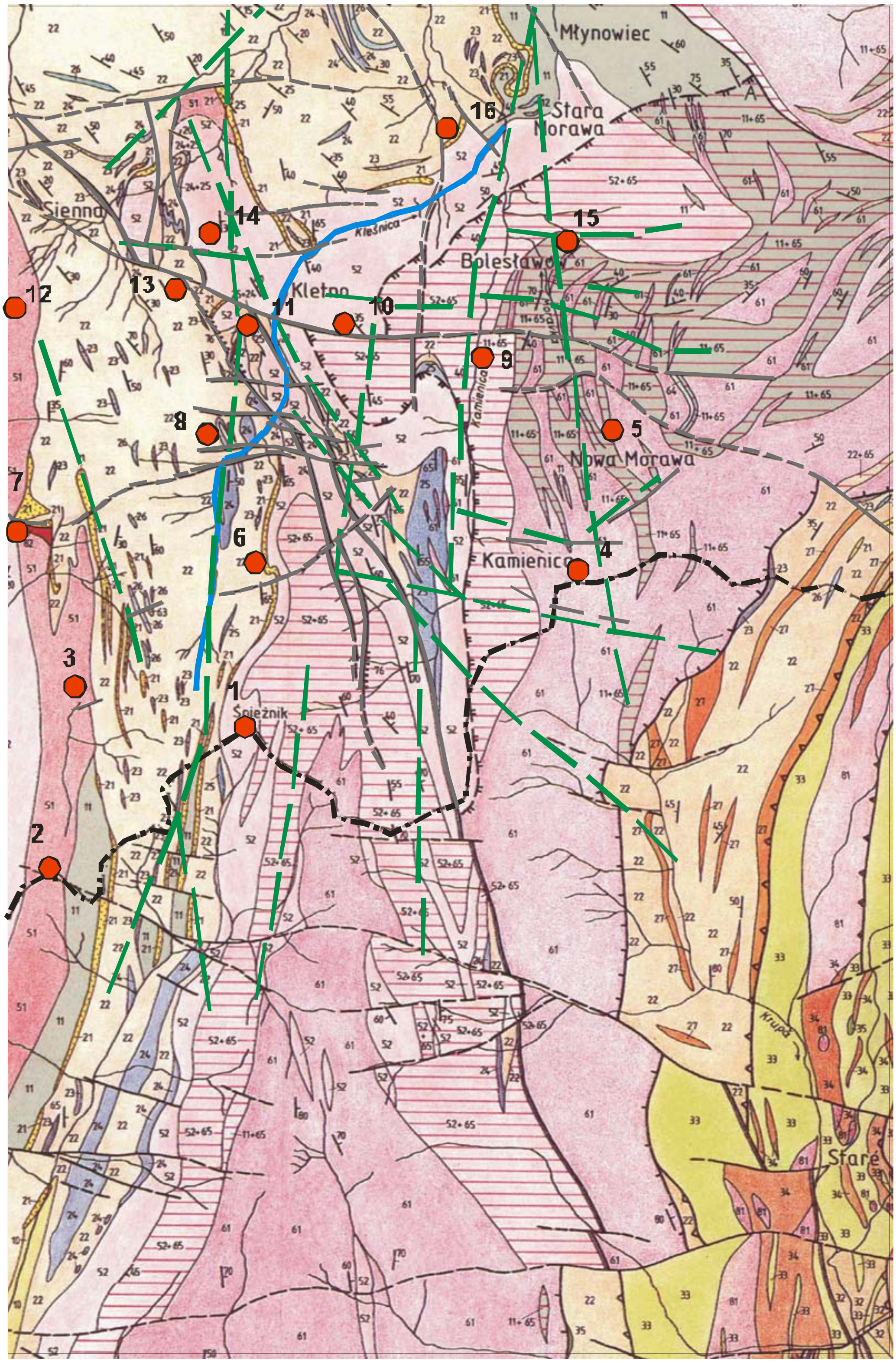

Fig. 1 Geological structures (according to Don and Opletal, 1996), photolineaments (by Graniczny, 1996) and points of the Śnieżnik Kłodzki Massif network - Polish part.

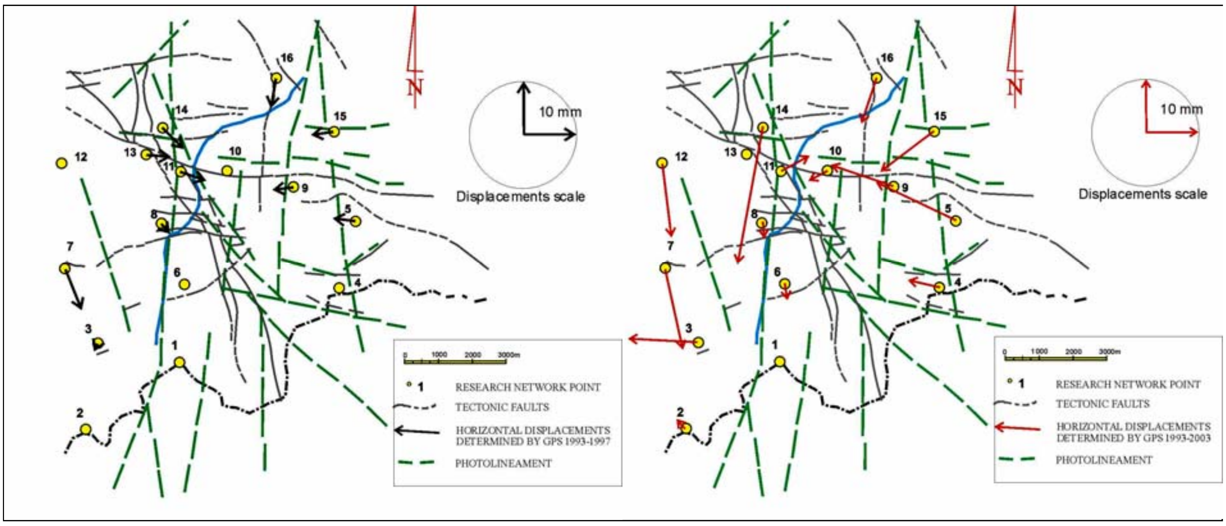

Fig. 2 Horizontal displacements determined by GPS in the Śnieżnik Kłodzki network in periods: 1993-1997 (left) and 1993-2003 (right).

location of measurement stations/pillars has been correlated with geological and tectonic composition, forestation, marble quarry exploitation as well as morphology of the massif (Fig. 1). The pillars have been set directly on crystalline rock outcrops and in cases when this was not possible on foundations placed below ground freezing level. Station Stroma (6), fixed on crystalline parent rock, and has been included in the regional, international, SUDETY geodynamic network (Schenk et al., 2002). Only results from measurements in Polish part of network are presented in the paper.

3. MEASUREMENTS

SATELLITE GPS MEASUREMENTS

The satellite GPS measurements of the Śnieżnik Massif network were performed in period from 1992 to 2004. In 1992 and 1993 the measurements were carried out with 5 Ashtech MD-XII receivers and ASH700228D antenna sets by static method in 1h sessions. Each point was measured at least in two sessions. In 1996 and 1997 the measurements were carried out with Ashtech MD-XII and Z-12 receivers (2 hours' sessions). In 2003 (Cacoń et al., 2004) and 2004 measurements were realized simultaneously on all of the points in two 10h sessions but with various measurement instruments from Ashtech Z-12 P3, UZ-12 with antennas ASH700718B, ASH701975.01Agp, ASH700936D_M, ASH701945B_M and Trimble 4700 with antennas TRM33429.00+GP.

Results of the periodic satellite GPS static measurements have been calculated using Ashtech Office Suite for Survey ver. 2.11. The network has been adjusted as quasi free, using antenna phase centre models from NGS. Point Stroma' coordinates were signed as fixed. It was taken from solution of the SUDETY network in the ETRF 2000 system (Schenk et al., 2002). Horizontal displacements of the points were determined by SNET software in a local topocentric coordinate system (Kontny, 1999). Results from this analysis were presented in Figure 2.

In 1993-1997 the compression movement of the geological and tectonical structures in direction of major tectonical faults zone was observed. This zone is crossing the area of investigation in NW-SE. The analysis leaded for the period of 1993-2003 point to change both linear value of the horizontal vectors points movements and change of azimuths of these vectors. These deformations have been observed since 1997. Stations 5 and 11 are located close to Kamienica and Kleśnica rivers. Changes on pillars No. 3, 12 and 14 can be of quite another nature. The kind of point's 12 movements can be disturbed by construction of the view tower, built directly next to the observation pillar.

GRAVIMETRIC MEASUREMENTS

Measurements of Earth' gravity differences in the Śnieżnik Massif were realized in connection to the reference points fixed in East Sudety Mts. and to the National Gravity Reference Frame (POGK'99). The observations were leaded by team from Institute of Geodesy and Geodetic Astronomy (Warsaw University of Technology). Gravimeter LaCoste & Romberg Model G No. 986 with metal measurements system and gravimeter Scintrex CG-3M Autograv No. 9303205, with automatic results registration equipped with quartz measurement system, were used to this investigations. Control calibration of the instruments on the traverse Ząbkowice Śląskie – Kłodzko belonged to the National Gravity Reference Frame, was done before starting the measurements. In

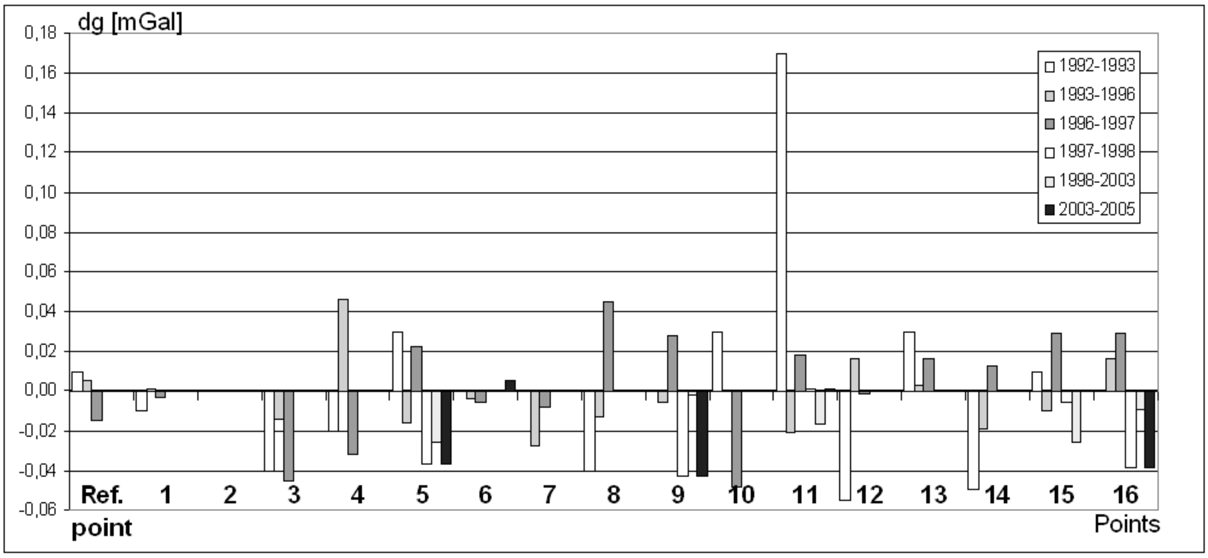

Fig. 3 Gravity variations in the Śnieżnik Kłodzki network determined by LaCoste & Romberg G 986 Scintrex CG3M 205 instruments (on the base of Barlik measurements, 2005).

the calculations of gravity differences the corrections were included due to the height of the instrument over the measurement point as well as tidal corrections pointed to gravity influence of Luna and Solar on the gravimeter indications. It is needed to mark that in 2003 and 2005 were realized the project on connection of the Sudetic geodynamics network with POGK'99. This guaranteed homogeneous and precise reference level for the geodynamical researches in the Sudety Mts. and uniform base for the determination of gravimeters' scale using the POGK'99. It has been also added the quantity of reference points in the gravimetric investigations in the Sudety area by including some POGK'99 points to the local and regional reference network points. Local reference Śnieżnik Massif network (Ząbkowice Śląskie, Kłodzko and Bolesławów) was connected to the network POGK'99, keeping all the criteria required in the primary gravity networks. Since 2005 there has been reached a homogeneous for the whole polygon level of the national network. Observations from the previous periods, realized on the base of a local reference network were recalculated. Gravimetric measurements on the points in the Śnieżnik Massif area were performed using the profile method connecting to the Bolesławów point. Scheme of the observation was A, B, C.....A, thanks to that the influence of instrument drift on the measurement results was eliminated (Barlik, 2005). Gravimetric changes in the Śnieżnik Massif network are presented in Figure 3.

Fluctuation of gravity observed in the beginning of the researches was probably caused by consolidation of the marks with the massif. A huge change of gravitation was also observed in 1997. This can be connected with a significant humidity of the ground due to the disaster water flood in July 1997. Nowadays it has been observed tendency to the decrease of gravitation for most of the measurement pillars. In previous periods this tendency showed the opposite direction. Probably these changes are connected with gradual oscillate uplifting of eastern and northern parts of the polygon. In the western part this phenomena appears to be of the opposite nature.

CLINOMETRIC OBSERVATIONS

Measurements of the observation pillars inclination were carried out using analogue clinometer (Cacoń, Ćmielewski, 1992). The investigations helped to evaluate the pillars stability. Instrument placed in the centring bush of the pillar's head enabled determination of the current movement of the centre mark in the local horizontal coordinates system N, E or directly deflection of the vertical. The principles of determining the centre marks components are presented in the paper by Jamroz (2000). Results of the clinometric observations in chosen periods are presented in Figure 4.

It is worth to note that changes of the pillars inclination are similar in two described periods.
Small differences in azimuth and local centre mark displacement value were found on the 7, 11 and 14 stations. This confirms the stability of the concrete pillars. Recently the stations number 13 and 16 are damaged.

4. CONCLUSIONS

Analysis of the results from repeated GPS satellite measurements, gravimetric and clinometric, pointed that changes of the western part of the Śnieżnik Massif major tectonic fault zone are probably the nature of displacement in direction S-SE.

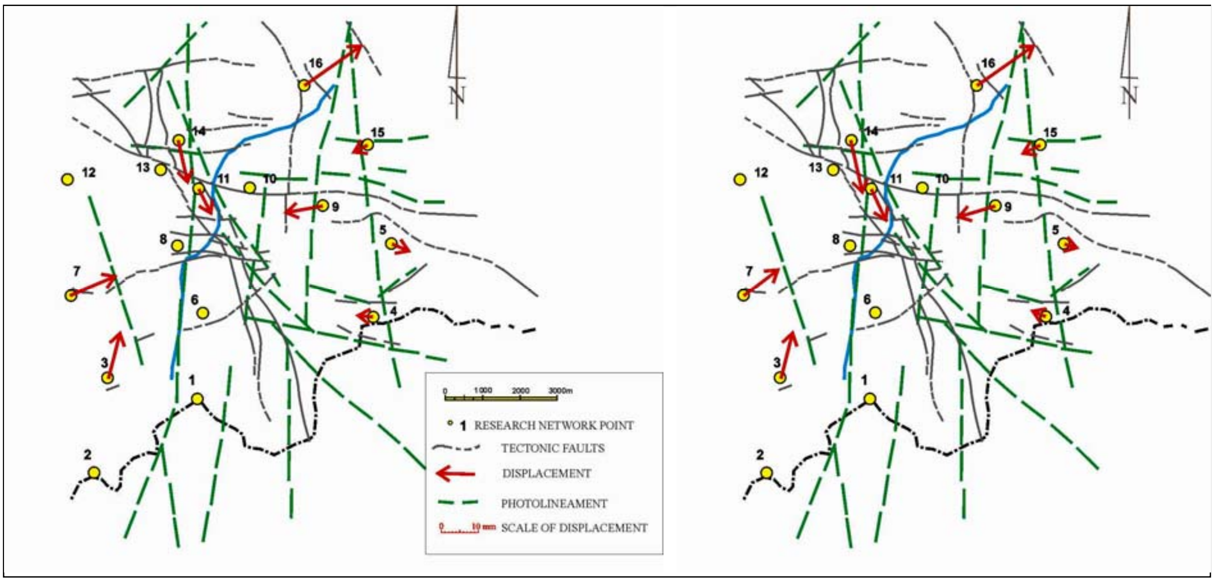

Fig. 4 Changes of inclination in the Śnieżnik Kłodzki network determined by clinometer in periods: 1993-1997 (left) and 1997-2003 (right).

On the eastern side of the zone the compression character of the movement is still observed. After 1997 these movements probably were more intensive or this variation was incidental. At the same time Kontny et al. (2005) pointed that variations observed using crack gauges TM-71 in Bear's Cave interior (Kleśnica fault crossed in SW-NE major tectonic faults zone in the Massif) have a compression character in NW-SE, parallel to the mention zone. Strike-slip movements detected by crack gauges in the Cave not corresponded with GPS measurements results.

Variations in the tectonic fault zone in the Śnieżnik Massif (parallel to the Sudetic Marginal Fault-SMF) are different from the movements characterized by Kontny (2003) in the SMF zone on the base of satellite observations in the Sudetic geodynamical polygon GEOSUD (Fig. 5). Deformations observed in the Śnieżnik Massif are probably local. Additionally these movements could be disturbed by the flood in 1997 and intensive marble quarry exploitation. It was connected with removing from the neighbourhood point No. 8 about 3.75 millions tons of the rock material. Kletno II quarry was exploited in the years of 1966-1969 and the output was about 182000 tons of limestone. The quarry Kletno I was exploited longer in the years of 1964 -1993 (1995) and the output was 3462000 tons of the rock material. Variations caused by removing the rock material could affect results of the measurements in the beginning part of investigations. On the other hand explosive character of the exploitation could also transform tensions distribution in the massif and induce part of the movements. The rest 106000 tons was the waste pile located between points 8 and 11. These heaps were eliminated till the end of 90-ties of XXth century. Massif deformation monitoring will be continued.

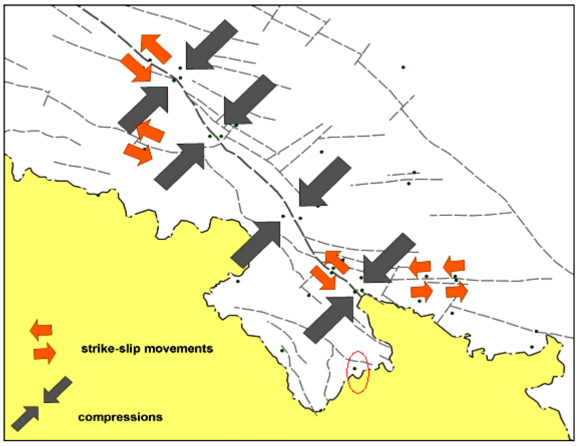

Fig. 5 Śnieżnik Kłodzki area (red ellipse) on the background of interpretation of GPS measurements results from GEOSUD network in term 1996-2002 (by Kontny, 2003).

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