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LOCAL GEODYNAMIC NETWORK KARKONOSZE – THE RESULTS OF THREE YEARS OF MEASUREMENTS AND FIRST INTERPRETATIONS

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ABSTRACT

The KARKONOSZE geodynamic network has been established in the Western Sudetes in year 2000. The GPS network consists of 19 points located on the area of the Karkonosze Mts. and its foreland. The KARKONOSZE network is connected with and also composes western parts of the GEOSUD and SUDETES geodynamic networks. Three measurement campaigns of the local geodynamic network KARKONOSZE were realized (2001-2003). The data from GPS observations was processed using BERNESE v.4.2 software, in the ITRF reference frame with connection to the "Wrocław" GPS permanent station. In the paper the comparison of preliminary results from data processing of the three GPS KARKONOSZE 2001-2003 campaigns are presented. The horizontal velocity vectors of the stations and geometrical changes of vectors for pairs on *network points were calculated to assess changes taking place in the investigated area.*

KEYWORDS: GPS, geodynamic researches, Karkonosze Mts.

1. INTRODUCTION

The process of the Earth's crust development is a continuous one with periods of intensified activity separated by times of relative stagnation. There are no grounds, observing this process, to accept the view that present-day movements, in each past and future epoch, should follow diametrically different principles. Consequently through investigations of the processes occurring on and in the Earth's crust we contribute to the knowledge of their past.

The Sudety Mts. and Fore-Sudetic Block area is considered to be a mosaic of tectonic blocks undergoing movements, different in direction and magnitude *(Walczak, 1972, Dyjor, 1975, 1993; Guterch et al., 1975; Sokołowski, 1975; Jahn, 1980; Migoń, 1996)*. The region constitutes a border zone between the Bohemian Massif and the Eastern-European Platform. Different blocks (terranes) are characterised by homogenous geological composition, distinct from that of neighbouring terranes and are separated by tectonic zones and deep splits having generally lateral shift character (*Mizerski, 2000*). The Karkonosze Mts. with the adjacent Valley of Jelenia Góra, part of the Izerskie Mts. and the Kaczawskie Mts. are ranked as the Western Sudety Mts. The Karkonosze rock massif had originated as a result of a magma intrusion consisting of several invasions and had started approx. 330 Ma and lasted for about 45 Ma *(Mierzejewski, 1985; Pin et al. 1988)*. The area covered by the research is one of the most active in Poland as a result of varied geology and occurrence of proved and probable faults. This activity is manifested by numerous records of recent and sometimes present-day local geodynamic movements (*among others*: *Dowgiałło et al, 1989; Dyjor, 1975, 1993; Oberc, 1975, 1985; Mierzejewski 1985, 1997, 2003; Sroka, 1991; Aleksandrowski, 2003).* The lack of gravimetric stability in the area is one of the causes for these movements. The fact that the research area belongs to seismically active regions, particularly to the Intra-Sudetic fault zone (*Schenk et. al., 1997*), is also significant. The need to carry out research arises from location of large hydro-engineering structures: Sosnówka and Plichowice dams, as well as engineering objects e.g. tunnel in Trzcinsko, in the area. All of them are situated in known dislocation zones.

2. DESCRIPTION OF THE RESEARCH AREA AND REALIZED SATELLITE GPS MEASUREMENTS

The Karkonosze research network, an enlargement and augmentation of the SUDETY network (Kontny, 2003), shown in Fig. 1, consists of 19 points stabilized on particular blocks (terranes) in the investigated area. The location of points has been correlated with geological and tectonic composition of the Karkonosze massif and adjacent areas. The final decision on particular locations of points was

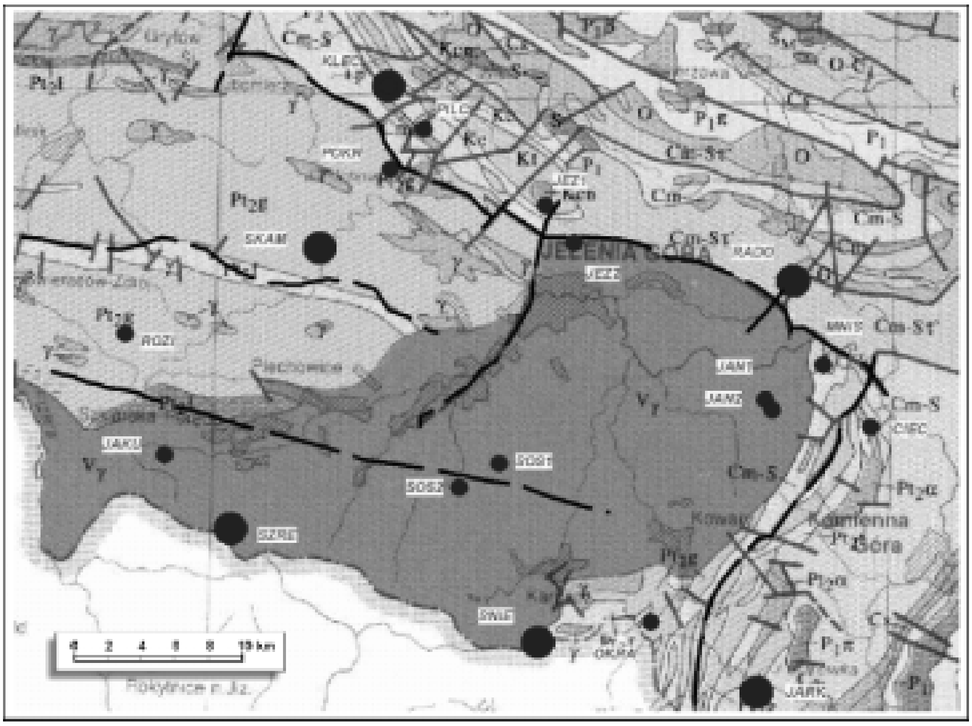

Fig. 1 Scheme of the Karkonosze research network arrangement

preceded by a series of field surveys. The description of principles behind the points' arrangement was given in papers: (Kontny et al., 2002; Mąkolski & Bosy, 2003).

The research network points have been stabilised with reinforced concrete blocks. All of the points have been set up on crystalline rock outcrops, some directly on rocks, others in the ground. The blocks have been fitted with mounts for precise, forced setting up of measurement instruments.

The measurements of present-day geodynamic movements realized with satellite GPS method were started in 2001. Three measurement campaigns were accomplished to this date in 2001, 2002 and 2003. Annual satellite observations have been carried out during 4 measurement days, each time at the end of August/beginning of September period. The measurements have been performed with dual frequency Ashtech receivers. The observations in respective measurement days have been realized with 12 sets of surveying instruments. The final scheme of measurements, modified after the experiences gained from the first campaign in 2001 and described in articles (Kontny et al., 2002; Mąkolski & Bosy 2003; Mąkolski et al., 2003), has been realised uniformly during the other two campaigns in 2002 and 2003. As a general rule, the observations in the network have been realized hierarchically. Representative points (SNIE, SZRE, SKAM, KLEC, RADO) have been selected for particular blocks, separated by dislocations, and measured in four 24h sessions.

3. PROCESSING OF MEASUREMENT RESULTS IN THE RESEARCH NETWORK

The processing of satellite GPS observations in the KARKONOSZE network for 2001, 2002 and 2003 measurement campaigns was preformed, as mentioned in the introduction, with Bernese GPS Software v. 4.2. *(Hugentobler et al., 2001)*. In the data processing the strategy of local network solution presented in papers *(Bosy & Kontny, 1998; Bosy et al., 2003)* was used. On the grounds of above-mentioned work a ***BPE*** module has been developed allowing automation of the calculation process. The foundations for realisation of the calculation process adopted for the Karkonosze network in the following stages of the calculation process was presented in articles: *(Kontny et al., 2002; Mąkolski & Bosy, 2003; Makolski et al., 2003)*.

First stage of the processing consisted of quality and quantity check of the observations, performed with ***teqc*** software developed by UNAVCO Inc. *(http://www.unavco.ucar.edu/software/teqc/teqc.html)*, according to the principles described in the paper: *(Bosy & Figurski, 2003)*.

Next step of the processing with Bernese software includes definition of a system of independent baselines. In the case of networks such as the Karkonosze one, where the observation material is qualitatively (various receivers and antennas) and quantitatively (different observation times) heterogeneous, use of the SHORTEST method *(Mervart, 1995)*, which is the best for local networks,

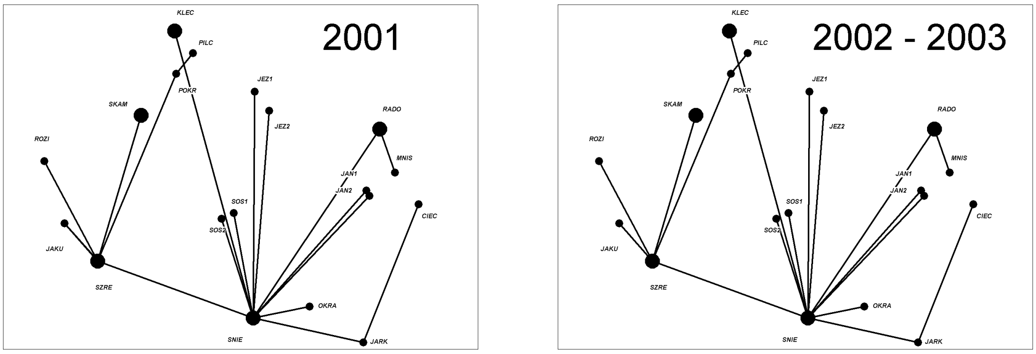

Fig. 2 The final arrangement of independent baselines for the 2001, as well as 2002 and 2003 campaigns.

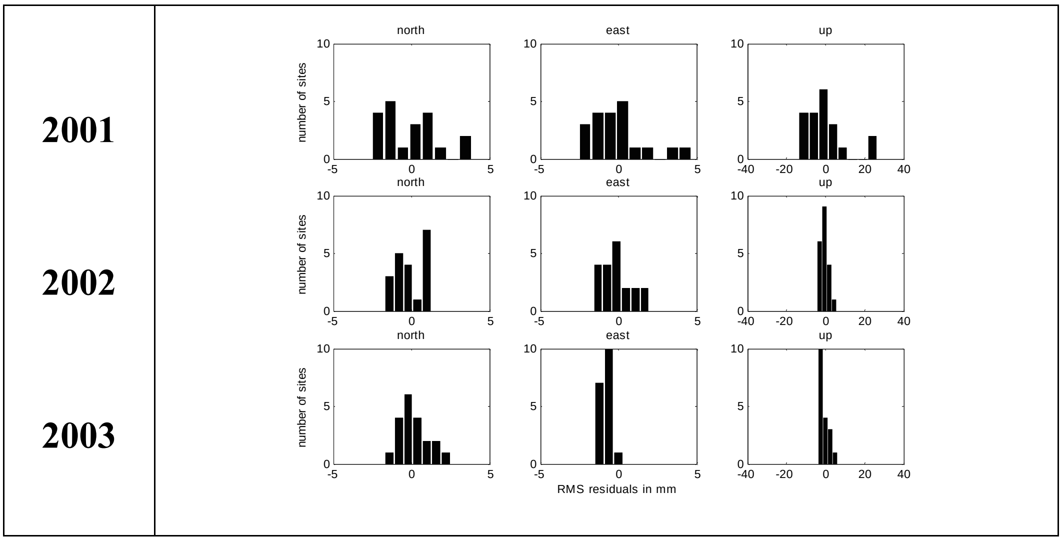

Fig. 3 The distribution histogram of unweighted RMS mean errors of coordinate residuals for 2001, 2002 and 2003 campaigns

is not an optimum solution. Therefore, in this case, a method for selection of independent vectors based on the SHORTEST method but which included the maximum conformity for choosing vectors measured with the same antennas in the 2001 campaign and the 2002 and 2003 ones, has been used *(Bosy & Figurski, 2003)*. Ultimately, for the processing of all three campaigns, a homogenous vector arrangement, presented in Fig. 2, was introduced.

Antenna phase characteristics for particular sets of instruments were adopted basing on the data from National Geodetic Survey (NGS) in the USA.

It was decided to use two-stage procedure of ambiguity resolution, as the observational material originated from various receiver types *(Bosy et al., 2003)*. In the first step, ambiguity solution was obtained for a linear wide-lane L_5 combination with CODE ionosphere model set a priori *(Schaer, 1999)* and determined (on the centimetre level) station coordinates from solution of the L_3 ionosphere-free linear combination. In the second run ambiguity solution was obtained from L_3 combination with introduced fixed ambiguities from wide-lane method and narrow-lane ambiguity resolution.

The GPS observation processing in networks used for geodynamic investigations requires the reference system to be defined. Solution in the ITRF2000 system was chosen for the KARKONOSZE network. Individual observation sessions within the frames of each campaign have been processed with connection to the „Wrocław" GPS/GLONASS permanent station, which had coordinates, determined for each day of observations based on the known ITRF2000 velocities.

The quality of solutions obtained for particular measurement campaigns is presented in Fig. 3.

The above-mentioned results of epoch solutions for particular campaigns have shown greater accuracy in case of the 2002 measurements in relation to the year 2001. The output of observation processing from the 2003 campaign has shown similar levels of accuracy as in the case of 2002 campaign.

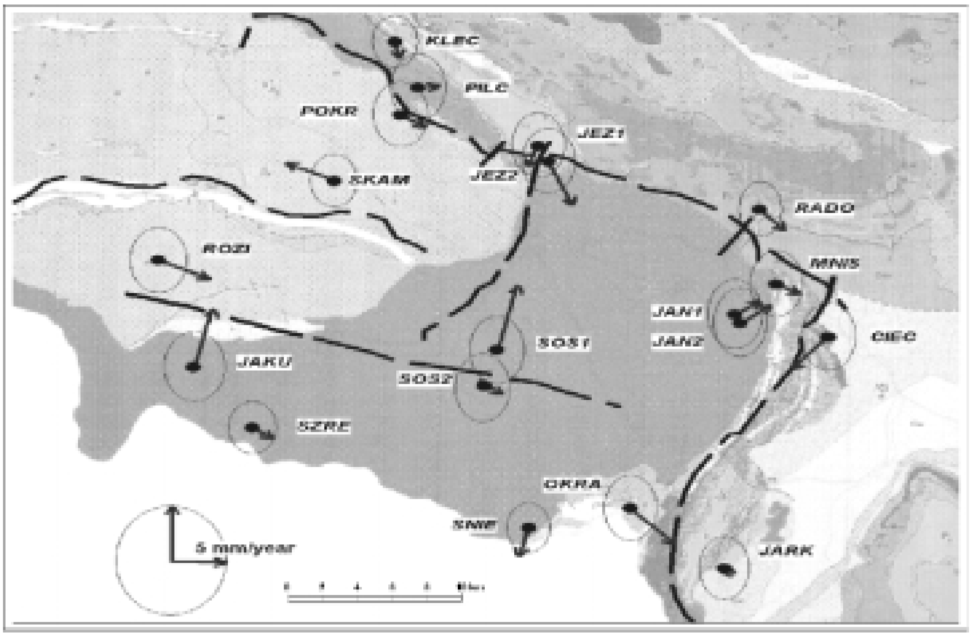

Fig. 4 The horizontal velocity vectors representing movement of the KARKONOSZE network points and confidence ellipsoids (95%)

4. ANALYSIS OF THE MEASUREMENT RESULTS IN RESEARCH NETWORK

The ADDNEQ module *(Brockmann, 1996)* of Bernese GPS software has been used to calculate kinematics parameters of the research points basing on satellite GPS measurements *(Hugentobler et al., 2001)*. The module allows combination of solutions for separate measurement sessions in order to calculate coordinates in a reference epoch (ITRF2000 system, 1997.0 epoch), as well as linear velocities of points. Velocity estimation is performed in three stages according to the procedure proposed by Braun *(2002)*:

1. computation and recording of relative weighting coefficients (variation components) for particular sets of NEQ equations;
2. computation of the point coordinates and velocities with introduction of previously determined weighting coefficients;
3. determination of the correct scaling coefficient for accuracy parameters (scaling of single difference observation mean error values– SIGMA – through calculation of the coordinates' group mean error to unit weight mean error ratio).

At the current stage of the research determination of the point height change velocities (vertical components of the velocity vector) has been left out due to a very short measurement period and significantly greater errors, in GPS technique, of vertical component estimation in relation to horizontal ones.

Horizontal components of the velocities for KARKONOSZE network points have been calculated in ITRF2000 global system; components of local velocities ("intraplate") have been also calculated. The local velocities have been obtained through subtraction of the continental plate movement velocities determined from the APKIM2000 kinematic model (*Drewes & Angermann, 2001*) from the ITRF2000 velocities. The graphical representation of the calculated horizontal velocity vectors against the area's geology and tectonics is shown in Fig. 4.

In general, points located on the northern side of the Intra-Sudetic Fault (KLEC, PILC, JEZ1, RADO, MNIS) and points located in the eastern part of the research area (JAN1, JAN2, JARK) are characterised by low movement velocities, in general within the limits of determination accuracy. High and significant (exceeding double mean error of estimation) velocity vectors have been calculated for points situated in the western and central parts of the area (SKAM, ROZI, JAKU, SOS1, JEZ2), as well as for the OKRA and CIEC points in the eastern part. The directions and values of the point velocities do not show clear correlation with their location in relation to major tectonic structures of the area. This may be caused by local movement character of some points or influence of, yet unknown, disturbing factors. It is difficult to determine, on the grounds of three observation epochs, if the lack of distinctive linear trends in position changes of certain points results from non-linear character of their movement or the effect of observation gross errors. The influence of disagreeing observations may be reduced through the use of resistant estimation methods, however these are effective for minimum of four measurement epochs *(Kontny, 2003)*. An example of distribution of

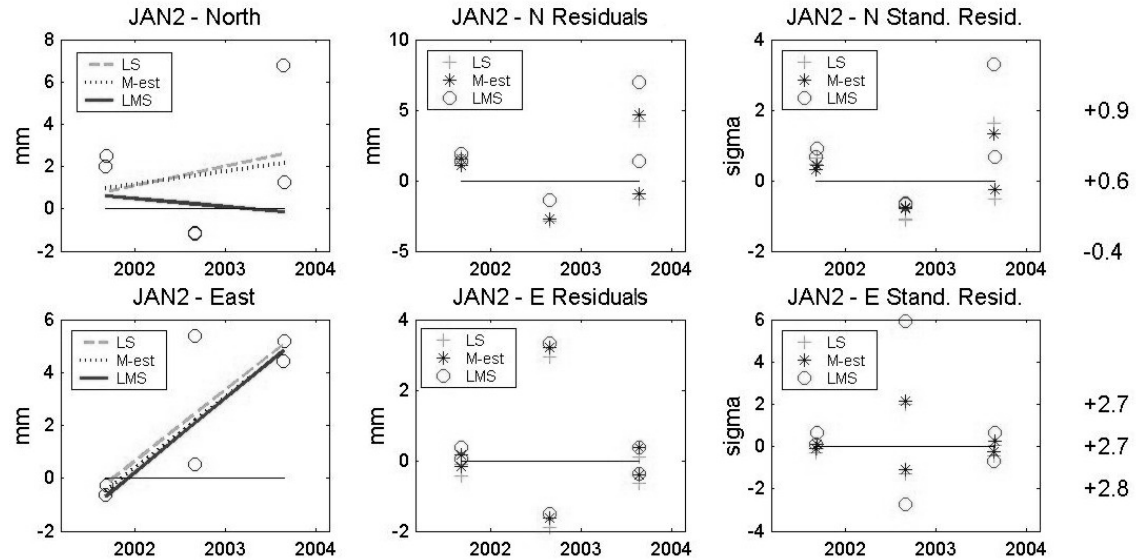

Fig. 5 The graph showing distribution of estimation residuals of horizontal velocity components for point JAN2 with three methods

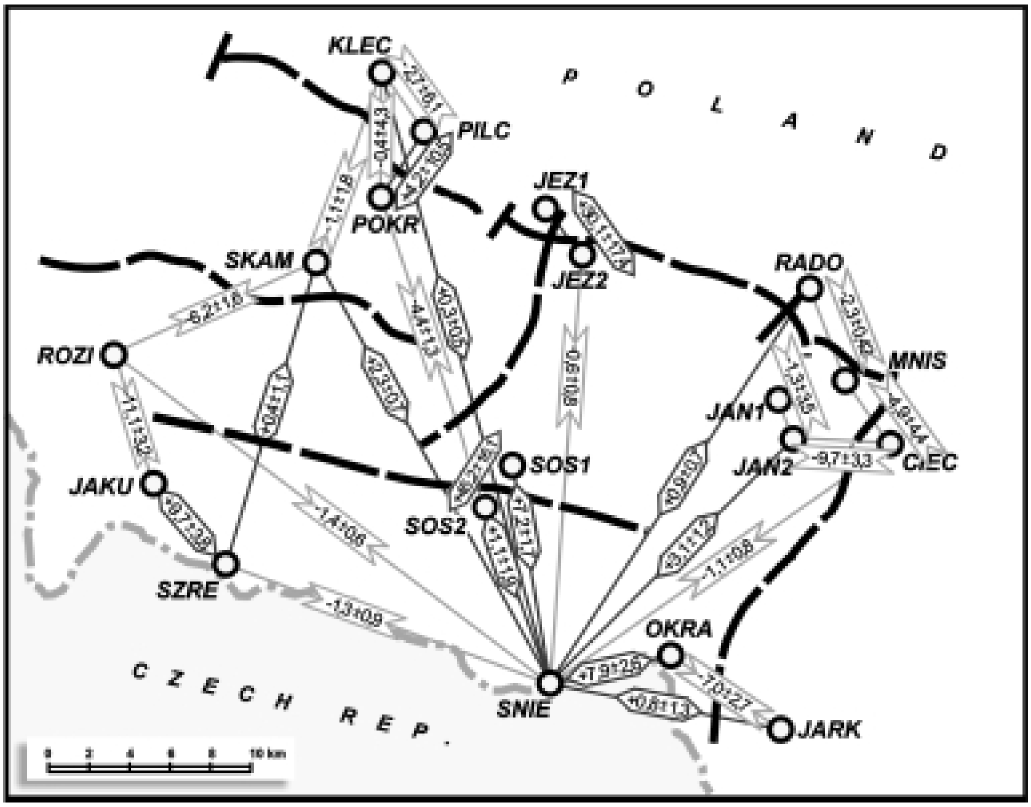

Fig. 6 The velocities of relative length change for selected KARKONOSZE network vectors

residuals in estimation of horizontal velocities for JAN2 point performed with the least squares (LS), M-estimation (M-est) and least-squares median (LMS) methods is shown in Fig. 5.

Present-day tectonic activity of the investigated faults can be assessed through analysis of base line geometrical changes (vectors) determined from pairs of points situated on both sides of the faults. In the KARKONOSZE network research velocities of relative length and rotation changes for selected vectors have been calculated according to the principles presented in the work *(Kontny, 2003)*. The values of these parameters are shown schematically in Fig. 6.

For all of the vectors perpendicular to the Intra-Sudetic Fault the geometrical change parameters are within the estimation error limits, therefore there are no grounds to assume that this structure is presently active. The reduction of vector lengths occurs in the Niedamirow-Przybkowice thrust zone – vectors: (OKRA-JARK, JAN2-CIEC, MNIS-CIEC). In case of the first two vectors the value of length reduction is significant. Different directions of vector rotation may be the result of mining exploitation, near the Mecinka village located between Janowice Wielkie and Marciszow (Ciechanowice), which has in fact ended. Substantial changes of vector lengths have been registered near Sosnowka water reservoir. These may be caused by activation of the Karkonosze fault as a result of filling up the reservoir between the first and second measurement cycle and a very low water level during the third one. Changes of vector lengths have also occurred in the Izerskie Mts. region. These may be attributed to changes happening on the Izerski graben faults (*Oberc, 1975*) and strengthened by mining activity in the uppermost parts of the Wysoki Grzbiet.

5. CONCLUSIONS

The realisation of measurements in the Karkonosze network, located in difficult, partly mountainous terrain have allowed further enhancement of result processing methodology for satellite observations in precise local networks. The results obtained have cognitive and practical value. Nonetheless it should be noted that comparatively short, two-year period of observations can not be the base to draw conclusions with regard to the geodynamics of the Karkonosze Mts. and adjacent areas. It may however present certain trends of change for particular points of the network with relation to the general geological composition of the region. If a situation arises, when the changes indicated in this paper are confirmed, a decision to inform the appropriate services responsible for the safety of people and engineering structures should be made. The information on possible changes should also be passed on to services engaged in designing new constructions with the intention to alter the planned locations or adjust the selected design parameters to withstand the possible ground changes.

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