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TEN YEARS OF GRAVIMETRIC MONITORING ON THE POINTS OF GEODYNAMIC NETWORKS IN THE SUDETY MTS

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ABSTRACT

In the paper ten years of gravimetric monitoring on the points of a geodynamic networks in the Sudety is reported. This material allows for an attempt to be made to discover tendencies in gravity changes. The first measurement cycle took a place in 1992 and was related to the region of the Śnieznik Massif and the Paczków Graben (Barlik et al., 1999). Over the ten years the network became larger involving, by 2003, 78 points which were observed on a yearly basis (Barlik et al., 2001). In this article the observations of ten years are analysed in investigations of characteristic points or structures relating to groups of points, where the behaviour of gravity indicates a clear trend. It was recognised the tendency of arising the gravity in upper parts of Szczeliniec network. In opposite, the decreasing of gravity was pointed out in Kłodzki Śnieżnik massif. Karkonosze Mts. has very complicated, divided into subparts in gravity changes trends. Situation touching the gravity field in Paczków Graben is clear. The eastern part is characterised by moderately paced increase of gravity.

KEYWORDS: gravimetry, geodynamics, time variations of gravity

INTRODUCTION

Determination of changes in gravity plays a large role in contemporary geodynamics. Permanent gravity measuring stations, which also exist in Poland, are used to construct perfect tide models. It is, therefore, possible to outline the role of observation of the gravity undertaken on a regular basis over time on selected points of objects of geodynamic investigations. Changes in gravity cannot be interpreted in one dimension (Birò, 1983). Such a narrowing of the direction of interpretation, e.g. only in the effect of changes in height is not acceptable with regard to the sensitivity of the relative gravimetric method. Gravimetry should be viewed as the **n**-th dimension, used to indicate and to confirm tendencies already recorded by other technologies. Movement of a point manifesting itself in height changes or in the horizontal co-ordinates may, through the use of gravimetry, be confirmed or additional information may be found allowing for a more complete interpretation.

For this reason, this paper covering ten years of measurement in geodynamic networks in The Eastern Sudety is focused on the indication of interesting tendencies and places which characterise a clear trend recorded over a time period of ten years.

OBSERVATIONS AND SCALE OF THE GRAVIMETRIC NETWORK

Since 1992 ten measurement cycles have taken place on the area of the Sudety polygon. The scope of the work increased gradually. In 1992 measurement covered the Śnieznik Massif network, the Paczkow Graben and the Szczeliniec network. Since 1997 our monitoring covered points of the GEOSUD II network, located along the Sudetic Marginal Fault from the environs of Paczków to Zlotoryja. Since 2001 the observation network has increased to include the points of a geodynamic polygon in the Karkonosze (Mąkolski et al., 2003).

Since 1992 all measurements have been carried out using astatic gravimeters: the LaCoste & Romberg, model G and the Scintrex Autograv CG-3M. Determination of the gravity values was carried out using the profile method. In order to take readings of the LC&R gravimeter the interpolation method developed in the Institute of Geodesy and Geodetic Astronomy was applied, which guaranteed reading precision at a level of 1 μGal (Pachuta, 1998). The shape of gravimetric traverses was worked out by assuming the linear drift coefficient. As a reference value (level) the value for Earth's gravity at a point in the Agricultural University (AU) building in Wrocław was established in 1992. This value, which was achieved by connection with the absolute measurements station in the Astro-geodetic Observatory in Jozefoslaw, near Warsaw. Connected to the establishing of a reference point in 1992, a calibration baseline was also created in order to ensure the uniformity of the scale in the later measurement cycles. That base was established between the observed stations in Wrocław, Braszowice, Paczków, Bolesławów and Karłów. This base represented a reference to the "Wrocław AU" level. Since 1997, as a result of a extending the network to the west in the Dobromierz region, the Zlotoryja and Jawor areas, the points of the Polish National Gravity Network (PNGN) situated in Kamienna Góra, Szklarska Poręba and Bolków are used as a reference level for the western part of the GEOSUD network. These points define the "Karkonosze" reference level. In 2003 a connection was made between the points on the Wrocław – Karłów calibration base and the PNGN points. This allowed the unification in the reference level in the western and eastern parts of the polygon. Both gravity levels were replaced with the national level defined by points of the national network. This manner of investigation is more favourable for a number of reasons: - the layout of the points in the national network allows for a shortening of the span; - it ensures the correctness of the gravity values measured in relation to 17 absolute gravity points over the area of Poland, which means these values can be used to define the system of levelling corrections; - in cases where a new object is added to the test network it ensures a quick transformation to the uniform reference level; - it ensures the capacity to maintain a uniform scale in relation to the national calibration base.

Fig. 1 presents the test networks and the PNGN points in the Sudety region.

PRESENTATION OF RESULTS

In Fig. 1 a schematic representation of the areas successively connected to the investigated network. The description of and the commentary on the results is based on this representation.

THE BYSTRZYCKIE MOUNTAINS

In the Bystrzyckie Mountains unit in the eastern part of the GEOSUD network there are two observed points: Spalona and Boboszów. Noteworthy "behaveiour" is characterised by gravity at the Spalona point.

Fig. 1 Schematic representation of the PNGN points and points of the local reference network set up in 1992 against the background of the studied areas

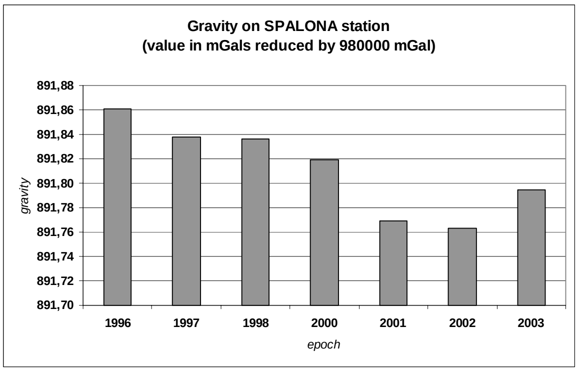

Fig. 2 Variations in gravity at the Spalona point

From the start of observations in 1996, a clear tendency of falling gravity values can be seen. Over a period of 6 years this fall reached a level of almost 0.1 mGal = 1μm·s^{-2}. In 2003 this tendency was probably reversed, but this will have to be confirmed in future by next gravimetric measurements in order to be able to speak of any oscillation in the character of changes of gravity at this station.

THE SUDETIC MARGINAL FAULT IN THE DZIERŻONIÓW AREA

Three points near Dzierżoniów created a profile situated crosswise in relation to the edge of the main Sudety Fault. These are part of the widened GEOSUD II network. The first observation campaign took place in 2000. Notwithstanding the short period of measurement, interesting gravity behaviour can be seen at a number of points. Fig. 3 presents a graph of changes in gravity at the Kamionka point. It is characterised by clear trend of rising in gravity. Another point in this group – Bielawa – shows clear stability.

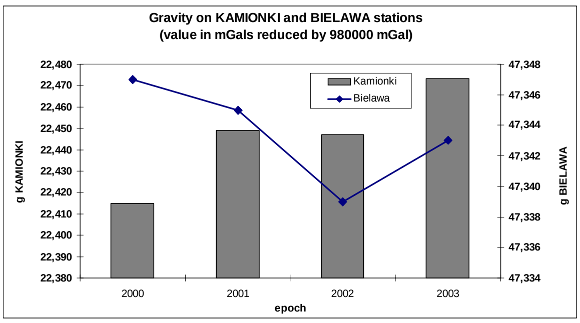

Fig. 3 Changes in gravity at the Kamionki and Bielawa points

THE SUDETIC MARGINAL FAULT IN THE ZLOTORYJA AND STRZEGOM AREAS

The profile is similar to that of Dzierżoniów running crosswise to the fault edge in the Zlotoryja and Strzegom areas. At the – Strzegom, Bronowek and Szymanow stations– a remarkable stability in gravity can be noted. At the point in Strzegom the amplitude of changes in the value **g** are only 2μGal. At the western situated profile in the Zlotoryja area there is a clear trend in decreasing of gravity. At the Kozów station a particularly high intensity can be seen. Diminishing in gravity recorded over three measurement cycles are equal to almost 0.1 mGal. For the remaining points this fall is less high in value, but it is equally unambiguous.

THREE DIMENSIONAL TEST NETWORKS SZCZELINIEC WIELKI AND POLICE – OSTAŠ (IN THE STOŁOWE MTS.)

In the three-dimensional test network in the Stołowe Mountains in the Karłów area, gravimetric observations were also carried out at the foothill of the Szczeliniec mountain, in the lower part of the mountains and also on Szczeliniec Wielki. The mean square error (r.m.s.) for gravity between the reference points in Karłów and stations in the upper parts of Szczeliniec (points No. 110, 112 ad 113) has been established as 6.9 μGal (Fig. 4). Taking this in mind a slow but meaningful increase in gravity was found at points in the upper part of the three-dimensional network. This reached about 60 μGal over the last seven years.

Analysis of the results obtained in the Czech part of the investigated field, Police – Ostaš leads to the conclusion that at a uniform rate there is a rise in gravity at the points Bezdekov and Chlum of about 20 μGal in the years 1996 – 2002, while the trend is a fall at the Pod Klučkem station. Changes at the other points of this polygon are somewhat ambiguous.

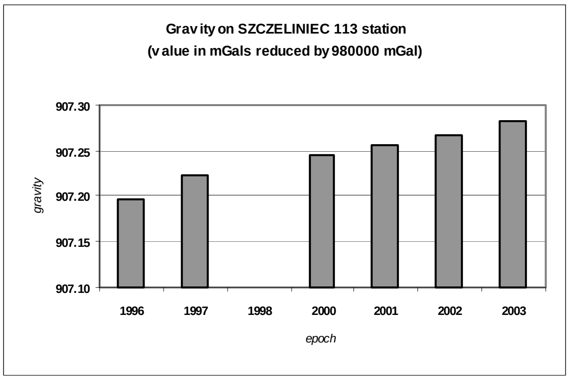

Fig. 4 Changes in gravity at the Szczeliniec point No. 113

THE ŚNIEŻNIK KŁODZKI MASSIF

The reference base for gravimetric measurements in the Śnieżnik Kłodzki Massif was the station in Bolesławów, installed in 1992 and directly connected to the points in Wrocław and Józefosław. In high mountain areas observations were carried out using a Scintrex CG-3M gravimeter with a seismic filter switched on. The most stable stations were the points at the Stroma, Sremkowiec and Młynsko peaks.

Generally, in the high mountain areas a slow decrease in gravity was noted of about 30 to 60 μGal. The reason of such phenomenon may be noted in a dehumidification of ground and cut-out the forests. In the lower part of this investigated massif the fall of gravity of about 50 μGal was noted at Nowa Morawa station. That may an effect of a flood in 1997 and then a dehumidification in the vicinity of the station. On the remaining stations registered gravity variations in a noise of observation errors have been cointained.

PACZKÓW GRABEN

Gravity changes in this region we divide into two sections – for western and eastern parts of the graben.

In the western part of the investigated field, the most stable point Byczeń has been pointed out. The monotonic gravity arise at Złoty Stok point appeared, and the decrease on Kłodzko station. These variations during the period 1997 – 2003 came up to 50 μGal. The r.m.s. of gravity differences was estimated ±4.7 μGal.

In the eastern part of the Paczków Graben observations were characterised by a mean error of Δg of about 6.5 μGal. A general trend of moderately paced increase of gravity in this part of the polygon was noted, although there are also oscillating changes visible which are clearly linked to meteorological conditions. The most stable stations for gravity in the period from 1997 to 2003 were those in Lubrza, Radzikowice and Trzebina.

THE "DOBROMIERZ" MICRO-NETWORK

The Dobromierz net consists of five points located directly in the vicinity of the water reservoir in Dobromierz (Fig. 5). This object was included in the test network in 2001. Three observation cycles have taken place there up to now. Analysis of the results shows a fall in gravity at those points in the southern part of the network. At the points to the north of the reservoir a rise in the value for gravity has been noted. Annual changes in gravity can be given as a few μGal. These changes fit within the value of a mean error in gravimetric determinations.

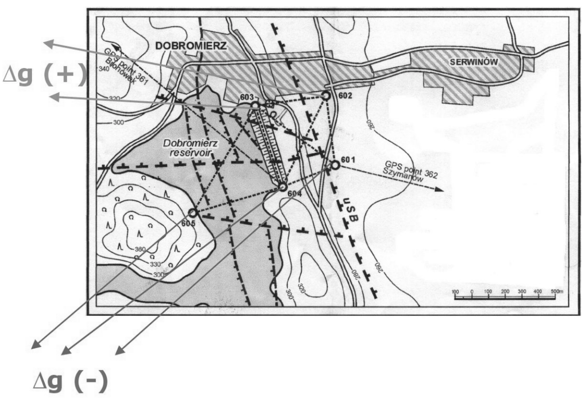

Fig. 5 Location of points on Dobromierz micro-network

KARKONOSZE

The network of gravimetric points in this region, which includes the Jelenia Góra valley area and the upper part of the Karkonosze, became the part of a research project in 2001.

Analysis of the changes in gravity obtained in Karkonosze and Jelenia Góra valley leads to the following conclusions:

- The peak areas of the Karkonosze are located in the Karkonosze granite structure. The gravimetric spans to these stations hold the highest values. This causes a great deal of uncertainty in the results, which show a lack of opportunity for unambiguous interpretation. The average change in gravity between the years 2002 and 2003 was – 7 μGal, while in 2001 - 2002 it was +4 μGal. Of the five stations located in this area a particular attention should be paid to the Snieżka 2 point which shows a clear trend in rising gravity.
- In the Izerskie Mountains structure, there is a decrease in gravity of about 10 μGal per annum. This trend can be seen most clearly at the point in Stara Kamienica.
- In the Kaczawskie Mts analysis of the relative gravimetric measurements shows a slow decrease in gravity of the order of 10 μGal per annum. This trend has a diversified character, but can be seen at every point in this area.
- In the Kamienne Mts there are diversified trends. In the years 2001 - 2002 there was a clear fall in gravity, while in the period between 2002 and 2003 there was a slight Earth's gravity rise.
- At the stations located in Jelenia Góra valley an interpretation shows opposite trends. Changes in gravity observed during two observational periods are different in character, but uniformly minute in comparison with the accuracy of the measurements. In our opinion this constitutes an argument for the stability of this structure.

ESTIMATION OF THE ACCURACY OF THE GRAVIMETRIC OBSERVATIONS IN THE EASTERN SUDETY

In order to evaluate the accuracy of the gravimetric determinations carried out, a second observation on selected points was performed for every measurement cycle sometimes at another day of the campaign. From this, through an analysis of the divergences between the pairs of results achieved, it was possible to define the root mean square error in the gravity determination using the formula:

$$m = \pm\sqrt{\frac{[\delta\delta]}{2n}}$$

where: $\boldsymbol{\delta}$ – the difference between the results for the pair of observations, $\boldsymbol{n}$ – the number of pairs observed.

On the basis of these divergences a r.m.s. error of gravity was obtained for example:

2001: 11.2 μGal (22 μGal in the upper mountain part, 6.1 μGal in the Fore Sudetic Block);

2002: 15.3 μGal (16.9 μGal in the upper mountain part, 6.7 in the Fore Sudetic Block);

2003: 8.5 μGal, compared to that in the Karkonosze of 11.3 μGal.

It is possible to calculate the average m.s. error of gravity for points located in the lower part of the mountains as 12 μGal. In the areas situated higher, because of the greater values of gravity differences, it is at a level of 20 μGal. This obviously depends on the accuracy of the instrument, the reading methods and, mainly, on the quality of the determination and stability of the coefficient of the gravity meter scale.

To take a critical stance in relation to the results obtained, a comment should be made about the effect of the quality of the assessment of the scale coefficient on the accuracy of measurement of differences in gravity, which was addressed in an earlier paper (Pachuta, 1998).

In our analysis the assumption was made that the calibration span, created using two points of the PNGN, has a value of Δg = 70 mGal. Each of the fundamental points in the state network has a defined value for gravity taking into account an error of $m_g \in$ (8-14 μGal). The standard difference in gravity between these points can therefore be said to show and average mean error of $m_{\Delta g} \in$ (12-20 μGal). The assumption is then made that the span is measured with an error of 5 μGal. After taking the error value into consideration for the model value of the differences in gravity this gives the result that for the span under consideration, the error is defined at a level of $(2 - 3)\cdot 10^{-4}$. This uncertainty about the definition of the coefficient of the scale is directly proportional in effect on the uncertainty in defining the gravity difference. For example, for the difference Δg = 100 mGal this leads to an average m.s. error of 20 - 30 μGal.

For measurements on points in the Karkonosze network the maximum value has to be considered, Δg_{max} = 321 mGal. In one single event, for the Szklarska Poręba – Śnieżka span, that difference was 207 mGal.

The straightforward, analysis of accuracy highlights the unfavourable aspect of the relative gravimetric measurements in the Sudety, in terrain with large height differences. This may be a reason of an increasing in the error in defining the gravity values, which is a result of the accuracy of the determination of the coefficient of the gravimeter scale. The way in which this effect can be eliminated is an installation of a precise gravimetric base covering the largest increment in gravity. In the Karkonosze region the best location for such a base might be e.g. the Karpacz – Śnieżka span, and in the Snieznik Massif the Lądek Zdrój – Rykowisko span. The difference Δg would be at a level of 120 mGal.

FINAL REMARKS

To conclude, summing up the determination of the gravity variations in Lower Silesia over a period of 10 years, the necessity to combine analysis of changes in the Earth's gravity field with analysis of other geodetic observations, in particular levelling and changes in height or other morphological and geological events is approved out conclusion. This ought to allow to define the places which are particularly tractable for changes in gravity and for modelling the elimination of the effect of changes in the shape of the sub-surface mass. This indicates a need for complex analysis of the expanse and the region in the Czech part of the Eastern Sudety.

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