Acta Geodyn. Geomater., Vol. 6, No. 2 (154), 155–161, 2009

GRAVITY MEASUREMENTS IN THE REGION OF THE GEODYNAMIC NETWORK HIGHLANDS (THE BOHEMIAN MASSIF)

Roman KUJAL, Vladimír SCHENK and Zdeňka SCHENKOVÁ

Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic, v.v.i., V Holešovičkách 41, 182 09 Prague, Czech Republic
**Corresponding author's e-mail:* kujal@irsm.cas.cz

(*Received* April 2009*, accepted* June 2009)

ABSTRACT
During 2007 and 2008 there were realized gravity measurements using the relative gravimeter Scintrex CG-5 on sites of geodynamic networks HIGHLANDS and fundamental gravity sites of the Czech Gravity Reference Network. The gravity measurements were concentrated on monitoring the long-term trends of gravity acceleration changes among individual measurement sites. The methodology of measurement was optimized and preliminary time changes in gravity differences among sites were determined.

KEYWORDS: gravity measurement, geodynamic network HIGHLANDS, the Bohemian Massif, geodynamic processes

INTRODUCTION

Regional geodynamic network HIGHLANDS (Schenková et al., 2007) was established to monitor recent movement activity of geodynamic structures in broader area of the Czech-Moravian Highlands (Schenk et al., 2002, 2003, 2006, 2009). The attention was paid to three structural areas – Železné hory Mts., Boskovice Furrow and Moldanubicum. The first two areas are located at the edge of the Moldanubicum, in places with potential higher geodynamic activity; the third one is situated in the Moldanubian and Třebíč Pluton. The gravity measurements presented in this study complement the site GPS measurements to contribute geodynamic studies of geological structures.

The gravity measurements were carried out by gravimeter CG-5 of Scintrex with the sensitivity of 1 microGal and the precision of repeated measurements of 5 microGal. The gravimeter measures relative values of gravity and saves them to the memory. The apparatus automatically corrects the tilt of the gravimeter, internal temperature of the gravity sensor, tides and partially corrects the time drift. It automatically measures the gravity during selected period with given interval of individual measurements. The resulting value of relative gravity including standard deviation is calculated from values given by converter with a frequency of 6 Hz. The gravimeter automatically eliminates the extreme values to avoid their influence on gravity. The measurements have low dependency on the atmospheric pressure; the barometric coefficient is 0.15 microGal/kPa, which corresponds to a change of 1 microGal to 66.7 hPa. Similarly, the dependency on magnetic field is very low: 1 microGal to 100 000 nT.

GRAVITY FIELD MEASUREMENTS

Gravity measurements were carried out on 7 sites of geodynamic network HIGHLANDS (Schenková et al., 2007): BENE (Benetice), HORI (Hořice), NOSA (Nové Sady), OSIK (Osiky), PAVL (Pavlov), PEKL (Peklůvko) and ZABL (Zábludov), on 2 sites of neighbouring geodynamic network (Schenk et al., 2006): SEDL (Sedletín) and SPAL (Spálava) and on 5 sites of the Czech Gravity Reference Network (CGRN). Implementation of gravity measurements on the CGRN sites together with the gravity measurements carried out on geodynamic network HIGHLANDS enable to evaluate all gravity values in absolute gravity, because the CGRN sites are given in absolute values. GPS and CGRN sites and meteorological stations, serving for evaluation of meteorological conditions during the measurements, are marked in Figure 1.

The measurement sites were divided into three areas:

(a) Moldanubicum - GPS epoch sites PEKL, PAVL, BENE and CGRN Horní Cerkev site,

(b) Železné hory Mts. - GPS epoch sites SEDL, SPAL and CGRN Habry site, and

(c) Boskovice Furrow - GPS epoch sites ZABL, OSIK, HORI, NOSA and CGRN Sebranice and Černá Hora sites.

Between the areas of Železné hory Mts. and Boskovice Furrow there were also measurements in CGRN Polička site.

The gravity measurements with the relative gravimeter Scintrex CG-5 were carried out in three periods, while the third period was divided in two time intervals:

I. period	spring 2007	21. 5. 2007 – 24. 5.2007
II. period	autumn 2007	17.10.2007 – 18.10.2007
III. period	summer 2008	10. 6. 2008 – 12. 6.2008
		23. 6. 2008 – 24. 6.2008

Configuration and time setup of daily measurements during these periods are given in Figure 2 where sites of daily measurements are delimitated. During the first period, the sites of the CGRN were not measured so that the daily measurements on individual sites were tied to the measurements in a reference site. The measurements were carried out over quite long distances. The measurements during the second period, comprising only one CGRN site, were done in a similar way. During the third period, there were included four CGRN sites and the sites of daily measurements were less distant. The measurements on coinciding sites were usually 2- to 3-times repeated during two consequent days and individual areas were not tied together.

During the first two periods, the daily measurements were carried out by the profiling method (Trakal and Lederer, 2003). During the third period, the measurement was carried in a rotation manner when the last site was followed by the measurement on the first one. During one day, all sites were measured 2 to 4 times.

The GPS site is a concrete rectangular block having a base of 40x40 cm and a height from 40 to 100 cm and on its top a steel plate with a screw thread is embedded. Every block is firmly anchored into bedrock (Schenk et al., 2006; Schenková et al., 2007). During the gravity measurements a special stilt was placed in these GPS sites to ensure identical position and orientation of the gravimeter in a given site. In the CGRN sites the gravimeter was centred above the metallic mark of site stabilisation and its orientation was controlled by a compass. The side pack-sheet ensured the protection against wind. At each site, the altitude between a lower plane of the gravimeter and the upper plane of CGRN or GPS sites was measured by a sliding ruler with the precision of 0.1 mm.

At each site there were registered gravity values in one-minute intervals, from which the software installed in gravimeter automatically calculated the mean gravity value. During the first and second period these datasets were terminated by the operator. He was able to subjectively evaluate the measurement errors and when he found the error of last measurements sufficiently low he terminated the measurements. Therefore these series do not have the same length. During the third measurement period, based on previous experience, there was introduced a uniform measurement interval of 20 minutes at each site with the interval of individual measurements of 1 min.

DATA PROCESSING

Relative gravity values registered by the gravimeter Scintrex CG-5 during the field measurements were directly processed by the gravimeter software and automatically corrected for the influence of tilt changes, tides, sensor temperature, and partially for the measurement time drift. Further data processing included the knowledge of precision of relative Scintrex gravimeter (Blecha, 2006; Lederer, 2009). It turned out that the meteorological conditions recorded by the stations in the areas of gravity measurements together with the variations of magnetic field monitored by the station Budkov did not influence the measurements. The gravimeter calibration constant was repeatedly determined on the gravity base between Prague and Miličín. The processing included the corrections for the gravimeter height above the surface (Mareš, ed., 1984).

Gravimeter time drift was determined for each daily measurement as a function of time. The measured data were processed by a system of the 1st to 3rd order equations using the rms method that allowed the best fitted polynomial to be chosen (Lukavec and Lederer, 2006). This polynomial approximated the gravimeter time drift and enabled to calculate the residuum for each measurement at each site for each time – the residuum was expressed as the difference between the measured value and the value approximated by the given polynomial (Fig. 3). Corrected gravity values of daily measurements were tied using the measurements on reference sites and from the tied measurements the relative gravity values were obtained.

In three investigated areas – in the Moldanubicum, in the Železné hory Mts. and in the Boskovice Furrow – there were selected sites of regional geodynamic networks located close to the tectonic faults, where recent movement activity is expected. Measured sites were located on both sides of these faults. Processing of the measured data was aimed at monitoring of the gravity differences in time among these sites. Since the field gravity measurements in 2007 did not comprise the measurements in CGRN sites and there was no overlapping of measurements among the areas, it was not possible to evaluate the measured data in absolute gravity. Further processing included the separate comparison of direct gravity values from gravimeter for daily measurements in individual areas and their correlation among themselves. The comparison of time changes in gravity differences for 2007 and 2008 was done for the following site couples:

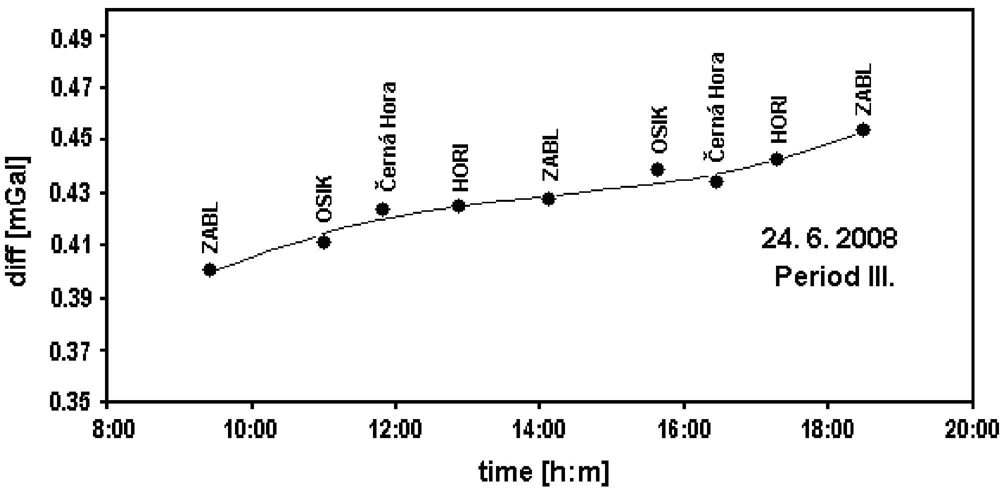

Fig. 3 Example of time drift changes for daily measurements of 24th June 2008.

Table 1 Relative gravity acceleration for the period of 2007 and 2008.

area	site	relative gravity [mGal]	
		2007	2008
Moldanubicum	PAVL	4636.130	4855.991
	PEKL	4637.748	4857.621
	BENE	4654.417	4874.270
Boskovice Furrow	HORI	4676.682	4905.166
	OSIK	4659.285	4887.792
	ZABL	4705.476	4933.982
Železné hory Mts.	SPAL	4669.436	4890.675
	SEDL	4684.113	4905.342

a) PAVL-PEKL, PAVL-BENE, PEKL-BENE for Moldanubicum area,
b) HORI-OSIK, HORI-ZABL, OSIK-ZABL for Boskovice Furrow area and
c) SPAL - SEDL for the Železné hory Mts. area.

RESULTS AND DISCUSSION

The relative gravity values for the period of 2007 and 2008 (Table 1) were used for determination of gravity differences between individual sites and detection of their annual changes. The gravity differences among sites and their time changes are summarized in Table 2. Figure 4 shows time changes in gravity differences [microGal] for individual sites couples with error bars. Site couples are sorted for individual areas.

For the Železné hory Mts. area (Fig. 4), the gravity differences during the period of 2007-2008 did not show pronounced changes and in comparison with the other two areas they show a relatively low error of measurement.

In the Moldanubicum area, we can notice a decline of gravity differences in east direction with increasing time (Fig. 4). It seems that this trend could be correlated with the movements distinguished in this area by GPS (Schenková et al., 2009). In the area after four annual campaigns two zones with extension trends were detected: WNW-ESE extensions acting across the granitic Central Moldanuabian Massif and

Table 2 Gravity differences for individual site couples and their changes in time for the period of 2007 – 2008.

area	site couple	gravity difference [mGal]		annual change of gravity difference [microGal]
		2007	2008	
Moldanubicum	PEKL - PAVL	-1.618	-1.630	-12
	PAVL - BENE	-18.287	-18.279	8
	PEKL - BENE	-16.669	-16.649	20
Boskovice Furrow	OSIK - HORI	17.374	17.397	23
	ZABL - HORI	-28. 816	-28. 794	22
	ZABL - OSIK	-46.190	-46.191	-1*)
Železné hory Mts.	SPAL - SEDL	-14.677	-14.667	10

*) value is under the precision of gravimeter

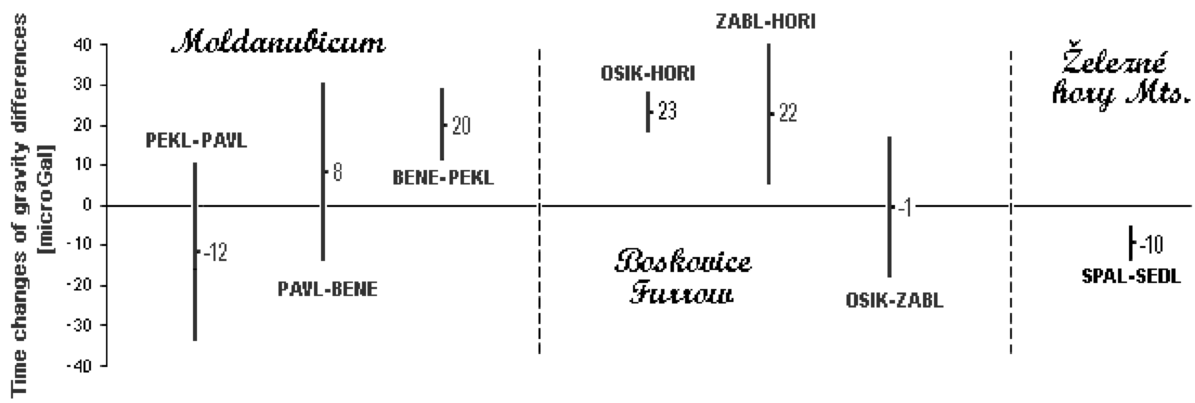

Fig. 4 Time changes of gravity differences [in microGal] for the period of 2007-2008 for site couples (with error bars).

NE-SW extensions in the Moravicum existing along the Boskovice Furrow.

For the Boskovice Furrow area during the period of 2007-2008 there were almost no changes in gravity differences for sites situated in the same side of the Furrow and significant differences were observed between sites located on different sides of the Furrow (Fig. 4). This fact could indicate possible existence of both vertical and horizontal movements along and across the Boskovice Furrow (Schenková et al., 2009).

However, it is evident that the observed gravity differences and their explanations give only very preliminary information. It is known that occurrence of extensions in the Earth crust rock complexes brings about occasionally a drop of rock matter which consecutively could induce gravity differences. Nevertheless, this explanation of gravity differences has to be taken with high reserve. Moreover, in our case, because of a short observing period and still relatively high scatter of both GPS vertical movements and gravity differences we are not able now to compare the observed GPS and gravity data mutually. At the moment we can only note that recent observed trends of both quantities are not in mutual contradiction.

CONCLUSION

Even if only two annual gravity campaigns have been carried out, the gravity measurements showed that there are time differences in gravity changes among sites, which are not contradictory to the geodynamic conception of the HIGHLANDS region.

The verification of the gravity differences requires the continuation of gravity measurements using the methodology applied in 2008: (a) to measure the gravity at each site for 20 minutes in one-minute intervals, (b) to include the measurements of the CGRN sites and (c) for the HIGHLANDS region, to realize daily measurements in maximum 3 sites with triple repetition. Further gravity measurements must prove if detected gravity differences cannot be influenced by variable (e.g. hydrogeological) conditions during different periods of measurements. Only long term time changes of gravity differences can show how much these changes are related to the geodynamic activities. In future this type of gravity investigations will be completed with simultaneously performed absolute gravity determinations in the region. Without such exhaustive gravity measurements the relative measurements can give only general opinion on gravity field pattern.

ACKNOWLEDGEMENTS

The authors express their thanks to the Grant Agency of the Academy of Sciences of the Czech Republic for the financial support (Project IAA300460507) that help them to build the geodynamic network HIGHLANDS and to realize the epoch gravity measurements. Measurements were partly also supported by the Ministry of Education, Youth and Sports of the Czech Republic (Projects LC506 and 1P05ME781) and the Targeted Research Programme of the Academy of Sciences of the Czech Republic (Project 1QS300460551).. The authors wish to extend their sincere thanks to M. Grácová and Z. Fučík, who participated in gravity measurements, and to F. Mantlík, who organized gravity measurements in 2007.

REFERENCES

Blecha, V.: 2006, Methodology of measurements by gravimeter Scintrex with microgal resolution. Transactions of the VŠB - Technical University of Ostrava, Civil Engineering Series, 6, 2, 17–21, (in Czech).

Lederer, M.: 2009, Accuracy of the relative gravity measurement. Acta Geodyn. Geomater., 6, No. 3 (155), in print.

Lukavec, P. and Lederer, M.: 2006, Gravity measurements in the geodynamic network Sudety. Acta Geodyn. Geomater., 3, No. 3(143), 117–123.

Mareš, S. (ed.): 1984, Introduction to Applied Geophysics. SNTL, ALFA. Prague. 581pp.

Schenk, V., Cacoń, V., Bosy, J., Kontny, B., Kottnauer, P. and Schenková, Z.: 2002, The GPS geodynamic network SUDETEN – Five annual campaigns (1997-2001). Data processing and results. Acta Montana, Ser. A, No. 20 (124), 13–23.

Schenk, V., Schenková, Z., Cacoń, S., Kontny, B., Bosy, J. and Kottnauer, P.: 2003, To geodynamic interpretations of GPS data monitored on the EAST SUDETEN network. Acta Montana, Ser. A, No. 24 (131), 87–97.

Schenk, V., Schenková, Z., Grácová, M. and Kottnauer, P.: 2006, Preliminary site movements in the GPS West Sudeten network. Acta Geodyn. Geomater., 3, No. 3 (143), 45–51.

Schenková, Z., Schenk, V. and Grácová, M.: 2009, Recent geodynamic pattern of the northern and eastern parts of the Bohemian Massif based on GPS measurements. IASPEI General Assembly 2009, Abstracts, Council for Geoscience, Cape Town, CDROM, G1.

Schenková, Z., Schenk, V., Mantlík, F. and Grácová, M.: 2007, Regional geodynamic network HIGHLANDS, the Bohemian Massif. Acta Geodyn. Geomater., 4, No. 4 (148), 207–215.

Trakal, J. and Lederer, M.: 2003, Methodology for measurement in Czech Gravity Reference Network (CGRN). Report, Land Survey Office. Pratur, (in Czech).

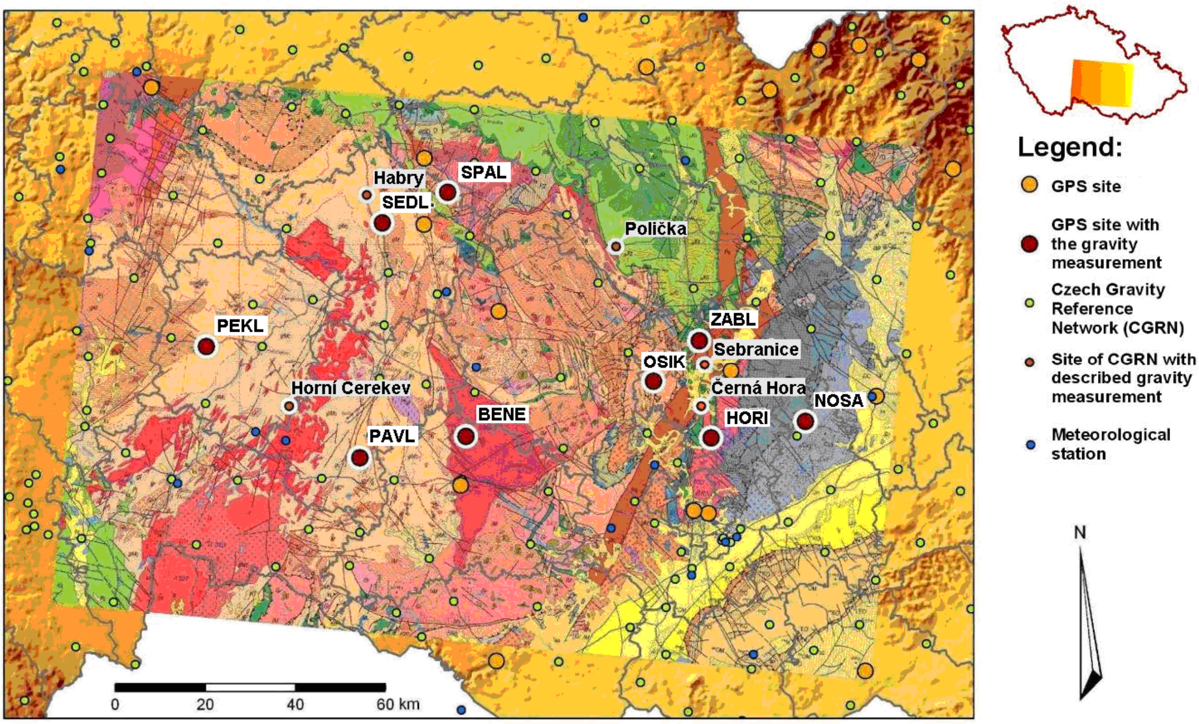

Fig. 1 GPS and CGRN sites where the gravity measurements were performed; background: the geological map 1:500 000 (© the Czech Geological Survey, Prague).

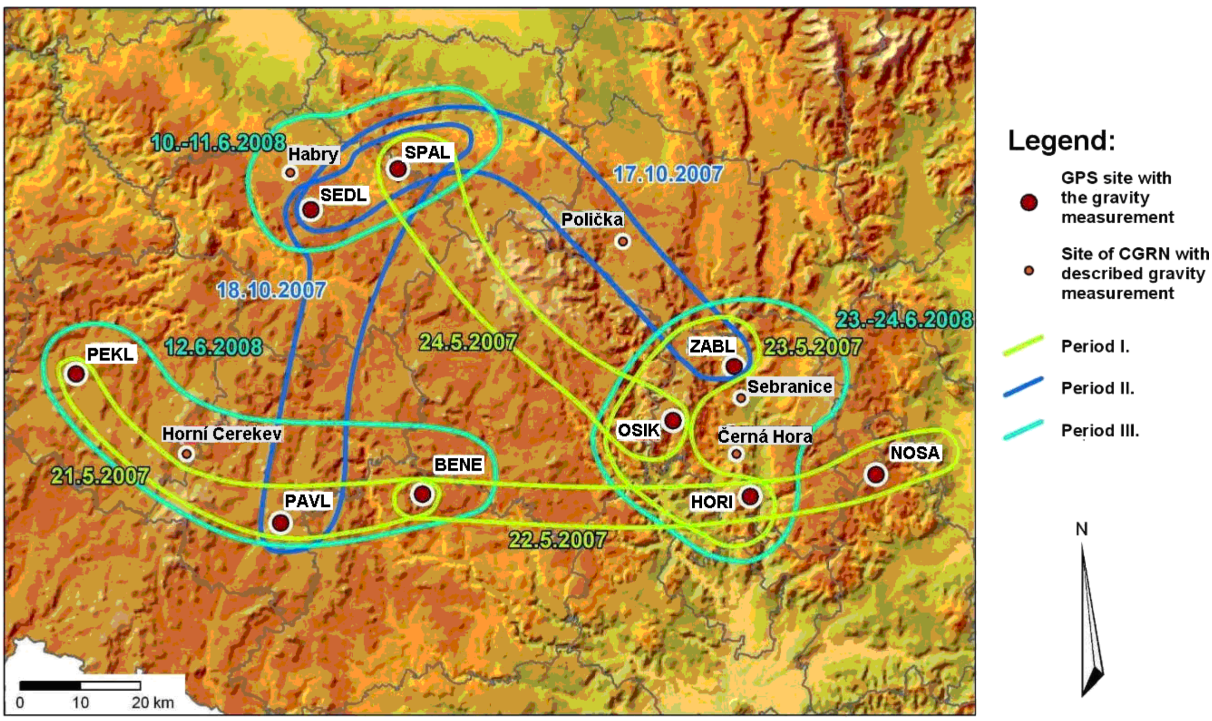

Fig. 2 Sets of daily gravity measurements of the I., II. and III. Periods.