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GRAVIMETRIC INVESTIGATIONS IN THE WEST BOHEMIA SEISMOACTIVE ZONE – INITIAL STAGE

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Abstract. In 1991 the first local experimental investigation of non–tidal temporal changes of gravity was started on the active fault zone. In 1993 a complex geoscientific project was launched in Geophysical Institute to study displacements of crustal blocks. Besides other research (seismology, GPS, precise levelling, geology etc.), gravimetric measurements within essential part of the GPS network have been introduced, with gravity stations located straight on GPS stabilization. Up to now five campaigns have been completed and another two are under processing within the initial stage of the three–years period. The measured data provide information on accuracy and also prove the existence of certain temporal non–tidal gravity variations.

1. Introduction

Application of gravimetry in combination with geodetic methods, such as GPS (Global Positioning System), VLBI (Very Long Baseline Interferometry), SLR (Satellite Laser Ranging) for crustal movement detection has been reported by more authors (Torge et al., 1992; Okubo, 1992), most recently by Groten and Becker (1995). Besides blocks displacements, some other phenomena may be monitored or registered, like groundwater table variations connected with geodynamical processes within upper crust. The principal problem is the data accuracy with regard to the level of possible amplitudes of gravity changes. In case of relative gravity measurements, the LaCoste&Romberg gravity meters represent top instrumentation. Our LCR Model D with μGal resolution ($10^{-8}\,\mathrm{m.s^{-2}}$) has been calibrated on the latitude calibration line between Litoměřice and Miličín (approx. 200 mGal).

2. Tectonic Setting

The region is located on the crossing of two major tectonic zones of the western part of the Bohemian Massif – the so called Ohře rift zone (NE–SW) and the Cheb–Domažlice graben with the significant Mariánské Lázně fault (NNW–SSE), Fig. 1. The Cheb Tertiary sedimentary basin was originated in this area in consequence of vertical displacements. The dip slip character of the fault was confirmed only to limited extent by fault plain solution of the main shock of the 1985/1986 earthquake swarm (Zimová and Špičák, 1987). The horizontal component was more apparent than the vertical one. However, more investigations in this field are expected.

In the region there are still manifestations of recent tectonic activity, e.g. the youngest Quaternary volcano of Komorní hůrka, hot and mineral springs, increased heat flow, CO_2 emissions, mud volcanoes and local earthquakes. Seismic activity has a swarm–like pattern with a certain cycle of repetition. During a few last decades, the strongest one occurred in 1985/86. In Fig. 1, epicentral zones, defined by Horálek et al. (1996), are shown by black dots.

3. GRAVIMETRIC INVESTIGATIONS

3.1. Testing Period in 1991

In fact, the area around the stations GPS 4 and 5 was the first place of experimental microgravimetric investigations already in 1991. A short profile M crossing the marginal basin fault (seismoactive part of the Mariánské Lázně fault) shown in Fig. 2, was measured and some special methods were applied there. For example, four stations M3, M5, M6 and M9 of the line were measured all the day with two relatively very good quartz Scintrex CG–2 gravity meters in the sequence 6 — 9 — 6 — 5 — 3 — 5 — 6 — 9 — ... etc. This attempt to register any non–tidal high–frequency changes of gravity has brought unexpected results. In Fig. 3, the differences between the stations M3, M5 and M9 with regard to the station M6 are presented. In detail, each curve represents the difference between drift control curves of the two particular stations during the day. According to the very similar character of the changes registered with two different instruments (each of quite different instrumental drift) the results seem to be realistic. The striking sinusoidal character of the changes is not relevant to tidal variations, because of shorter period (wavelength about 3 hours only). From the results obtained, it was not possible to decide, whether the relative changes of gravity took place on this station or on the three others.

As no common phenomena could be considered as the source of changes (tides, groundwater, ground moisture, air–pressure, etc.), it was concluded that some dynamic processes in the ground produce detectable effects on gravity. However, this new knowledge must be examined by a much larger set of new data before attempting to explain such effects.

3.2. Complex Investigation Period Starting in 1993

In 1993 a local GPS network (inner net) was set up in the seismoactive area among Skalná, Luby and Kraslice for repeated geodetic measurements (Horálek et al., 1994). Later more distant stations have been established to cover much larger area (outer net), so that ambient relatively stable blocks are involved in sufficient extent (Špičák et al., 1996).

Gravimetric observations are concentrated on a SW–NE principal profile (crossing two active faults) and two net closures connected with this profile (Fig. 4). The

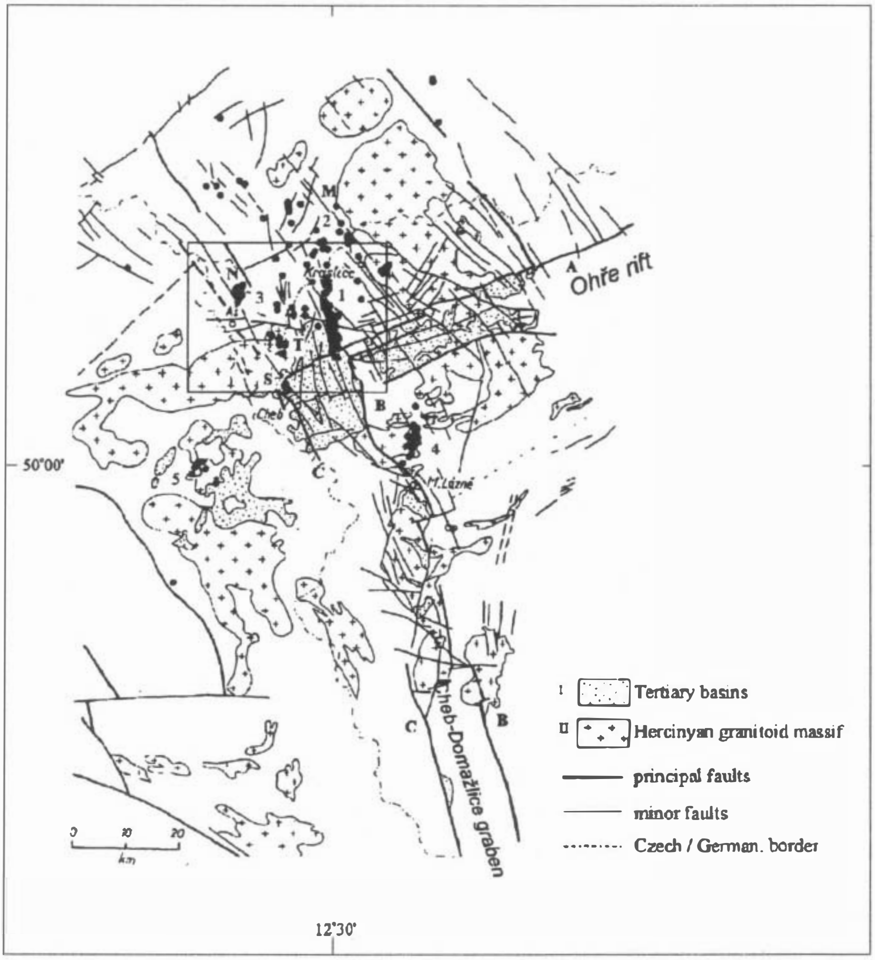

FIG. 1. Geological and tectonic scheme of the seismoactive region in Western Bohemia and the main micro–earthquake focal zones (adopted after Dudek 1987 and Horálek et al. 1996). The area under study is marked by a rectangle (see Fig. 4)

I – Neogene sediments of the Cheb and Sokolov basins and in other smaller areas

II – Hercynian granitoid massifs

Principal tectonic faults: A – Krušné hory f., B – Mariánské Lázně f., C – Tachov f. and Bohemia quartz–lode, M and N – minor faults related to areas 2 and 3

Black dots – epicentres of seismic events 1991–1995 (areas: 1 – Nový Kostel, 2 – Kraslice, 3 – Aš, 4 – Lazy, 5 – Marktredwitz, S and T - minor clusters of events)

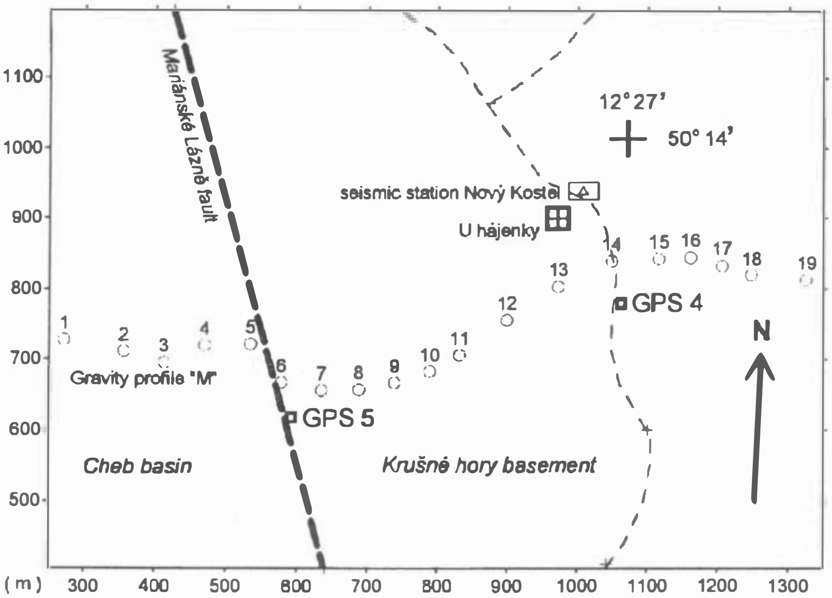

FIG. 2. Microgravimetric profile M (close to the seismic station Nový Kostel) crossing the Mariánské Lázně fault between stations M5 and M6. GPS points 4 and 5 are also shown. Experimental measurements were carried out on the stations M3, M5, M6, M9 by quartz gravity meters CG–2. (Stations of the profile M are not identical with GPS–gravity stations in Fig. 4.)

goal of the investigation is to register local non–tidal changes of gravity, analyse possible influences of various phenomena, like groundwater oscillations, and contribute to the location of the most active deformation areas (Mrlina, 1996).

Since 1993, a new LaCoste&Romberg Model D No.188 gravity meter has been introduced for the measurements in order to obtain high precision. After the initial two campaigns in autumn 1993 and spring 1994, accuracy limits were tested and gravity changes evaluated. As the gravity differences were far beyond accuracy limits (Fig. 5), there was a good reason to continue with the measurements.

In all the campaigns, each net connection was measured six times in average, with independent control of accuracy. After averaging the values for each connection, both closures were calculated and the total misclosure just as well, with the results in Tab. 1.

The values in Tab. 1 represent the high standard of measurements, if we take into account the distance between stations, difficult access to some of them, elevation differences, cold and wet weather in spring and autumn, etc. In average, the r.m.s. of measured gravity ranges between 5 and 12 μGal in all campaigns.

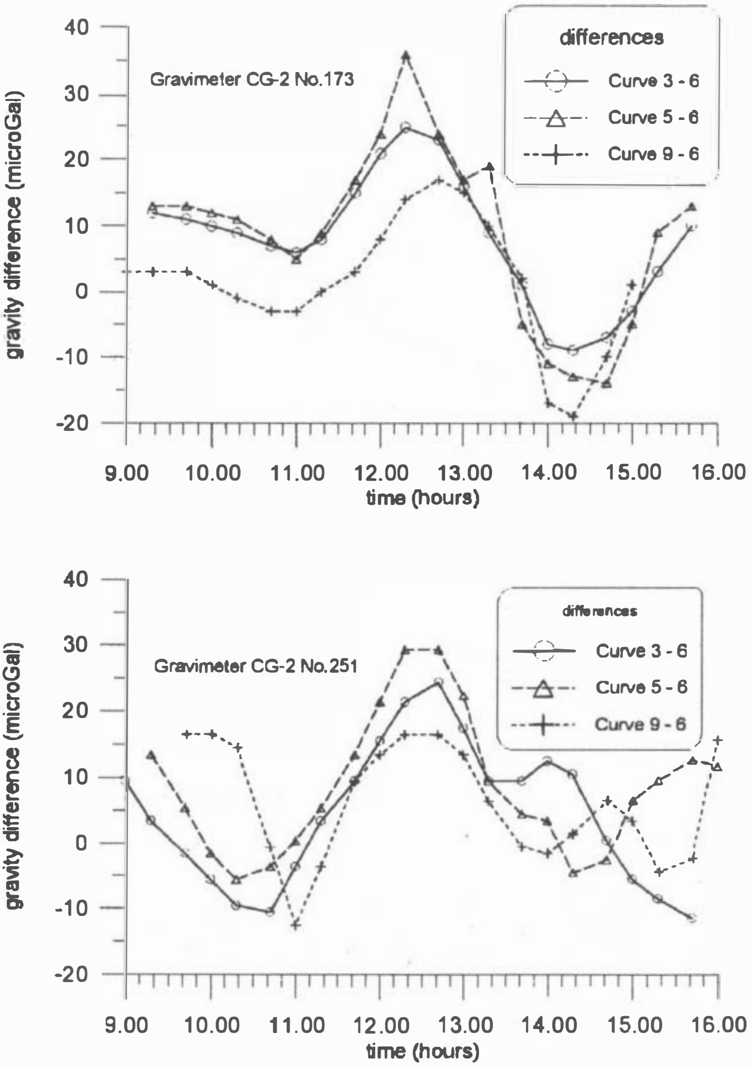

FIG. 3. Short–term differences of measured gravity on the profile M (location in Fig. 2). Temporal differences at stations 3, 5 and 9 with regard to 6 (reference station within the fault zone) were calculated from particular drift control curves (e.g. drift curve at station 3 minus drift curve at station 6, etc.)

The new method of precise gravity meter positioning on GPS stabilizations was applied. The meter is set up on a special base plate, connected to the GPS pipe stabilization at the level of 1 m above the ground. The position is perfectly identical

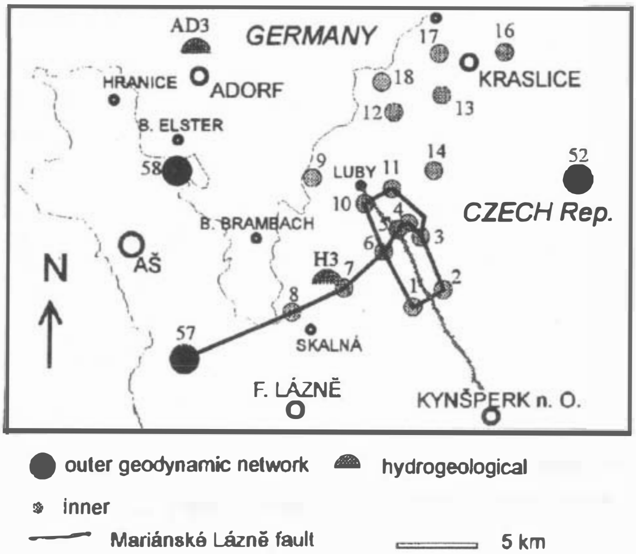

FIG. 4. Scheme of the substantial part of the GPS networks in the central seismoactive area. Gravimetric ties between selected GPS points demonstrate the measurement system. Hydrogeological borehole H3 controls groundwater level

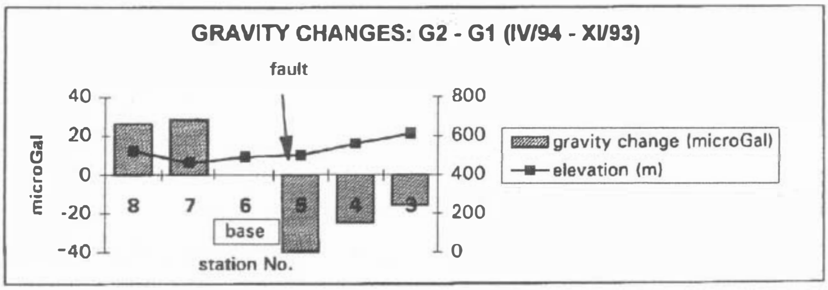

FIG. 5. Temporal changes of gravity calculated from the two initial campaigns in 1993 (G1) and 1994 (G2) along the axial profile between the stations 3 and 8. Rough elevations document stations position in the Cheb sedimentary basin (6, 7) and in the crystalline complex of surrounding highlands (3, 4, 8)

each time of measurement and acts as a "filter" for the effect of ground moisture and other possible changes in the close vicinity of the point. Moreover, during each campaign the groundwater level is controlled in the H3 borehole at the station 7 site.

TAB. 1. Gravity misclosures in μGal for gravimetric loops in Fig. 4

closure	XI/93	IV/94	X/94	V/95	XII/95
6–10–11–3–4–5–6	+19	+3	0	+2	−3
6–5–4–3–2–1–6	−22	−7	−3	0	—
6–10–11–3–2–1–6	−3	−4	−3	+2	—

Five campaigns have been carried out and processed up to now, with short periods in between (6 months). The temporal differences in gravity were calculated for the stations along the principal profile and two closures, see Fig. 6. According to the character of changes, which is not chaotic, the stations could be divided into 3 groups, each with specific position to the main Mariánské Lázně fault (compare Fig. 4 and 6). The group A has its gravity maximum in campaign 3, the group C in campaign 2 and the group B have had no significant maximum up to now. Similarly, the groups gravity minima also differ in time. So there is a striking difference in gravity variations between the stations south–west and north–east, respectively, of the main fault zone. Maximum amplitudes of the changes reach even 50 μGal, which corresponds with examples presented by Groten and Becker (1995).

As all necessary corrections and reductions of the data were applied, and with respect to the block stability (no significant displacements were registered by GPS), the gravity changes should be connected with inner dynamic processes in the rock massif of the upper crust. However, the total observation period is still too short for statistical confidence and complex geophysical analysis.

4. PROBLEMS AND CONCLUSIONS

In this initial stage, we are well aware of the problems connected with this kind of investigations:

- What do we measure?
  - the expected recent crustal movements are too small to be registered (elevation changes probably will not produce sufficient change of gravity)
  - density changes resulting from tectonic deformations are of unspecified extent with regard to different stress regime than, e.g., in coal mines (Mrlina, 1994)
  - the total mass involved in the deformation is unknown
- What we have to monitor simultaneously:
  - groundwater level in order to calculate respective corrections in case of significant level change
  - 3D coordinates by differential GPS measurements with long observation time in order to acquire high precision data
  - height changes in a selected block among GPS stations 6, 5, 4, 3 and 11 by precise levelling
  - weather conditions
- What additional information we need:

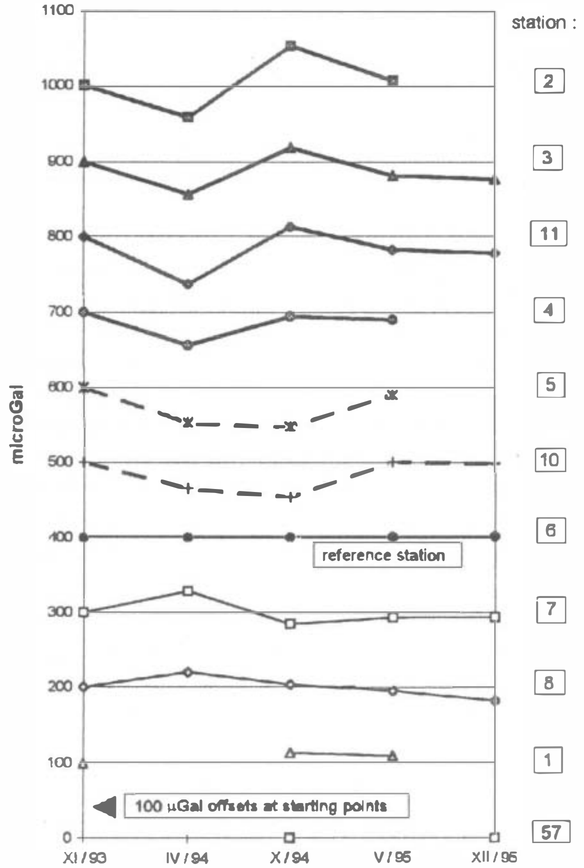

FIG. 6. Temporal changes of gravity on selected stations of the geodynamic network in Western Bohemia in the period 1993–.1995. Stations are grouped according to different character of the changes:
A) stations 2, 3, 4, 11 – NE of the fault (slopes of the crystalline complex of the Krušné hory Mts.)
B) stations 5, 10 – close to the fault
C) stations 1, 7, 8, 57 – SW of the fault (1, 7 – Tertiary basin; 8, 57 – granite complex of the Smrčiny Mts.)
Station 6 – reference station

– seismological data on all events according to magnitude and location

– an absolute gravity measurements: fortunately, a new absolute gravity station was established in Kraslice in 1995 in compliance with the suggestion of Mrlina (1993), so that since 1996 all campaigns can be connected to an absolute gravity

station
– any other geoscientific information on processes which may produce significant effect on gravity or other monitored parameters.

Generally, this study proved the possibility to register temporal and spatial changes of gravity by precise gravity measurements with a LaCoste&Romberg Model D gravity meter in the seismoactive area in Western Bohemia. The data show specific character obviously related to the position of stations with regard to the Mariánské Lázně fault. As no significant block displacements were recognized by geodetic observations during the period under study, just as well as groundwater level oscillations, the gravity changes may be explained by dynamic processes within the upper crust. However, for the interpretation a longer investigation period is necessary to reach certain statistical confidence and analyse the correlation between gravity changes and natural seismic activity.

Acknowledgements

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