

RELATION BETWEEN GRAVITY TIME VARIATION, VERTICAL SURFACE MOVEMENTS AND SEDIMENT THICKNESS IN THE CARPATHIAN BASIN

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ABSTRACT

The investigation of phenomena, influencing the short time variation of gravity, has gained importance with the increasing accuracy of gravity meters. Accordingly, we have studied vertical surface movements, attributable to two effects: compaction of sediments, on the one hand, and structural movements, on the other in the young sedimentary Pannonian Basin. In most of the deep sedimentary regions positive correlation can be found between sediment thickness and subsidence. As a consequence of subsidence, observation points on the surface get into a different equipotential level of the Earth's gravity field. Calculating the effects of the vertical surface movements, determined by repeat levelling, for a 10-year time span, the variation of gravity in general should be about 3 μGal ($1 \mu\text{Gal} = 10^{-8} \text{m/s}^2$), but at special places it may reach as much as 10–20 μGal .

Keywords. Time variation of gravity, vertical surface movements, sediment thickness

1 VARIATION OF GRAVITY FIELD

Accuracy of gravimeters has reached such a high level nowadays that formerly neglected side effects in the μGal range have to be taken into consideration, even if geodynamic processes are the subjects of our investigation. Vertical surface movements are generally treated as vertical crustal movements although movements of different origin cannot be separated by geodetic measurements.

In the case of vertical surface movement, points on the surface get into a different equipotential level of the Earth's gravity field. Because of this the change of gravity is

$$\delta g = VG \cdot \Delta h \quad (1)$$

where $VG = \partial g / \partial h$ is the vertical gradient of gravity and Δh is the value of the vertical surface movement. The well-known normal value of vertical gradient is: $\partial g / \partial h = 0.3086$

mGal/m, but the actual value of VG may differ significantly. Accordingly, the same values of Δh surface movement give different δg gravity changes depending on the values of vertical gradients. In Table 1, the VG values, determined in Hungary are presented (Csapó–Völgyesi 2002).

Table 1. Vertical gradient values determined at Hungarian gravity stations

Name of gravity station	Observed VG
Balassagyarmatmat	0.3208
Budaörs	0.3082
Budapest 1	0.2519
Budapest 2	0.2849
Budapest Technical University	0.3000
Debrecen	0.3075
Dunaújváros	0.3087
Gellért-hegy	0.3269
Gyula	0.2913
Penc	0.3098
Pécs 1	0.3180
Pécs 2	0.3088
Rózsadomb	0.3042
Sóskút 1	0.3604
Sóskút 3	0.3806

In Hungary, the average value of vertical surface movements is 1 mm/year, but locally this value may reach as much as 8 mm/year. Using the normal value of VG , in a 10-year span, the average value of vertical surface movements should result in $3\mu\text{Gal}$ change in the gravity field, while the maximum may bring about as much as 10–20 μGal .

2 GEOLOGICAL CONDITIONS

Apart from occasional foundation problems of levelling base points, in the Pannonian basin – where the surface is covered by young, unconsolidated sediments – vertical surface movements may be attributed to two factors: compaction of sediments and structural movements.

As 85 % of the area of Hungary belongs to the Pannonian basin, compaction of sediments (depending on their composition and thickness) influences significantly the levelling data. Therefore it is expedient to investigate the relations between sediments (their extension and thickness) and surface movement data. If compaction is determined and corrected for, crustal movements of geodynamic origin can be separated.

The Pannonian basin is the central part of the Carpathian basin, surrounded by the Alps, the Carpathians and the Dinarides. The Pannonian basin itself is divided into smaller sub-basins of different types. The largest of them is on its western part the Danube-Rába basin, shared by Hungary and Slovakia, while in the East the Great Hungarian Plain contains the Békés basin and the two deepest depressions, the Makó-Hódmezővásárhely and the Derecske troughs (See Fig. 1).

Both the time of initiation and the rate of subsidence of the different sub-basins may differ significantly.

The more detailed description of geological conditions is given by (Völgyesi, Szabó, Csapó 2004).

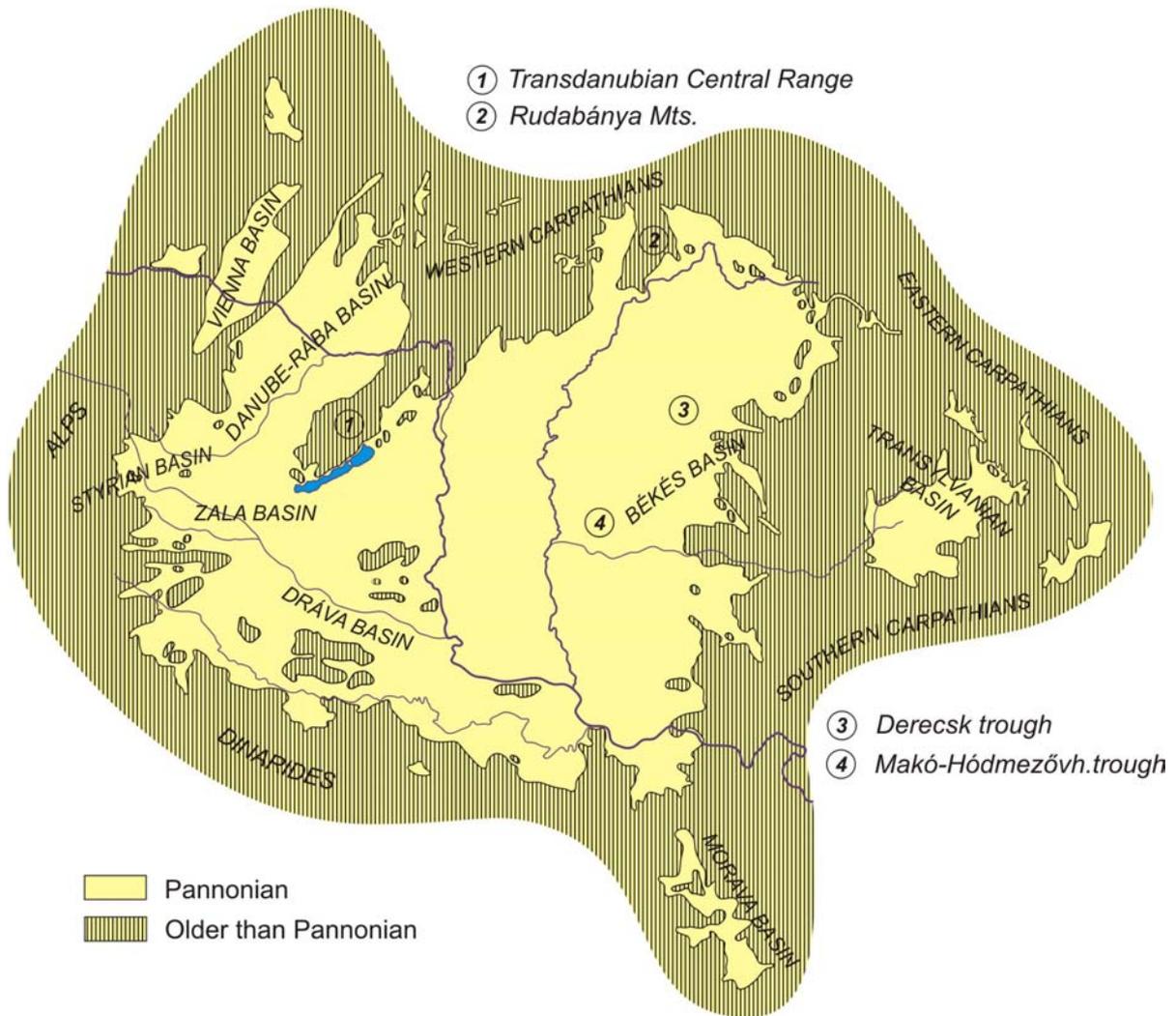


Fig. 1. Distribution of Pannonian sediments in the Carpathian Basin, according to Carte Géologique Internationale de l'Europe 1:1500 000 (1969).

The Lower and Upper Pannonian base, as well as thickness of Quaternary maps were constructed by the Geological Institute of Hungary (MÁFI), originally in the scale of 1:200,000 – in areas of detailed investigation in the scale of 1:25,000 – and published in the scale of 1:500,000 (Csiky et al. 1986, Csiky 1987, Sikhegyi 1995). About the reliability of these maps (Jámbor 1985) has written the following: “All available borehole data were used, although in the published map only a fraction of these holes are plotted, because of technical reasons. Constructing the isolines, for interpolating between boreholes the filtered gravity map of the National Petroleum Company (OKGT) and, at some places, their seismic data were utilized.”

The majority of deep boreholes are oil- and gas-exploration holes, with rare coring in the Pannonian sequence. For marking out geological horizons, well logging provided information. Naturally, in well logging curves, based on different physical parameters, those horizons can be identified unambiguously which represent sharp contrast between density, resistivity or velocity of under- and overlying rocks; the main such horizon being the basement. If Lower Pannonian sediments were deposited directly on the basement, that horizon is reliable, however, to decide whether older than Pannonian

sediments occur or not, is very difficult, even if the borehole has penetrated deep enough. The Lower and Upper Pannonian, as well as the Upper Pannonian and Quaternary contacts carry even more ambiguity.

The distribution of oil-exploration deep boreholes is extremely disproportionate, comparing the in-field and between fields borehole spacing. Interpolation by gravity data is only justified in the case of the Pannonian base horizon, and within areas of similar geological build-up. Seismic reflections can be correlated with geological horizons but their reliability depends on their age, i.e. on the applied technique.

3. SURFACE MOVEMENTS AND THE GRAVITY EFFECTS

Concluding the above-written aspects, it is obvious that geological data are burdened by heavy ambiguities. On the other hand, the average least square error of vertical surface movement is ± 0.97 mm/year (Joó 1996). In our investigation, to decrease ambiguities as much as possible, the following method was used: Starting out from the surface movement map (Joó 1995), data were sampled at a 5 km rate along the levelling lines. This method was chosen to avoid the interpolation errors introduced by using geological data in map construction. Thus our data set can be regarded reliable and independent from any geological considerations. Location map of levelling lines is given in Fig. 2. Next, the depths data of the following geological horizons were determined in the sampling points: the Pannonian base, Lower and Upper Pannonian contact and base Quaternary. This latter was deduced from the Quaternary thickness map, as the few metres thickness of the Holocene can be neglected, compared to other possible errors. These data were plotted for 24 levelling lines (in lines 23 and 25 no useful sediment data were found), and are presented in Fig. 3. The numbering of these graphs corresponds to that of the levelling lines in Fig. 2, where even the directions of the profiles are also given. On the horizontal axis the distance from the starting point is given in km, on the vertical axes, on the left side the depths data of the geological horizons in m, while on the right side the vertical surface movement data are given in mm/year.

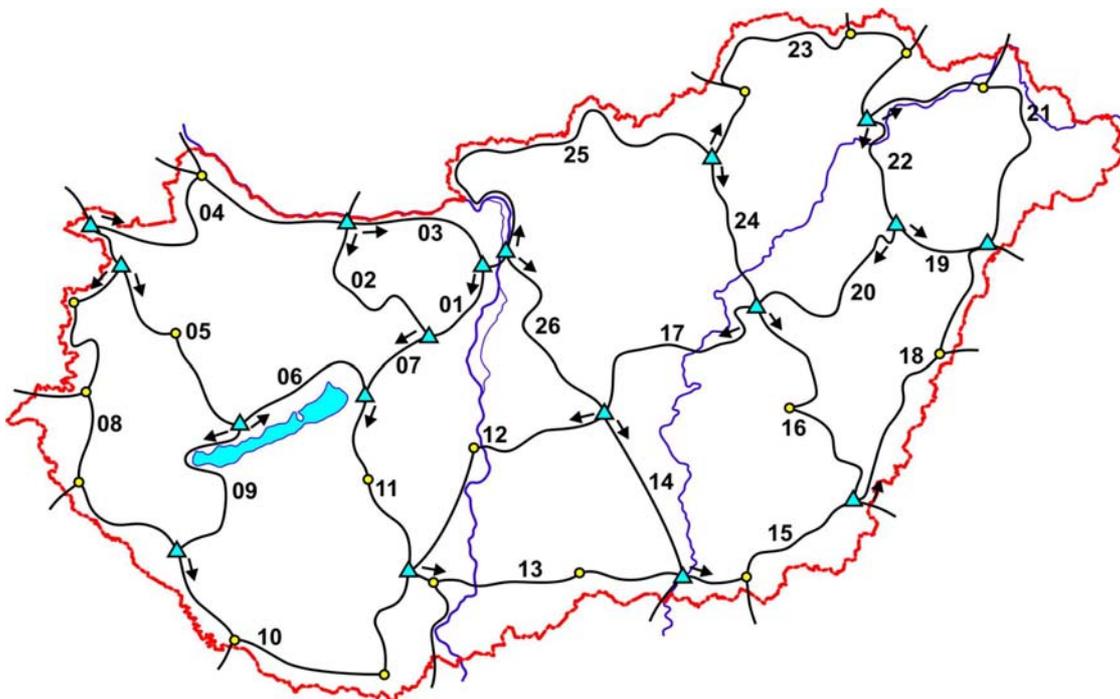
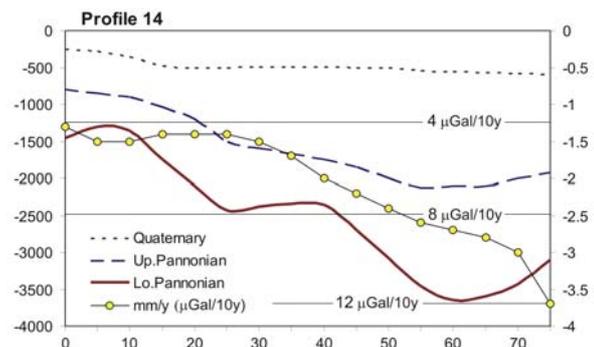
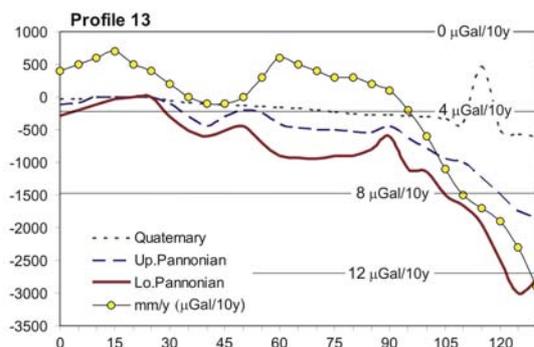
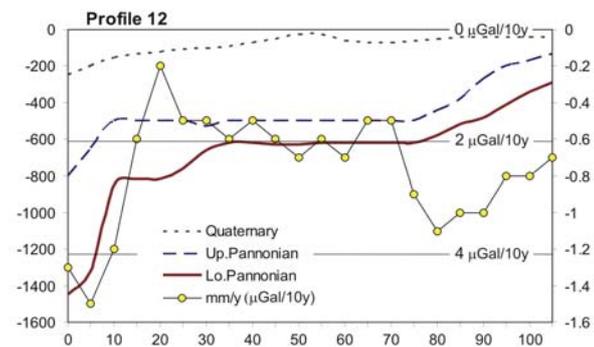
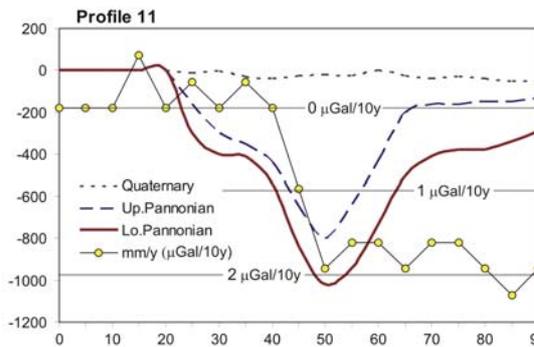
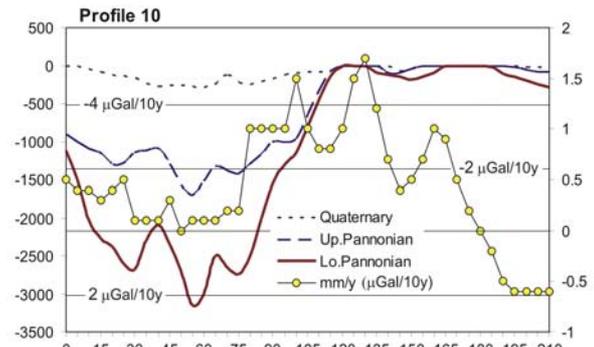
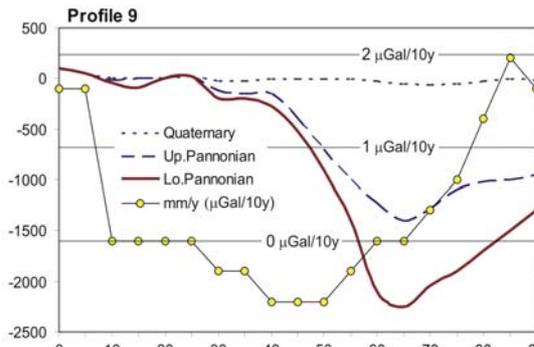
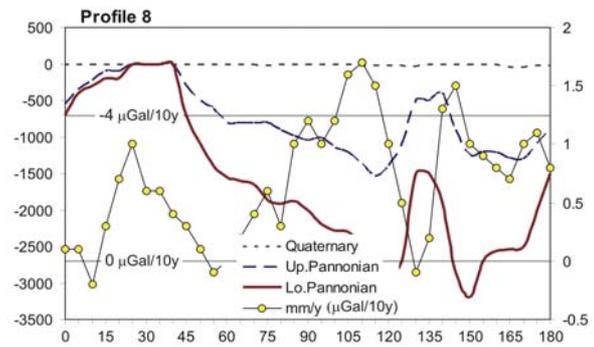
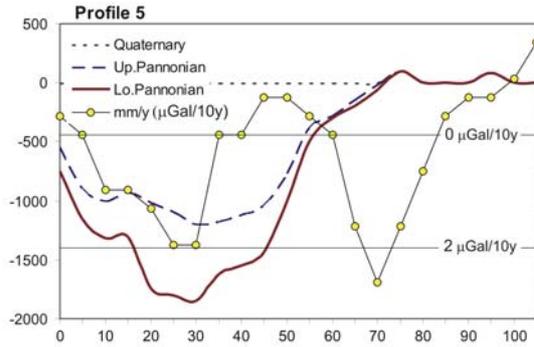
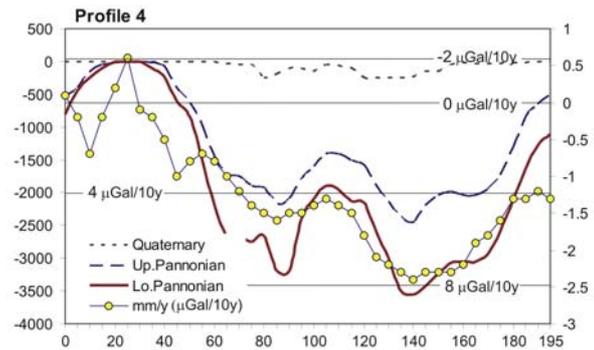
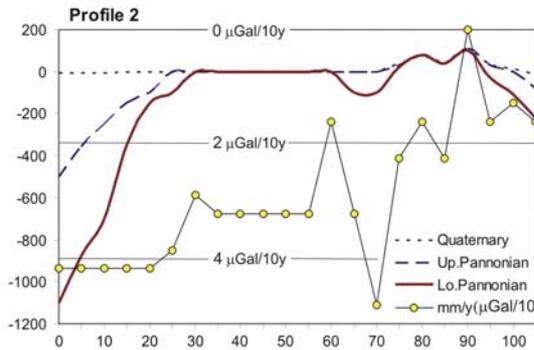


Fig. 2. Location map of levelling profiles with direction of sampling



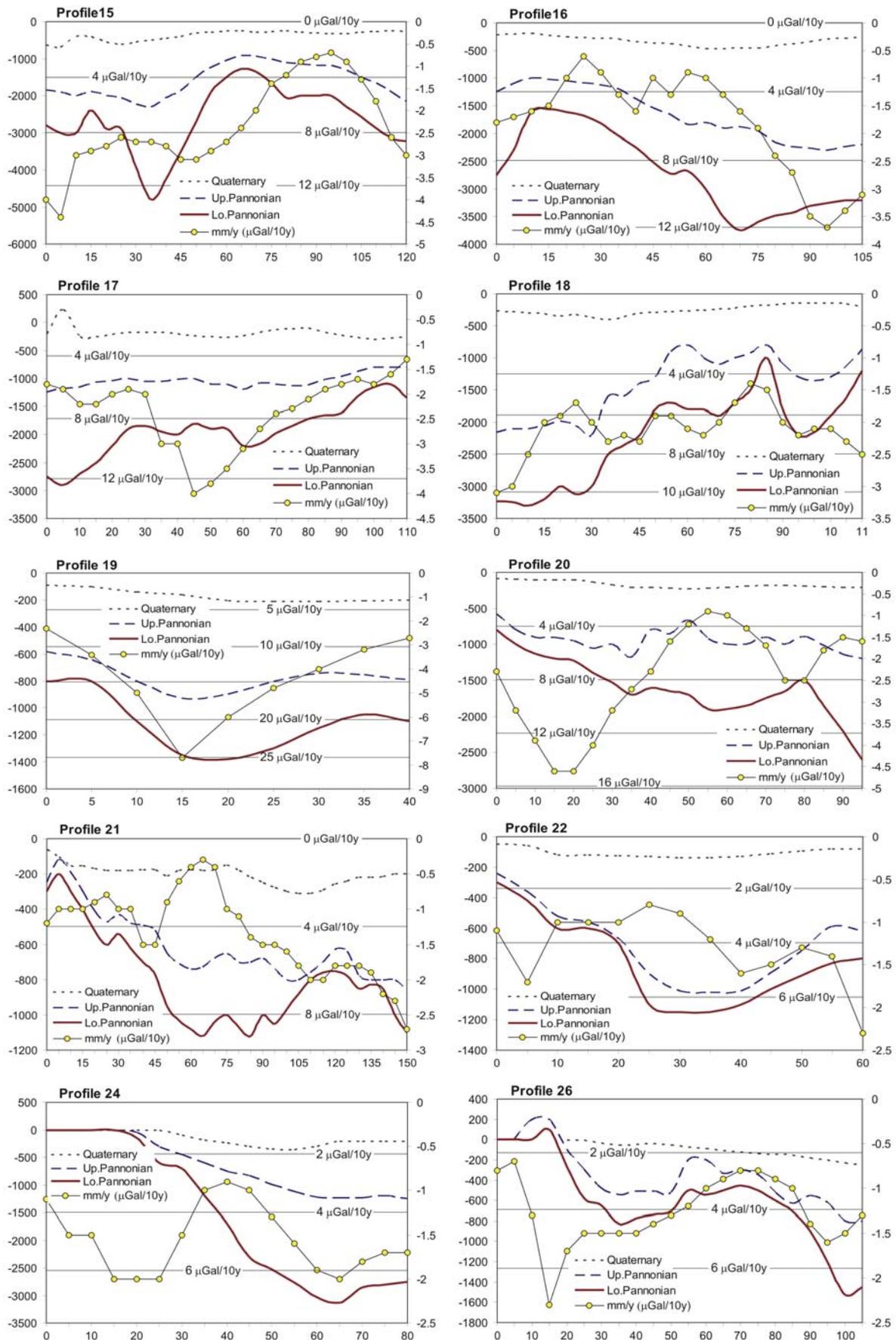


Fig. 3. Sediment thickness, velocity of vertical surface movement and gravity changing along levelling lines.

Based on the presented graphs, we have calculated the expected gravity effect δg of the vertical surface movement for each profile by equation (1). The normal value of vertical gradients $VG = 0.3086 \text{ mGal/m}$ was used for the computations. The results are presented as an isoline map in Fig. 4.

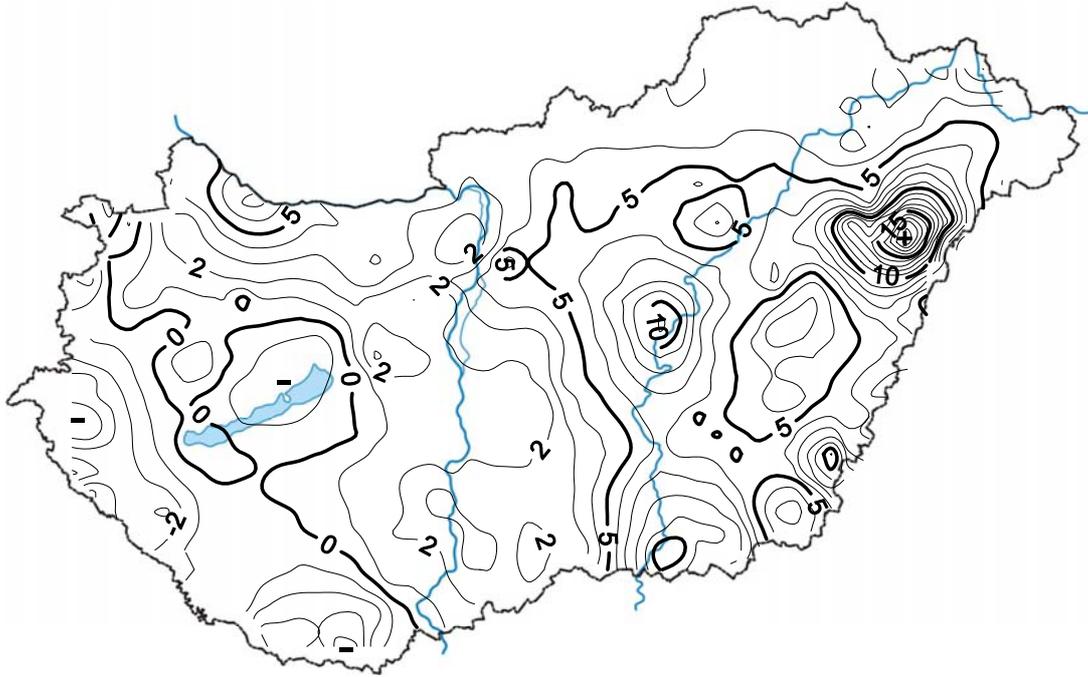


Fig. 4. Calculated gravity effect of vertical surface movements (isolines in $\mu\text{Gal}/10 \text{ years}$)

4. CONCLUSIONS

Studying more closely the graphs, it can be seen, that in spite of all uncertainty, in most cases positive correlation exists between sediment thickness and surface movement. Preliminary correlation computations show significant differences in the degree of correlation between sub-basins, the highest deviation was found in the Zala basin, with negative correlation. Accordingly, no uniform correlation can be expected for the whole area of the Pannonian basin between sediment thickness and surface movement, or between sediment thickness and gravity variation, respectively.

Supposing that the correlation differences of sub-basins can be attributed to differences in geological build-up, those sections of the levelling lines should be collected for further study, which shows similar correlation characteristics. Simultaneously those sections should be discarded in which man-made effects (fluid extraction, mining activity etc.) dominate in surface movement data.

Since gravity variations due to water-table fluctuations are in the same order of magnitude (Szabó 1977; Csapó, Szabó, Völgyesi 2003), separation of the gravity effects of different sources needs further investigation.

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