GRAVITY PROFILE 2GM ACROSS THE TATRA MTS. – INTERPRETATION (NORTHERN SLOVAKIA)

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Abstract: The gravity profile 2GM from the Spišská Belá to the NW to Tatranská Javorina village crosses the Tatra Mts. at their eastern end (Fig.1). The Tatra Mts. forms an elevated half-horst, with northern slope covered by Paleogene flysch sediments. The area south from the mountains dropped down for 3 km, northern slope is gently dipping to the north. Bouguer anomaly curve and the electric resistivity sounding reflect this tectonics, showing sharp gradient at the south and smooth dip north of the Tatra slope.

Key words: Gravity modeling, Northern Slovakia, Tatra Mts., Inner Carpathian Paleogene, resistivity profile, tectonics

Introduction

The gravity measurements were effectuated along the line 2GM, which starts south of the Spišská Belá town, oriented to the NW to the eastern edge of the Tatra Mts., crossing mountains upstream the Biela canyon to Ždiar village. Then running under the northern slope of the Belanské Tatry Mts. it turns to the north to Tatranská Javorina at the Slovak-Polish border (Fig.1, 2). Total length of the 2GM line is 32 km.

The aim of the measurements was to obtain and interpret detailed data across the distinct geological discontinuity, here called Tatra fault (in Slovak: *podtatranský zlom* – see also Gross 1973). Along the profile was effectuated also the basic vertical electric resistivity sounding (VES).

Geological setting

The investigated area belongs to the Inner Carpathian realm (Biely et al. 1996). The Tatra Mts. is the northernmost of the elevated core mountains, surrounded with

Paleocene sedimentary apron. The mountain's granite core is overlaid with autochthonous Mesozoic sedimentary sequence, and Cretaceous Alpine napes along the northern slope. The napes are irregularly displaced over the whole region also under the area covered by Paleogene sediments. We find places void of some of the napes; on the other hand, there are areas, where napes are duplicated.

The eastern part of the outcropped Mesozoic consists of the double-decked Krížna nape, over the normal Tatric cover. Total amount of tectonically stacked Mesozoic sequences is about 3 km in thickness. These sediments are dominantly of carbonates (dolomites, limestones, limy shales) in classical developments of the Tatric and Krížna sequences (Polák in Janočko et al. 2000, Nemčok et al. 1993).

For our interpretation is noteworthy a presence of the leucocratic granitoids, which seems to concentrate in the upper part of the granite core and outcrops to the west of our profile (Nemčok et al. 1994). These granites are generally lighter than the rest of the magmatic and metamorphic complex.

The latest sediments in the area are of Quaternary age, which are of the (peri-) glacial and glacifluvial origin. The most of them form important slope apron attaining at places some tens of meters in thickness on the southern piedmont of the Tatras. In the area crossed by our profile, they amount to some few meters of thickness only. Anyway in some places under the glacifluvial apron on the southern slope there are indicated also pelitic sediments of undefined age (probably late Neogene?) in separated local depressions, in thickness up to 200 m (Gross et al 1999, Mikuška et al. 1996).

The Tatra Mountains form asymmetrical complicated half-horst structure with southern steep fault constraint (Tatra fault). The estimated relative uplift of the Tatras along this fault is more than 3000 m. The fault along its length seems to shallow its inclination to the depth – listric fault (Gross et al. 1999).

The northern slope of the Tatra Mts. gently sloping to the north displays a transgression of the Inner Carpathian Paleogene *Podtatranská group* (Gross et al. 1984), which lies over tectonically disturbed Mesozoic napes (Kœiązkiewicz 1972). The transgressive carbonaceous complex, known also as the *Tatra Eocene* (Bieda 1959), is from several meters to few hundreds of meters thick. This is followed by the flysch sequence, in the Polish part known under the name *Podhale flysch* (Kœiązkiewicz 1972). This flysch pile of the sediments was originally of some 2 to 3 km thick, but nowadays considerably reduced by erosion at places.

Structural analysis (Mastella 1975, Mastella – Ozimkowski 1979) and the remote sensing data shows that close to the present erosion rim of the Eocene sediments (in order of few km) runs a more-less distinct E–W oriented disruption zone called also the North Tatra boundary (Potfaj et al. 1995).

Gravity data – methodology of the measurements

Gravity measurements were realized by the means of the high-accurate gravity meter CG-3. Accuracy of the measurements was ± 0,015 mGal. The topographic elevations were determined by technical leveling. The calculation of the Bouguer anomalies was made according to the methodology generally used in the international cooperation among Slovak, Poland, Czech republic and Ukraine, e. i. were used new formulae for the computing of the normal gravity and appropriate corrections (Królikowski et al. 1999). The reduction density of 2,67 $g.cm^{-3}$ was chosen. The terrain topographic corrections were calculated for the radius to 166,7 km.

Quantitative analysis has been done by $2^{3/4}$-D modeling by the software GM-SYS ®. The gravity line is situated to the Central Carpathian gravity minimum, which is embedded by narrow longitudinal positive anomaly. For the MOHO-discontinuity as well as Lithosphere / Asthenosphere boundary we used the calculated model of Šefara et al. (1996) and Bielik (1999).

Vertical electric resistivity sounding (VES)

A vertical geophysical section was constructed from interpreted curves of VES. Values higher than 500 Ωm in the middle part of the profile we ascribe to Mesozoic rocks of Krížna nape. Southern part of the profile with resistivity 10 - 100 Ωm we interpret as flysch intercalation of sandstones and claystones. Values of 130 - 430 Ωm on the surface of the northern part are by surprise higher than measured in the Zakopane IG-1 well (Rokosz, 1973), though the lithology seems to be the same.

Seismic data

The seismic line 753/93 (to depth of 6 sec. TWT) runs in SE-NW direction and crosses our gravity profile near the Rakúsy village (Vozár et al. 1999, Baráth et al. 1996) (Fig. 2). From the original material we reinterpreted the course of some important reflection horizons. Thus the top of highly reflective layer on the 0,5 sec. TWT is interpreted as the base of the Paleogene sediments, and the transparent channel

between the 1,5-2,5 sec. TWT as a „granitic“ layer. Reflective horizons beneath this channel down to 5 sec. TWT (equals 10-15 km) are already in the upper crust, which is well layered. A layering here is of tectonic origin (thrust and shear zones). Different undefined paleotectonic units (such as hypothetical Penninicum, or Inačevo–Kričevo unit...) are interpreted by various authors, but we do not favorize any of the geological ascriptions, as there is no relevant data to present state of research.

Interpretation

Our model (Fig. 3) is based on the surficial geological situation extrapolated to the depth along the profile line. The large-scale physical properties of the lithosphere are plotted to this profile.

The selection of the density of Paleogene sediments seems to be too light according to the data from the boreholes (Šariš 1 – Pícha in Koráb et al. 1986). On the other hand they are slightly higher than refer Stránska et al. (1986) –generally between 2,5 and 2,6 $g.cm^{-3}$.

The strong gravity gradient of the Bouguer anomaly curve is caused by the tectonic contact of the Tatra Mts. with the Inner Carpathian Paleogene sediments at south. Local anomalies caused by different sources are visible on the curve, for example the small, but marked local negative anomaly in the center of the profile, we interpret as a subsurface karst-and-cave phenomenon, with differential density of –0,1 mGal.

An expressive contact of low resistivity and high resistivity area in the middle part of the section we assume to a tectonic contact of the Vysoké Tatry Mts. core with Tertiary sediments of the Popradská kotlina depression.

Conclusion

The gravity measurements along the 2-GM line confirmed some geological presumptions and interpretations as:

-The northern slope of the Tatra Mts. sinks gently to the north. The existence of the North Tatric boundary cannot be confirmed until the profile will be prolonged to the north to Polish territory.

-The Tatra fault along the southern slope of the Tatra Mts. was confirmed. The disrupted zone may consist of several minor associated faults. The dip of the (fault) zone seems to be steep at the surface according to electric resistivity measurements, and in depth declines to the south, resembling a listric fault.

-In the Mesozoic sequences of the Krížna nape at the eastern termination of the Tatras we suggest karst-and-cave phenomena indicated by local, but distinct negative anomaly.

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Captions to fig. 2:

1 – 2: Inner Carpathian Paleogene (Podtatranská group): 1 – Eocene (Podhale) flysch sequences; 2 – Eocene Nummulitic and carbonaceous limestone and breccia

3: Mesozoic sedimentary complexes (Tatro-Veporic)

4 – 5: Granitoid core: 4 – light leucocratic granites; 5 – granites, granodiorites and other magmatic rocks

6: Area of negative Bouguer anomaly more than –40 mGal

7: Faults

8: 2GM line

9: Seismic lines

Captions to fig. 3:

1: Quaternary glaciflufial and Late Neogene (?) lacustrine sediments

2: Inner Carpathian Paleogene: with different proportion of the sandstone/claystone ratio

3: Mesozoic (Tatro-Veporic) complexes; mainly limestones, dolomites, quartzites); karstified at places (a)

4: Tectonised rocks along the fault zone

5: Granitic layer, with „light“ leucocrate granites in the top

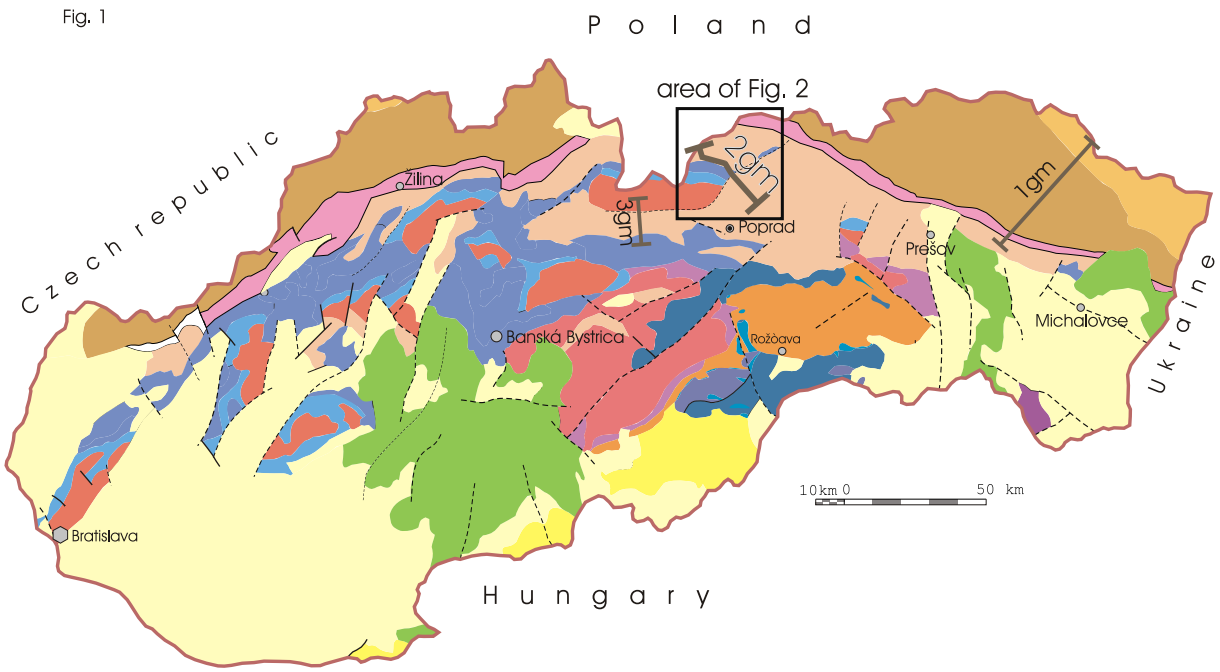
6: Layered methamorphic complexes of the upper crust

7: Lower (?) crust elements

8: Faults

9: Differential density

Fig. 1


P o l a n d
area of Fig. 2
2gm
3gm
1gm
Czech republic
Žilina
Poprad
Prešov
Michalovce
Banská Bystrica
Rožňava
Bratislava
Ukraine
H u n g a r y
10km 0
50 km

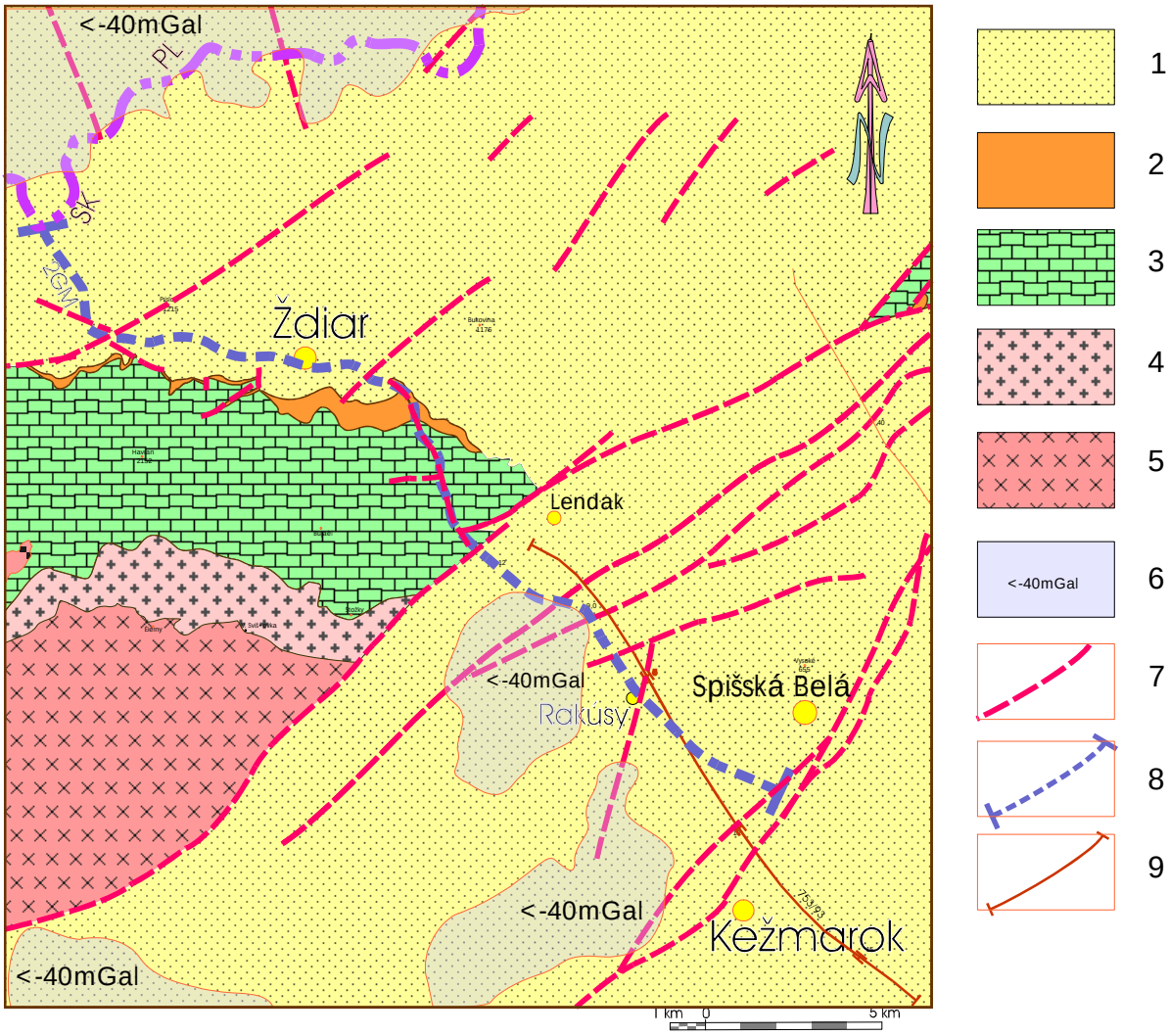
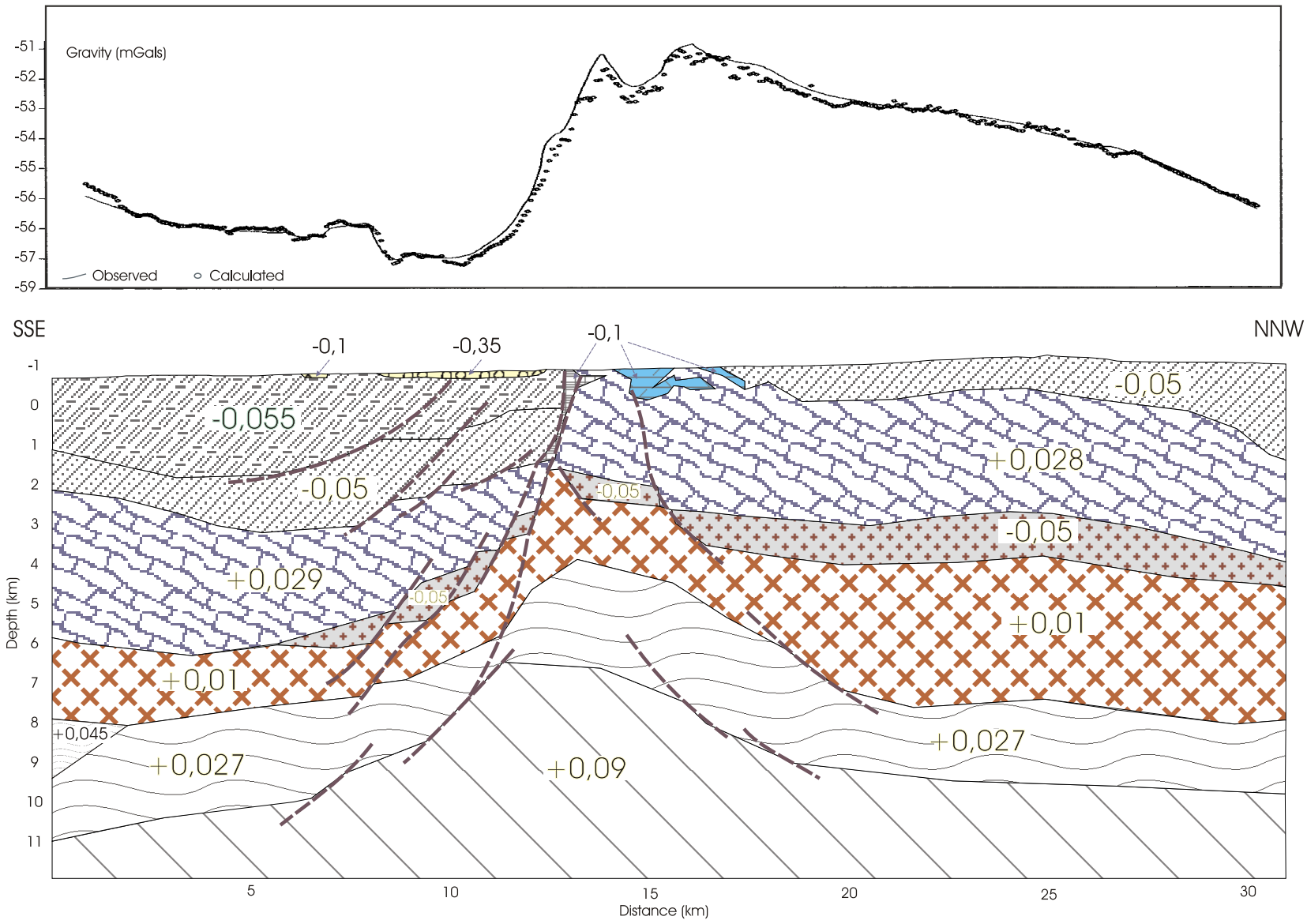

<-40mGal
PL
SK
ZGM
Ždiar
Lendak
<-40mGal
Rakúsy
Spišská Belá
<-40mGal
Kežmarok
<-40mGal
1 km 0 5 km
1
2
3
4
5
<-40mGal
6
7
8
9

Fig. 3


Gravity (mGals)
-51
-52
-53
-54
-55
-56
-56
-57
-59
Observed
Calculated
SSE
NNW
-0,1
-0,35
-0,1
-0,055
-0,05
-0,05
-0,05
-0,05
+0,028
+0,029
+0,01
+0,01
+0,045
+0,027
+0,09
+0,027
Depth (km)
Distance (km)
5
10
15
20
25
30