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INTERPRETATION OF THE GRAVITY ANOMALY OF AN AMPHIBOLITE BODY IN THE MALÉ KARPATY MTS.

(Figs. 7, Tabs. 1)

Abstract: On the basis of an application of an inverse three-dimensional gravimetric problem, we have interpreted for the first time the gravity anomaly of an amphibolite body in the southern part of the Malé Karpaty Mts.

Резюме: На основе применения обратной трехмерной гравиметрической задачи мы первый раз интерпретировали весовую аномалию тела амфиболитов в южной части Малых Карпат.

Introduction

In the last years we could observe an increased interest of geologists and geophysicists in the Malé Karpaty Mts. This interest has been conditioned mainly by the discovery of new facts about their structure, especially the allochtonous position of the crystalline complex of this mountains (Mahel', 1980).

The dominating member of the Malé Karpaty Mts. crystalline complex (Cambel—Kamenický, 1982) are the Variscan granitoid rocks (Bratislava and Modra massifs), which form more than two-thirds of the area of the Malé Karpaty Mts. crystalline complex. The largest zone of crystalline schists is situated in the so-called Pezinok—Pernek crystalline complex, which separates the two massifs. Fundamental rocks of the Malé Karpaty crystalline schist complex, besides extensive granite massifs, are crystalline schists of Lower Palaeozoic age. They are biotite phyllites, biotite-garnet schist-gneisses to biotite-garnet gneisses and chlorite-sericite phyllites without biotite. Among the crystalline schists of the Malé Karpaty Mts. area are also various types of amphibolite rocks, which represent metamorphosed diabases and their pyroclastics, or hypabyssal bodies belonging to magmatic rocks of the complex. This complex (Cambel—Kamenický, l. c.) is assumed to be pre-orogenous in the evolution of the Variscan geosyncline. The proportion of metabasites in the core mountain ranges is largest in the Malé Karpaty Mts.

The increased interest in geological structure of the Malé Karpaty Mts. has influenced also the speeding up of gravity mapping in the southern part of the mountain range on the scale 1 : 25 000, as this area was one of the few areas of Slovakia not surveyed on this scale. As a consequence, the Malé Karpaty Mts. are comparatively less explored from the point of view of gravity investigation (and it could be said that not only from this point of view).

The result of gravity mapping is a map of Bouguer anomalies (for $\sigma = 2.67$ kgdm^{-3}), on the scale 1 : 25 000, which has been completed by workers

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of Geofyzika, nat enterpr., branch Bratislava (S z a l a i o v á et al., 1982) and also qualitatively interpreted by them. Within the scope of this qualitative interpretation, some important (even paradoxical) phenomenons of the relation of gravity field to the geological structure of the Malé Karpaty Mts. have been pointed out (K u r k i n—M i k u š k a—O b e r n a u e r—P o s p í š i l, 1984).

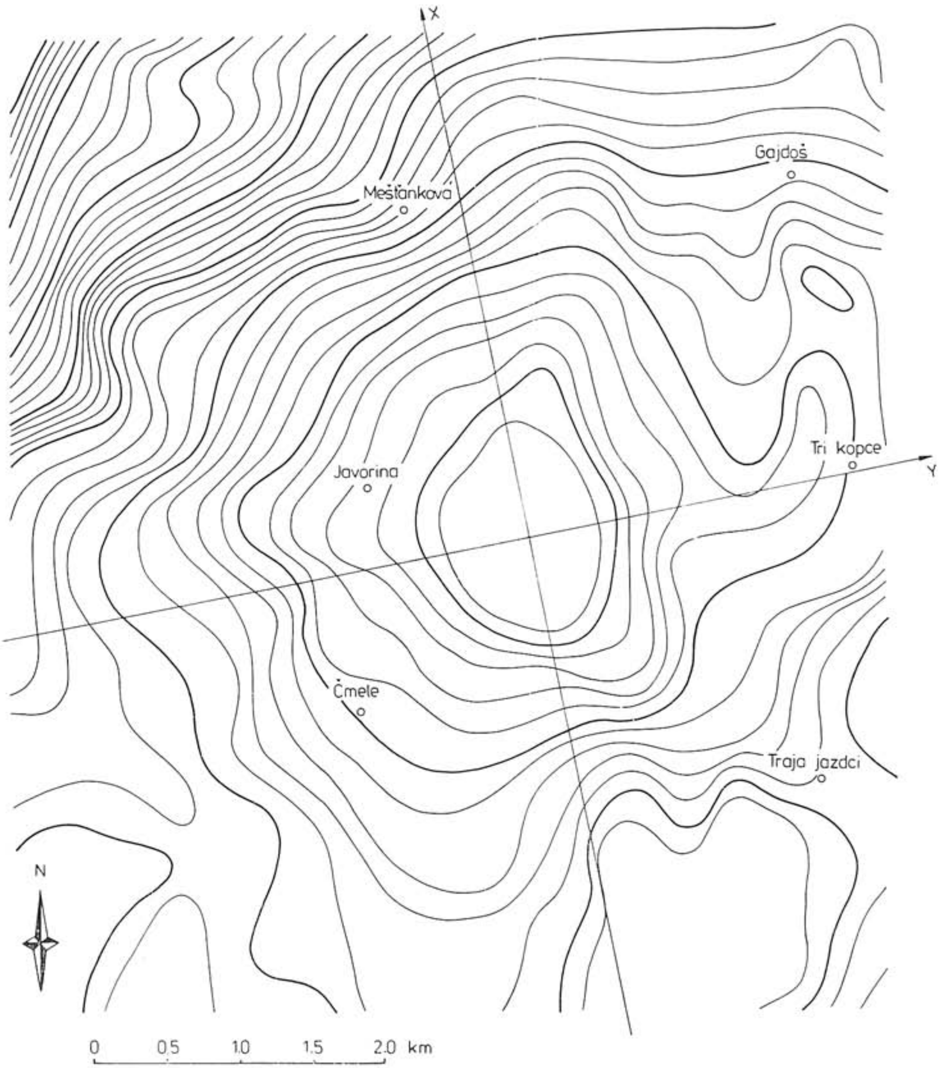


Fig. 1. Bouguer gravity map.

On the Bouguer gravity map, the southern part of the mountain range is displayed as an outstanding regional gravity elevation, evoked by the effect of heavier Palaeozoic and Mesozoic rocks. This phenomenon was known also in the past (Fusan et al., 1971; Plančár, 1980; Bielik, 1980). From the results of a detailed gravity mapping it is, nevertheless, possible to observe a number of local (residual), relatively positive as well as negative anomalies in this elevation area. The areally most extensive one spreads approximately between the elev. points Traja jazdci — Tri kopce — Gajdoš — Mešťankova —

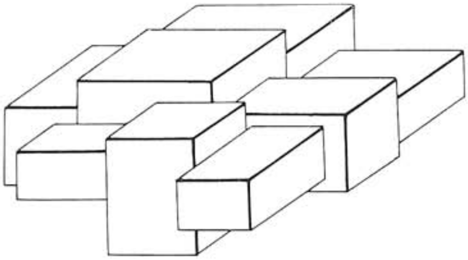


Fig. 2. Model composed of rectangular prisms.

Čmele (Fig. 1). Its amplitude is approximately 205—210 μms^{-2}. On the basis of an analysis of the gravity field in relation to main rock types we judge that the anomaly is a manifestation of especially amphibolite rocks of the Malé Karpaty Mts. Palaeozoic, which emerge on the surface on this territory. As this anomaly appears as one of the most prominent elements of the gravity field, it became the object of our interest. In other words, we attempted its quantitative interpretation with the help of an inverse gravimetric problem. This was solved by iteration method of least squares for the interpretation of three-dimensional gravity field (Dyrelius, 1972; Dyrelius—Bina, 1973).

The basic or primary model used to solve this method is composed of a system of rectangular prisms (Fig. 2). The gravitational effect of a prism is expressed in a form easily programmable on a computer, while it is no problem to find an expression of the effect of a complex of such prisms. The gravitational effect of irregular masses at any arbitrary point can be then calculated by an approximation of their shapes by prisms. The parameters of position of the prisms to the calculated points can be changed; this is used to make the model of an anomalous body more accurate. This process (Sitárová—Bielik, 1984) has a good stability and it converges well. Assuming that we know the depths of the upper surfaces of the prisms, the lower surfaces are adjusted by iteration process until the gravitational effect of the whole model corresponds (in the least-square sense) with the measured data.

The interpretation process

The first, but very important step of interpretation is the separation of gravity effects of which the interpreter assumes that they are connected with concrete anomalous masses interesting for him, from the effects which are of no interest. It is thus the case of a problem of separating residual as well as regional anomalies from the Bouguer gravity map. The character of the residual anomaly depends on the qualitative determination of the regional effect defined by Roy (1961) as an anomaly which we would measure if the investigated structures were separated in space and their effects were not disturbed by too deep or too wide sources. In this sense, the residual anomaly is really a residue after an ideal removal of the regional effect. For the determination of the regional field, graphical or numerical methods are used. The graphical method, which was applied in our case, is biased by subjective approach of the

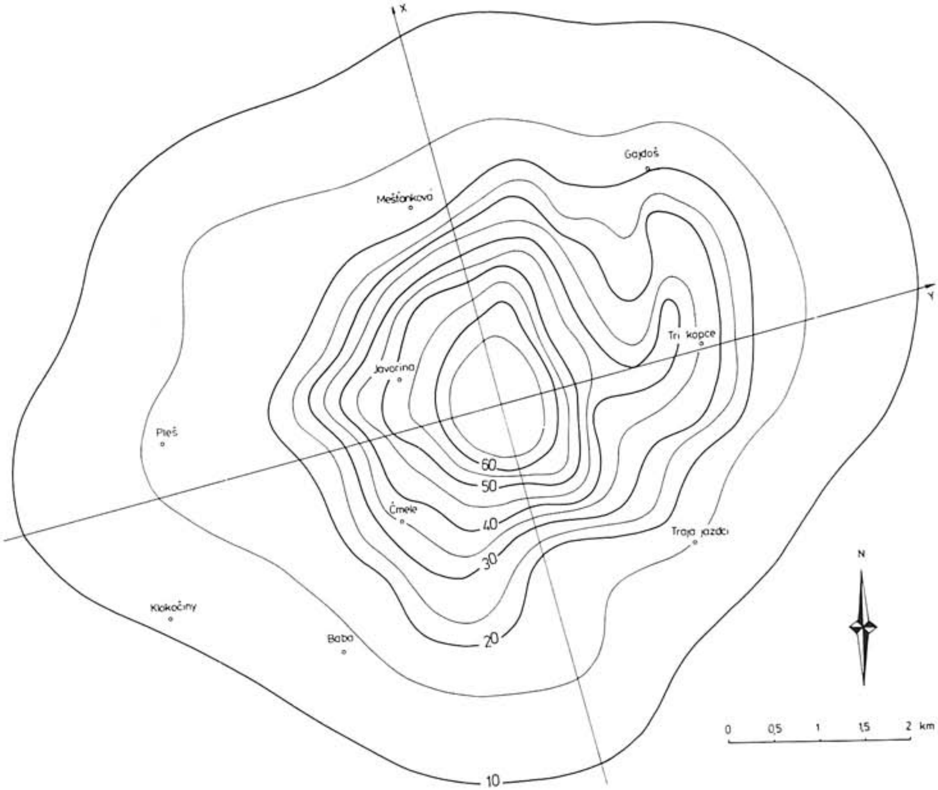


Fig. 3. Residual gravity map.

interpreter, but it permits an application of his knowledge of the geological structure. The regional background has been determined on more profiles crosscutting the anomalous area; on the basis of them we have elaborated its areal image. By substracting the regional background from the measured values of Bouguer anomalies we obtained the local anomaly of the gravity field which should, with the greatest possible probability, express the effect of the investigated anomalous body. The maximal amplitude of the anomaly is approx. 66 μms^{-2}. From Fig. 3 it follows that the centre of the anomaly is situated approx. 1 km ESE from the elev. point Javorina. The sigmoidal bends of the isoanomalies of the gravity field in the NNW-SSE direction (westwards from the elev.

point Tri kopce) are caused by surfatial emergence of granodiorites and crystalline schists less dense compared with the heavier amphibolite rocks. Further we digitalised the investigated anomaly in 131 points of a square lattice with a step $\Delta x = \Delta y = 250$ m.

The surfatial exposure of amphibolite rocks (Mahel—Cambel et al., 1972) as well as the shape of the anomaly indicate the manner in which the

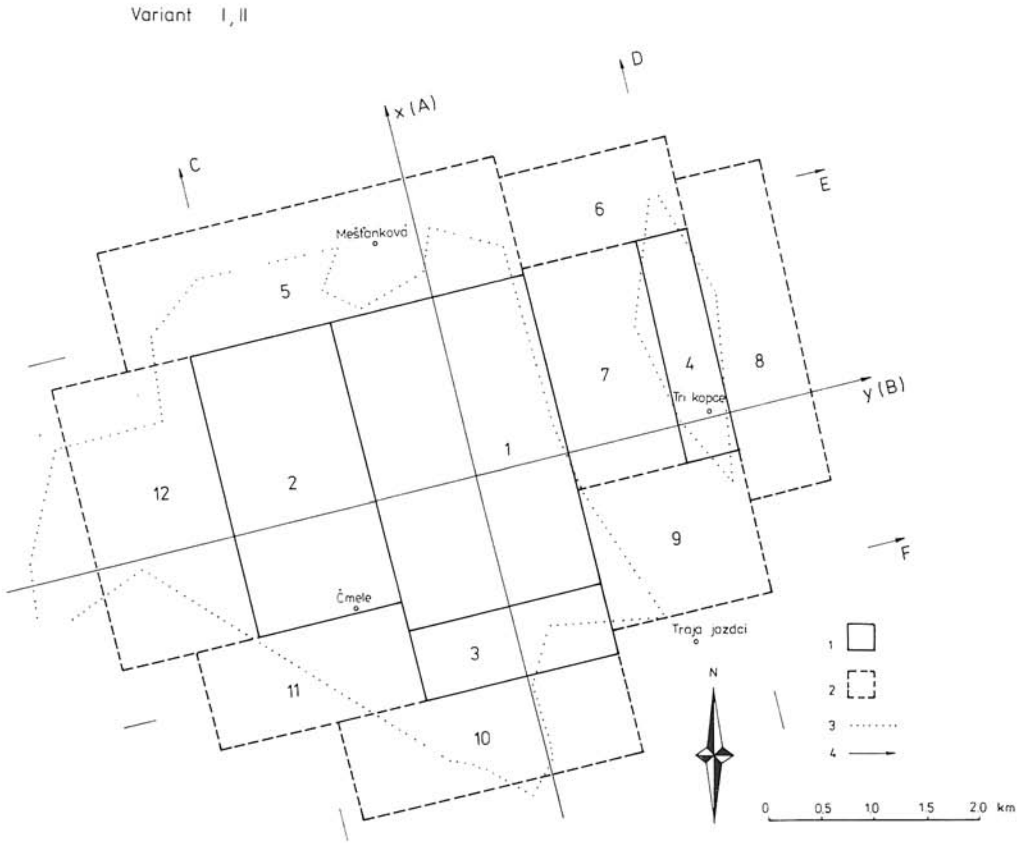


Fig. 4a.

prisms approximating the anomalous body should be distributed and the manner in which the depths of their upper bases should be determined. The primary model has thus been constructed on the basis of smoothened (or simplified) contours of the surfatial exposure of amphibolite rocks and of the shape of the investigated anomaly. This model has then been tested with varying distribution of prisms, depths of their upper surfaces and density contrasts so, that the sum of squares of the residues of the calculated gravitational effect and the values of gravity should be as low as possible. From a greater number of testing models we put forward the schemes of only four interpretation models. In our work we denominated them as the variants I, II, III, IV (Figs. 4a, b, c). Their common trait is that the anomalous body is approximated by 12 rectangular prisms with a differential density of $\Delta\sigma = 0.2$ kgdm^{-3}; at the same time the prisms denominated as No. 1—4 have depths of upper surfaces equal to 0 m. The depth of the upper surfaces of the prisms No. 5—12 is in the variants I,

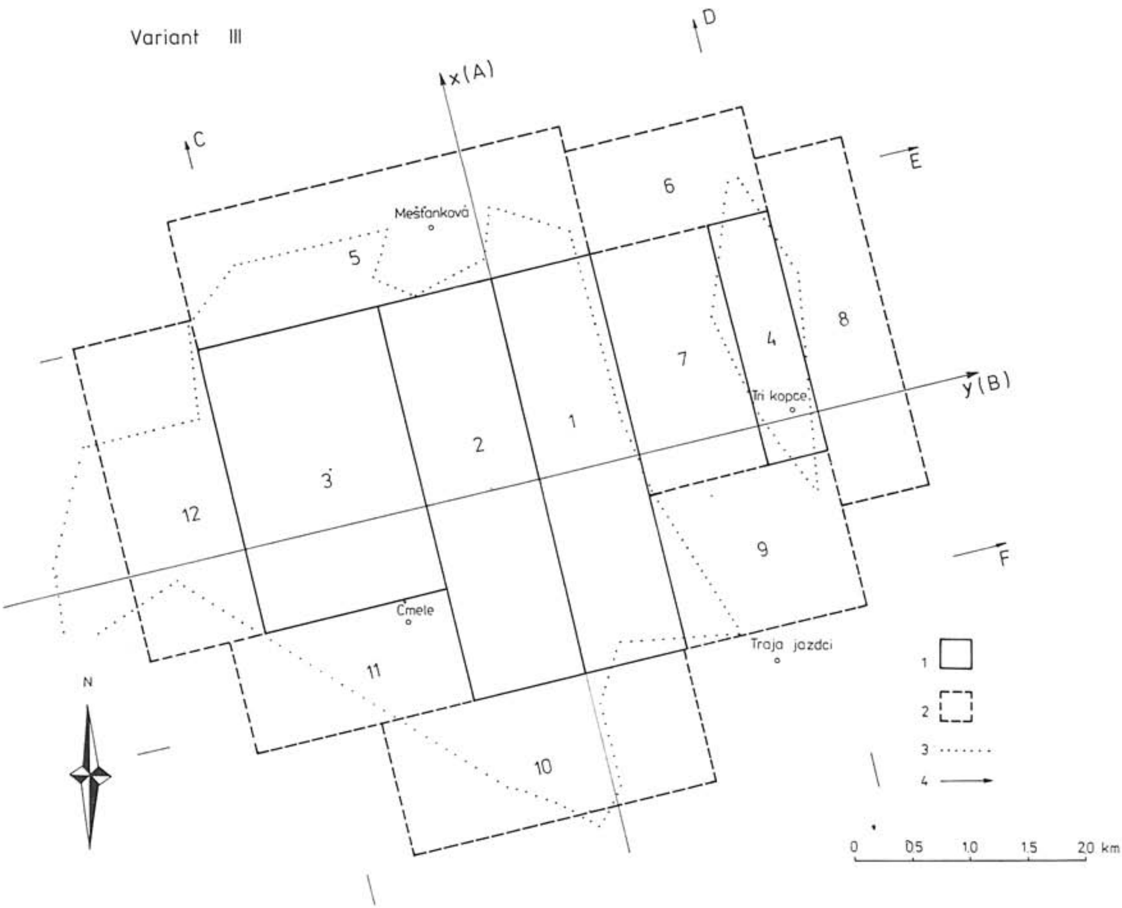


Fig. 4b.

III, IV (II) equal to 100 m (50 m). The distribution of the prisms in the variants I and II is thus the same, only the depths of their upper surfaces are different.

Achieved results

The results of quantitative interpretation with the help of an application of the method of Dyrelius (1972) for a three-dimensional gravimetric problem are displayed in Tab. 1 and illustrated by Figs. 5—7. In the Tab. 1 are stated the calculated unknown depths of the lower bases of the individual prisms for all variants. On the Fig. 5 are selected correlations of gravity effects and calculated gravitational effects of the interpretation model (for the variant I) on the profiles X = 0 and Y = 0. The selected sections of the models approximating the anomalous body along the profiles A, B, C, D, E, F are presented

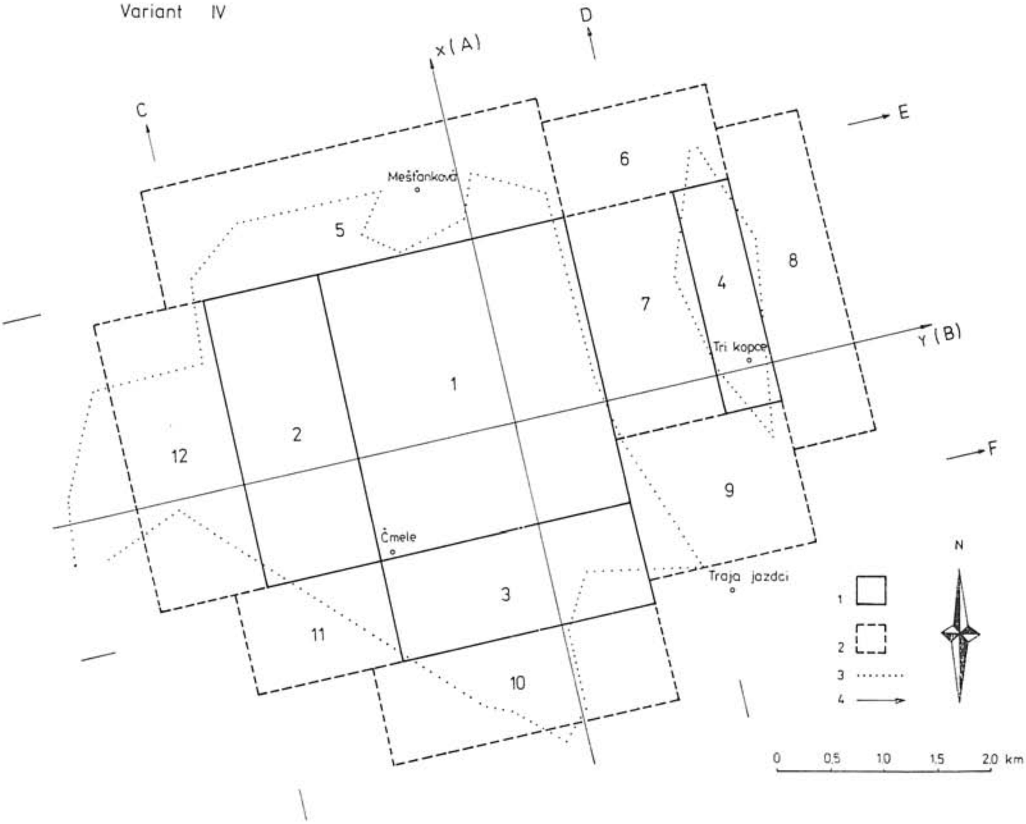


Fig. 4c.

Fig. 4. Distribution of prisms in the final interpretation model.
Explanations: 1 — contour of surfatial prism; 2 — contour of subsurfatial prism; 3 — simplified contours of surfatial exposure of amphibolite rocks; 4 — course of the profile of a vertical section of the model.

on Figs. 6 a, b, c, d. A general image of the achieved results can be received from a view at Figs. 7a, b, c, d. Here are depicted the perspectives of the resulting three-dimensional model, divided by several sections along the X and Y axes, for each variant.

From a general analysis of the achieved results it follows that the anomalous body reaches its greatest thickness in its central part, which can be characterised

Table 1

Table of depths of upper and lower surfaces of prisms

No. of prism	Depth of upper surface of the prism [m]				Depth of lower surface of the prism [m]			
	Variant							
	I	II	III	IV	I	II	III	IV
1	0	0	0	0	1298	1331	832	1091
2	0	0	0	0	270	276	1366	123
3	0	0	0	0	102	111	239	274
4	0	0	0	0	529	815	387	445
5	100	50	100	100	256	195	276	253
6	100	50	100	100	311	240	317	323
7	100	50	100	100	405	290	621	511
8	100	50	100	100	440	296	478	462
9	100	50	100	100	408	322	390	471
10	100	50	100	100	409	328	260	404
11	100	50	100	100	377	304	338	342
12	100	50	100	100	323	254	324	356

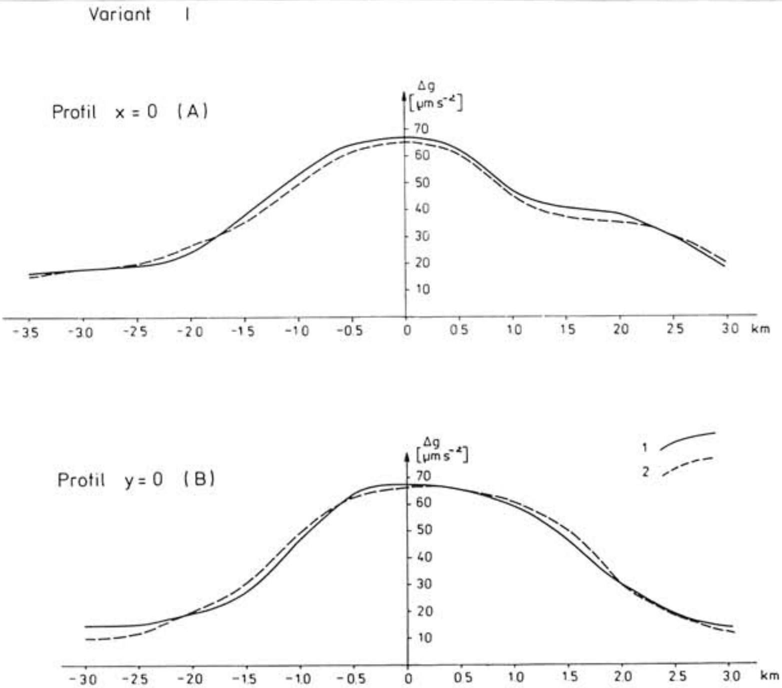


Fig. 5. Profile along the X and Y-axes.
Explanations: 1 – measured gravity field; 2 – calculated gravitational effect.

by the prism No. 1 in the variants I, II, IV, or by the prisms No. 1 and 2 in the variant III. The maximal thickness in this part varies between 832 m and 1331 m. Its average value is approx. 1200 m. The thickness of the body outside the central part is substantially smaller. When not taking into consideration the anomalous masses spreading between the elev. points Traja jazdci and Gajdoš (prism No. 4), the thickness of the body in its lateral parts is on average only about 234 m. In the case of the prism No. 4, the depth of its lower surface varies between 387 m and 815 m.

Conclusion

From the point of view of a three-dimensional quantitative interpretation of gravity anomalies, the applied method proved to be very advantageous. It is one of the few methods which give a possibility to compute the depth of the lower surface of the anomalous body — i. e. one of the most important parameters, but also one of the most difficult to determine. In addition, this method is relatively simple, easy to programme and very effective. The computation of one model on the computer SIEMENS 4004/150 took for five iterations on average only 12.3 seconds.

Nevertheless, in present we cannot make an unambiguous statement as to its practical exactness, i. e. about the exactness of the calculation of the lower base of the investigated anomalous body of the Malé Karpaty Mts. Firstly, in spite of a good correspondence of the measured gravity values and the calculated effect of the approximated anomalous body, the inverse gravimetric problem is not unambiguous. Because of this, we propose in our paper four different variants of the resulting model. Secondly, in this area, up to this date, no exact geological — geophysical data exist concerning the depths of this amphibolite body, which we could compare with the calculated depths. We also know that if there are a priori known geological — geophysical data available to the interpreter, the area of ambiguity narrows considerably.

In spite of the mentioned facts we think that the achieved results of the quantitative interpretation of the investigated anomaly entitle us to state a few hypotheses. We do not agree with the opinion of Bialostocky et al. (1976) who presume that the source of this marked positive anomaly of gravity field is a very deeply rooted element formed by heavy rocks, which occur in depths of the order of 1 km beneath the amphibolite rocks. As our results have shown, the opposite is true: it is the heavy amphibolite body with a density of $\sigma = 2.91$ kgdm^{-3} (Eliáš—Uhmann, 1968), with its "roots" in its central part up to a depth of approx. 1200 m, by which it is possible to explain the cause of this anomaly. This conclusion is justified also by other facts. Namely, if we would admit the existence of a source of the anomaly according to the presumption of Bialostocky et al. (l. c.), it would be a case of a regional anomaly, not of a residual one. However, the general analysis of the gravity field negates this presumption. After deducting the gravity effect of the body, this anomaly practically vanishes from the image of the field on the Bouguer gravity map. In addition, if this were a case of a deeply rooted element consisting of heavy rocks, the density of this element would have to be even considerably higher ($\sigma = 2.91$ kgdm^{-3}) than the density of amphibolite rocks to manifest itself in the measured gravity field in such shape and intensity

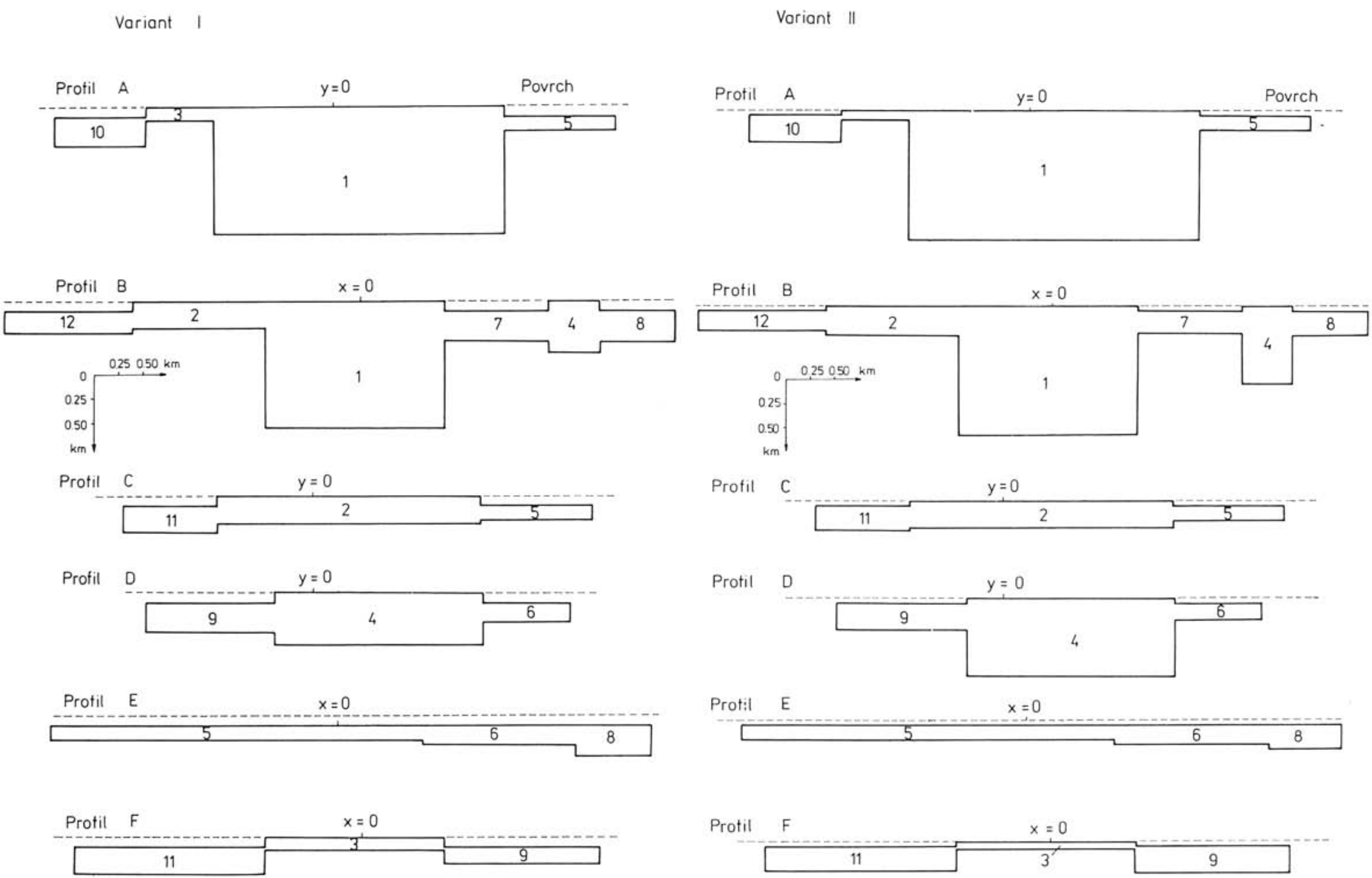


Fig. 6. Vertical cross-sections of the best-fitting model.

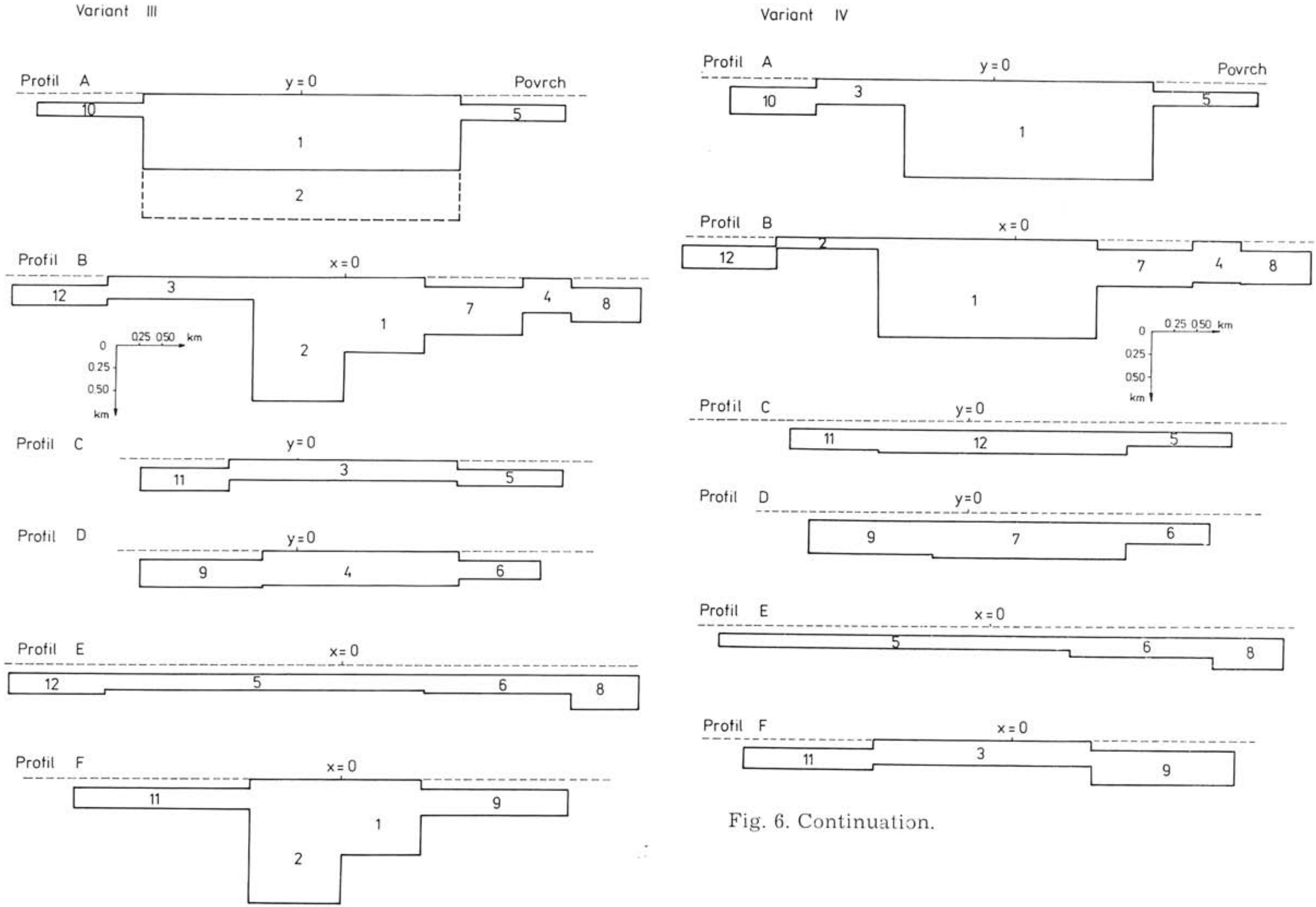
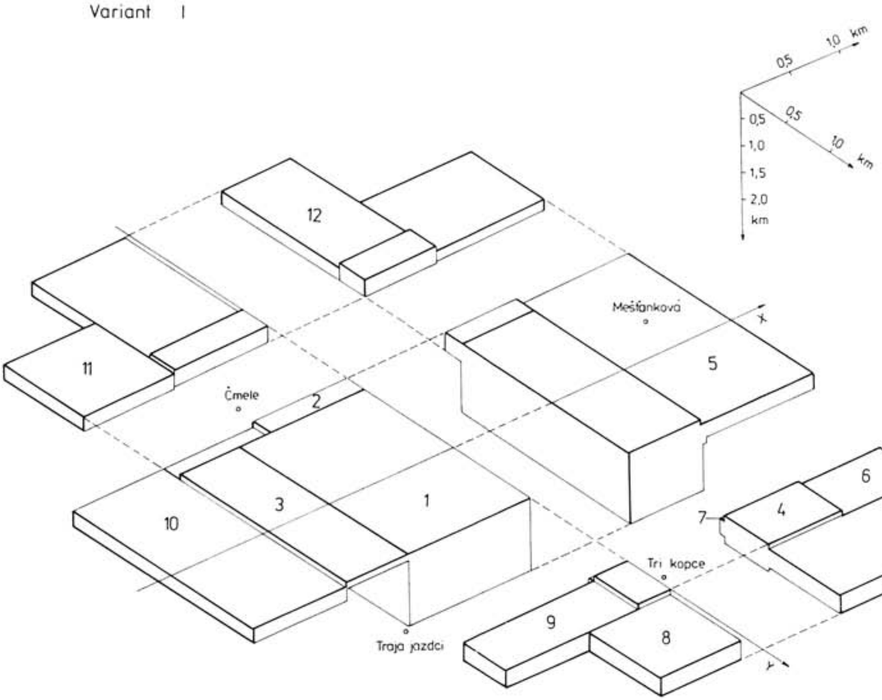
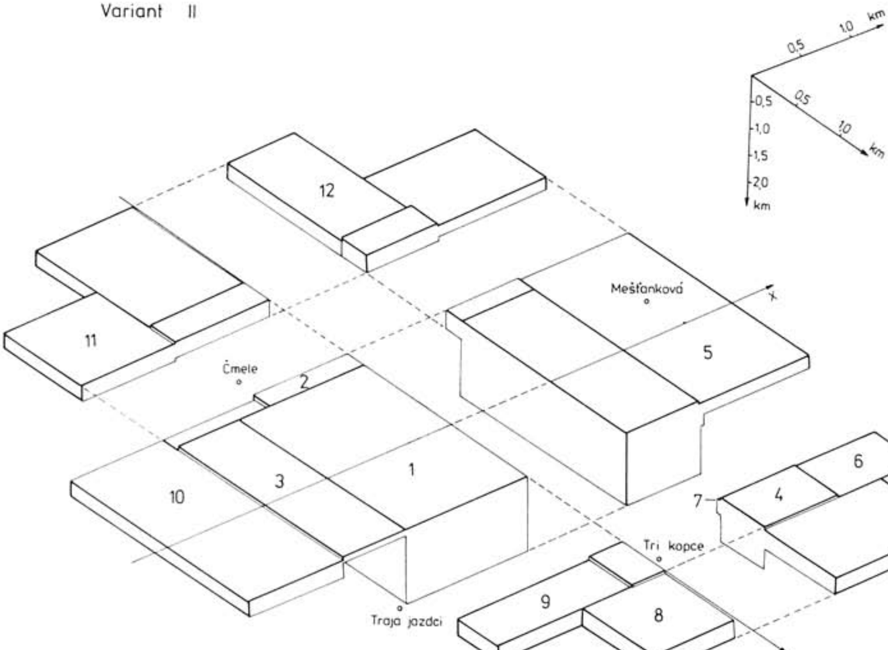


Fig. 6. Continuation.


Variant I
0,5
1,0 km
0,5
1,0
km
0,5
1,0
1,5
2,0
km
12
11
Mešťanková
X
5
Čmele
2
10
3
1
6
7
4
Tri kopce
9
8
Traja jazdci
Y


Variant II
0,5
1,0 km
0,5
1,0
km
0,5
1,0
1,5
2,0
km
12
11
Mešťanková
X
5
Čmele
2
10
3
1
6
7
4
Tri kopce
9
8
Traja jazdci
Y

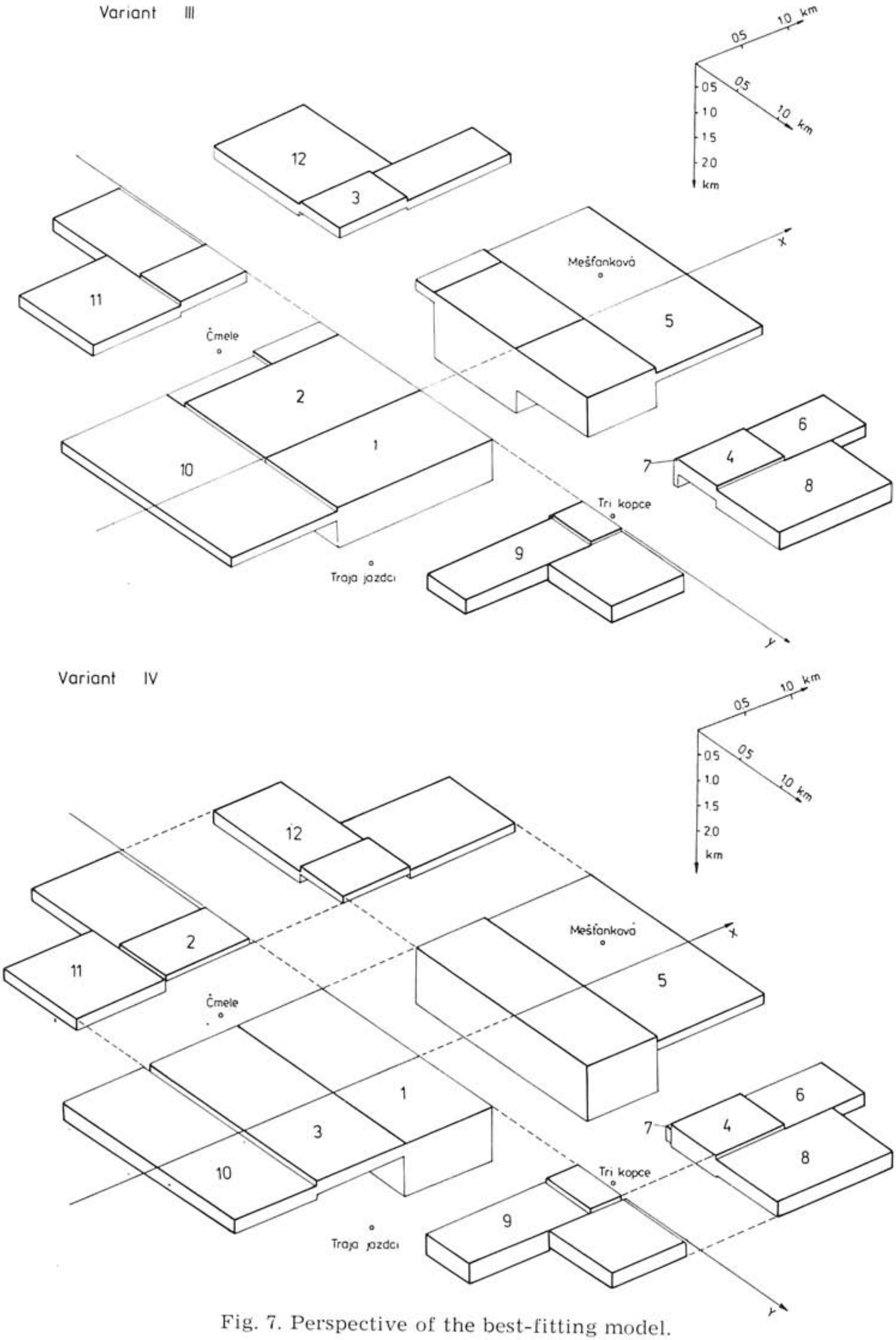


Fig. 7. Perspective of the best-fitting model.

as this anomalous area appears. On the basis of knowledge of the density characteristics of the rocks of the inner Western Carpathians, this presumption does not appear to us to be well-founded.

From everything what was said it follows that the verification of the interpretation models proposed in this paper requires a more detailed geological — geophysical survey. Nevertheless, in spite of the mentioned facts we think that the achieved results bring the first valuable information on quantitative data of the size and depth of the investigated anomalous body.

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