CHARACTERISTICS OF THE GEOLOGICAL AND GEOPHYSICAL STRUCTURE OF THE PANAGYURISHTE ORE REGION ACCORDING TO GRAVITATIONAL DATA

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ABSTRACT. Analysis and interpretation of gravitational field in scale 1:100000 are performed for the investigation of the geological and geophysical structure of the Panagyurishte ore region.
The density of the different petrography types varies in a very wide range – from 2.53 up to 3.02 g/cm^3, creating in such a way a good precondition for the effective utilization of data connected to the gravitational field distribution.
The compound analysis and the component characteristics of the gravitational field are performed on the base of the observed field Bouguer anomalies and the following transforms: upward continuations at heights from 1 km up to 10 km, with a step of 1 km; calculation of average values for circle radii R = 3, 5, 10 and 15 km; calculation of the variation anomalies compiled from the centre-point and ring method of Griffin using circles of radii R = 1, 3, 5 and 10 km; downward continuations to depths 1, 2 and 3 km.
The compound analysis and interpretation of the Panagyurishte ore region gravitational field gives reason for the following conclusions: the territory under study is situated in a regional gradient field that is including the western part of the Srednogorie gravity minimum; the ore deposits and the ore showings are located along the gradient transitions of the gravity minimum; in the depth interval down to about 5-10 km by predominant influence are characterized the metamorphic complex having increased density (positive anomalies) and the granitoids and the rocks of the volcanic complex having relatively decreased density (negative anomalies); in the depth interval down to about 3 km important influence has also the additional destruction of the rocks connected to the ore-forming processes.

ХАРАКТЕРИСТИКА НА ГЕОЛОГО-ГЕОФИЗИЧНИЯ СТРОЕЖ НА ПАНАГЮРСКИ РУДЕН РАЙОН ПО ГРАВИТАЦИОННИ ДАННИ

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РЕЗЮМЕ. За изследване на геолого-геофизичния строеж на Панагюрския руден район е извършен анализ и интерпретация на гравитационното поле в мащаб 1:100000.
Разпределението на плътността на петрографските видове е в много широк диапазон – от 2.53 до 3.02 g/cm^3, което е основна предпоставка за ефективно използване на данните за разпределението на гравитационното поле.
Общият анализ и компонентната характеристика на полето на силата на тежестта са извършени въз основа на наблюдаваното поле в аномалии Буге и следните преобразования: аналитично продължение в горното полупространство на височина от 1 до 10 km със стъпка 1 km; аритметично усредняване с радиус 3, 5, 10 и 15 km; изчисляване на вариационните аномалии по метода на Андреев-Грифин с радиус 1, 3, 5 и 10 km; аналитично продължение в долното полупространство на дълбочина 1, 2 и 3 km.
Комплексната интерпретация на гравитационните данни дава основание да се направят следните основни изводи: изследваната територия се разполага върху регионално градиентно поле, което обхваща западната част на Панагюрския гравитационен минимум; рудните находища и рудопроявленията се разполагат по градиентните преходи на гравитационния минимум; в дълбочинния интервал до 5-10 km основно отражение намира разпределението на метаморфния комплекс с повишена плътност (позитивни аномалии) и гранитоидите и скалите от вулканския комплекс с относително понижена плътност (негативни аномалии); за дълбочинния интервал до около 3 km съществено влияние оказва и допълнителното разуплътняване на скалите, свързано с рудообразователните процеси.

Introduction

Analysis and interpretation of the gravitational field in scale 1:100000 are performed for the investigation of the geologic-geophysical structure of the Panagyurishte ore region. The territory under study includes 5427 km^2. It is aligned in N-S direction and has a rectangular shape with dimensions 67 x 81 km.

The position of the studied area is illustrated on the map of the depths towards the Moho boundary (Fig. 1).

The Panagyurishte ore region is situated in a zone characterized by depths towards the Moho boundary in the range of about 38-40 km and by a relatively small gradient of variation of these depths.

The thermal field characteristics for the studied territory are illustrated by the distribution scheme on level – 300 m, shown in Figure 2 (Velinov and Boyadzhieva, 1981). The Panagyurishte ore region is located into an elongated in NW-SE direction positive thermal zone, with temperature values along the line Popintsi-Panagyurishte-Assarel in the range of 30-35^o.

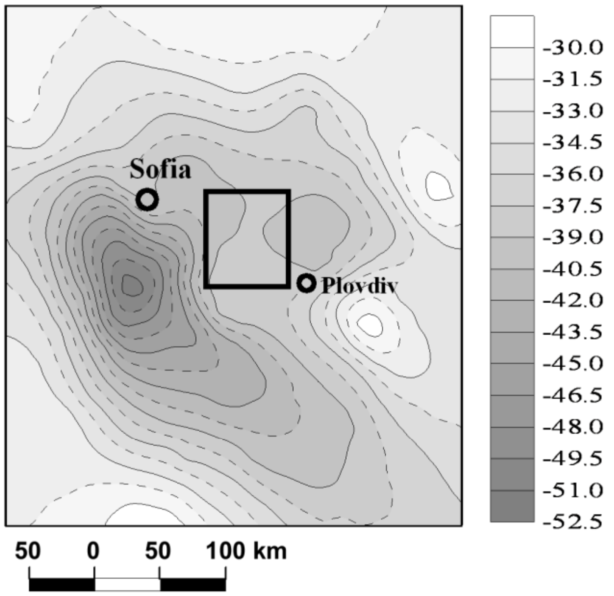

Fig. 1. Map of the depths (in kilometers) towards the Moho boundary (Boykova , 1999) and position of the studied area.

The compound analysis and the component distinction of the gravitational field are performed by the utilization of selected transforms. For the recalculation are applied traditional methods (Baranov, 1975; Telford et al., 1990; Гравиразведка, 1981, etc.). The quantitative interpretation is performed along selected profiles by the application of the selection and regularization method (Ставрев, Радичев, 1990). The obtained results are presented as schemes and as sections along selected profiles.

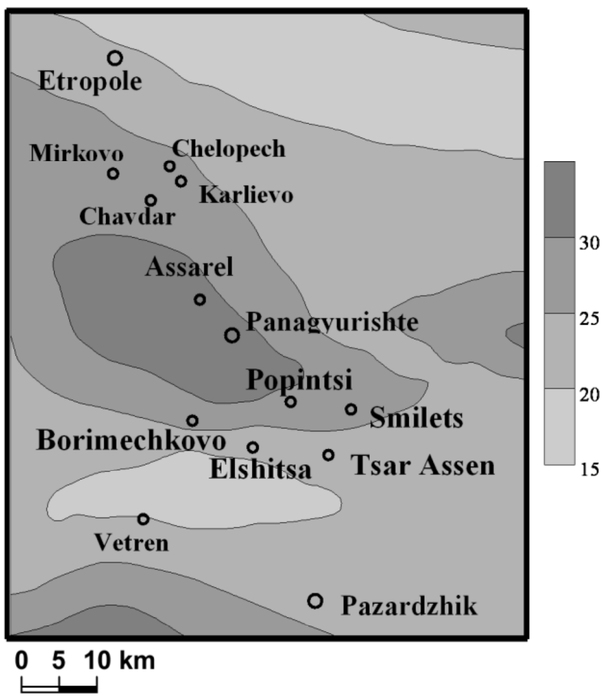

Fig. 2. Scheme of the thermal field distribution (in ºC) on level - 300 m. (Velinov and Boyadzhieva, 1981)

The summarized data (Raditchev et al., 1999; 2002, etc.) for the density and the magnetic susceptibility of the rocks that are composing the Panagyurishte ore region are presented in Table 1.

The density distribution for the different petrography types varies in a very wide range – from 2,53 up to 3,02 g/cm^3. There is a considerable overlapping of the possible density variation boundaries for the different rock types, but nevertheless, one can observe a relatively well-expressed differentiation according to the average values of this parameter. A decreased value of the density is characteristic for the dacites and the dacite tufaceous breccia of the volcanic complex, that have an average density of 2,55-2,56 g/cm^3.

The monazite-diorites are separated by a higher value for the average density – 2,71 g/cm^3. For the granodiorites and the porphyrites of the hypoabyssal complex, as well as for the andesites of the volcanic facies, the average density is 2,61-2,64 g/cm^3. The basaltic andesites are characterized by a relatively high density – the average value of the parameter is 2,76 g/cm^3. The rocks of the intrusive facies can be separated by their increased density values, as the average density for the diorites is 2,78 g/cm^3 and for the gabbro – 2,92 g/cm^3. For the gneisses of the metamorphic facies is characteristic a relatively higher density – average value of 2,71 g/cm^3, if compared towards the rocks of the volcanic and the hypoabyssal facies.

The metasomatic changes have regular influence over the density of the hypoabyssal and the volcanic rocks. The process of propylitization in the volcanic rocks is connected with an increased content of chlorite, epidot, albite, pyrite and calcite. These are minerals with relatively high density, which, for example, is up to 3,50 g/cm^3 for the epidot. Respectively, the propylitization leads to a relative increase of the density. The processes of sericitization and of potassium feldspatization and biotitization are leading to a relative decrease in the density of the subvolcanic rocks.

Analysis and interpretation of the gravitational field

The compound analysis and the component characteristics of the gravitational field are performed on the base of the observed field Bouguer anomalies and the following transforms:
- upward continuations at heights from 1 km up to 10 km, with a step of 1 km;
- calculation of average values for circle radii R = 3, 5, 10 and 15 km;
- calculation of the variation anomalies compiled from the centre-point and ring method of Griffin using circles of radii R = 1, 3, 5 and 10 km;
- downward continuations to depths 1, 2 and 3 km.

According to their morphological peculiarities and the carried information, the obtained transformed fields can be systematized in two groups :
- relatively regional fields – the upward continuations and the fields of average values for different circle radii;
- relatively local fields – the residual fields derived from the upward continuations and the fields of average values for different circle radii, as well as the variation anomalies compiled from the centre-point and ring method of Griffin using circles of different radii and the downward continuations.

Table 1. Summarized data for the density ρ (in g/cm³) of the rocks, composing the Panagyurishte ore region

Age	Facies	Type of rocks	ρ [g/cm³] 2,5 2,6 2,7 2,8 2,9 3,0
Upper Cretaceous	Intrusive (abyssal)	Diorites	
		Gabbro	
		Monazites	
	Hypoabyssal	Granodiorites	
		Diorite - , quartz-diorites and granodiorite-porphyrites	
		Quartz-monazite-diorites	
	Volcanic	Andesites	
		Andesite tuffs	
		Andesite tufaceous breccia	
		Basaltic andesites	
		Dacites	
		Dacite tufaceous breccia	
Palaeozoic	Intrusive	Granitoids	

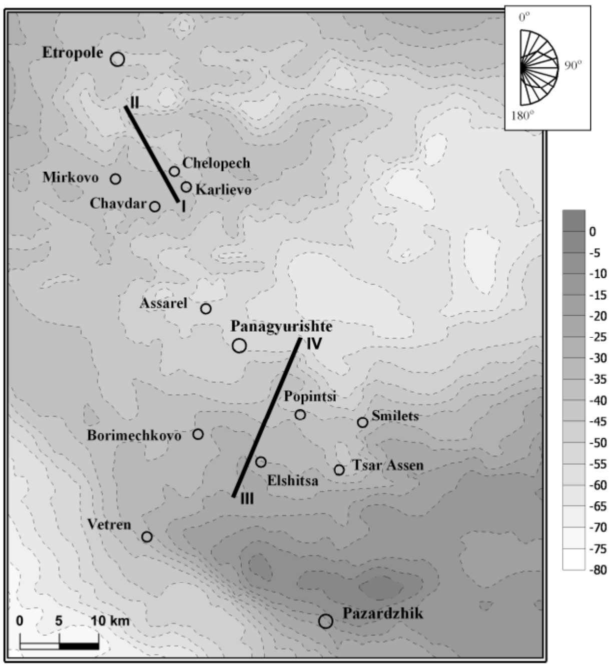

Fig. 3. Scheme of the Bouguer anomalies (in mGal) of the observed gravitational field, the position of the studied lines and a rose-diagram of the field isolines orientation.

The scheme of the Bouguer anomalies of the observed gravitational field (Fig. 3) is characterized by a negative background of about –40 mGal and by some pronounced positive and negative anomalies. The background and the anomalies are well-distinguished on the transformed fields.

The regional fields reflecting the depth structure of under about 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 km respectively (the upward continuations and the fields of average values for different circle radii) are showing that the territory under study is including the western part of the Srednogorie gravity minimum and the north-western part of the Maritsa gravity transition. The gradient of these fields increases regularly with the decrease of the depths. In Figure 4 is illustrated the scheme of the regional gravity field distribution, derived from the upward continuation at height H=10 km, which is reflecting the main elements of all regional fields. The compound analysis of the regional fields gives reason to be accepted without ambiguity that the gravity minimum is mapping the granite core of the Srednogorie anticlinorium. The ore deposits and the ore showings are located along the gradient transitions of the gravity minimum. This is the reason to be assumed that in the contact area between the solid granitoids and the host rocks is formed a zone having relatively higher permeability and that the magma intrusion during the Cretaceous period took place along channels located in this zone. It is entirely possible that these channels are a reflection of a common magmata centre.

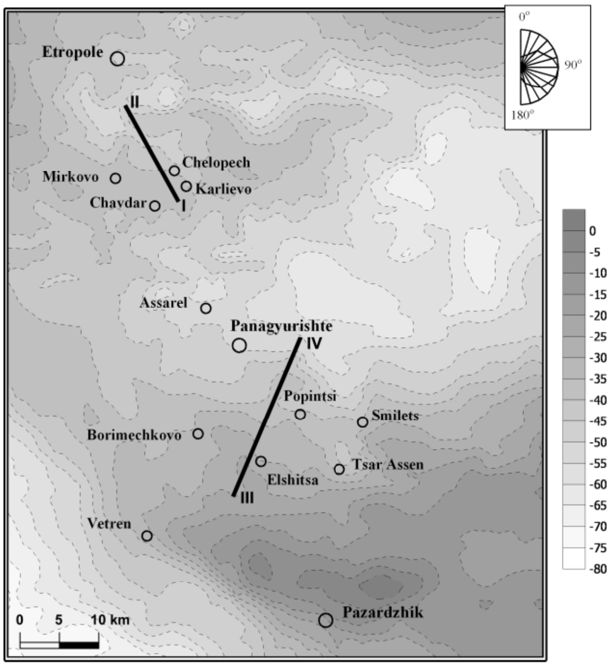

Fig. 4. Scheme of the regional gravity field distribution (in mGal), derived from the upward continuation at height H=10 km and location of the main ore deposits and ore showings.

The residual gravitational fields derived from the upward continuations at heights from 1 km up to 10 km, with a step of 1 km, the residual gravitational fields derived from the calculation of average values for circle radii R = 3, 5, 10 and 15 km, as well as the gravitational fields variation anomalies distributions compiled from the centre-point and ring method of Griffin using circles of radii R = 1, 3, 5 and 10 km are used for the study of the density non-uniformities distribution in the geological section with accents on different depths down to about 10 km. The basic elements of all these schemes are one and the same.

In Figure 5 is illustrated the scheme of the gravitational fields variation anomalies distribution compiled from the centre-point and ring method of Griffin using circle of radius R = 10 km. In Figure 6 are shown the main positive and negative anomalies pronounced not only on the above-mentioned scheme, but also on the residual gravitational fields derived from the upward continuations and from the calculation of average values for different circle radii.

Taking into account the geologic map and the rocks physical characteristics, a compound analysis of these schemes is performed and the main sources causing the gravity anomalies are distinguished. In the depth interval down to about 10 km by predominant influence are characterized the metamorphic complex having increased density (positive anomalies) and the granitoids and the rocks of the volcanic complex having relatively decreased density (negative anomalies).

In the complex structure of the Panagyurishte ore region the predominant influence of each one of the complexes is pronounced very well (Fig. 6). The vast positive anomaly 1p in the southern part of the scheme (outside the boundaries of the Panagyurishte ore region) is striking NW-SE and is mapping the complex influence of the metamorphic complex and the Srednogorie neointrusions that have relatively increased density.

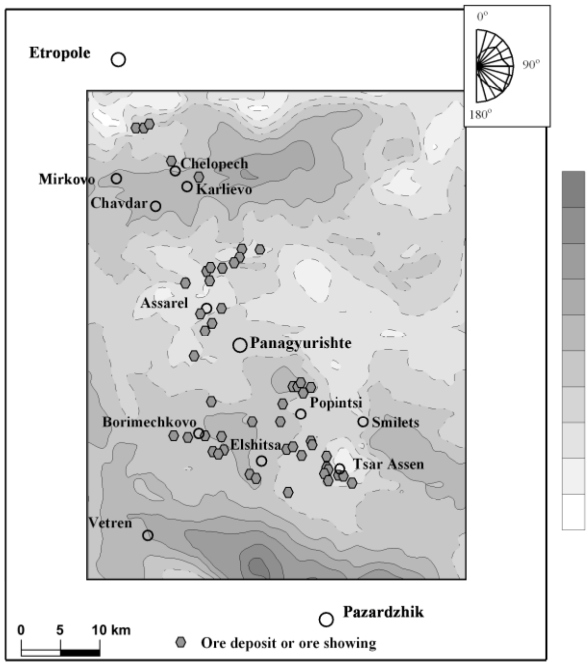

Fig. 5. Scheme of the gravitational fields variation anomalies distribution (in mGal), compiled from the centre-point and ring method of Griffin using circle of radius R=10 km and location of the main ore deposits and ore showings. Included is a rose-diagram of the field isolines orientation.

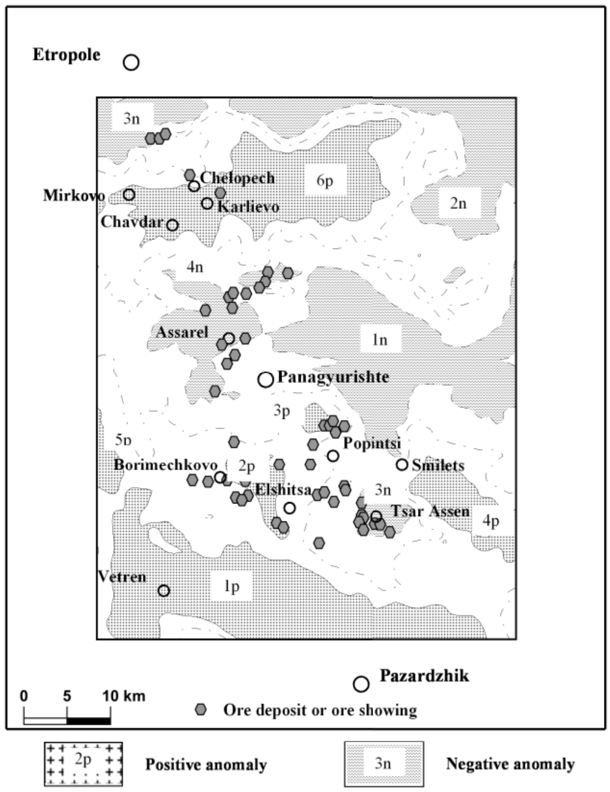

Fig. 6. Scheme of the gravitational field distribution zoning, reflecting the influence of the density non-uniformities in the depth interval down to about 10 km and location of the main ore deposits and ore showings

The positive anomalies 2p, 3p, 4p, 5p and 6p are reflecting without ambiguity the influence of the metamorphic complex in the areas where it is characterized by a bigger thickness.

The negative anomalies 1n and 2n are mapping the granitoids of the Srednogorie anticlinorium. The negative anomalies 3n, 4n and 5n are revealing the areas characterized by a bigger thickness of the volcanic complex having relatively decreased density.

In Figure 7 is illustrated the scheme of the gravitational field downward continuation which is reflecting the density non-uniformities distribution down to about 3 km. In this depth interval additional influence are causing the ore-forming processes that normally contribute for the local destruction of the host rocks. That is the main reason for the well-pronounced negative anomalies near Tsar Assen, Popintsi, Assarel and Chelopech.

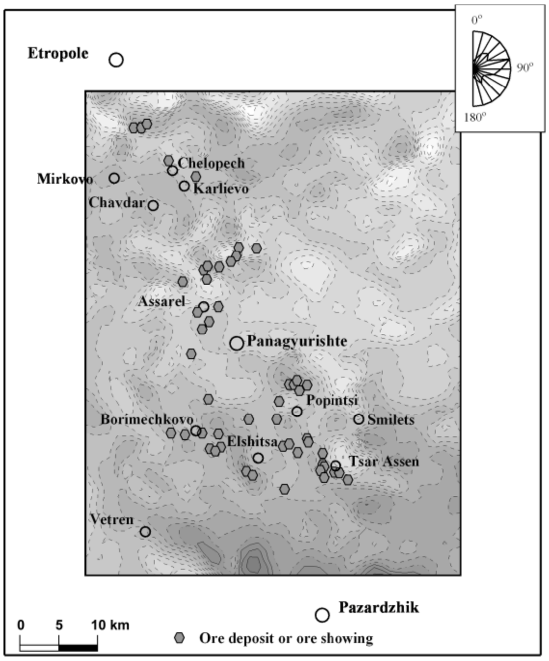

Fig. 7. Scheme of the gravitational field downward continuation to depth H=3 km and location of the main ore deposits and ore showings. Included is a rose-diagram of the field isolines orientation

Along selected profiles on the gravitational map is performed quantitative interpretation. It shows that the metamorphites which are causing the positive anomalies have residual density +(0,2-0,3) g/cm^3.

Along the profiles I-II and III-IV (see Fig. 3) is illustrated the distribution of the geomagnetic field vertical component ΔZ and the distribution of selected gravitational fields. Quantitative interpretation is performed, according to average residual densities. The obtained geologic-geophysical models of the sections along the lines are illustrated in Figure 8 and Figure 9.

Along profile I-II (Fig. 8) the regional gravitational field is showing stable behaviour having values around –18 mGal. The observed gravitational field and the variation anomalies compiled from the centre-point and ring method of Griffin using circle of radius R=10 km, respectively, differ insignificantly and both show a slightly negative trend towards the end of the profile. For the variation anomalies the decrease in the values is about 20 mGal. This negative trend is probably connected to the hydrothermal processes that are causing destruction of the host rocks. The field distribution of the downward continuation to depth H=1 km is very well differentiated. The composed geologic-geophysical model reflects the local influence of the low density Quaternary depositions and the effect of the metamorphic complex, characterized by high density.

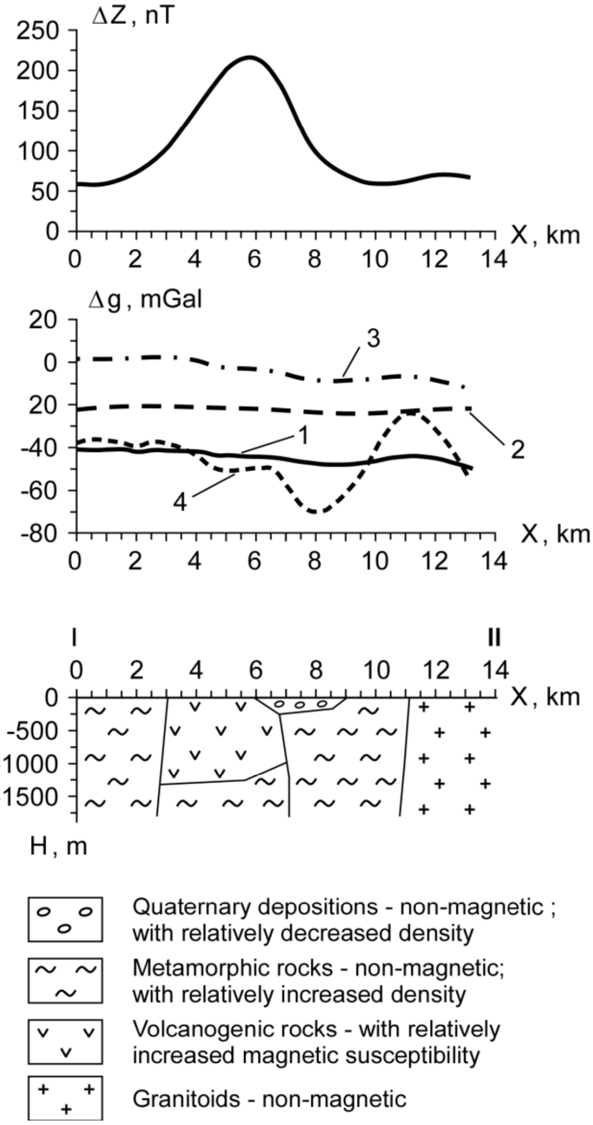

Fig. 8. Distribution of the geomagnetic field vertical component ΔZ; distribution of the observed gravitational field (1), the upward continuation at height H=10 km (2), the variation anomalies compiled from the centre-point and ring method of Griffin using circle of radius R=10 km (3) and the downward continuation to depth H=1 km (4) along profile I-II (see Fig. 3); geologic-geophysical model along the profile.

Along profile III-IV (Fig. 9) the regional gravitational field is characterized by a linear negative trend towards the end of the profile having values from about –11 mGal down to about –22 mGal. This trend is reflecting the transition towards the regional Srednogorie gravity minimum that is mapping the Srednogorie anticlinorium granitoids. The observed gravitational field and the variation anomalies compiled from the centre-point and ring method of Griffin using circle of radius R=10 km, respectively, differ insignificantly with the observed field reflecting the regional linear background. The field distribution of the downward continuation to depth H=1 km is very well differentiated. The composed geologic-geophysical model reflects the local influence of the metamorphic complex, characterized by high density.

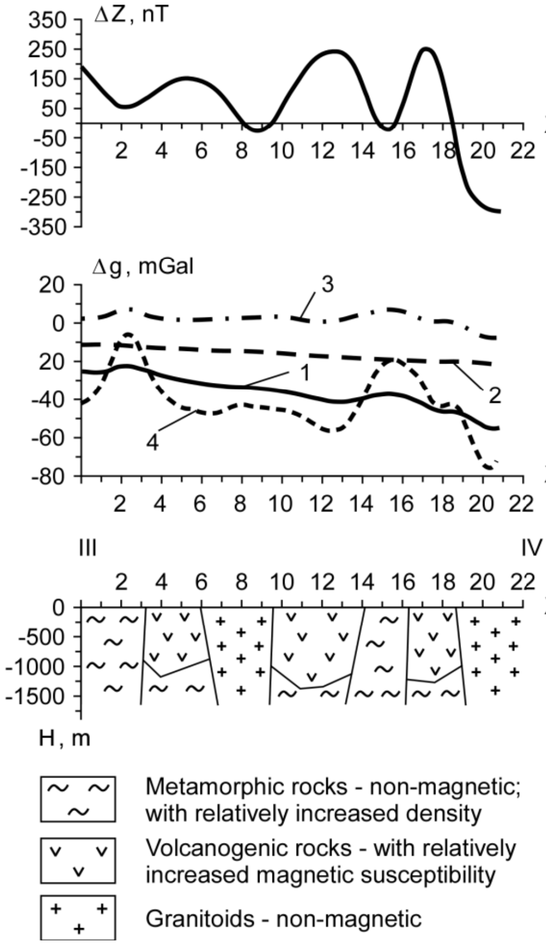

Fig. 9. Distribution of the geomagnetic field vertical component ΔZ; distribution of the observed gravitational field (1), the upward continuation at height H=10 km (2), the variation anomalies compiled from the centre-point and ring method of Griffin using circle of radius R=10 km (3) and the downward continuation to depth H=1 km (4) along profile III-IV (see Fig. 3); geological-geophysical model along the profile

The compound analysis of the obtained results is showing that the territory under study is situated in a regional gradient field that is including the western part of the Srednogorie gravity minimum. In the depth interval down to 5-10 km predominant influence has the distribution of the granitoids and the metamorphic complex, both having increased density (positive anomalies) and the rocks of the volcanic complex characterized by relatively decreased density (negative anomalies). In the depth interval down to about 3 km important influence has also the additional destruction of the rocks connected to the hydrothermal processes.

Conclusions

The compound analysis and interpretation of the Panagyurishte ore region gravitational field in scale 1:100000 gives reason for the following conclusions:

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- The territory under study is situated in a regional gradient field that is including the western part of the Srednogorie gravity minimum. Most probably the granite core of the Srednogorie anticlinorium causes this minimum. The gradient of the regional fields increases regularly with the decrease of the depths.
- The ore deposits and the ore showings are located along the gradient transitions of the gravity minimum. This is the reason to be assumed that in the contact area between the solid granitoids and the host rocks is formed a zone having relatively higher permeability and that the magma intrusion during the Cretaceous period took place along channels located in this zone. It is entirely possible that these channels are a reflection of a common magmata centre.
- In the depth interval down to about 5-10 km by predominant influence are characterized the metamorphic complex having increased density (positive anomalies) and the granitoids and the rocks of the volcanic complex having relatively decreased density (negative anomalies).
- In the depth interval down to about 3 km important influence has also the additional destruction of the rocks connected to the ore-forming processes. This is an important precondition for developing a technique based on the analytical downward continuations of the gravitational field that will help the outlining of the Central Srednogorie ore fields.

References

Гравиразведка. *Справочник геофизика*. 1981. М., Недра, 398 стр.

Ставрев, П., Р. Радичев. 1990. Система моделей и программ для интерпретации магнитных и гравитационных аномалий. – В: *35-тый Международный геофизический симпозиум*, Варна, 1990, т. III, 569-577.

Baranov W. 1975. *Potential Fields and their Transformations in Applied Geophysics*. Gebruder Borntraeger, Berlin - Stuttgart, 141 p.

Popov, P., R. Raditchev, S.Dimovski. 2001. Geology and evolution of the Elatsite-Chelopech porphyry copper-massive sulphide ore field. – *Annual of the University of Mining and Geology*, 43-44, part I, 31-43.

Radichev, R., S. Dimovski, M. Tokmakchieva. 1999. Modelling of gravity and magnetic anomalies for the conditions of the Panagurishte ore region. – *Bulg. Geophys. J., 25,* 1-4, 135-149.

Radichev, R., S. Dimovski, M. Tokmakchieva. 2002. Modelling of gravity and magnetic anomalies for copper deposits in the Central Srednogorie Region. – *Минно дело и геология*, 3-4, 55-60.

Telford W., L. Geldart, R. Sheriff, D. Keys. 1990. *Applied Geophysics*. Cambridge University Press, Cambridge, 843 p.