

STRUCTURAL FEATURES OF THE BOROVITZA DEPRESSION AND ITS PERIPHERY, ACCORDING TO GEOPHYSICAL DATA

Alexander Tzvetkov¹, Lidia Nikova²

¹ University of Mining and Geology "St. Ivan Rilski", Sofia 1700, Bulgaria, E-mail: atzvetkov@hotmail.com

² "Lian Geoconsult" Ltd, 58 "Ivan Asen", Sofia 1124, България, E-mail: lidia@declera.com

ABSTRACT

Integrated interpretation of the available regional gravity, airborne magnetic, gamma-ray spectrometry and earthquake distribution data is performed to study the metamorphic basement morphology of the Borovitzia depression and its periphery and the peculiarities of the tectonic and magmatic setting.

The Borovitzia depression is characterised by an intensive gravity low and specific magnetic field that reflect the basement morphology and the volcanic cover features. Vertical displacements of the metamorphic basement, as well as the presence of concealed acidic volcanic centres, subvolcanic and intrusive bodies, are revealed. The Besvodno-Novakovo NW striking regional fault zone outlined from the geophysical data divides the Borovitzia depression into two parts. The presence of large annular gravity and magnetic anomalies interpreted as peripheral ring faults, filled up with ignimbrites, where considerable sinking of the basements occurs, provide additional support for the assumption that it is a calderas-type volcano-tectonic depression. At the northern periphery of the Borovitzia depression the Topolovo structure is outlined connected with uplifting of high-density ophiolitic rocks.

Several centres of acid volcanism are distinguished within the depression. Specific gravity, airborne magnetic and gamma ray spectrometry anomalies define a large volcanic structure at the intersection of east-west and north-northwest faults in the area of Tri mogili village. The constructed gravity and magnetic models show that the above mentioned anomalies are caused by steeply dipping to the south sheet like acid volcanic bodies.

INTRODUCTION

The Borovitzia volcano-tectonic depression is located at the northwestern part of the East Rhodopes Paleogene depression. According to Ivanov, R. (1972) it is a calderas-type elliptical structure, formed as a result of a vast eruptions of mainly rhyolitic tuffs, agglomerates, ignimbrites, and lavas, which overprints an inhomogeneous Pre-Paleogene metamorphic basement. The volcanic rocks are divided into a latite-andesite-rhyolite sequence of acid and intermediate volcanics and a felsitic rhyolite sequence. Concentric and radial faults and dyke-swarms related to calderas collapse are mapped at the eastern and western periphery of the structure. Linear faults and dyke-like structures, which are related to basement dislocation, are observed as well.

The great thickness of the volcano-sedimentary cover and the lack of deep boreholes in the depression area, determine the importance of the geophysical data to study its inner structural and magmatic peculiarities. Up to now, the geophysical information in the Borovitzia depression area has been used either in quite regional aspect (Dachev, Ch., 1988; Josifov, D. et al., 1990; Josifov, D., 1990; Katskov, N. et al., 1988) or in terms of studying some structural and metallogenic aspects of its marginal parts (Josifov, D. et al., 1985; Maneva, B. et al., 1990; Nikova, L. et al, 1996).

The present work includes the Borovitzia depression and part of its periphery. The morphology of the metamorphic basement, some features of magmatic and fault structures are studied on the basis of gravity, magnetic and airborne gamma-ray spectrometry data and earthquake centers location.

METHODOLOGY

Analysis and integrated interpretation of the available gravity and airborne magnetic and gamma ray spectrometry data at 1:50 000 and 1:25 000 scales is carried out. 2-D density and magnetic models are constructed, using SIGRAV-23 and SIMAG-21 programs (Stavrev, P. et al., 1988; 1991), which uses polygonal models of uniform averaged density and effective magnetization values. Optimization of the models is performed using interactive parameter selection method. In accordance with the seismological data (Shanov, S. and Kostadinov, V. 1992; Dachev, Ch. 1988), it is assumed that the Moho discontinuity rises from west to east to about 4 km and to about 2 km from south to north in the area studied.

The depth to the basement is determined by the method of consecutive approach (Nikolski, U., et all, 1975) using geologic-geophysical cross sections, constructed along several modeling lines. Attention is paid to locate the modeling lines near basement outcrops and drill holes that crosscut basement rocks, which reduces the interpretation ambiguity.

PETROPHYSICAL STUDY

To study the petrophysical parameters of the main litologic unit in the area about 1300 samples from earth's surface and boreholes were analyzed. A summary of the results from the statistical analysis is shown at table 1. The acid volcanic rocks-rhyolites, ignimbrites, dacites are characterized by relatively low density ranging from 2,34 to 2,36 g/cm³, low magnetic susceptibility (about 400.4π.10⁻⁶SI), and high natural remnant magnetization (NRM). The measurements on oriented samples collected from rhyolites and ignimbrites shows that the NRM

vector is directed opposite to the inductive magnetization vector – the inclination ranges from -30° to -60° . The intermediate volcanic rocks – coarse and porphyry latites, andesites, etc. have higher densities ($\sigma_{cp} = 2,52-2,64 \text{ g/cm}^3$).

Some of them have also high magnetic properties, while others are nonmagnetic. Density heterogeneities within the outcropping at the periphery of the depression metamorphic rocks are determined.

Table N 1 Physical properties of the rocks from the Borovitza depression area and its periphery

N	Lithological unit	Density			Magnetic susceptibility			Remanent magnetization		
		Number	Average g/cm^3	Confid. interval	Number	Average $10^6/4\pi, \text{SI}$	Confid. interval	Number	Average 10^3 A/m	Confid. interval
1.	Ignimbrites	27	2,34	2,30-2,35	20	446	220-800			
2.	Rhyodacites	30	2,43	2,41-2,47	18	440	290-800	18	34000	(20-58) 10^3
3.	Rhyolites	99	2,36	2,29-2,47	65	407	350-600	42	1730	(1,2-1,9) 10^3
4.	Rhyolitic tuffs	79	2,17	2,12-2,20	41	148	90-200	32	5200	(3,2-6,5) 10^3
5.	Monzonites	100	2,63		100	862				
6.	Coarse-porphyric latites	69	2,52	2,52-2,54	68	1754	1300-1900	62	1600	(1,1-2,0) 10^3
7.	Middle-porphyric latites	68	2,53		120	256	190-320	120	188	85-205
8.	Fine-porphyric latites	92	2,63	2,60-2,66	92	2368	2000-2750	92	1287	(0,9-2,1) 10^3
9.	Andezites	49	2,64	2,62-2,66	29	1863				
10.	Granites	16	2,58	2,52-2,64	21	135		21	57	40-80
11.	Granodiorites	58	2,53		15	1182		15	52	39-74
12.	Serpentized ultramafics	127	2,52	2,49-2,54	127	3535	3210-3860	9	3720	(2,0-7,1) 10^3
13.	Unaltered ultramafics	37	2,80	2,72-2,89	36	50	20-80	6	41	25-96
14.	Marbles	20	2,70		20	18				
15.	Biotite gneisses	272	2,63		271	39		165	28	
16.	Amphibolites	209	2,83		209	198		145	184	
17.	Amphibol-biotite gneisses	34	2,78		19	110		54	38	
18.	Schists with garnet	10	2,83		10	30		4	108	
19.	Gneiss-granites	24	2,61		23	59		4	0	

The biotite gneisses have an average density of 2,62-2,65 g/cm^3 , the underlying gneiss-granites – 2,61 g/cm^3 , while rock samples from orthoamphibolites and metagabbro, collected at the surface and from a deep borehole near villages Lenovo and Mouldava, shows densities varying around 2.80 g/cm^3 . The later rocks are considered to be oceanic crust remnants-metaphiolites (Kozhoukharova, E, 1984) that constitute the upper part of the large Rhodope nape system (Burg et al, 1990). The geophysical signature of the ophiolites is studied earlier on Bulgarian and Greek territory (Nikova, L. et al., 1995, 1996; Tzvetkov, A., Tzvetkova, D., 1995; Maltezou, F. and Loucoyannakis, M., 1993).

REGIONAL POSITION OF THE BOROVITZA DEPRESSION

Distinct N-S, W-E, NW and NE striking regional geophysical anomalies are interpreted as regional deep penetrating fault zones, part of them causing displacements of the metamorphic basement (fig.1). The Dolnoslav fault zone is recognized as elongated to the north-south intensive gravity gradient, positive north-south trending magnetic anomalies, caused by serpentinite bodies, and concentration of earthquake centers at a depth of 5-10 km. Such a combination of geophysical anomalies is interpreted as reflecting the presence of a regional structure which southward extension may be characterized by the prominent Central Rhodope gravity gradient. According to the deep seismic data and the constructed models the gradient is associated with a regional gently dipping to the east reflection and density boundary (A. Bелев, 1996, L. Nikova et al., 1996). Its geological nature is still discussed. To the north of Assenovgrad similar gravity anomaly has a NW strike and might be related to the Northern Rhodope fault zone (Bonchev, E., 1961).

As a result of previous interpretations of the gravity and magnetic data the Laki, Novakovo-Pilashevo and Zenda-Spahievo lineations are outlined at the northern and eastern periphery of the depression (Josifov, D. et al., 1990; Katskov, N. et al., 1988). They are interpreted as vertical displacements of the metamorphic basement as well as pathways for different types of magmatic activity – centers of acid volcanism, intrusive and subvolcanic bodies and dikes. Earthquake centers at a depth of 8-12 km are observed in the area of Konoush and Popovitza NW striking faults, outlined by the gravity and magnetic data. In addition to the linear features of the geophysical fields, a number of circular or elliptical anomalies are outlined, that are interpreted as sinking or uplifting blocks of the metamorphic basement.

Intensive, gravity high at the northern periphery of the depression is interpreted as an uplifted block of the metamorphic basement, called the Topolovo structure (fig. 1). It coincides partly with the so-called Topolovo wedge (I. Boyanov et al. 1983).

According to the constructed 2-D density models, the gravity high is explained in terms of an uplift of high-density metamorphics near the earth's surface. The mentioned structure is heterogeneous in respect to the basement topography and composition. The western and northern parts of the Topolovo structure are more elevated, while it is sinking gradually toward the southeast. Local gravity highs within the large anomaly are observed to the north. They are attributed to the presence of thick, shallow masses of high density ultramafic rocks (ophiolites) outcropping near the village Mouldava. Intensive gravity low observed in the Topolovo village area is associated with a concealed granitic intrusion,

partly outcropping to the south and cross cut by several drill holes to the north of the village.

Several large gravity minima are interpreted as concentric structures, related to downward dislocation of the metamorphic

basement. These are the Borovitza, Dragoينو, Briastovo and Tatarevo depressions (fig. 1). Intensive magnetic anomalies - common signature of the volcanic centers are observed in the area of the mentioned gravity lows.

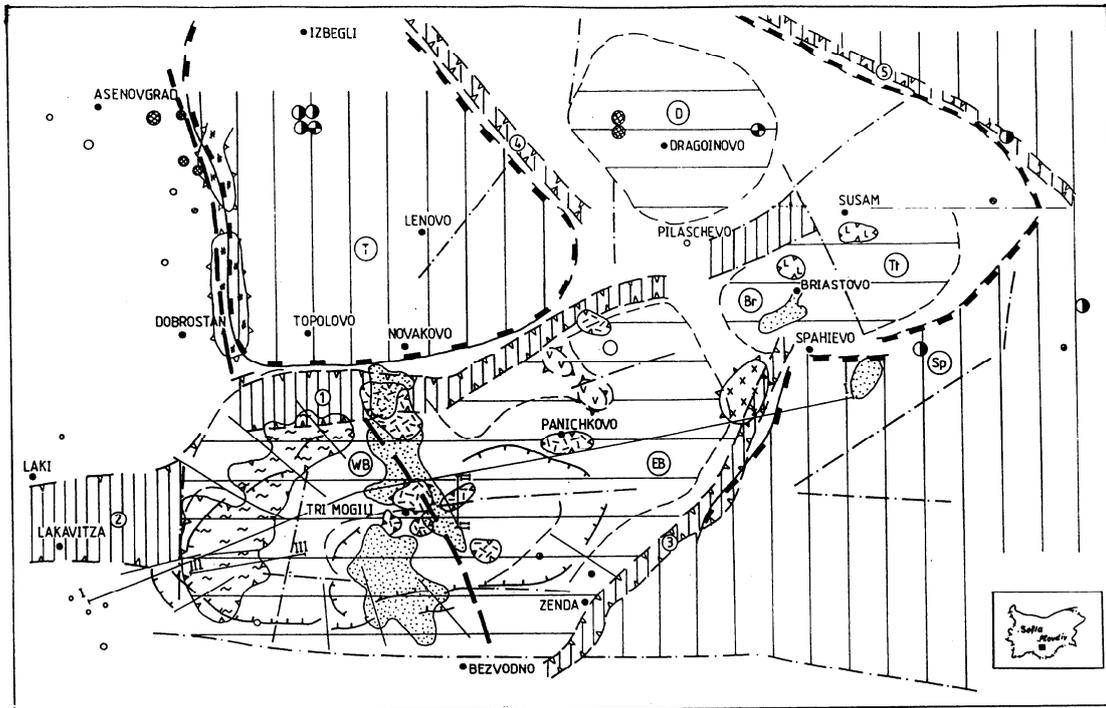
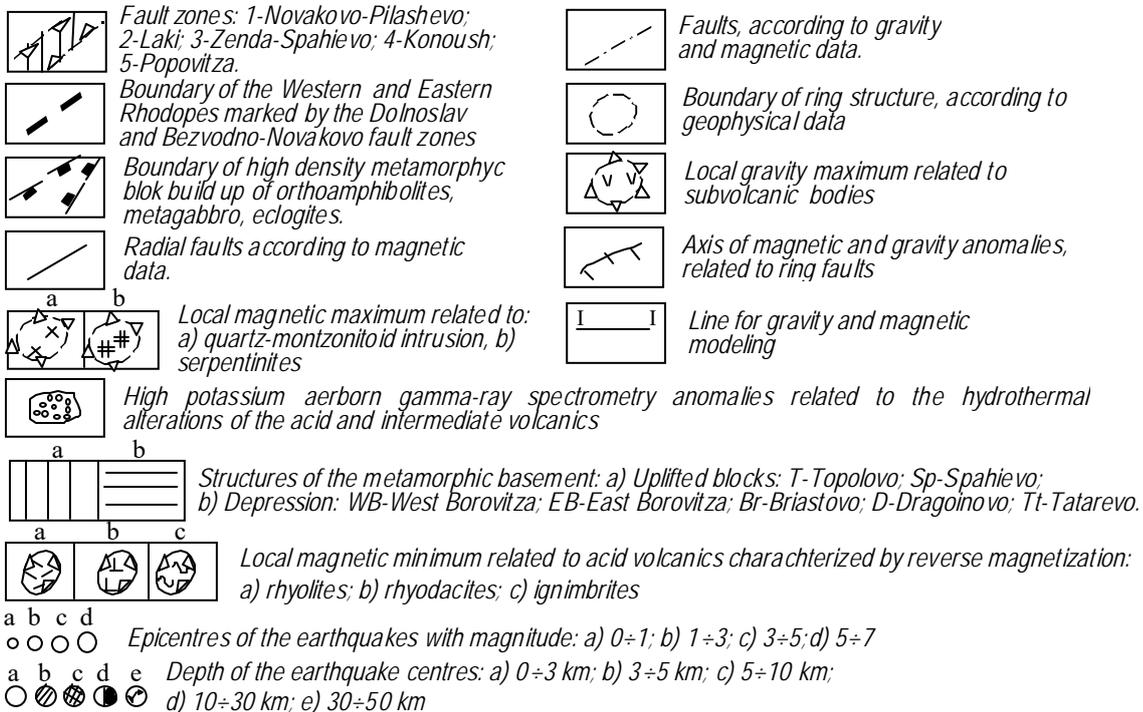


fig.1 Structural scheme of the Borovitza depression area according to the geophysical data



STRUCTURAL AND MAGMATIC FEATURES OF THE BOROVITZA DEPRESSION

The Borovitza depression is characterized by a large gravity minimum and concentration of positive and negative magnetic anomalies which are due to the considerable sinking of the metamorphic basement and the emplacement of a thick pile of

relatively low - density and high magnetic volcanic rocks. The constructed contour map of the metamorphic basement top (fig.2) clearly outlines the depression as a NE striking elliptical low. The western, northern and southeastern periphery are characterized by a sharp sinking of the basement top along concentric and linear faults. The Bezvodno-Novakovo fault zone, which is considered to be a part of the mentioned above

regional Dolnoslav structure, divides the Borovitza depression into two different parts - the west (WB) and the east (EB) ones – fig.1. Intensive negative magnetic and gravity anomalies predominate to the WB. 2-D gravity and magnetic models

along ines I-I and II-II (fig.3, 4a) present the model of the causative bodies as shallow, dipping to the south slabs, related to the outcropping low density, high NRM ignimbrites.

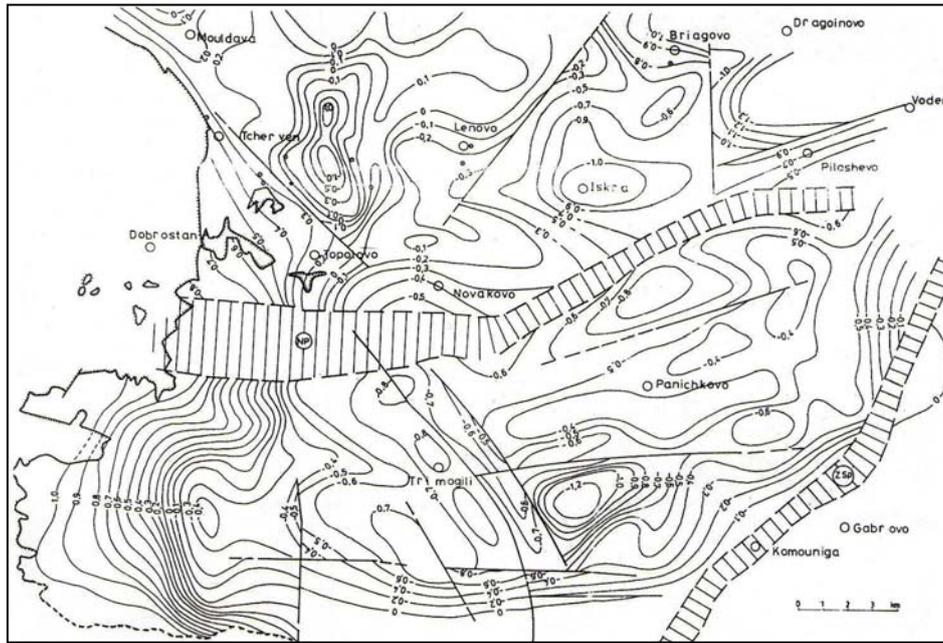
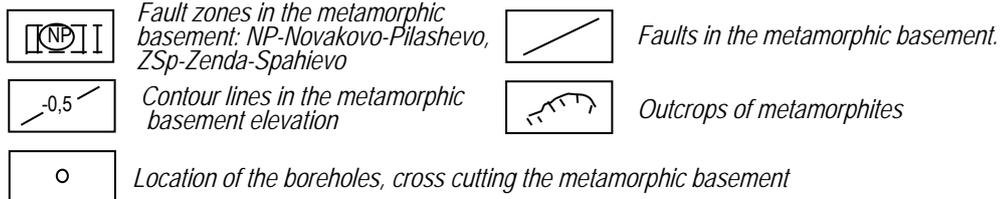


Figure 2 Map of the Pre-Paleogene basement elevation in the Borovitza depression



The shape and type of the anomalies suggest that they might reflect the presence of typical calderas-type peripheral ring faults filled with ignimbrites (G. Macdonald, 1972). Radial faults are also outlined at the west Borovitza structure, which are characterized by breaks of the contour lines of the magnetic and partly of the gravity maps. The observed in this block magnetic, gravity and gamma-ray spectrometry potassium anomalies are typical for the concentric volcanic structures environment.

The Eastern part of the depression (EB) is characterized by low intensity magnetic field and low abundance of the radioactive elements. According to the density models the increase of the gravity field to the east is explained with a gradual uplift of the metamorphic basement, the upper most part of which is build up of high - density ophiolitic-type rocks (fig. 3).

An internal concentric structure (the Mourga structure) is observed at the central part of the Borovitza depression. It is bounded by concentric negative and positive magnetic anomalies to the south and to the north respectively (fig. 1). The Bezvodno-Novakovo fault zone cross cuts the Mourga structure.

Local magnetic high flanked to the north and to the south by concentric magnetic lows and above the background potassium anomalies is observed at the Tri mogili area. These anomalies are located at the intersection of an E-W fault with

the Bezvodno-Novakovo fault zone (fig. 1), along which several intermediate volcanic dikes have been mapped (Boyanov, I. et al., 1991). A 2-D magnetic model along line II-II (fig.4b) shows a south dip of the causative rhyolitic dike, characterized by a reverse polarity of the NRM. The top of the dike-like body is at 0,8 km and the bottom – at about 2-2,4 km. It is assumed that the concentric magnetic anomalies are probably related to centers of acid volcanics. Thus, the geophysical data suggest the presence of a large volcanic center in the Tri mogili area. To the south it consists of several volcanoes located within a concentric fault. Hydrothermal alteration of the rocks is observed at the northern periphery of the volcanic structure. The modeling line II-II runs trough the northern part of the structure. A similar volcanic center confined to the Bezvodno-Novakovo fault zone is established at the Syruar dere area to the north of the Tri mogili center. It is characterized by several negative magnetic anomalies from the 1:10 000 scale magnetic map. High values of the NRM (in average $1900 \cdot 10^{-3}$ A/m) are established by laboratory measurements on samples from the earth's surface. The geophysical anomalies and the geological evidence show the presence of hydrothermal alteration, related to the volcanic edifice.

Intensive local negative magnetic and gravity anomalies, observed near Iskra and Doushka villages are studied. It has been established that the anomalies are related to a rhyolitic body intruded along a fault zone.

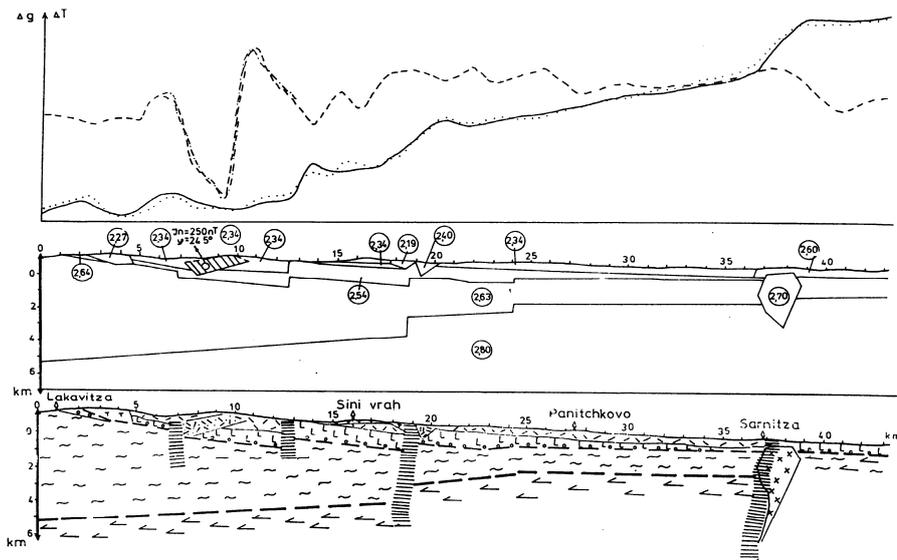


Figure 3. Density and magnetic model and the corresponding geological cross-section along line I-I.

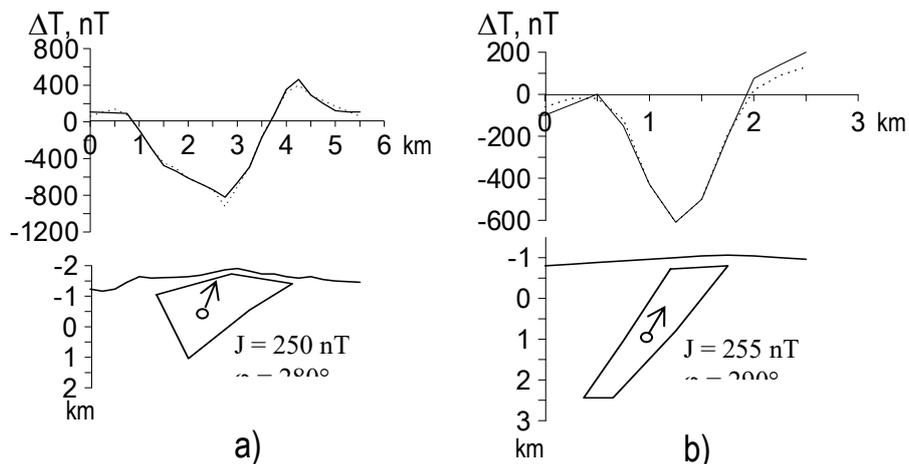
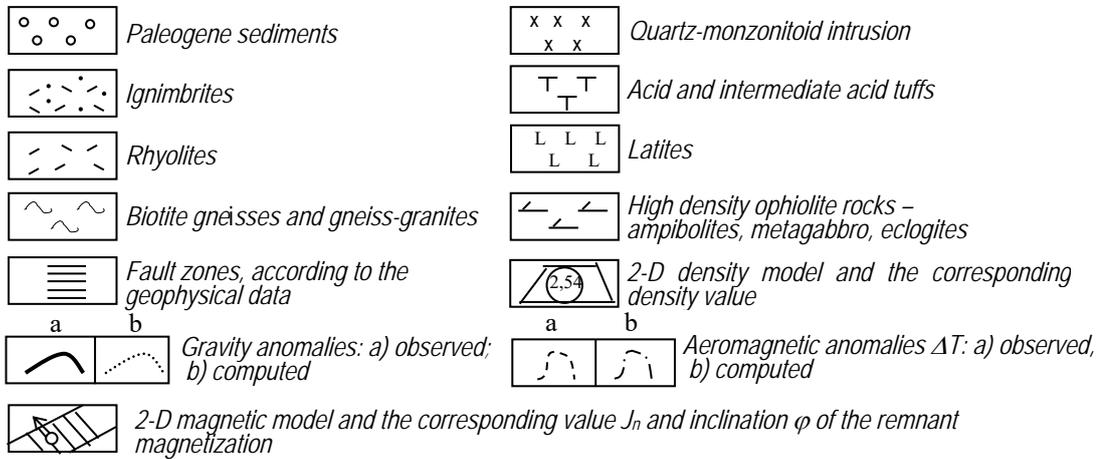
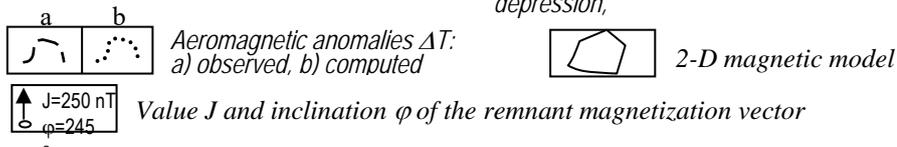


Figure 4. Models along aeromagnetic profile lines: a) III-III – in the western periphery of the Borovitzha depression,



CONCLUSION

- According to the geophysical data, the Borovitzha depression is determined as a northeast trending complex

structure of elliptical shape. The established sinking of the metamorphic basement along steeply dipping concentric faults and the presence of radial faults suggests that it might be

considered as a calderas-type structure. The Bezvodno-Novakovo NW fault zone is outlined and it is interpreted as a south extension of the Dolnoslav regional fault zone within the Borovotza depression. The two fault zones are considered to be fragments of a common more regional structure which is expressed to the south by the Central Rhodope gravity gradient. The Bezvodno-Novakovo fault zone divides the Borovitza depression into two parts - the Western and the Eastern that have different geophysical characteristics, associated with differences in the composition and the thickness of the Tertiary volcanic cover.

- The geophysical data reveals the presence of large volcanic centers and associated hydrothermal alteration in the vicinity of the Bezvodno-Novakovo fault zone near the village Tri mogili and Saraiai dere. They may be considered as possible indices of concealed ore mineralizations at depth. More interesting is the southern part of the Tri mogili structure because of the inferred uplifting of the boundary between the acid and intermediate volcanics.

- At the northern periphery of the Borovitza depression a large gravity high is associated with an uplifted block of high - density metamorphics named the Topolovo structure. The 2-D density models, constrained by density laboratory information suggest that the Topolovo structure is built up in the upper part of high - density (in average 2,80 g/cm³) ophiolitic rocks - amphibolites, ultramafics, and schists. Such types of rocks have been established recently at a number of sites in Bulgarian and Greek Rhodopes.

REFERENCES

Boncev, E., 1961. Notes on the main fault structures in Bulgaria. *Works on the geology of Bulg., Ser. Stratigr. & Tect., Bulg. Acad. of Sc.*, 2, 5-29 (in Bulg.).

Boyanov, I., Dragomanov, L., Goranov, A., 1983. Structure of the Pre-Neogene basement of Plovdiv depression. *In: Maritza suture and block setting of the Bulgarian Srednogorie*. Bulg. Ak. of Sc., Problem IX of the Socialists countries Ak. of Sc Intern. Collabor., Sofia, Bulgaria, 80-104. (in Russian)

Boyanov, I., Kozhouharov, D., Goranov, A., Shiliafova, G. Ruseva, M. 1995. Explanatory note to the geological map of Bulgaria at a scale 1:100 000. *Geol. Inst. of the Bulg. Acad. of Sc., Geol.&Geoph. Corp.*, Sofia, 77 p. (in Bulg., Engl. Summ.).

Burg, J.-P., Ricou I.-E., Ivanov, Z., Godfriaux, I., Dimov, D., Klain, L., 1996. Syn-metamorphic nappe complex in the Rhodope Massif. Structure and kinematics. *Blackwell Science Ltd, Terra Nova*, 8, 6-15.

Velev, A. 1996. Deep seismic profiling of the earth's crust along the regional line Ivailovgrad - Ardino. *Journ. of the Bulg. Geol. Soc.*, 22, 2, 91-109.

Dachev, Ch. 1988. Structure of the earth's crust in Bulgaria. Sofia, *Technika*, 334 p. (in Bulg., Engl. Summ.).

Ivanov, R. 1972. Volcano-tectonic structures in the Borovitsa depression. *Bull. Geol. Inst., ser. Geochim., miner. and petrogr.*, 21, Bulg. Acad. of Sc., Sofia, 193-210 (in Bulg., Engl. Summ.).

Josifov, D. 1990. Magma chamber structures in the East Rhodopes – geophysical characteristic and metallogenic significance. *Geol. Balc.*, 21, 6, Sofia, 91-106 (in Rus., Engl. Summ.).

Jossifov, D., Nedev, V., Tsvetkov, Al., Pchelarov, V., Latifian, J. 1985. Correlation of the lead-zinc metallizations in the Central Rhodopes with some elements of the geophysical fields. *Proc. 30-th Intern. Geophys. Symp.*, Moscow, 85-106 (in Rus., Engl. Summ.).

Josifov, D., Maneva, B., Tsvetkov, Al., Tsvetkova, D., Pchelarov, V. 1990. Geotectonic position and structure of Spahievo ore field. *Geol. Balc.*, 20, 1, Sofia, 45-65 (in Bulg., Engl. Summ.).

Katskov, N., Latifian, J., Todorov, T. 1988. The deep structure of the Central Rhodopes in light of medium-scale gravimetric studies. *Journ. of the Bulg. Geol. Soc.*, 49, 2, 1-12 ((in Bulg., Engl. Summ.).

Kozhoukharova, E., 1984. Origine and structural position of the serpentinized ultrabasic rocks of the Precambrian ophiolitic association in the Rhodope Massif. I. Geologic position and composition of ophiolite association, *Geol. Balc.*, 14, 9-36.

Macdonald, G. 1972. *Volcanoes*. Univ. of Hawai, Prentice-Hall, Inc, Englewood cliffs, New Jersey, 431 p.

Maltezou, F., Locouyannakis. 1993. Geophysical evidence for the subsurface distribution and mode of emplacement of ophiolites in the Eastern Rhodope region, N. Greece. *Tectonoph.*, 218, 355-365.

Maneva, B., Josifov, D., Nikova, L., Tzvetkov, A., Tzvetkova, D. 1990. Structural control of the basement mineralization in the Borovitza depression Periphery, southeastern Bulgaria. *Geol. Rhod.*, 2nd Hell.-Bulg. Symp., Thessaloniki, 390-398.

Nikolski, U., Cogan, L., Milai, T. 1975. Geologo-geophysical investigations of the tectonics, magmatism and metallogeny of Kavkaz. L. Nedra, 365 p. (in Rus).

Nikova, L., Tzvetkov, A., Tzvetkova, D., Nedev, V. 1995. Gravity and aeromagnetic study of the inhomogeneities in the metamorphic rocks of the South-Eastern Rhodope region, SE Bulgaria. *Proc. of the XV Congr. of the Carp.-Balk. Geol. Assoc.*, 4/3, Athen, 1995.

Nikova, L., Georgiev, V., Malinov, O., 1996. Structural and metallogenic studies in Spahievo ore field: integrated geophysical and geological interpretation. *Extended Abstracts, First Congress of the Balkan Geophysical Society*, Athen, 1996, 148-149.

Shanov, S., Kostadinov, I. 1992. Configuration of the deep geophysical discontinuities beneath the territory of Bulgaria. *Geol. Balc.*, 22, 2, 71-79.

Stavrev, P., Nedev, V., Khristova, I. 1988. A system of computer programmes for 2-D magnetic interpretation. *Proc. of the 33rd Intern. Geoph. Symp.*, Prague, B (II), 300-309 (in Rus., Engl. Summ.).

Stavrev, P., Nedev, V., Raditchev, R. 1991. A system of computer programmes for gravity interpretation. *Proc. of the 36th Intern. Geoph. Symp.*, Kiev, (in Rus., Engl. Summ.).

Tzvetkov, A., Tzvetkova, D. 1995. Geophysical characteristic of the ophiolitic rocks in the south-eastern metamorphic border of the Eastern Rhodope lowering. *First National Geophysical Conference, Abstracts*, Sofia, 20-21.

Recommended for publication by Department of Applied Geophysics, Faculty of Geology and Prospecting