# SOME PRELIMINARY RESULTS ON THE INVERSION OF SEVERAL MAGNETIC ANOMALIES FROM SOUTH BULGARIA WITH FINITE DIPOLES

#### Zhelev, Zh.P. and Petrova, T.D.

Geophysical institute of the Bulgarian Academy of Sciences, "Akad. G. Bonchev" str., block 3 , Sofia 1113, Bulgaria

#### ABSTRACT

Several magnetic anomalies from South Bulgaria are interpreted with a set of final dipoles. Their sources are approximately determined. Some reversals are definitely established in this region. Because of the incorrectness of these problems however, it cannot be said for certain that these are the real sources of the observed fields. This problem is a subject for future research. In this sense at present, the so obtained solutions represent mainly one better model of the anomalous magnetic field in this area, which is also important for the geophysical science and practice.

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### Zhelev, Zh.P. and Petrova, T.D.

# ΠΕΡΙΛΗΨΗ

Μαγνητικές ανωμαλίες από τη Ν.Βουλγαρία ερμηνεύονται με ένα σύνολο πεπερασμένων διπόλων. Οι πηγές τους καθορίζονται κατά προσέγγιση. Ορισμένες αντιστροφές διαπιστώνονται χωρίς αμφιβολία στην περιοχή αυτή. Εξαιτίας όμως των αβεβαιοτήτων στο πρόβλημα αυτό, δεν είναι δυνατό να επιβεβαιωθεί ότι αυτές είναι και οι πραγματικές πηγές του πεδίου. Το πρόβλημα είναι θέμα μελλοντικής έρευνας. Υπό αυτή την έννοια, οι λύσεις αυτές αντιπροσωπεύουν προς το παρόν ένα καλύτερο μοντέλο του ανώμαλου μαγνητικού πεδίου της περιοχής, κάτι που επίσης είναι σημαντικό για τη γεωφυσική επιστήμη και πρακτική.

### INTRODUCTION

It is well known that, for solution of the inverse magnetic problem in the global case, models of dipoles (Zidarov, 1965, 1968, 1990 ; Zidarov and Bochev, 1969) and current loops ( Zidarov, 1968, 1990 ; Zidarov and Petrova, 1978, 1983) are usually used.

In a previous study ( Zhelev and Petrova, 1993 ) it was suggested, that for local, and to some extend, regional investigations, it would be better to use final dipoles (FD) because they usually have better approximating possibilities, as in this case, the different charges are usually too distant one from the other. A number of numerical experiments, confirming these assumptions, were made. The influence of the observational

errors on the precision of the solution were studied.

The main purpose of the present study is to check the possibilities of this method in real conditions. That is why some magnetic anomalies from the territory of South Bulgaria are treated with it. A reasonable results are obtained.

#### RESULTS AND DISCUSSION

Four anomalies are analyzed by this technique. On the map (see the fig. 1) they are marked with the letters - A1 , A2 , A3 and A4 , respectively for convenience. The corresponding local coordinate systems -  $0_1 X_1 Y_1$  and  $0_2 X_2 Y_2$ , in which the observations and the results are presented, are also given there. The orientation of the X and Y axes are eastwards , and northwards respectively. The Z axis is directed downwards,



Fig. 1. Situation map of the interpreted anomalies  $A_1$ ,  $A_2$ ,  $A_3$ and  $A_4$  respectively and izolines of the anomalous vertical component of the field ; o - towns ;  $O_1 X_1 Y_1$  and  $O_2 X_2 Y_2$ coordinate systems.

perpendicular to the observational plane-XOY. The vertical, component of the anomalous magnetic field is used in this case (Kostov and Nozharov, 1974). The relative unit (the distance between two divisions on the coordinate axes) used for the coordinates and the lengths of the FD is 10 km.

The obtained results are shown on the tables (1 to 4). Solutions with one and two FD are used. More complicated models are not tried, as they fit the observations well enough ( the corresponding mean square deviation ( MSD ) in most of the cases almost coincide with the respective approximation errors (45 nT) (Kostov, 1971) of the map (Kostov and Nozharov, 1974), from which the observations are extracted, and the number of the observations are too limited here.

On the tables, besides the parameters  $\xi_k$ ,  $\eta_k$ ,  $\zeta_k$ ,  $m_k$ ;  $\xi''_k$ ,  $\eta''_k$ ,  $\zeta''_k$ ;  $l_k$ ;  $\alpha_k$ ,  $\beta_k$ ,  $\gamma_k$ , where  $\xi_k$ ,  $n_k$ ,  $\zeta_k$  and  $\xi''_k$ ,  $n''_k$ ,  $\zeta''_k$  are the coordinates of the first and second end of the k-th FD respectively,  $m_k$  - its mass,  $l_k$  - the length and  $\alpha_k$ ,  $\beta_k$ ,  $\gamma_k$  the corresponding cosine directors, the following parameters (Zhelev and Petrova, 1993) are listed there for convenience :

- the corresponding functional F (X) (Zhelev and Petrova, 1993),

representing the sum of the squares of the differences between the observed and models field,

- the respective MSD (Zhelev, 1990)

 $\sigma = [F(X) / (N - n)]^{1/2}$ 

where N is the number of the observations and n - the number of the unknowns,

- the gradient G ( X ) of the functional, etc.

The values of the functional and the corresponding MSD show (see the tables) , that the models fit the observations well in all of the cases presented here. The corresponding gradient points out, that in all of them the optimum of the functional has been achieved.

Some of the charges on the tables are marked with the expression - " far away from the observational region " or something similar, which means that they are too deep or out of it, so that their contribution in the observational field is rather small and can be ignored without considerably affecting the approximation possibilities of the model. In such cases, the corresponding directional cosines are not uniquely obtained, as the determination of these charges is not very stable. The values of the lengths are not also very real in such cases.

In a previous study (2helev and Petrova, 1993) on this subject, this model is found with better approximating possibilities - the respective MSD in almost all the cases here is usually a little smaller than the corresponding approximation error. At first it seems, that the corresponding solutions have not very clear physical meaning ( or at least not entirely in agreement with our expectations ), but taking into account that some of the charges are out of the bounds of the anomalies, they are quite reasonable.

Thus the obtained solutions represent mainly one better model of the anomalous magnetic field in this region. One comparatively rough idea about the location of the corresponding sources can also be find in the tables. Mainly, the determination of the magnetization here is not very stable. In spite of this however, it is quite clear from the results, that the magnetization of the sources of A3 and A4 anomalies is inverse to that of A1 and A2 respectively (the corresponding FD are oriented in the opposite direction). Thus, in some sense, reversals are undoubtedly established here for first time with this method.

As in almost all of the cases some of the charges usually escape away from the observational grid, and practically have no contribution in the model, we decided to try to solve this problem also with point masses (PM) only. This was done by the corresponding computer program prepared for the solution of the respective inverse gravity problem (without any changes et all) (2helev, 1972, 1990). The corresponding results are shown on the same tables. Here, the obtained coordinates  $\xi_k$ ,  $\eta_k$ ,  $\zeta_k$  of the PM

show approximately only the location of the upper charges of the magnetic bodies. Obviously, in the solutions here practically there is no real information about the orientation of the magnetization.

This technique representation with PM was used by Zidarov (Report of GFI, BAS, 1991) for interpretation of some magnetic anomalies from North Bulgaria. In mathematical and programming aspect it entirely coincides with the method of the solution of the inverse gravity problem with a final set of PM (Zidarov, 1965, 1968, 1990 ; Zhelev 1972, 1990 ; Bochev and Georgiev, 1974 ; Zhelev and Georgiev, 1985), worked out about 20 years ago, and repeatedly used (Zhelev and Georgiev, 1985 ; Zhelev, 1990 ; Zidarov, 1990) up to now in the geophysical science and practice. Specially for our latitudes, one such simplification is in some cases possible, mainly because the total field vector is almost (the cosine directors of the normal field vertical ín Panagurishte, in 1960 are  $\alpha = 0.01$ ,  $\beta = 0.60$ ,  $\gamma = 0.80$ , where the orientation of the axes is the same as in the fig.1 ) , and some of the charges are usually very deep and usually have comparatively small contributions in the observations. We must remember however, that such alleviation is not always possible. Especially it is not possible in places, where the orientation of the total magnetic vector is almost horizontal (for example equator) . Besides, in some cases the remanent on the magnetization may turn the magnetization vector in such a direction, that to be unfavorable for models with PM only.

As can be seen from the tables, the approximating possibilities here are a little worse in comparison with these of the FD (the respective MSD is a little larger than the corresponding approximation error), but the obtained solutions seem to be with a little more real physical meaning and easier for interpretation. But having in mind that in South Bulgaria the remanent magnetization often exceeds several times the inductive, and the reversals are not an exception (Kostov and Nozharov, 1974), it is difficult to say at present for certain which of these solutions are better and to what degree they correspond to the real magnetic structure of the region. That is why, we decided to include all more representative solutions with FD and PM into the paper, so that the readers can use them, but only in combination with additional geophysical, geological or other information.

Of course, not all the solutions with PM and FD are entirely different. For example, the results for A3 anomaly almost entirely coincide. For A4 they are very similar - the main difference is in the fact that in the solution with FD some of the charges escape away from the observational grid, but this is not very essential here. There is some similarity also in the upper charges of A2 and partly of A1 anomalies - some of the corresponding bottom charges also ( analogous the PM ) have almost no contribution in the observations, as are out of the limits of the anomalies (see the respective tables and the fig.1). If these comparatively small differences cannot be explained with the full ignorance of some of the charges in the PM model, then probably they are connected with the fact, that the solutions with FD are obtained without any restrictions at all. Solution of the inverse magnetic problem with a system of FD and PM - two FD (or four PM) a linear trend represent the field of the "Al" anomaly (Fig.1). and Table 1.

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Solution with FD : 35.10 <sup>5</sup> .14.10 <sup>-</sup>		2.10	4.46	2.74	57.
		3.59	5.40	. 30	ai
N = 42 ; 0 = 37.31		. 50	25.	80	
	N	3.61	5.37	. 57	60.
a little away from the observational region :		2.73	1.17	. 26	4
		- 20	98	- , 07	
Parameters ( a , b , c ) of the trend :		-257. 33	-1.67	8.50	
Parameters : F	2	بد جو	$n_k$	×	e <sup>x</sup>
Solution with PM: .51.10 <sup>-5</sup> .27.10 <sup>-1</sup>	1 1	1.77	4.49	1.67	16.8
	A)	2.83	5.84	1.75	12.
N = 42; $G = 46.87$	(7)	4.48	5.32	1.18	6.0
	4	3.50	4.38	002 ·	N
parameteres ( a , b , c ) of the trend :		-158.25	-9.41	90. r	

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The relative unit used for the coordinates of the elementary sources is 10 km

Table 2. Solution of the inverse magnetic problem with a system of FD and PM-two FD (or three PM) and a linear trend represent the field of the "A2" anomaly (Fig.1).

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	Solution with FD : . 25.10 5 .83.1	د <del>ا</del> ع	1	1.35	1.24	1.52 1.75	15.01
	N = 25 ; x = 47.60			1.27 .27	60 90 90 90	)	- J
	a little surv from the observations from		N	ν Ω α	C) 1 2005 2005	н. 67 0	21 . 4
	0 11 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			. 60	74	. 17	
	Parameters ( a , b , c ) of the trend :		1	-1 96, 08	-8.17	51.44	
	Parameters : F		×	A A	$\sigma_k$	ć, k	Ĕ
I	Solution of PM : 22.10 <sup>5</sup> . 93.1	ں ہ <u></u> ی		1.25	1.05	1.60	16.0
	N = 25 ; $arphi = 46.98$		N (9	2. 41 3. 74	8. 91 9. 91 9. 91	2. 04 0. 40	30.0 1.50
	parameteres ( a , b , c ) of the trend :		1	-356, 70	-54.76	31.88	

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	ата с. с. с. с. т. т.	ū)	~		ب <sup>م</sup> ب <sup>م</sup> ب	х х х . х х х	е <u>-</u>
1	Splution with FD : .13.10 $^{\rm S}$ .85. far away from the observational region : N = 16 ; $\sigma$ = 38.11	1, 10 -5		1.63 166.10 .77	1.36 694.60	1.30 636.80 .22	-3.29 2820,40
	Parameters (a, b, c) of the trend:			5.75	6.53	-21.27	
	ראר אר	U	×	× ×	n <sub>k</sub>	*	e <sup>×</sup>
1	Solution with PM : .13.10 <sup>5</sup> .95.	.10 -5		1.63	1.36	1.30	-3, 29
	N - 16 ; 0 = 38.11						
	remeteres (a, b, c) of the trend:			5, 75	6. 53	-21.27	

Table 4. Solution of the inverse magnetic problem with a system of FD or PM - two FD (or three PM) and a linear trend represent the field of the "A4" anomaly (Fig.1).

Farameters: r r	5 57.10 -5 gion: gion: 80.10 -2	× ~ ~ ~ ~	້ ແລະ ເຊິ່ງ ເຊິ່ ເຊິ່ງ ເຊິ່ງ ເຊີ່ ເຊິ່ງ ເຊີ່ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊິ່ງ ເຊີ່ ເຊິ່ງ ເຊີ່ ເຊີ ເຊີ່ ເຊີ່ ເຊີ່ ເຊີ່ ເຊີ່ ເຊີ່ ເຊີ່ ເຊີ ເຊີ ເຊີ່ ເຊີ່ ເຊີ່ ເຊີ ເຊີ ເຊີ ເຊີ່ ເຊີ ເຊີ ເຊີ ເຊີ ເຊີ ເຊີ ເຊີ ເຊີ	່າ : 2000 ສະ 2000 ສ 2000 ສ 2000 ສ 2000 ສ 2000 ສ 2000 ສ 2000 ສ 2000 ສ 2000 ສ 2000 ສ 2000 300 3000 3000 3000 30	γγγγγγγγγγγγγγγγγγγγγγγγγγγγγγγγγγγγγ	ε <sup>×</sup> , × μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ
$= 40$ ; $\sigma = 40.69$	'n	N	4.63 1.53	1.61 8.81	4.10 - 4.13 -	-240.69 -229.57
vrameteres ( a , b , c ) of the trend		270	6. 90 -	237.13	-9. 78	

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#### CONCLUSIONS

It may be said in conclusion, that the model of FD has indeed better approximating possibilities. In this sense, the obtained solutions represent mainly one better model of the anomalous magnetic field in this region, which is also very important for the geophysical science and practice. Naturally, they also give one rough idea about the location of the sources and the orientation of the magnetization (some reversals are established here for first time with this method), but owing to the incorrectness of these problems, they can be used by the readers, but only in a combination with other independent information.

The solutions with PM are with comparatively smaller approximating possibilities, but with a little more real physical meaning. Though the differences here are not very significant, probably at present they give a little better idea about the location of the sources of the field, and can be used in the practice, but also only with additional information.

Thus it can be added at the end, that the so obtained results, are one good basis for further geophysical investigations and geological interpretations in the future. Of course, better results may be expected, on the basis of more detailed observations and some improvements in the method - with suitable limitations on the model.

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