Host medium influence on magnetovariational anomalies of 2D local bodies

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SUMMARY

In this paper the authors consider the influence of the host medium on the morphology of the magnetovariational (MVP) anomaly of a local object with a relative conductivity of the section 10,000 Sm·m and 500 m depth. Conclusions are based on mathematical modeling. The results have shown that the covered rocks are the main cause of a local anomaly distortion. The presence of large regional structures and resistivity changing of bottom layers have a weak effect on local anomaly disturbing. The anomaly of a local object can be isolated as a result of subtracting a regional component from the Wiese matrix of the original field. The express-interpretation of MVP data and inversion codes can be applied for the described anomaly.

Keywords: Magnetovariational method (MVP), induction vector, tipper, regional effect, local anomalies

INTRODUCTION

Two groups of methods are based on measuring the natural alternative electromagnetic (EM) field of the Earth: magnetotelluric (MT) (Berdichevsky and Dmitriev 2009) and magnetovariational (MVP) (Rokityansky 1982). In the MT sounding method 4 horizontal components (Ex, Ey, Hx, Hy) are measured. In the MVP method, 3 orthogonal magnetic components (Hx, Hy, Hz) are studied. Both methods can be operated independently, but it is more expedient to use them together. This 5-component EM method is an effective tool for solving a wide range of geological exploration tasks.

The response functions in the MVP method are the induction vector and the tipper (Rokityansky 1982). Earlier it was shown that by means of using the singular points on the pseudo-sections of the tipper, it is possible to quickly estimate the parameters of 2D and 3D anomalous objects of a simple geometric shape (Ingerov and Ermolin 2010, Ermolin et al. 2014). The algorithms developed by the authors can be called "the method of express-interpretation of magnetovariational data". This technique has been developed for a homogeneous half-space. But in real conditions we deal with a complex environment and the responses of various geological objects are superimposed on each other. Large lateral inhomogeneities of the Earth's crust and the upper mantle create anomalies. The MVP method can find these anomalies at a distance of up to several hundred kilometers. As a result, the response from the local searched object is considerably distorted, and it becomes impossible to apply the express interpretation methods. At the same time, it is interesting to separate the local component from the regional influence. The current state of this problem is described by (Berdichevsky and Dmitriev 2009). On the qualitative level, the first division of the regional and local components of the real part of the induction vector was shown in the work (Lozovoy et al. 2018). The quantitative interpretation of the separated local component is an unresolved issue nowadays. The purpose of this work is to estimate the influence of different variants of the horizontal layered host medium and regional 2D conductors on the parameters of the anomaly created by a local body of a simple geometric shape. The most important goal is the answer to the question: is it possible to use the separated local part for further quantitative interpretation?

METHODS and MODELING RESULTS

We have performed mathematical modeling by means of the WinGLink software. 2D anomalous body of a regular geometric shape is taken as a basic geoelectrical model. This local object was described in the authors' previous work (Ingerov and Ermolin 2010). Within the framework of this paper the parameters of the anomalous local object are (the cross section of the body (200x200 meters), the resistivity (4 Ohm-m), the depth to the upper edge (500 meters)) have not been changed. The object was placed in a horizontally layered medium, shown in figure 1a. The model consists of several key elements: a sedimentary cover with the thickness of 200 m and the resistivity of 20 Ohm-m (total longitudinal conductivity of 10 Sm), a regional conductive layer, the boundary of the earth's crust (M) and the boundary of the lithosphere sole (L). The studies were divided into 3 stages.

At the first stage the most significant pseudo-sections of the MT and MVP responses, calculated from the basic model (Figure 1-a) were analyzed. The object clearly appears in the MT and MVP response in spite of the presence of an overlapping cover. In the impedance phase of the TE-mode, the object is displayed on 2 period ranges (Figure 1c). The first range is around 0.02 seconds (the amplitude of the anomaly is 6 degrees). The second range is around 2 seconds (the amplitude of the anomaly is 3 degrees). On the section of induction vectors (Figure 1d), the anomalous body appears at a period of 0.25 seconds. In case of using both MT and MVP methods, the object appears over a wide range of periods (3 decades). In practice, you can use the range where the data quality is better. It should be noted that using the data of induction vectors in Parkinson convection (pointed to the conductor), the presence of an anomalous body and the direction to it can be detected at a distance of 2 km (Figure 1d). The TE-mode anomaly attenuates at a distance of 0.7 km.

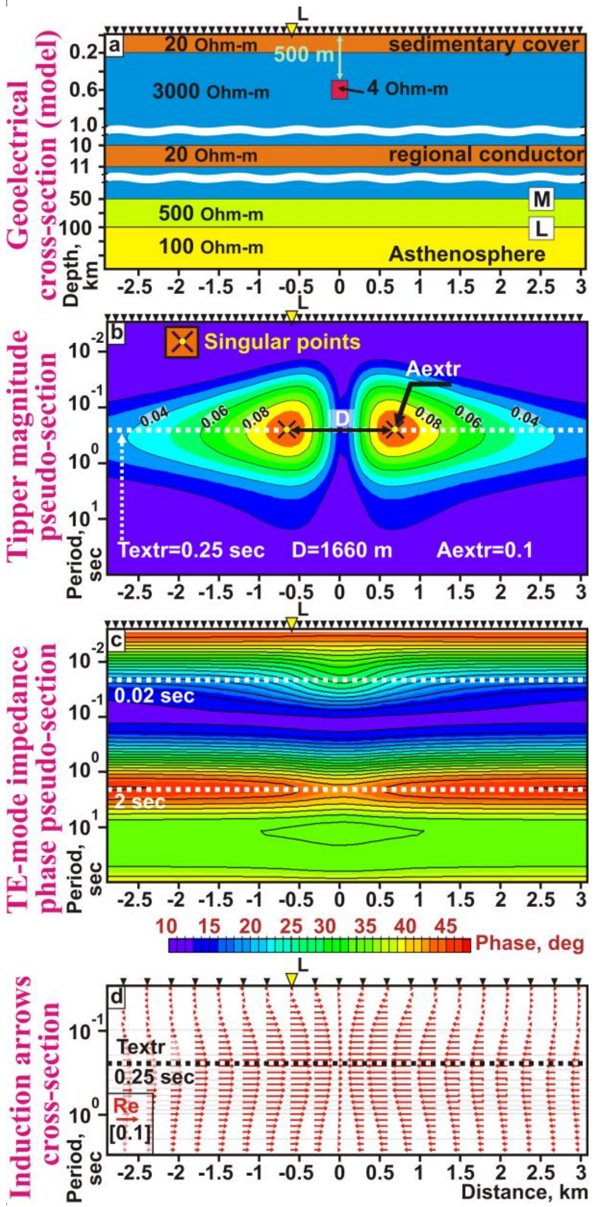

Figure 1. Geoelectrical basic model (a), Pseudo-sections of the response functions (b).

On the tipper pseudo-section (Figure 1b), the object appears as a paired anomaly having 2 maxima (2 singular points) with the amplitude of 0.1 at the period Textr = 0.25 seconds. The authors gave a formula for an operative estimation of the anomalous conductivity of the cross-section G. It is determined as the multiplication of the cross sectional area and the anomalous electrical conductivity (Ingerov and Ermolin 2010). Using this formula, the G value of the illustrated in figure 1a object is increased by 67%. The authors think it occurs because according to (Ingerov and Ermolin 2010) the object was placed in a homogeneous half-space with a resistivity of 3000 Ohm-m. At the top, the object was covered by a 25 m thick cover with the resistivity of 100 Ohm-m (total longitudinal conductivity is 0.25 Sm). Obviously, the difference is caused by the difference in the host medium.

At the second stage of the study, the thickness and resisitivity of the covered rocks and the resisitivity of the asthenosphere changed. In addition, for different host mediums, the influence of a regional conductor located at a distance of 40 km was estimated. The model of the suture zone was taken as a regional conductor. The authors compared the parameters of singular points on the tipper cross-sections (period – Textr, maxima amplitude - Aextr and at the distance between the maxima - D). The results of the comparison are shown in Table 1. It can be seen that if total conductivity of overlapping rocks changes, the parameters of the singular points (Textr, D, Aextr) on the tipper cross-section alter considerably (Table 1a). There are no fundamental changes of singular points parameters in case the asthenosphere resistivity changes. It is more important that there is no change in case of adding the suture zone, situated 40 km away from the local object, in the cross-section (Table 1b). This fact significantly expands the applicability of the methods of MVP data express-interpretation in practice and provides opportunities for dividing the response into the local and regional components.

Table 1

a	Difference in singular points for models with 0.25 Sm and 10 Sm	
Period (Textr)	Distance (D)	Amplitude (Aextr)
66.94 %	358 m	0.287

b		Local body	Local body, asthenosphere resistivity 1 Ohm-m	Local body and suture zone
25 m cover, 100 Ohm-m (0.25 Sm)	Textr (change)	0.248 c	0.250 c (0.81%)	0.249 c (0.20 %)
	D (change)	1276 m	1283 m (7 m)	1280 m (4 m)
	Aextr (change)	0.098	0.098 (0)	0.096 (0.002)
200 m cover, 20Ohm-m (10 Sm)	Textr (change)	0.082 c	0.082 c (0.37%)	0.081 c (0.91%)
	D (change)	1665 m	1656 m (9 m)	1634 m (31 m)
	Aextr (change)	0.385	0.385 (0)	0.393 (0.008)

At the third stage, the influence of the regional conductor on the local anomaly was estimated. The suture zone was located at a different distance from the local anomaly. The geoelectrical models for the distances of 40, 7.5 and 0.4 km are shown in Figure 2a. The tipper magnitude pseudo-sections calculated from the models are shown in figure 2b. The parts of the tipper magnitude pseudo-sections where the local anomaly appears are shown in figure 2d. The white isolines illustrate the response of the local anomalous body without the suture zone presence. The results of the calculation in case of the local body absence are shown in figure 2c. If the regional structure is located at a distance of 40 km from the local anomalous object (Figure 2a-1), the anomaly morphology from the local object is practically not distorted. This can be seen from a detailed examination of the pseudo-section of the tipper (Figure 2d-1). White isolines closely parallel the anomaly morphology. Therefore, we can use express-interpretation methods.

When an anomalous object is located at a distance of 7.5 km from the suture zone (Figure 2a-2), the low-period part of the anomaly of the local object is distorted (Figure 2d-2). We cannot determine the parameters of singular points. But the presence of a local object can be assessed at a qualitative level by the presence of a less distorted high-frequency part of the anomaly. Figure 2 in section e-2 shows the projections of the real and imaginary parts of induction vectors calculated for the model shown in Figure 2a-2. Curves R+L correspond to the models where both a regional conductor and a local object are present. The R curves are calculated only for the regional conductor (there is no local object). The curve L (Figure 2e-4) is calculated only for a local object (there is no regional structure). It can be seen that the local object on the R+L curve is clearly visible for a period of 0.25 seconds. Moreover, the value of the maximum period and the amplitude of the vectors coincide with the curve L. The authors performed a subtraction of the values of the components of the matrix R from the components of the Wiese matrix R+L. The final curve is presented in the same section in figure 2e. This is the curve of the vectors (R+L)-R. If the curves of the induction vectors (R+L)-R and L have to be compared, it is difficult to visually distinguish them. Consequently, after dividing the regional and local parts by subtracting the components of the Wiese matrix, we can apply the express-interpretation or inversion technique to the magnetovariational data.

If the regional object is located from a local object at a distance less than the depth of the latter (Figure 2a-3), it is practically impossible to determine the presence of a local object even at a qualitative level. Nevertheless, with the formal subtraction (R + L)-R, we obtain a curve of the vectors that does not fundamentally differ from the vectors of the local object (L). A more detailed comparison of the real part of induction arrows between L and (R+L)-R curve for 7.5 and 0.4 km separation of the local body and the suture zone are shown in figure 3.

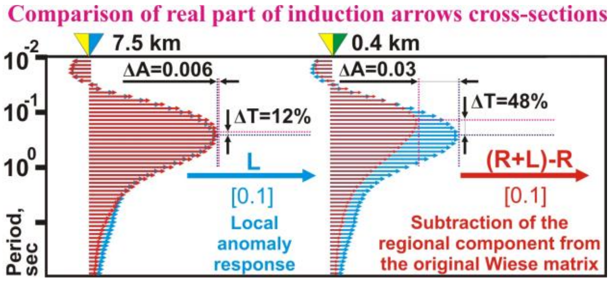

Figure 3. Comparison of induction arrows.

If the distance of the regional structure and the local object is less than the depth up to upper edge, the difference of (R+L) and L curve of induction arrows is greater than the field measurement error.

Conclusions

The modeling results have shown that for the local anomalous object with a relative conductivity of the cross section of 10^4 Sm-m and a depth of the upper edge of 500 m, the following conclusions are valid:

1. The host medium affects the morphology of the magnetovariational anomaly. The morphology of the anomaly is primarily related to the parameters of the sedimentary cover.

2. If the local and regional anomaly can be visually separated, the presence of large remote regional conductors in the studied area has a very weak effect on the shape of the anomaly from the local 2D object.

3. The local magnetovariational anomaly, distorted by regional anomalies, can be isolated by simple subtracting the regional constituent of the components of the Wiese matrix from the original field. The local component determination is most correct when the anomalous object is removed from the regional conductor at a distance greater than the depth up to upper edge of the anomalous object.

4. If the regional component is correctly taken into account, the methods of express interpretation of magnetovariational data and inversion can be applied to the isolated anomalies. At the same time, it is necessary to determine the parameters of the horizontally layered host medium and take the influence of the host medium into account.

5. The local body appears on the AMT and MVP responses in different frequency bands.

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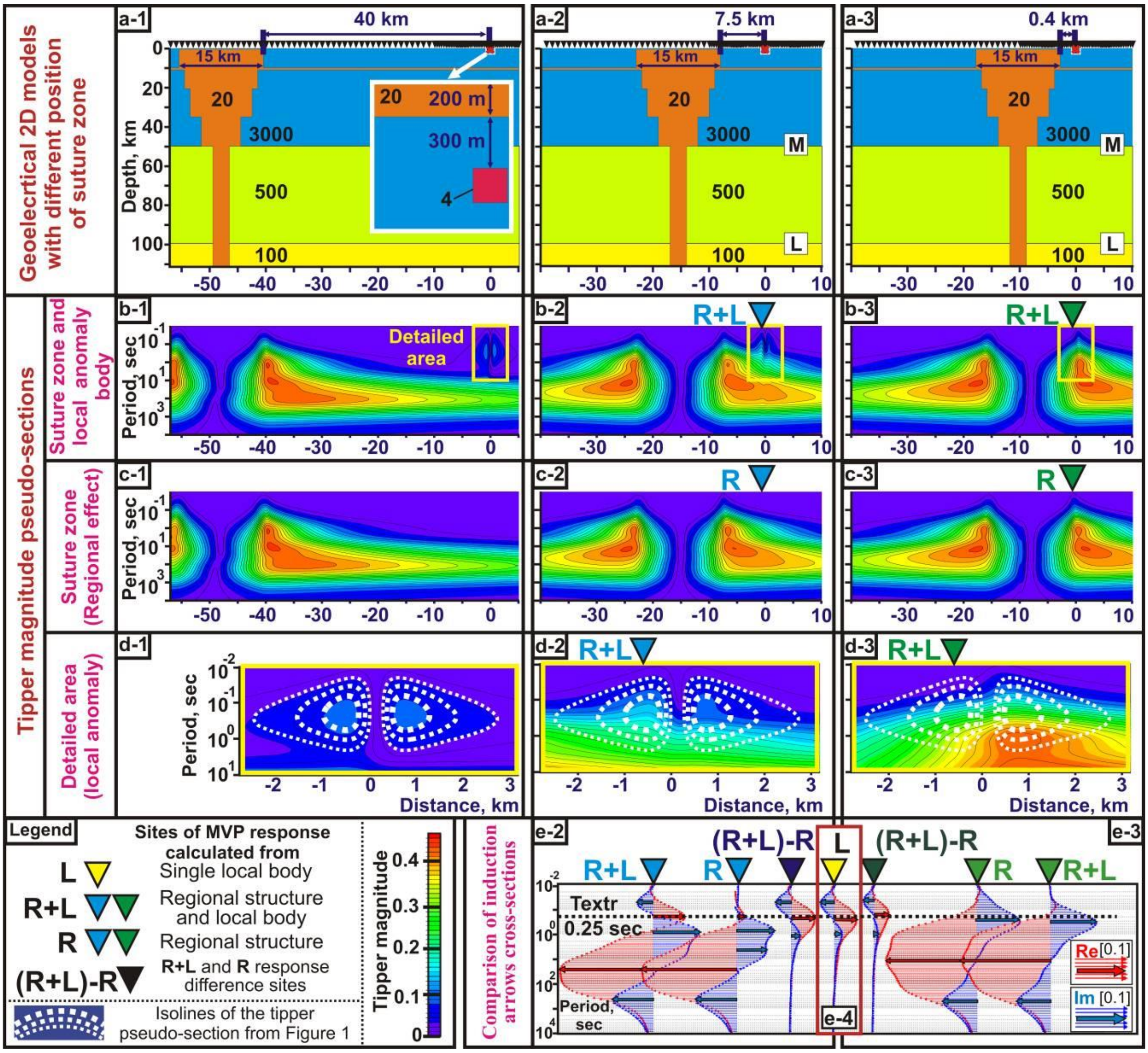

Figure 3. 2D geoelectrical models (a); pseudo-sections calculated from models containing: a local body and a regional structure (b, d), only a regional structure (c). e - projections of real (red vectors) and imaginary (blue vectors) parts of induction vectors in the Parkinson convention (pointed to conductor).