Field technique optimization in ore exploration by using magnitotelluric

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ABSTRACT

The natural electromagnetic field of the Earth is used in magnitotelluric (MTS) and magnitovariation profiling (MVP) methods. Aa result of this powerful MTS-MVP source and its global distribution, the remote geoelectrical heterogeneity (separated from measurement grid) appear in response function. In this work, on the basis of 3D modeling, it is shown that the 5-component AMT-MVP investigation grid can be decreased by 4-8 times. It can be done by using far-sensitive MVP measuring to detect the object situated aside from measuring stations. The anomaly object axes position can be estimated by using induction arrows map of rare measuring grid. The relation of horizontal size (L/a) and vertical section conductivity (G) of simple 3D ore body can be estimated by any tipper magnitude curve. After that, detailed lines should be recommended to estimate the main ore body parameters. There are AMT-MVP results in Quebec province (Canada) presented in this work. The exploration example shows that ore body situated in several kilometers away from measured grid can be detected by MVP data. The 3D modelling results and practical examples show the AMT-MVP integration as a very effective (and optimal in terms of field work cost) technique in ore-solid exploration.

Keywords: magnitovariation profiling, tipper, induction arrow, field technique optimization

INTRODUCTION

The natural electromagnetic field of the Earth is used in magnitotelluric sounding (MTS) and magnitovariation profiling (MVP) methods (Berdichevsky and Dmitriev 2009). As results of powerful MTS-MVP source global distribution, the remote geoelectrical heterogeneity (separated from measurement grid) appear in response function. This effect was named as an "induction effect" in 70-80-ties of the 20th century. It was regarded as introducing errors in 1D model interpretation of MTS data. But this effect can be used in MVS method (Rokityansky 1982) to detect anomalies situated away from measurement stations. The MVP data express-interpretation methods to 2D anomaly bodies parameters estimation was presented in previous works (Ingerov and Ermolin 2010, Ermolin at al. 2011, Ingerov at al. 2013). It is possible to use this 2D method to estimate simple 3D anomaly objects parameters but some corrections are needed (Ermolin et al. EAGE 2014). The main parameters of 2D anomaly object with isometric cross-section can be estimated using an audiomagnetotellurics (AMT) and MVP data of distant station (Ermolin et al. 2014).

The field work optimization is urgent in our days as a result of increasing AMT method application in ore exploration. The using of the distant sensitivity effect of MVP method is a good means of saving money (of decreasing the measuring grid). The ideas of potential reducing of the 5-component magnitotelluric measuring grid were presented in previous works (Ingerov et. al. 2009). The argument that the rare magnitotelluric grid can be used (distance between lines is 4-6 times bigger than ore body width in the plan) can be used for localization of anomaly ore objects anomalies has been presented in this work on the basis of 3D modeling. The MVP response functions (induction arrows, tipper amplitude and phase) are more important to localize ore objects. It is easy to identify the position of detail lines by using these functions and then to estimate the parameters of anomaly object. There are AMT-MVP results in Quebec province (Canada) has been presented in this work as a practical example.

3D MODELLING TECHNIQUE AND RESULTS

The modelling parameters. 3D body with isometric in XZ cross-section has been selected as an object of research. The square side (a) is equal to 200 m (body section – 200x200 m). The body length in Y axis direction (L) is equal to 1600 m. Thus the L/a = 8. The center of the body is situated at 600 m depth. As for solid ores, this object is very promising even with large body depth. The host rocks resistivity is equal to 1000 Ohm-m. Resistivity of anomaly object is equal to 4 Ohm-m. On the top of the model is the layer with resistivity 100 Ohm-m emulating the weathering rocks. The AMT-MVP response function has been calculated by using WinGLing software. The grid of 50x50 m has been used. The geometric center of the body has coordinates X=0, Y=0, Z=-600 m. Y axis and XY AMT curves is directed to the north.

Modelling results. AMT-MVP parameters maps are shown in the figure 1 at 0.008 seconds periods (125 Hz) because all response factions are more anomalous at this period. On the maps we show parameters as the additional isolines while map constructing by 2 double lines only (X -600, X -400, X 400, X 600). There are two anomalies on the tipper magnitude map (Figure. 1a) behind two side of the body. The anomalies are elongated parallel to the body axis. A thin minimum is being observed over the body center. However if we use only 4 above-stated lines for map construction, we will see one large anomaly (additional isolines). It allows detecting the ore body presence and estimating it roughly on the map. The best way of detecting the ore body on the map is analyzing of induction arrows map (Figure. 1b) in Parkinson convection (pointed to the conductor). Induction arrows definitely show the body position. It allows to select the position of detailing line to the body strike and across body approximate center (Line Y 0).

The ore body AMT anomalies on the map are very weak (Figure. 1c-f). The body appears in XY component only (parallel to the body strike). Although the XY impedance phase map has got a 3-4 degree anomaly but this anomaly is local (over the body center only). It is 300 meters wide that requires 300 m distance between exploring lines. While the using of the MVP parameters allows to detect the object by applying 800-1200 m line spacing. It permits to decrease the volume of recognizing work in 3-4 times. As will be shown below, the some stable parameters of ore body can be estimated by using tipper curves measured away from the ore body.

The tipper magnitude curves in different area situations have been shown in Figure 2. Over the anomaly center (A curve), in 200 m from the body axis (B curve), in 1000 m distance off the body axis (C curve). First of all we have to mention that the period value in maximum tipper magnitude is constant for any curves. This fact allows to estimate the effective longitudinal conductivity of the body section (G). G = (body section square)/(effective resistivity of the ore body). The formula G = Textr•2•10^5 for 2D objects was shown in previous work (Ingerov Ermolin 2010). If we use this dependency for A tipper curve (Figure. 2), then G = 1300 Sm•m. In previous work (Ermolin et al. EAGE 2014) the simple 3D ore body with different relationship between length (a) and width (a) was presented. For 3D object presented in (Ermolin et al. 2014 EAGE) the Textr decreases in 8-10 times if L/a = 8. If G=1300 increases in 8-10 times (L/a correction), then calculated value will be near G value of investigation model (G = 200m•200m / 4 Ohm-m = 10 000 Sm•m). It was approved (Ermolin et al. 2014 EAGE) that L/a relation can be estimated by using Textr, Tmin and Tmax from isolines 0.5 from maximum at the tipper magnitude cross-section. P parameter ($P = (Textr)^2/(Tmin \cdot Tmax)$) reflecting L/a relation was suggested. The P = 0.37 has been calculated for the A curve by using this simple formula. It corresponds to the object with L/a value equal to from 6 to 10 (L/a=8 for our investigated model). The same values have been calculated for B and C and other curves on the area.

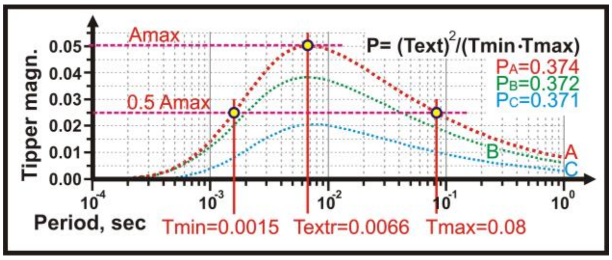

Figure 2. Tipper magnitude curves.

The tipper magnitude and phase pseudo-section can be analyzed to select detail line position. On the tipper magnitude pseudo-section across X +600 line (Figure 3a1) there is a positive anomaly elongated in horizontal direction. The shape of the tipper magnitude anomaly (Figure 3a1) and non changing of the value on tipper phase (Figure 3a2) definitely indicate the line-aside position of the anomaly body. The map of induction arrows should be constructed at the period of tipper magnitude maximum. It is obvious that the line position should be situated across the tipper anomaly maximum. The object appears very faintly in AMT parameters. But the main problem that we cannot determine if the object is situated under the line or away from line.

The AMT-MVP response functions of detailed line (Y 0 line) have been presented in the figure 3b1-4. The ore body can be well seen in the XY AMT component (parallel to body strike) and in MVP response functions. The center of the body can be detected by vertical gradient zone on tipper phase pseudo-section (Figure 3b2). The simple formula was suggested for 2D object presented in work (Ermolin and Ingerov 2010) to estimate the depth of the anomaly body center H = 0.42•D, where D is the distance between extremums on the tipper magnitude cross-section. H = 0.42•800 м = 336 м has been calculate by using this formula. The decreasing of H together with L/a was shown in (Ermolin et al. EAGE 2014). If L/a value is about 8, then H decreases in 2-1.7 times. The depth close to the depth of the body investigated in this work (H=600m) can be calculated by using L/a correction.

AMT-MVP EXPLORATION IN QUEBEC PROVINCE (CANADA)

AMT-MVP field work was done in 5-component variant in the promising area in the central part of Quebec province. MTU-5A equipment was used. AMTC-30 magnetic sensors were installed by using special tripods. The 5-th component technique was described in (Ermolin and Ingerov 2011). The three lines in longitudinal direction were measured on insistence of the customer in summer period of 2002 (black points in figure 4). The lines did not detect any interested anomalies. However a conductive object was detected in the North-West part of the area by direction of induction arrows at 10 Hz. The detailed work was not made in summer because of the lake and the swamp. The detailed work was done without groundings in winter of 2003 using MVP method (blue points in the figure 4). Three component measurements were done by using the same equipment. Diagonal lines were grown step-by-step on the lake surface from the first investigated grid. As a result the ore was localized and two detailed AMT-MVP lines were done. In fact, the ore body was found 3-5 km away from the first survey grid.

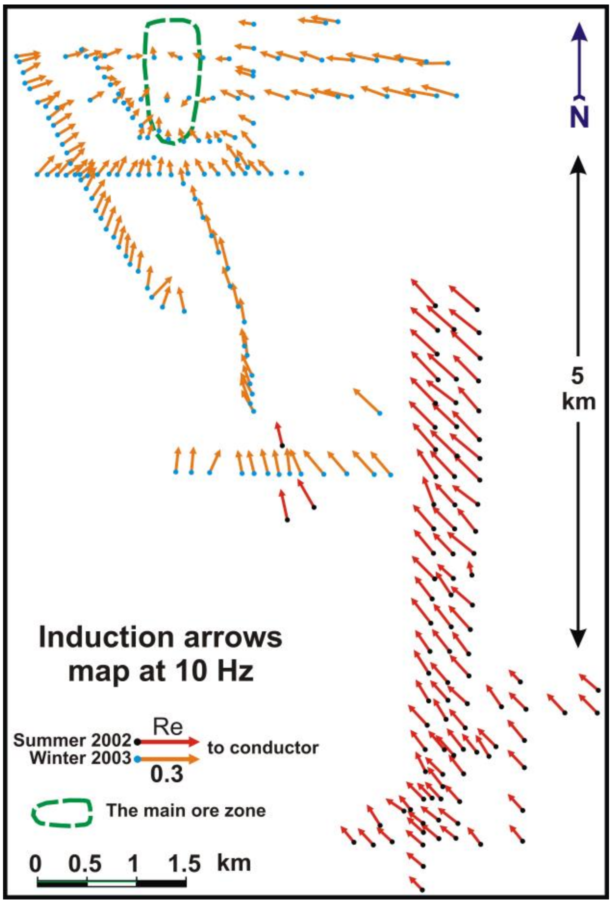

Figure 4. Induction arrows map at 10 Hz.

CONCLUSION

The 5-component AMT-MVP investigation grid can be decreased in 3-4 tames by using far-sensitive MVP measuring to detect the object situated aside from measuring stations. The relation of horizontal size (L/a) and vertical section conductivity (G) can be estimated by anyone tipper magnitude curve. The anomaly object axis position can be estimated by using induction arrows map of rare measuring grid. It allows estimating the detailing AMT-MVP line position to determine the main parameters of ore body. The exploration example shows that the ore body situated in several kilometers away from measured grid can be detected by MVP data.

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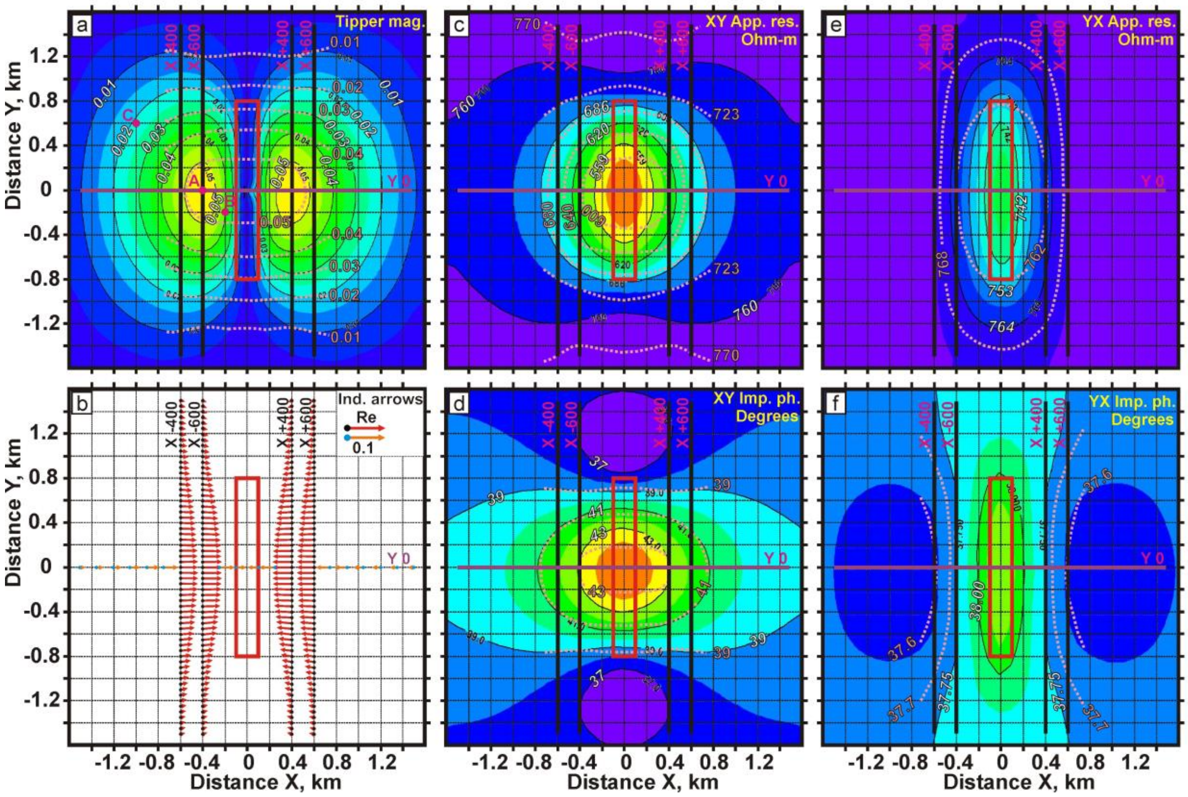

Figure 1. AMT-MVP map parameters at 0.008 second (125 Hz). a – tipper magnitude; b – induction arrows in Parkinson convection (pointed to conductor), apparent resistivity (c,e) and impedance phase (d,f) in XY (c,d) and YX (e,f) direction.

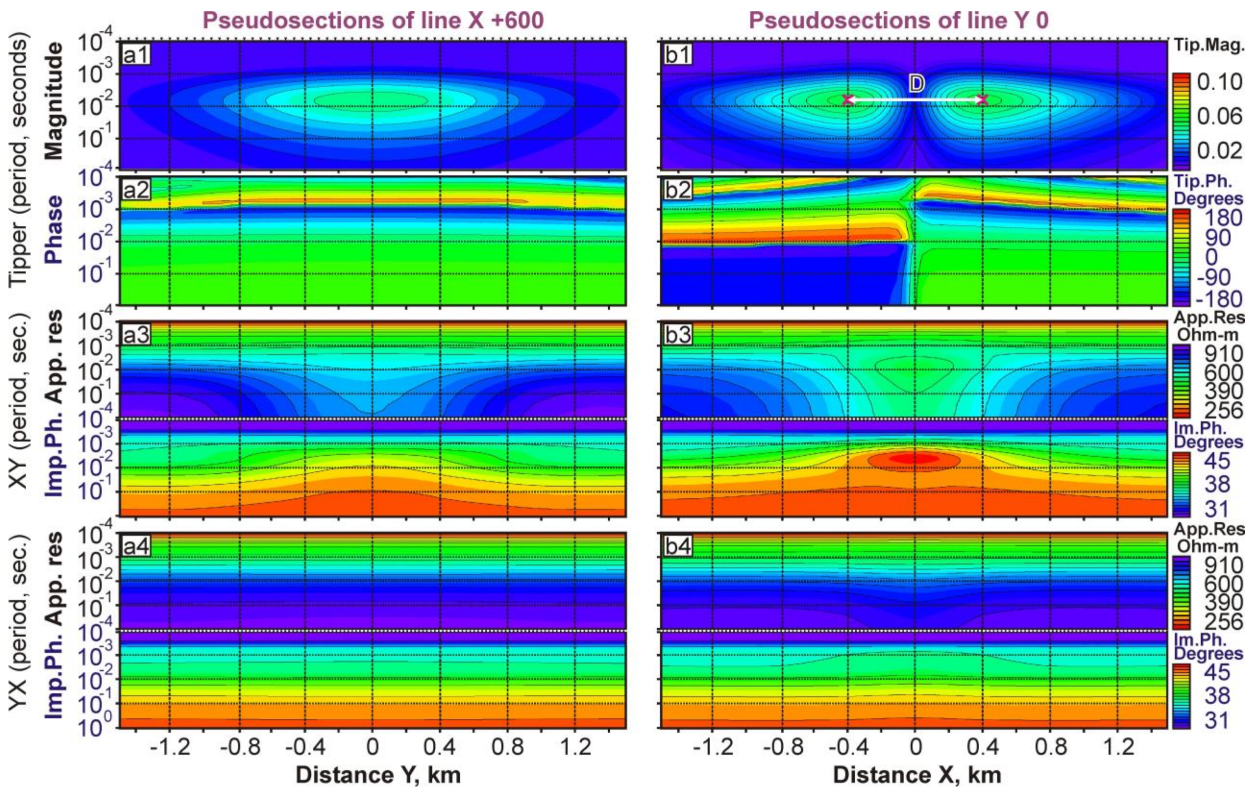

Figure 3. Pseudo-sections across Y +600 (a1-4) and X 0 (b1-4) lines. Tipper magnitude (a1,b1); tipper phase (a2,b2), apparent resistivity and impedance phase along XY (a3,b3) and YX (a4,b4) directions.