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Natural field IP for exploration of deep polarizable objects

Nikita Zorin
Moscow State University
Moscow, Russia
Nikita.zorin.geophys@gmail.com

Andrey Yakovlev
Moscow State University
Moscow, Russia
Mail@nw-geophysics.com

SUMMARY

The depth of conventional IP exploration is usually restricted by several hundreds of meters, which is insufficient for some geophysical tasks. We discuss the possibility of application of the magnetotelluric response functions for measuring the IP effect of the crustal conductors. A model example shows that theoretically the natural field induced polarization technique may provide with the information about very deep polarizable objects.

Key words: natural field induced polarization; magnetotellurics; IP; deep exploration.

INTRODUCTION

Natural field induced polarization or NFIP is a geophysical method based on recovering of the IP response from magnetotelluric (MT) data. Since MT field is essentially characterized by significant depths of penetration into the earth's interior, there was always a great interest of NFIP application for exploration of deep polarizable targets (Gasperikova and Morrison, 2001; Gasperikova *et al.*, 2005). We address this issue in the present paper and demonstrate some potential capabilities of the NFIP technique to detect an induced polarization response of a body which lies at the depths absolutely unreachable for conventional IP exploration.

The current state of the NFIP theory and methods of its application in practice are described in (Zorin *et al.*, 2015). Particularly, from there it follows that horizontal magnetic field at low frequencies is inherently insensitive for IP effect and NFIP technique should be based on working with the components of the so-called telluric tensor, which relates the total electric field in a survey site with that at a remote reference site. The approach is generally applicable for detecting of polarizable bodies of almost any shape (2D and 3D) and resistivity (excluding the very conductive ones).

The NFIP anomalies obtained with the help of the telluric approach are comparable to those of the conventional gradient-array IP technique (Zorin *et al.*, 2015). Consequently, the depth of effective NFIP exploration is mostly governed by the dimensions and conductivity contrast of the polarizable body, and by the spacing between the reference and the survey sites. For example, if the depth of burial of a strongly polarizable body is less than its typical dimensions, than it may potentially be discovered with the NFIP technique, which thus could be useful in exploration of large porphyry ore deposits at the depths of 500 – 1000 meters, where the application of the conventional IP method becomes challenging due to a number of well-known reasons (Gasperikova and Morrison, 2001).

If we are interested in the depths of more than 1 km all of the existing IP methods become useless and NFIP technique may turn out to be a source of unique scientific information about the earth interior structure. For example, let us consider the problem of extensive crustal conductors, which lay at huge depths (about 10 km) and are widely encountered both in continental rift zones and in stable crustal environments. Their existence may be explained by saline water, crustal magma, hydrated minerals, graphite, ductile flow mechanisms, geometrical effects and other reasons (Jiracek *et al*., 1983), hence any additional information would be useful for better understanding of the subject. If a deep conductor consists of graphite or other highly polarizable minerals this could be potentially revealed by NFIP method.

MODELING

The crustal conductors usually represent strongly elongated (quasi 2D) extensive bodies (eg. see Varentsov et al., 2014). To examine the applicability of the NFIP method for such objects we used the simplified model shown at Fig. 1.

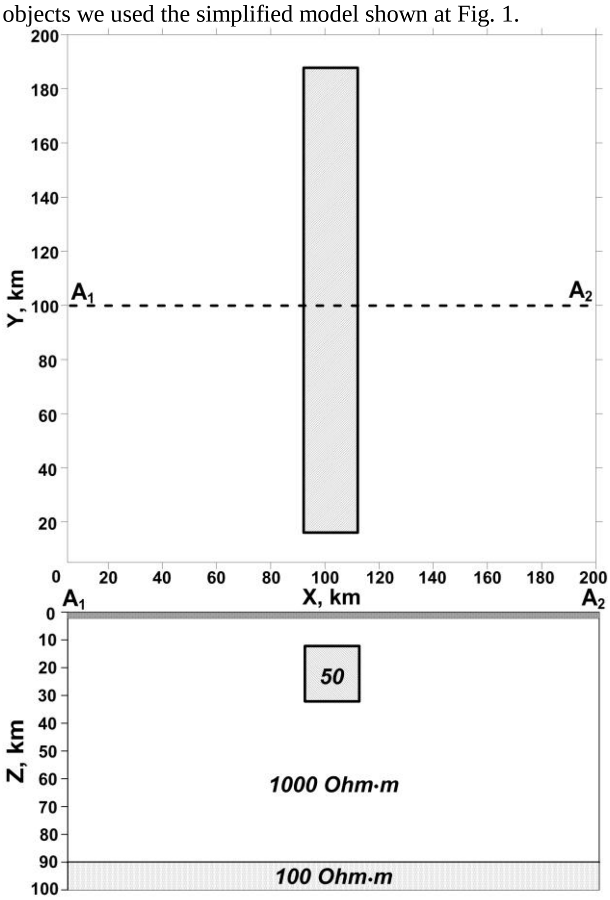

Figure 1. 3D model of a crustal conductor

The crustal conductor represents a huge (180km x 20km x 20 km) elongated body placed in a resistive layer of a three-layered background medium as shown at Figure 1. The telluric response of the model for the frequency 0.0001 Hz is given at Figure 2. The upper half of the picture shows the phase shift of the telluric tensor components (Txx, Tyy, and Teff) due to induction effects in medium, the lower half represents the IP sensitivity (see Zorin *et al.*, 2015) of the mentioned transfer functions.

It could be clearly seen from Figure 2 that even at such a low frequency the induction phase shifts are rather high and for all of the components stay about -1° over the conductive body. From the other hand, the IP response of graphite at very low frequencies may easily reach the values of 15° and more (Pelton et al., 1978), which, taking into account that the IP sensitivity of the longitudinal component Tyy over the polarizable body is well above 20%, means that it may produce a 3-4° IP phase shift on the surface, which could theoretically be observable.

CONCLUSIONS

We have shown that in certain conditions the positive IP effect of the deep crustal conductor may significantly overwhelm the negative induction effects and thus could be theoretically observable. The important thing is that for strongly elongated (quasi 2D) highly conductive objects the NFIP data should be rotated to become *parallel* to the polarizable body, in order to make the S/N ratio higher.

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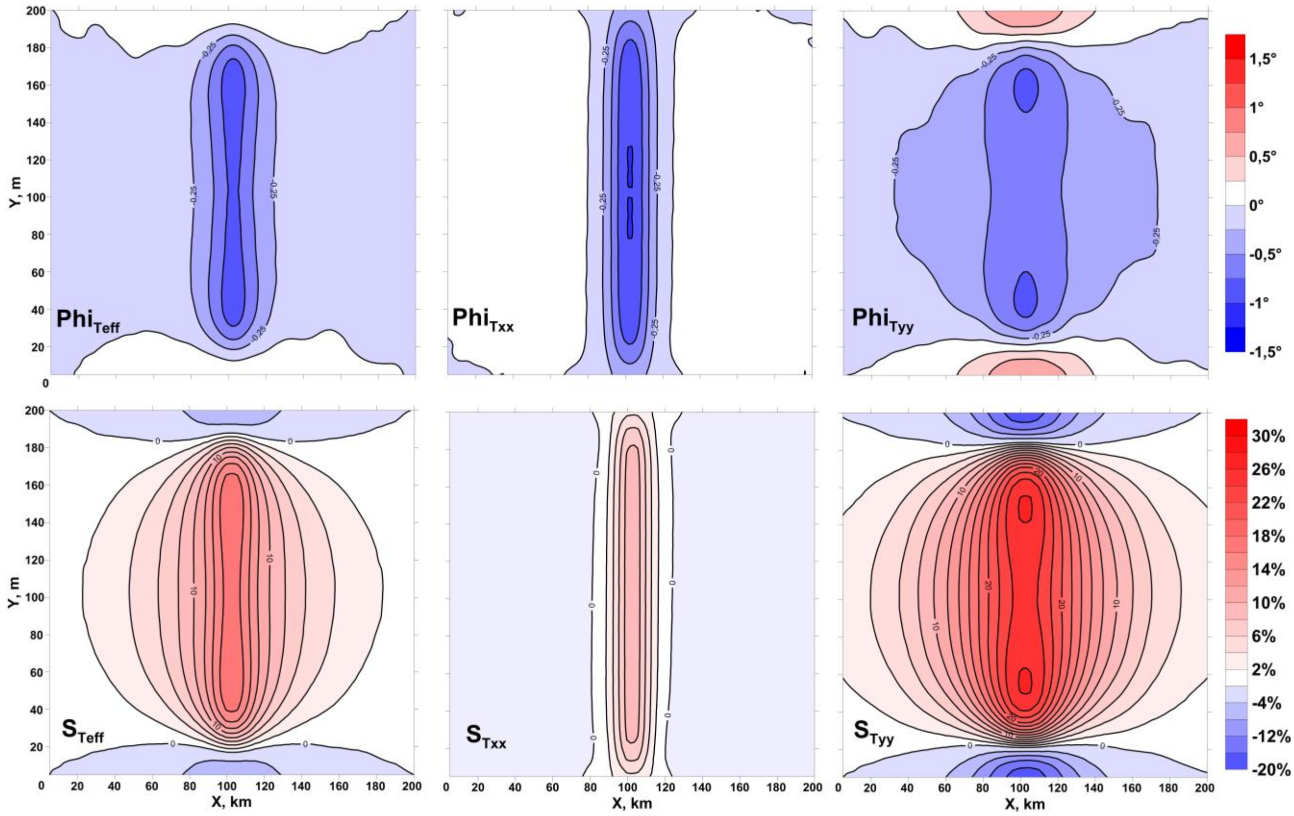

Figure 2. The telluric response of the model (f= 0.0001 Hz): induction phase shifts (upper half) and IP sensitivities (lower half).