Interpretation TEM-data by the program "Modem3D" for 3D modeling of transient electromagnetic field

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Anomalous conductive area was detected in 1955 by the vertical electrical sounding (VES) in the Kolyvan district of Novosibirsk region (near village Laptevka). Later this fact was confirmed by the Novosibirsk group of geophysicists by magnetic-variation sounding (Vanyan, Krotevich, 1967). The conductive anomaly lies in the north-south direction. The total longitudinal conductivity in the anomalous zone is characterized by a sharp increase (from hundreds to several thousands of S/m). However the exact contours and the material constitution (what is most importantly) of the conduction band has not yet been established.

In 2010-2012 scientific production enterprise of geophysical equipment "Looch" with IPGG SB RAS conducted a complex of geophysical and geochemical methods (gravity prospecting, magnetic prospecting, MT sounding, TEM, geochemistry) on the above-mentioned site. The joint interpretation of the data confirmed the presence of conductive anomaly.

This paper is concerned with interpretation of areal transient electromagnetic (TEM) soundings with the use of mathematical modeling. The 3D geoelectric model by the example of site near village Laptevka (Novosibirsk region) is constructed. The work was realized in two stages: the first stage – inversion of the TEM data in the model of a horizontally layered medium, the second - the creation of 3D geoelectric model using Modem3D (authors Kremer I.A., Ivanov M.I.). The forward 3D problem of transient electromagnetic field is solved by vector method of the finite elements for three-dimensional unstructured mesh consisted of tetrahedra. The result of Modem3D calculation is the time domain electromagnetic responses received in lines or loops. Mathematical modeling of TEM responses in media with complex geological structure is very resource-intensive, and therefore to improve performance the system of distributed computing was used (GRID-system), set up in IPGG SB RAS (Martyanov et al., 2009).

TEM measurements were performed by the loop-in-loop (coaxial) and spaced loop-loop arrays (200x200 m transmitter, 50x50 m receiver, spacing 200 m). The measurement scheme is shown in Figure 1a. About 90 data points (pickets) was measured at study area. At first, TEM data were inverted using 1D time domain inversion code TEM-IP (Antonov, Kozhevnikov, Korsakov, 2010). The quality of sounding data interpretation was assessed using the root-mean-square (RMS) deviation: $RMS = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left[\frac{f^{\exp.}(t_i)-f^{theor.}(t_i)}{f^{\exp.}(t_i)}\right]^2}$, where $f^{\exp.}$ - experimental data, $f^{theor.}$ - modeled TEM responses, N – number of times.

As a result of one-dimensional inversion geoelectric sections were obtained consistent with complex data. The quality of curve fitting did not exceed 0,01-0,03.

On the second stage of data interpretation TEM-data using Modem3D program three-dimensional geoelectric model was built based on one-dimensional received above. Two cross profiles of three-dimensional model: profile 1: 101-110, 21-28, 29-44; profile 2: 121-130, 02-15 are considered for a better visual analysis. These measurements are indicated in the diagram (Fig. 1a), the red and green lines. The sections on these profiles are shown in Figure 1b-c. The construction took place in several iterations: firstly, three-dimensional model was constructed in accordance with the obtained one-dimensional, then the model was adjusted in the most problematic (poorly-selected) locations. The use of GRID-system of IPGG SB RAS accelerates the process of adjustment by dozens of times. As a result, three-dimensional model of media has been constructed. RMS errors for all transients of the studied area, with rare exception, does not exceed 0,1. Taking into account the manual selection of three-dimensional model such deviation can be considered as satisfactory.

This may be noticed in the analysis of three-dimensional model that thickness of the conductive layer (0,2-0,4 Ohm) increases and reaches to 600 m in the north-west direction (profile 1) and northerly direction (profile 2). In the opposite directions thickness of the considered layer decreases and resistance increases (0,7-1,2 Ohm). Therefore, we can conclude that anomalous conductor is nearly invisible in the south-east direction. As follows from the first profile (Fig. 1b).

If we consider the individual pickets and the quality of the fitting experimental data and modeled transient responses (RMS), it can be stated that the most curves are matched with high accuracy (RMS = 0,03) both for 1D and 3D interpretation. For some pickets the standard deviation is close to 0,1 in the case of 3D modeling. One of the reasons for this discrepancy may be the presence of local 3D inhomogeneities.

We can draw the following conclusions:

Possibility of accelerating three-dimensional modeling (Modem3D) is shown for mapping of shallow structural formations by TEM sounding using GRID-system of IPGG SB RAS.

Possibilities of three-dimensional modeling are demonstrated and step-by-step approach for obtaining of three-dimensional model is shown by the example site near village Laptevka (Novosibirsk region).

Prospects for the development of effective tools for the interpretation of the TEM data using network resources IPGG SB RAS, Modem3D and advanced algorithms of inversion data are estimated.

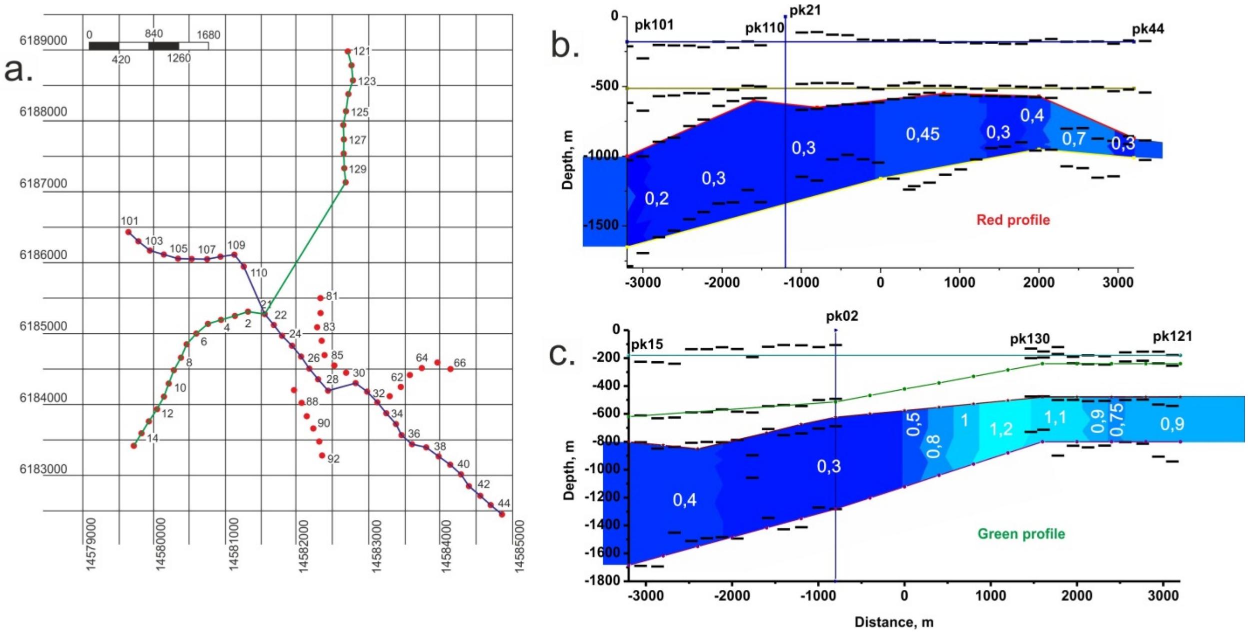

Fig. 1 The measurement scheme (a) and profiles for 3D modeling.
The geoelectric sections for red (b) profile and green profile (c). White numbers are resistivities (Ohm).
Lines with symbols are boundaries of layers of 3D model, black dashes are boundaries of 1D inversion.

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References:

1. Krotevich N.F., Vanyan L.L Effect of sudden geoelectric irregularity on the geomagnetic short-period pulsations [Text] // Geomagnetic explorations. – Moscow. – 1967. – P.36 – 39. (in russian).
2. Martyanov A.S., Teitelbaum D.V., Serdyuk K.S., Vlasov A.A., Eltsov I.N. Using vacant network resources of a company for solving geophysical problems requiring much computation // NTV “Karotazhnik”. – Tverj: Izd. AIS. – 2011. – №11(209). – P. 56-64 (in russian).
3. Ivanov M.I., Kateshov V.A., Kremer I.A., Epov M.I. Software Modem3D for interpretation IP-affected TDEM data // Notes of Mining Institute. – 2009. – vol. 189. – P. 242 – 245. (in russian)
4. Antonov E.Yu, Kozhevnikov N.O., Korsakov M.A. “TEM-IP” – system for interpretation induction transient sounding under polarizable medium // Geobaykal – 2010. First International Research and Application Conference on Electromagnetic Research Methods: Abstracts. – Irkutsk. – 2010. – CD-ROM. (in russian)