Frequency-domain induced polarization: application to a paleovalley, Ugra national park (Russia, Kaluga region)

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Introduction

Study of ancient paleovalleys is an actual task since they are associated with various placer mineral deposits. One of the largest Miocene paleochannel deposit structures (N1) is located in close vicinity of the geophysical research base (Aleksandrovka village, Ugra national park, Kaluga Region). Based on the parametric borehole data from the research base, it can be assumed that the paleochannel deposits are tens of meters thick. Therefore, this paleovalley is among the deepest and largest ones in the central part of the East European Platform.

The first geophysical survey consisted of magnetometric acquisition at the scale of 1:2,500. Two narrow linear zones of north-western strike appear on the magnetic local component map. It was decided to perform an additional vertical electrical sounding and induced polarization (VES-IP) survey with detail step on several profiles across the strike of the magnetic anomaly to obtain more detailed data about the structure of the identified object in the vertical section.

Data acquisition

Special multichannel stations and multi-electrode arrays are typically used for electrical resistivity tomography surveys. However, there are alternative where measurements are performed with the conventional symmetric four-electrode Schlumberger array and a special linear spacing which allows for 2D data inversion. The VES-IP array used by us was described earlier (Shevnin and Bobachev 2009). The current electrode spacing range (AB/2) was measured from 3 to 105 m. Potential electrodes distance 2 and 14 m long were used. The profile step was 10 m in the centre of the anomaly and 20 m on the profile flanks. Four measurement profiles were covered. The distance between the profiles was 60 m. Measurements were performed in the frequency domain at 0.6 and 19 Hz. The apparent polarizability was calculated through the Differential-Phase Parameter (DPP), which can be used for estimating the IP phase, according to the following empirical formula $\eta_k = -2.5\times\text{DPP}$ (Kulikov and Shemyakin 1978; Zorin 2013).

Interpretation of the results

The obtained results were interpreted using automatic 2D inversion ZondRes2D software. The interpretation models for electric resistivity tomography profile №2 up to the depth of 20 m are shown in Fig. 1. The vertical scale was doubled for better representation of the near-surface section structure. The resistivity model (Fig. 1b) primarily reflects the lithology. Dry sands have the highest resistivity, while clays are characterized by lower values. The sand lens reaches its maximum thickness of about 8 m at 100-120 m of the profile. A relatively thin horizon with increased polarization values which appear at low frequencies 0.6 Hz was identified at the depth of 4-5 m in the centre of the sand lens (Fig. 1c). Our previous studies in the vicinity of the Alexandrovka based on the IP method showed that this maximum is most likely associated with partial water saturation - capillary fringe zone located above the ground water level in the sands (Kulikov et al. 2013). The rock mass that creates the high-frequency 19 Hz induced polarization anomaly belongs to the conductive horizon located under the western side of the sand lens (Fig. 1d). The position of this anomaly matches well with the maximum of the local magnetic field component (Fig. 1a). This match leads to the assumption that both anomalies have the same nature.

The profile №2 passed in the 60 meters to the wells drilled for confirmation of the magnetic anomaly in the winter of 2013. According to the results of magnetic susceptibility measurements in the wells were found magnetite-containing clays in the interval of 4 to 9.5 m. Deposits with magnetic susceptibility exceeding $200\ 10^{-5}$ SI units were detected in well drilled in the southwestern part of the profile starting from the depth of 23 m. Laboratory measurement results (Kulikov et al. 2013) and our experience of surveys on other sites show that rapid IP field decay is characteristic of rocks that contain magnetite. This assumption is consistent with the obtained results, since the high-frequency IP anomaly spatially matches the local magnetic field anomaly (Figs 1ad). In our case the magnetite is of alluvial genesis and was deposited along the river-bed.

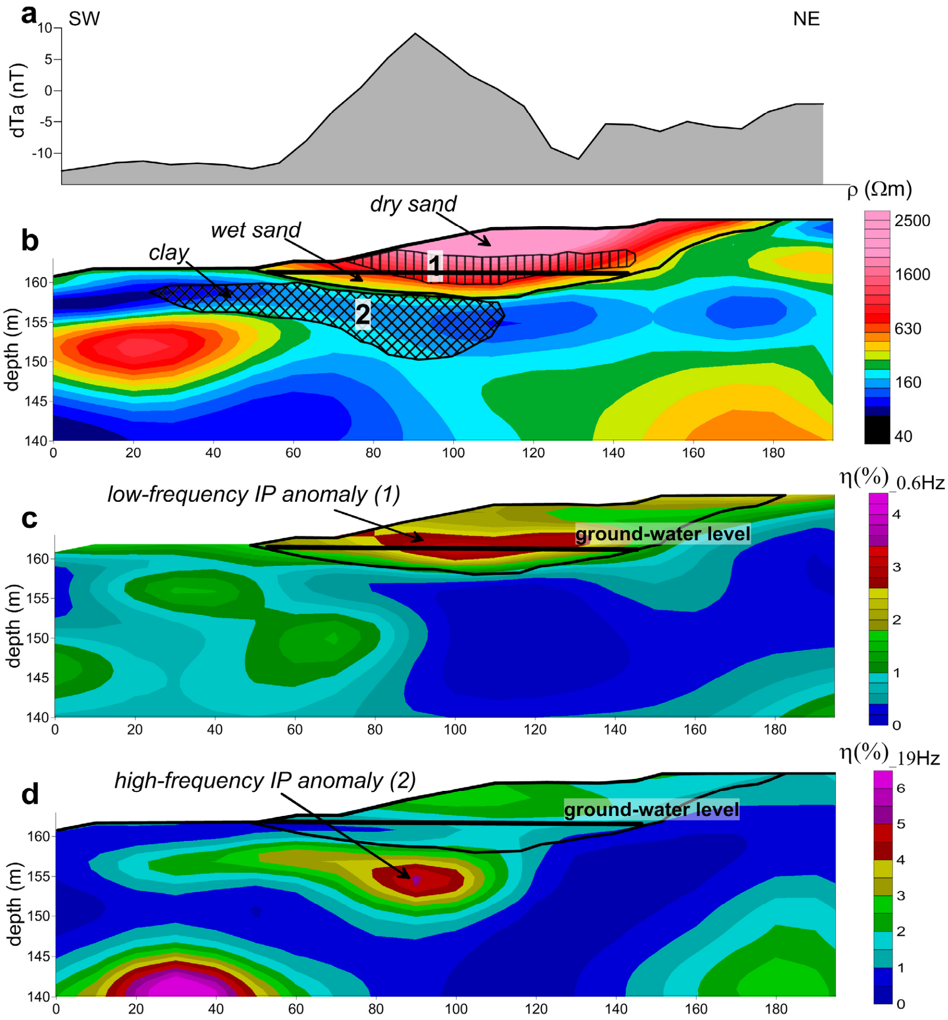

Fig. 1: Magnetic field graph (a), 2D inversion results: (b) resistivity model at frequency 0.6 Hz, (c) polarizability model at 0.6 Hz and (d) 19 Hz.

Conclusions

The geophysical survey carried out using electrical and magnetic exploration methods provided updated data on the structure of a large paleovalley in the National Park Ugra. VES-IP method with detail step and linear spacing were employed to achieve the project objectives. A definite relationship was established between the magnetic field anomalies and high-frequency induced polarization anomalies. Drilling operations carried out based on the magnetic measurement results confirmed that magnetite-containing alluvial deposits were indeed the source of those anomalies. The electrical exploration results can be used as a starting model for interpretation of magnetic survey data, which allows creating a 2D magnetic model of the paleovalley.

References

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