GLACIAL SEDIMENT RESISTIVITY ANISOTROPY MEASUREMENTS (KALUGA REGION, RUSSIA)

Alexei A. Bobachev, Dmiri K. Bolshakov, Igor N. Modin, Vladimir A. Shevnin
Moscow State University, Geological Faculty, Dept. of Geophysics, 119899 Moscow, Russia
ihor@geophys.geol.msu.ru.

OBJECTIVES

The Aleksandrovskoye Plato, having the area of about 1 km^2, is situated on the border of Kaluga and Smolensk Regions (Central Russia) on the left bank of the Ugra River (left tributary of the Oka River) near the mouth of the Vorya River. The glacial sediments properties on the Plato are peculiar in some in some features. The grains of sediment rocks are oriented differently in different rock varieties and in different locations in the geological cross-section (Lavrushin, 1992). This results in physical properties difference depending on the spatial direction, particularly, in resistivity anisotropy.

Very small resistivity directional variation is peculiar about anisotropy of this origin. Anisotropy coefficient is less than 1.1. The effect of other factors - geological noise, inaccurate array positioning, etc. - is thus likely to prevail over the effect of the anisotropy itself. The experiments implemented were targeted at detecting weak resistivity anisotropy of this kind. Traditional arrays (Schlumbeger, Wenner, pole-pole), are not suitable for this purpose due to their low sensitivity to anisotropy. It has been demonstrated recently (Bolshakov et al., 1998) that arrow-type (AT) array is theoretically sensitive enough for solving the problems of the kind.

In the course of the experiment the latter statement was verified experimentally. The field technique of azimuthal measurements was tested and improved as well, along with the technique of distinguishing the effects of resistivity anisotropy and local inhomogeneities of anisotropy.

FIELD EXPERIMENTS

Azimuthal measurements were implemented at 12 observation points (point-to-point distance 100 m) along the observation line 1100 m long with the AT array (AM=15 m, AN=20, B electrode was removed 100 m to the north from first oservation point). The array coeffitient $K=\pi \cdot AM \cdot AN/(AM-AN)$ is that of pole-dipole Shlumberger array. Potential difference was measured using the ANCh-3 (Kishinev Geophysical Eqiupment Plant, USSR) at 12 azimutal direction (every 30 degrees) with two measurement line positions (MN_1 and MN_2) at each direction. Low-frequency (4.88 Hz) AC of 10 mA was used in the current line.

The observation line with the azimuth of 63 degrees (ENE) was situated on the Aleksandrovskoye Plato, passing from Aleksandrovka Village to Maloye Ustje Village. The measurements were fulfilled in winter (average temperature in the course of experiment was about -20°C). To decrease the transient resistance between the steel current electrode and the ground strong salt solution was poured on the earthing point. The measured potential difference values varied from 0.5 mV to 10 mV and the corresponding apparent resistivity made from 40 Ohm·m to 400 Ohm·m.

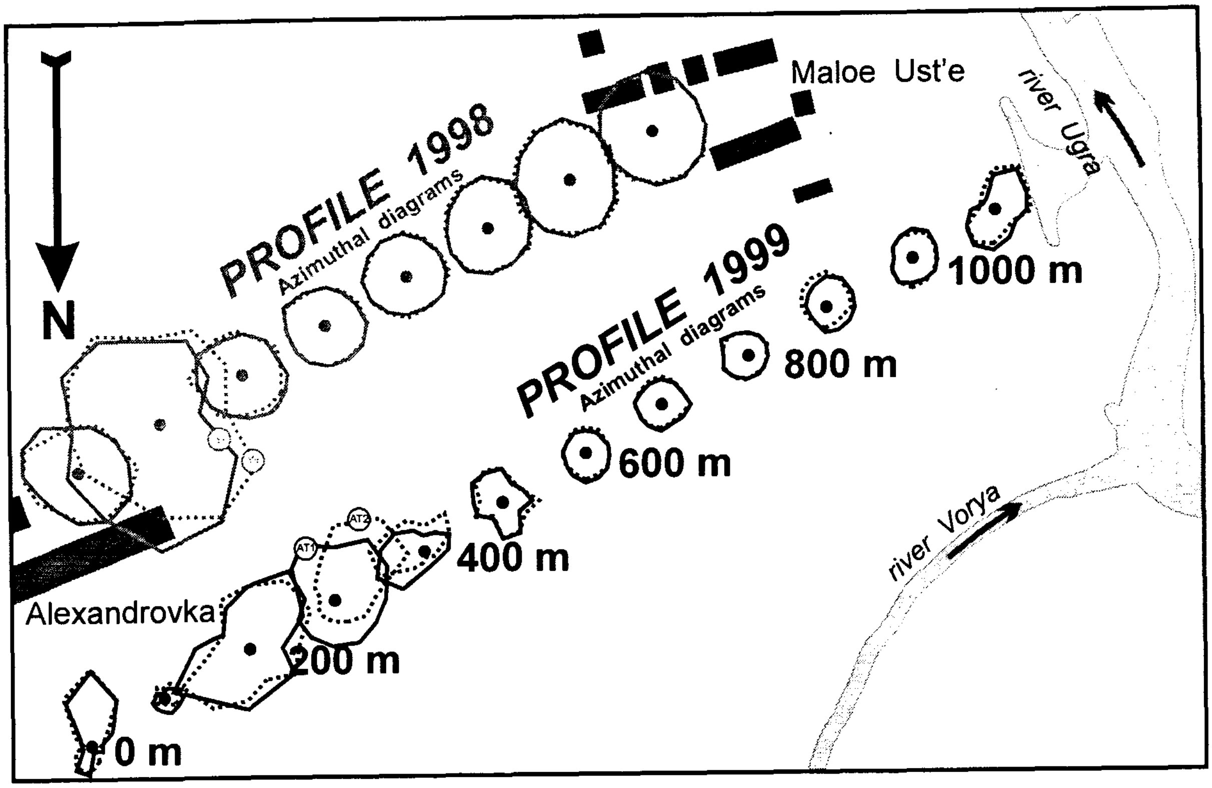

Fig.1. Azimuthal resistivity survey (1998, 1999) of glacial sediments.

Azimuthal diagrams of apparent resistivity for MN1 and MN2 coincide in case of homogenous anisotropic medium. Their difference results from the effect of local inhomogeneties. The diagrams for 12 points are presented at Fig. 1, «Azimuthal diagrams». The *AnizPack* set of programs (Dept. of Geophysics, Geological Faculty, Moscow State University, Russia) was used for data processing and interpreting. The values of strike azimuth (with its accuracy), apparent anisotropy coefficient, diagram asymmetry, O/E ratio (the ratio of sums of odd and even harmonics of diagram's spectrum) along with lateral, transverse and average resistivity (for anisotropic semi-space model) values were estimated in the course of data interpreting. The 1999 data and result of interpreting are presented at Fig. 2. together with 1998 data for the same object.

The 1998 observation line (700 m, 8 observation points, point-to-point distance 100 m), shifted 250 m to the north from the 1999 line, is parallel to the latter. The 1998 azimuthal measurements were implemented with Y-array (Bolshakov et al., 1998). The 1998 are presented by the apparent resistivity azimuthal diagrams for MN_1 (marked Y+) and MN_2 (marked Y-).

Non-contact electric soundings (15 observation points, point-to-point distance 50 m) were implemented in 1998 along the azimuthal measurements observation line. Non-contact electric soundings with the electrical antenna moving from the current electrode A (effective length of 1 m) at the frequency of 625 Hz (current value 20 mA) were implemented with the ERA equipment (ERA Co., St. Petersburg, Russia). The sounding spacing were from 5 to 50 meters with 5 m interval. The sounding data were processed and interpreted using the *IPI* set of programs (Dept. of Geophysics, Geological Faculty, Moscow State University, Russia). The upper part of the geological cross-section according to the sounding is presented at Fig. 2.

DISCUSSION

The 1999 and 1998 are well correlated.

The 1998 values of resistivities (Fig. 2., gray lines at «Resistivity» graph) vary from 30 Ohm·m in the middle part of the observation line (points, 350, 450) to 70 Ohm·m at the ends (points 150, 750, 850). The greatest transverse resistivity value (150 Ohm·m) is reached at point 250, while the greatest difference of transverse and lateral resistivities is observed at points 150-350. The 1999 values of resistivities (Fig. 2., black lines at «Resistivity» graph) vary from 20 Ohm·m in the SW part of the observation line (points 600-1000) to 200 Ohm·m in the middle and NE parts (points 0, 300, 400). The greatest transverse resistivity value (300 Ohm·m) is reached at point 200, while the greatest difference of transverse and lateral resistivities is observed at points 0, 200-400,1100.

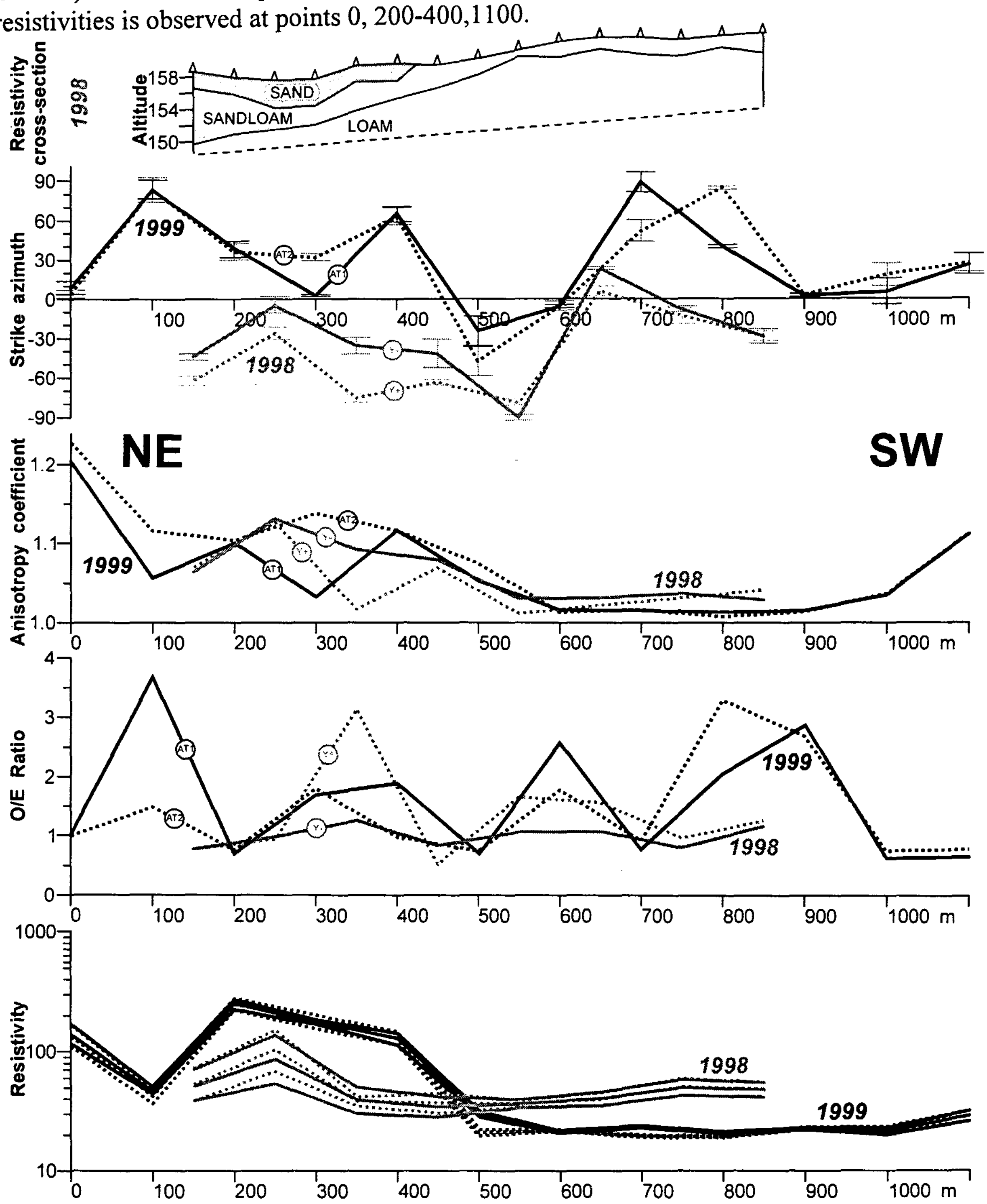

Fig.2. Results of azimuthal resistivity survey (1998, 1999) of glacial sediments.

The 1999 values of anisotropy coefficient (Fig. 2., black lines at «Anisotropy coefficient» graph) vary from 1.01 at points 600-900 to 1.2 at point 0, while the 1998 values of anisotropy coefficient (Fig. 2., gray lines at «Anisotropy coefficient» graph) vary from 1.01-1.04 at points 5500-850 to 1.13 at point 250. The greatest difference of anisotropy coefficient values (from 1.01 to 1.13) is reached at points 300 and 350 for both arrays, while the smallest differnce value is reached at points 200 (average value about 1.10) and 600 (average value about 1.02).

The 1999 strike azimuth values (Fig. 2., black lines at «Strike azimuth» graph) vary from -20 degrees at point 500 to 80-90 degrees at points 100 and 700. The accuracy of strike azimuth estimation varies from 2 to 20 degrees. The 1998 strike azimuth values (Fig. 2., gray lines at «Strike azimuth» graph) vary from -90 degrees at point 550 to 20 degrees at point 650 with the same accuracy limits. The 1998 strike azimuth average value (about -30 degrees) differs from that of 1999 (about 30 degrees).

Calculations for the two-model with anisotropy in each layer with Y-array proved, that strike azimuth rotation after shifting the observation line (250 m distance between 1998 an 1999 observation lines) may result from decreasing the thickness of the first layer from 4-6 m to 1 m, keeping other model parameters (the first layer: average resistivity of 90 Ohm·m, anisotropy coefficient 1.1, strike azimuth -30 degrees, vertical dip; the second layer: average resistivity of 50 Ohm·m, anisotropy coefficient 1.05-1.1, strike azimuth 30 degrees, vertical dip) unaltered. The effect of the second anisotropic layer increases as the thickness of the first layer decreases.

The effect of 2D and 3D local inhomogeneties can be another reason of strike azimuth rotation. The contact of sands and sandy loams between points 400 and 450 distinguished by 1998 soundings (Fig. 2, «Resistivity cross-section») with supposed strike azimuth -30 degrees is probably the cause the effect under consideration.

The accuracy of strike azimuth estimation (and other properties of the cross-section as well) is controlled by the effect of local inhomogeneties: the greater is the latter, the worse is the former. The O/E ratio provides the quantitative estimation of this effect. For the data under consideration (both 1998 and 1999) the O/E ratio (Fig. 2, «O/E Ratio» graphs), reaches the smallest values of 1 and less at points 0, 200, 500, 700, 1000, 1100, proving that the effect of the inhomogeneties is the weakest at these points, compared to other points with O/E ratio value varying from 1.5 to 3.5.

CONCLUSION

Under severe winter conditions geophysical survey was implemented and data of satisfactory quality were obtained. Using special arrays made it possible to gain azimutal data influenced by very weak resistivity anisotropy of the geological cross-section. The anisotropy coefficient values, estimated in the course of data interpreting, vary from 1.01 to 1.2 with the average value of 1.07. The detected resistivity anisotropy is likely to prove the geological data telling that the grains of the sedimentary rocks are oriented. Grain orientation is the factor resulting in weak resistivity anisotropy.

REFERENCES

1. Yu. A. Lavrushin. Quarternary sediments structure near the Aleksandrovka Geophysical Training and Proving Site. Internal report. Moscow State University, Geological Faculty. 1997 (in Russian).

2. D. K. Bolshakov, E. V. Pervago, I. N. Modin, V. A. Shevnin New step in anisotropy studies: arrow-type array. IV Meeting environmental and engineering geophysics. Proceedings. Barcelona, Spain, 14-17 September 1998. P.857-860.