# ANISOTROPY EFFECTS INVESTIGATIONS BY RESISTIVITY METHOD IN SOME INHOMOGENEOUS MEDIA.

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Resistivity method is commonly used to investigate horizontally-layered media as sounding, and inhomogeneous media as profiling. There is also the third fundamental model - anisotropic halfspace. Anisotropy commonly is investigated with the circular resistivity measurements. Anisotropy of rock properties is widely spread. Its investigation helps to understand geological situation, and vice versa, - ignoring anisotropy results in wrong data interpretation.

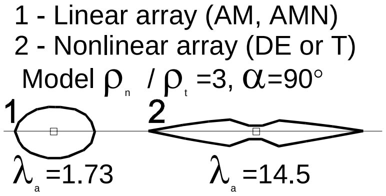

Fig.1. The ellipses for two arrays.

Anisotropic halfspace is a classical and well-known model. The fact is, that being used over anisotropic halfspace, all "linear" arrays (AM, AMN, AMNB, dipole axial) give the anisotropy ellipsis with the axes ratio proportional to þ, and "nonlinear" arrays, like dipole equatorial (DE) and three-pole array (T), - give the ellipsis with the axis ratio proportional to $\lambda^5$ (fig.1,1, fig.1,2).

When all electrodes of any array are on the earth surface, the dip angle of anisotropic layers cannot be found. It may be done when current electrode is placed at some depth in the borehole. T-array with current electrode in borehole has high sensitivity to anisotropy. The anisotropy ellipse obtained with this array is an asymmetrical figure. Asymmetry coefficient for T-array (fig.2) is greater than for AM or AMN arrays. Using a nomogram, as on fig.3, for T-array with current source on depth, it is possible to detect dip angle and all other anisotropy parameters.

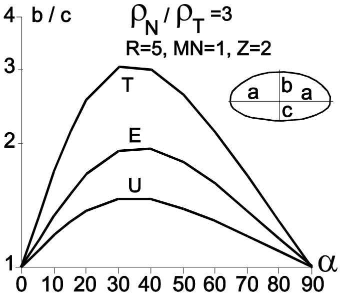

Fig.2. Dependence of ellipse asymmetry from dip angle.

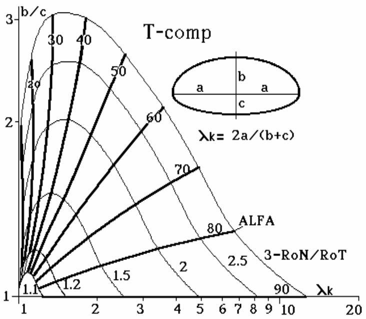

Fig.3. The nomogram for anisotropy estimation for T(DE) array.

When circular resistivity measurements are fulfilled in many points, a problem of their interpretation occurs. To make the process of interpreting more simple the program CRM for interactive (manual and automatic) interpretation was created. Testing this program shows that program works correctly even in case of noticeable (up to 20%) errors in data. When the medium is not exact anisotropic half-space model, the program gives "apparent" values of parameters, but analysis of their changing along the profile helps to solve geological problems (see the example on fig.7).

In practice, situations corresponding to models, more complicated than anisotropy halfspace, are rather frequent. We investigated two such models: vertical contact of two anisotropic media and anisotropic basement under isotropic overburden. These investigations were carried out to meet some practical demands. Near vertical contact of both media with different directions of anisotropy the circular profiling diagrams became distorted and have additional maximums in the directions of two azimuths of anisotropy (fig.4).

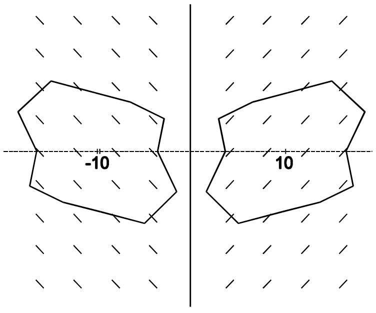

Fig.4. The circular diagrams near vertical contact of two anisotropic media.

The model of anisotropic halfspace with isotropic overburden often occurs in practice. This model is accompanied by many paradoxal phenomena. We investigated and compared the behavior of several arrays (AM, AMN, DE). Over anisotropic halfspace AM and AMN give identical results, but when overburden is present, their results are different (fig.5). The dipole equatorial array keeps the maximum sensitivity here. AMN (and AMNB) array, depending the r/h ratio, changes the azimuth of the longer axis of the ellipse. For a large range of r/h (from 1 to 10 in fig.5) the so called "anisotropy paradox" for AMN array does not exist. "Transversal" VES curves over halfspace with overburden look like three-layered of K-type, instead of two-layered form, and the difference between "longitudinal" and "transversal" $\rho_a$ curves is very noticeable.

Fig.6 shows modeling results (for U, E and DE arrays) over the real geological situation on the Patil Hill (the Crimea, the Ukraine). Overburden thickness is 10 m. Sensitivity of E array to anisotropy is low at r/h=4 (fig.6,C, $\lambda_a$ =1), while the sensitivity of U and D arrays is quite satisfactory. At r/h=3 (fig.6,B) $\lambda_a$ for E array is even smaller than 1.

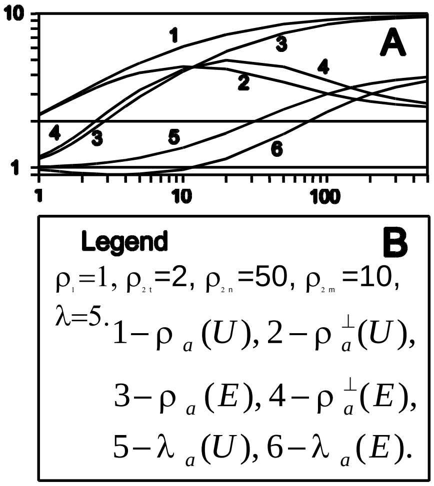

Fig.5. $\rho_a$ and $\lambda_a$ graphs for U and E arrays over layered earth.

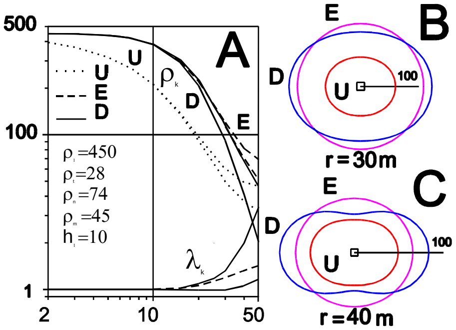

Fig.6. Modeling results for the place Patil.

Result of the investigation shows that the problem of anisotropic media with overburden is quite different from both anisotropic halfspace and two layered isotropic medium. The influences of anisotropy and layering are mixed in a large interval of r/h values. The most complicated and paradoxic are the results for gradient array (AMN, AMNB). Anyone should be very careful during interpretation data for gradient array with supposed anisotropy in lower halfspace and check the interpretation with the help of modeling. We recommend using dipole equatorial array with its high sensitivity to anisotropy.

The practical experience of resistivity investigation at many different geological situations shows that the geophysicists should be always ready to meet anisotropy and take it into consideration when interpreting any practical data. In the city of Donetsk (the Ukraine, 1991) the problem of detecting small-amplitude fracture zone in the place of forecoming house building could not be solved effectively using the usual electrical profiling. Circular resistivity measurements along the profile with their quantitative interpretation gave the opportunity to find out the location of fracture zone (fig.7). On fig.7,A circular diagrams for 4 points (NN 1,5,7,8), on fig.7,B - 10-points fragment of the profile with graphs of $\rho_T$ and $\rho_N$, on fig.9,C - azimuths of long axis of resistivity ellipses and on fig.7,D - values of $\lambda$ are presented. $\rho_T$ graph has no noticeable details and $\rho_N$ has two maximums in sites 5 and 7. Maximums of $\lambda$ are also located in sites 5 and 7 (fig.7,D). Mean values of $\lambda$ are about 1.05-1.1 and extremums in sites 5 and 7 are 1.3-1.4. So, it is possible to suggest that the fracture zone boundaries are located at sites 5 and 7.

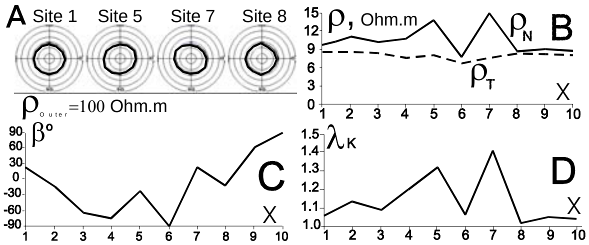

Fig.7. Field results over fracture zone in Donetsk.

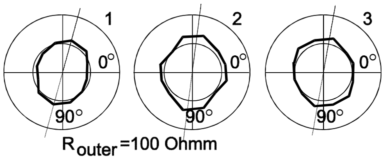

Fig.8. Anisotropy measurements in Mexico.

In Nuevo Leon (Mexico) circular resistivity measurements with dipole axial array were carried out on the territory of the future water reservoir. Obtained anisotropy ellipses (fig.8) allowed to find azimuths and extent of fractures in rocks. The fractures appeared to be directed across the dam. Probable water leakage was estimated for this case and some recommendations how to strengthen the curtain to prevent leakage from the reservoir were made.

Results of the investigation prove that the problem of anisotropic media with overburden differs considerably from both the problems of anisotropic halfspace and two-layered isotropic medium. The effects of anisotropy and layering cannot be separated in a vast range of r/h values. The results for gradient array (AMN, AMNB) are the most complicated and paradoxical. One should be very careful when interpreting data for a gradient array with supposed anisotropy in lower halfspace and check the interpretation results by modeling. We recommend to use dipole equatorial array with its high sensitivity to anisotropy.