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# The effects of formation anisotropy in induction logging.

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It is well known that essential part of oil-gas collectors are almost periodic thin-laminated structures consisting of thin seams with different conductivity. For the purposes of forward modeling of electromagnetic fields one can replace this medium by the effective uniform anisotropic medium if the value of skin-layer in each seam is much greater than its' thickness. Along with such macroanisotropic objects there are strongly metamorphosed rocks (e.g. gneisses) having microanisotropic conductivity, caused by the inner structure. There are a lot of papers where numerical modeling of electromagnetic responses in the layered transversally isotropic medium is discussed. Geologically it corresponds to the situations when stratification is parallel to the layers' boundaries. But if thin seams or planes of primary fissuring are inclined to the layers' boundaries, the forward modeling problem is becomes more complicated. This problem is discussed only in a few papers. Some problems of modeling is discussed insufficiently enough, some were not discussed at all. Among the last ones the analysis of influence of the dip angle of anisotropy on the induction logging data concerns.

To uncover the effects of dipping anisotropy the solver for forward modeling was created. The theoretical basis of this solver is the Maxwell's equations in the quasi-stationary approximation. To get the solver we used the 2-D Fourier-Bessel transformations. The results of modeling was compared with analytical solutions for an arbitrarily oriented magnetic dipole in a uniform medium and also with the results of finite difference scheme of G.A. Newman and C.J. Weiss [1]. On the basis of the solver we obtained the analytical approximations of electromagnetic field in the case of small dip angle of anisotropy.

On the basis of approximate analytical solutions we established that dip angle of

anisotropy have the essential influence on the behavior of electromagnetic fields and therefore on the induction and electromagnetic logging data. This influence reveals in following:

1. the electric charges and currents induced in the medium are quadrupole in character;
2. the maximum of electric charge density is reached in the region with the largest value of dip angle;
3. in the case of the vertical magnetic dipole in the dipping anisotropy medium the vertical electrical field and induced vertical electrical currents are present;
4. the correction for vertical magnetic field of the vertical magnetic dipole has the second order by the small dip angle of anisotropy, therefore the small dip angle will not influence on logging data of such probes.

On the basis of results of numerical modeling we established that using the traditional data interpretation methods of alternating currents logging in the formations with dipping anisotropy one can get the geoelectrical models that incorrectly describe the parameters of real medium, because of the modeling discrepancy; it is significant that using coaxial probes one can not uncover these defects. Comparing the low-frequency descriptions for magnetic field of alternating magnetic dipole in a uniform isotropic space and a dipping anisotropic space we estimated the modeling errors of apparent resistivity determination. Also we propose the new algorithm of determination of all components of conductivity tensor of formation. This algorithm was checked on the synthetic data and its results were analyzed.

References

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