P71

Full Wave Form 2.5D Inversion of Time Domain Induced Polarization

A.E. Kaminsky* (KGE Astra), V.L. Luhmanov (KGE Astra) & A.V. Sakovskaya (KGE Astra)

SUMMARY

According to the results this method of interpretation Time Domain IP is highly effective (Figure 1). It must be emphasized, that using IP parameters, such as decay time, give us new opportunity for interpretation.

Introduction

A lot of works in geophysics are devoted to IP interpretation. Theoretical basis of the method was made in the second part of 20th century [Seigel, 1962, Komarov, 1976, Semenov, 1960]. Success in solving the field's geophysics task have led to the fact that the method has become very popular.
Due to development of technical base at the last time appear new methods of electrical exploration, such as an electrotomography. IP electrotomography is applied in Russia recently. In spite of this we have quite a lot of materials to say that this method is highly effective to use in ore and engineering geophysics.

Full wave form 2.5D Inversion of Time Domain Induced Polarization

This work deal with problem of Time Domain Induced Polarization (TDIP) data interpretation for tasks of Ore geophysics. The field data is acquired using the TDIP method. There are two typical approaches to interpret this type of data. The first is to invert separately each time window; the second is to invert integral parameter (chargeability, apparent polarizability) basing DC theory. But such approaches have some shortcomings. In one case, there is no functional dependence between neighbor time windows. In the second case, the results are quite rough and have no information about of IP decays shape.

For solving this problem is proposed two-dimensional (2.5D) forward and inverse modeling of Time Domain Induced Polarization. Special software was developed based on this algorithm. It allows calculated and inverted IP decays for geoelectrical.

The forward modeling is based on the finite elements method, which is better than finite difference. [Dey&Morrison, 1971, Pridmore et all, 1981].

To obtain the result in the time domain, it is necessary to use frequency domain. Most popular frequency analogue of Cole-Cole replace the resistivity to:

$$\rho'(\omega) = \rho_0 \cdot \left(1 - \frac{\eta}{100}\left(1 - \frac{1}{1-(i\omega\tau)^C}\right)\right)$$

During modeling point-source field the earth is divided into triangular cell's mesh. The cells are characterized by various complex resistivities. The potential inside the cell is approximated by a linear basis function.

$$N(x,z) = \frac{(a + bx + cz)}{2A}$$

Point-source field in the interior of two-dimensional earth has three-dimensional structure. Fourier transform gives a solution by using spatial frequency.

$$\frac{\partial}{\partial x}\left(\sigma'\frac{\partial\phi(\omega)}{\partial x}\right) + \frac{\partial}{\partial z}\left(\sigma'\frac{\partial\phi(\omega)}{\partial z}\right) - \lambda^2\sigma'\phi(\omega) = -I\delta(x)\delta(z)$$

$$\frac{\partial\phi(\omega)}{\partial n} + \nu \cdot \phi(\omega) = 0$$

Where

$\phi(\omega)$ – spectral potential,

λ – spatial frequency,

I - current value,

σ – complex conductivity,

δ – Dirac delta function.

The complex electrical potential values of point-source for certain frequency can be obtained using calculation for a set of spatial frequency and further, inverse Fourier transform for calculated values of spectral potential.

The frequency domain solution $U(\omega)$ is converted to the time domain by using Fourier transform.

$$U(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} U(\omega)\frac{e^{-i\omega t}}{-i\omega}d\omega = \frac{2}{\pi}\int_{0}^{\infty}\mathrm{Re}\,U(\omega)\frac{\sin\omega t}{\omega}d\omega$$

Numerical filter is created for Fourier transform. Traditional, for filter building use pair functions relations $\frac{\omega}{1+\omega^2} \leftrightarrow e^{-t}$.

Selection of numerical filter for inverse Fourier transform is an important stage in forward modeling. Speed and accuracy of forward modeling deal with digital filter parameters, which are the following: node number and abscissas (frequencies).

When designing linear digital filter, we have taken into account parameters of time mode: length of impulse and pause, shape of impulse.

We analyzed some geoelectrical models in a wide frequency range. Final results show that correlation between complex signal and frequency for the most models changes smoothly. This is allowed to use relatively short filters. The comparison results of using different length filters show that mostly it is possible to use only 20-25 nodes.

The inverse modeling (determine geoelectric parameters) is based on Occam inversion [Constable et all, 1987]. The developed algorithm allows to invert parameters jointly or separately. Each parameter's type affects differently to response (has different sensitivity). Thus, during inversion development, it is very important to choose norm of model parameters and data. Logarithmic and linear-logarithmic norms are used for parameters in the earth, and linear-logarithmic for data. This is allowed to considerably reduce dynamic range of matrix Jacobean. A special attention was paid to the smoothing and speed factor for each type of parameters.

The resulting algorithm was tested on different synthetic models and field data. For synthetic data inversion algorithm gives good results (Figure 1).

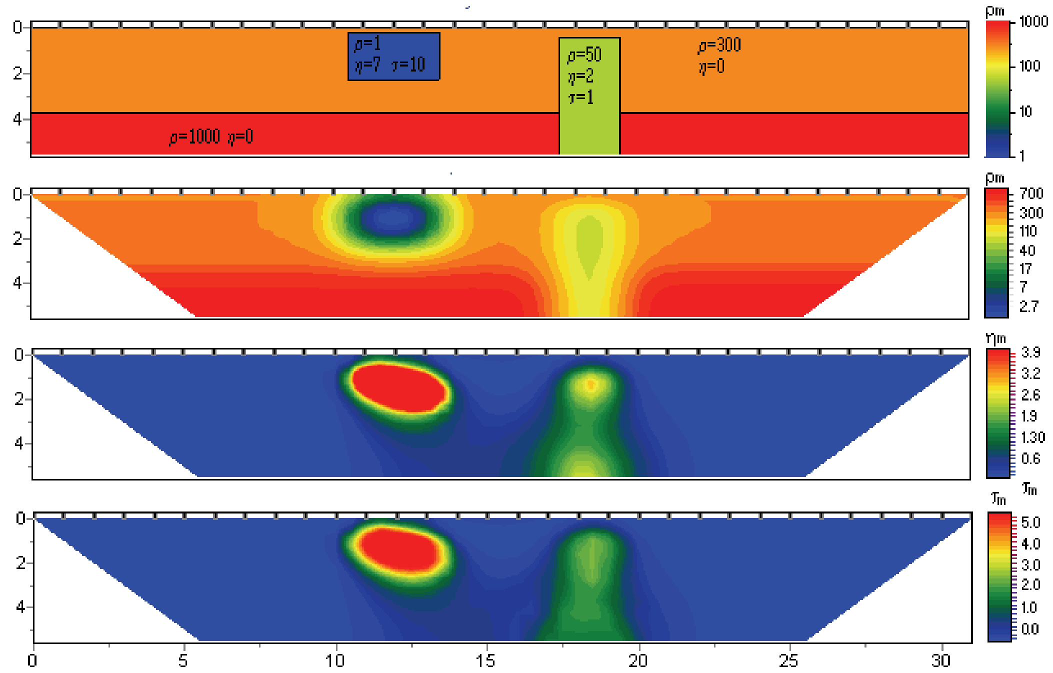

Figure 1 *Inversion of the synthetic TDIP data for original model in the upper part. Pole-dipole array, 500 points with 5% noise. ρ, η and τ sections.*

The interpretation of real field data much more difficult. The main difficulty during interpretation is a strong correlation between the cell's parameters. If all parameters are inverted at the same time, it is a high probability to obtain false objects. Therefore, parameters should be inverted consistently. It is important to specify the limits of parameters □ and C. While inversion it was used a special algorithm for solution linear equation system. This algorithm slows down the outranged parameters speed.

While inversion it was used a following algorithm:

1. At the first stage, obtain a resistivity section according voltage signal. For resistivity sets limits in range 5-10%.
2. Than resistivity and polarizability inverse together (range within) for voltage signal and decay's integral parameter – chargeability. For polarizability sets limits in range 5-10%.
3. At the end stage, all parameters and data are inverted. In general, parameter C is not inverted or it has high smoothness factor.

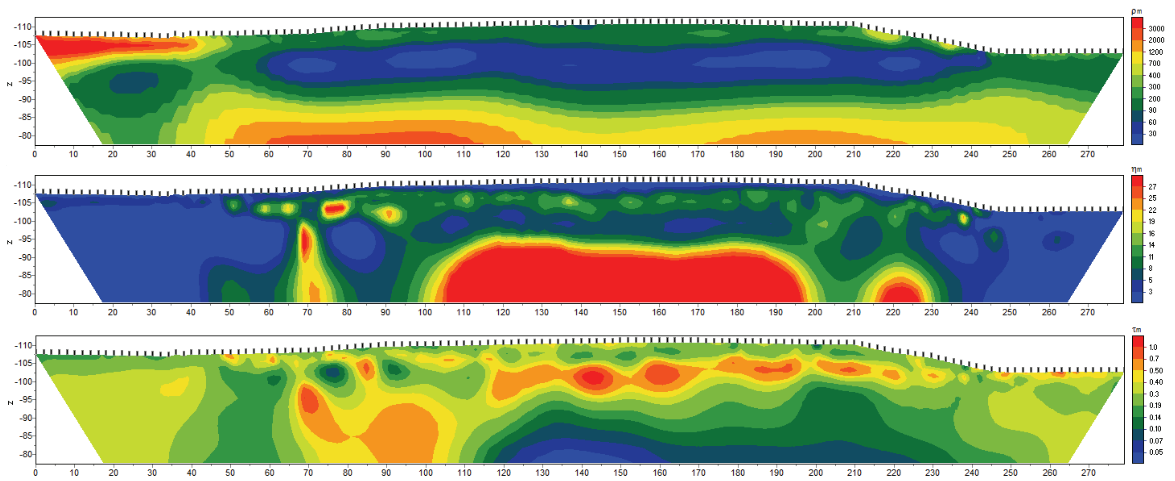

Figure 2 *Inversion of the field data. ρ, η and τ sections. Data provided by Professor T. Dahlin (University of Lund, ABEM instruments).*

This algorithm was tested with the electro-tomography IP data kindly provided by Professor Dahlin (Figure 2). In this example, solved the problem environment pollution. Model for the data set is rather stable. We run number of inversions with different parameters and the models was very similar.

Conclusions

According to the results this method of interpretation Time Domain IP is highly effective (Figure 1). It must be emphasized, that using IP parameters, such as decay time, give us new opportunity for interpretation.

References

Komarov, V.A. [1976] Correlation between time parameters of Induced Polarization and size of body. *Methods of exploration geophysics*, **26**, 109-114.

Kormiltsev, V.V. [1976] Sand-clay rock induced polarization. Equipment and Induced polarization decay form. *USC AN USSR*. 41-68.

Dey, A. and Morrison, H.F. [1979] Resistivity modeling for arbitrarily shaped three-dimensional structure. *Geophysics*, **44**, 753-780.

Seigel, H. [1962] Induced polarization and its role in mineral exploration. *Canadian Min. Metall. Bull*., **55**(600), 242 -249.

Constable, S., Parker, R., Constable, C. [1987] Occam's inversion: A practical algorithm for generating smooth models from electromagnetic sounding data. *Geophysics*, **52**, 289.

Pridmore, D., Hohmann, G., Ward, S. and Sill, W. [1981] An investigation of finite-element modeling for electrical and electromagnetic data in three dimensions. *Geophysics*, **46**, 1009-1024.