JOINT INVERSION OF TEM AND DC SOUNDINGS

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Abstract

It is well known that DC (direct current) soundings are very sensitive to resistive layers and structures imbedded in section and insensitive to conductive layers. To the contrary, TEM (transient electromagnetic method) is sensitive to conductive layers and insensitive to resistive ones. The real paper describes the way of joint inversion both DC and TEM data in 1D class of layered sections providing construction of a single model satisfying all experimental data. Essential property of the way is interactive fitting of parameters of the section.

The problems arising at interpretation of TEM sounding data are well-known:

- weak sensitivity of the method to the poor conducting layers and rock blocks;
- loss of an information about subsurface layers in the hole zone of early TEM times;

DC soundings meet some problems as well, namely:

- effects of shielding existing even in thin high-resistance layers limit depth and resolution of soundings;
- great extent of equivalence of the models obtained at the data inversion;
- ineffective ratio between sounding depth and the size of electrode remote.

However joint research based on both methods is capable to concentrate advantages of each method and decrease essentially their imperfections.

The developed DC-TEM RESEARCHER tool for inversion of TEM and DC data is based on analysis and joint inversion both TEM and DC data in the class of layered sections. Joint inversion consists in search of a minimum of misfit functional

$$\Omega = \alpha \left\| \rho_{DC} - R_{DC} \right\| + (1-\alpha) \left\| \rho_{TEM} - R_{TEM} \right\|$$

where ρ_{DC} and ρ_{TEM} are experimental values of apparent resistivity for DC and TEM methods, R_{DC} and R_{TEM} are the model values corresponding 1D layered model of section single for both methods, $\|\cdot\|$ - the norm which is determined by the experimental data of apparent resistivity and their errors,
$0 \le \alpha \le 1$ is the factor regulating the contribution of each method in the functional Ω. In case of TEM the errors determining norm $\|\cdot\|$, are calculated directly during field measurements, and for DC by the results of measurements with the fixed centre of soundings and various orientation of AMNB line

$$\left\| \rho - R \right\| = \sum \left(\frac{\rho - R}{\rho} \right)^2 \exp(-3\Delta / \rho)$$

Δ is the error of measurements for each time *t* (TEM) or remote AB (DC), summation is carried out over all *t* and AB.

The robust technology for suppressing of "heavy tails" of measurements to decrease the weight of bad measurements in the functional Ω is applied. In the minimization process the factor α smoothly changes from 1 to 1/2 (or from 0 to 1/2), that allows to avoid a local minima of the functional. In the beginning a model appropriate to the data of only TEM or

DC method is used as the start model then the model's parameters gradually and interactively changes the data on the basis of both methods. This strategy is essential element of the process of the problem's solution. 2D and 3D geological structures are represented as the geoelectric images, constructed like tomograms on the base of local 1D TEM and DC inversions adjusting the data of profile or array measurements.

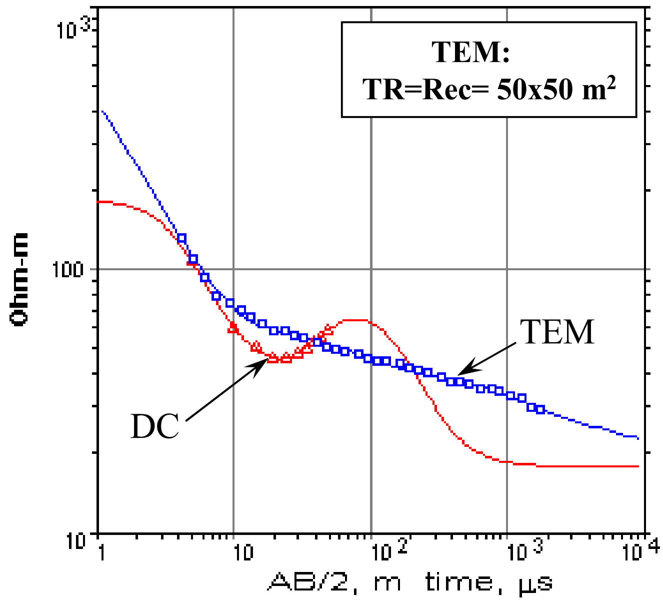

Fig. 1

Fig. 1 gives the experimental TEM and DC data, measured above the Russian platform's sediments as well as the modeling curve of apparent resistivity, calculated on the basis of joint inversion (α=1/2).

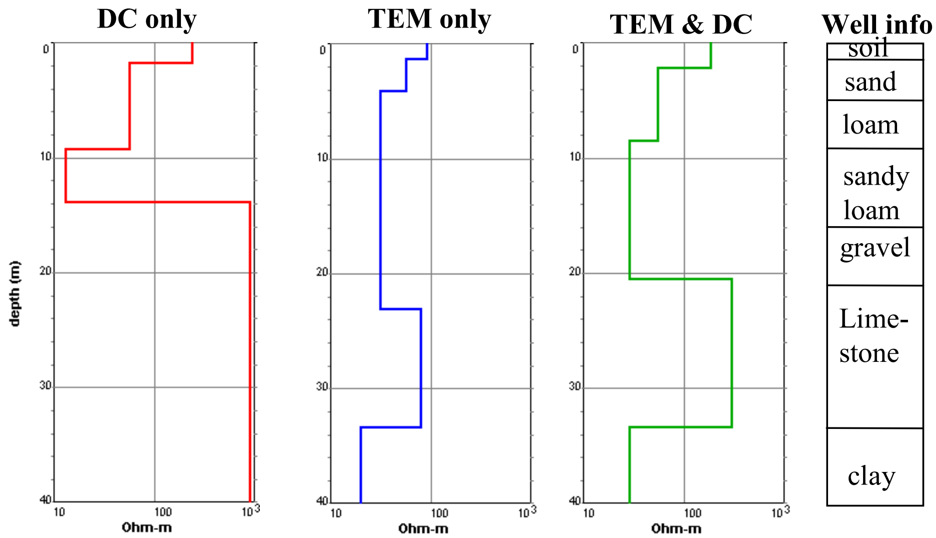

Fig. 2

Fig. 2 represents the results of 1D inversion for three variants of inversion:

a) only DC data (α=1), (Schlumberger configuration MN=2 m),
b) only TEM data (α=0), (one-loop 50m×50m configuration),
c) both TEM and DC data, (α=1/2),
d) geological section constructed according the well located in the centre of TEM and DC measurements.

At individual inversions the misfit (mean square deviation) between modeling and experimental data is minimal and situated within the confidence limits of the error range. In the case of joint inversion this misfit is for certain more, however it is still located within the confidence limits. As one can see, in spite the model and experimental curves of apparent resistivity in case of separate inversions are quite close, the found sections are rather far from the geological data. At joint inversion the result is very close to the real geological data.

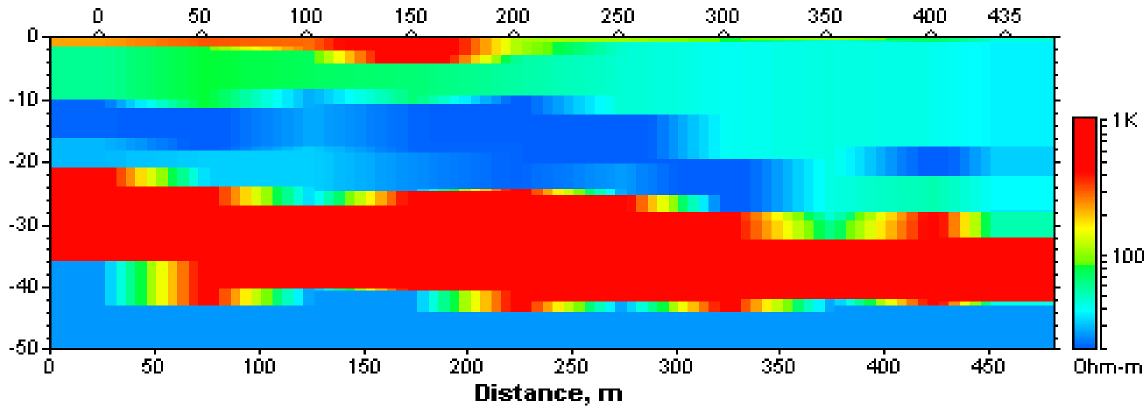

Fig. 3

The geoelectric section along the profile constructed as the tomogram is given in Fig. 3. Picket 0 corresponds the data presented in Fig. 1 and Fig. 2 (well).

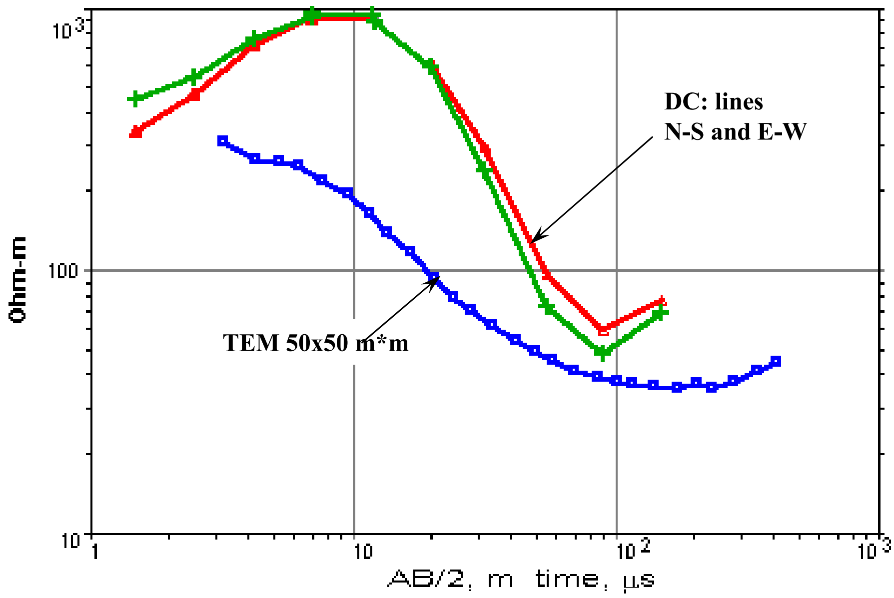

Fig. 4

DC and TEM curves shown in Fig. 4 were measured above the geological structure characterized by interbedding of limestone (head water horizon) and clay (confining layer).

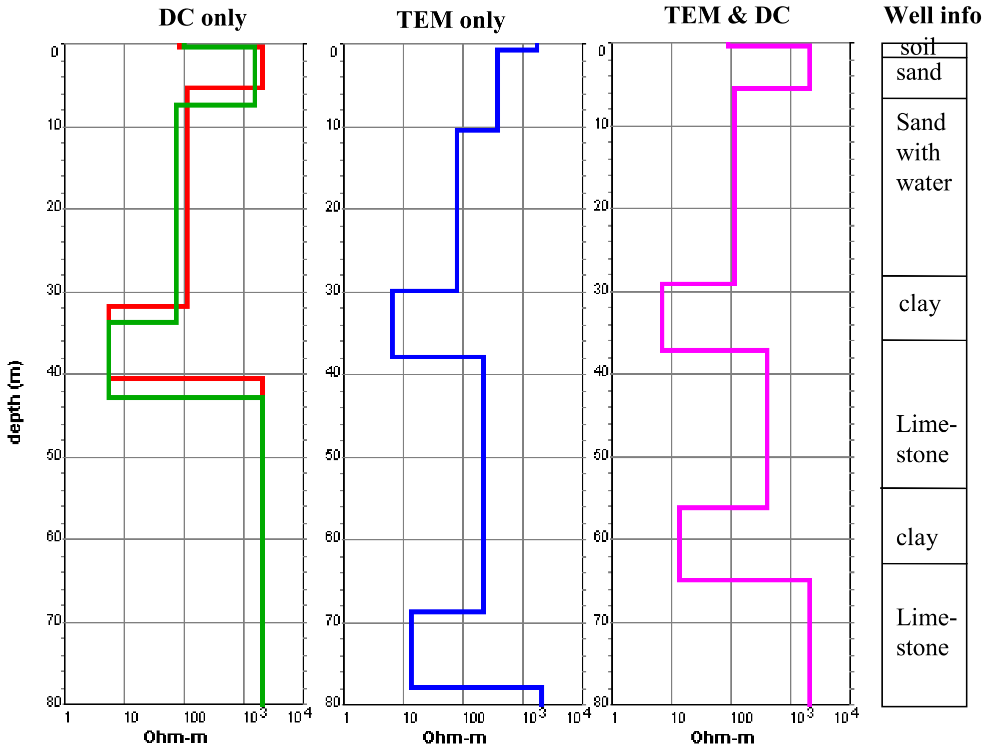

Fig. 5

Inversion of the DC data (Fig. 5 a) locates with the acceptable error the top clay confining layer and the level of superficial groundwater. However at maximal remote AB/2=150 m, DC does not penetrate into the second confining layer (h ~ 55 м) as rather high-resistance limestone create the screen for electric currents. TEM (5b) inversion incorrectly determines the level of subsoil waters, but well allocates the top clay confining layer. However the depth of the clay layer is defined with rather large error (~70 m instead of 55 m) because of the underestimated resistivity value of limestone composing first water horizon. At joint inversion DC and TEM (Fig. 5c) all main boundaries of layers (Fig. 5d) are determined with the acceptable accuracy.

Conclusion

Joint DC and TEM 1D inversion allows defining parameters of well and poorly conducting layers of section whereas DC and TEM separately, rather often, does not let to make that. Interactive DC-TEM fitting of the parameters of section is of basic importance of the method.