Time-lapse resistivity imaging inversion

Meng Heng Loke[1,2]
[1] *presently at* School of Earth Sciences, The University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom.
[2] *formerly at* School of Physics, Universiti Sains Malaysia, 11800 Penang, Malaysia.
(email : drmhloke@hotmail.com)

Paper presented at the 5th Meeting of the Environmental and Engineering Society European Section, Sept. 6-9 1999, Budapest, Hungary.

In studying the changes of the subsurface resistivity with time, two-dimensional resistivity imaging surveys are often repeated over the same line at different times. Such studies include the flow of water through the vadose zone, changes in the water table due to water extraction, flow of chemical pollutants and leakage from dams.

Normally, the data from the surveys conducted at different times are inverted independently, frequently with a smoothness-constrained least-squares inversion method (deGroot-Hedlin and Constable 1990). The changes in the subsurface resistivity values are then determined by comparing the model resistivity values obtained from the inversions of an initial data set and the later data sets. In many cases, such an approach has given satisfactory results. However, in theory, since the inversion of each data set is carried out independently, there is no guarantee that the differences in the resistivity values are only due to actual changes in the subsurface resistivity with time. Each inversion attempts to minimise the difference between the observed and calculated apparent resistivity values for an individual data set without taking into account the model obtained from the initial data set.

The use of joint inversion techniques using three different types of cross-model constrains is investigated in this paper. The model obtained from the inversion of the initial data set is used as a reference model to constrain the inversion of the later time-lapse data sets. Firstly, a simple damped least-squares constrain to minimise the differences in the model resistivity values between the initial model and the time-lapse model was used. The second method uses a least-squares smoothness constrain to ensure that the differences in the model resistivity values vary in a smooth manner. Thirdly, a robust (Claerbout and Muir 1973) smoothness constrain which minimises the absolute changes in the model resistivity values was used.

Figure 1a shows a test model where the base model has a 50 ohm.m faulted block at the bottom-left side with a surrounding medium of 10 ohm.m. In the time-lapse model, a small rectangular block with a resistivity of 20 ohm.m was added. This is a relatively difficult test model as the apparent resistivity anomaly caused by the faulted block is much large than that caused by the small block (Figures 1b and 1c). Figure 2 shows the differences in the resistivity of the models obtained from the inversion of the initial and the time-lapse data sets. Ideally, the difference section should show a value of 100% where the small block is located and 0% elsewhere. The difference sections for all the inversion methods do show large positive values of over 70% at the location of the small block. However, the section obtained with independent inversions with no cross-model constrains show significant changes in other areas, particularly near the upper-right corner of the faulted block (Figure 2a). The distortions are smaller with the damped least-squares (Figure 2b) and the least-squares smoothness cross-model constrain (Figure 2c) methods. However, the best result is obtained with the robust smoothness cross-model constrain method (Figure 2d).

References

Claerbout, J.F. and Muir, F., 1973. Robust modeling with erratic data. Geophysics, **38**, 826-844.

deGroot-Hedlin C. and Constable S.C. 1990. Occam's inversion to generate smooth, two-dimensional models from magnetotelluric data. Geophysics **55**, 1613-1624.

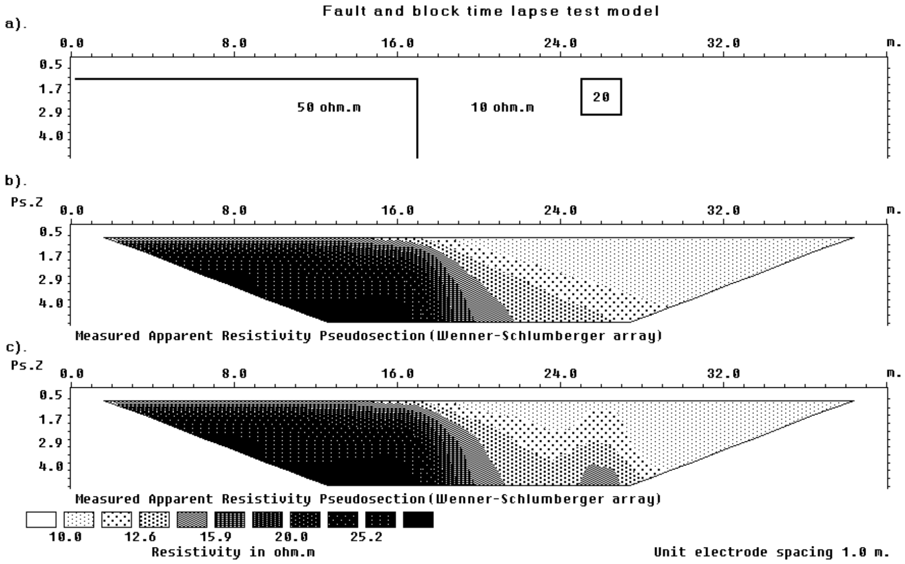

Figure 1. (a). Test model with large faulted block and small rectangular block. (b). Initial apparent resistivity pseudosection due to the large faulted block alone. (c). Time-lapse apparent resistivity pseudosection with the additional small rectangular block.

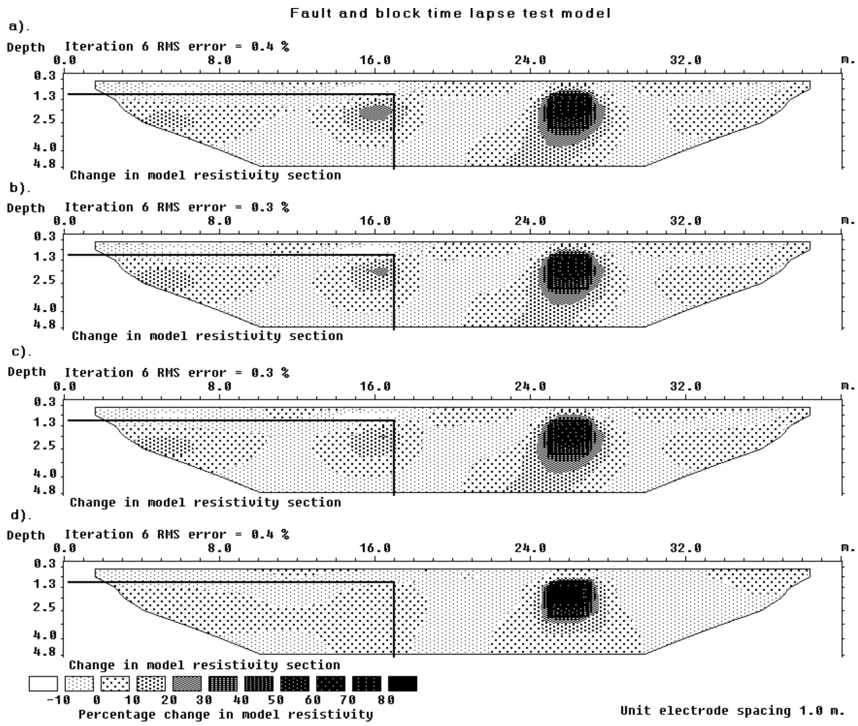

Figure 2. Change in the model resistivity section obtained from the inversion of the initial and time-lapse apparent resistivity data sets using (a) independent inversions, (b) a damped least-squares, (c) a least-squares smoothness and (d) a robust smoothness cross-model constrain.

Ref : Loke, M.H., 1999. Time lapse resistivity imaging inversion. Proceedings of the 5th Meeting of the EEGS European Section, Em1.