3-D Electrical Resistivity Tomography: optimizing field operation and resolution.

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Summary

We present a field procedure and data acquisition strategy for conducting 3-D Electrical Resistivity Tomography (ERT) surveys. Data was acquired along perpendicular sets of 2-D lines. Apparent resistivity data from the individual 2-D ERT lines were combined and inverted using a 3-D resistivity inversion code. The results demonstrate that, with a proper array design, the high resolution 3-D ERT images can be produced. Three-D surveys will save site the time and effort lost due to uncertainty in the interpretation of 2-D images, which is caused by features in the 2-D inversion images resulting from 3-D effects.

Introduction

The Electrical Resistivity Tomography technique is a powerful tool that is used for engineering and environmental site assessment. Most of the problems associated with environmental and engineering applications are inherently 3-D. However, 2-D ERT data acquisition and inversion techniques have dominated resistivity surveys. Images resulted from 2-D ERT surveys can contain spurious features caused by 3-D effects. This usually results in mis-interpretation of the observed anomalies in terms of the magnitude and location.

In this study, we have utilized the ERT technique to monitor the electrical conductivity (EC) of the subsurface beneath a decommissioned sour gas processing plant. Glycols and amines and their degradation by-products contribute to the electrical conductivity of the soil and groundwater. In the following, we demonstrate the effects of 3-D features on 2-D ERT images. We present a 3-D ERT field operation and data acquisition strategy. We demonstrate that the 3-D ERT surveys increase the resolution and reliability of the results.

2-D ERT survey

The 2-D ERT survey was conducted using Wenner configuration with 1 m electrode spacing (Figure 1). The ERT line crosses an installed 4-m

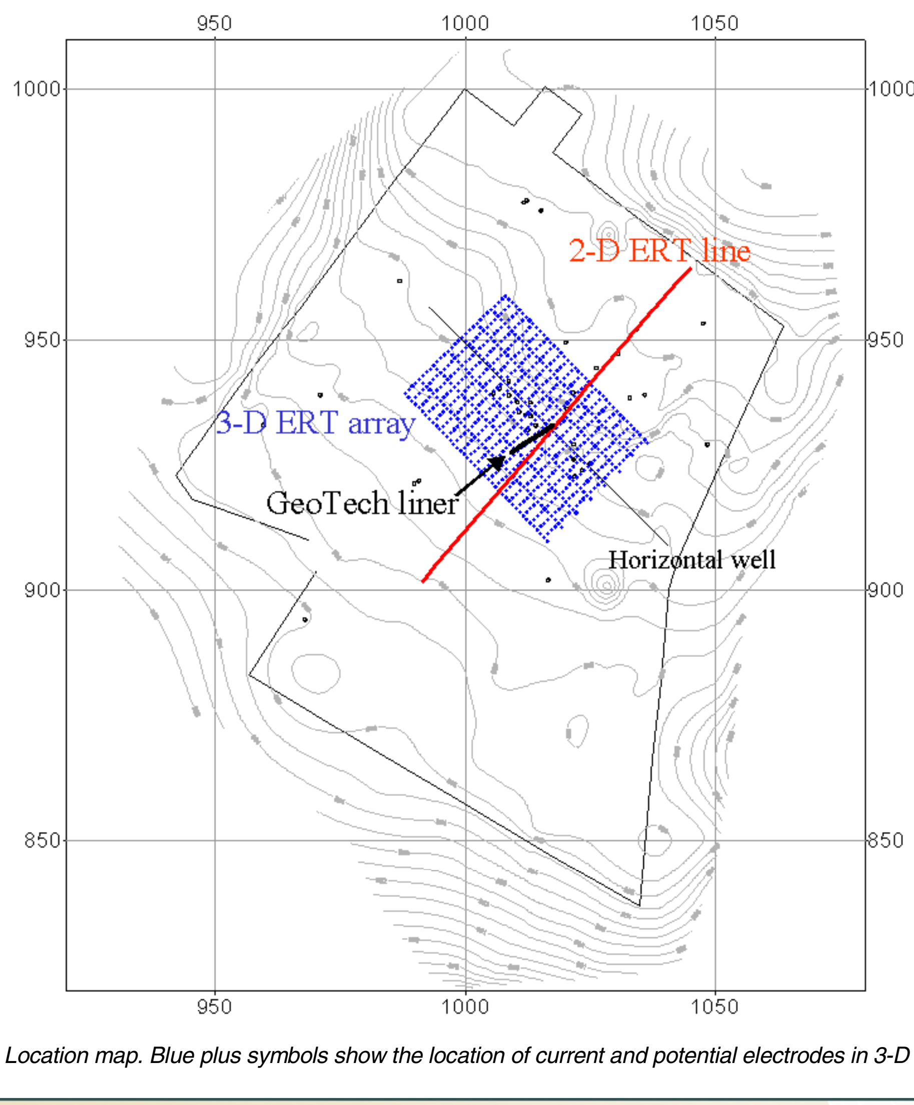

Figure 1. Location map. Blue plus symbols show the location of current and potential electrodes in 3-D ERT array.

deep horizontal well and runs almost parallel to a geo-textile liner at the middle of the survey line. The geo-textile liner was installed to isolate a region of the horizontal well. Apparent resistivity data was inverted to true resistivity using a 2-D inversion code (Loke and Barker, 1996a). The inverted results (figure 2) show a strong conductivity low in shallow depth from 926 to 933 m offset, where it parallels the geo-textile liner. It represents highly resistive geo-textile materials. Beneath this shallow low conductivity anomaly, a highly conductive zone is observed. This conductive anomaly has a conductivity exceeding 500 mS/m and extends to the bottom of the conductivity model. Based on these results, a push-tool conductivity (PTC) measurement was conducted at the location of the observed conductive anomaly. However, EC PTC data did not encounter any conductive anomaly at the depths indicated in the image. The anomaly was interpreted as 3-D features out of the survey line plane.

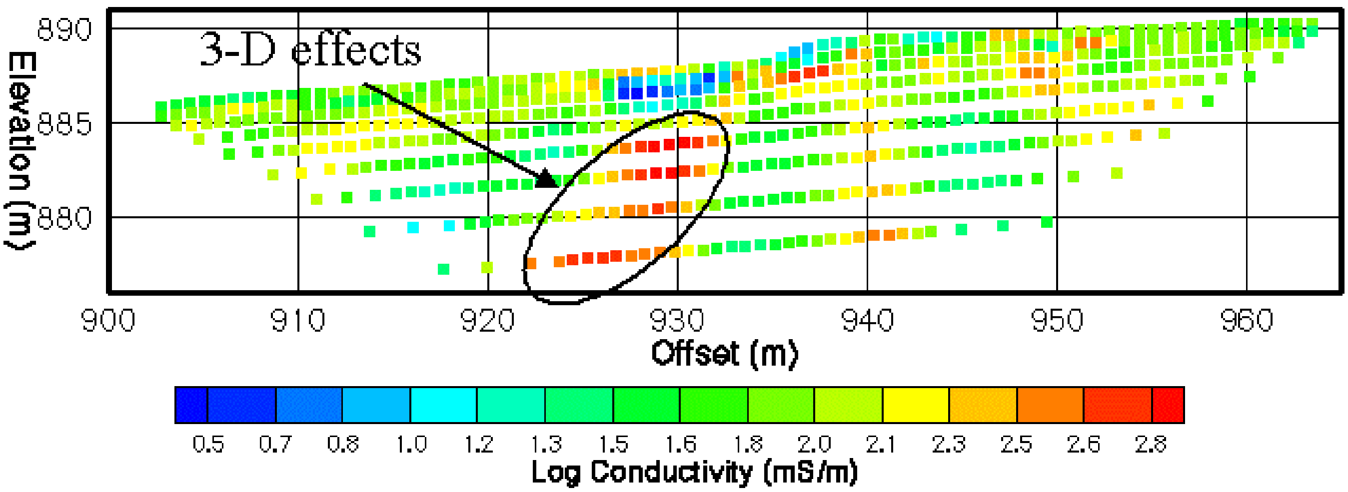

Figure 2. Conductivity section after inversion of 2-D ERT line.

3-D ERT survey

Previous studies of the subsurface demonstrate that the site is highly inhomogeneous and EC can change rapidly within a short distance. A 3-D ERT array with relatively sparse net of parallel and perpendicular 2-D lines was conducted to simulate a 3-D dataset (figure 1). The ends of each line and line intersections were surveyed in and marked with a total station to provide horizontal position and elevation control. Eight individual 2-D ERT lines with 42 electrode stations, 1 m electrode spacing along the line, and 4 meter separation between the lines were conducted parallel to the horizontal well. Perpendicular to these lines, a total of twenty-one shorter 2-D ERT lines with 28 electrode stations, 1 m electrode spacing, and 2 meter separation between lines were carried out. The crossing lines fill the gaps between the lines and also reduce grid orientation effects. Wenner configuration and dipole-dipole configuration were used for long and short individual 2-D ERT lines, respectively. The Wenner array has the advantages of good vertical resolution and greater signal to noise ratio and dipole-dipole array is more sensitive to the lateral variations in EC as well as better depth coverage at the ends of the lines. A combination of these two array types optimizes resolution power in both lateral and vertical directions. The data from the crossing lines were combined to create a 3-D ERT dataset with a total of 6327 datum points.

The data were inverted using 3-D resistivity inversion code (Loke and Barker 1996b). The inversion algorithm uses a new implementation of the least-square method based on incomplete quasi-Newton optimization technique. Topography was incorporated into the inversion and a 3-D finite-element model with $42 \times 29 \times 11$ grids and 11480 model parameters was used. Inversion process took 52 hours on a 850 MHz Pentium powered PC to reach RMS misfit of 4.01% after 14 iterations. Figure 3 shows a horizontal slice of the inversion results for depth of 0.35 - 0.75 m. Results show a highly inhomogeneous subsurface in terms of the electrical conductivity distribution. A low conductivity linear feature at the middle of the section is due to the geo-textile liner. To the west of the liner, highly conductive anomalies are observed. These anomalies are interpreted to be responsible for the observed highly conductive anomaly on the 2-D ERT image. Figure 4 shows a vertical section of the 3-D inversion results where it parallels the 2-D ERT line. The geo-textile liner has been resolved as a low conductivity anomaly. However, the highly conductive anomaly beneath the liner seen on the 2-D ERT image is not seen in this image. Figure 5 shows vertical EC profile results from 2-D and 3-D ERT inversions and PTC measurement. The EC values from the 3-D ERT inversion correlate well with the EC values from PTC measurements at this location.

Discussion

The examples indicate that, with a proper field design, the 3-D ERT technique is a feasible approach for environmental and engineering geophysics problems. It provides a high resolution image of the subsurface EC distribution while minimizing lateral effects. Consequently, it reduces the time and effort required to interpret and examine the reliability of the anomalous features resolved in a 2-D ERT image. Data acquisition along 2-D lines speeds up field procedure and by combining the data from parallel and crossing lines a 3-D ERT dataset can be acquired. The dense spacing along the lines provides reasonable horizontal resolution, and electrical anomalies are properly located in the final images.

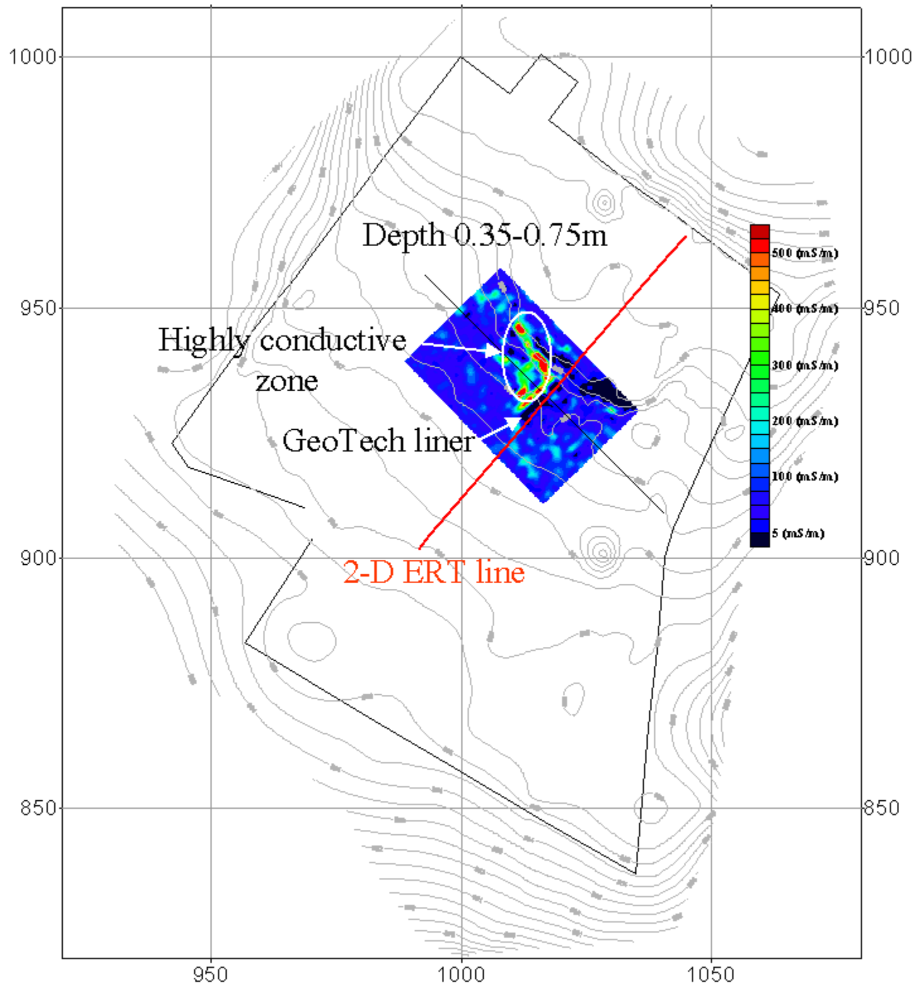

Figure 3. Depth slice from 0.35 to 0.75 m after inversion of 3-D ERT data.

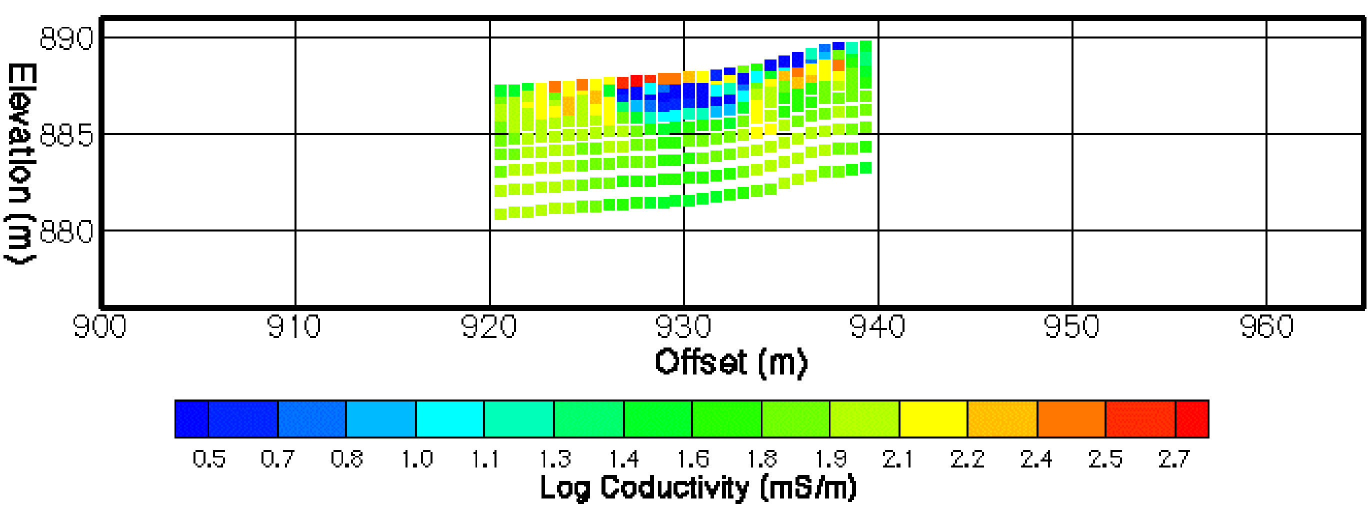

Figure 4. 2-D conductivity section after inversion of 3-D ERT data. The section coincides the 2-D ERT line where it parallels 3-D ERT array.

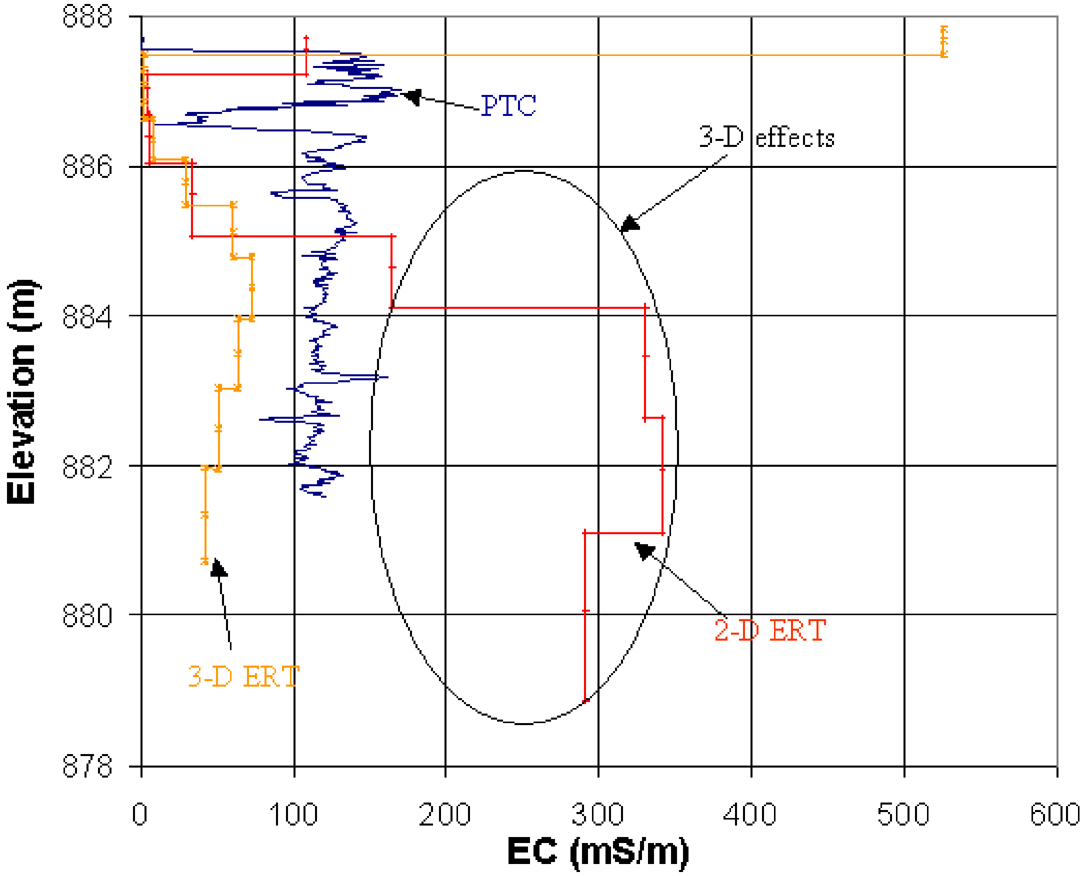

Figure 5. Vertical EC profile results from 2-D ERT and 3-D ERT inversions and PTC measurement.

Acknowledgements
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References

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