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Data Density and Resolution Power in 3D DC Resistivity Surveys

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Summary

Resolution power of a field 3D DC dataset is examined by gradually reducing the data density by removing selected transmitters from the dataset. A mineralized target zone with known geometry and resistivity is used to compare the inversion results for each subset. The results indicate that a high density measurements are essential in retrieving accurate geometry of the target. True 3D grid distribution provides an omni-directional dataset in which the subsurface is sampled by measurements having many different orientations.

Introduction

DC (and IP) surveys are mainstream geophysical techniques for detection, mapping, and delineation in mineral exploration. In this paper, we isolate and discuss the resistivity (DC) parameter of the survey result. Such surveys are usually conducted along a profile and the measured data, so-called apparent resistivity, represents the volumetric average of the subsurface true resistivity variation. A true resistivity model of the subsurface is estimated through inversion of the measured data. However, the DC measurements are geometrically controlled, therefore the survey design and the measured data may not adequately sample the resistivity of subsurface (Gharibi and Bentley 2005). Additionally, in complex geological settings the 2D inversion process and models could be severely biased by heterogeneity and 3-dimensional effects (Bentley and Gharibi 2004, Zhang et al. 2017).
In last decade advances in resistivity equipment and processing software have allowed for deployment of large number of receiver dipoles over a survey area and inversion of the measured data may be performed using a 3D approach. True 3D surveys, such as Orion3D, are designed to probe the subsurface in many orientations to reduce the geometrical bias. Additionally, a large number of data is produced by omni-directional transmitter-receiver pairs across the survey area. The sample volume of the dataset in this kind of survey generally exceeds several tens of thousands of data points. This high-density dataset produces adequate data overlap to enhance resolution in inversion models. However, it increases the field effort and inversion processing time. In this paper we examine data density in an Orion 3D survey and investigate resolution of the inversion model with respect to a known geological target. A number of different survey scenarios are inspected by extracting subsets of the DC data from the complete dataset. The subset datasets are subsequently inverted using the 3D inversion algorithm with the same inversion parameters and the resulting inversion models are compared in terms of their ability to resolve the known deposit.

Survey and Method

An Orion3D DC-IP survey was conducted over a gold and silver-bearing deposit in south central Nevada, USA. The pole-dipole configuration was used with 420 receiver dipoles and 596 current injection points distributed in a regular grid over a ca. 2.2 km×3.2 km survey area (*Figure 1*). The dataset was inverted using the UBC 3D inversion code (Li and Oldenburg 2000). To evaluate effect of data density in the final results two subsets of data are extracted with different number and layout of the injection points and inverted using the same inversion parameters. These datasets include; center-line transmitters and center point transmitters. A known mineralized zone is used to evaluate the resolution power of each inversion (*Figure 1*).

Examples and Results

The inversion result using the full dataset is shown in *Figure 2* (top images). The inversion includes more than 200k data points. The location of a known mineralized zone is shown along with the inversion model. Based on the geological setting, the mineralized zone is associated with an isolated high resistivity in this area. A close-up resistivity isosurface at 115 Ωm around the mineralized area is shown. The gold assay grades along the existing drill holes illustrate a very close correlation with the 115 Ωm resistivity isosurface. It is evident that the full dataset inversion results successfully identify and map the geometry of the known deposit with high resolution.
The center line injection dataset was inverted using the same inversion parameters used in the full set inversion. This dataset includes all 420 receiver dipoles and only 192 injections as shown in *Figure 1*, resulting in a total of ~70k data points after error conditioning. The inversion result using the center line dataset is shown in *Figure 2* (middle images). The result shows less detail compared with the full set inversion result. The known deposit is poorly resolved because the local resistivity model displays less contrast with the surrounding rocks.

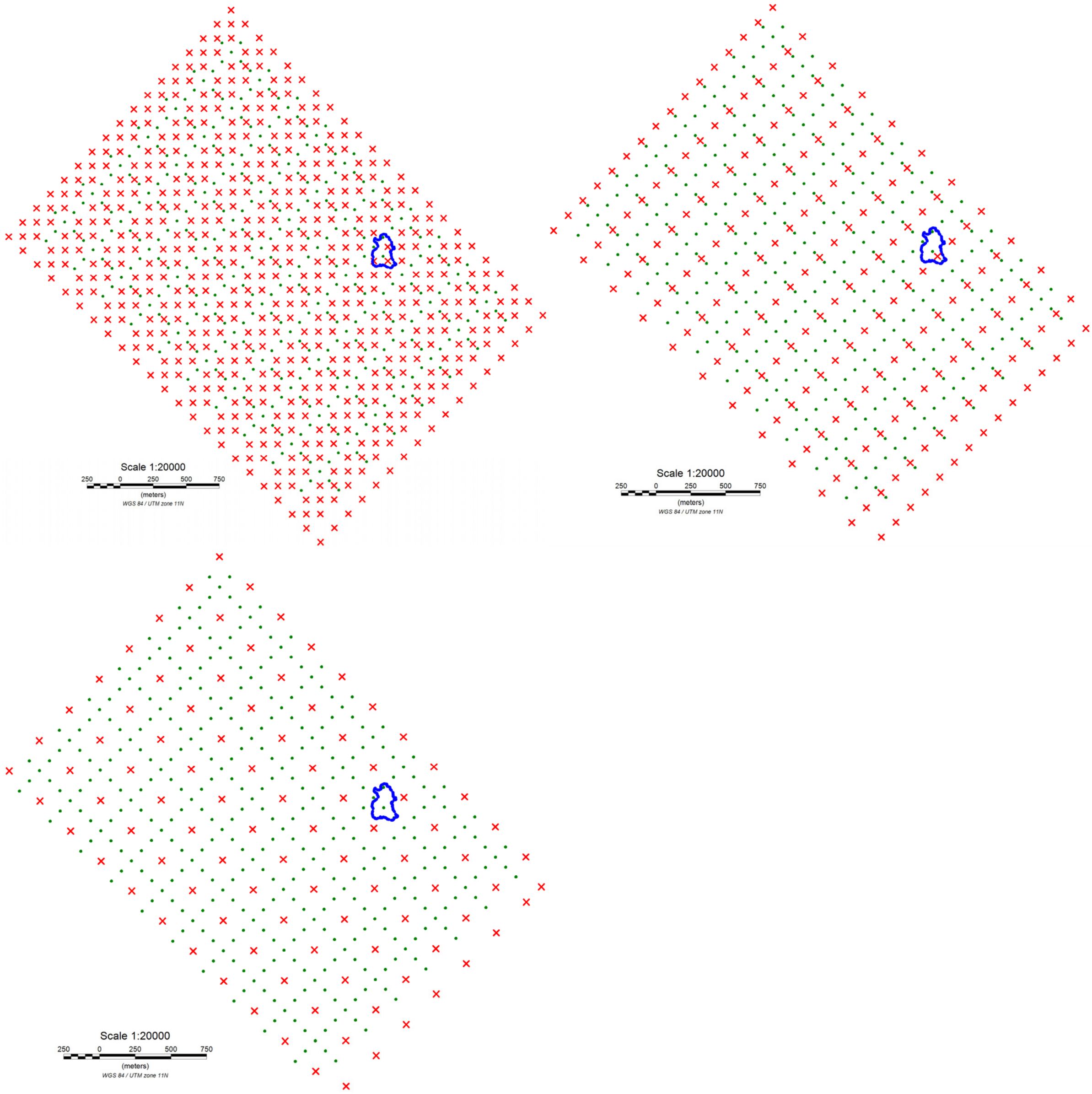

Figure 1 *Receiver dipole locations (green circles) across the survey area. Injection locations are shown as red crosses for complete (top-left), center-line (top-right), and center points (bottom-left) data subsets. The blue line outlines the the known deposit.*

The center points injection dataset includes all receiver dipoles and 96 injections (*Figure 1*). The dataset includes a total of ~35k data points after error conditioning. The inversion uses the same parameters as the other two tests and the results are similarly shown in *Figure 2* (bottom images). The known deposit area is barely isolated from the background resistivity and it may be said that version of the resistivity model does not detect and map the mineralized zone.

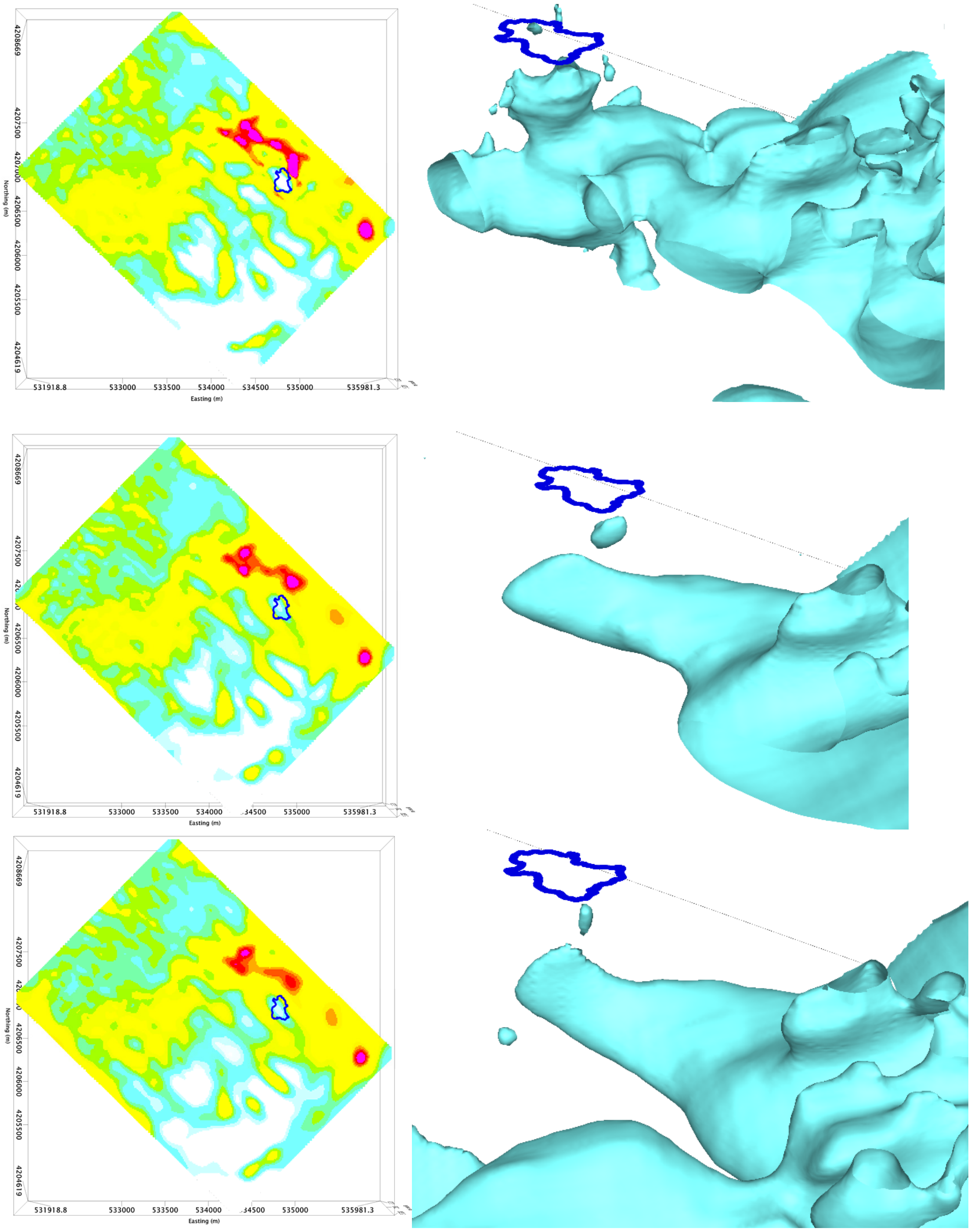

Figure 2 *Inversion results (left column) and zoomed-in resistivity isosurface at 115 Ωm around the known deposit location (right column) for the full dataset (top), center line injections (middle), and center point injections (bottom). Inversion results are shown as a plan view from the top and cut at the deposit level (~250 m below the surface). The deposit outline is shown in blue.*

Conclusions

A True 3D resistivity survey successfully resolved a known mineralized zone with high accuracy and resolution. High density measurements are essential in retrieving accurate geometry of the target. True 3D requires a large number of receivers and transmitters oriented in a grid distribution. The grid distribution provides an omni-directional dataset in which the subsurface is probed by measurements having many different orientations.
Subsampled datasets, simulating reduced survey designs, were created by removing the receiver-transmitter pairs in certain geometries. The inversion results using subset datasets clearly indicate that high data volume is critical to adequately delineate and resolve the geometry of the subsurface in the deposit area. The known deposit used in this study represents a geometrically complex target which can readily be missed in surveys with sparse spatial sampling.

References

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