ASEG-PESA 2015
Geophysics and Geology together for Discovery
24th International Geophysical Conference and Exhibition
15 – 18 February 2015 Perth, Western Australia

A comparison of 3D DCIP data acquisition methods

Darcy McGill
Quantec Geoscience Ltd
Toronto, ON, Canada
dmcgill@quantecgeoscience.com

David Farquhar-Smith*
Quantec Geoscience Ltd
Perth, WA, Australia
dfarquharsmith@quantecgeoscience.com

SUMMARY

Several approaches to 3D DC resistivity are examined by using data acquired by a high resolution ORION 3D pole-dipole omnidirectional 3D DCIP survey that successfully mapped a known mineralised zone.

Subsets of the real-world data are used to examine the effects of reduced numbers of receiver dipoles and also reduced numbers of current injections.

To compare the full-scale 3D survey results with other commonly-used systems, a third data subset simulates an offset-injection type survey.

The results show that the high-density omnidirectional method produces superior resolution of geologic structures compared to other methods that collect less dense and directionally biased data.

Key words: 3-dimensional, resistivity and IP, DCIP, ORION 3D, omnidirectional, pole-dipole

INTRODUCTION

In recent years, resistivity and IP (DCIP) acquisition has evolved from a conventional purely two-dimensional (2D) method to a variety of systems offering differing levels of three-dimensional (3D) acquisition. Commonly used offset-injection systems acquire data on multiple parallel receiver lines, with or without orthogonal receiver dipoles. The ORION 3D pole-dipole system, however, uses a network of simultaneously measured orthogonal dipoles and a dense pattern of current injection poles to collect high-density omnidirectional DCIP data throughout the survey area.

To examine the resolution of the high-density omnidirectional approach to 3D DCIP acquisition, we examine the inversion results from an ORION 3D survey that was used to successfully map a known mineralised zone with a high degree of precision.

Subsets of the full data set have been inverted independently to evaluate the effectiveness and mapping resolution of lower-density approaches to DCIP data acquisition, including the commonly-used offset-injection type survey method.

DCIP ACQUISITION METHODS

Omnidirectional 3D DCIP acquisition methodology

The ORION 3D method acquires DCIP data simultaneously on a network of orthogonal receiver dipoles laid out over the survey area. A dense pattern of current injections results in a large data set that densely samples the subsurface. Measuring the entire network of dipoles for the whole survey also delivers omnidirectional data; each dipole is read with current injections from all directions (Figure 1).

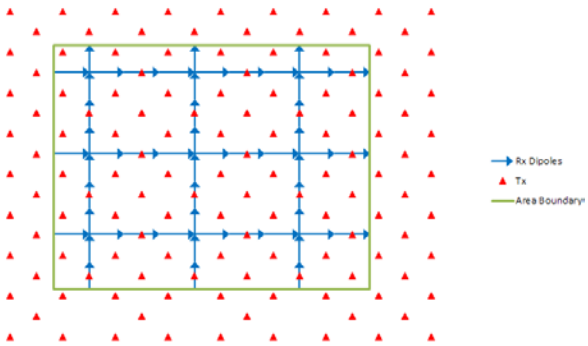

Figure 1. Typical layout of a portion of an ORION 3D omnidirectional survey. Receiver dipoles are shown as blue arrows, current injection points as red triangles.

Full waveform data is acquired in the time domain for all dipoles as well as the 100% duty-cycle transmitter current waveform, and processed using a hybrid frequency domain method (Halverson et al., 1981) to yield resistivity and chargeability values.

Offset injection DCIP acquisition methodology

The offset injection pole-dipole method typically measures two parallel lines of receiver dipoles with a single line of current injections between them, and rolls this setup along to cover the entire survey area (Figure 2).

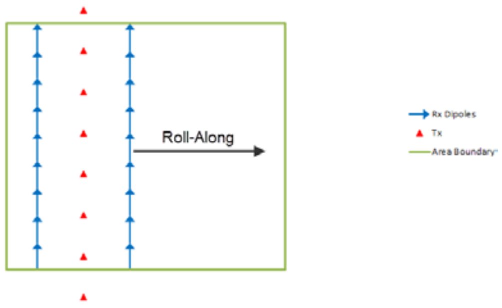

Figure 2. Typical offset injection survey layout. Receiver dipoles are shown as blue arrows, current injection points as red triangles.

SURVEY AND RESULTS

An ORION 3D survey was conducted over the Hidden Hill gold deposit in the Golden Arrow prospect (Ristorcelli and Christensen, 2009) in south-western Nevada, USA. DCIP data was acquired from 420 100 m receiver dipoles using approximately 600 current injection points over an approximately 2 km x 3 km survey area. A total of 280,000 DC resistivity and IP data points were collected over a period of 15 survey days. Data conditioning ensured that only high-quality data were included in the final 3D inversions.

The DC resistivity inversion results resolved the known Hidden Hill mineralised zone with a high degree of precision. Therefore, in subsequent sections, inversions of different subsets of the DC resistivity model are used to evaluate the resolution of several possible survey methodologies.

All datasets were inverted using the UBC DCIP3D inversion code (Li and Oldenburg, 2000). To simulate different survey methodologies, three different subsets were extracted from the full data set.

<u>Full Data Set</u>
The inversion of the full data set used all receiver dipoles and current injection poles. After conditioning, approximately 210,000 data points were included in the final inversion. The inversion mesh used 37.5 m x 37.5 m cells in the horizontal directions, and vertical cells starting at 15 m thick, increasing with depth. The model used approximately 600,000 cells. The same inversion mesh was also used for the subset data inversions, and a half-space was used as the starting model for all inversions.

The resistivity model shows a well-defined discrete resistive zone associated with the Hidden Hill deposit (Figure 3). The Hidden Hill deposit has been drilled extensively and the assay data show very good correlation between the 115 Ω·m DC resistivity iso-surface and the extents of the deposit (Figure 4).

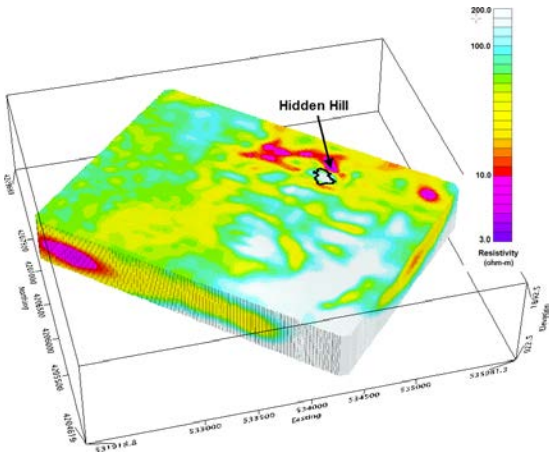

Figure 3. Full data set DC resistivity model, cut to 250 m depth. Hidden Hill is resolved as a discrete resistive zone.

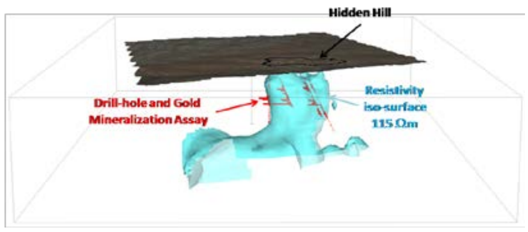

Figure 4. Drill holes and gold assay correlation with the 115 Ω·m resistivity iso-surface at Hidden Hill.

Gharibi et al. (Istanbul 2012) compare a number of hypothetical subsets of the full data set to evaluate the question of data redundancy in the ORION 3D method. Two of these subsets are reproduced here to illustrate the separate effects of reducing the number and direction of receiver dipoles (subset 1) and reducing the number of current injections (subset 2).

<u>Data Subset 1: Unidirectional Receiver Dipoles</u>
This data subset uses parallel receiver dipoles oriented at grid azimuth 0° (45° true), in lines spaced 300 m apart (Figure 5).

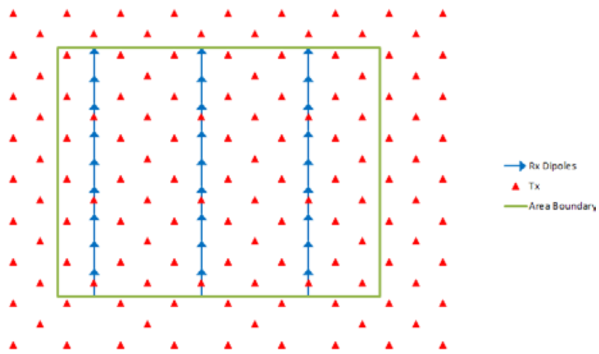

Figure 5. Example unidirectional receiver survey layout. The complete set of current injections is used along with dipoles oriented at grid azimuth 0°.

Approximately 106,000 data points were used in the 3D inversion of the 0° azimuth subset data, presented as Figure 6.

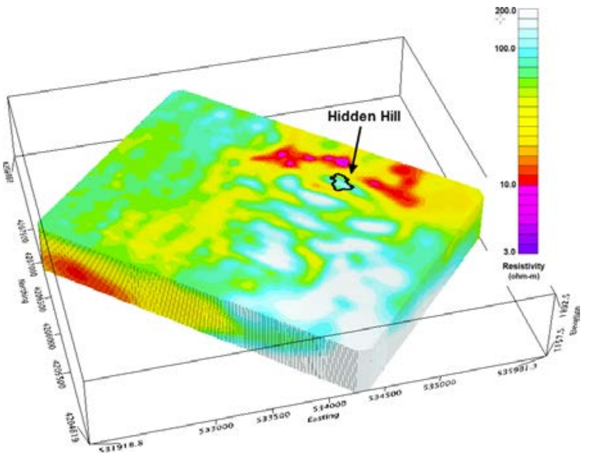

Figure 6. Unidirectional receiver DC resistivity model, cut to 250 m depth. The outline of Hidden Hill is shown.

The resistive zone associated with Hidden Hill is elongated perpendicular to the lines of receiver dipoles, and begins to merge with the resistive zones to the south and east of the deposit. Particularly in the western portion of the survey area, stripes in the model parallel to the receiver dipoles become evident.

Data Subset 2: Reduced Current Injections

This data subset uses the complete set of receiver dipoles from the full data set, but uses only a reduced set of current injections arranged in lines parallel to the grid azimuth 0° (45° true) receiver dipoles (Figure 7).

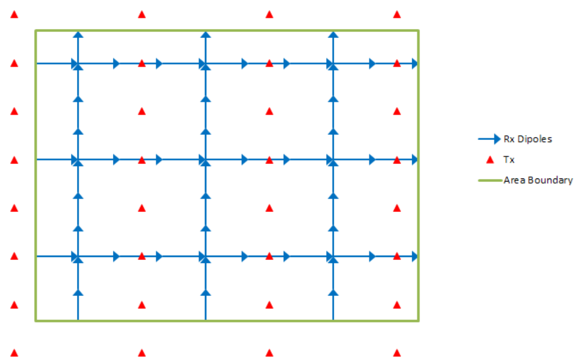

Figure 7. Example reduced injection survey layout. The complete set of receiver dipoles are used, but current injections are reduced to lines spaced 300 m apart, with 150 m between injections along line.

A total of 120 current injection poles were used for this subset, resulting in approximately 73,000 data points used for the 3D inversion, presented as Figure 8.

As with subset 1, the resistive zone associated with Hidden Hill becomes elongated and begins to merge with other resistive zones around the deposit. As a result of the sparse current injection pattern, the model shows subtle bias along the receiver dipole orientations (45° and 135° true), again most evident in the western portions of the model where the data relief is lowest.

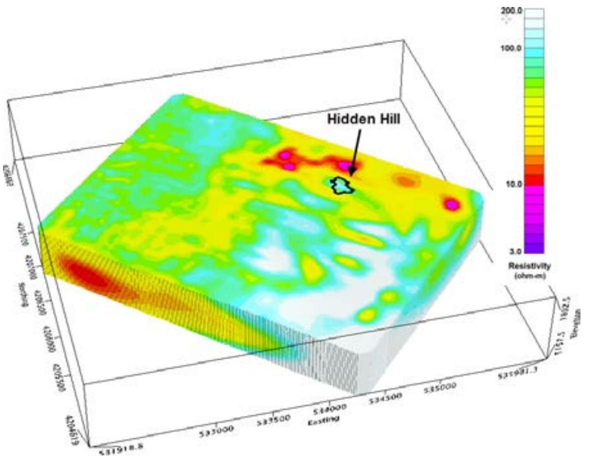

Figure 8. Centre line injection DC resistivity model, cut to 250 m depth. The outline of Hidden Hill is shown.

Data Subset 3: Offset Injection Pattern

This data subset simulates an offset-injection survey as shown in Figure 2; a single line of current injections, spaced 150 m apart along line is centred between two parallel lines of receiver dipoles, 300 m apart, oriented at grid azimuth 0° (45° true). This setup is rolled along to cover the whole survey area.

The offset-injection subset, which uses significantly reduced numbers of both receivers and current injections when compared to the full ORION 3D model, resulted in approximately 8,600 data points that were used in the 3D inversion, presented as Figure 9.

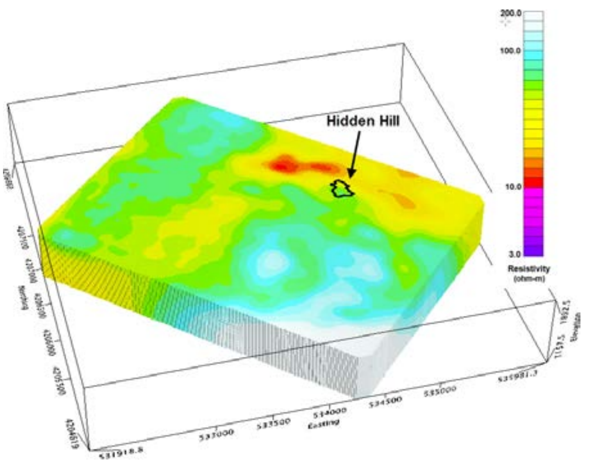

Figure 9. Offset injection DC resistivity model, cut to 250 m depth. The outline of Hidden Hill is shown.

The model resulting from the offset-injection data set reveals the effects of the reduced number of available data points. The resistive response associated with the Hidden Hill deposit is no longer resolved as a discrete zone, but becomes a poorly resolved lobe on the edge of a much broader moderately resistive area. In general, the model is much smoother and shows less detail than the models from the full data set and also the other subsets with reduced numbers of data points.

CONCLUSIONS

The full data set from the ORION 3D survey resolves the resistive body of the Hidden Hill deposit accurately in three dimensions. Assay results from drilling confirm that the discrete resistive body resolved in the 3D DC resistivity model correlates very well with the known mineralised zones.

To examine the effects of less dense and directionally-biased data sampling, inversions were performed on data subsets using unidirectional receiver dipoles and a directionally oriented current injection pattern. Inversion models of DC resistivity from both of these data subsets show a reduced ability to resolve the Hidden Hill deposit in 3D and also show directional bias in the model relating to transmitter-receiver geometry.

The data subset that simulates a roll-along offset injection survey uses approximately 1/24 the number of data points as the full data set, and the resulting 3D DC resistivity model reflects the sparse sampling. The Hidden Hill deposit is not resolved as a discrete resistive body, but becomes part of a larger resistive zone, and the resulting model shows much less resolution than models from either the full data set or the subsets using reduced numbers of receivers or injections.

To accurately resolve the complex three-dimensional resistivity distribution of a real geological environment without directional bias from transmitter-receiver geometry, an omnidirectional data set acquired from a network of orthogonal receiver dipoles and a high-density pattern of current injection poles is required.

ACKNOWLEDGMENTS

The authors would like to thank Nevada Sunrise Gold Corp. for permission to use their data and present these results.

REFERENCES

Gharibi, M., K. Killin, D. McGill, W. B. Henderson, and T. Retallick, 2012, Full 3D Acquisition and Modelling with the Quantec Titan based 3D System - The Hidden Hill Deposit Case Study: 22nd International Geophysical Conference and Exhibition, ASEG, Expanded Abstracts, 200-203.

Gharibi, M., K. Killin, D. McGill, and W. B. Henderson, 2012, Data redundancy in an omnidirectional 3D DC resistivity dataset. International Geophysical Conference and Oil & Gas Exhibition, Istanbul 2012.

Halverson, M.O., Zinn, W.G., McAlister, E.O., Ellis, R., and Yates, W.C., 1981. Assessment of results of broad-band spectral IP field test. In: Advances in Induced Polarization and Complex Resistivity, 295-346, University of Arizona.

Johnson, I.M., 1984. Spectral induced polarization parameters as determined through time-domain measurements. Geophysics, v. 49, 1993-2003.

Li, Y., and Oldenburg, W., 2000. 3-D inversion of induced polarization data. Geophysics, v 65 (6), 1931-1945.

Ristorcelli, S., and O. Christensen, 2009, Updated Technical Report on Golden Arrow Project, Nye County, Nevada, USA: Mine Development Associates, Mine Engineering Services.

Sheard, N., 1998, MIMDAS: A new direction in geophysics: Presented at the 13th International Geophysical Conference and Exhibition, ASEG.