Spectral Time Domain IP - Factors Affecting Data Information Content and Applicability to Geological Characterization

A. Rezvani* (Lund University), T. Dahlin (Lund University), P.I. Olsson (Lund University), G. Fiandaca (Aarhus University) & P. Ahnfelt (Boliden Mines)

SUMMARY

A DCIP survey with different timing settings, electrode arrays, cable spreads and waveforms (50% and 100% duty cycle waveform) were carried out over the Liikavaara deposit in northern Sweden. All the measured data were inverted using AarhusInv. Measured data with 100% duty cycle waveform, which is much faster than the conventional 50% duty cycle waveform, present significant improvements in the quality of IP-data. It was also attempted to increase the data quality by separating current and potential cables. Tau and C parameters from time domain IP were compared in different time bases and spreads. These two parameters appear to be sensitive to the duration of current injections in which; decreasing the time base causes diminished anomalies in Tau and partly in C. Although measurement with separated spreads improved the data quality, it did not have any significant effect on these two parameters. Moreover correlation of sulphide content matched well with the inverted models, which confirms the applicability of the DCIP method in mineral exploration.
Introduction

Since the 1900s electrical resistivity and induced polarization methods are one of the common geophysical survey techniques which are applied in subsurface studies and in particular in mineral exploration. In this paper we present results from test measurements with different arrays, waveforms, cable spreads and time base in order to compare the data quality in different methods in the mineral exploration context. The test was carried out over a well-documented Cu-Au sulphide mineralization known as Liikavaara close to the Aitic mine in northern Sweden (unpubl.results).

Methods

The field work was performed over the Liikavaara mineralization zone in northern Sweden, using an ABEM Terrameter LS. Various measurement techniques were carried out, including:

- 100 % and 50 % duty cycle waveform (Olsson et al. 2014).
- Single cable spread and separated cable spreads for current transmission and potential measurements (Dahlin and Leroux 2012).
- Different pulse lengths for current on- and off-time (1 s, 2 s, 4 s).
- Electrode separation 5 m and 10 m.
- Multiple gradient and pole-dipole electrode arrays.

The tests are summarised in the table below.

<table>
<thead>
<tr>
<th>Array</th>
<th>Spread</th>
<th>Length</th>
<th>Time base</th>
<th>Wave form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple gradient</td>
<td>Single</td>
<td>700 m, 800 m</td>
<td>4 s</td>
<td>50%</td>
</tr>
<tr>
<td>Multiple gradient</td>
<td>Separate</td>
<td>405 m</td>
<td>1 s, 2 s, 4 s</td>
<td>50%, 100%</td>
</tr>
<tr>
<td>Pole-dipole</td>
<td>Separate</td>
<td>405 m</td>
<td>2 s</td>
<td>50%, 100%</td>
</tr>
</tbody>
</table>

The results were inverted for resistivity and IP using Res2inv and AarhusInv (Fiandaca et al. 2013), however only the latter results are presented here.

Results and Discussion

Figure 1 shows IP decay curves for different waveforms in different spreads and time bases. All the curves are selected from the same coordinate intervals and same depth. As seen in Figure 1, the IP decay curves show more disturbance in the single spread measured with 50% duty cycle waveform, specifically in the first time windows and in the separated spreads there is a remarkable improvement. The 100 % duty cycle waveform measurements represent high data quality in all profiles and there was less need for filtering noisy curves in Workbench-Aarhus software. This improvement is more prominent for the pole–dipole array.

Figure 2 illustrates Tau and C models, which are expected to be related to the mineralization texture (grain size and grain size distribution), for different injection time and different spreads. Measurements with 4s on-off time, regardless of single or separated spreads, produce almost the same depth of the anomaly location, whilst measurements with shorter time bases (2s and 1s) produce anomalies at shallower depths. This can be seen more clearly in the relaxation time (Tau). These differences could be related to two factors: 1) Decrease in signal amplitude as a function of shorter acquisition time, so that the tau/C differences may be masked by ambient noise; 2) With shorter acquisition time ranges, the resolution on the spectral parameters decreases also without changes in the relative noise content.
Figure 1 IP decay curves for different time bases, waveforms and spreads. X axis shows time (s) and Y axis shows chargeability (mV/V).

Figure 2 Tau and C models for different injection time and different spreads.

Figure 3 illustrates the mineralization zone (marked with dash lines) and the surrounding high resistive host rock (purple) as well as the correlation of the model with the sulphur contents of two boreholes close to the survey line. The sulphur grades show a rather good match with the resistivity...
model and as it is expected, higher sulphide content corresponds to lower resistivity values. However the corresponding depth to the very high sulphur contents (2.6% and 3.7%) are indicating medium anomalies (yellow), whilst the very low resistive zone (blue), is corresponding to relatively lower sulphur content (below 1.5%). This can be due to the variety of different sulphide types which makes some parts more conductive. Since iron-rich sulfides have higher conductivity compared to cooper-rich, we assume that iron rich sulphides are concentrated mostly in the central part of the mineralization zone (blue) and by getting further from the core of the zone, copper/iron ratio is increasing in the sulphides.

Figure 3 Resistivity model over the mineralization zone (marked with dash lines). Sulphur contents from two boreholes (located along 20 m and 30 m northern part of our survey line) are compared with the inverted model in AarhusInv.

Figure 4 presents IP models (in addition to the resistivity models), in which the mineralization zone does not show any anomaly, whilst the sounding rock mass does. This halo of anomaly representing disseminated sulphide around the ore zone. In all the measurements these anomalies are quite similar. In Figure 4, all measurements with different injection times and different wave forms are compared to every measurement time. There is not a significant difference between these models as well as the suggested mineralization zone interval and host rock, although there are big differences in the field data acquisition time.

Conclusion

This study shows that the acquired IP data are of higher quality when applying 100 % duty cycle waveforms, and an additional advantage is decreasing the measuring time. Separation of current and potential cables also served to increase data quality (fewer number of noisy curves), particularly for the early time windows. This has to do with the fact that the effects from capacitive coupling (one of the main source of disturbance) decrease with time and, thus, mostly have a significant impact only on early time windows. Different injection time does not show any effect on the final models in resistivity and IP. However, Tau and C parameters appear to be sensitive to the duration of current injections in which, decreasing the time base causes diminished anomalies in Tau and partly in C mainly due to two factors: 1) decreasing signal level with shorter acquisition time, and the tau/C differences may be covered by the noise and 2) decreasing resolution on the spectral parameters with shorter acquisition ranges. Measurement with single or separated spreads does not have any significant effect on these parameters. Moreover, correlation of sulphide content matched well with the inverted models, which confirms the applicability of the DCIP method in mineral exploration.
Figure 4 Inverted IP and resistivity models for different time bases and waveforms (50% and 100% duty cycle).

Acknowledgements

I wish to thank Boliden for partly funding this research project and providing an opportunity for the geophysical field operations, and also companies ABEM/Guideline Geo AB, Formas, BeFo and SBUF (as part of the Geoinfra-TRUST programme: http://trust-geoinfra.se/) that helped to produce data necessary for this research topic. In particular, I would like to thank Katri Vaittinen (Boliden), Jimmie Lahti & Per Hedblom (ABEM), Torleif Dahlin (Lund university) for major assistance in the field. In addition, Torleif Dahlin, Paal Ahnfelt, Ulf Söderlund, Per-Ivar Olsson & Gianluca Fiandaca are acknowledged for their academic supervision and support for Azade Rezvani’s M.Sc.thesis.

References

