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Published in:
Proceedings of the 4th international workshop on induced polarization

2016

Document Version:
Publisher's PDF, also known as Version of record

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SUMMARY

A DCIP survey, i.e. a geoelectrical survey with combined measurement of DC resistivity and induced polarization (IP), was conducted in southern Sweden. The purpose was to identify soil depth and bedrock structures and variations in rock quality.

Data were acquired data with 100% waveform from which IP of good quality data were extracted. The inverted model sections show a wide variation in the electrical properties of the bedrock that are expected to relate to variation in rock quality. The results, together with results of other geophysical methods, form the basis for a drilling program in order to identify variations in quality rock of importance to the construction of an underground facility.

Key words: DCIP, time-domain IP, 100% waveform, rock quality.

INTRODUCTION

A DC resistivity and time-domain induced polarisation (DCIP) survey was carried out along four lines at Önneslöv close to Dalby in southern Sweden. The purpose of the survey was to map variations in rock quality as part of site investigations for a planned underground facility. Seismic surveying was made along three of the lines during the same week as the DCIP survey. Magnetic profiling has also been made in the area.

Unstable rock and water bearing rock are common problems in underground construction, and in addition small thickness of rock cover above the facility can created stability problems. Electrical Resistivity Tomography (ERT) has proved to be a useful tool for mapping variations in rock quality that can be linked to variation in rock quality with relevance for underground construction (e.g. Rønning et al 2014; Danielsen and Dahlin 2009; Dahlin et al. 1999), and in this study we aim at refining the characterisation by adding information from the IP effects.

METHOD

Data acquisition was made along 4 lines of 800 – 1000 m length, with three parallel and one perpendicular line (Figure 1). A double cable spread with in total 162 electrodes at 5 m separation was used resulting in an 810 m long layout. The layout with separated electrode cable spreads was employed in order to ensure as good quality data as possible for the IP data by reducing the risk of capacitive coupling in the cables (Dahlin and Leroux 2012) and. A complicating factor for the data acquisition was that a major road with heavy traffic was crossed by three of the lines, which was handled by drilling horizontal boreholes under the road, in which extension cables were used to link together the spread on each side of the road (Figure 1).

Data were measured with an ABEM Terrameter LS with 12 measuring channels using multiple gradient array (Dahlin and Zhou 2006). Data were recorded using a 100% duty cycle waveform (Olsson et al 2015) and 4 s long transmitted pulses.

DCIP data were extracted from the full waveform recordings, saved with a data rate of 3750 Hz, employing a data filtering and processing procedure presented by Olsson et al (2016). For the inversion presented here the IP data were saved as integral apparent chargeabilities.

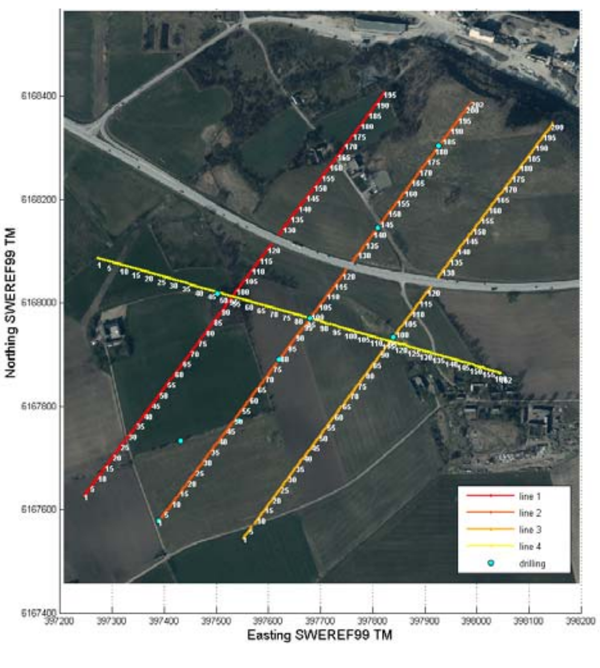

Figure 1. Layout of survey lines in relation to road and quarry.

The contact resistances varied from some hundred Ω to more than 10 kΩ, with mean resistances between 2.2 – 3.8 kΩ. The measured sections contain between 3298 and 4264 data points each, where the number varies depending on the length of the line and the number of electrodes that were excluded in connection with the crossing of roads. Although power supply harmonic noise and spikes, presumably from electrical cattle fences, are seen in the full waveform recordings integrated data are of good quality. Hence only 2 - 8 data points were rejected from each of the data sections before inversion.

Res2dinvx64 (ver. 4.04.35) was employed for inverting the data using L1 norm (robust) inversion.

A large quarry is located immediately north of the investigated area (Figure 1) which gives an excellent overview of the geological conditions that can be expected, and an example is shown in Figure 2. After the DCIP and seismic survey a number of representative points for drilling were pointed out, and in total eight percussion boreholes were drilled to a depth of 200 – 250 m. Geophysical logging is underway for some of the boreholes at the moment of writing.

Figure 1. Example of a vertical weathered zone in the quarry which is situated next to the survey area. Notice the highly fractured character of the rock mass surrounding the zone, it is typical for the rock that is exposed in the quarry.

RESULTS

The resistivity models (Figure 3a and Figure 4a) show a top layer with lower resistivity with mostly less than 10 m thickness, but in some places there is up to 20-30 m thickness (e.g. Line 1-400 m; Line 3-550 m). This top low resistivity layer is interpreted as soil. In some places where the underlying structures have low resistivity, there is no clear boundary between the upper and lower layers (e.g. Line 1-730 m; Line 2-700 m; Line 3 - 600 m). In parts of the area a thin layer with higher resistivity on top of the low-resistivity upper layer can be seen.

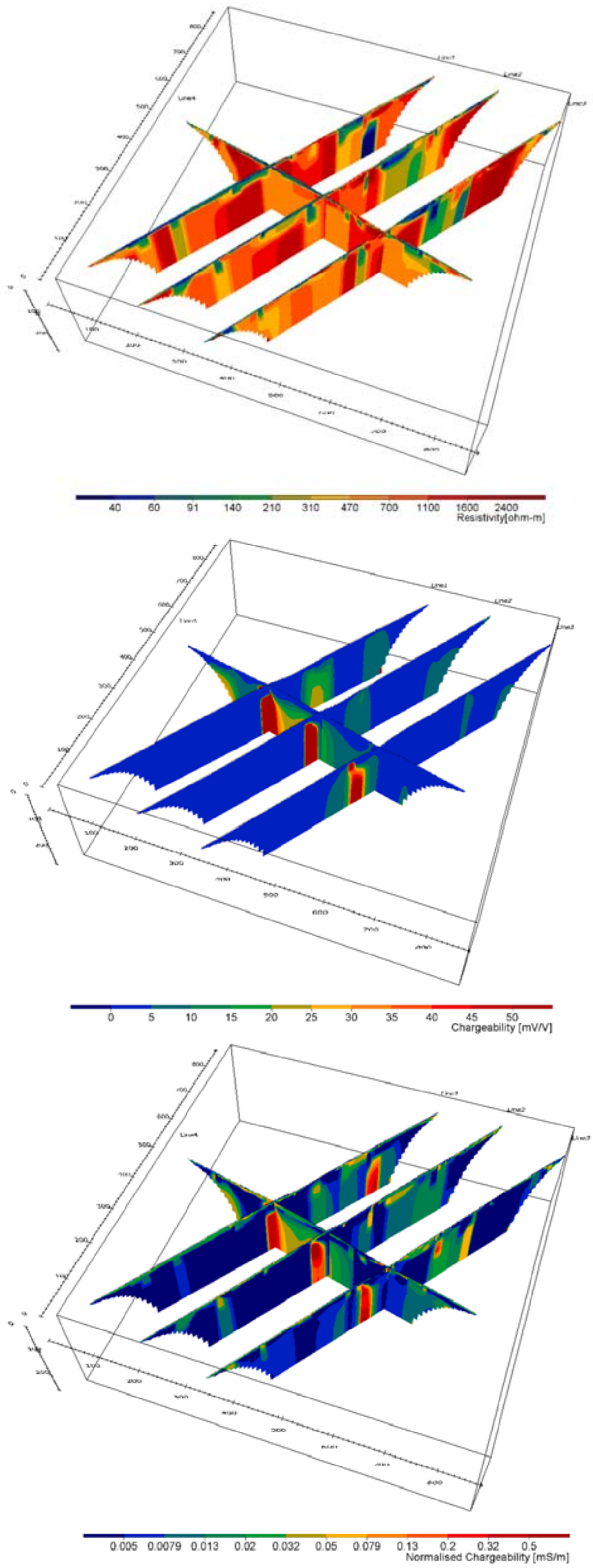

Figure 3. Overview of inverted models from Önneslöv; a) resistivity, b) chargeability, c) normalised chargeability.

The resistivity sections (Figure 3a and Figure 4a) are otherwise dominated by a number of more or less vertical structures with alternating low and high resistivity. The resistivity of these zones vary from under 40 to over 2400 Ωm, with large zones with resistivities of a few hundred Ωm.

This is interpreted as bedrock with varying degrees of fracturing and weathering, where the bedrock consists of gneiss, amphibolite and dolerite dykes and minor elements of other rocks. The most highly resistive parts are expected to be composed of rock with a relatively low fracture density, while lower resistivities suggest higher degree of fracturing and possible weathering. The most low-resistive zones are expected to be associated with the most weathered parts of the rock, which may be associated with stability problems during underground construction. Crystalline rock with resistivity in the range of hundreds Ωm can be interpreted as water bearing, where potentially high hydraulic conductivity that can provide rock engineering problems.

IP models for the three parallel lines (Figure 3b and Figure 4b) are similar in that all exhibit a sharp and distinct anomaly with a high chargeability close to the centre of the section (>100 mV/V). This zone is also visible in the shorter perpendicular line but with a more extended appearance, as one might expect since the zone is crossed with a different angle to the line. Furthermore, there are more diffuse zones with increased chargeability in the north-eastern part of the three parallel lines. The most distinct zone coincides with a zone of lower resistivity. The zone can be interpreted as rock with a high degree of fracturing and weathering, and mineralization, e.g. a fractured and weathered dolerite dyke. Because the zone is below or close to a telephone cable which is no longer used, it cannot be completely ruled out that it is caused by it, but the depth the top of the anomaly above the edge and their extent at depth to the contrary. The more diffuse zones with elevated chargeability can be caused by tectonised and fractured rock, with mineralization and weathering.

The normalized chargeability (Figure 3c and Figure 4c) shows basically the same as the previous, but some nuances emerge more clearly. For example, a transition that could constitute the transition between soil and fractured rock emerges in parts of sections.

CONCLUSIONS AND OUTLOOK

The DCIP survey shows a top layer that is reflecting depth to bedrock and a wide variation in the electrical properties of the bedrock that appear to reflect the variation in rock quality which is expected at Önneslöv judging from the nearby quarry. Data will be inverted for spectral IP parameters, and an in-depth analysis of the DCIP models along with documentation from drilling, sampling and analysis will be done with the aim to characterize the rock in terms of variation in the properties of relevance to underground construction. The information obtained from the available percussion drilling is however limiting the possibilities to find correlation between the drilling documentation and the geoelectrical models. Geophysical borehole logging is done as complement to feedback detailed results from borehole measurements to DCIP model sections, to allow for more detailed analyses and more extensive interpretation. The borehole measurements include flow log, natural gamma radiation, sonic and resistivity-IP.

ACKNOWLEDGMENTS

Funding for the work was provided by Skanska Sverige AB, Formas - The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, (ref. 2012-1931), BeFo - Swedish Rock Engineering Research Foundation, (ref. 314 and 331) and SBUF - The Development Fund of the Swedish Construction Industry, (ref. 12718 and 12719). The project is part of the Geoinfra-TRUST framework (Transparent Underground Structure, http://www.trust-geoinfra.se/). We thank Skanska Sverige AB and Sweco Environment AB for a fruitful cooperation.

REFERENCES

Dahlin T. and Leroux V., 2012, Improvement in time-domain induced polarisation data quality with multi-electrode systems by separating current and potential cables: Near Surface Geophysics, 10, 545-565.

Danielsen, B.E. and Dahlin, T., 2009, Comparison of geoelectrical imaging and tunnel documentation. Engineering Geology, 107, 118–129.

Dahlin, T. and Zhou, B., 2006, Multiple-gradient array measurements for multichannel 2D resistivity imaging: Near Surface Geophysics, 4, 113-123.

Dahlin, T., Bjelm, L. and Svensson, C., 1999, Use of electrical imaging in site investigations for a railway tunnel through the Hallandsås Horst, Sweden, Quarterly Journal of Engineering Geology, 32(2), 163-173.

Olsson P.-I., Dahlin T., Fiandaca G. and Auken E., 2015, Measuring time domain spectral induced polarization in the on-time – decreasing the acquisition time and increasing the signal levels: Journal of Applied Geophysics, 123, 316-321.

Olsson P.-I., Fiandaca G., Juul Larsen J., Dahlin T. and Auken E., 2016, Doubling the spectrum of time-domain induced polarization by harmonic de-noising, drift correction, spike removal, tapered gating and data uncertainty estimation, Geophysical Journal International, submitted manuscript.

Rønning J.S., Ganerød G.V., Dalsegg E., Reiser F., 2014, Resistivity mapping as a tool for identification and characterisation of weakness zones in crystalline bedrock: definition and testing of an interpretational model, Bull Eng Geol Environ, 73, 1225–1244.

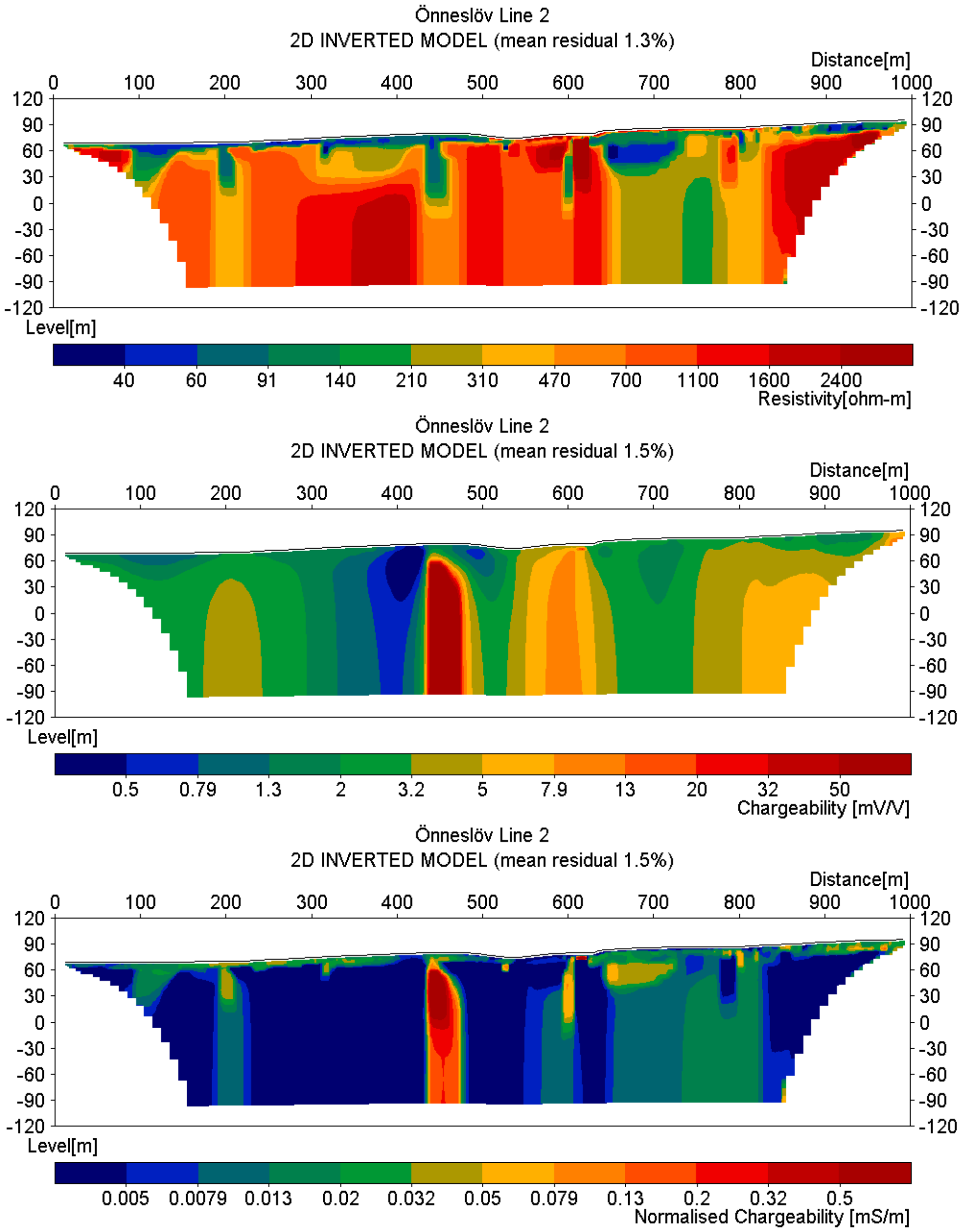

Figure 4. Inverted models from Line 2 at Önneslöv; a) resistivity, b) chargeability, c) normalised chargeability.