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Mapping the lithotypes using the in-situ measurement of time domain induced polarization: El-log

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SUMMARY

This study presents a novel application of the El-log-drilling technique for measurement while drilling of the DC, time domain IP and gamma log. In addition pore water samples can be taken at arbitrary levels. The technique itself is developed in Denmark and has been widely used in the field of ground water and environmental studies. The El-log drilling method yields detailed information on small changes in lithology, sediment chemistry and water quality and with data comparable to what can be obtained in the laboratory. .

We collected the data at a landfill site located near Grindsted in the southern part of Denmark. The purpose of the study was 1) to obtain a direct correlation between the undisturbed geophysical logs and surface measurements, 2) correlation of IP parameters to lithology and grain size distribution and 3) to investigate any correlation with effluent and IP parameters. We inverted the recorded resistivity and IP decays using full decay modelling with the Cole –Cole model and found that the chargeability correlates very well the clay content in the sandy aquifer.

Key words: El-log, Borehole IP, Time domain IP, Cole-Cole model

INTRODUCTION

An accurate delineation of subsurface lithology is achieved by geophysical borehole log, particularly gamma and electrical logs used in hydrogeological investigations. Often the electrical logging is carried out after the borehole is made where the measured formation resistivity is affected by the borehole fluid. However, with the El-log drilling techniques it is possible to measure the geophysical properties of undisturbed formations. In Denmark this technique has been widely used for hydrogeological studies in unconsolidated sediment (Sørensen and Larsen, 1999).

In the present study, we have exploited the El-log method for in-situ measurements of the time domain induced polarization signal together with the resistivity measurements. The data represent undisturbed samples comparable to what can be obtained by measurement in the laboratory. The data were collected close to a landfill located at Grindsted (southern part of Denmark). Later on, IP data were inverted using the Cole-Cole model (Fiandaca et al., 2012). An interpretation made together with gamma log reveals a detailed description of different lithological units.

METHOD AND RESULTS

Ellog Method

The Ellog is a high resolution drilling technique used in groundwater and environmental investigations in unconsolidated sediments. With this method apparent formation resistivity and chargeability are measured using the electrodes integrated with the hallow stem augur. In addition, it measures the gamma radiation, and water samples can be taken at any arbitrary level. The electrodes are embedded in insulating material and connected through the cables to the resistivity meter on the ground (Figure 1) while the gamma sensor is inside the auger close to the tip. The water sampler device is also inside the auger and is connected with tubes to the surface.

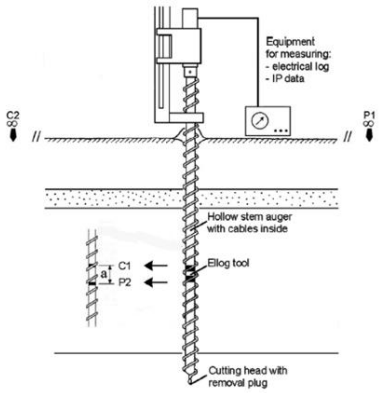

Figure 1 Principal sketch of the El-log drilling rodP are the potential electrode and C are the current electrodes. The distance a is equal to 20 cm. A gamma log is located inside the auger. Water samples are taken through inlets close to the drill tip. Modified from Sørensen and Larsen, 1999.

The field site and data acquisition

The field site is located at Grindsted landfill in the southern part of Denmark (Figure 2). The landfill is located on a glacial outwash plain with 10.12 m quaternary sand layer in the top and a regional tertiary sand layer, which extends to the depth of 80m and is confined by a clay layer. The target of the investigation is to delineate the inter-bedded thin layers of clay and lignite.

For recording of resistivity and IP data we used the LS-Terrameter instrument by ABEM. The instrument was remote controlled by an in house developed instrument that also acquired the gamma log data. A Pole-Pole type of configuration was used for measurement where three potential and one current electrodes were embedded in the augur and two electrodes were placed on the surface as remote electrodes. The on and off time length for the time decay measurement was 4 seconds. The full waveform data were recorded at a sampling rate of 3750 Hz. The positions of the boreholes (B1, B3 and B5) are shown in figure 2.

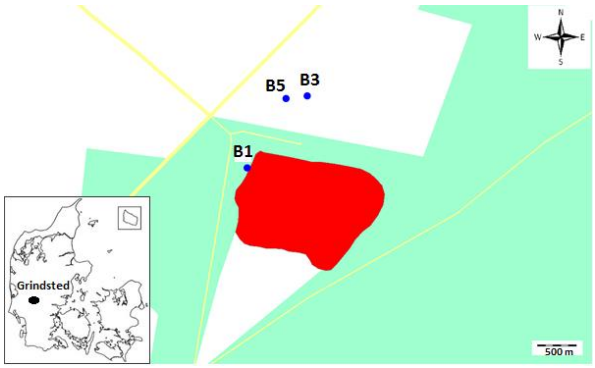

Figure 2 Location of the field site: landfill is shown in red, boreholes are shown by blue dots

Data processing and Inversion

IP signals suffer from two major problems during data acquisition- 1) Noise from power lines, which limits the use of the signal at early times 2) Background-potential drift in the measured signal distorting the shape of the IP decays in the late times. In order to recover the maximum spectral information from the time domain IP data, a recently developed signal processing algorithm (Fiandaca, et al., 2015) is applied on the full waveform recorded signal. Using this algorithm, the fundamental frequency of power lines and their harmonics are cancelled, thus allowing the use of earlier and narrower gates down to a few milliseconds. After the harmonic de-noising and removal of background drift, the signal is re-gated using logarithmically scaled gates.
The data were inverted following Fiandaca et., al (2012) (Auken et al. 2015). This code uses the Cole-Cole model for parameterization and takes into account full waveform, stack size and filter characteristics of the instrument. The data space consists of apparent resistivity and apparent chargeability for each gate and the model space consists of the four Cole-Cole parameters namely, resistivity (ρ), chargeability (m0), relaxation time (τ) and frequency exponent (c).

Results

Figure 3 shows the inversion results (including normalized chargeability) from the borehole B3 along with the gamma log. Total drilling depth for this borehole was 32.5 m. A geological log was made one meter apart from the Ellog and is also shown in Figure 3. The different lithological units correlate well with gamma, resistivity and the m0 log. The high chargeability peak (~100 mv/v) around 10 m 15 m and 27.5 m are very well correlated with the thin mica saturated clay and lignite layers, which is also strongly supported by the peaks in gamma log. The low resistivity seen from a depth of 17 m to 27m is the zone where contamination from the landfill is observed. Overall, results show very good agreement with the geological log.

CONCLUSIONS

The presented study shows how in-situ measurements of resistivity, IP and gamma log data are efficiently collected with the El-log method. Spectral information was retrieved using the 1D inversion of full time decay data. The method has shown that it is possible to make a very accurate correlation between geology and the geophysical parameters.

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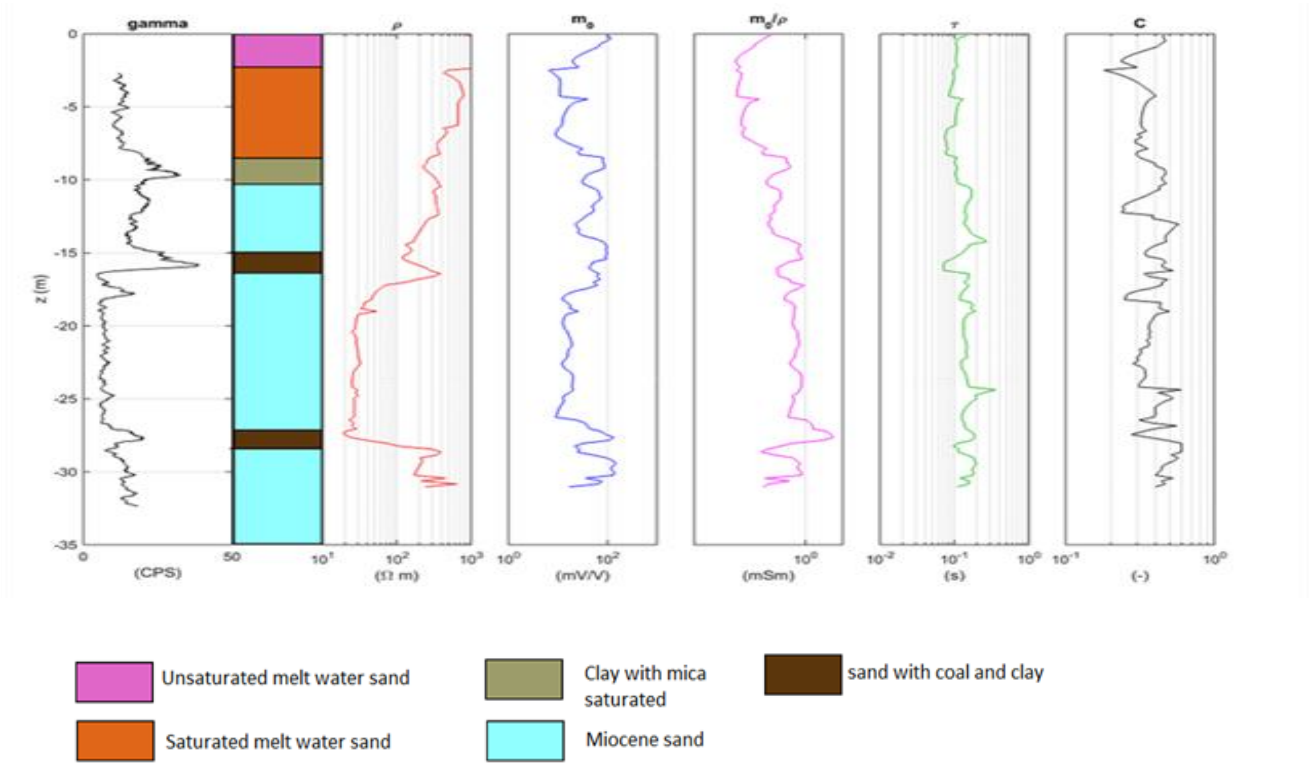

Figure 3 Inversion results of borehole B3, Geological log are shown between the resistivity and gamma log. Color code represents the different lithological units