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

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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 the (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 (IP) signal together with the resistivity measurements. The data represent undisturbed samples comparable to what can be obtained by measurement in the laboratory. Furthermore, water samples are collected during the El-log acquisition, and possible correlations between IP signature and contamination can be investigated. The data were collected close to two landfill sites in Denmark. The landfill are located at Grindsted(Southern part of the denmark) and at Samsø (an island in eastern denmark). We present the results only form the Grindsted landfill.

Methodology

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 (Figure 1). 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 2 and 3) while the gamma sensor is inside the auger close to the tip (Figure 4). The water sampler device is also inside the auger and is connected with tubes to the surface.

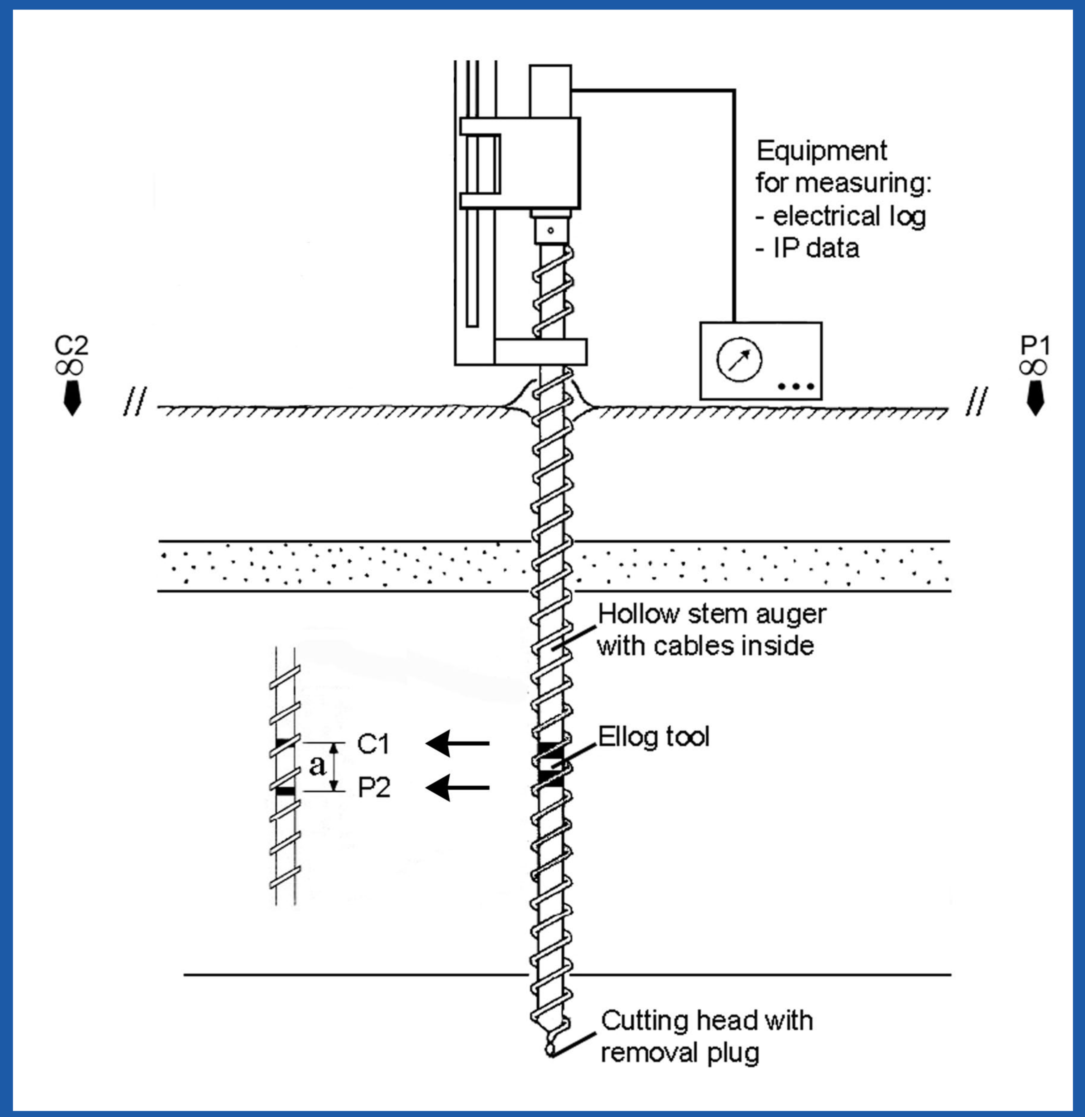


Figure 1 Principal sketch of the El-log drilling rod P are the potential electrode and C are the current electrodes. The distance a is equal to 20 cm. A gamma log is located inside the auger. Water samples are taken through inlets close to the drill tip. Modified from Sørensen and Larsen, 1999.

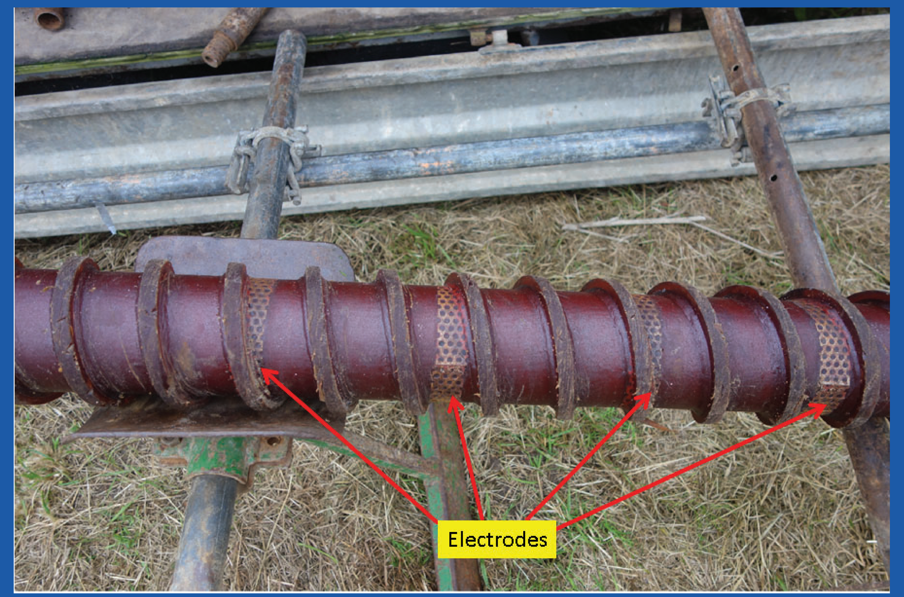


Figure 2 Position of Electrodes on drill stem

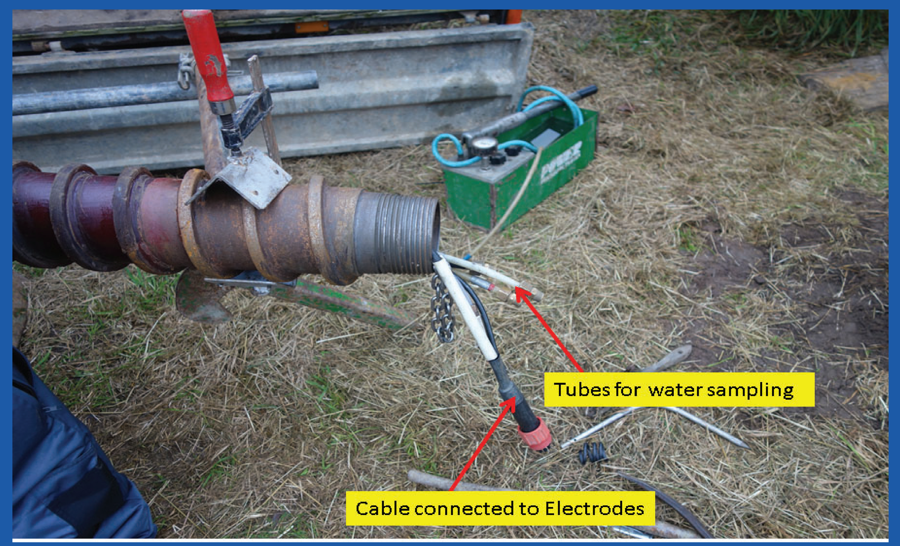


Figure 3 Cable connections and water samling Tube

Figure 4 Tip of the Auger (Drilling bit)

Data Acquisition and Inversion

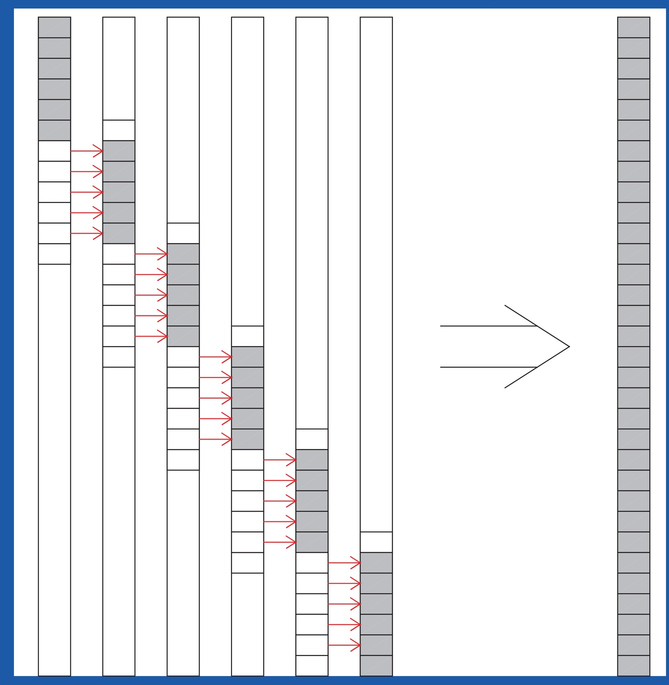
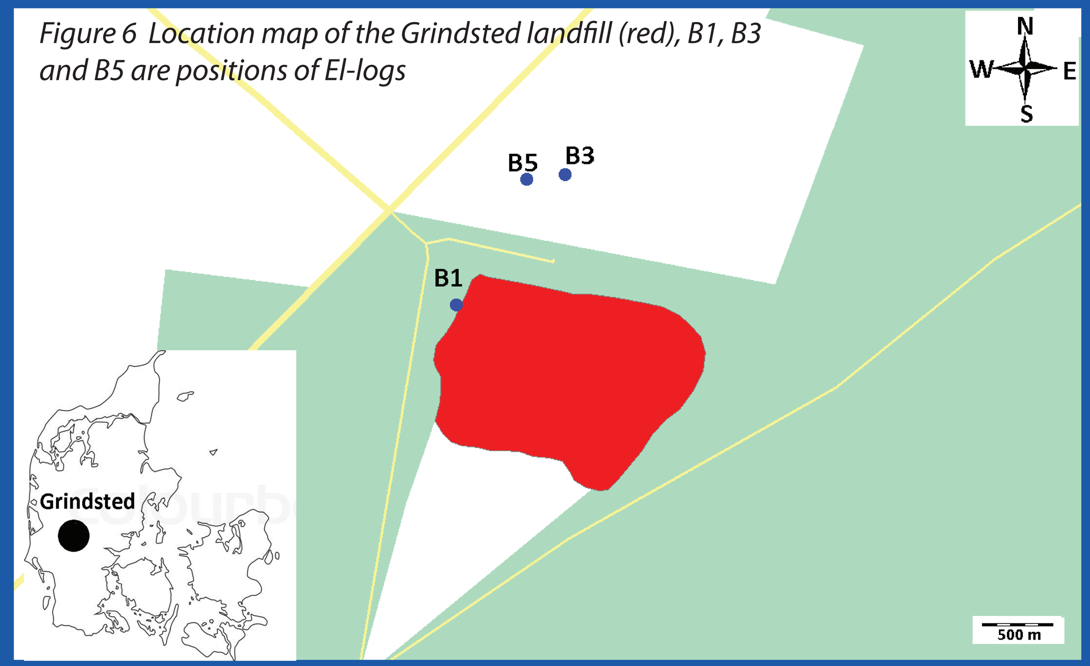


Figure 5. Split of a 32-layers 1D model (grey model) in six 13-layers laterally-constrained sub-models for computational efficiency. The red arrows represent the lateral constraints.

Data Acquisition

The resistivity, IP and gamma data are measured continuously while drilling. For resistivity and IP data the Terrameter-LS instrument by ABEM is used, in a pole-pole configuration with one potential and one current electrode embedded in the auger and two remote electrodes on the surface. Both 50% and 100% duty cycle acquisitions (Olsson et al., 2015) are supported, and full-waveform data are processed for harmonic noise and drift removal following Olsson et al. (2016).

Figure 6 Location map of the Grindsted landfill (red), B1, B3 and B5 are positions of El-logs



Inversion

For inversion of the resistivity and IP data the algorithm described in Auken et al. (2015) is used. To speed up computations the full 1-D model containing hundreds of layers is split into several sub-models containing only a few tens of layers and the data are subdivided in subsets grouped by depth. The inversion is then carried out in parallel on the sub-models/datasets and the full model is reconstructed by stitching the sub-models after inversion (Figure 5).

Field Example

Results from the Grindsted landfill are presented and position of the boreholes are shown in figure 6.

Figure 7 shows the inversion results in term of Cole-Cole parameters (Pelton et al., 1978) from the borehole B1 along with the gamma log. A geological log made one meter from the Ellog is also shown.

High chargeability peaks (~100 mV/V) around 12 m, 20 m, and 30 m are very well correlated with the thin clay and lignite layers, which is also supported by the peaks in the gamma log. Overall, the results show a very good agreement with the geological log. Notably, the peak on the m0 parameter at around 20 m extends a few meters above the lignite layer, where the strongest contamination is present.

Grain size distribution on samples collected during drilling and magnetic susceptibility log will be carried out to support the interpretation of the IP anomalies.

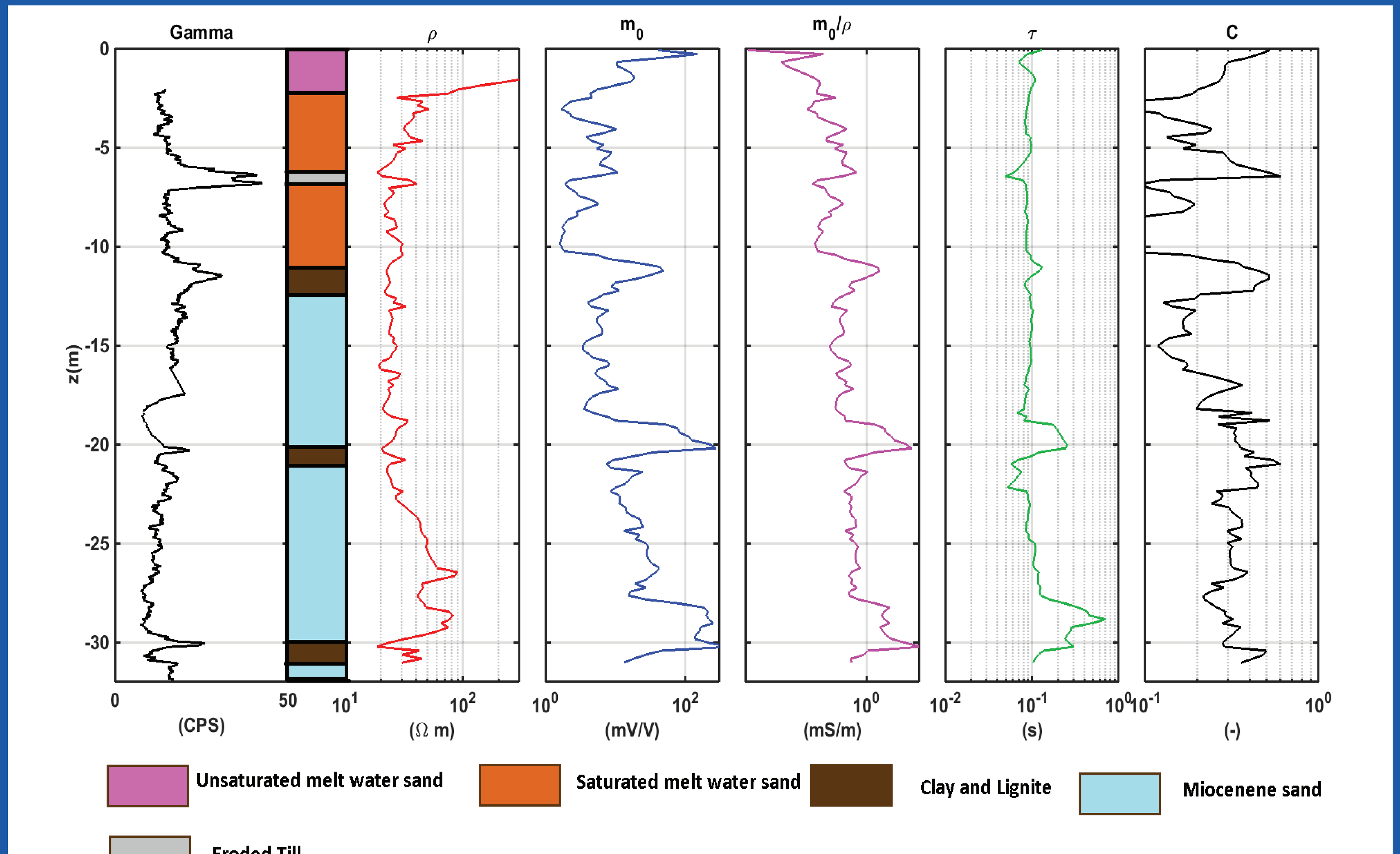


Figure 7 Inversion results of IP data shown along with gamma log and lithology

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 of a undisturbed formation was retrieved using the 1D inversion of full time IP decay data. The method has shown that it is possible to make a very accurate correlation between geology and the geophysical parameters, however IP parameter might also be linked with contamination .

References

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