Mapping possible flowpaths of contaminants through surface and cross-borehole spectral time-domain induced polarization

Thue Bording, Gianluca Fiandaca, Pradip Kumar Maurya, Anders Vest Christiansen, Esben Auken, Hydrogeophysics Group, Aarhus University
Knud Erik Klint, GEUS

HYDROGEOPHYSICS GROUP
AARHUS UNIVERSITY

Introduction

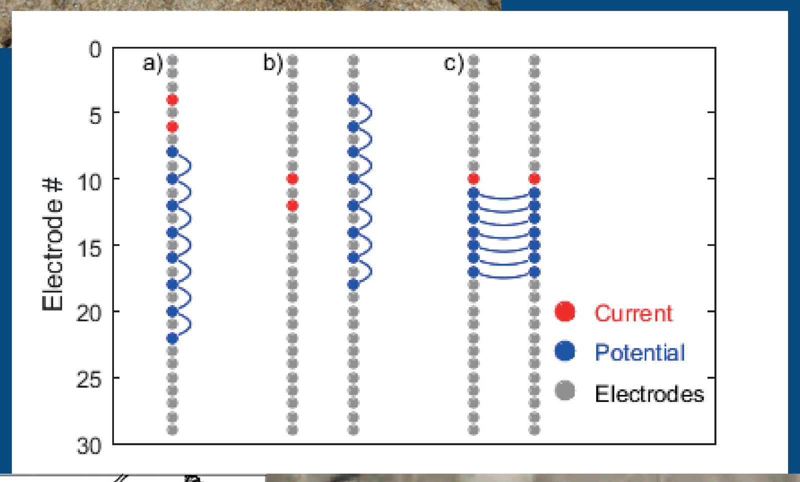
In the Capitol Region of Denmark, several sites are contaminated due to various human activities. A large fraction of these sites are in clayey moraines, where the flow of pollutants predominantly occurs in sand lenses or sandy layers. Boreholes are normally drilled in order to describe the geology, but boreholes alone do not always provide the necessary resolution to map out such sand lenses, which is why the Capitol Region initiated a project to evaluate different cross-borehole geophysical methods for mapping sand lenses/layers. A test site was established in an uncontaminated gravel pit near Hedehusene, Zeeland, Denmark (Kallerup grusgrav).

Our contribution was with spectral time-domain induced polarization (Fiandaca et al., 2012, 2013), due to its capability in lithotype discrimination (e.g. Chongo et al., 2015; Gazoty et al., 2012), while other research groups performed georadar and seismic cross-borehole acquisitions. After measurements the entire test site was dug out, and the geology was described and compared to the geophysical results.

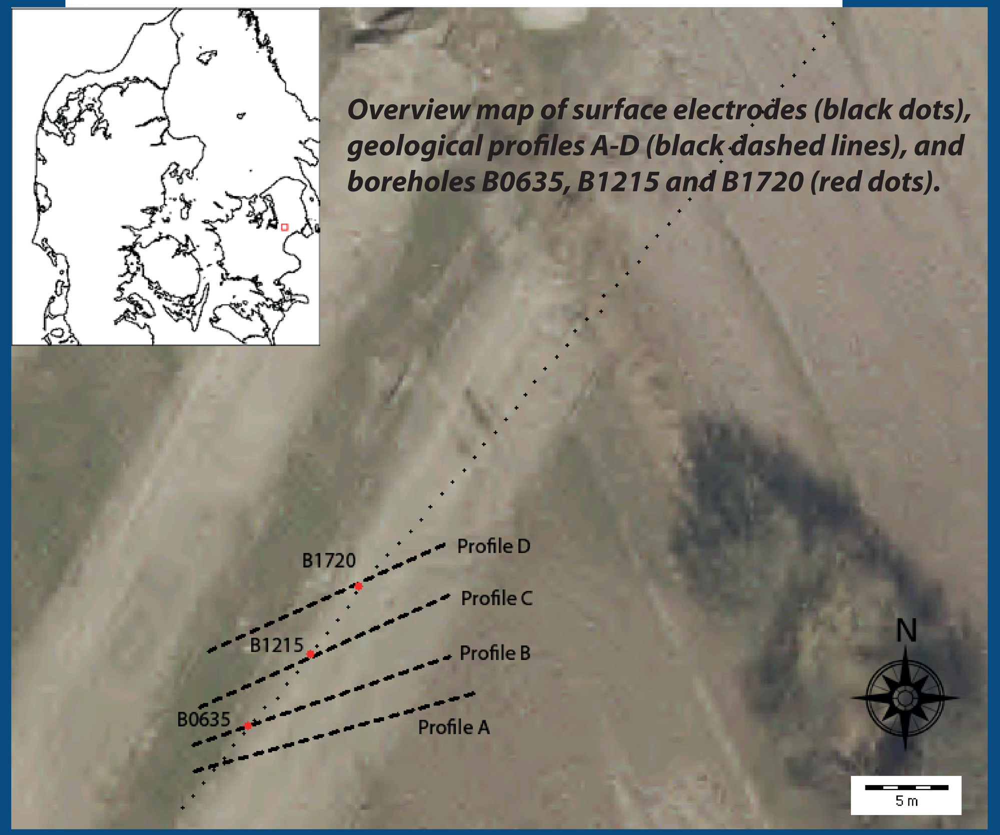
Data Acquisition

Electrode tubes inserted into a borehole

The measurements were carried out late in 2015. The electrode array consisted of a NE-SW oriented surface profile with three boreholes. The surface profile was 63 m long with an electrode spacing of 1 m. The boreholes were drilled at the 6.35 m, 12.15 m and 17.20 m positions along the surface profile with 50, 45 and 47 electrodes, respectively. Custom made tubes fitted with circular electrodes, with a vertical spacing of 20 cm, were inserted in each borehole, and the boreholes were backfilled with sand and watered

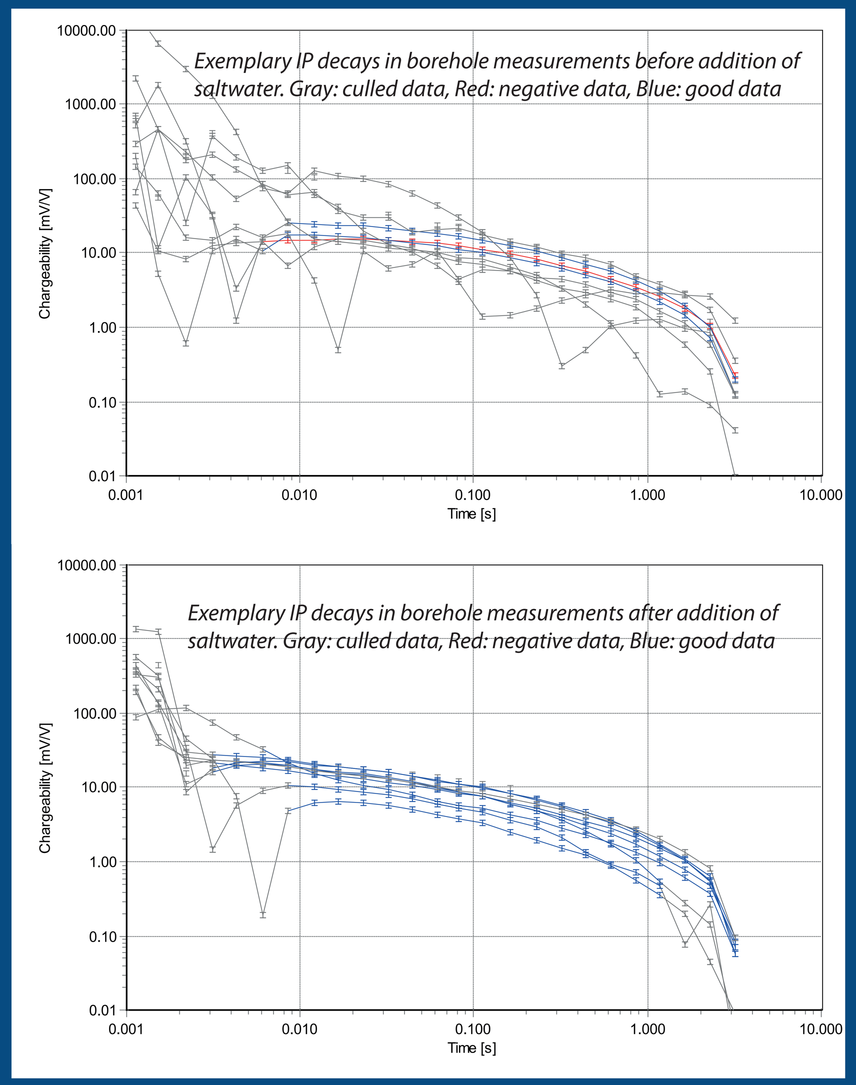


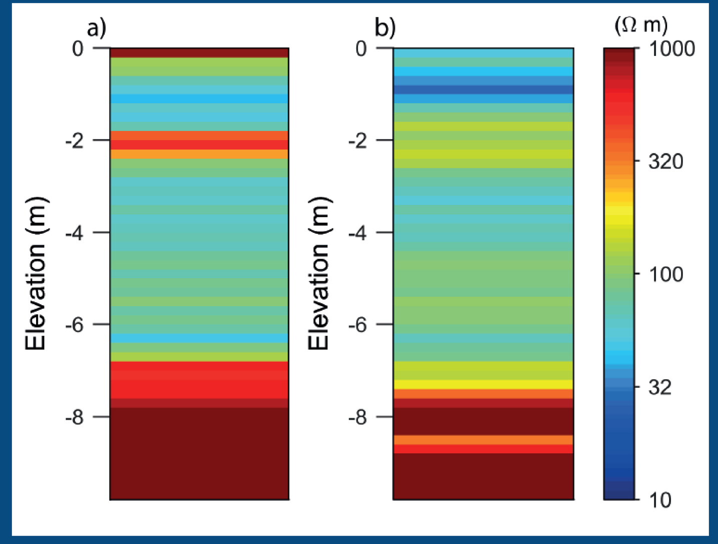
Array types used in boreholes. a) Collinear dipole-dipole. b) parallel dipole-dipole configuration used in cross-borehole measurements. c) equatorial dipole-dipole configuration used in cross-borehole measurement



Overview map of surface electrodes (black dots), geological profiles A-D (black dashed lines), and boreholes B0635, B1215 and B1720 (red dots).

Contact Resistance

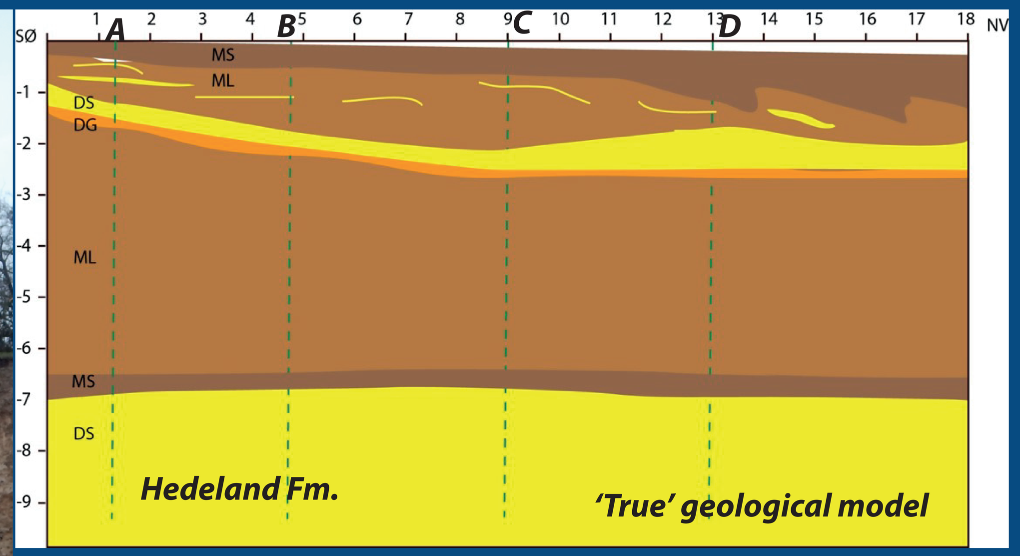




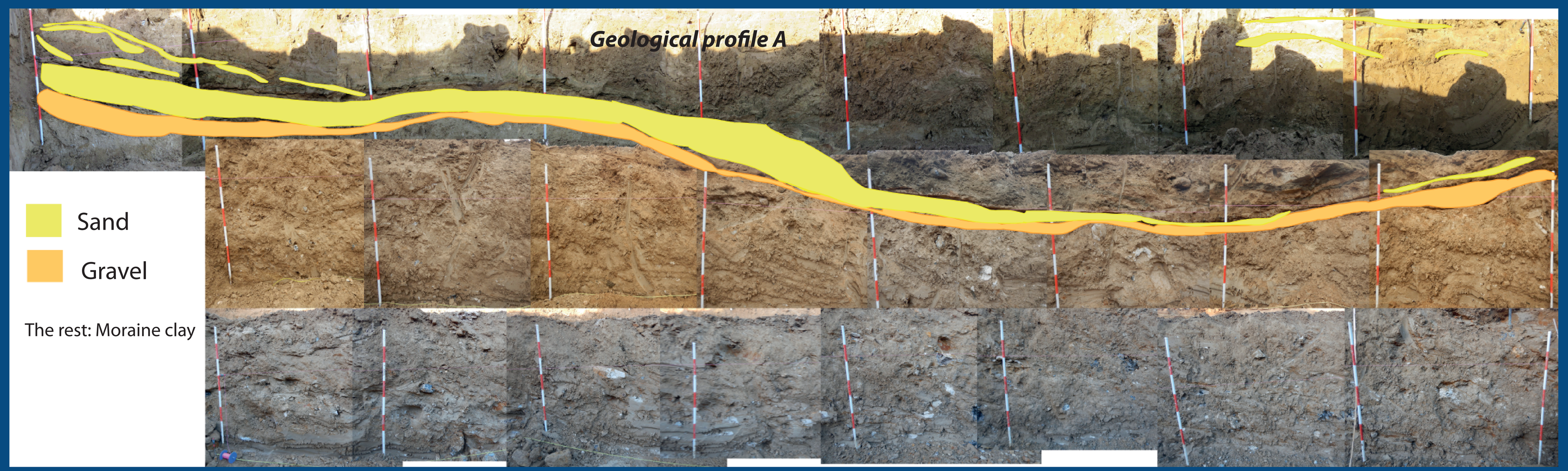
1D DC inversion of single borehole data before (a) and after adding saltwater (b)

The contact resistances measured in the boreholes just after the borehole installation were in the order of a few kΩ, but after a few hours they increased to tens of kΩ, due to the drainage of the water at the bottom of the boreholes (the water table being well below the borehole depth). Test TDIP acquisitions with borehole sequences showed poor data quality due to the high contact resistance. Consequently, around 100 liters of salt water were poured in each borehole, resulting in a permanent decrease of contact resistance in the kΩ range. The added saltwater greatly reduced the noise in the IP decay, but also introduced a conductive anomaly at the bottom and near the boreholes.

Geology

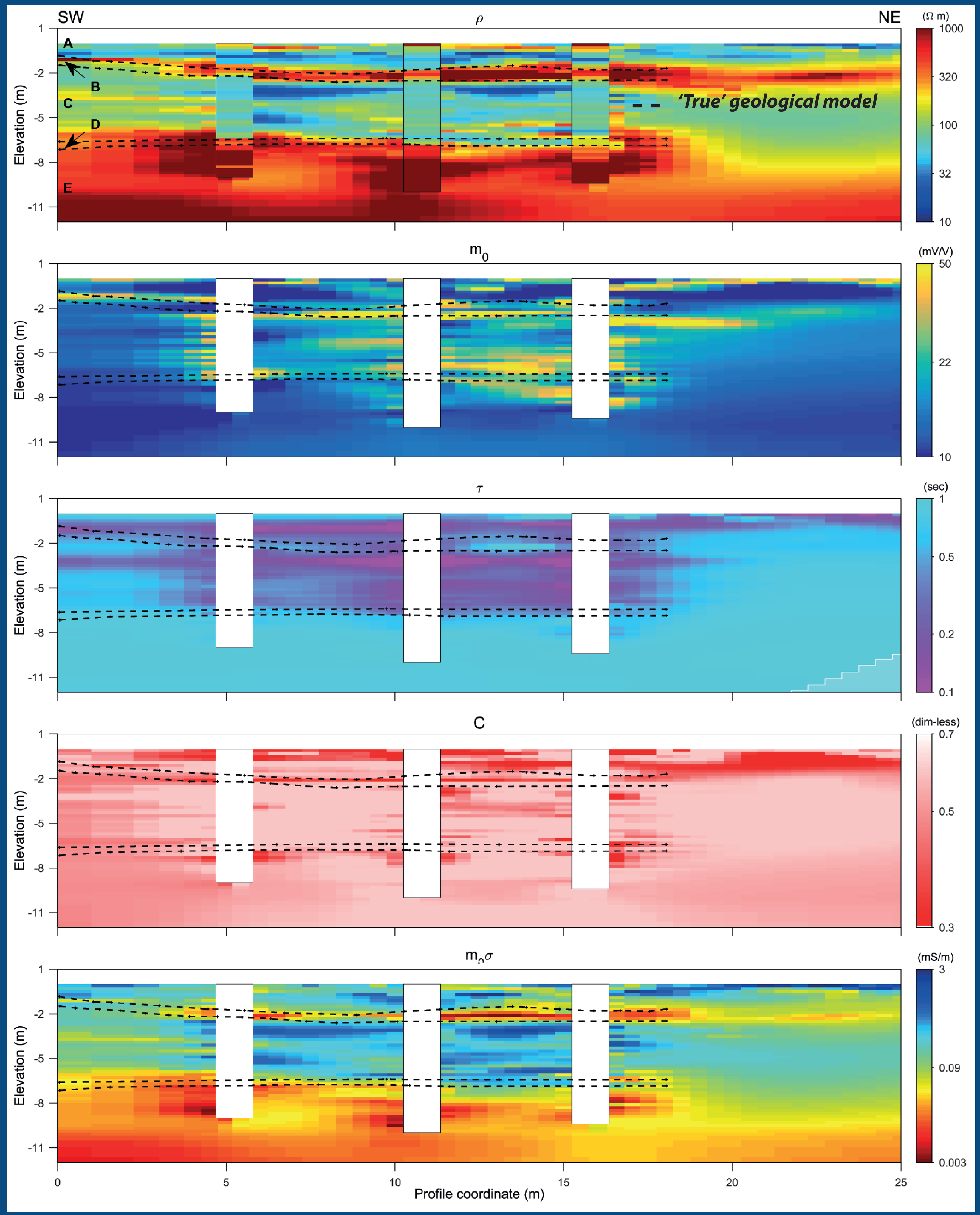


The site was dug out along four profiles A-D, and a gelogical model was constructed by stitching high resolution photos together.
The target formation in the gravel pit is the Hedeland Fm. which is overlain by 6-10 m of moraine clay.
Within the moraine clay, relatively thin sand layers were known to be present, and the purpose of the study was to determine if such thin layers could be detected by cross borehole measurements.
A geological profile along the DCIP profile was constructed using the geological profiles A-D.



Inversion Results

2D TDIP inversion results. Shown here are resistivity (ρ), chargeability (m_0), relaxation time (τ), frequency exponent (C) and normalized chargeability (m_0/ρ). The model cells in the borehole surroundings are blanked out, for masking the saltwater effect and simplify the readability of the figure. In the resistivity section, instead of masking the cells in the borehole surroundings, the 1D DC inversion models retrieved from borehole-only data before adding saltwater are superposed to the cross-borehole inversion model.
The dashed lines are the layerboundaries from the geological excavation. Despite of the alterations in the parameter distributions close to the boreholes, it was possible to retrieve the distribution of sand lenses/layers at the site, as confirmed by the geological excavations.



Conclusion

The inversion results show a connected resistive sand layer seen to be present at 2 m depth. The top of a highly resistive layer is seen 6-7 m below the surface, which corresponds to the Hedeland Fm. Internal structures is clearly visible in the moraine till between 2 m and 7 m, with the DC and IP parameters suggesting the presence of less conductive layer. The overall geology has been confirmed by the excavation performed for verifying the geophysical results.

The results will be compared in detail with the results obtained by the other geophysical methods.

References

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