Topic 3-Non intrusive geophysics for pollution plume mapping inside an operating plant

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*We present Electric Resistivity Tomography and Induced Polarization (ERT/IP) data from an industrial site in SE Norway. The case study is situated in a coastal setting, on a sea-front property of some 1500 m^2paritally situated on outcropping bedrock and natural sediments or backfill. The area has an extensive history of industrial use and hydrocarbon contamination in the past. The current land owner has invested in large scale remediation efforts to stop observed HC leakage into the sea water. As the property is still in industrial use, the ground is not accessible for removal of contaminated soil or for detailed mapping of the source and extend of contamination. To improve our overall understanding of the site we have acquired 5 ERT/IP profiles. The aim for the near surface geophysical survey was to map bedrock topography and potentially the extent of the contaminant plume without stopping the work in the factory (**Figure 1**).*

We simultaneously measured resistivity and chargeability data with a 12-channel, time-domain, full-waveform recording unit [Terrameter LS; ABEM, 2010]. This unit connects simultaneously 2 electrodes to input current and 10 electrodes to measure the resulting voltage, leading to a significant increase in survey speed (~20min for one 64-electrode layout). Stainless steel electrodes were used for the survey and we used the same cable for current and potential electrodes. IP data were integrated over ten 100 ms long time windows with 0.6 seconds current on-time and 1.01 seconds off-time Measurements were conducted along 5 profiles from 20 to 120 m length. Profiles A, C, and D were located inside the plant. The northern end of B was out of the plant. Profile E was located outside in the street. The survey lasted 2 days. The depth of investigation varies from a few meters to 20 m depending on the maximum length of the electrodes spread.

Figure 1: IP survey in a working plant.

The resistivity and chargeability data were individually processed by standard, commercial two-dimensional inversions software [RES2DINV; Loke, 2004]. The models are plotted in **Figure 2** and **Figure 3** using Paraview [Henderson, 2007].

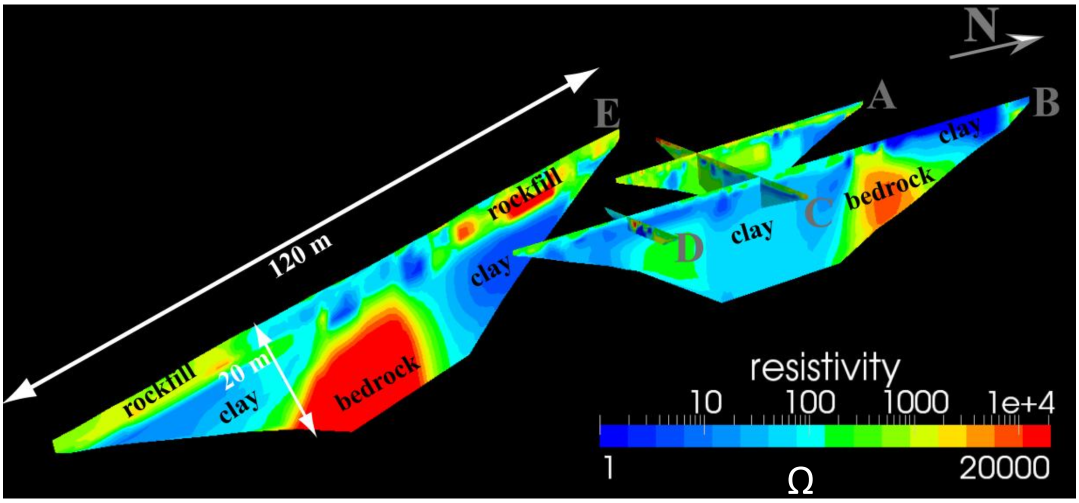

Figure 2: 3D view of the resistivity models with tentative geological interpretation.

Based on existing geotechnical maps, we defined materials with resistivity below 80 Ωm as clay (blue in the resistivity color scale) and materials with resistivity above 1000 Ωm as bedrock (yellow to red). Materials with resistivity between 80 and 1000 Ωm (green) could be moraine or rock fill. Further, there are indications of quick clay in the area, typically within 5 – 80 Ωm. The basement topography is very variable in the area and previous geotechnical drillings hit bedrock at depths from 1.2 to 22.5 m. Our resistivity models agree extremely well with the geotechnical soundings due to the good resistivity contrast between clay and igneous rock.

The modelled chargeability reveals some highly polarized areas along all five profiles. These heterogeneities may be due to different sources and in order to remove the effect of high resistivity contrast between the clay and the bedrock we normalized the chargeability models against the resistivity models. As suggested by Slater and Lesmes [2002], the normalized chargeability gives an image with a cleaner appearance with respect to chargeability anomalies. The normalized chargeability models are shown in **Figure 3**. All of the anomalies located inside the building lie between 0.5 m and 6 m depth. But there is also a surface anomaly on the northern end of profile B and a deeper anomaly on profile E.

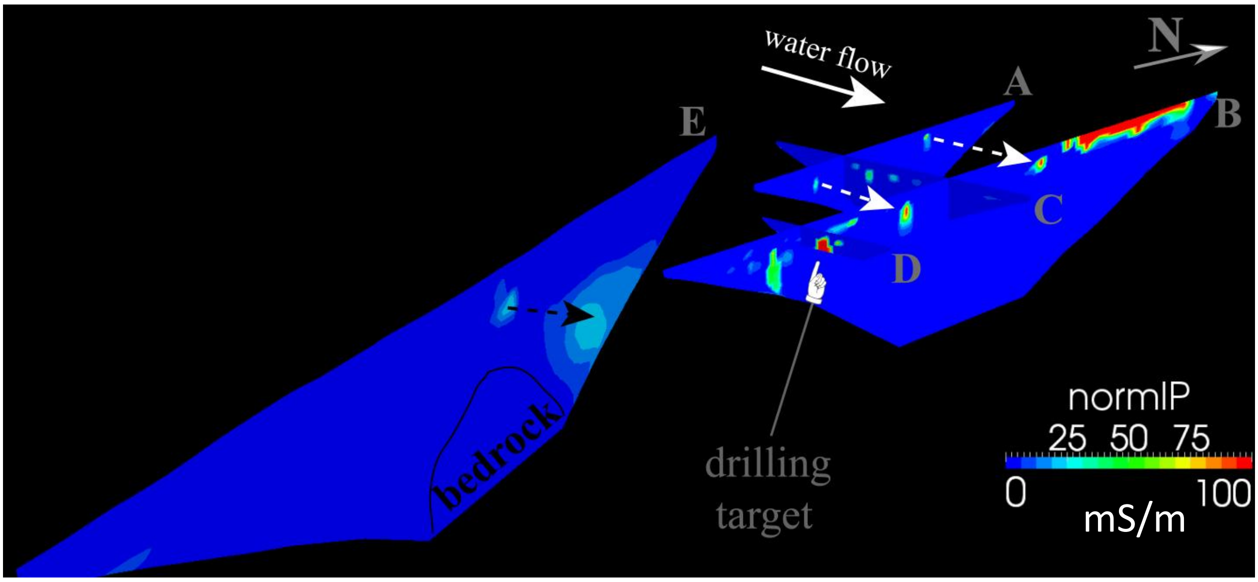

Figure 3: 3D view of the normalized IP models with tentative interpretation of the pollution migration: white dashed arrows show the hydraulically driven flow while the black one shows the gravity driven flow.

Based on 3D visualisation (**Figure 3**) and integration with the local geology and hydrogeology, we propose that the contamination follows the known easterly direction of ground-water flow (white dashed arrows). Lateral spreading may also occur in the direction of dip of the bedrock acting as a lithologic barrier (black dashed arrow). Like all geophysical methods resistivity and chargeability data are ambiguous, meaning that many different "models" can produce the same data. To narrow down the number of possible models, other geological information such as borehole data is needed. The area highlighted by the arrow on **Figure 3** shows the highest anomaly and will be drilled during Summer 2011 in order to validate the IP model.

References:

ABEM, 2010. Terrameter LS, Instruction Manual, www.abem.se.

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Henderson, A., 2007. ParaView Guide, A Parallel Visualization Application.Kitware Inc.

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