Delineation of a free phase chlorinated hydrocarbon plume with resistivity and TDIP

S. Johansson(1), P.-I. Olsson(1), M. Lumetzberger(2), T. Dahlin(1), H. Rosqvist(3) and C. Sparrenbom(3)

(1) *Engineering Geology, Lund University, Sweden*
(2) *Geosciences and Natural Resource Management, Copenhagen University, Denmark*
(3) *Geology Dept., Lund University, Sweden*

Drilling with subsequent laboratory tests on soil and groundwater samples is the conventional method used to delineate contamination plumes in soils. Chlorinated hydrocarbons, which belong to a group of fluids referred to as DNAPLs (Dense Non-Aqueous Phase Liquids), implicates especially severe conditions since they are very toxic and only a small amount can cause serious pollution of the ground water when dissolved. All pure DNAPLs are non-polar fluids and electrical insulators, and studies have shown that soil saturated with DNAPLs leads to a reduced dielectric constant of the medium (Ajo-Franklin et al. 2006 and references therein).

Resistivity and time domain IP (DCIP) data were measured at a field site in southern Sweden. The site is a former dry cleaning facility situated over a major aquifer, and the ground is heavily contaminated with chlorinated hydrocarbons, namely tetrachloroethylene (PCE) and its degradation products. A wetland is closely situated east of the site. The aim of the measurements was to investigate how well the soil contaminated with free-phase PCE could be delineated with DCIP. Several drillings together with soil and groundwater samplings have been made at the site, providing reference data approximately showing where two main plumes of free-phase PCE in the soil can be expected. Presence of free-phase PCE was expected to give rise to high-resistive anomalies and IP-effects, as previously indicated for instance by Cardarelli and Di Filippo (2009).

The DCIP measurement arrangement on the actual plot consisted of ten roughly parallel 2D profiles and one U-shaped 3D profile enclosing them. The mean length of the profiles was about 80 meters, and spacing between the profiles and between the in-line electrodes were both 2.5 meters. The DCIP measurements were made with the ABEM Terrameter LS instrument using separated cables for transmitting current and receiving potentials. The pole–dipole array was used with the remote electrode located approximately 500 meters away. The DCIP data were inverted in Res3Dinv version 3.08 (Geotomo Software), using robust data and model constrains with incomplete Gauss-Newton optimization methods. Both elevation and coordinates of the electrodes were incorporated in the inversion of the 3D model. The final model RMS error was 3.56 % for resistivity and 4.52 % for chargeability.

Inverted 3D models of resistivity and chargeability are visualised in Fig. 1. According to drillings, the bedrock begins at about –15 mamsl in the western part of the site and at –25 mamsl in the east. The vertical extension of the models reaches down to –12 mamsl, i.e. above the bedrock surface. A layer of heterogeneous fill material with varying resistivities covers the surface throughout the site. The low resistivity values below the fill material in the easternmost part of the resistivity model probably correspond to the thick layers of clay, peat and dy encountered in the drillings towards the wetland. The chargeability model shows that this area also gives rise to IP-effects, which further supports this interpretation.

In the western part of the site, the soil consist of mainly sandy chalk till between roughly –2 to –15 mamsl according on the drillings. The low resistivity section close to the surface could correspond to a documented 1–2 meter thick layer of varved clay situated below the uppermost fill material. The surrounding anomalies with higher resistivity (~100 Ωm) could be interpreted as till. However, they are of limited horizontal extension; the resistivity is much lower in the northern parts of the model (although this is not visible in Fig. 1). Also, the anomalies reach the surface at two locations, even though the drillings suggest a continuous layer of varved clay above the till.

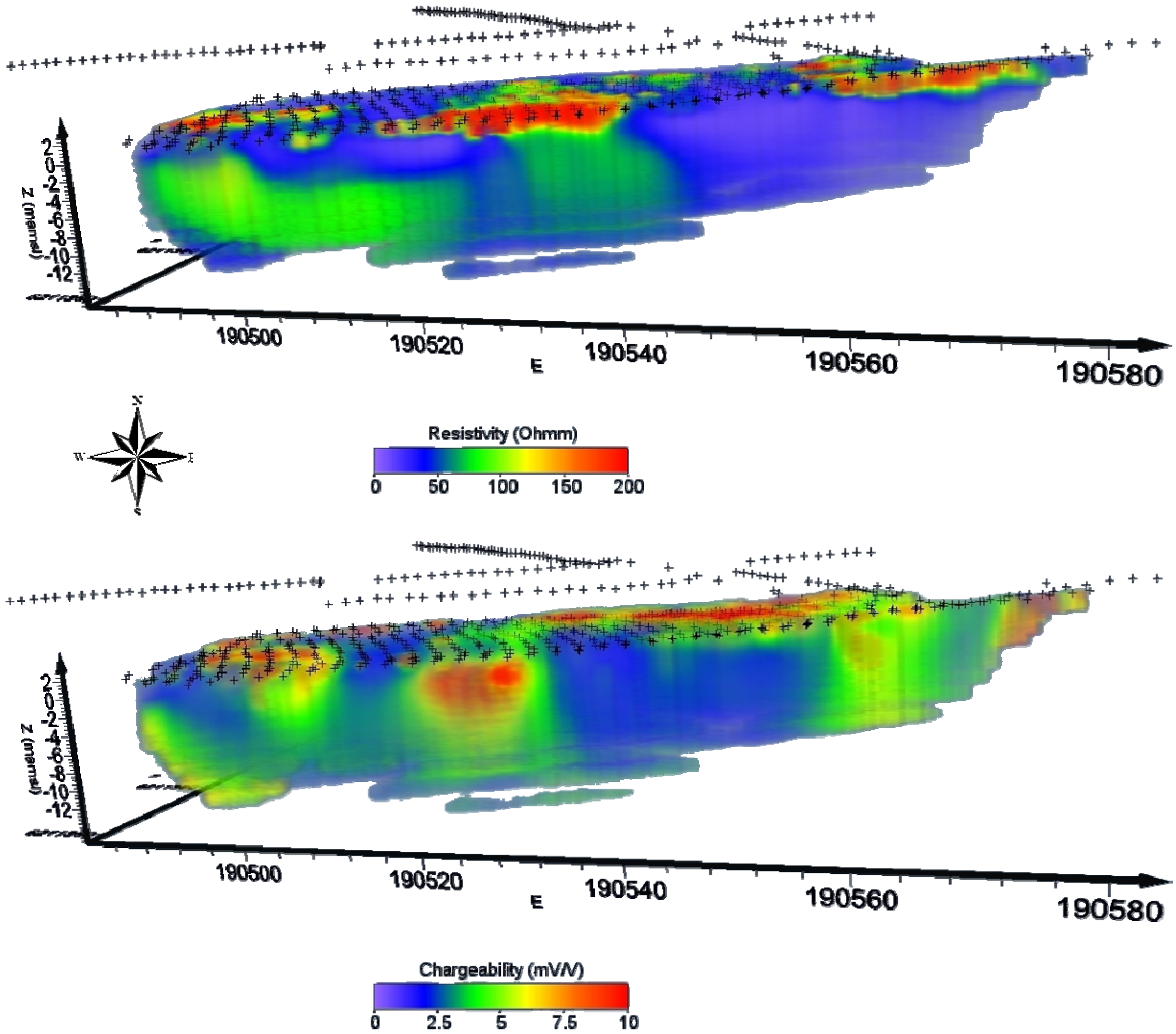

Fig. 1: View over the inverted 3D resistivity model (top) and chargeability model (bottom).

The chargeability model shows two main anomalies with elevated chargeability in the western part of the site. If the resistivity and chargeability models are compared to each other, it can be seen that the IP anomalies coincide with zones of low resistivity. Taken the elevated chargeability in the westernmost edge of the model into account, it seems as if IP-effects occur around the edges of the zones of high resistivity in the western part of the site.

It is probable that the high resistive anomalies in Fig.1 correspond to the sought two plumes of free-phase PCE situated in the sandy chalk till. Their locations correspond approximately to the location expected according to the soil sampling. The shape of the westernmost anomaly suggests that PCE first sank vertically thorough the till, where after it due to gravitational forces now is migrating eastwards along the tilting surface of the bedrock. The IP-effects encountered in the vicinity of the presumed free-phase PCE-plumes may be caused by the degradation of PCE in interfaces between the contamination and water. This could lead to a gradient of free chloride ions in the pore water surrounding the free-phase PCE. However, the data must be further evaluated against chemical soil and water sampling results in order to establish and understand their origin.

References

Ajo-Franklin, J.B., Geller, J.T. and Harris, J.M., 2006. A survey of the geophysical properties of chlorinated DNAPLs. *J. Appl. Geophys.*, 59, 177-189.

Cardarelli, E. and Di Filippo, G., 2009. Electrical resistivity and induced polarization tomography in identifying the plume of chlorinated hydrocarbons in sedimentary formation: a case study in Rho (Milan - Italy). *Waste Management and Research*, 27, 595-602.