CONTRIBUTION OF GEOPHYSICS TO GEOLOGICAL MODELS

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INTRODUCTION

The near surface underground of the North European Basin (Belgium, The Netherlands, parts of Germany, Denmark, and Poland) is mainly composed of gravel, sand, till, and clay of Quaternary and Tertiary origin. Although originally more or less horizontally layered, disturbances of the layer sequence by glacial tectonics (especially deep erosional valleys) and uplift of salt domes are frequent (Figure 1). This can lead to complicated underground structures which make the correlation between boreholes difficult or impossible. Therefore, geophysical measurements are an essential tool for the construction of geological models.

The application of geophysical techniques, especially seismic and resistivity methods, for geological modeling is demonstrated in this paper. Technical developments of the last decades allow excellent reflection seismic results even in the near surface depth range. With resistivity techniques, the distribution of clay free material (sand, gravel) and clayey material (till, clay) can be achieved. Airborne electromagnetic techniques allow a fast mapping of the clay-sand distribution. Combining the results of seismic and resistivity techniques lead to underground models that show, e.g., for hydrogeological purposes, the sequence of groundwater bearing layers and clayey dividing layers.

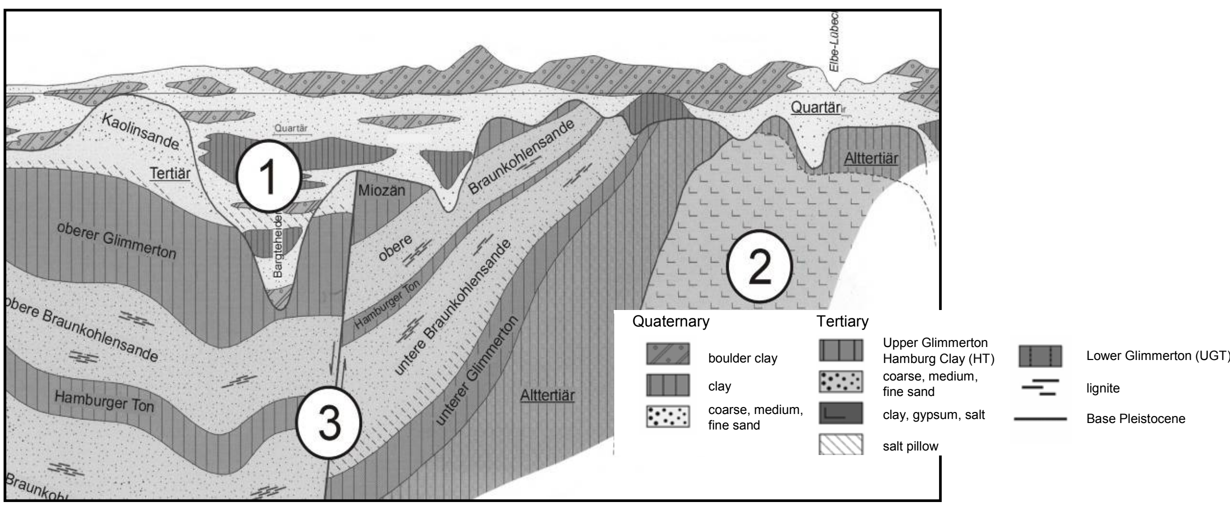


Figure 1. Typical underground structures of the North-European Basin: (1) buried Pleistocene valleys, (2) salt domes, and (3) faults.

EXAMPLE 1: BURIED VALLEYS

A system of buried valleys was created in the North European Basin by subglacial erosion during the ice ages. Filled with sandy material, these are of great importance for water supply. In the scope of the project, BurVal geophysical techniques were applied to survey buried valleys in Denmark, the Netherlands, and Germany. Reflection seismic measurements make the (mainly asymmetric) shape of the buried valley visible giving information of its depth, extent, and the contact to the surrounding layers. For material identification of the buried valley and surrounding deposits, airborne electromagnetic surveys (time and frequency domain) were flown.

As an example, the superposition of the vertical resistivity section to the seismic section (Figure 2) shows that the buried valley is carved into Tertiary clay layers (blue, low resistivities), while the valley fill consists, at least partly, of sandy material (red, high resistivities). These sandy regions are covered by a clay layer (blue). Because of the low permeability of the clay, a good protection of the sandy valley aquifer is provided (see also Figure 3).

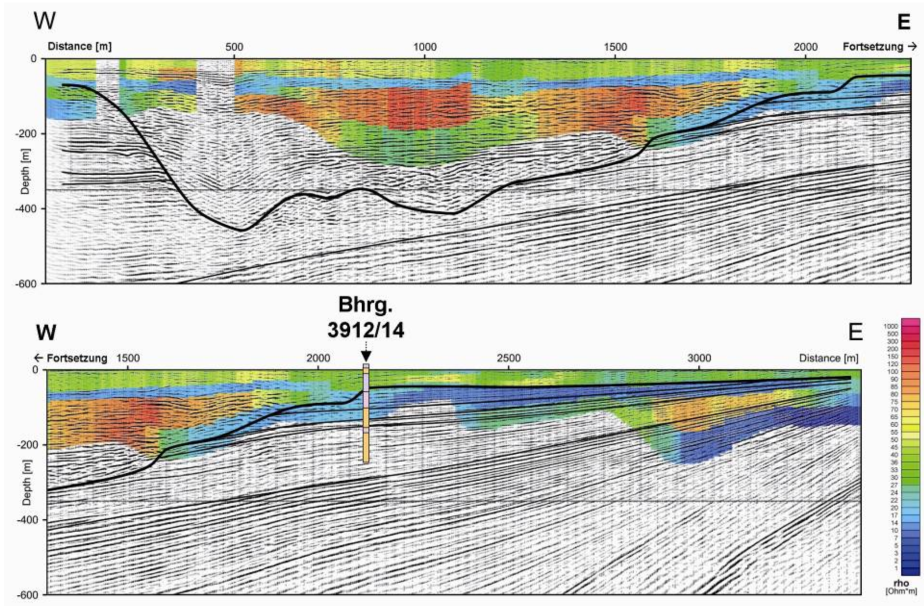
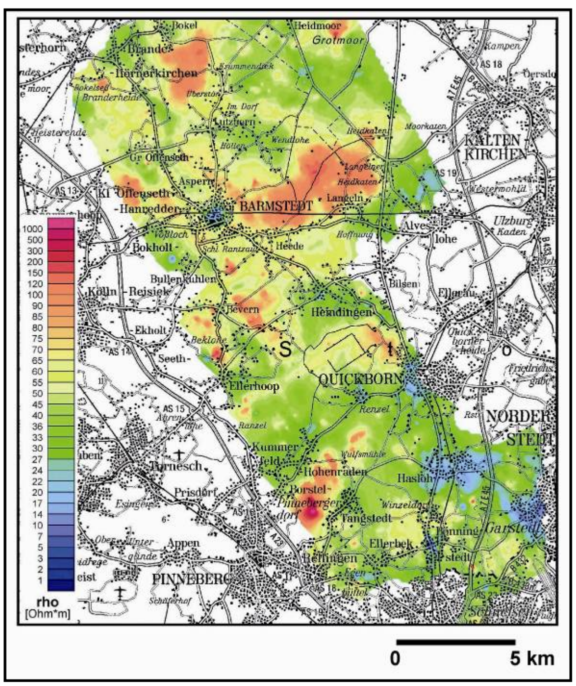


Figure 2. Seismic image of a buried valley with superimposed electrical resistivities from an airborne electromagnetic survey (Department of Earth Sciences, University of Aarhus, Denmark). Low resistivities (blue) refer to clayey material, while sandy material is characterised by high resistivities (red).



Airborne electromagnetic surveys can cover large areas leading to the 3 D distribution of electrical resistivities. Sandy regions with high hydraulic conductivity are characterised by high electrical resistivities, while clayey layers with low hydraulic conductivity are showing low electrical resistivities. This relationship of electrical resistivity and hydraulic conductivity is not unique (resistivities ranging from 50 - 70 Ωm can be related to fine sand or to till with low clay content), so the interpretation of electrical resistivities must be handled with care. An example of an airborne resistivity map from a buried valley area is shown in Figure 3. Some regions with high resistivities (red) interpreted as sand with high hydraulic conductivities are clearly visible. Here surface and precipitation water can infiltrate with relatively high velocity (Röttger et al. 2005) leading to high groundwater recharge, but leading also to possibly fast contaminant transport (high aquifer vulnerability).

Figure 3. Airborne resistivity map for the depth level of 0 m below sea level for Ellerbeker Rinne northwest of Hamburg (BURVAL Working Group 2006, Wiederhold et al. 2008). This survey was flown by Bundesanstalt für Geowissenschaften und Rohstoffe (Hannover, Germany).

EXAMPLE 2: FAULT ZONE

The Sieverstedt fault zone in northern Germany is caused by salt dome uplift resulting in a depth shift of layers of up to 500 m. This leads to an interruption of aquifers which are important for the water supply of the nearby town of Flensburg. Seismic measurements to localise and characterise this fault zone were carried out in the scope of a

Danish-German research project funded by the European community (LANU/SJA 2002, Wiederhold et al. 2002). A compilation of results is shown in Figure 3. Different dips of the layers on opposite sides of the fault zone and the shift of corresponding layers are clearly visible.

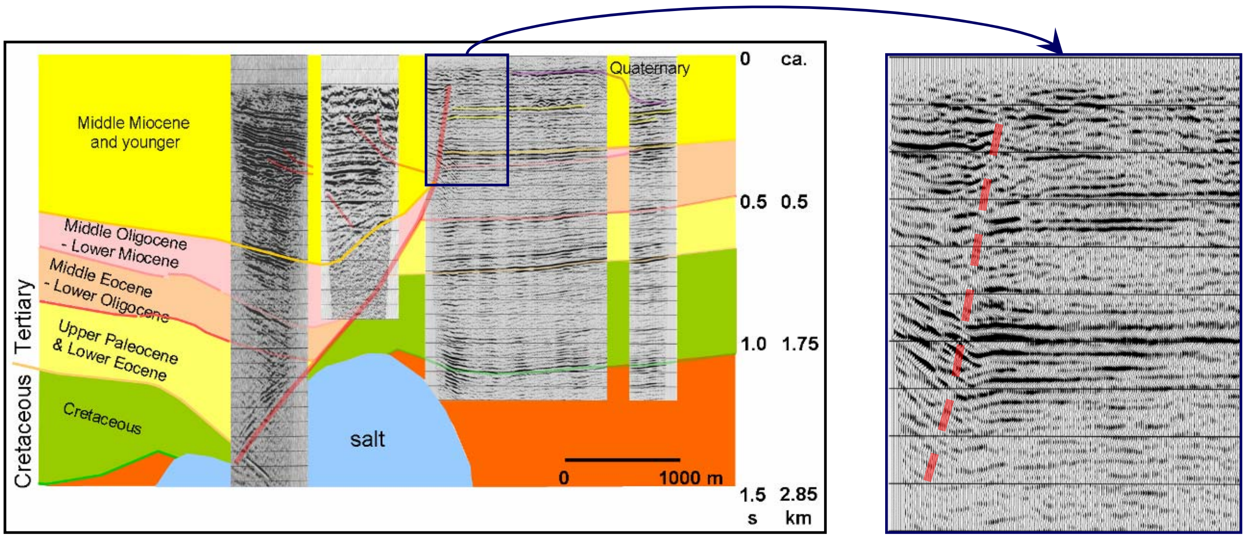


Figure 3. Seismic image of a fault zone (superimposed to Tectonic Atlas of Northwest Germany, Baldschuhn et al. 2001).

ACKNOWLEDGEMENT

The BURVAL project was co-financed by the European Union in the framework of the INTERREG IIIB North Sea Region Programme.

REFERENCES

Baldschuhn, R., Binot, F., Fleig, S. and F. Kockel. 2001. Geotektonischer Atlas von Nordwest-Deutschland und dem Deutschen Nordseesektor - Strukturen, Strukturentwicklung, Paläogeographie. - / Tectonic Atlas of Northwest Germany and the German North Sea Sector - Structures, Structural Development and Palaeogeography: Geol. Jb. A 153, 88 p., 3CD's; Hannover.

BURVAL Working Group 2006. Groundwater Resources in Buried Valleys – a Challenge for Geosciences: LIAG Hannover, 303 p.

LANU/SJA. 2002. Grundvand til Sønderjylland og Schleswig. - / Grundwasser für Sønderjylland und Schleswig: Abschlussbericht INTERREG Projekt, Landesamt für Natur und Umwelt Schleswig-Holstein (Flintbek) und Sønderjyllands Amt (Tønder).

Röttger, B., Kirsch, R., Scheer, W., Thomsen, S., Friborg, R. and W. Voss. 2005. Multifrequency Airborne EM Surveys – a Tool for Aquifer Vulnerability Mapping: In: Butler, D.K. (Ed.): Near surface geophysics, investigations in geophysics no. 13: 643-651, Houston TX (Society of Engineering Geophysicists).

Wiederhold, H., Binot, F., Kirsch, R., Scheer, W. and C. Stadtler. 2002. Geophysical investigation of a hydrogeological important fault structure: Extended abstract, 8th Meeting Environmental and Engineering Geophysics, Aveiro, Portugal.

Wiederhold, H., Rumpel, H.-M., Auken, E., Siemon, B., Scheer, W. and R. Kirsch. 2008. Geophysikalische Verfahren zur Erkundung und Charakterisierung von Grundwasserleitern in Quartären Rinnen: Grundwasser, DOI 10.1007/s00767-008-0068-7.