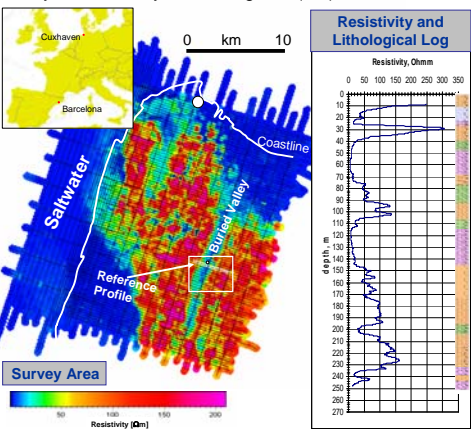


The BurVal Project

The interregional **Buried Valleys** project funded by the European Union was an international investigation of glacial valleys in Northern Europe using various geophysical and hydrogeological methods. Buried valleys are potential groundwater reservoirs and important for future supply of drinking water (www.burval.org).

Area of Investigation

One of the investigation areas is the Cuxhaven-Bremerhaven valley, which was carved up to 300 m deep into Tertiary sediments by glacial melt-water flow. The valley is filled with Quaternary sediments: coarse sand and gravel, overlain by fine and medium grained sand and silt. In the upper part deposits of Lauenburg Clay exist, which differ from the surrounding material by their high electrical conductivities. Thus, they are easily detectable by electromagnetic (EM) methods.

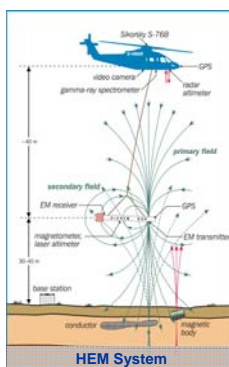


Methodology

A combination of different methods is useful for a comprehensive image of buried valleys. From reflection seismic we know the rough structure of the valley. We applied electrical and electromagnetic (EM) methods to investigate the structure of the filling (see figure on the left). Within the BurVal project we had the first possibility to generate datasets of two different airborne electromagnetic methods in the same area: the BGR HEM system (Siemon et al., 2004) operates in frequency domain and the SkyTEM system of the University Aarhus (Sørensen & Auken, 2004) works in time domain. For the comparison, ground based transient electromagnetic (TEM) (Steuer & Siemon, 2005) and continuous vertical electrical soundings (CVES) were commissioned by the Leibniz Institute for Applied Geosciences (GGA-Institute). The geological a-priori information (see resistivity and lithological log) indicates that in the area of interest a sufficiently large resistivity contrast exists within the investigation depth range of these techniques.

Helicopter Electromagnetics (HEM)

- DIGHEM V-BGR bird (Fugro Airborne Surveys)
- 5 frequencies, horizontal coplanar: 380 Hz, 1.8 kHz, 8.6 kHz, 41 kHz, 192 kHz
- Coil separations: ~ 6.7 m
- Flight speed: 140-150 km/h
- Bird altitude: 30 m
- Sampling distance: 4 m



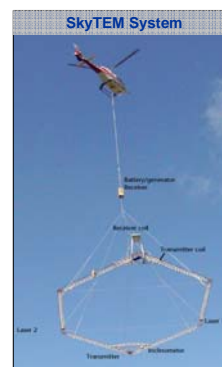
Continuous Vertical Electrical Sounding (CVES)

- RESECS multi-electrode system
- Wenner-Array: 5 m electrode spacing

Transient Electromagnetics (TEM)

Helicopter TEM

- SkyTEM system from Aarhus
- Low moment: 7000 Am²
 - Time range: 17-1400 μs
- High moment: 47 000 Am²
 - Time range: 150-3000 μs
- Flight speed: 18 km/h
- System altitude: 20-30 m
- Sampling distance: 35 m



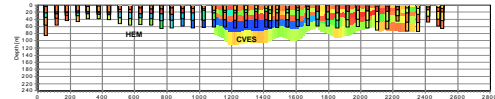
Ground Based TEM

- Protem 47 (analogue)
- Central loop configuration
- Transmitter moment: 30 000 Am²
 - Time ranges: 16-7040 μs

1-D Inversion Results

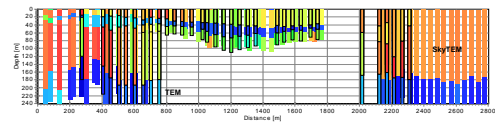
Vertical Resistivity Section of the Reference Profile

HEM and CVES



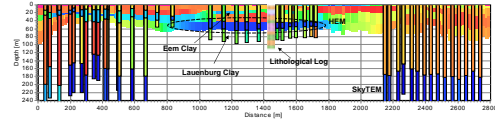
The CVES data were inverted with 1D lateral constrained inversion. HEM and CVES detect a conductive layer at about 20 m depth which could be identified as Eem Clay. The conductive layer between 40-60 m could be identified as Lauenburg Clay.

SkyTEM and TEM



SkyTEM and TEM inversion results are nearly identical, TEM has a better data quality and resolution of the model parameters.

HEM and SkyTEM

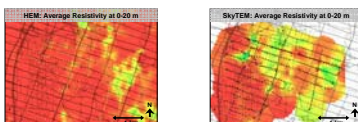


The comparison of HEM and SkyTEM shows a conformance in the location of the Lauenburg Clay. TEM cannot resolve the conductive layer at 20 m depth. Here, HEM has a better resolution and additionally detects the Eem Clay, this layer is verified by lithological and resistivity logs. SkyTEM detects the bottom of the Lauenburg layers and a conductive layer at about 180 m depth outside the valley. HEM provides a higher spatial resolution and SkyTEM enables a higher investigation depth.

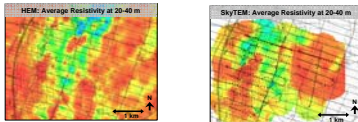
Resistivity Maps

The maps show the average resistivity at different depths based on the 1D inversion results of HEM and SkyTEM data. On the HEM maps additionally the results of the SkyTEM data are shown as coloured dots to emphasise the difference of the results of both methods.

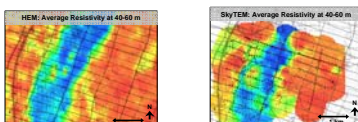
The valley appears in the SkyTEM results at shallower depths than the valley is visible in the HEM results (0-20 m).



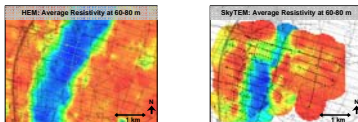
At 20-40 m the resistivity structure is quite similar.



The clay layer is found by both methods at 40-60 m.

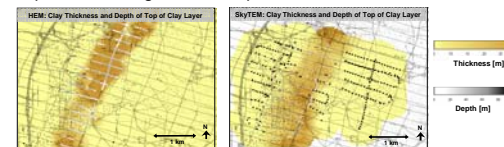


As the penetration depth of HEM is lower than of SkyTEM, HEM is not able to resolve the bottom of the Lauenburg Clay layer and it seems to be too broad at 60-80 m.



Clay Thickness Maps

The maps show the thickness of the clay layers with resistivities of 5-25 Ωm in the upper 100 m depth. The clay thickness is an important parameter for groundwater reservoirs and can be helpful to delimit groundwater protection areas.



Conclusion

Datasets of two different airborne electromagnetic methods were compared with each other and with ground based data in a part of the Cuxhaven-Bremerhaven valley. The inversion results of the electric and the EM methods are consistent. Helicopter-borne electromagnetics (HEM) clearly outlines both lateral extent and depth of the Lauenburg Clays, but the clay limits the depth of investigation: Where thick conductive layers exist, HEM often fails to penetrate the clay. Transient electromagnetics (TEM and SkyTEM) additionally help to outline the thickness of the clay and to detect a conductive layer at about 180 m depth outside the valley. TEM is not suitable to detect the shallow area. On one hand the cost-efficient and very fast HEM system in frequency domain compete against the more expensive time domain system with the higher investigation depth. Ground geophysical measurements are, on the other hand, often more accurate, but they are definitely slower than airborne measurements. It depends on targets of interest, time, money and man power available which method or combination of methods should be chosen.

References

- Sørensen, K. & Auken, E. (2004): SkyTEM – a new high-resolution helicopter transient electromagnetic system. *Exploration Geophysics*, 35, 191-199.
- Siemon, B., Eberle, D.G., Binot, F. (2004): Helicopter-Borne Electromagnetic Investigation of Coastal Aquifers in North-West Germany. *Z. geol. Wiss.*, Berlin 32 5/6, 385-395.
- Steuer, A. & Siemon, B. (2005): A comparison of HEM, TEM and SkyTEM measurements at a buried valley in Northern Germany. 11th European Meeting of Environmental and Engineering Geophysics- Near Surface 2005, Palermo, Italy.