AGS Aarhus GeoSoftware

Inversion of ground conductivity meter data for mapping of raw materials

ABSTRACT

Access to raw materials is important for our society and the extraction of it can be very expensive. It depends on several factors such accessibility, volume and depth of the raw material. To get the knowledge of the extent of the material, traditionally boreholes have been drilled in a grid, which is very expensive. A quicker and less expensive method is to map the area with a geophysical instrument such as a ground conductivity meter. By processing and inversion of the data, the results given as maps and profiles are highly detailed and can reduce the number of boreholes. By correlating the inversion models with boreholes, the geology of the area can easily be interpreted and reduce both time and costs of the extension of e.g. a gravel pit.

This paper will show a case from a gravel pit where mapping with and inversion of geophysical data done in few hours gives much highly detailed results of the thickness of the moraine clay overlaying the glacial sand/gravel deposits. These results can be used to see where it is cost-effective to extract the raw materials and where to place the boreholes to analyze the quality of the raw materials.

Using geophysics and Aarhus Workbench in raw material mapping

Mapping raw materials is normally done by drilling a grid of boreholes to gain detailed knowledge of the materials depth and extend. This method is often expensive and time consuming, especially if the area consists of complex geology.
Within the last years there has been a significant development of geophysical equipment with a big lateral and spatial resolution that can map at high speed. Using this equipment along with the integrated GIS interface, processing, inversion and QC tools of Aarhus Workbench, gives new possibilities to effectively use geophysics methods to get a full surface coverage when mapping raw materials. The results will give a better understanding of the geology which is not possible to gain with information from boreholes alone. By using the inversion models from Aarhus Workbench along with borehole information to translate the geophysical data into raw material geology, mapping of raw materials can be done quicker and cheaper with better results than what you can correlate from just boreholes.

This paper presents results from a gravel pit at Kalbygård in Denmark which is a project made by Aarhus University and Central Denmark Region.

The purpose of this project is to map the thickness of the moraine clay above the glacial gravel and sand from geophysical data and finally make a detailed geological interpretation by comparing with borehole data for validation.

The instrument

The ground conductivity meter DUALEM-421 is an electromagnetic instrument which uses induction to get information from the subsurface. The instrument is a 4-meter-long tube that contains a transmitter coil in front and receiver coils at the end at a distance of 1, 2 and 4 m from the transmitter, which gives a penetration depth around 5-10 m, depending on geology.

The transmitter generates an electromagnetic field (primary field), which induces current fields in the subsurface. The current in the subsurface then generates a new electromagnetic field (secondary field), which is measured in the receiver coils. This secondary field can be translated to resistivity or conductivity and will be dependent of the water content, soil type, etc.
E.g. clay will have a high conductivity and sand/gravel will have a low conductivity.

The instrument is protected in a white tube placed on the sledges and towed behind an ATV, giving a mapping speed up to 20 km/h with a sampling frequency of 10 Hz, which gives a high lateral resolution. A differential GPS is logged along with the data with a sampling rate of 5 Hz and data points are interpolated between the GPS points.

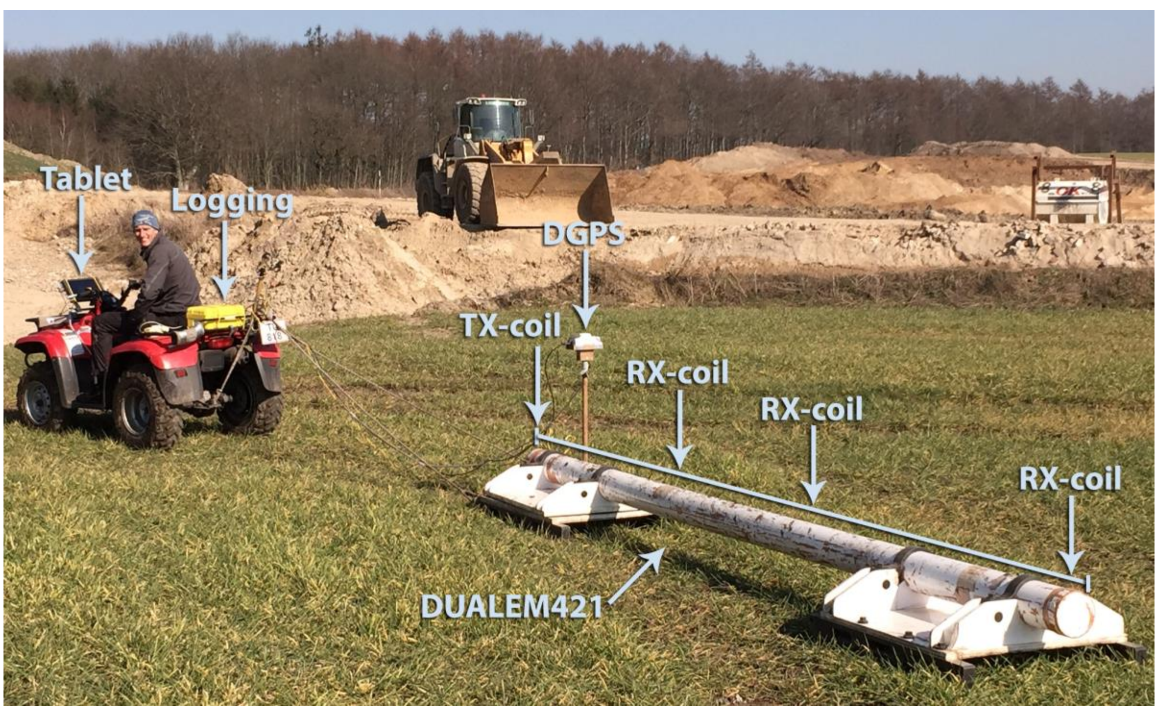

Figure 1. The DUALEM-421 system on two sledges towed behind an ATV.

Aarhus Workbench software

Aarhus Workbench is a unique and comprehensive software package for processing, inversion, and visualization of geophysical and geological data. The package integrates all steps in the workflow from handling the raw data to the final visualization and interpretation of the inversion models. The Aarhus Workbench package includes dedicated data processing modules for many geophysical data types, in an integrated GIS platform. It uses the robust and fast inversion code AarhusInv.

GCM module

The GCM (Ground Conductivity Meter) module includes import, processing, and inversion of GCM data. Any coil configuration can be imported and inverted. System information is easily added during data import. Processing, quality control, and inspection of inversion results are integrated with the GIS interface providing the user with a complete overview of the workflow from raw data to final results. Modelling and presentation to the customer is carried out with the well-known functions of the Aarhus Workbench so that integrating with boreholes, creating reports etc. is easily done and only a few clicks away.

Key features

- Flexible and easy to use importer, which supports any kind of GCM system setup
- Fully developed processing tools and automatic data filtering
- Integrated with the GIS interface
- Automatic LCI/SCI data inversion
- Visualization of data, inverted models on the GIS interface and on cross sections
- Integrated QC tool

Kalbygård data mapping

The gravel pit at Kalbygård is 30 hectares and consists of moraine clay overlaying glacial sand and gravel. The thickness of the layers is very different within short distances. The moraine clay varies from 10 m in some areas to non- existing in other areas.

A 50-hectare area around the gravel pit has been mapped with the DUALEM-421 instrument and 15 boreholes up to 10 m deep have been drilled (figure 2). With the DUALEM-421, 50.200 data points have been recorded with a line spacing of 10-20 m and 30 cm between data points along the lines.

The survey time was 3½ hours and the following processing, inversion and interpretation took 3 hours.

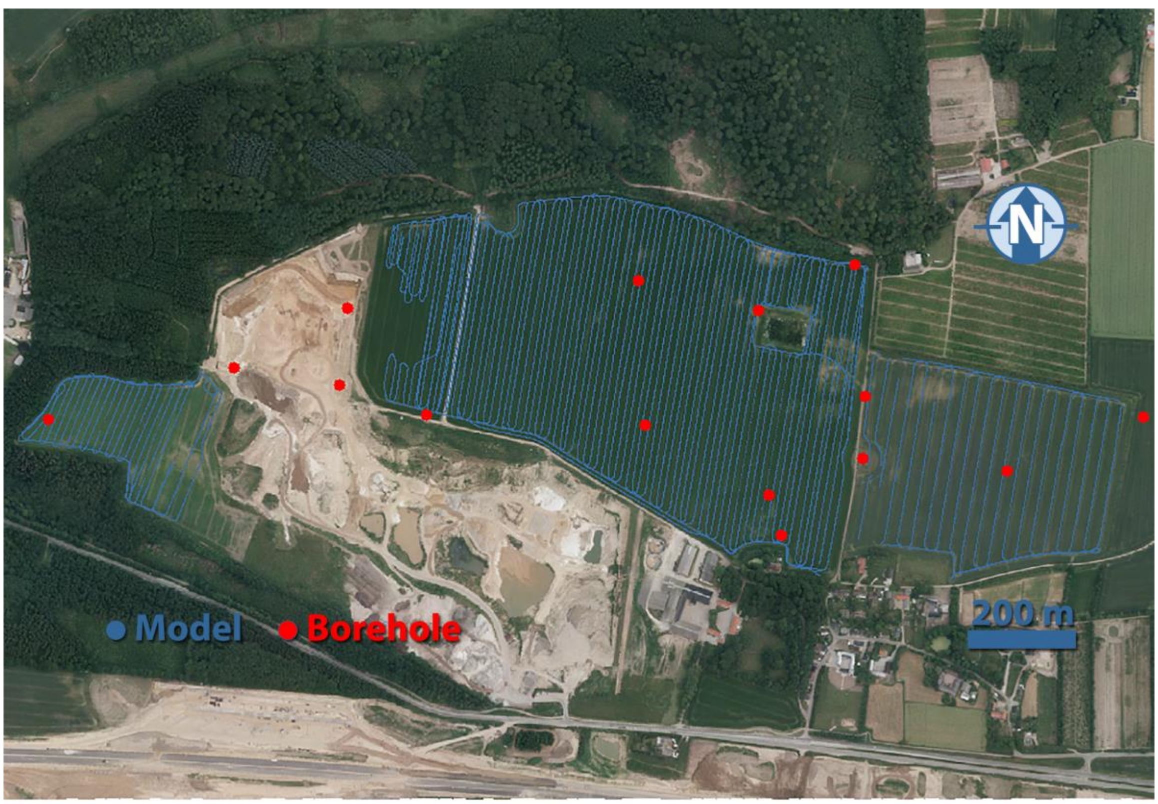

Figure 2. Map of the gravel pit at Kalbygård. The blue lines are mapped with the DUALEM-421 instrument and the red dots are boreholes.

Data processing and inversion

Negative data and noisy data due to couplings from buried cables have been removed in the processing. Data within 5-10 m near known buried cables have been removed. Most negative data are seen at the end of lines where the ATV turns and gets too close to the instrument.
To get a better signal to noise ratio, the data has been averaged with a median filter with a distance of 1 meter. An absolute uncertainty of 1 ppm and a relative uncertainty of 5% has been added to data.

Data has been inverted with a 12-layer 1D SCI inversion (Spatially Constrained Inversion). An SCI inversion is a 1D inversion with 3D constraints. There are constraints on resistivity along lines, between lines and between layers. Inversion settings are listed in table 1.

		Value
Starting model	Number of layers	12
	Starting resistivity [Ωm]	100
	Layer thickness first layer [m]	0.1
	Depth to last layer [m]	10
	Layer thickness distribution	Logarithmic increasing with depth. Fixed.
SCI constraints	Horizontal constraint - resistivities [factor]	1.3
	Reference distance [m]	1
	GCM height above ground	28,5 cm
	Vertical constraint - resistivities [factor]	2.0
	Number of SCI cells	1

Table 1. Inversions-properties, smooth SCI setup.

The Depth Of Investigation (DOI) is also calculated for each inversion model. The DOI gives an estimate to which depth the models can be trusted for interpretation.

Results

The results are represented as mean resistivity maps, profiles and thickness of the moraine clay. Model information below the DOI has been removed from the profiles and maps. Colors from blue to yellow (values below 110 Ωm) represents moraine clay and colors from orange to purple (values above 110 Ωm) represents sand/gravel. Gravel will have a higher resistivity than sand (purple color).

Figure 3 is the mean resistivity maps in the depth interval of 2-3 m (top picture) and 3-4 m (bottom picture). The mean resistivity maps indicate how different the geology in the area is and how fast it changes with depth.

Figure 4a and 4b is resistivity profile 1 and profile 2 located in figure 4c. Each profile includes boreholes and has a black line, which marks the boundary of 110 Ωm that defines the thickness of the moraine clay. The map with the thickness of the moraine clay in figure 4c is created from this boundary.
There is a good correlation between the geophysical models and the borehole information. Also, the thickness of the moraine clay varies several meters within the survey area and a lot of these places will not be seen with borehole information alone. On profile 2 purple structures with very high resistivity is seen. Unfortunately, there is no borehole information in these areas but it is expected to be coarse gravel deposits.

In figure 4c the depth to the 110 Ωm boundary has been mapped with information from all 50.200 inversion models. This boundary is also displayed in the squares representing the boreholes and the correlation of the boundary between boreholes and inversion models are good for all boreholes except one.

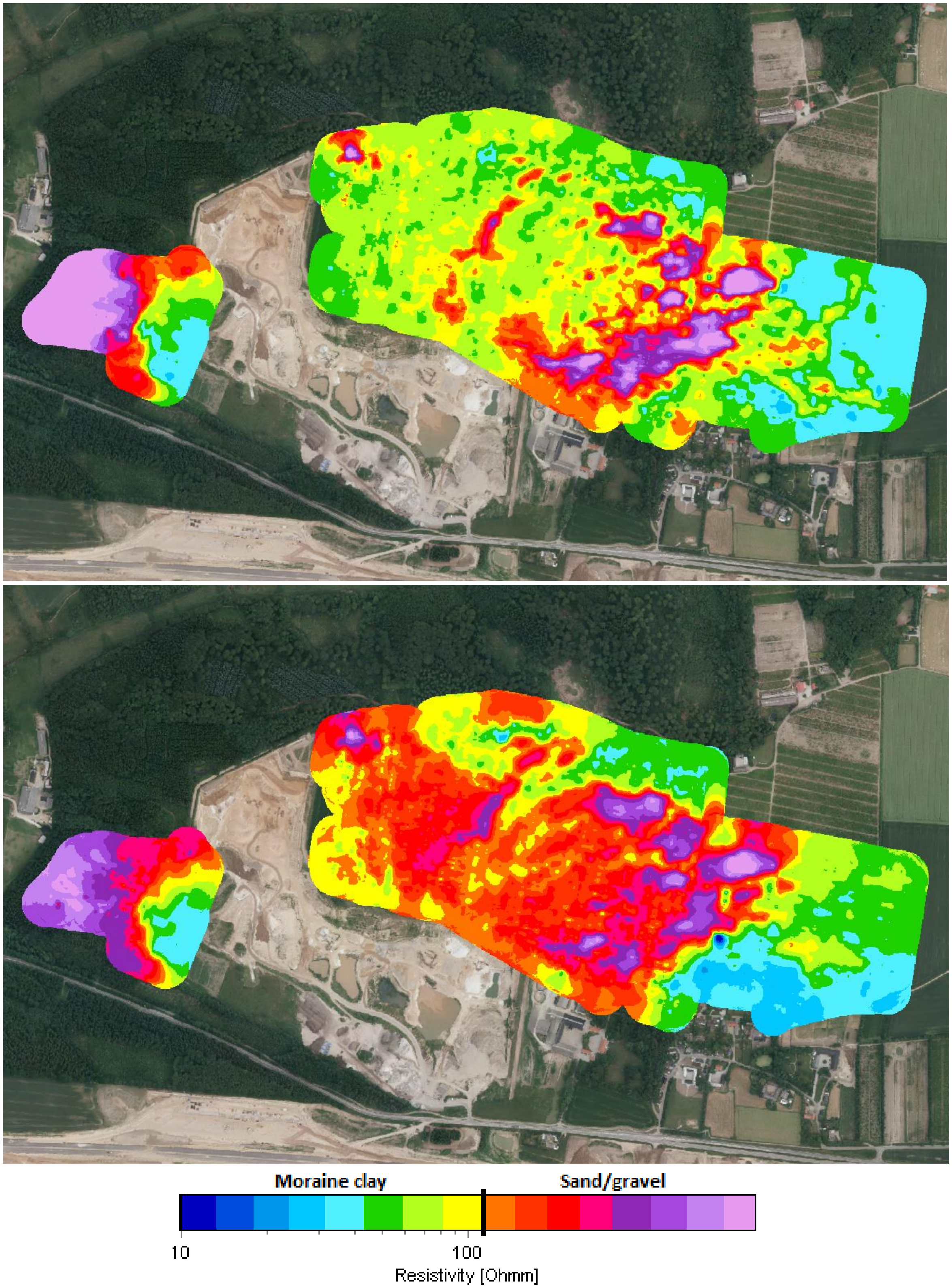

Figure 3. Top: Mean resistivity map in the depth interval 2-3 m. Bottom: Mean resistivity map in the depth interval 3-4 m.

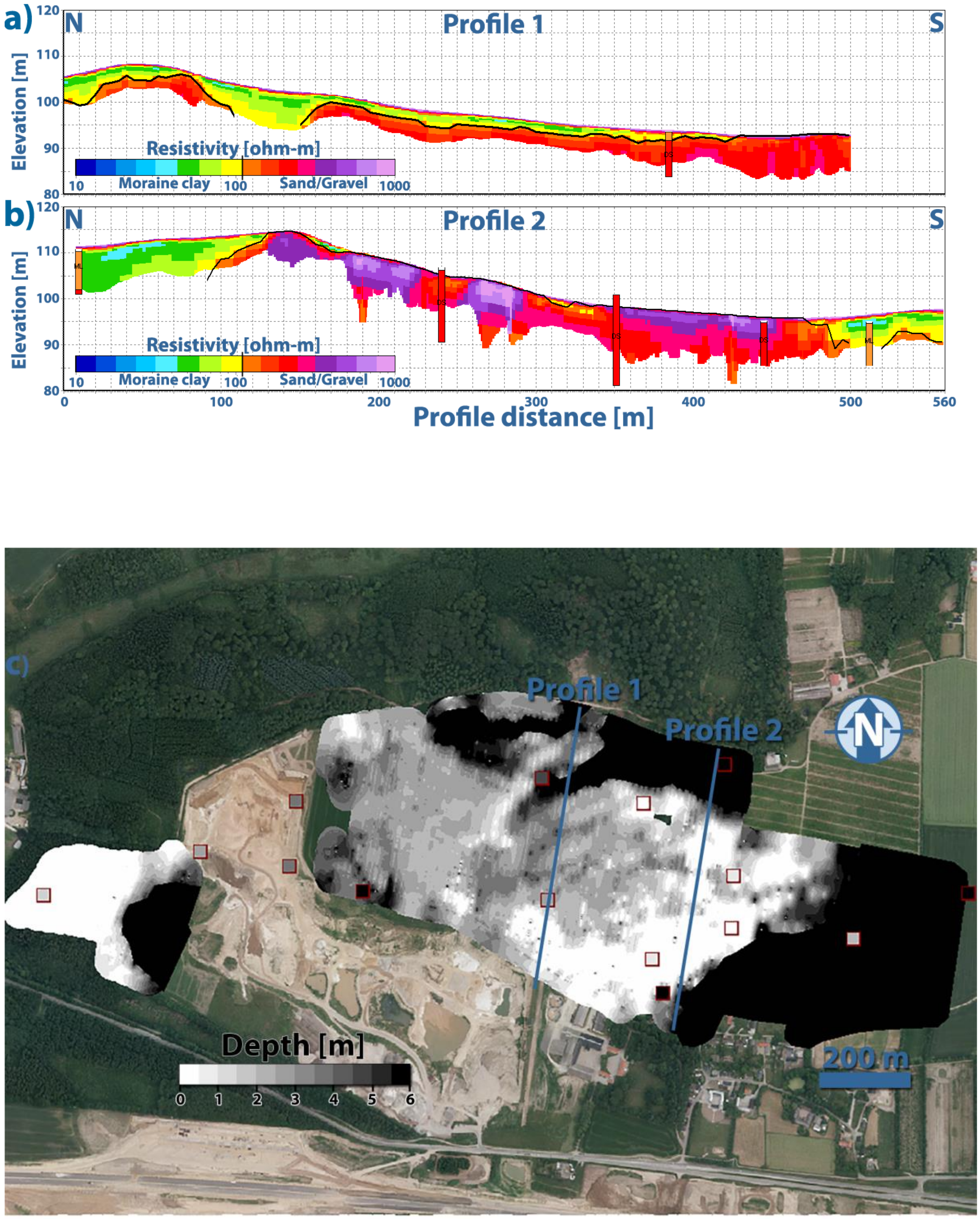

Figure 4. a) Profile 1 with boreholes. b) Profile 2 with boreholes. The black line shows the boundary between the moraine clay and sand/gravel. c) Map with thickness of the moraine clay and location of profile 1 and 2. Squares are borehole locations.

CONCLUSION

Using geophysical data to map raw materials is efficient, covers a big area in few hours and results in maps and profiles with high detailed information. Combining these results with borehole information to describe the geology, the thickness of the overburden can easily be determined. This information can be used to locate new areas that is profitable to use as gravel pits.
By using the geophysical data in the beginning of a new excavation also gives a cost-effective mapping by pinpointing where to put the boreholes, reduce the number of boreholes and increase the detail level of the results.
Last, the area that can be covered with this geophysical method is much bigger than with boreholes alone. A total of 6 hours is used to do field work and processing and inversion of data, which makes this a quick method to screen the geology in the subsurface.

This article is focused on mapping of raw materials, but processing and inversion of ground conductivity meter data can be used for many other purposes like: vulnerability mapping, mapping of soils, archaeological structures, human installations and geotechnical engineering projects.

Thanks to

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