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B029

## 2D and 3D Resistivity Imaging in an Investigation of Boulder Occurrence and Soil Depth in Glacial Till

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### SUMMARY

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The uncertainty regarding depths to bedrock and occurrence of boulders in glacial till can make the planning of a major road construction more difficult. Despite the fact that geophysics is frequently used in many applications and also occurs as a natural method to solve problems in geotechnical engineering, it has often a subordinate role as a site investigation method prior to road construction in Sweden. This project aims at evaluating 2D and 3D resistivity imaging to determine soil depths and track boulders in glacial till. Hopefully, the extent of the excavations preceding a road construction will thus be better estimated in the future, as the geotechnical investigations are suitably complemented. When compared with existing geotechnical data and brought together, both the 2D and 3D resistivity methods are regarded as good producers of reliable soil depth models. However reference data from alternative methods must always be used for validation and calibration of results. It is shown that a 3D resistivity dataset, consisting of a number of parallel CVES profiles, in some cases can give significantly improved resistivity models.

## Introduction

The uncertainty regarding depths to bedrock and occurrence of boulders in glacial till can make the planning of a major road construction more difficult. Despite the fact that geophysics is frequently used in many applications and also occurs as a natural method to solve problems in geotechnical engineering, it has often a subordinate role as a site investigation method prior to road construction in Sweden. The Swedish Road Administration is currently in search of alternative methods to clarify the structures of the subsurface and to act as a complement to geotechnical investigations. Cost estimation of such works depends highly on the correct estimation of bedrock depth and boulder occurrence. A strongly undulating bedrock surface under varying soil cover or blocky tills require extensive drilling for a clear image of the investigated volumes and there is no guarantee that the traditional drilling methods are successful. The possibilities of applying geophysical methods for planning of levelling and trenching in blocky tills are of special interest. Hopefully, the extent of the excavations preceding a road construction will thus be better estimated in the future, as the geotechnical investigations are suitably complemented.

This project aims at evaluating 2D and 3D resistivity imaging to determine soil depths and track boulders in glacial till.

## Methodology

Investigations have been carried out in the vicinities of two future roads, in Svärtinge, northeast of Norrköping and in Brämhult, in the outskirts of Borås.

Before the investigations a geological expectation model has been established for each site. The model for Svärtinge shows the existence of gneiss bedrock under a sandy till of minor depths with normal occurrence of boulders, bordering on clay soils in the east part of the field area. A number of thin diorite dikes with orientation West-Northwest and fracture zones with orientation North-Northwest are found in the area. The Brämhult site seems to similarly consist of a gneiss bedrock topped by a sandy till, but the soil depths appears to be a bit more varied and the frequency of boulders considerably higher (Figure 1).



Figure 1 Blocky till surface close to the Brämhult field area. The market area is 10x10 meters and more than 70 % of the surface is covered with boulders (Hilldén, 1984).

The geophysical data gathering has been carried through using refraction and surface wave seismic methods, ground penetrating radar and resistivity surveys in the form of Continuous Vertical Electrical Sounding (CVES). However, this paper includes results only from the resistivity investigations. The 3D resistivity surveying presented here is performed as a set of parallel 2D surveys, i.e. measurements are only made in one direction over the target area. The inline minimum electrode distance is 2 m in both cases. Compared with 3D surveys where measurements are made in more than one direction this approach is fast and logistically simple and has at least in some cases similar resolution capability (Papadopoulos et al., 2005). While it is necessary to plan a 2D survey with respect to the strike of the

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geological structures, a 3D survey and inversion will be much less sensitive to the angle at which the measurement profiles cross structures. An example of this can be seen in Figure 2.

The resistivity data was processed chiefly with the 2D-inversion software RES2DINV, but also with the equivalent 3D-program of RES3DINV. For 3D smooth inversion the same approach is used as for 2D smooth inversion, with the difference that the model in this case consists of a 3D grid. 3D inversion is considerably more time-consuming than 2D inversion, even though the development of faster computers have made it feasible, and an important aspect of 3D inversion is that it requires a dense data coverage in order to be meaningful, which again falls back on the data collection with increased investigation time and cost as an effect. Where a 3D environment is prominent, the 3D resistivity survey with subsequent 3D inversion can give increased detail and accuracy of the resulting resistivity model compared to that given by 2D inversion.

### Case Study

The Svärtinge investigations presented here consist of eleven lines measured with gradient array configuration in the X direction (West to East), covering an area of 40\*80 metres and with 4 m distance between lines. Figure 2 presents the inverted models. The results from this area show an underlying base of high-resistivity material cut by a somewhat northerly orientated zone of lower resistivities at all levels. Further up the lower resistivities are spread over the western parts whereas the uppermost layers again show higher resistivities.

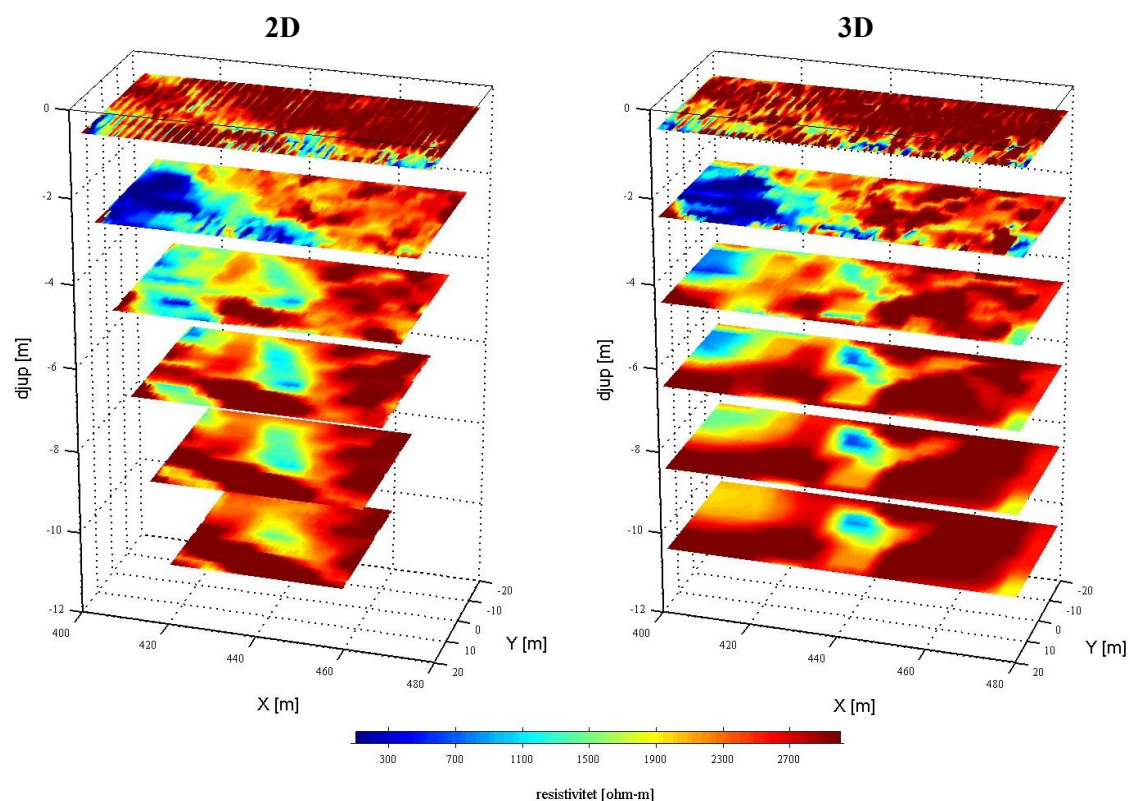


Figure 2 Inverted resistivity model section from the Svärtinge area. (left) 2D inversion and (right) 3D inversion.

In an interpretation of the results the base is built up from bedrock partly weathered in the orientation of the mentioned fracture zones. Upon the bedrock lies presumably a sandy till with a ground water level at about 2 metres depth, above which the soil is very dry and therefore creates high resistivity values. The soil depth seems to vary from 0 up to 7 metres and nothing in the results points at high boulder occurrences. In the 3D inversion result two low resistive zones, almost perpendicular to each other, can be seen in the central part of the

investigated area. The result from 2D inversion does not resolve these features, especially there are problems for the two southernmost profiles (at Y=15 and 20 m).

The resistivities of the Brämhult area were investigated along nine parallel lines, each 120 metres long and with 2 m distance between lines. The results from two of the profiles are shown in Figure 3 and in Figure 4 the 3D-inverted layer sections of the area are displayed. The profiles have a generally resembling appearance, with high resistivity in the lower levels topped by a thin low-resistive layer, with local anomalies of higher resistivities.

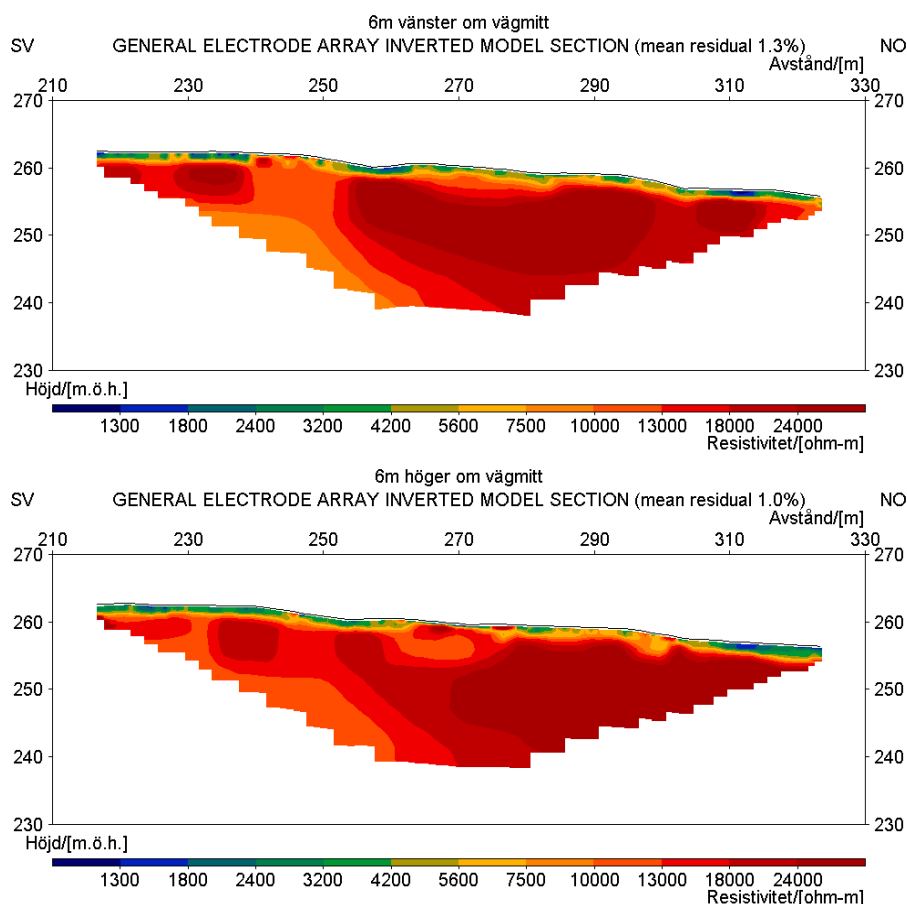
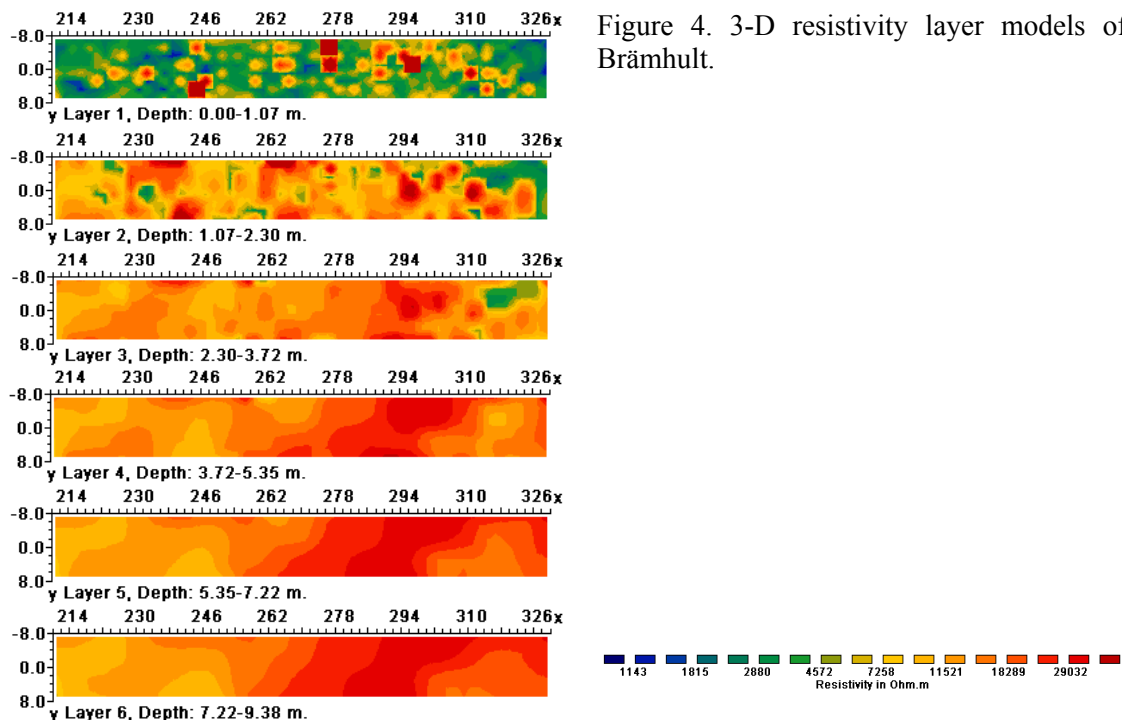


Figure 3. Two of the Brämhult resistivity profiles, located 6 metres on each side of the centre line.

Although it might be tempting in an initial interpretation to assume bedrock covered with a thin layer of soil, this does not at all agree with the results from the seismic investigations which signalled greater soil depths. After interpreting the two methods together it was presumed that some of the high-resistive areas actually are built up by large boulders, fragments of rock and very dry material. Upon that and partly weathered bedrock lies a sandy till in which boulders are probably embedded, thus the high-resistivity anomalies in the upper layers, best seen in Figure 4 below. The soil depths seem to vary between about 3 and 7 metres.



## Conclusions

When compared with existing geotechnical data and brought together, both the 2D and 3D resistivity methods are regarded as good producers of reliable soil depth models. However reference data from alternative methods must always be used for validation and calibration of results. It is shown that a 3D resistivity dataset, consisting of a number of parallel CVES profiles, in some cases can give significantly improved resistivity models. Even though the 3D calculations are more time-consuming it can be justified for environments with prominent 3D structures that prevent good results with 2D techniques. It should, however, also be noted that in many geological environments the 2D inversion is sufficient.

## References

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