Investigating remains of an early modern manor in Noer (Schleswig-Holstein) using 3D ERT and GPR – first results

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Abstract
Buried remains of an early modern manor are investigated using ERT and GPR. For this purpose, 3D approaches are applied for high-resolution imaging. The results of both methods are interpreted in combination with archaeological findings.

Keywords
archaeological prospection; early modern manor; Electrical Resistivity Tomography (ERT); ground penetrating radar (GPR); 3D inversion

Introduction

Manors are a cultural-historically important part of the landscape in Schleswig-Holstein (Germany) giving insights into land tenure of wealthy families, life and agriculture in the early modern age (i.e., Rasmussen 2010). There are two manors known to be present near Noer, 20 km northwest of Kiel (Fig. 1). One of them, being subject of this study, is suspected to have been a brick building with glass windows from the 16th to 17th century (Grüneberg-Wehner et al. 2016). Nowadays, there are no remains left above ground. Only a small hill reminds of the former manor.

The site and its direct surroundings were already investigated by Costard et al. (2022). They could show that geophysical methods are generally suitable to resolve remains of the former manor, such as wall structures or parts of the floor. Costard et al. (2022) conclude that the magnetic prospection could provide a fast overview of the manor's structure. However, the result was disturbed by many short-wavelength magnetic anomalies caused by surficial brick debris. Their Electrical Resistivity Tomography (ERT) results delivered a floorplan of remaining walls, while ground penetrating radar (GPR) could resolve some floor structures.

Methods

In this study, 3D ERT and GPR measurements were conducted to get a higher resolution image of the remaining buried manor structures. The GPR data were collected on 4th March 2022 while the ERT data were measured on 26th and 27th March 2022.

3D ERT

The 3D ERT measurements took place on a quadratic area of 31m x 31m, located above the known manor remains. The electrodes were arranged along a grid with 1m in- and crossline spacing. A RESECS multi-channel system (GeoServe 2017), developed by GeoServe, was used to conduct the measurements. As it is possible to measure up to eight parallel channels with the RESECS system, there were

Fig. 1: Site plan of the investigation area in Noer (Schleswig-Holstein). Source: Google Earth.

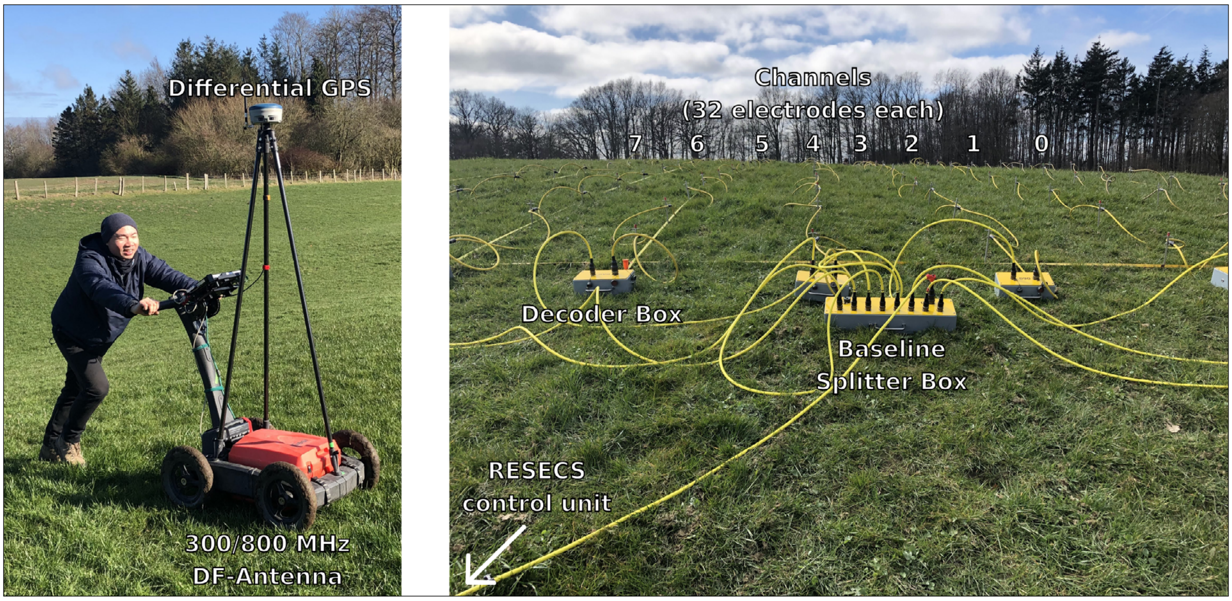

Fig. 2: Setup of GPR (left) and ERT measurements (right).

always eight lines (with 32 electrodes each) built up simultaneously. Each line was connected to two decoder units making it possible to address each electrode for current injection or potential measurements. The decoder units were in turn attached to a baseline splitter box, addressing the different channels (Fig. 2, left).

For this study, the dipole-dipole configuration was chosen because of its high lateral resolution (Okpoli 2013) and the shallow target depth. The 3D configurations were implemented by using one Master line, where the electrical current was injected, and 7 Slave lines with additional potential measurements. After finishing all measurements on one Master line, the whole setup was shifted in positive crossline direction. This process was repeated until the Master line reached the final crossline position. All in all, 93024 data points were collected, which took two people two days of work.

As a first step of data processing, measurements with bad data quality were excluded. That includes data points with current strengths below 0.5 mA, potential differences lower than 0.1 mV, geometric factors higher than 7000 m and/or standard deviations exceeding 10%. Following, an

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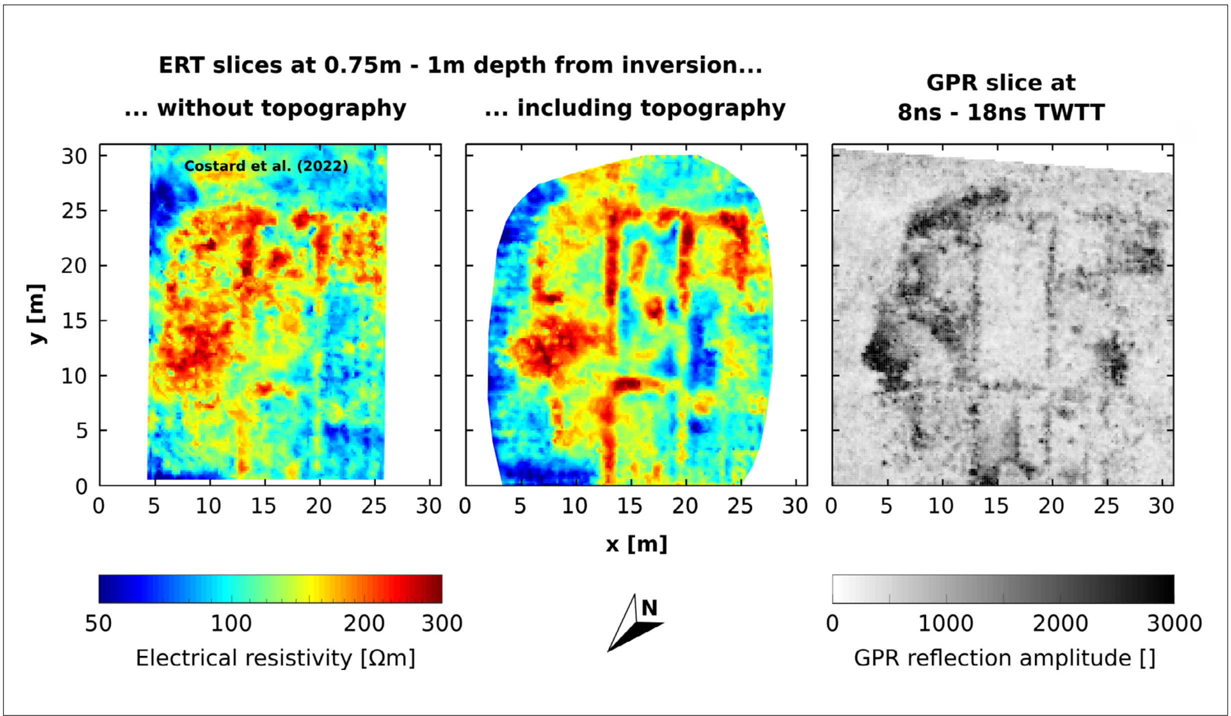

Fig. 3: Results of geoelectric 3Dinversion without (left) and with inclusion of topography (center), both shown as depth slices 0.75-1 m below the surface. Results of GPR measurements, shown as time slice from 8 ns to 18 ns (right).

underground model was created and discretized with the three-dimensional finite element mesh generator GMSH (Geuzaine and Remacle 2022). In doing so, the topography was included which is a difference to the approach by Costard et al. (2022). The underground model was then used for a 3D inversion by means of the open-source Python software package PyGimli (Rücker et al. 2017). Finally, the results were illustrated using MATLAB.

GPR

GPR measurements were done using a survey system designed by *GSSI*. It consists of a Dual-Frequency Antenna (300/800 MHz) mounted on a frame with four wheels (Fig. 2, right). A Differential GPS by *STONEX* was used for positioning of the system.

The profiles were orientated in northeast-southwest direction, which is perpendicular and parallel to the known manor remains. The crossline spacing between two profiles was 30cm. The GPR measurements covered the entire ERT area and some parts beyond.

The time range of each scan was set to ca. 100 ns (300 MHz) and 50 ns (800 MHz) respectively, while each scan consisted of 512 samples. Scans were triggered every 1 cm by a survey wheel, which is installed on the cart.

Processing of the GPR data was conducted with an In-house software named *DTplot,* and included the following steps:

1. Excluding GPS outlier
2. Setting spacing of traces to 2cm
3. Correcting for time-zero offset
4. Subtracting in- and crossline offsets
5. Applying gain
6. Calculating and plotting time slices

Results

3D ERT

An exemplary depth slice through the inversion result shows linear structures with higher resistivity values of ca. 200-300 Ohmm in an otherwise less resistive background model (Fig. 3, center). The high resistive patterns are mainly orientated parallel to the in- and crossline direction. There are four southeast-northwest aligned structures at local coordinates x = {7 m; 13 m; 20 m; 25 m} and two southwest-northeast lineaments at y = {9 m; 25 m}. The linear structures are perpendicular to each other and thus form rectangular shapes. Another high resistive and elliptical anomaly is present in the northeastern part of the investigation area. Apart from that, the inversion result shows relatively low and homogeneous resistivity values of ca. 50-100 Ohmm.

Compared to the inversion result by Costard et al. (2022), the high-resistive structures are more defined and higher in contrast.

GPR

The results of the GPR measurements are shown in shape of a time slice at 8-18 ns (Fig. 3, right). All absolute reflection amplitudes in this time window are stacked for each pixel. The resulting figure shows linear structures with high amplitudes which are very similar to the high resistive anomalies in the geoelectric inversion. However, the lineaments are much sharper and well-defined than in the ERT result. This leads to the visibility of more substructures like the feature at x = 17 m and y = 2-7 m. The reflection pattern gets more diffuse in the northeastern part of the investigation area. Nevertheless, higher amplitudes are visible at the point where the elliptical anomaly is in the ERT depth slice. In between the lineaments and especially in the outer parts of the survey area, the GPR reflections are rather weak.

Discussion

By including the topography in the 3D geoelectrical inversion and using a Dual-Frequency GPR antenna, it was possible to get more detailed images of the electrical resistivity distribution and the GPR reflectivity.

The presented anomalies with high electrical resistivity, high GPR reflection amplitudes and linear character are a strong indication for man-made structures. Putting these findings into the cultural-historical context of the site, it is quite sure that these are the remains of an early modern manor. While the linear structures are probably wall remains, the other extensive anomalies could be remains of floors or something similar as discussed by Costard et al. (2022).

The varying electrical resistivity values along a common lineament could be due to different conservation states. Assuming the moisture content to be constant in the surrounding soil, high resistivity values are an indicator for well-preserved wall parts, while lower resistivity is a sign of advanced weathering.

Other archaeological findings such as fragments of glazed tiles and pottery suggest that the manor was inhabited by wealthy residents (Grüneberg-Wehner et al. 2016). As mentioned by Costard et al. (2022), the floor plan, which could be reconstructed by the geophysical measurements, is very similar to another mansion in Nuetschau close to Lübeck, Germany. Another similarity is a surrounding moat (Lafrenz 2015). Taking all these findings into account, the manor in Noer could be dated from the middle of the 16th century to the end of the 17th century AD (Grüneberg-Wehner et al. 2016).

Conclusion

Three-dimensional Electrical Resistivity Tomography and ground penetrating radar surveys were conducted on an early modern manor site near Noer in Schleswig-Holstein. It could be shown that it is possible to map remains of former walls and floors with both methods. While the GPR is capable of imaging the structures more precisely and well-defined, the ERT seems to help interpreting the conservation state of different parts of the building.

Inclusion of topography in the 3D geoelectrical inversion and the usage of a Dual-Frequency 300/800 MHz GPR antenna led to significant improvements in the ERT and GPR results and thus in mapping the manor remains.

In combination with the archaeological interpretation, it can be stated that the manor was used from the 16th to the 17th century by wealthy residents.

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