Archaeologia Polona, vol. 53: 2015, pp. 536-539

Mapping medieval turf buildings with geophysical methods

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KEY-WORDS: magnetics, GPR, ERT, EMI, seismics, turf building

INTRODUCTION

The successful application of geophysical methods in archaeological prospection is conditioned by a contrast in the physical parameters between the object of interest and the surrounding material, mostly soil. Geophysical methods commonly applied in archaeological prospection include magnetics, ground penetrating radar (GPR), electromagnetic induction (EMI) and electrical resistivity romography (ERT). These techniques are based on contrasts in magnetic susceptibility, dielectric permittivity and electrical resistivity, respectively. The application of seismic surface waves is less common, but a small number of studies exists (e.g., Castellaro *et al.* 2008; Woelz and Rabbel 2005; Grandjean and Leparoux 2004; Nasseri-Moghaddam *et al.* 2007). Seismic measurements depend on contrast in elastic constants.

The objective of the present article is to test which geophysical prospection method or combination of methods is most suitable for investigating the remains of ancient turf buildings. The challenge lies in the fact that turf buildings can be expected to show only slight physical contrast with the surrounding soil, because both consist of basically the same material.

METHODS

Five methods were tested on the ruins of a known turf building that was part of the Viking-age farm at Skeggjastaðir in Western Iceland. Remains of the turf walls are visible as elevations barely a few centimeters high, contrasted with the surrounding soil.

Magnetic, GPR and EMI (both electrical conductivity and in-phase component) measurements were carried out in an area covering the whole ruin. Two ERT profiles with electrode spacing of 0.25 m were measured across the turf building. Seismic data were acquired with a

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source-geophone pair moved over the whole area with 0.5 m grid point spacing. The data were analyzed for changes in surface wave resonance frequency resulting from anthropogenic changes in the subsoil. More details of all the methods can be found in Wunderlich *et al.* (2015).

RESULTS

The magnetic, seismic, EMI and GPR measurement results of the investigated area show the location of the turf building (Fig. 1; indicated by the dashed line). The magnetic map shows some strong and intermediate anomalies in the area of the building, mainly on the north and south walls, and the southeastern corner (Fig. 1a). The EMI IP signals (Fig. 1c) integrate over an effective depth of 1 m and correlate well with the magnetic anomalies as expected, because the IP component is proportional to the magnetic susceptibility.

The line of anomalies in the southern part of the ruin is also found in the GPR timeslice between 8 ns and 14 ns (Fig. 1e), corresponding to an approximate depth of 20 cm to 35 cm (calculated with a velocity of 5 cm/ns). This high reflection energy corresponds to stones and tumbled turf blocks that are visible as diffraction hyperbolae in the radargrams.

The seismic Rayleigh wave frequency slice between 30 Hz and 40 Hz (Fig. 1b) shows a fall in the middle part of the amplitude. This corresponds to the ruin. An effect of the thinning of the top soil layer is also visible on the northeastern side of the area.

The electrical conductivity measured by EMI shows a rectangular anomaly of lower values (<1 mS/m) compared to the surroundings (Fig. 1d). This corresponds to the turf walls. The existence of a conductivity contrast between the turf walls and the surrounding turf is also visible in the inverted ERT profiles crossing the building (Fig. 1f). They show the walls as high electrical-resistivity anomalies. At a depth below approximately 1 m, the resistivity increases sharply to values larger than 3000 Ωm, corresponding to bedrock.

CONCLUSION

Because the methods depend on different physical parameters, they map different parts of the turf building. Methods measuring electrical conductivity (or resistivity), such as EMI (conductivity component) and ERT, are sensitive to the turf in the walls. Stones lining the inside or outside of the turf walls as part of the foundation can be seen by methods sensitive to the magnetic susceptibility of volcanic stones, that is, magnetics and the EMI IP component. Sometimes bog iron incorporated in the turf walls can also be imaged by these methods. GPR maps the stones, but also the turf walls due to changes in dielectric permittivity. In the case of turf walls, permittivity is influenced mainly by differences in porosity and water content compared to the surrounding turf. The amplitude decrease of the seismic Rayleigh wave resonance peak is to be explained by an increase in seismic velocity in the building area (Wunderlich *et al.* 2015; Wilken *et al.* 2015).

ACKNOWLEDGMENTS

The authors received funding from the German Research Foundation (DFG) in a project (RA 496/26-1) within the frame of the Priority Program 1630 "Harbours from the Roman Period to the

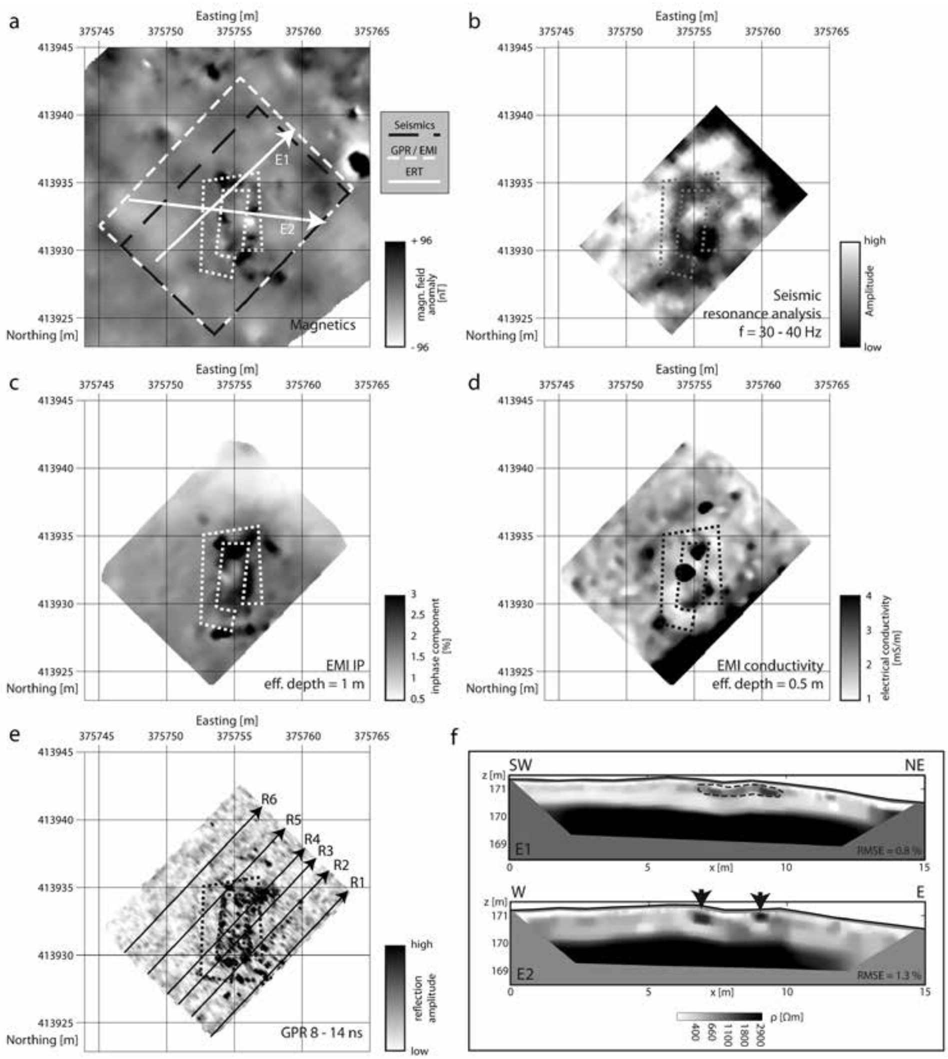

Fig. 1. Resulting maps of magnetic (a), seismic (b), EMI (c and d), GPR (e) and ERT (f) measurements of an area surrounding the turf building in Skeggjastaðir (ruin indicated by dotted lines) (modified from Wunderlich *et al.* 2015)

Middle Ages". We would also like to thank the town of Mosfellsbaer and the National Museum of Iceland, the Icelandic Ministry of Education, Science and Culture, The Arcadia Trust, Norvik, the Norwegian Kulturdepartment, the UCLA Center for Medieval and Renaissance Studies, the landowners of Skeggjastaðir Dísa Anderiman and Guðmundur Helgi Víglundsson, the association of friends and sponsors at Kiel University, L. Costard, S. J. Hansen, C. Mohr, S. Splettstoesser and all the students participating in the field course.

REFERENCES

Castellaro, S., Imposa, S., Barone, F., Chiavetta, F., Gresta, S. and Mulargia, F. 2008. Georadar and passive seismic survey in the Roman Amphitheatre of Catania (Sicily). *Journal of Cultural Heritage* 9: 357-366.

Grandjean, G. and Leparoux, D. 2004. The potential of seismic methods for detecting cavities and buried objects: experimentation at a test site. *Journal of Applied Geophysics* 56: 93-106.

Nasseri-Moghaddam, A., Cascante, G., Phillips, C. and Hutchinson, D.J. 2007. Effects of underground cavities on Rayleigh waves - Field and numerical experiments. *Soil Dynamics and Earthquake Engineering* 27: 300–313.

Wilken, D., Wunderlich, T., Majchczack, B., Andersen, J. and Rabbel, W. 2015. Rayleigh-wave Resonance Analysis: a Methodological Test on a Viking Age Pit House. *Archaeological Prospection,* DOI: 10.1002/arp.1508

Woelz, S. and Rabbel, W. 2005. Seismic prospecting in archaeology: a 3D shear-wave study of the ancient harbour of Miletus (Turkey). *Near Surface Geophysics* 3: 245-257.

Wunderlich, T., Wilken, D., Andersen, J., Rabbel, W., Zori, D., Kalmring, S. and Byock, J. 2015. On the ability of geophysical methods to image medieval turf buildings in Iceland. *Archaeological Prospection*, DOI: 10.1002/arp.1506