Archaeologia Polona, vol. 53: 2015, pp. 531-536

Imaging the AD 1500 Katla tephra inside the Leiruvogur "Inner Skiphóll" harbour using GPR

Dennis Wilken[a], Tina Wunderlich[a], Wolfgang Rabbel[a], Davide Zori[b], Sven Kalmring[c] and Jesse Byock[d, e]

KEY-WORDS: GPR, Iceland, tephra, topographic migration

INTRODUCTION

After the discovery of Iceland in the 9th century, people from all over Scandinavia emigrated to the island. Mosfell Valley, which is found in the southwest of Iceland, was settled during

[a] Institute of Geosciences, Department of Geophysics, Christian-Albrechts-University, Kiel, Germany
[b] Baylor Interdisciplinary Core, Baylor University, Waco, USA
[c] Centre for Baltic and Scandinavian Archaeology, Schleswig, Germany
[d] Cotsen Institute of Archaeology and Scandinavian Section, University of California, Los Angeles, USA
[e] University of Iceland, Department of History and Viking Studies Program, Reykjavik, Iceland

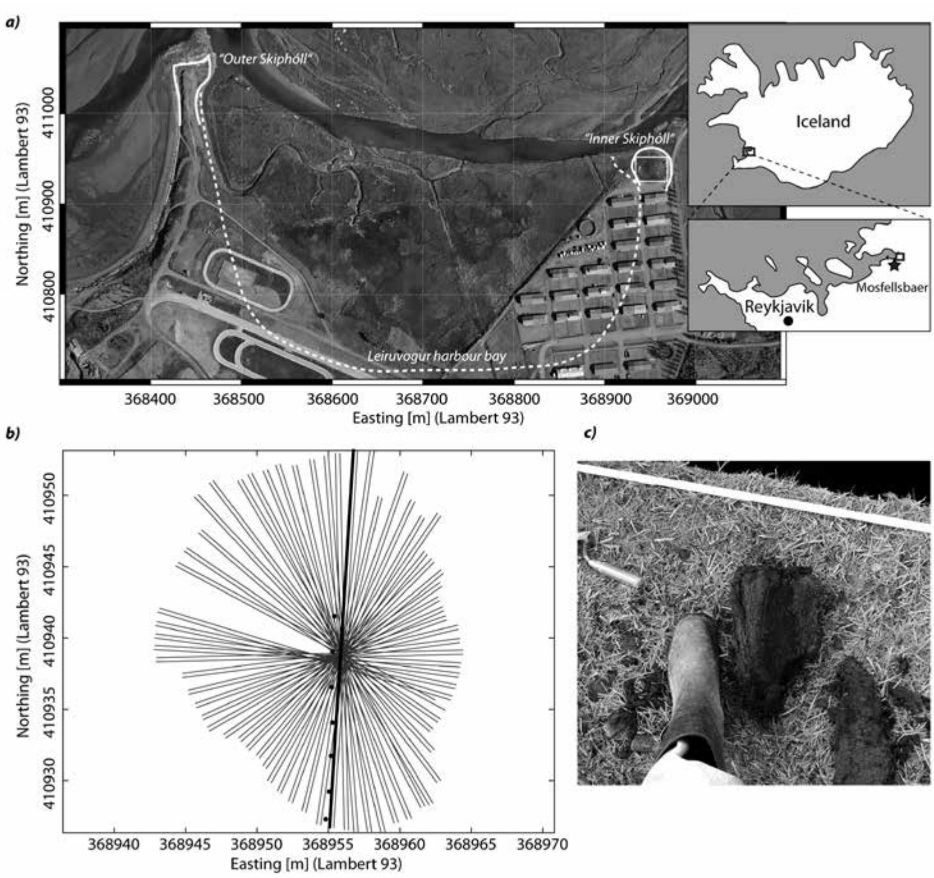


Fig. 1. Map showing the Leiruvogur site with its possible coastline (white dashed line) and the two Skiphóll landmarks, flanking the possible harbour bay (a) and map of the measured GPR profiles (grey lines) (b), position of the sample profile in Fig. 2 (line) and coring positions (dots); image of the AD 1500 Katla tephra layer (c)

the early days of the *landnám* (period of land-taking, AD 870–930). As "home to the Mosfell chieftains, a powerful Viking Age family of leaders, warriors, farmers and legal specialists" (Byock and Zori 2013), the region was one of the country's cultural centers. Leiruvogur Bay connects the valley to the sea (see map in Fig. 1). The coastal landscape of Leiruvogur itself has all the makings of a natural harbour, where ships could anchor to "wait out winter storms and load cargo and passengers" (Byock and Zori 2013). Modern structures in the area make the exploration difficult; one of the few places that seem to be left untouched is the so-called "Inner Skiphóll", a hill that could have once been used as a landmark for incoming ships.

A GPR survey was conducted on the Inner Skiphóll. The first aim of that study was to image the volcanic ash (tephra) layer of the AD 1500 Katla eruption. Every subsurface structure beneath this layer must be older and could already have existed during the Viking Age. Furthermore, if it were possible to determine the depth of the tephra throughout the mount, then the topography of the AD 1500 Inner Skiphóll could be reconstructed in more or less general terms.

METHODOLOGY

A GSSI SIR 3000 with a 400MHz antenna was used. 69 profiles were performed, crossing the top of the hill (Fig. 1 b). Topography measurement and positioning was done with a RTK-DGPS system. The profiles show one gap to the east, which was an area that was not accessible during the time of measurement. Standard processing steps included averaging of traces, resulting in a 2 cm trace distance and adjusting of time zero.

Problems for GPR on structures with strong topographic changes have been well documented in, e.g., Goodman *et al.* (2006) and Leckebusch and Rychener (2007). The main issue is that profiles have to be corrected for pitch and roll when pulled over a variable surface. Collecting data on profiles crossing the center/crown of a mount minimizes the roll variation of the antenna (Baldwin 2013). Nevertheless, the tilt movement along the profile has still to be considered. Common topographic correction approaches are geometric corrections and cannot lead to better images of the subsurface reflectivity without proper migration of the data, because the wave energy is not confined to a ray perpendicular to the surface. Goodman *et al.* (2006) and Leckebusch and Rychener (2007), for example, proposed to perform migration prior to topographic correction. The migration would focus the energy distributed over to the radiation pattern of the GPR antenna. This is not feasible because diffractions appear deformed due to topographic changes in the time sections, which leads to migration errors. Lehmann and Green (2000) proposed a topographic Kirchhoff migration and showed that topographic migration should be applied when the topographic change is of the same order as the investigation depth and when the surface gradient exceeds 10%. Both arguments apply in the presented case.

In this presentation, we used a simple migration approach based on semicircle superposition (Schneider 1978). The basic idea of semicircle superposition is that the energy recorded at traveltime t may be reflected from all scattering subsurface points on a half-circle with the radius $(t/2)v$ (v is the wave velocity). The recorded energy is thus smeared along this circle in the x–z (depth) domain. Based on Huygen's principle, reflecting events and diffractions are superposed. In our migration algorithm, this circle smearing is done only along a circle section defined by an assumed aperture of the antenna (which was determined to be 30°) and oriented regarding the topographic slope. The velocity used for the migration was estimated to 6 cm/ns by diffraction curve fitting.

In addition to GPR, seven shallow coring samples were taken, wherein the Katla tephra was identified as a black ash layer with a thickness of a few centimeters (see sample in Fig. 1c). The depth of the tephra in the corings enabled identification of the corresponding GPR reflector, which was then picked where possible.

RESULTS

An example GPR section appears in Fig. 2a, whereas Fig. 2b shows the same section but with topography migrated. The image also comprises the depths of the tephra layers in the cores (white rectangles). A clear tephra reflector can be assigned (dashed line). This reflector was picked up where

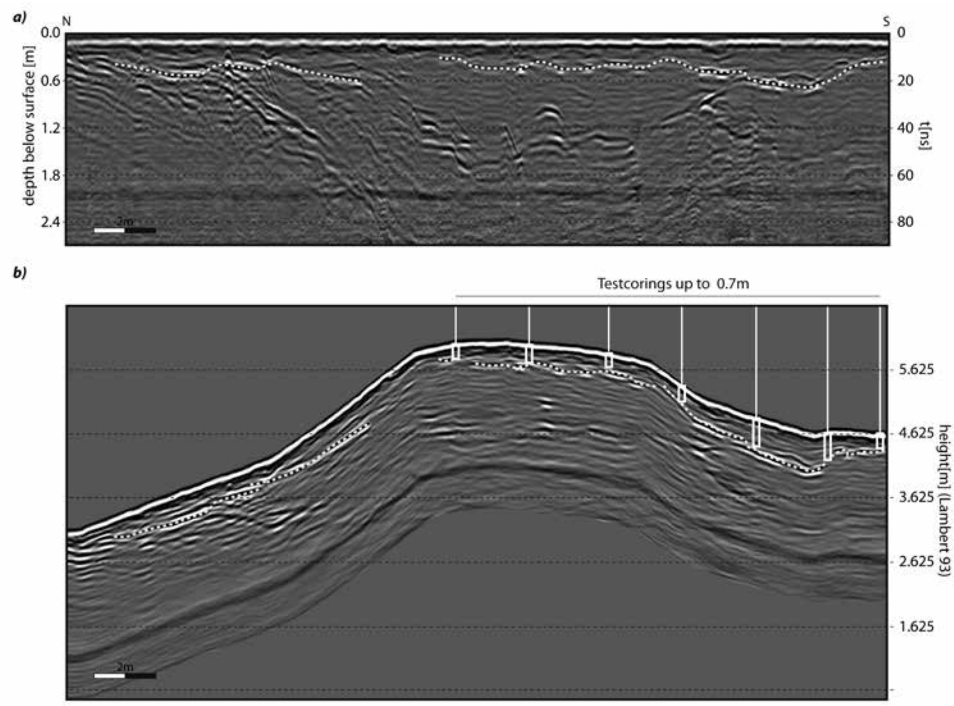
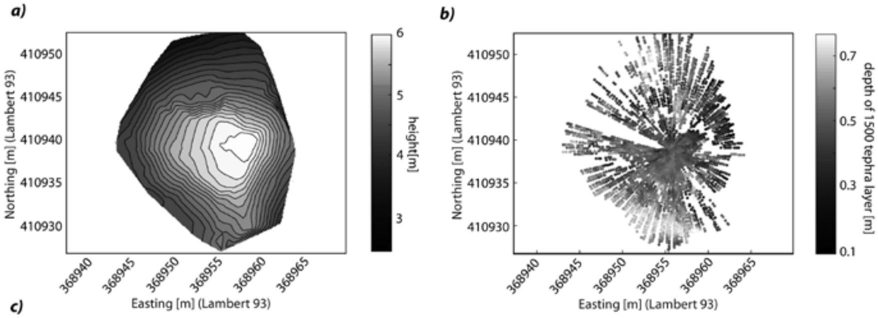


Fig. 2:. Sample GPR time section (a) and migrated GPR depth section (b); white rectangles indicate the depth of the AD 1500 tephra layer in the core samples. The dashed line shows the interpreted tephra reflection event

possible in all the profiles, resulting in a map of tephra depths. The topography of the mount is shown in Fig. 3a and the tephra depths below that topography in Fig. 3b. The depths of the Katla tephra could be identified in most of the area and changes by up to 0.5 m throughout the mount. From that depth an approximate topography of the AD 1500 Skiphóll was reconstructed (Fig. 3c). The mount has basically kept its shape in time, while showing more soil accumulation in the western part.

CONCLUSION

The project showed the potential of using GPR to image a distinct volcanic ash layer inside a mount structure at the Viking Age harbour site of Leiruvogur. Accurate topographic migration led to an almost complete image of the depth of that ash layer, which coring identified as the AD 1500 Katla tephra. The GPR results enabled the part of the mount that is below that layer and thus younger than AD 1500 to be reconstructed. By showing the potential of GPR to image such layers, dating of anomalies in GPR measurements becomes possible in Iceland whenever tephra layers can be attached to reflections with the help of coring.



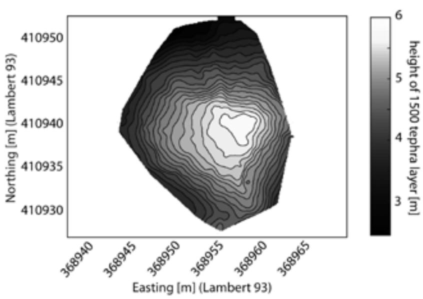


Fig. 3. Topography of the Inner Skiphóll as a height in the Lambert 93 coordinate system (a) and the picked depth of the AD 1500 Katla tephra below the surface (b); reconstructed approximate surface of the AD 1500 Inner Skiphóll (c)

ACKNOWLEDGMENTS

The authors received funding from the German Research Foundation (DFG) in project RA 496/26-1 within the frame of Priority Program 1630 "Harbours from the Roman Period to the Middle Ages" (von Carnap-Bornheim and Kalmring 2011). 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, and the UCLA Center for Medieval and Renaissance Studies.

REFERENCES

Baldwin, E. 2013. Within the round barrows of Stonehenge landscape: Surveying topographically complex monuments with GPR. In W. Neubauer, I. Trinks, R.B. Salisbury and C. Einwögerer (eds), *Proceedings of the 10th International Conference for Archaeological Prospection,* 230-232. Vienna.

Byock, J. and Zori, D. 2013. *Viking Archaeology, Sagas and Interdisciplinary Research in Iceland's Mosfell Valley*, 197-218. Backdirt.

Von Carnap-Bornheim, C. and Kalmring, S. 2011. DFG-Schwerpunktprogramm 1630, Häfen von der Römischen Kaiserzeit bis zum Mittelalter. Zur Archäologie und Geschichte regionaler und überregionaler Verkehrssysteme. *Jahresbericht Zentrum für Baltische und Skandinavische Archäologie,* 28-31, Schleswig.

Goodman, D., Nishimura, Y., Hongo, H. and Higashi, N. 2006. Correction for Topography and the tilt of Ground-penetrating Radar Antennae. *Archaeological Prospection* 13 (2): 159-163.

Leckebusch, J. and Rychener, J. 2007. Verification and topographic correction of GPR data in three dimensions. *Near Surface Geophysics* 5 (6): 395-403.

Lehmann, F. and Green, A.G. 2000. Topographic migration of georadar data: Implications for acquisition and processing. *Geophysics* 65 (3): 836–848.

Schneider, W.A. 1978. Integral formulation for migration in two-dimensions and three-dimensions. *Geophysics* 43 (1): 49-76.