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Marine magnetic and seismic measurements to find the harbour of the early medieval Slavic emporium Groß Strömkendorf/Reric, Germany

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INTRODUCTION

Groß Strömkendorf, situated north of Wismar on the coastline of the Baltic Sea, was an emporium in early Slavic times. Large parts of the emporium and the adjoining burial ground have been excavated (Schmölcke 2004; Pöche 2005; Tummuscheit 2011; Jöns 1998), but no evidence for a harbour place has been found. This might be due to erosion of the coastline and a rising sea level, which is 0.5–1 m higher compared to early medieval times (Klug 1980). This leads to the conclusion that large parts of the former mainland are today underwater or have been destroyed by erosion. In the shallow water in front of the emporium, a linear structure that may be associated with a channel is visible in aerial images; in combination with an inlet to the open waters further to the south, it suggests the position of a perfect natural harbour place.

Geophysical surveys in the shallow water in front of the emporium were aimed at investigating the structure and the inlet, as well as its surroundings to find evidence of probable harbour structures of wood and indications of further settlement activity on the former mainland.

METHODS

To map the relatively large area underwater a small boat was used with four Fluxgate magnetometers mounted in front of it. The sensors can be lowered 0.5 m into the water to bring the sensors closer to the ground (Fig. 1a). Positioning was made with a RTK-DGPS with 1–2 cm accuracy. To delete the influence of metal on the boat, a mean value was calculated for every profile and subtracted from the measurements. Although the height of the sensors can be varied, it is not possible to measure with a constant height above the ground. Therefore, a downward field continuation was applied to transform the magnetic measurements to a constant level above ground during processing.

In addition to the magnetic measurements, high-resolution marine reflection seismic measurements were carried out to gain also depth information for the structures. These measurements were done by pulling a seismic pinger source and two hydrophones on small floating

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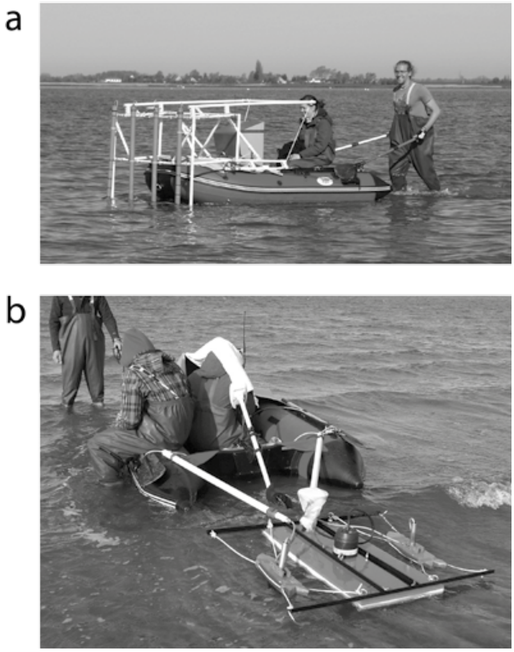

Fig. 1. Measurement setups for magnetics (a) and seismics (b)

bodies behind the boat (Fig. 1b). The pinger emits an acoustic pulse (4kHz Fuchs-Müller wavelet) into the water, which is reflected from the sea bottom, but also transmits into the ground and is reflected at geological interfaces. The reflected energy is recorded by the hydrophones. The processing consists of bandpass filtering, deconvolution to sharpen the signal, trace normalization and smoothing of the sea bottom, which is necessary to eliminate the effect of small waves moving the boat up and down. The recorded traveltime of the seismic waves can be transformed into depth by assuming a full water saturation of the marine sediments that allows using a constant propagation velocity of approximately 1500 m/s.

RESULTS AND CONCLUSION

The magnetic map shows strong linear anomalies around 80 m in front of today's coastline, coinciding very well with the landward border of the channel feature seen in aerial images, and is thus interpreted as the former coastline. Seismic profiles running from the coast seawards show slightly dipping reflectors beneath the aerial photo anomaly; these die out at the points where the linear magnetic signals were observed. A channel-like structure is visible below the aerial-image anomaly, but westward of it.

The magnetic map shows also some areas with accumulation of round anomalies. Their interpretation is at this moment unclear. One of these areas was used as a test for downward field continuation (Fig. 2). The water depth in this area ranges from about 0.5 m close to the shore in the east to about 1 m seawards. Magnetic measurements were made with sensors 10 cm below the water surface.

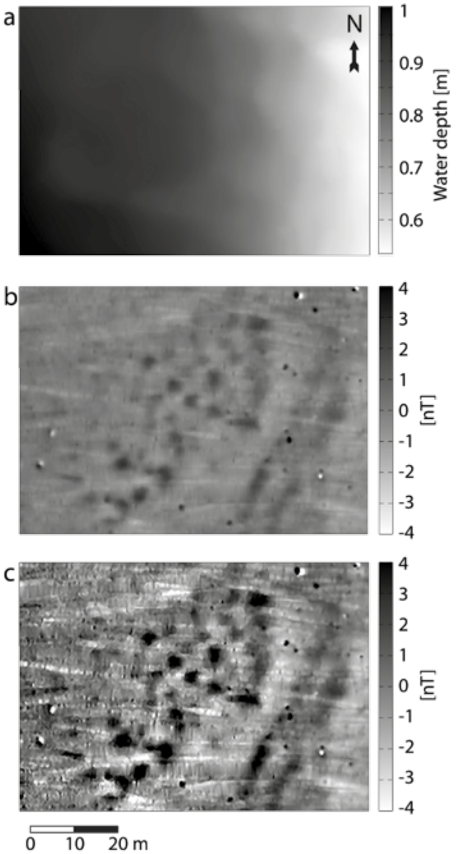

Fig. 2. Example of downward field continuation of the magnetic data: (a) water depth derived from seismic measurements, (b) originally measured magnetic map with sensors 10 cm under the water surface, and (c) downward continuation of the magnetic data to a constant level 20 cm above the ground

This distance from sensors to the ground, growing to the west, weakens and widens the anomalies. Compensating for this effect was a downward field continuation, using an approximation given by Fedi and Florio (2002). The procedure of analytical continuation can be performed in source-free space for any harmonic function (e.g., Kellog 1929: 384), also for the magnetic vertical component difference, as the output of processed fluxgate data. This was tested by us for complex magnetic models (not shown in this abstract, using REGCONT software, Pasteka *et al.* 2012). This produced a magnetic map, as if it was measured 20 cm above the seafloor. The procedure of downward field continuation increases the amplitudes and sharpens the anomalies. Unfortunately, also the noise is strongly increased. To minimize this effect, the magnetic maps were 2D-median-filtered median filtered before and after the downward continuation over three samples.

The combination of marine magnetic and seismic measurements has great potential in finding and investigating former coastlines, and narrowing down the position of the possible harbour site. Reflection seismic measurements can be used to provide depth information for anomalies found on the magnetic map, which is easier to measure over larger areas.

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