

# Barge or tjalk? A wreck investigation in the tidal flats of North Frisia

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## Abstract

We present a case study on the applicability of geophysical methods to map shipwrecks in the coastal zone. We present results of magnetic gradiometry, electromagnetic induction, and photogrammetry.

## Keywords

archaeological prospection; EMI; magnetic gradiometry; shipwreck; tidal flats

## Introduction

East of the island of Südfall in the German tidal flats, a shipwreck was observed by wanderers and first investigated by archaeologists in 1998 (Archaeological survey of Schleswig-Holstein 2009) (Fig. 1a). Local oral tradition speaks of a cargo sailing vessel that capsized during a storm around 1900. The ship was loaded with tidal gates and was on its way from Husum to the Halligen (tidal islands).

### 1998 find description

The 1998 archaeological investigation reports frame heads and planks of a ship's side over a length of 11 m (Fig. 1b). They describe the remains of a flat-bottomed vehicle, probably the remains of a barge or lighter. The original length could not be determined. The width of the preserved wreckage is about 5.2 m. The very wide keelson plank (0.65 m) was striking. The flat bottom is 0.55 m below the surface of the tideland. Typical iron fittings of one or more tidal gates on the ship's floor as well as several iron fragments in the wreck and its surroundings were reported. Due to the general conditions, the wreck was not uncovered, so that observations are limited to exposed components.

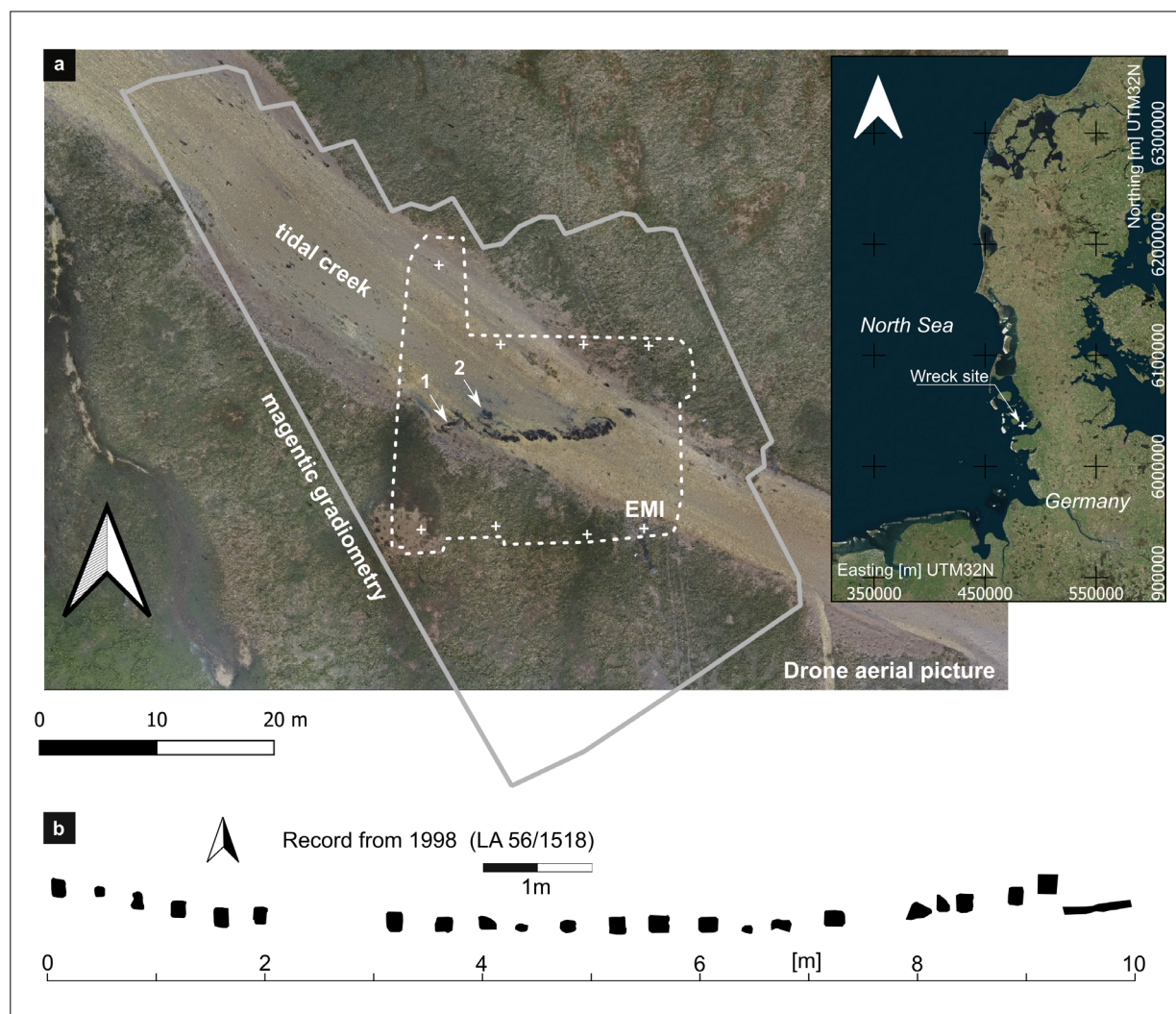
The shipwreck was re-investigated during a campaign in September 2022 and prospected geophysically (magnetic

gradiometry and electromagnetic induction) and archaeologically (in situ inspection and drone photography). The investigation and upcoming analysis tried to answer the following questions:

1. How does the wreck appear in gradiometry and frequency domain electromagnetic induction (FDEMI)?
2. Is there more wood remaining than the visible frame heads and planks?
3. How does the observed metal influence the data?
4. What is the size of the wreck?
5. And in conclusion, what type of ship might it be?

## Materials and methods

A magnetic gradiometer survey was performed using an array of six fluxgate gradiometers (Foerster fluxgate differential vertical component magnetometers) with an internal vertical sensor distance of 0.65 m, a horizontal sensor spacing of 0.5 m and a sampling frequency of 20 Hz. Accurate positioning was achieved by RTK (Real Time Kinematic) DGNSS (Stonex S9i). The arithmetic mean was subtracted from the data of each profile. The resulting values were



**Fig. 1:** a) Right : map with the position of the wreck site. Left: drone aerial picture of the site together with magnetic gradiometry and EMI investigation areas (solid grey, dashed white outline). b) Re-drawing of the finds from 1998 after Archaeological survey of Schleswig-Holstein (2009).

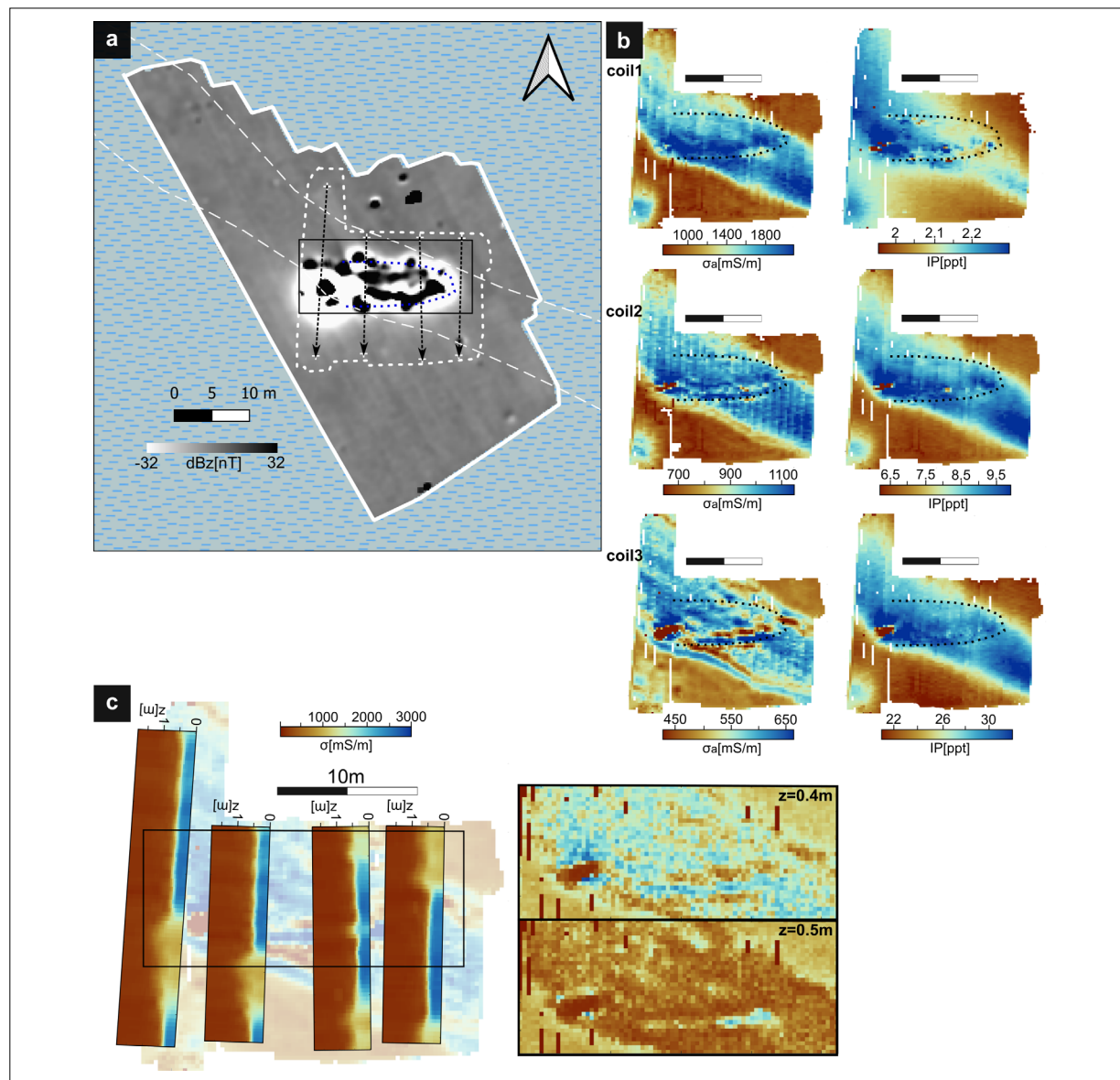
binned inline and interpolated cross-line (using linear interpolation) in order to form a data grid of 0.2 m bin size.

In a second attempt, we used the FDEMI (frequency domain electromagnetic induction) CMD Mini-Explorer by GF Instruments. The device consists of one transmitter and three receiver coils. The planes of the coils were oriented horizontally (horizontal coplanar, HCP). The distance between the transmitter and receivers were 0.32, 0.71, and 1.18 m. Further details on the method and its usage in tidal flats can be found in Wilken et al. (2022a). Beyond EMI mapping, we performed 1D conductivity inversions on profiles and on a small area to investigate the sensitivity to the wreck remains.

Furthermore, a high resolution aerial image of the area was performed by drone photography using a DJI Mavic 2 pro with additional RTK GPS module (Fig. 1a).

## Results

The wreck can still be traced over a length of about 11 m, aligned east-west and lying on an even keel. Currently, only bulkheads on the southern long side are visible of the ship's construction, which correlates with the observations of the survey in 1998. While at that time the dimensions of the frames were measured 10 x 15 cm, this



**Fig. 2:** a) Magnetic gradiometry map. Dashed white lines indicate the EMI area and the tidal creek. Black solid line and dashed lines indicate the area and profiles of 1D EMI conductivity inversions. b) Apparent conductivity and In-Phase (IP) maps of the three different coil separations. c) Inverted conductivity profiles (left) and depth slices through pseudo 3D conductivity cube (right).

could not be confirmed in the recent survey due to poor preservation and heavy growth of seaweed. The frames point relatively vertically upwards in the midship area, but make a bend in the bottom, the so-called Kimmung. This shows that it was a flat-bottomed vessel, which allowed a high cargo volume and safe dry-docking at low tide.

At the western end of the wreck lies a massive wooden structure (“1” in Fig. 1) that can be addressed as the stern knee. This is the connection between the keel and the stern, i.e. the bow and the stern of the ship respectively.

According to current information, it is not possible to say which of the two ends of the ship it is. However, due to the tilted position of the stern knee, it can be said that the bow or stern has snapped off due to their heavy weight.

Another massive component, which lies further in the center of the wreck (“2” in Fig. 1), is presumably the keel. In 1998, the width of this keelson plank was given as 65 cm.

Figure 2 shows the results of the geophysical measurements. In Figure 2a the magnetic gradiometry map is shown in the 32 nT range, showing the outline of the


wreck in terms of magnetic signal. Figure 2b shows the apparent conductivity and In-Phase (IP) maps of the three different EMI coil separations. The outline of the magnetic feature is shown as black dotted line, framing visible signals from the wreck. Figure 2c shows example profiles and depth slices of the conductivity. The most striking structure visible in the profiles is the waterbody of the tidal creek with typical conductivities of up to 3000 mS/m. Wreck features appear strongest, where surface finds are still present in the water column.

## Discussion

Regarding the observed keelson plank, unfortunately a mast shoe or other relics of a sailing vessel could not be documented, so that it cannot be said with certainty whether it was a lighter or a sailed vessel such as a tjalk. The dating of the ship is still fraught with questions. Due to the rather poor preservation of the wood, no wood sample has been taken for dendrochronological age determination. However, it is noticeable that the frames are at least partly made of iron or reinforced with it. This type of construction indicates that the ship was built at the end of the 19th/beginning of the 20th century (Menzel 1997).

The gradiometry furthermore allows a containment of the whole wreck even for its northern, submerged side. Though an estimation of the ship's total length and width is possible being about 20 m by 6 m. This length is in the typical range of a tjalk. On the western side of the wreck, a strong magnetic anomaly as well as an IP and conductivity anomaly is observed, highlighting the stern knee and its wooden and (submerged) metal components. If this is the stern of the ship, large metal components could indicate a rudder hinge.

Due to the strong influence of the tidal creek on the EMI data, it shows only few indications of wreck remains beyond the surface finds. Although IP data of e.g. medium coil separation show weak indication of the northern edge of the wreck. The construction wood itself, if remaining in the subsoil, is not observed as clear as for example in Wilken et al. (2022a), who showed a clear signal of wooden wreckage in a more sandy tidal flat area, that is dry during low tide. In the present case more silty subsoil and water running down the tidal creek recommends a combination of gradiometry and EMI. A geophysical prospection and a feasible recording methodology of such archaeological features are of high interest in tidal flat areas, as

erosion by tidal creeks and storm surges endangers the heritage of the area (Wilken et al. 2022b). 

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