Deal with steel: investigating the wreck of the heavy cruiser *Admiral Scheer*

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Abstract
In this paper, we present, for the first time, a World War II warship imaged underground, in a silted up harbor. Only reflection seismic measurements and electrical resistivity tomography allowed prospecting of the target at challenging depths from 4 m to 12 m below surface.

Keywords
archaeological prospection; battleship; ERT; seismics; World War II

Introduction

Individual, large (German) naval units, like battleships, such as the *Bismarck* or the *Graf Spee*, experience great public interest, while their sister ships are rather unknown. This also applies to the *Admiral Scheer*, the sister ship of the battleship *Graf Spee*, which, due to a long and intensive period of service (1934 to 1945), is one of, if not the most successful, ship in the German Navy history. One month before the end of the Second World War, it capsized after a bombing raid on the port of Kiel. The wreck of the ship was subsequently filled in with sediments and debris, sharing the fate of the entire naval harbor basin.

The *Admiral Scheer* was built as the second of three armored ships of the 'Germany' class at the Wilhelmshaven shipyard. The ship was commissioned on November 12th, 1934 and was named in honor of Admiral Reinhard Scheer. It is noteworthy that ships of this class were the first larger German naval units whose hulls were welded and not riveted and which were powered using diesel instead of traditional steam engines. Despite their small size (186 m in length), the ships were heavily armed with six 28 cm guns. Therefore, the three ships of this class were known as pocket battleships. After several missions between 1936 and 1945 the *Admiral Scheer* was called back to Kiel on March 18th 1945. On the evening of April 9th 1945, during a bombing raid, five 'tall boy' bombs were dropped on the ship. The hull on the starboard side was damaged and the ship capsized in the shallow harbor (Figure 1, top right). In July 1945, British forces began to dismantle those parts of the wreck that were still above water. Pictures published in the local newspaper *Kieler Nachrichten* show that the entire stern as well as the tank turret and parts of the machinery were recovered. The harbor basin was then filled in the early 1950s with sea sand and debris and a drainage channel was dug. This channel describes a slight curve, which is often associated with the outlines of the wreck.

Materials and methods

The *Admiral Scheer* represents an important piece of German naval and Kiel's regional history and is a unique investigation target due to its size and depth of burial on land within an urban environment.

The presented investigation began with the evaluation of the Allied aerial photographs, showing the ship overturned to starboard. Later photos show that the stern and front sections were removed. The preserved midship area was removed down to the water level. Based on buildings visible in the photos and still present

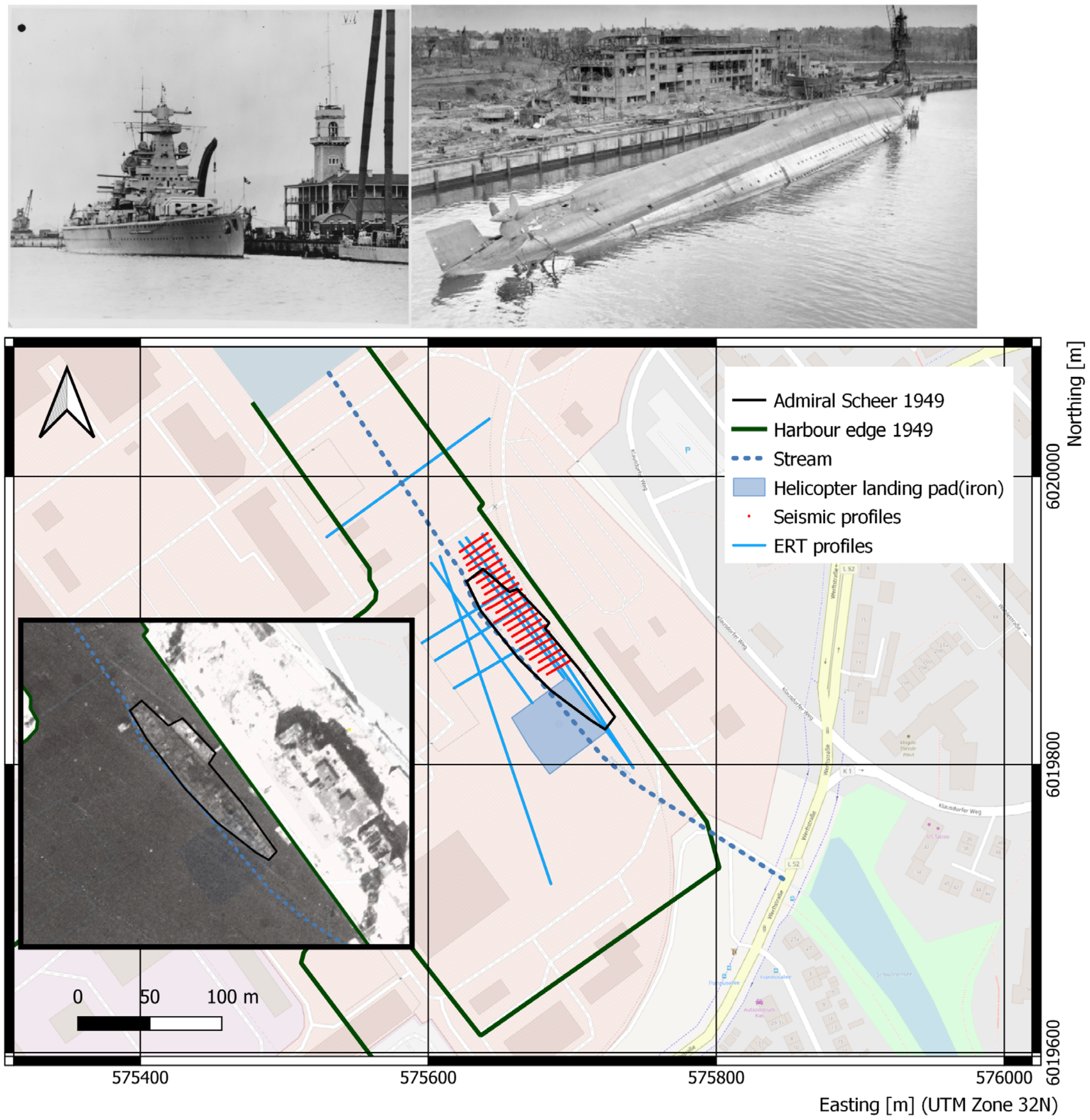

Fig. 1: Photographs of the ship and investigation area. Top left: the *Admiral Scheer* (NH 59664 Naval History & Heritage Command). Top right: the capsized *Admiral Scheer* (Imperial War Museum). Below: Map showing the locations of the measuring profiles in relation to the old harbor basin. The approximate location of the wreck based on an aerial picture from 1949 (inset of map) is outlined in black.

today, an approximate positioning was obtained for the remains of the wreck (Fig. 1). These remains are expected to be located at a depth of four to twelve meters. An object like the *Admiral Scheer* consisting of steel, with water filled cavities at such depths, poses a real challenge for geophysical prospection (e.g. Passaro 2010 & Passaro et al. 2009), especially on land. Above that, the accessible area is bounded to the east by a railway and to the west by the drainage channel. The range of feasible geophysical methods is thus greatly reduced. The classical methods of archaeological prospection, magnetic gradiometry, ground penetrating radar (GPR), and electromagnetic induction (EMI) were tested but could, if ever, only scratch at the surface of the wreck. Magnetic measurements only show a large dipole anomaly and are affected by the railway and urban power cables. Therefore, seismic reflection and electrical resistivity tomography (ERT) measurements were used, offering the greatest potential to reach most parts of the wreck. Shear-wave reflection seismics were conducted on 19

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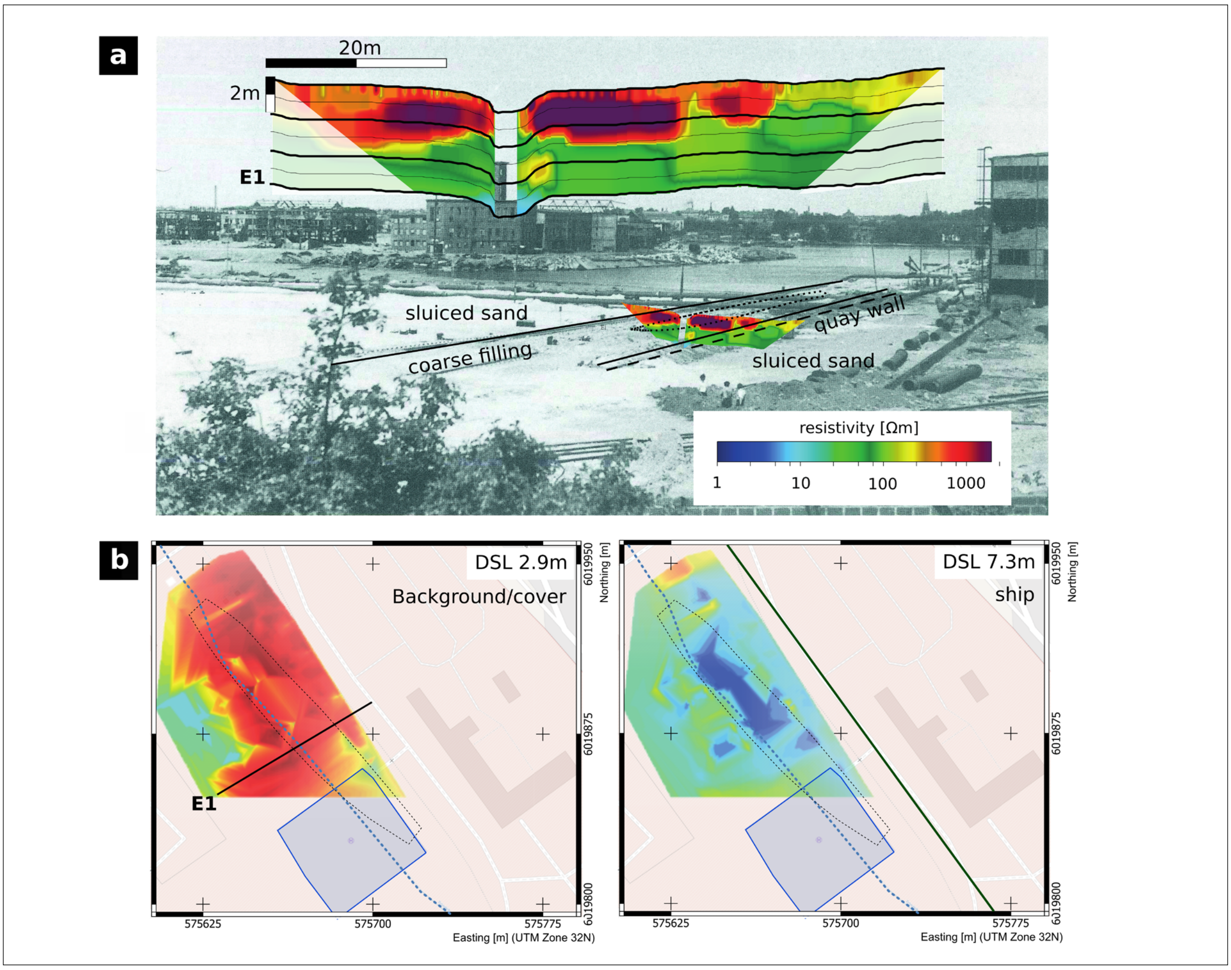

Fig. 2: a) Photograph of the Deutsche Werke Kiel (Koop/Schmolke 1993, 212) and ERT tomogram of profile E1. b) Two example ERT depth slices representing top material of harbor basin filling and wreck remains.

profiles with a crossline distance of 5 m (Fig. 1), each including 24 10 Hz S-wave geophones spaced at 1 m inline distance in SH orientation. Sledge hammer blows were placed between the geophones. Data processing included bandpass filtering, trace normalization and time gain, f-k filtering, and the creation of time slices. Time to depth conversion was implemented using an average shear wave velocity of 120 m/s.

Nine ERT profiles were measured with the RESECS2 (Geoserve) multi-electrode system, with 48 to 96 electrodes depending on the profile length. Electrode spacing was 1m and measurements were conducted in three configurations (dipole-dipole, Wenner-alpha and Schlumberger). All profiles were inverted with the same inversion parameters using Res2DInv.

Results

Figure 2a shows the old navy harbor basin after its refilling. The picture shows clear differences in the refill material. Above the wreck, the material appears coarser in the image, which is also reflected in the ERT data as high-resistivity area. Figure 2b shows electrical resistivity depth slices interpolated from profiles E1-E9. The example slices show the extent of the coarser filling material in the area of the wreck (down to more than 3m of depth) and at greater depths resistivities far below the resistivity encountered in the harbor entrance on E7 (representing soil saturated with groundwater), which we therefore address as an anomaly caused by the wreck.

Figure 3 top right shows an example seismic profile together with an outline of a cross-section of the tilted

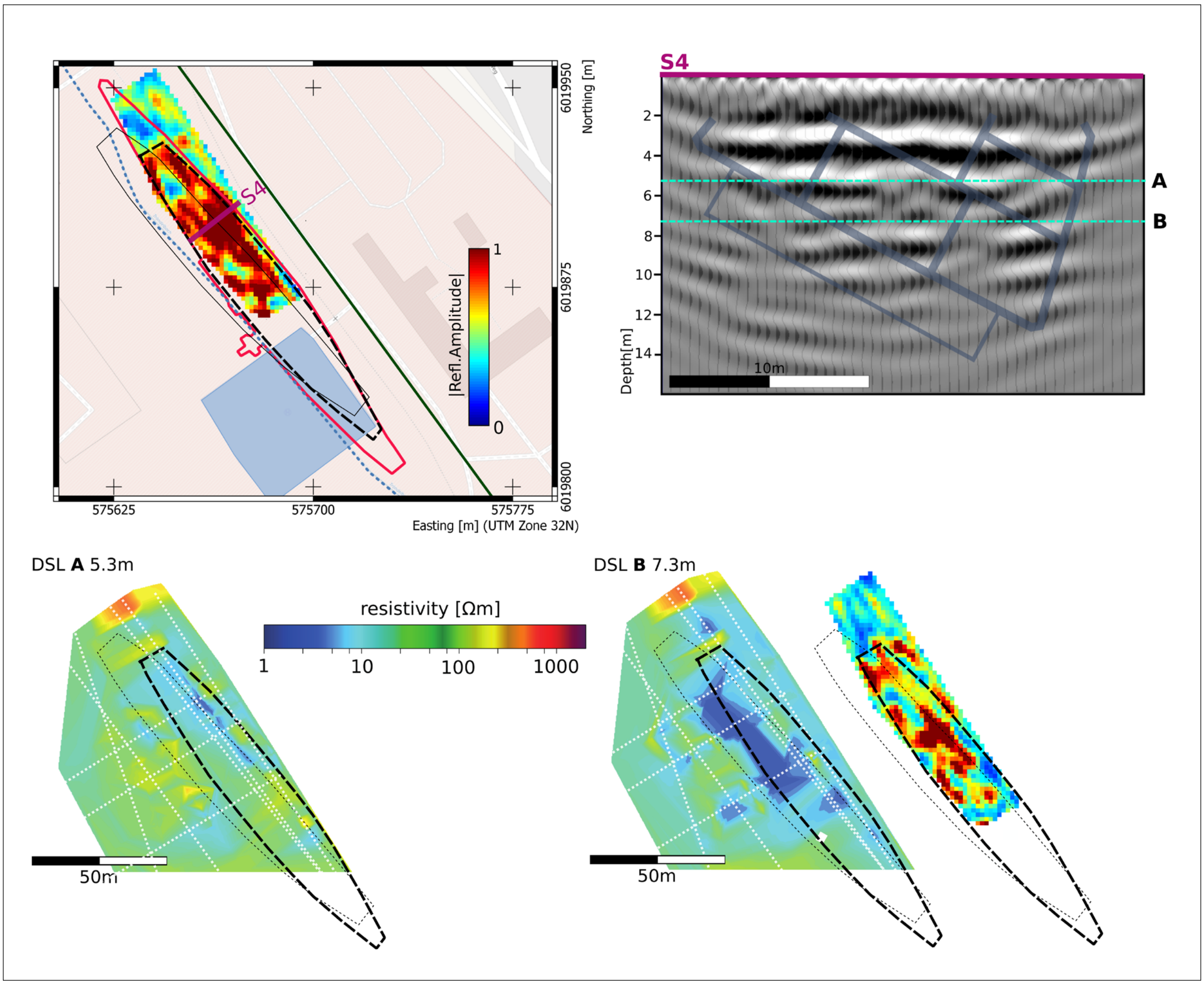

Fig. 3: Top left: Outline of the Admiral Scheer, based on aerial photographs (dotted line). The image also shows an exemplary seismic depth slice and the adjusted position of the wreck based thereon (dashed line). Top right: examplary profile S4 with the depths of the depth slices and an outline of the wrecks cross-section indicated. Below: two depth slices from ERT (DSL A) and ERT and seismics (DSL B).

ship based on original blueprints. The top left image shows an exemplary seismic depth slice calculated from all profiles at a depth of 5.3 m, with the position of the wreck based on an aerial photo superimposed (dotted line). The reflection amplitudes of the seismic profiles clearly reflect the shape of the wreck and therefore allow its position to be corrected (dashed line).

Discussion

The results show that ERT was able to distinguish the coarse harbor refill above the wreck from the sluiced sand around, providing its extent and thickness. In the deeper parts one low resistive area becomes visible, probably reflecting the wreck's mixture of steel, water-filled cavities and debris. This anomaly is slightly shifted westwards in comparison to the seismic results, probably due to side effects caused by the nearby drainage channel. In the seismic profiles, the reflections coming from the wreck are clearly visible, allowing the shape of the ship to be traced quite accurately (Fig. 3). Nevertheless, spatial resolution of both methods is not sufficiently high to distinguish individual parts of the ship; profile density would need to be increased towards 3D ERT (like in e.g. Rabbel et al. 2015, Günther et al. 2006). In terms of seismic prospection, Full Waveform Inversion (FWI) approaches could lead to an increased imaging resolution (e.g. Köhn et al. 2019), probably allowing for an interpretation of the wreck's substructure.

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In summary, the measurements prove that the aerial photo from March 29th 1949 represents the state in which the *Admiral Scheer* was buried. Large parts of the hull and superstructure have been preserved in the buried harbor basin until today, covered by more than three meters of sand and debris.

References

Rabbel W, Erkul E, Stümpel H, Wunderlich T, Pasteka R, Papco J, Niewöhner P, Baris S, Çakin O, PeksenE. Discovery of a Byzantine Church in Iznik/Nicaea, Turkey: an Educational Case History of Geophysical Prospecting with Combined Methods in Urban Areas. Archaeological Prospection 2014;22:1–20. doi: 10.1002/arp.1491

Günther T, Rücker C, Spitzer K. Three-dimensional modeling and inversion of DC resistivity data incorporating topography – II. Inversion. Geophysical Journal International 2006;166:506–517. doi: 10.1111/j.1365-246X.2006.03011.x

Koop G, Schmolke K-P. Die Panzerschiffe der Deutschland-Klasse. Schiffsklassen und Schiffstypen der deutschen Marine 4 (Bonn 1993).

Köhn D, Wilken D, De Nil D, Wunderlich T, Rabbel W, Werther L, Schmidt J, Zielhofer C, Linzen S. Comparison of time-domain SH waveform inversion strategies based on sequential low and bandpass filtered data for improved resolution in near-surface prospecting, Journal of Applied Geophysics 2019;160:69–83. doi: 10.1016/j.jappgeo.2018.11.001

Passaro S, Budillon F, Ruggieri S, Bilotti G, Cipriani M, Di Maio R, D'Isanto C, Giordano F, Leggieri C, Marsella E, Soldovieri MG. Integrated geophysical investigation applied to the defnition of buried and outcropping targets of archaeological relevance in very shallow water. Italian Journal of Quaternary Sciences 2009;22(1):33–38.

Passaro S. Marine electrical resistivity tomography for shipwreck detection in very shallow water: a case study from Agropoli (Salerno, southern Italy). Journal of Archaeological Science 2010;37:1989–1998. doi: 10.1016/j.jas.2010.03.004