APPLICATION OF MODERN MARINE GEOLOGICAL RESEARCH METHODS IN SEARCH AND INVESTIGATION OF WRECKS AND OTHER SUBMERGED OBJECTS

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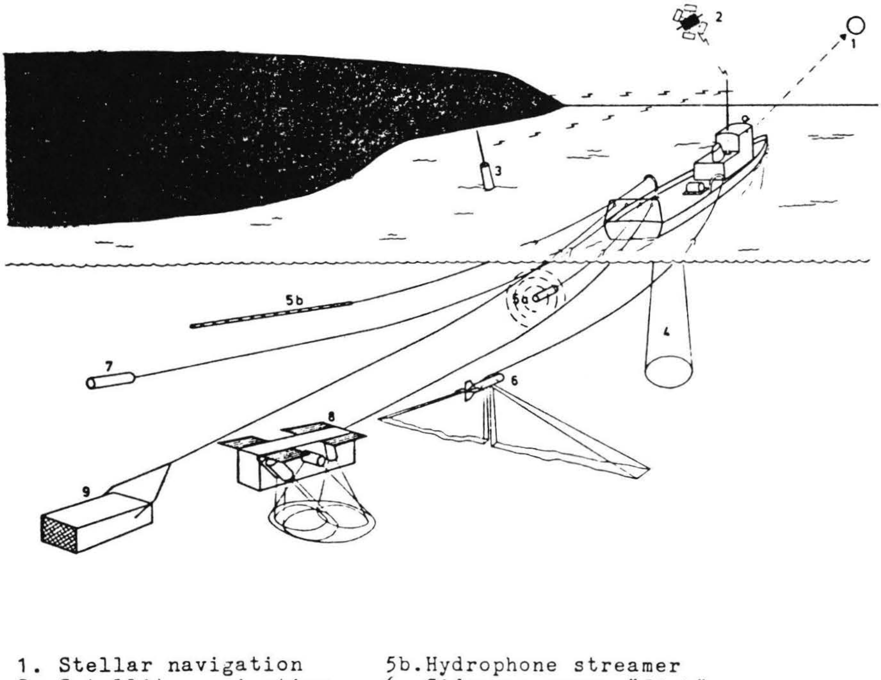
Precision echosounding, continuous seismic reflection profiling, side scan profiling, and magnetometer profiling from a research vessel traveling at uniform speed together with the development of accurate positioning at sea have made detailed geological seafloor mapping possible (Fig. 1). This means that simultaneous information concerning the depth of the sea, the structure and thickness of different sediment layers and the erosional or depositional conditions prevailing on the sea bottom can be acquired with great accuracy. All the methods mentioned are being presently used by the Geological Survey of Finland in geological seafloor mapping.



1. Stellar navigation
2. Satellite navigation
3. Radiobeacons
4. Echosounder
5a. Seismic soundsource
5b. Hydrophone streamer
6. Sidescan sonar "fish"
7. Magnetometer
8. Closed circuit TV
9. Dredge

Fig. 1. Research vessel doing marine geological seafloor mapping.

The survey echosounder of the research vessel uses two different frequencies (30 and 210 kHz) simultaneously. The high frequency gives accurate depth of the water, while the low frequency transducer gives information on the quality of the seafloor. The graphic recorder prints a continuous diagram of the results.

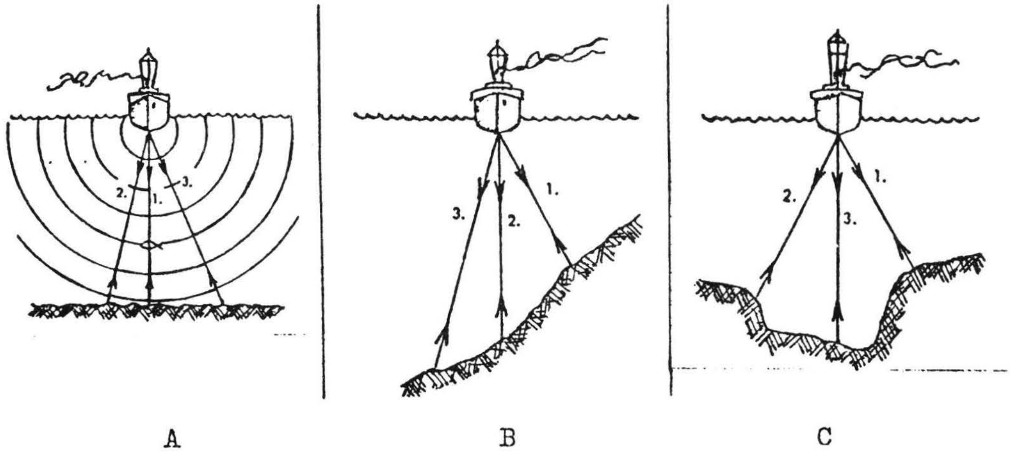


Fig. 2. The comparison between the actual depth and the sounded depth and its relation to the time of arrival of the echoes (Ryhänen & Ovaskainen, 1968).

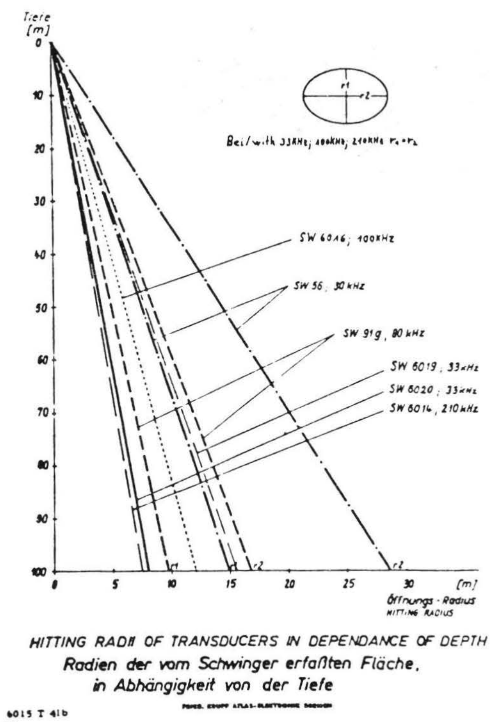


Fig. 3. The echosounder is able to see the seafloor at a specific angle depending on the frequency used (Service Manual, 1973).

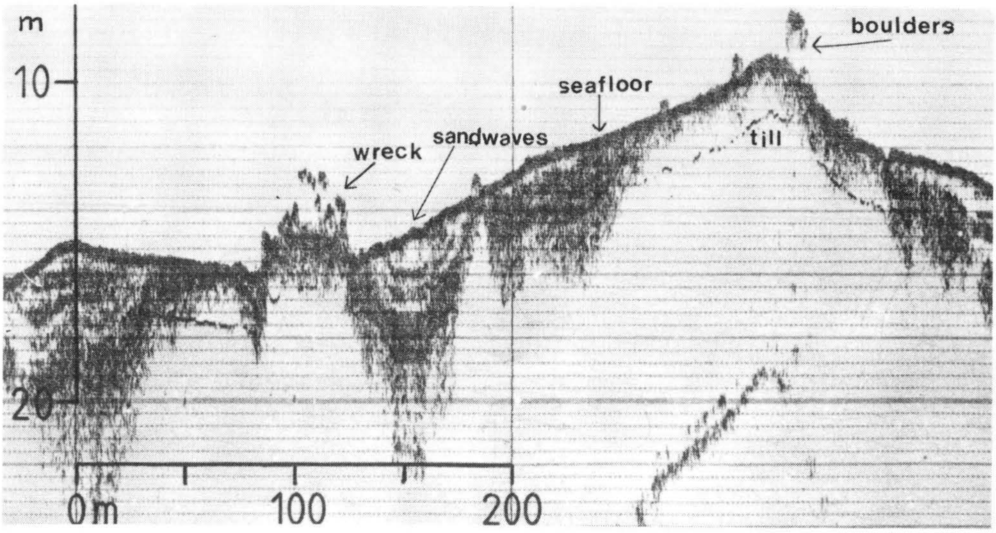


Fig. 4. Echosounding profile along the keel of frigate St.Nikolai.

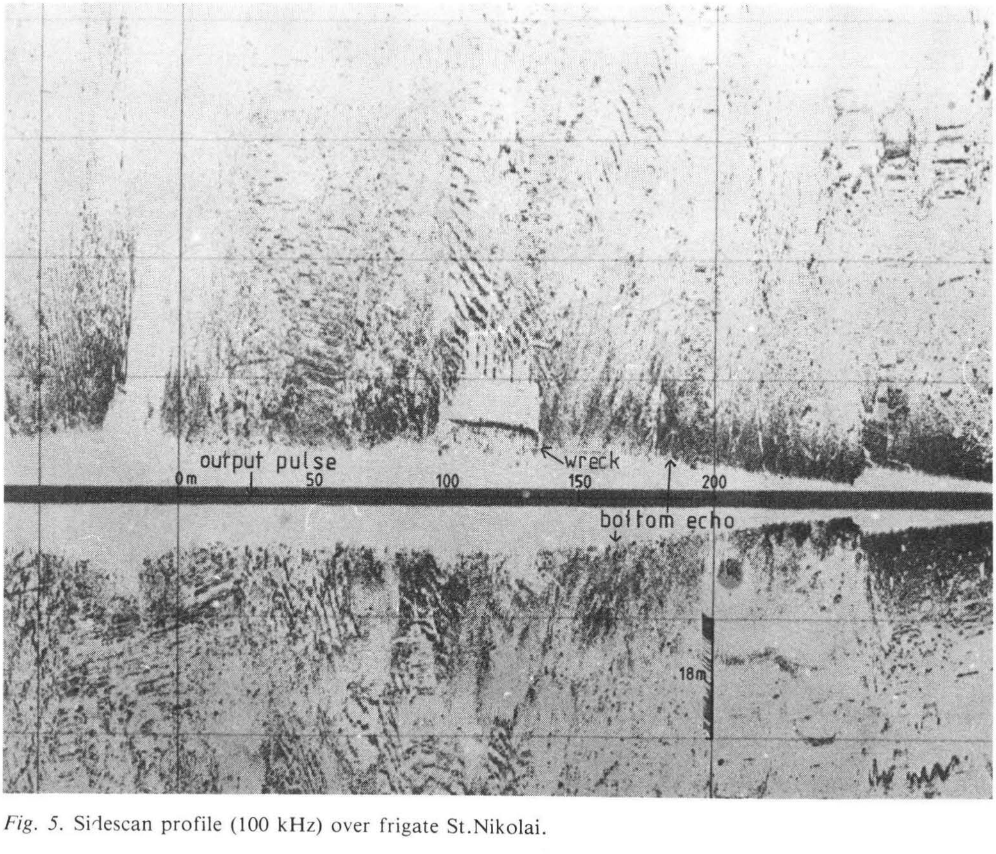


Fig. 5. Sidescan profile (100 kHz) over frigate St.Nikolai.

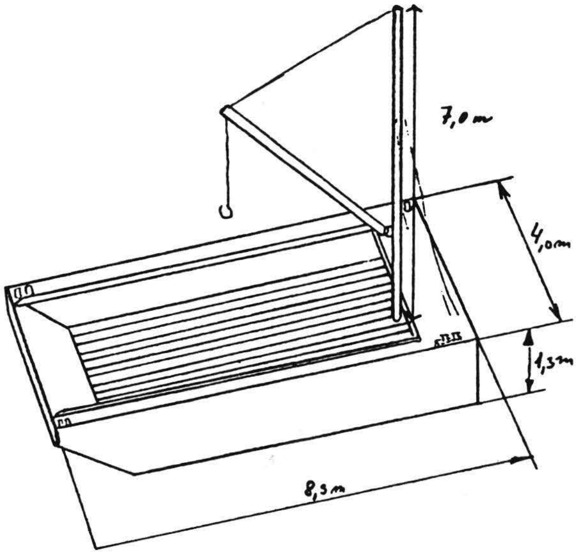


Fig. 6. The steelbarge.

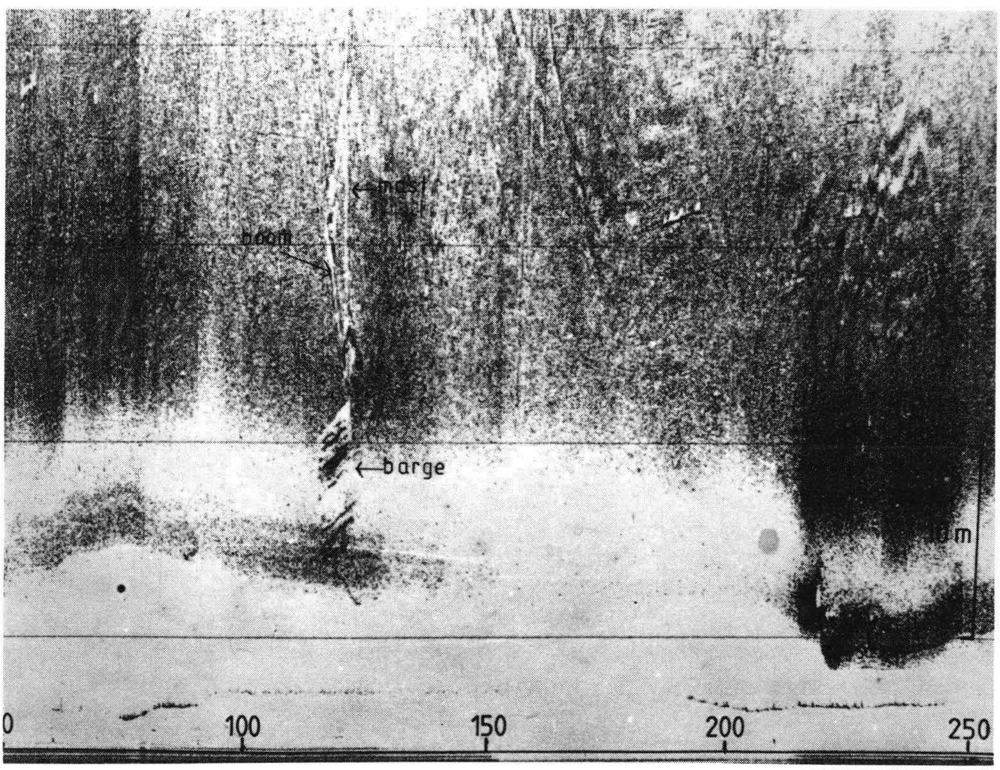


Fig. 7. Sidescan sonar (500 kHz) record of the barge.

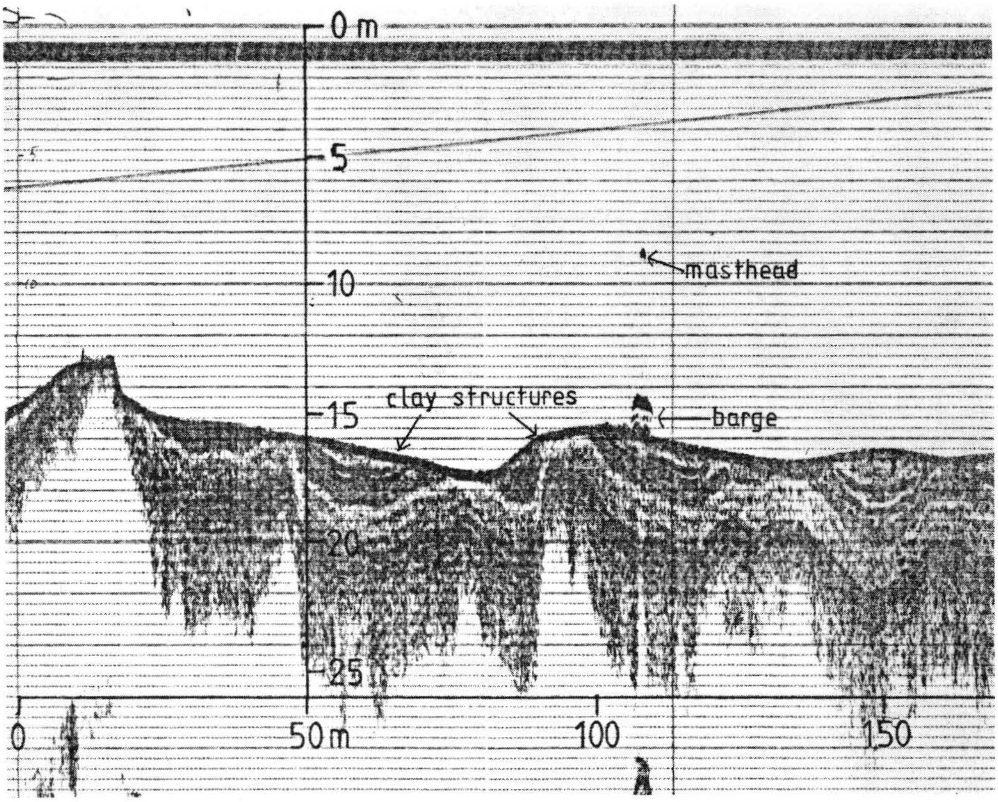


Fig. 8. Echosounding profile (30 and 210 kHz) of the barge.

The echosounder measures the time it takes a soundpulse to move from the vessel to the seafloor and back. The returned echo is transformed into an electric pulse which is registered as black spot on the paper of the recorder. The sounded depth is not always the same as the real depth (Fig. 2). The trace on the recorder indicating the seabottom, consists of several marks, recorded in the succession of their arrival. If the seafloor is flat (Fig. 2a) the sounded depth is equal to the actual depth. The case is different (Fig. 2b, 2c) if the seafloor is closer at the side of the vessel than right under it (Ryhänen and Ovaskainen, 1968).

Although an echosounder is principally used to measure depths, it is able to »see» more of the seafloor than just a single point below the sounding vessel. This beam angle is dependent on the frequency and physical size of the transducer. The 210 kHz transducer used, covers a circular area of about 4 m at a depth of 50 m and a radius of 8 m at a depth of 100 m. The 30 kHz transducer in use covers an elliptical area of the seafloor. At a depth of 100 m the area covered is approximately 15 m by 28 m (Fig. 3). In extreme cases the »side lobes» of the transducer may cause interference due to side echoes (Service Manual... 1973).

Figure No 4 represents an echosounding profile of the seafloor close to the town Kotka in SE-Finland. The depth of the seafloor varies between 9 and 16 meters. In the figure it is possible to identify different types of sediments on the seafloor. Till is covered with big boulders and the eroded surface of a clay basin is covered with a thin layer of sand or silt. The picture shows also a wreck by the name of St.Nikolai, lying

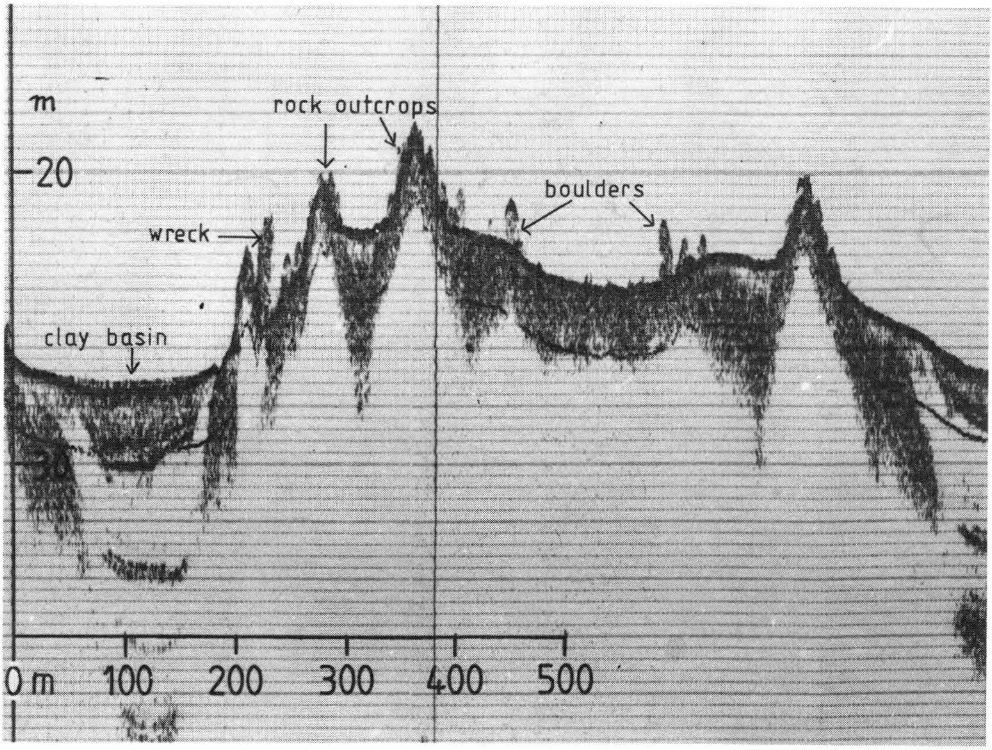


Fig. 9. Echosounding profile from the eastern part of the Gulf of Finland. A steelwreck is lying between the rock outcrops.

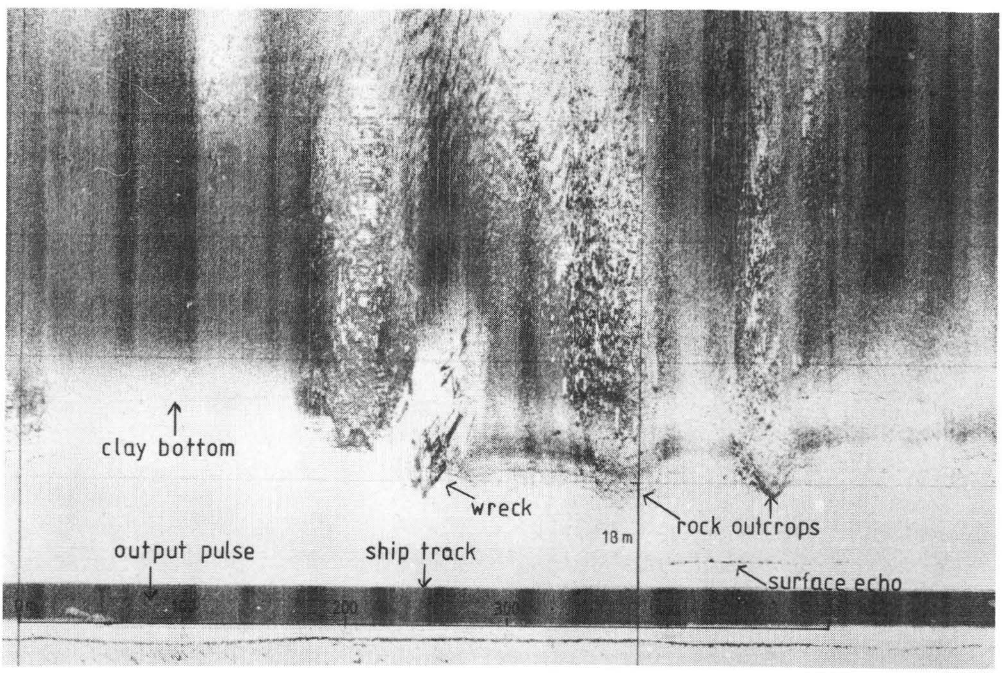


Fig. 10. A sidescan profile of the same steelwreck as in figure 9.

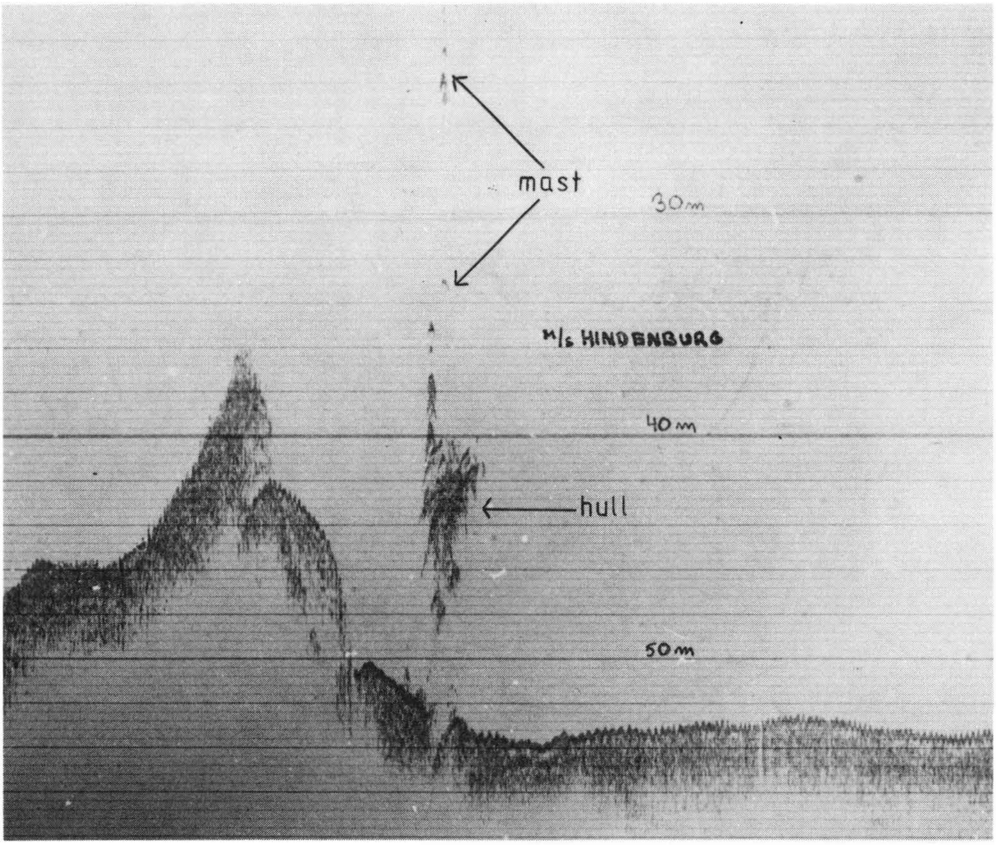


Fig. 11. m/s Hindenburg, echosounding profile.

at a depth of 16 m and rising about 3,5 m above the seafloor. The length of the wreck as measured from the echoprofile seems to be about 40 m.

On July ninth, 1790, there was a naval battle called the Ruotsinsalmi battle, fought just south of the present town of Kotka. Nearly 500 ships and over 30.000 men participated in the battle. It was a decisive battle for King Gustav the Third of Sweden against Russia. The Swedish fleet had one of its greatest victories. On the western wing of the Russian frontline there was the frigate St.Nikolai, which fought up to the moment it sank while still at anchor.

In 1948 divers found the impressive wreck in full armour. Because of fairway works the wreck was severly damaged and robbed, until archaelogical investigations in the year 1961 started, and the wreck was put under the protection of law (Ahlström 1983).

The graphic display of the side scan sonar towed behind the research vessel (Fig. 1) resembles an aerial photograph of the seafloor. Figure No 5 shows a graphic display of a (100 kHz) side scan sonar made close to the wreck of St.Nikolai. The broad horizontal line in the middle of the record represents the outgoing pulse from the underwater towed »fish». The soundbeams are projected to either side of the towed »fish» perpendicular to the direction of ship travel. The soundbeams are narrow in the horizontal plane (3/4°) and wide in the vertical plane (40° tilted down 10° from horizontal). The next line to show represents the seafloor directly below the transducer.

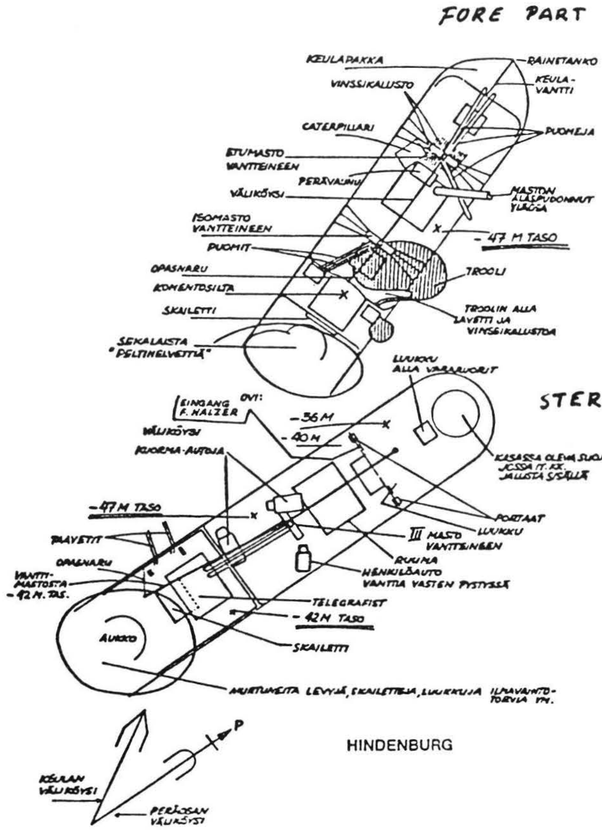


Fig. 12. Diver's opinion of how the wreck m/s Hindenburg is lying on the seafloor (Rouhiainen, 1978).

Behind this bottom echo the actual side scan echoes from the bottom terrain can be seen. When echoes are received from targets on the seafloor, their intensity on the graphic display depends on their different backscattering ability. A ligth area in the graphic display indicates either a smooth area with very low backscattering or an »acoustic shadow» behind a target, which projects from the seafloor. Sound, similar to light, is able to cast shadows. This results from the fact that an area behind a rock or other projection returns no sound to the transducer. By measuring various dimensions from the acoustic shadow it is possible to estimate the height of the feature (Instruction manual... 1980). The big boulders seen in the echosounding profile can be seen as black spots having light »shadows». The fluctuating ribbed surface originates from sand waves on the seafloor.

In the graphic display the wreck of St.Nikolai can be seen giving echoes at equal intervals. The figure has a long shadow. The wreck is lying perpendicular to the route of travel.

In the autumn of 1983 marine geologists of the Geological Survey of Finland were asked to search for a sunken barge in the archipelago east of Helsinki. The owner had not found his barge (Fig. 6) even though he had used divers and though he knew where he himself had lost it. The size of the steelbarge was length 8.3 m, beam 4.0 m, height 1.3 m, with a mast 7 m high.

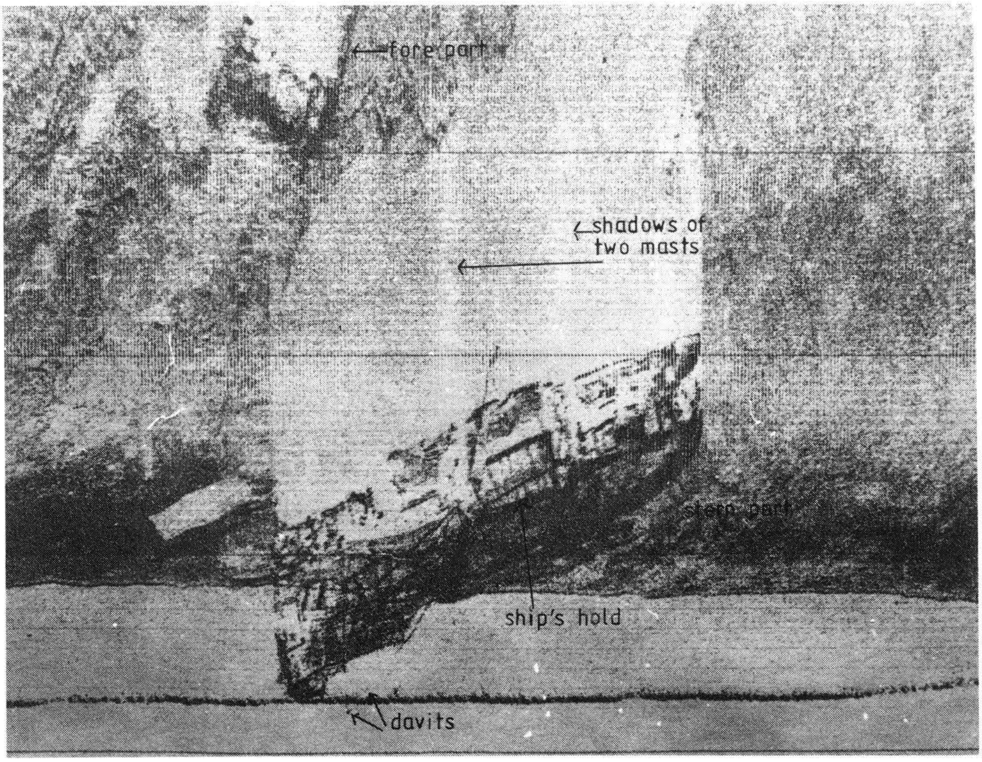


Fig. 13. Sidescan sonar record (500 kHz) of m/s Hindenburg.

After the owner had dropped a buoy where he estimated the barge to have sunk, the marine geologists started to search it with their research vessel using echosounder and side scan sonar. The positioning was accomplished with Motorola Miniranger system. In less than 5 minutes from starting the survey the graphic display of the side scan sonar (Fig. 7) printed out reflections of the barge. The geometry of the reflections and especially the shadows from the mast and the bottom correspond completely to the drawing (Fig. 6).

Figure No 8 represents an echosounding record of the barge lying upright on the seafloor. The depth of the sea is 16 m. From the picture, the height of the barge and its mast can be measured. The object was found at a distance of about 200 m from where the owner had dropped his buoy. The whole operation was over in two hours including the installation and the removal of the navigational reference stations.

The next example (Fig. 9) is chosen to show how difficult it is to distinguish an echo of a wreck from those caused by rock outcrops and huge boulders. The echosounding profile shows a seafloor topography of the archipelago in the eastern part of the Gulf of Finland. In the picture the depth of the sea varies between 25 m and 18 m from the surface of the sediment basin to the highest top of the outcrops. From the simultaneous side scan sonar record (Fig. 10), it can be deduced which of these echoes is produced by the steelwreck. The steelwreck gives a strong echo with definite geometric form differing from the echoes of the vast rocky areas on both sides.

In November 1942 a German troop-carrier called Hindenburg sank on the fairway leading from Utö to Turku in SW-Finland (Fig. 11). The 7,878 brt and 143 m long wreck lies at a depth of 52 m and one of its four masts rises to a depth of about 20 m. For sportdivers the wreck has been a challenge because of its huge size, the great depth of the sea and strong currents. Because of the cold, dark and harsh environment divers have found it difficult to decide whether the wreck is broken or not.

Figure No 12 is a copy of a drawing in a book called »Three Divers in the Archipelago». The drawing shows the divers' opinion of the way the wreck is lying on the seafloor. The fore and aft sections, broken apart, are pointing almost in the same direction. The upper drawing shows the fore part with two big masts, booms and shrouds. The lower drawing shows the stern part with the third mast with its shrouds situated in the middle. The main decks of the wreck are lying at depths of 42 m and 47 m (Rouhiainen, 1978).

Figure No 13 shows a 500 kHz side scan sonar record of m/s Hindenburg. Because of the unprecise navigation no vertical or horizontal scale is drawn on the picture. The wreck can be seen broken into two separate parts. The larger part of the wreck lying in the foreground has two masts and between them there can be seen a ships' hold. This part represents the aft part of the ship pointing to the right. The fore part lies broken in the background. The shadow of the stern is long and diffuse, giving however a profile of the main decks.

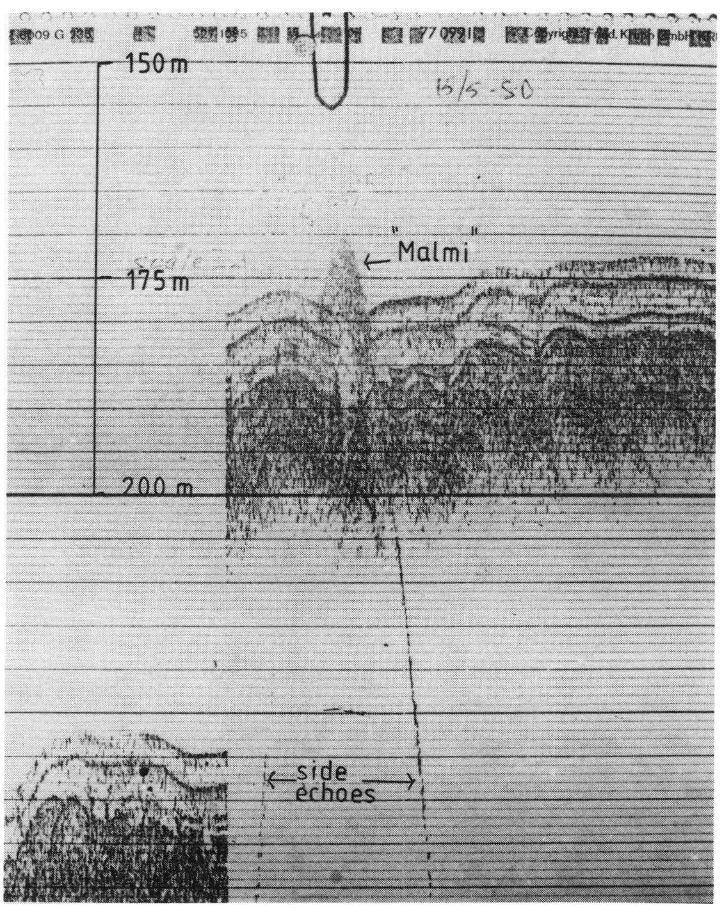


Fig. 14. Echosounding profile from the North Baltic showing the steelwreck m/s Malmi.

Figure No 14 is an echosounding profile from the North Baltic, where the depth of the sea is about 175 m. On the clay bottom there lies the big steelwreck of m/s Malmi. The height of the echo is about 10 m. No details can be seen from the wreck. This example is chosen to show how the side echoes (whiskers) from the wreck lies slightly off to the side of the sounding track.

These selected examples show how both the echosounder and the side scan sonar are, in ideal conditions, applicable to search and investigate wrecks. The examples shown were those of known and unknown wrecks made of wood and steel. The biological decomposition of wood causes the acoustic pulses of side scan sonar to be severely absorbed by the softened wood structures. This together with the physical degradation makes the identification of submerged wooden wrecks generally a lot more difficult than that of modern steel wrecks. The higher the frequency utilized in a side scan sonar, the better the resolution and also the chances of identification of submerged archaeological targets. However, the higher the frequency is the more of the acoustic energy is absorbed already while travelling through water thus severely limiting the range, i.e. the observation distance of the sonar.

The seafloor geology, the bottom topography, and the depth of the sea together with the size, materia, and geometry of the object play an important role in the estimation of the possibilities of finding the object on the seafloor from a restricted area in a limited time.

By using the echosounder and the side scan sonar together with precise navigation it is possible to give the exact position, direction, size, and maybe the soundness of the object. A more detailed investigation must be done with underwater camera eguipment or with the help of divers.

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