Translated Article

Mosaics of Sediments and Structures on the Seafloor Mapped by Side Scan Sonar

By Hannelore M. Fiedler and Doris Milkert, Federal Armed Forces Underwater Acoustics and Marine Geophysics Research Institute, Germany

Side Scan Sonar (SSS) as a method of acoustic remote sensing is used for mapping sediments and structures of the seafloor. SSS provides a picture of the seafloor comparable to aerial photographs. Recent technological advances in SSS systems have brought the objective of complete mapping of the seafloor into the mind of researchers. The survey of an area includes several single profiles, run on parallel tracks with a certain amount of overlapping. The main purpose of digital image processing is to focus on the specific characteristics in the sonar pictures and to correct them geometrically. In a second step the single profiles are inserted into a Geographical Information System (GIS) and combined to produce mosaics. Structures such as ripples and their crests are therefore shown continuously. A sediment classification based on the mosaic can be performed by discriminating the differences in acoustic backscatter from surface roughness.

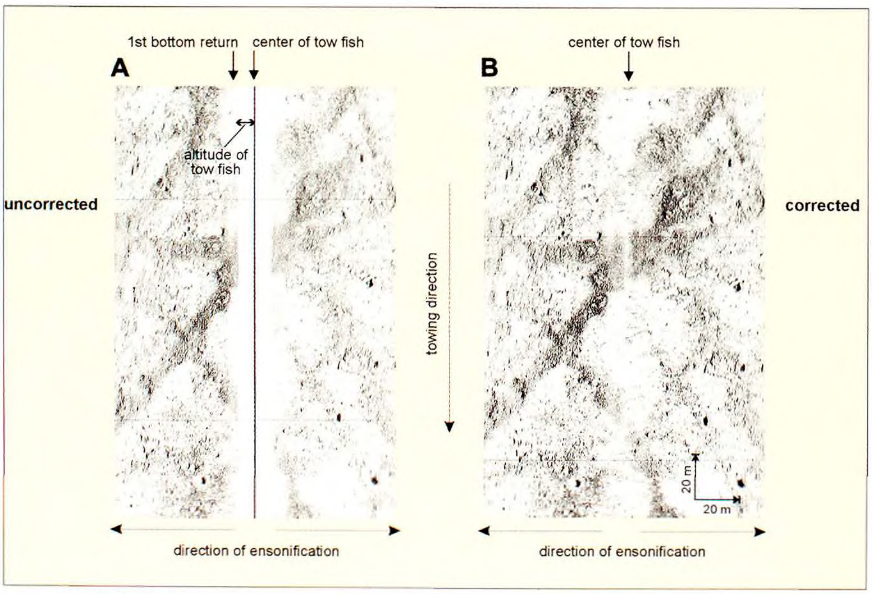

Figure 1: Side scan sonar recording of a dumping area near Warnemünde, Mecklenburg Bight. The darker stripes consist of more coarse material, the lighter areas of finer material
A: Figure with oblique distances between tow fish and bottom returns
B: The measured oblique distances are converted onto the horizontal line

Measurement System and Data Processing

With an SSS pictures and positions of the seafloor are related to the axis of the tow fish. For a precise interpretation the absolute position is required. With the help of DGPS (Differential Global Positioning System) the absolute position of the vessel is defined. The line and direction between the vessel and the tow fish can be measured by an acoustic tracking system with an ultra-short base line. Problems during the precise definition of the position can be caused by difficult weather conditions and by cross currents if the GPS-antenna is affected by roll, pitch and heave movement of the vessel. The tow fish does not move in a straight line either, it also is affected by roll, pitch and heave movement. Therefore, the position coordinates of the vessel and the tow fish have to be measured continuously and to be used for a correction of the measured positions.

The SSS-system used in the FWG is the system 2000 manufactured by Klein, USA. It consists of a tow fish with two frequencies (100 kHz and 500 kHz). Additionally, in the tow fish there are integrated sensors for temperature and pressure, course, roll and pitch, as well as the responder of the tracking system. The last mentioned sensors are necessary to determine the position of the tow fish as well as the position of objects on the seafloor.

The measured SSS-data are digitised in the tow fish. For processing, the data are delivered via the tow cable to an on-board unit. These raw data can be saved digitally and shown directly on a video display or a grey scale printer. During an analogue recording on a grey scale printer a data representation is possible with the help of the image processing, where the scale factor in the tow direction is the same as the one in the direction of the sound propagation (range).

Side Scan Sonar Recording

According to the measurement principle, the SSS measures the oblique distances in the direction of the sound propagation (range) to the seafloor. The oblique distances can be converted using the altitude of the tow fish above ground into the horizontal line and therefore, can be represented in a geometrically corrected way (Blondel and Murton, 1997). Figure 1 shows the difference between a corrected (Figure 1 A) and a non-corrected (Figure 1 B) SSS registration.

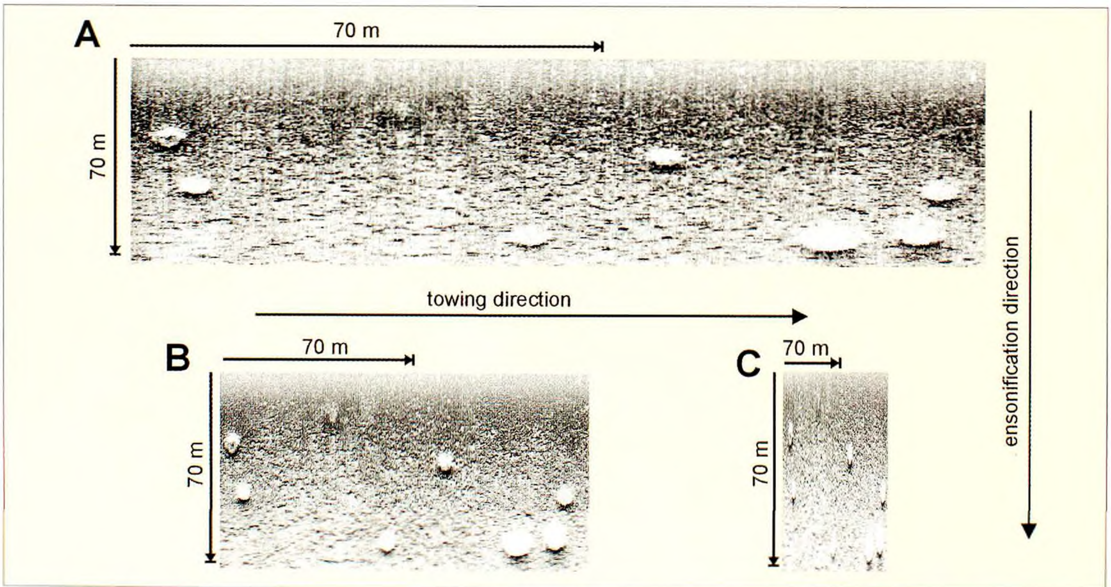

Figure 2: Side scan sonar recording of an area with circular structures (craters) on the seafloor with three different recording speeds

A: Recording speed too high, distorted presentation in tow direction

B: Recording speed corresponds to the scale of the range

C: Recording speed too low, distorted presentation in tow direction

In Figure 1 A, the measured oblique distances are shown and a distortion occurs which can be noticed near the tow fish.

In Figure 1 B, the oblique distances are converted into the horizontal line. A continuous sediment recording can be recognised. Here the scale in the tow direction is the same as the one of the sound propagation (range).

For the geometrically corrected representation of the measured SSS-data in the direction of movement, the ship's speed has to be included. This velocity is determined by DGPS and regulates the recording speed (e.g. the paper feed of a grey scale printer). Figure 2 shows an area with circular structures (craters) on the seafloor during three (A,B,C) different recording speeds. In Figure 2 A, the assumed tow speed is too high. Therefore, the circles turn into ovals in the tow direction. Figure 2 B corresponds to the real tow speed so that the scale in the tow direction is the same as the one of the range. Here the craters appear as circles. In Figure 2 C the tow speed has been chosen too low. Accordingly, circles become ovals in the direction of the range.

The method described above makes it possible to present a single profile geometrically corrected and scaled related to a local coordinate system. The tow direction is defined as one axis and - rectangular to this - the direction of the sound propagation (range) as a second axis.

Mosaics

In order to map sediments of the seafloor in areas of total coverage, several single profiles, run on parallel tracks with a certain amount of overlapping, are measured with the SSS (Fiedler and Wever, 1997). For combining the single profiles in one mosaic the absolute position of them is required. Therefore, the digital data of the profiles are prepared in such a way that they can be put together in a Geographical Information System GIS to produce a mosaic.

The SSS-data are processed by the ISIS software of Triton Elics and after that combined to a mosaic in the GIS Delph Map software, also a product of Triton Elics.

Figure 3 shows a SSS mosaic covering an area approx. 1,200 m x 900 m in the north of Schillig Reede (Jade Bay, North Sea). The different SSS profiles run from north to south which is recognisable by the lighter line in the middle of the profile. The sand dunes which spread from west to east run out in the east. The valleys of these sand dunes can be seen at the slopes of the branched white lines. On these sand dunes there are smaller ripples which run almost parallel to the crests of the sand dunes. The valleys of the ripples are recognisable as smaller white lines and the crests as small black lines (Ulrich, 1973; Milkert and Hühnerbach, 1997).

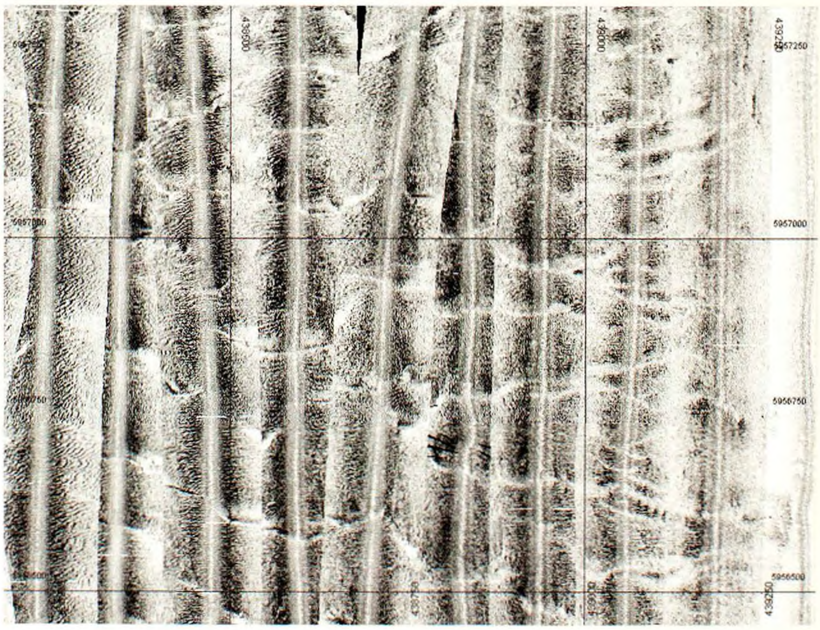

Figure 3: Side scan sonar mosaic of a ripple field near Schillig Reede, Jade Bay, North Sea. Coordinate grid: 500 m

Figure 4 shows a mosaic an area of approximately 4,000 m x 1,000 m of the Wattenberg Channel. The Wattenberg Channel is a filled trench of the ice-age in the north of Olpenitz in the western part of the Baltic Sea. Since the back scattered energy depends on the acoustic properties of the seafloor, the grey scale distribution enables a sediment classification. The higher backscattering due to the glacial till outcrops appears in a darker colour in the mosaic. Consequently, the weaker backscattering of the mud appears in a light colour. Since the channel is filled with mud, its course can be seen very clearly due to the grey scale distribution. At the edge there is the glacial till partly with bigger stones. With an increasing water depth there is a change from sand to mud in the deeper part of the channel (Seibold et al., 1971).

Classification

SSS mosaics give a picture of the surface of the seafloor, but no depth information. However, in the mosaics, an overall sediment classification becomes possible because of the grey scale distribution. It is, however, necessary to take undisturbed samples from the seafloor at characteristic positions.

To get an impression about the thickness of various sediment types, the SSS is combined with a 3.5 kHz Sub-Bottom Profiler (SBP). Figure 5 shows a SBP recording of a profile running from the south-east to the north-west along the Wattenberg Channel. In the SE, NW and central part of the profile the glacial till comes to the surface. Between are layers of mud with a thickness of up to 5 m. In the mud areas there can be seen a acoustic turbidity which means a deposit of released gases (methane) (Fiedler and Stender, 1994; Fiedler and Wever, 1998). Due to the gas bubbles an acoustic backscattering occurs.

The information from the SBP measurements does not only serve for the determination of the thickness of sediment layers but also gives a hint about the acoustical hardness of single sediment types. In the

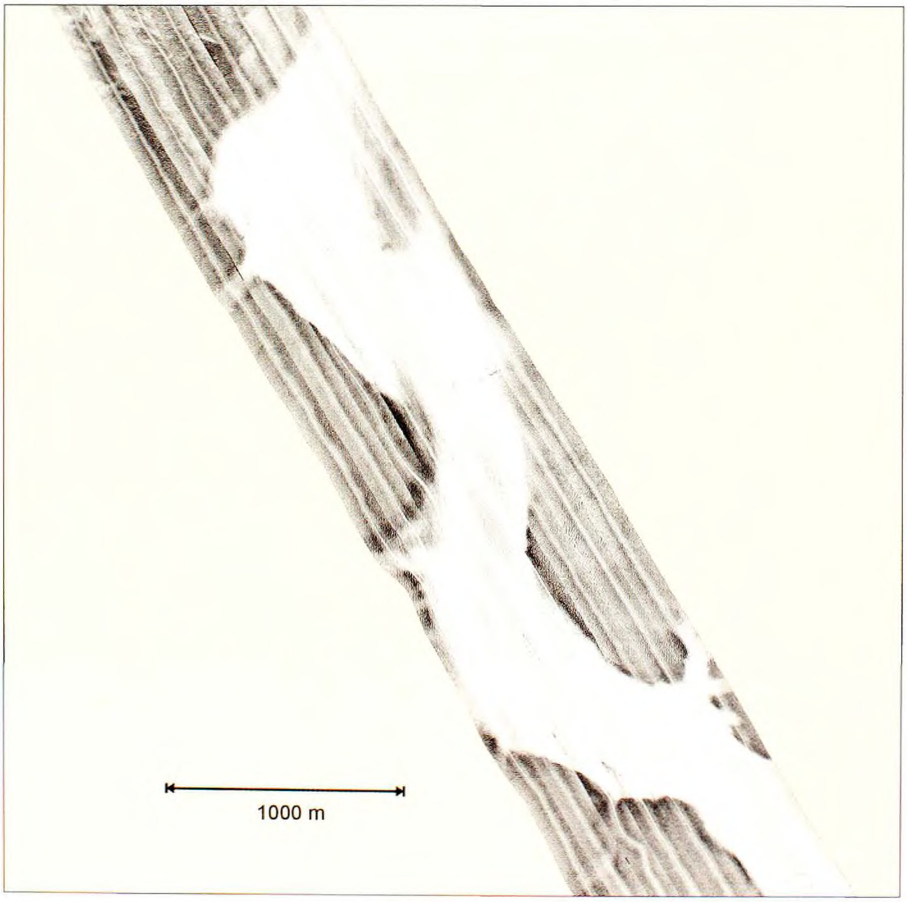

Figure 4: Side scan sonar mosaic of the Wattenberg Channel, western Baltic

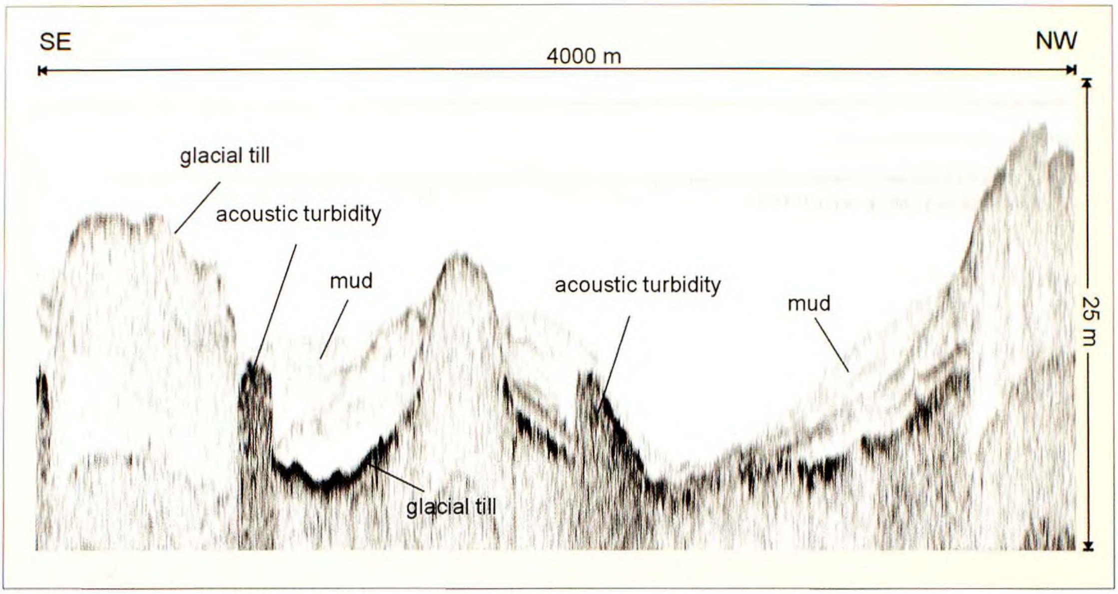

Figure 5: 3.5 kHz sub-bottom profiler recording of a profile through the Wattenberg Channel, western Baltic

future, the thickness of the sediments (e.g. mud) is to be included into the mosaic by using iso-lines.

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Biographies

Hannelore M. Fiedler studied geodesy at Hamburg University of Applied Sciences and graduated 1976. Additionally she studied environmental technique at Lübeck University of Applied Sciences. Since 1982 she is working for the Federal Armed Forces Underwater Acoustics and Marine Geophysics Research Institute (FWG) mainly with side scan sonar, sub-bottom profiling, seafloor mapping and the problems of positioning.

Dr. Doris Milkert studied marine geology and geophysics at Kiel University, where she completed her PhD in 1993. In the same year she moved to the Institute of Oceanographic Sciences in Wormley (UK) and since 1999 is working for FWG. Main research activities are connected to sidescan sonar, automatic seafloor classification and texture analysis.

E-mail: Fiedler@bwb.org
Milkert@bwb.org