Holocene Sedimentation from High-Resolution Chirp Sonar Data and IMAGES core MD99-2286 in Northeastern Skagerrak

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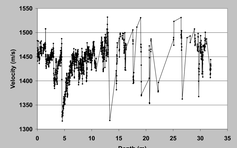
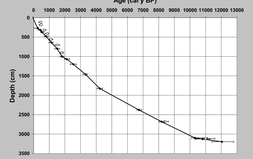
4 P-wave Velocity



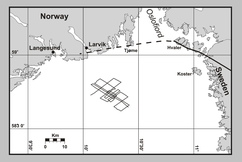
P-wave velocity in core MD99-2286, measured with 0.5-cm resolution using MSCL. The acoustic signal was lost due to insufficient coupling in the interval 10.8 11.7 m, and in virtually all measurements below 13 m. Abrupt changes in the core top are artefacts. The P-wave record shows that the sound velocity varies between 1400 and 1500 m/s in core MD99-2286.

5 AMS C-14 dating



AMS C-14 dating of core MD99-2286. The age model is shown with line connected black diamonds. Open circles show age estimates excluded from the age model because of reworking. Error bars denote 2 calibrated age ranges. The age model shows that core MD99-2286 spans the entire Holocene and uppermost Pleistocene.

6 Ice Recession



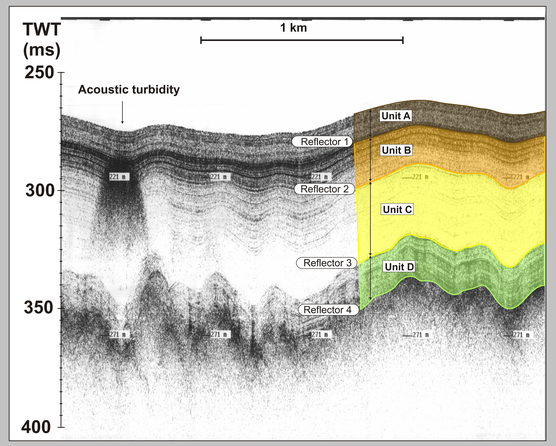
Drawn black/stippled line represents the location of the Hvaler/ Tjøme/ Trollhättan ice marginal zone, dated to 13 400-14 200 cal y BP (ref. 4, 12). The chirp sonar track lines are also shown. Based on the dated ice-marginal zones and an esimated ice recession rate of 100-200 m/y, it follows that the coring site of MD99-2286 was deglaciated sometimes between 14 500 and 13 600 cal y BP. Redrawn from ref. 12.

1 Introduction

Skagerrak is the deepest part and the major sediment trap of the North Sea. The investigated area is characterised by intense water mass mixing and high sedimentation rates, up to 1 cm/year (Boe et al., 1996), as a branch of the North Atlantic Current turns anti-clockwise, slows down and becomes mixed with other waters to form the Norwegian Coastal Current (figure 1). Present-day SSTs in Skagerrak are strongly linked to the NAO-index. This makes the Skagerrak a key area for our understanding of the late Quaternary oceanographic and climatic history of the North Sea region and adjacent land areas. Previous seismic studies in the Skagerrak (ref. 2, 3, 7, 9, 10, 12, 17, 18, 19) have demonstrated the presence of a prominent seismic reflector separating the upper relatively transparent units from the underlying stratified sequence. The age of this sharp reflector has previously been assumed to represent the Pleistocene/Holocene boundary (10 000 C-14 years BP = 11 500 cal y BP; informal working definition (ref. 6)).

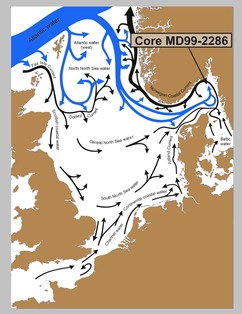
The present poster provides a detailed view of the Holocene stratigraphy in northeastern Skagerrak by reconstructing a 3D stratigraphic model from high-resolution chirp sonar data, multibeam bathymetry data from the Geological Survey of Norway (ref. 8), and sediment physical properties of IMAGES core MD99-2286. The age model based on 25 radiocarbon dates shows that core MD992286 spans 12 000 calendar years, thus encompassing the entire Holocene and the latest Pleistocene. Information on the sedimentary environment obtained from this work also provides the spatial context necessary for interpreting measured sediment proxies in core MD99-2286.

3 General Seismic Stratigraphy



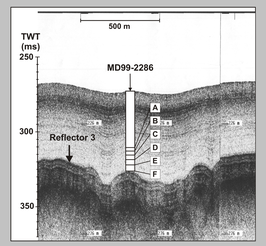
Chirp record showing the general stratigraphy of the survey area in northeastern Skagerrak. The defined seismic reflectors 1-4 and units A-D are indicated. A small patch of acoustic turbidity (indicative of shallow gas) is marked with an arrow. Depth labels indicate approximate depth from the tow-fish in metres based on a sound velocity of 1500 m/s. Average towing depth for the chirp sonar tow-fish was ca 15 m below sea level. Chirp section located at N58°43.9', E10°14.6'.

2 North Sea ocean circulation



General circulation pattern in the North Sea and Skagerrak. The relative magnitude of volume transport is indicated by the width of the arrows. Blue arrows indicate water entering the Skagerrak more or less directly from the Atlantic and black arrows indicate indirect transport via the North Sea (redrawn from ref. 4).

7 Calculated Core Penetration



Calculated penetration depth of core MD99-2286 in the closest located chirp sonar profile, based on different theoretical sound velocities, where
A = 1700,
B = 1600,
C = 1500,
D = 1400,
E = 1300,
F = 1200 (m/s). Reflector 3 is marked with an arrow. Measured p-wave velocities in core MD99-2286 suggests penetration down to between C and D. 4

8 Summary: The Pleistocene/ Holocene Boundary

Core MD99-2286 is 32.0 m long, and spans 12 040 calendar years. 5

The depth to reflector 3, previously interpreted as the Pleistocene/ Holocene boundary (11 500 cal y BP), is about 25 ms, corresponding to 37.5 m based on a sound velocity of 1500 m/s. 7

If the previous interpretation of the Pleistocene/ Holocene boundary in the seismic stratigraphy is correct, the core must penetrate through reflector 3. This requires a sound velocity of about 1200 m/s in the sediment, which is far below the measured values in the core of ca 1400-1500 m/s. 4 7

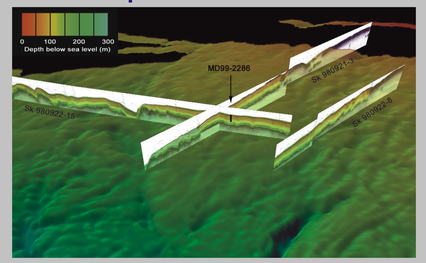
It follows that the sharp boundary between unit C and unit D, reflector 3, cannot represent the base of the Holocene as interpreted in earlier investigations (ref. 2, 3, 6, 8, 9, 11, 16, 17, 18).

There is no sharp boundary at the inferred depth of the Pleistocene/Holocene transition (11 500 cal y BP) in the chirp sonar profiles, nor any obvious lithological changes in core MD99-2286. 3 7

Methods

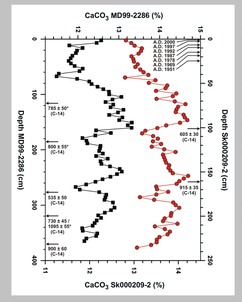
Chirp sonar data was acquired with an X-Star chirp sonar system using the SB-512 tow-fish, with a 1.5-7.5 kHz 40 ms long chirp pulse. **Carbonate content** in core MD99-2286 was measured using coulometry on 60-mg milled, freeze-dried bulk sediment samples. **P-wave velocity** was measured on split core halves using a GeoTek Multi Sensor Core Logger (MSCL), with a sampling resolution of 0.5 cm. P-wave data was calibrated to on-site conditions (temp. = 7° C, salinity = 35 ‰, water depth = 225 m). **Chronology** for core MD99-2286 is based on twenty-five AMS C-14 dates , performed on mixed foraminifera and species-determined mollusc shells by the institute of Particle Physics, ETH, Zürich, Switzerland. The radiocarbon dates were calibrated using the CALIB 4.3 software (ref. 12), with a R-value of -40 ± 25 C-14 years (ref. 11), assuming 100 % marine carbon, using the calibration data set MARINE98 (ref. 13). **Seismic interpretation** was performed in a 3D environment using Interactive Visualisation System's (IVS) dynamic 3D-visualisation software Fledermaus (integrating chirp profiles, bathymetry and core data). Grey-scale raster images of the processed chirp sonar data were displayed geo-referenced as "hanging curtains" using an average sound velocity of 1500 m/s.

3D Interpretation Environment



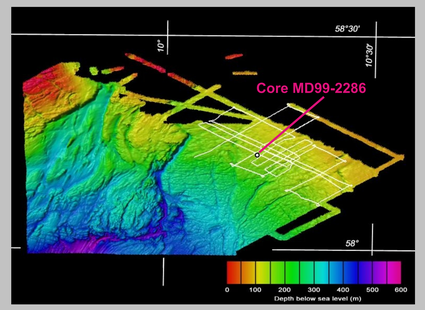
Oblique view of multibeam bathymetry and chirp sonar profiles around the coring location of MD99-2286. The chirp profile names are indicated, and the core MD99-2286 is marked with a black bar below the arrow. The bathymetric terrain model is made partly transparent in order to make the chirp profiles visible. Colours on the chirp profiles mark interpreted seismic units 2 . Multibeam bathymetry from Norwegian Hydrographic Service (ref. 8).

Core Correlation



A 2.4 meter long gravity core, Sk000209-2, was retrieved ca 800 m from core MD99-2286 in order to get full recovery of the surface sediments. The age model for core Sk000209-2 shows that the core top is of modern (zero) age, based on 7 ^{210}Pb-dates and 2 AMS C-14 dates. Age determinations for the two cores are indicated with arrows. A.D. age estimates refer to ^{210}Pb-dates, all other ages are reported in C-14 years BP. The three C-14 ages marked with asterisks (*) were excluded from the age model for core MD99-2286 because of reworking. Correlation between core MD99-2286 (black squares) and core Sk000209-2 (red circles) using carbonate content gives a correlation coefficient r = 0.67, significant with a confidence level of 99.9 %. Note the different depth scales. All data from core Sk000209-2 are from ref. 11.

3D View of Bathymetry and Chirp Sonar Trackline



Three-dimensional shadow relief model of the bathymetry in northeastern Skagerrak. Chirp sonar profiles are shown as white lines, and core MD99-2286 is indicated. Multibeam bathymetry data from the Norwegian Hydrographic Service (Ref. 8).

Conclusions

- Core MD99-2286 represents a continuous high-resolution record of Holocene and uppermost Pleistocene sediments
- Unit D is interpreted as glacial marine sediments rapidly deposited close to a calving ice front
- Reflector 3, separating the topmost relatively transparent sequence (units A+B+C) from the underlying stratified unit (D) is proposed to be older than the Pleistocene/Holocene boundary
- The change to Holocene conditions (lower unit C) is interpreted to have occurred during a continuous process of increasingly normal marine deposition, which gradually replaced the distal glacial marine sedimentation
- Unit C is interpreted as distal glacial marine sediments gradually changing to postglacial marine sediments deposited during latest Pleistocene to early Holocene times
- The uppermost units (A+B) represent marine Holocene sediments deposited in a more or less modern oceanographic environment

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