DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/96

Cruise Report

M/S Line Cruise to the Århus Bay
02.03.2003 – 07.03.2003

Jørn Bo Jensen and Troels Laier

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MINISTRY OF THE ENVIRONMENT

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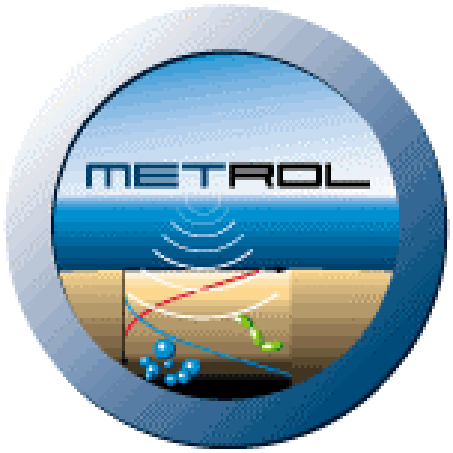
METROL

METHANE FLUX CONTROL IN OCEAN MARGIN SEDIMENTS

A research project supported by the **European Commission** under the Fifth Framework Programme and contributing to the implementation of the Key Action "Sustainable marine ecosystems" within the Energy, Environment and Sustainable Development

Contract no: **EVK3-CT-2002-00080**



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Contents

1. Cruise objectives

The overall purpose of the METROL field work in Århus Bay is to track possible seasonal and inter-annual variation of the geochemical zonation. On basis of the seismic data, samples will be obtained with gravity cores from target locations with different depths of the sulfate-methane transition zone:

The M/S Line cruise was devoted to shallow seismic work in the Arhus Bay, with the purpose to make detailed acoustic mapping of the seismic blanking, representing the distribution of methane in the sediments secondly attemts were made to establish the general stratigraphy of Århus Bay, in order to be able to relate the gas formation to specific units.
The seismic grid was planed on basis of existing shallow seismic data from the GEUS archive and concentrating on the central part of the Bay, in areas proven to consist of Holocene muddy sediments that contain gaseous methane.
Based on the seismic data, target positions for gravity cores were to be selected for the following **Henry cruise**10.-14.March**.** Co-ordinated by: Henrik Fossing (NERI).

2. Participants/participating institutions

Egon Hansen	GEUS
Jørn Bo Jensen	GEUS

GEUS: Geological Survey of Denmark and Greenland, Øster Voldgade 10 DK-1350 Copenhagen.

The survey ship M/S Line used for the seismic survey, is owned by the company:
NORD-MARINE.
Rosenlunds Sidevej 9
2791 Dragør
Tel.: +45 32 55 99 69
The contact person was Nikolaj Boesen

3. Description of the research area

In the Århus Bay region the Pre-Quaternary deposits mainly consist of Tertiary clays, partly modified by glacial deformations and covered by till deposits related to the Weichselian ice age main advance and icemarginal deposits from the final Baltic advance (Houmark-Nielsen,1987, Pedersen and Petersen, 1997, Rasmussen, 1977). The glaciodynamical elements shows up as ridges at the seabed, in between which lateglacial lake clay was deposited in a preface to the Holocene marine Littorina transgressive sand and highstand basin mud.

The present seabed reveals the central basin part of Århus Bay as a flat area (Fig. 1) dominated by mud (Fig. 2), while incised channels with mixed sediments characterises the north-western part just outside the city of Århus and in the south-eastern entrances to the Bay, south of Helgenæs.

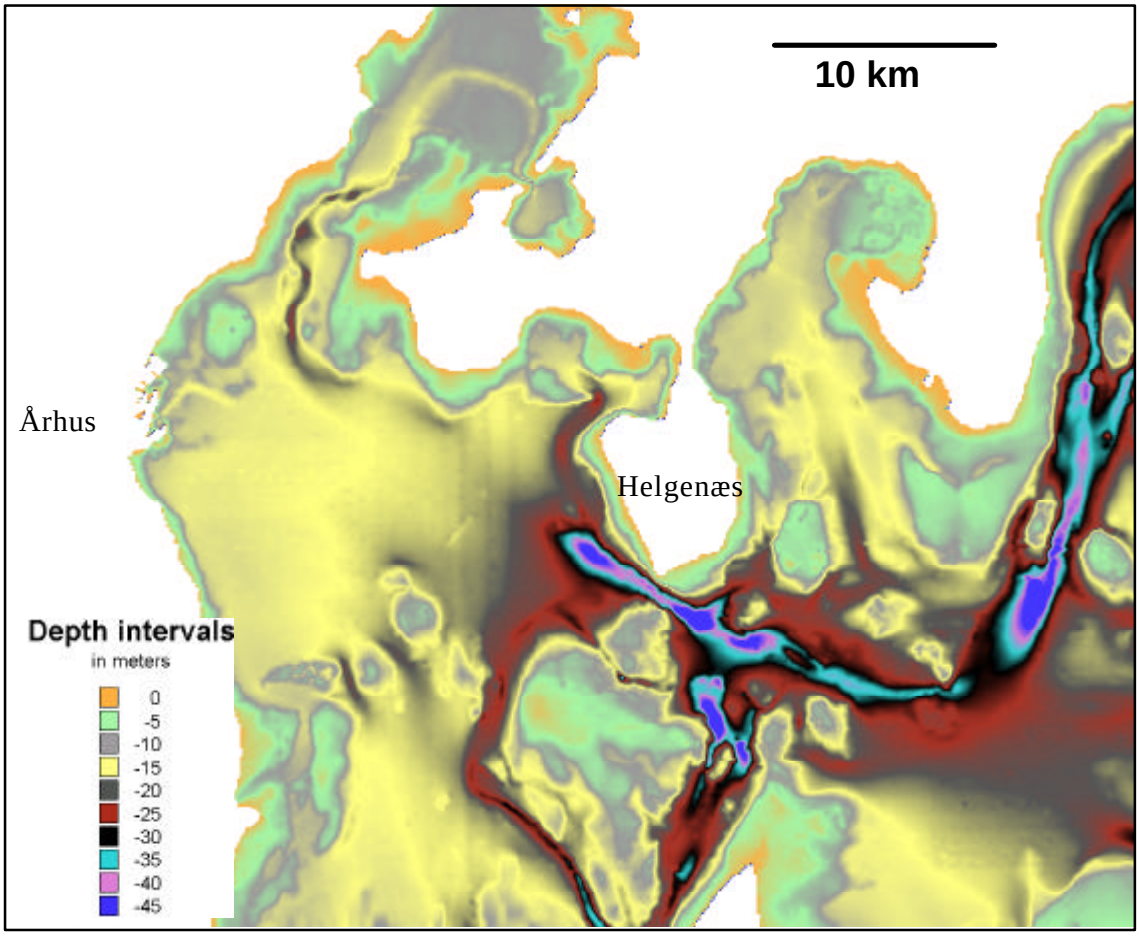

Figure 1. Bathymetric map of the Århus Bay region.

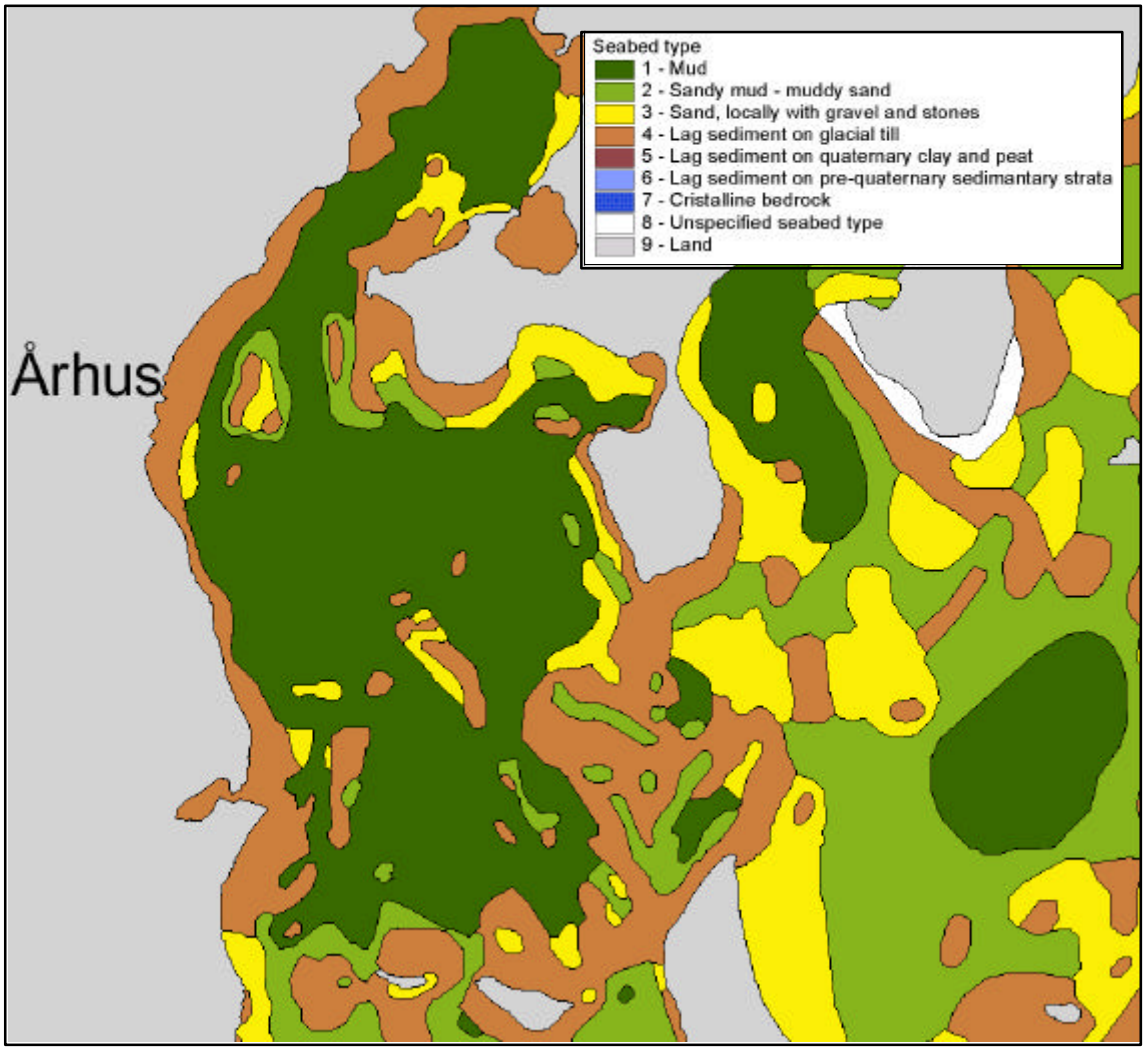

Figure 2. Seabed sediments in the Århus Bay region (Hermansen and Jensen, 2000).

Previous raw material investigations have shown (Fredningsstyrelsen 1983), that seismic studies indicates free methane gas (i.e. CH_4 bubbles) in the central quite homogeneous muddy are. There the mud sediment layer thickness exceeds 4 – 5m. The described general geological setting indicates that the free gas is formed in the Holocene mud and no contribution is expected from deeper formations.

4. Seismic equipment used

? X-Star Full Spectrum Sonar system, X-Star Tow Vehicle Model SB-0408. The acoustic returns are measured with the receiving array mounted on the tow-fish. The bandwidth of 9.6 kHz (0.4-10 kHz) gives a penetration of 10-50 m in sediments from sand to silt and a vertical resolution of 20 cm. A spectrum of 1-6 kHz proved to give the best results in the survey area.

? Depths were recorded at each fix-point using the ships echo sounder, Furuno Flv581 which was connected to the navigation computer.

? Single channel EG&G Boomer high resolution profiles with a centre frequency about (0.6-2 kHz) giving a penetration of 10–100m. The used streamer was a Design Projects 8 element streamer with a cable length of 2.8 m. Data was collected using a Delph Elics Seismic acquisition software. For this survey a sampling frequency of 8 or 10 kHz and a pulse transmitted with a sweep time of 0.2 ms have been used. The vertical resolution is 0,2-0.5 m

? Single channel GeoSpark 200 from Design Projects low frequency – low resolution – high penetration profiles with a centre frequency of 800-1200 Hz giving a penetration of 50 - 500 m. The used streamer was a Design Projects 8 element streamer with a cable lenght of 2.8 m. Data was collected using a Delph Elics Seismic acquisition software. For this survey a sampling frequency of 8 or 10 kHz and a pulse transmitted with a sweep time of 0.2 ms have been used. The vertical resolution is up to 0.5 m

? Navigation data was produced by the ships DGPS Koden KGP 913D system. The accuracy of the system is better than 5 m. All data from the cruise are in WGS84. The navigation instrument was connected to a computer loaded with NaviPac software. A correction for the position of the GPS antennas in relation to the ship and the seismic equipment (offset) was done before data acquisition.

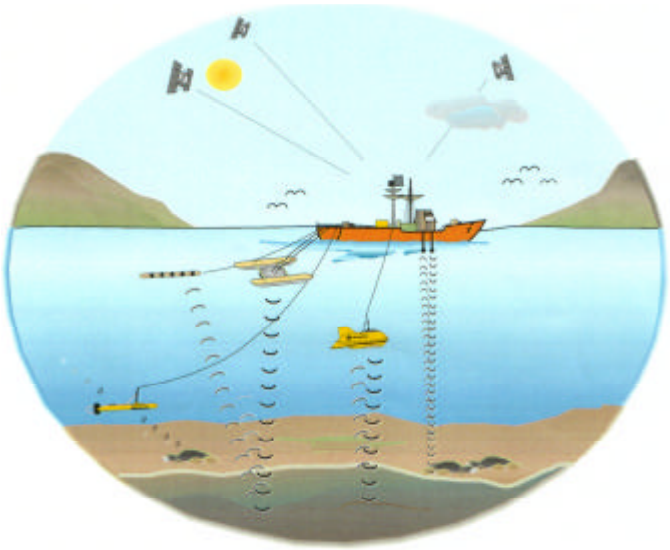

Figure 3. Seismic survey situation showing seismic equipment and GPS navigation.

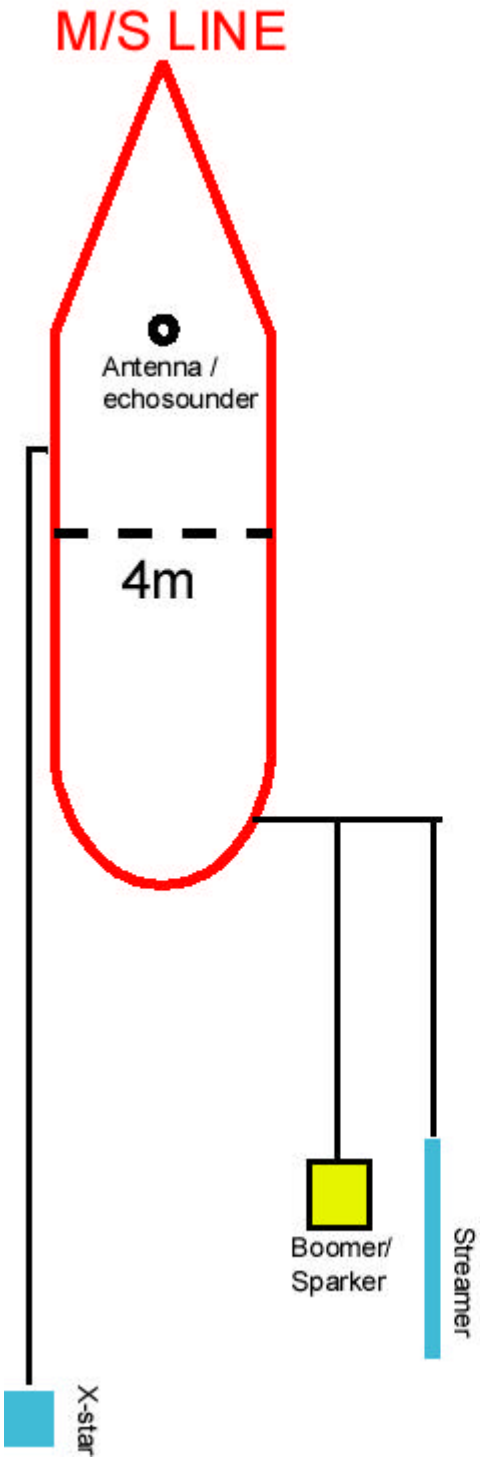

Figure 4. Left part: shows Instrument offsets on M/S Line in relation to Antenna position. Boomer/Sparker 6m starboard and 20m behind antenna, X-star 3m port and 25m behind antenna. B and C Photos shows M/S LINE.

Figure 5. Boomer catamaran dragged in starboard site behind M/S Line.

Figure 6. X-star fish onboard M/S Line

5. Narrative

Rigging period 24. – 28. February

Diary:

Sunday 2. March:
From Copenhagen about 7 p.m. and arrived at Århus about 10 p.m., where we booked at Hotel Cap-Inn. When we crossed the Great Belt, we realised that the wind speed was about 10 – 15m/s .

Monday 3. March:
Came onboard M/S Line about 8 a.m. and started preparing the ship for seismic work. Still the weather was rather windy up to 10m/s, slowly decreasing. About. 1 p.m. we were ready to leave the harbour and deploy the seismic equipment. Unfortunately the wind was still about 8m/s and it turned out that we could not handle the X-star fish from the port site in a boom specially designed for the survey. We had to give up and return to the harbour.
After some negotiation we decided to cancel the side-scan data collection and change the set-up to be able to drag the X-star fish form the middle part of the stern. The change of set-up was finished about 6 p.m. and we decided to prepare the seismic grid for the following day, which looked more promising in relation to the weather forecast.

Tuesday 4. march:
Arrived to the harbour at 8 a.m. and about 9.30 a.m. we had deployed the X-star in the water and the Boomer was ready. After a short testing period we started the data collection at line 502060. The weather was fine with wind speed of only 5m/s from southeast. Because of the weather conditions, the previous day the swells still had some effect on the Boomer data, while the X-star fish was positioned very steady about 5m below the surface. No side-scan data were collected.
The lines 502060 – 502071 were collected before we returned to harbour about 8 p.m..
The weather forecast for the following day was very bad and we decided to leave Line in Århus Harbour and go back to Copenhagen to wait for better weather

Wednesday 5. March:
Windy 10 – 14 m/s. No seismic survey.

Thursday 6. March: Gradually decreasing wind. We left for Århus about 8 p.m..

Friday 7. March: Arrived at the harbour 8 a.m. and after set up of the system we continued surveying with the X-star and Boomer about 9:30 a.m.. The weather was fine weak wind from south-west 5 – 8m/s. We succeeded to collect data from the lines 502072 – 572081 before the survey ended about 7 p.m..

Saturday 8. March. Arrived in the harbour 8 a.m.. We decided to make some regional lines crossing the Bay and prepared for X-star and Sparker seismic work. After start up of the system we surveyed the lines 502082 – 502085 in the time period 10 a.m. – 4 p.m.. After

return to the harbour we prepared the ship for return to Copenhagen. We left the ship about 8 p.m..

6. Onboard analyses

The seismic data were stored in digital formats and plotted on paper.
A preliminary interpretation of the seismic data was used for identifying different types of acoustic signatures indicating methane in the sediments. Seismic blanking is believed to indicate free methane. A number of locations were selected together with Henrik Fossing (NERI) in the evening of March 7th as basis for sampling at the Aarhus Bay Henry cruise March 10th and 13th March 2003
Five stations were selected (Fig. 7). Station M1 was positioned in the central part of the Bay where the seismic data revealed free methane gas at 3½-4 m depth (Fig 8). In this part of the Bay the seismic survey indicated quite homogeneous conditions for hundreds of m^2 with respect to the depth of free methane gas.
The four other stations were chosen along a transect with a methane zone approaching the sediment surface from Station M2 with no free methane in the top 4 m of the sediment to M5 with free methane within the upper 1-meter (Figs. 7 and 9).

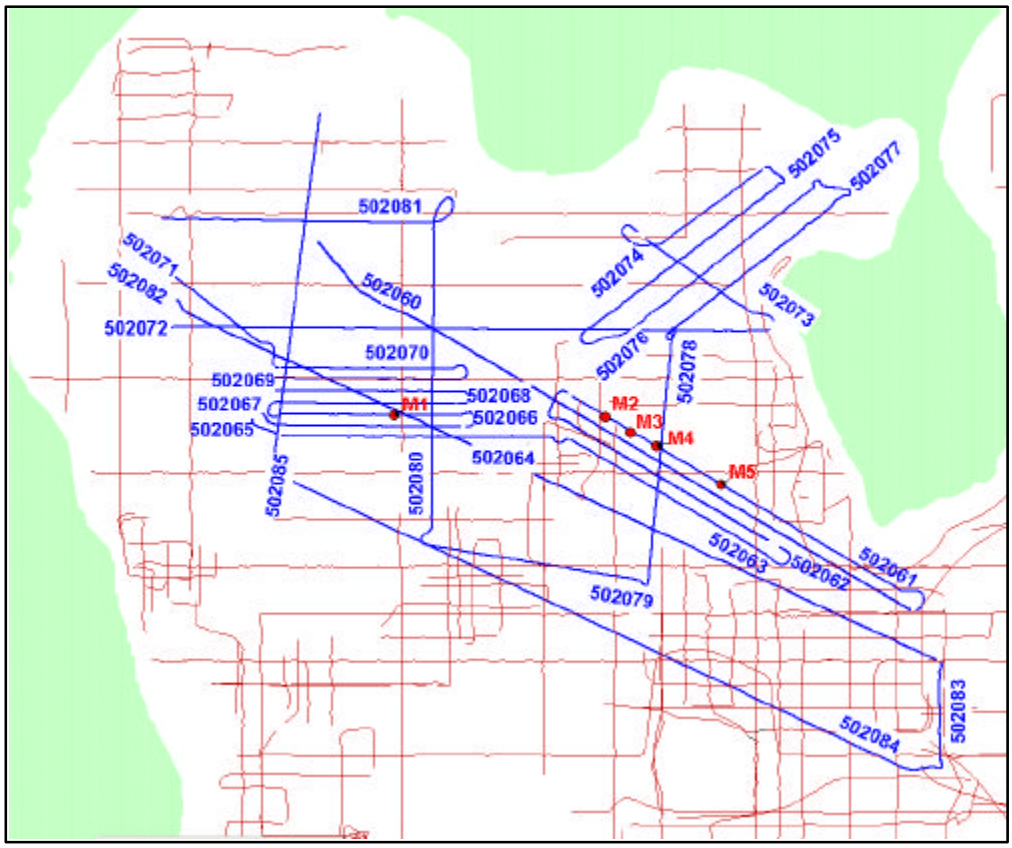

Figure 7. Seismic survey lines. Red lines are old seismic lines and blue lines are the M/S Line March 2003 seismic lines.

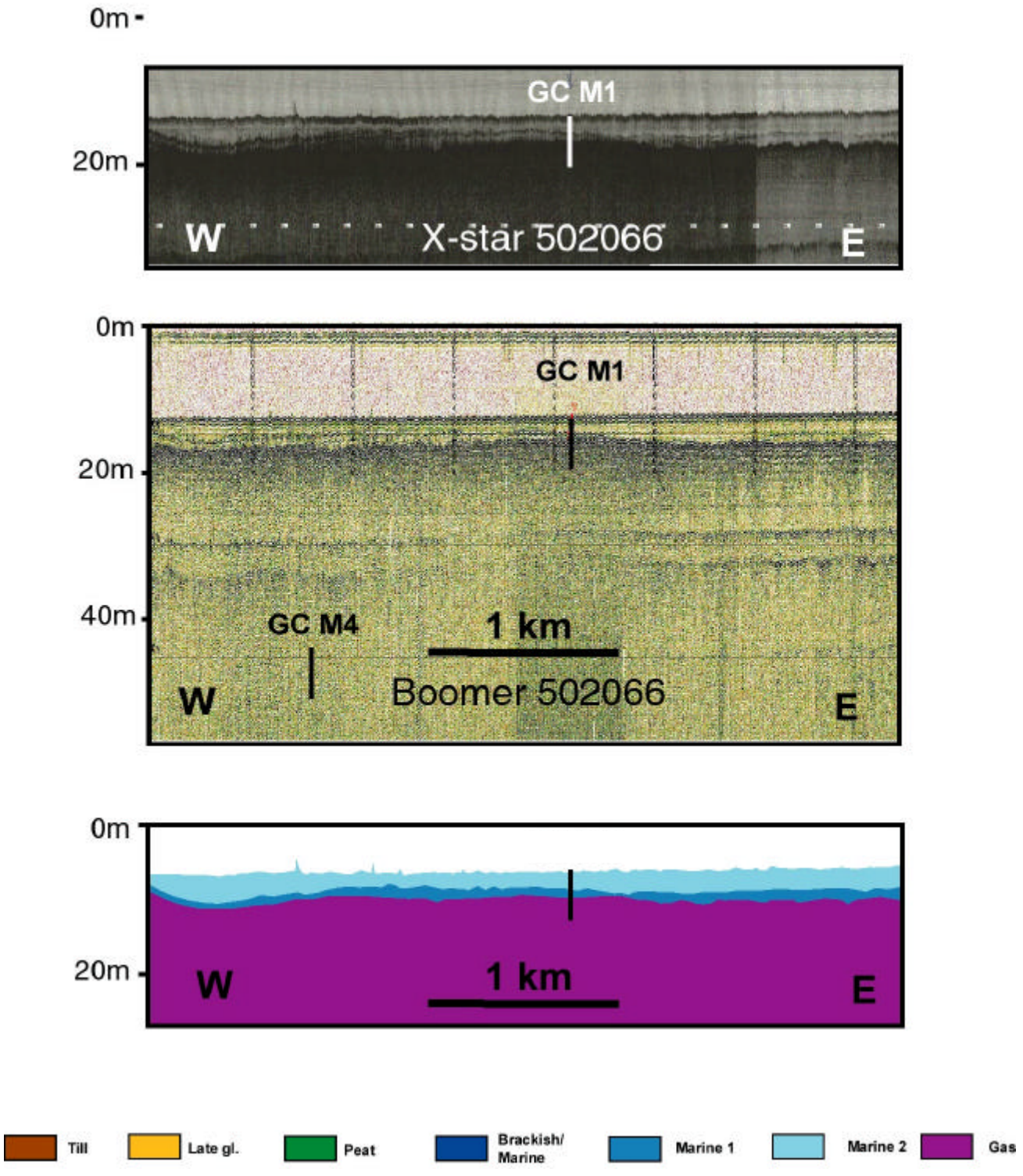

Figure 8. X-star and Boomer line 502066 with the gravity core GC M1 position indicated. The geological interpretation of the profiles is indicated as well.

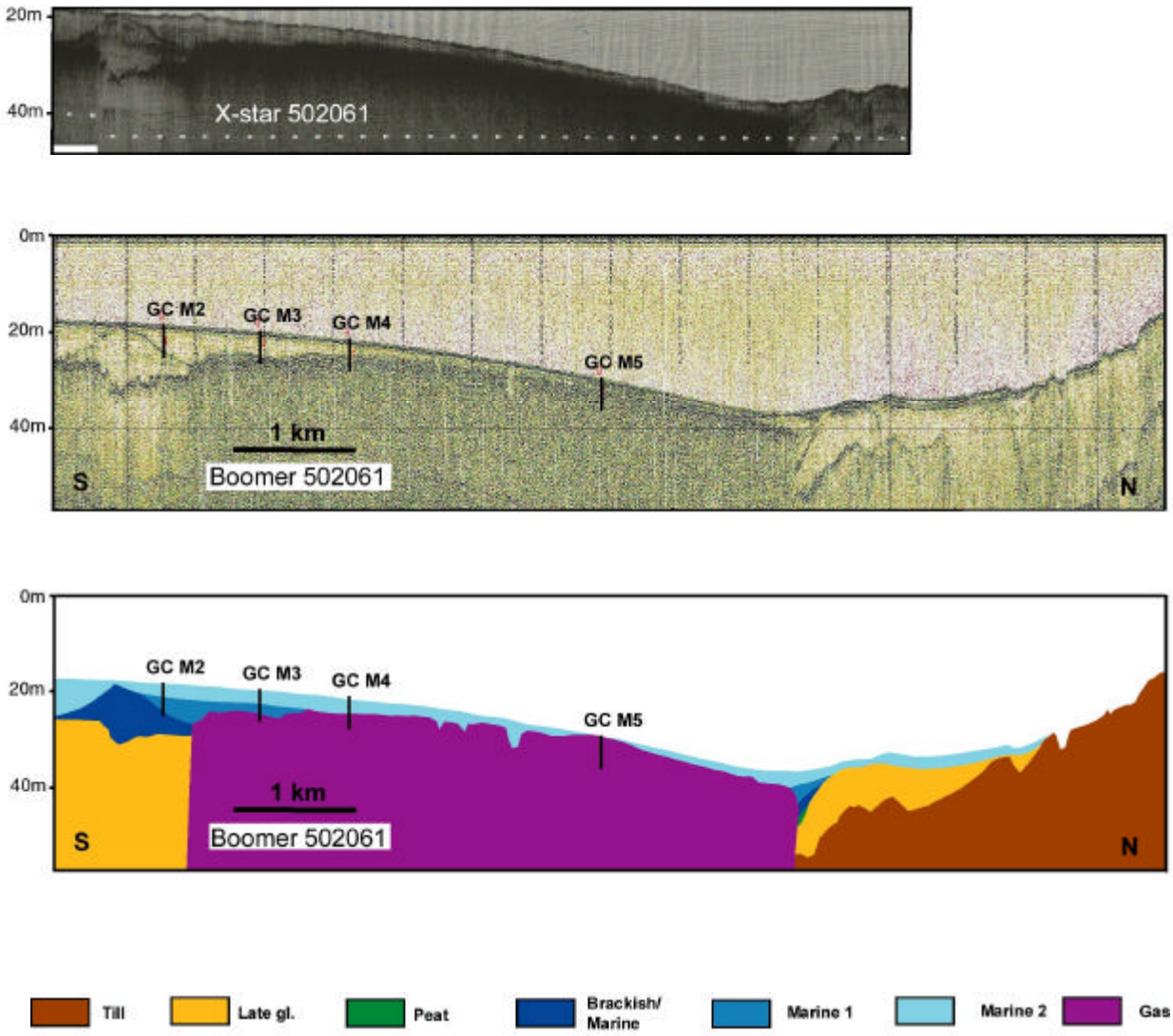

Figure 9 . X-star and Boomer line 502061 with the gravity core3 GC M2 to GC M5 positions indicated.
The geological interpretation of the profiles is indicated as well.

7. Preliminary results

As mentioned in the general description of the Århus Bay, the central part of the Bay is dominated by Holocene mud at the sea bed and previous seismic data indicates that methane gas is produced in the mud, resulting in a free gas phase when the mud exceeds a thickness of 4 - 5m.
The aim of the M/S Line cruise seismic survey was to supplement the existing data, to be able to, in details to, map the areas containing free methane in the sediments and the depth to the free gas surface. The survey was concentrated in the central and eastern part of the Bay, collecting Boomer and X-star data combined with few crossing sparker lines in order to establish the general stratigraphy.

7.1 The Århus Bay general stratigraphy

In order to establish the general stratigraphy 4 sparker lines (502082 – 502085) were surveyed, of which 502082 gave the best information.

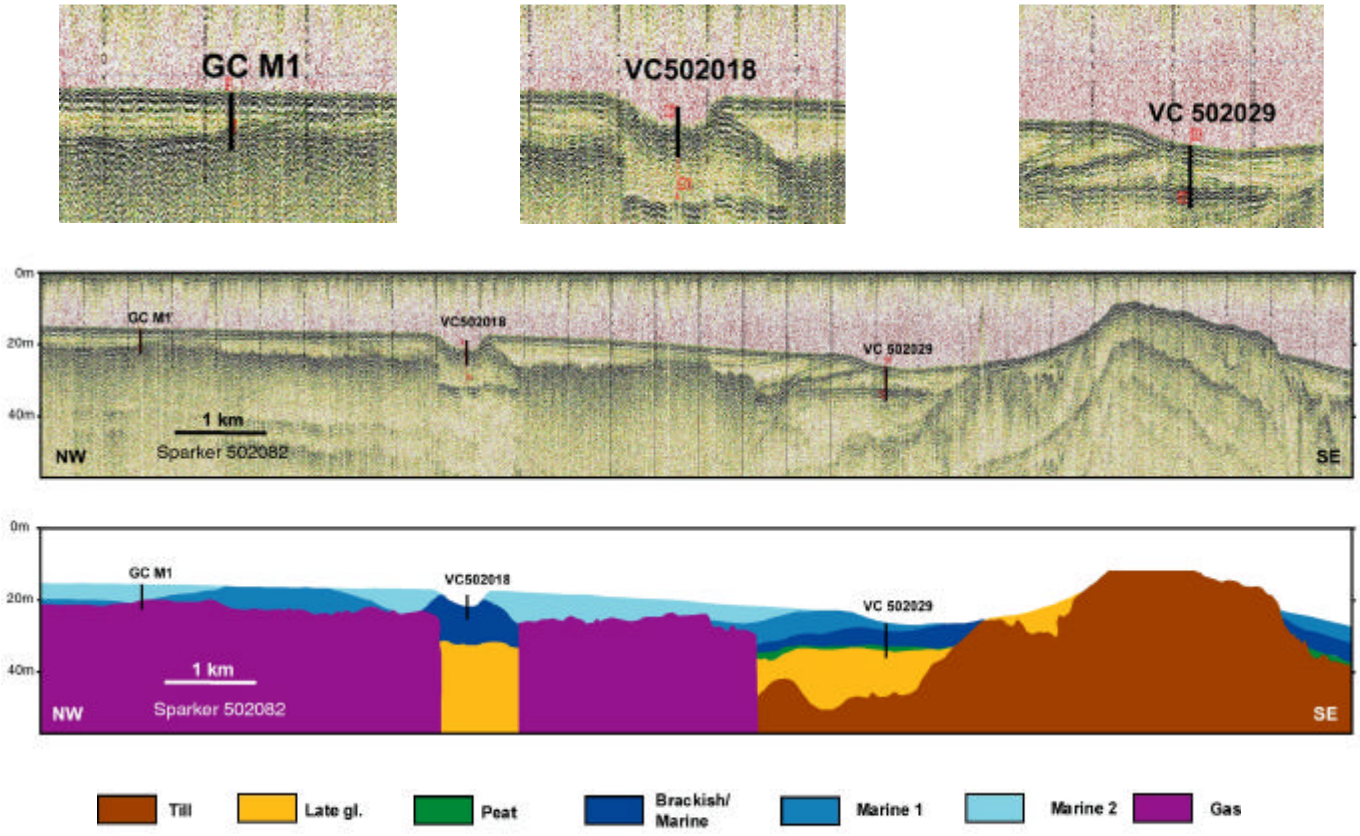

Figure 10. Sparker profile 502082 and the geological interpretation. For location see fig. 7.

No information on Pre-Quaternary sediments could be obtained from the seismic profiles. Thus the oldest seismic unit is interpreted as glacial till, probably related to the final Baltic advance (East Jutland advance). These tills form the ridges in the region and the basis of the basin areas. The glacial till is covered by lateglacial icelake clay-silt in the Århus Bay, reaching a thickness of upp to 10m. The existence of the clay–silt is documented by descriptions of old vibrocores from the region. The glacial till and the lateglacial clay–silt do not contain any organic matter and can not be regarded as the source of the methane gas.
In the deeper part of the Bay, early Holocene organic material and peat is described in few cores. A thin seismic unit is observed (Fig. 10) probably representing the early Holocene lowstand period, when most of the Århus Bay was dry land.
The 3 uppermost seismic units are related to the Holocene transgression of the region representing different hydrographical conditions, separated by unconformities. The lowermost unit partly drapes the basin area with clay sediments and partly shows prograding sandy coastal deposits around glacial ridges. Some shells are reported in old cores but it is unclear if it is brackish or marine deposits. Compared to the sedimentation in the Great Belt region, the unit could be brackish. The next unit (Marine 1 in Fig. 10) consist in general of marine mud to sandy mud covering most of the central part of the Århus Bay and some places reaching the present seabed in areas of erosion or non deposition. The distribution of the youngest seismic unit illustrates the sub-recent to recent sedimentation basin areas in the central part of the basin, in the protected area north-west of Helgenæs and an area with a supposed fast sedimentation rate south-west of Helgenæs, just west of the present channel inlet to Århus Bay.

7.2 Free methane in the Århus Bay sediments

A preliminary map of the distribution and depth to free methane in the muddy sediments has been produced on basis of mapping of the areas showing seismic blanking.
The combined information from the different seismic equipment's allowed a mapping of the distribution and depth to free gas in the intervals 0-0,5m, 0,5 – 2m, 2-4m and >4m.
The map (Fig. 10) shows that seismic blanking is found in the central part of Århus Bay in about 4m below the seabed. This is documented by a rather dense seismic grid as basis for the core sampling of station M1.
In the area south-west of Helgenæs, where the sedimentation rate is assumed to be high, the seismic blanking is found with gradually more methane towards the sediment surface. From the selected station 2 with no free CH_4 in the top 4 m of the sediment to M5 with free CH_4 within the surface 1-meter.
In the protected basin area North-west of Helgenæs the seismic blanking is similar to south-west of Helgenæs with supposed free methane very close to the seabed.

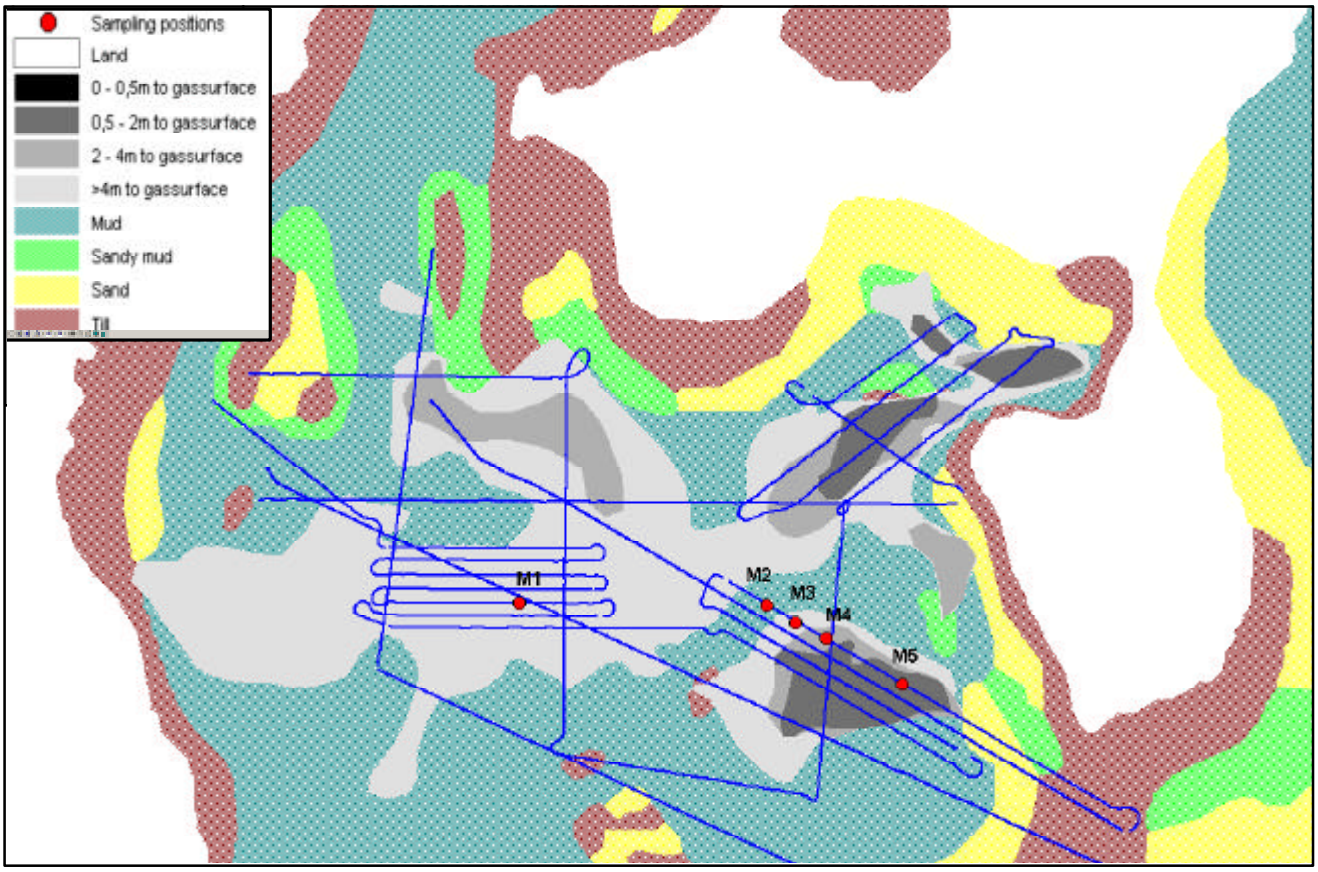

Figure 10. Distribition of seismic blanking representing free methane in the seabed sediments. The blue lines shows the line seismic grid and the M1-M5 sampling positions are the Henry gravity core positions.

7.3 Suggested future work

The distribution of the marine units is very important in the evaluation of sedimentation rates and very interesting in the future evaluation of source sediments for the gas formation in Århus Bay. Furthermore, the relation between the geological units and the distribution of methane is important.

Realising this the description of the general stratigraphy of the area must be improved considerably by collection of 4-5 cores covering the interpreted seismic units.

These cores must be studied in relation to sedimentology, machrofauna composition and , radiocarbon dating in order to establish a proper stratigraphy and possibly also Pb210 dating in the recent sedimentation areas in order to evaluate the deposition rate.

8. List of M/S Line 3. – 7. March seismic lines

Date	Line ID	Start N UTM32 WGS84	Start E UTM32 WGS84	End N UTM32 WGS84	End E UTM32 WGS84	Start Time	End Time
04.03.2003	502060	62223680	582106	6215876	594876	11:05	12:59
04.03.2003	502061	6216243	594049	6220481	587418	13:04	14:09
04.03.2003	502062	6219994	587049	6217200	591944	14:16	15:56
04.03.2003	502063	6216834	591980	6219353	587725	15:02	15.38
04.03.2003	502064	6219496	587468	6219586	581385	15:40	16:25
04.03.2003	502065	6219805	581251	6219823	585426	16:35	17:05
04.03.2003	502066	6220051	585398	6219975	581149	17:07	17:38
04.03.2003	502067	6220273	581185	6220286	585290	17:40	81:11
04.03.2003	502068	6220804	585256	6220546	581098	18:13	18:42
04.03.2003	502069	6220804	581207	6220796	585219	18:43	19:17
04.03.2003	502070	6221062	585149	6221080	581159	19:20	19:48
04.03.2003	502071	6221398	581214	6223682	578159	19:51	20:16
06.03.2003	502072	6221900	579000	6221800	591700	10:02	11:35
06.03.2003	502073	6222000	591800	6223800	589100	11:36	11:59
06.03.2003	502074	6223600	588900	6225300	591600	12:12	12:40
06.03.2003	502075	6225000	592000	6221700	587700	12:45	13:31
06.03.2003	502076	6221500	587800	6225000	592700	13:33	14:21
06.03.2003	502077	6224800	593400	6221700	589500	14:29	15:11
06.03.2003	502078	6221500	589600	6216400	584100	15:19	16:02
06.03.2003	502079	6216400	589100	6217300	584300	16:02	16:43
06.03.2003	502080	6217300	584300	6224500	584600	16:43	17:36
06.03.2003	502081	6224200	584800	6224200	578800	17:42	18:25
07.03.2003	502082	6222500	579100	6214700	595300	11:29	13:43
07.03.2003	502083	6214700	595300	6212600	595300	13:43	13:58
07.03.2003	502084	6212600	595300	6218900	581200	13:58	15:51
07.03.2003	502085	6218900	581100	6226500	582200	15:51	16:45

9. References

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