METROL
METHANE FLUX CONTROL IN OCEAN MARGIN SEDIMENTS

Cruise Report

Gunnar Thorson cruise

to the

Northern Kattegat

31.03. - 11.04. 2003

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within the Energy, Environment and Sustainable
Development

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1. Cruise objectives

The cruise integrated seismic studies of shallow gas occurrences and gas seeps in the northern Kattegat with geochemical analyses and microbiological process studies. Two study areas were selected:

A) The extensive depositional area in central northern Kattegat with holocene gassy sediments.
B) The areas east of Frederikshavn and in Læsø Rende with gassy sediments, subsurface plumes and gas seeps.

Earlier studies have shown that gassy sediments occur in large parts of the northern Kattegat. The gas bubbles are found in the upper tens of meters within the muddy and organic-rich holocene sediment. The upper boundary of gas occurrences varies from half a meter to more than ten meters. It was not clear to what extent the holocene deposits exerts the most important control on gas accumulation or whether deeper glacial and interglacial deposits are important gas sources. We therefore measured seismic profiles in areas suitable to understand these factors and compared the gas distribution with the distribution of dissolved methane in the pore water. Based on the seismic data, positions for sediment coring were selected.

The coring strategy distinguished two types of stations. Most stations were cored mainly to analyze the gradients of sulfate, sulfide, and methane in the pore water. Thereby, the subsurface depth of the sulfate-methane transition zone could be determined and compared to the presence or absence of in situ gas bubbles in the sediment. On a few stations an extensive program of analyses was run, including:

- pore water gradients of sulfate, sulfide, and methane
- rates of sulfate reduction, methanogenesis and methane oxidation
- solid phase geochemistry (POC, PON, sulfur and iron speciation)
- porosity, diffusion coefficients
- microbial populations: DAPI counts, FISH and 16S rRNA sequencing
- biomarkers and their isotopic composition
- isotopic compositions of methane, CO_2, and organic carbon
- ^{14}C-dating of methane and organic carbon

At each station at least one long core was sampled either with the gravity corer or the vibro corer plus an additional one with the shorter Rumohr lot. As the gravity corer and the vibro corer both tend to blow away and disturb the top sediment to several tens of cm depth, the Rumohr lot cores will be used to determine the absolute depths in the long cores. Since in both long and short cores the pore water sulfate gradients will be analyzed, the alignment of the long and and the short gradients will show how much of the long cores was lost.

2. Participants / participating institutions

Table 1. Participants of the two cruise legs

Name		Institution
Leg 1	Leg 2	
Fossing Dr. Henrik	Fossing Dr. Henrik	NERI
Quotrup, Tanja	Quotrup, Tanja	NERI
Lomstein Dr., Bente	-	Univ. Århus
Laier Dr., Troels	Laier Dr., Troels	GEUS
Jensen Dr., Jørn Bo	Jensen Dr., Jørn Bo	GEUS
Boserup, John	Boserup, John	GEUS
Troest, Peter	Hansen, Egon	GEUS
Jørgensen Prof. Dr., Bo Barker	Ferdelman Dr., Timothy	MPI
Borowski Dr., Christian	Borowski Dr., Christian	MPI
Knab, Nina	Knab, Nina	MPI
Parkes Prof. Dr., John	Brock Dr., Fiona	BRIS
Cragg Dr., Barry	Cragg Dr., Barry	BRIS
Gulin Dr., Maxim	Gulin Dr., Maxim	IBSS
Ion Dr., Gabriel	Ion Dr., Gabriel	GeoEcoMar

NERI:	National Environmental Research Institute, Department of Marine Ecology, Vejlsoevej 25, P.O.Box 314, DK-8600 Silkeborg, Denmark
GEUS:	Geological Survey of Denmark and Greenland, Øster Volgade 10 DK-1350 Copenhagen, Denmark
MPI:	Max Planck Institute for Marine Microbiology, Celsiusstr. 1, D-28259 Bremen, Germany
BRIS:	Biogeochemistry and Environmental Geochemistry Research Group, Department of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol BS8 1RJ, Great Britain.
IBSS:	A. O. Kovalevsky Institute of Biology of the Southern Seas, National Academy of Science of the Ukrane, Prospekt Makhimova 2, 99011-Sevastopol, Ukraine
GeoEcoMar:	National Institute of Marine Geology and GeoEcology, 23-25 Dimitrie Onciul St, 70318 Bucharest, Romania
Univ. Århus	University of Århus, Nordre Ringgade 1, DK-8000 Århus C, Denmark

3. Description of the research area:

Gas seeps in the northern Kattegat have lead to the formation of ^{13}C-depleted carbonate crust (δ^{13}C: -40 to -50 ‰) at numerous locations around the Læsø Rende area, over 60, some of which have attracted special attention e.g. the "bubbling reefs" (Jensen et al., 1992). In addition sub-sea floor gas-plumes in areas adjacent to the carbonate crusts indicate that methane is not consumed efficiently everywhere, before it reaches the seafloor. One of the purposes of the METROL Kattegat-cruise investigation was therefore to determine which factors control the occurrences of seeps/plumes, sediment characteristics as well as microbial activity.

In the Kattegat area, migrating gas and also in-situ methane are of microbial origin, however, seepage gas is considerably older than in-situ methane in adjacent areas (Laier et al., 1996). Thermogenic gas is not expected to be present in the area as no hydrocarbons were encountered in the Mesozoic sediments during drilling of an exploration well at Frederikshavn (Fig. 1). This well struck crystalline basement at 1286 m below surface (Fig. 2). The crystalline basement becomes even shallower as one moves in northeasterly direction from Frederikshavn towards Sweden (Fig. 2).

The source of the gas observed at the various seeps is most likely methane generated in the Eemian interglacial deposits (120 ka) that are capped by compacted glacial deposits (Laier et al., 1992). Minor reservoirs of this gas, 80-100 m below surface, have been exploited for household use in the Frederikshavn area (N. O. Jørgensen et al., 1990). The gas from similar reservoirs (possibly shallower) may leak to the surface through fractures in overlying seal of glacial clayey deposits. Thus, gas seeps/plumes occur where the Pleistocene (interglacial – glacial) deposits are shallow relative to the seafloor, i.e. towards SW in the profile in figure 2. Moving towards NE, the Holocene deposits increase in thickness, making it increasingly difficult to detect any gas from the Pleistocene that may reach the seafloor. Previous acoustic mapping in the area have indicated that when fine-grained Holocene deposits reaches thickness over 15-20 m, the concentration of in-situ generated gas exceeds that of the hydrostatic pressure and a free gas phase is formed (Fällt, 1982.)

The amount of gas released from a coastal site 5 km south of Frederikshavn as well as the dynamics of the individual seeps of this site was carefully studied by Dando et al. (1994). They also gave an estimate of the total gas release from the whole of the Kattegat area assuming that conditions were similar at all crust/seepage locations in the Kattegat. However, no geological information on the coastal site was provided by Dando et al. (1994a), therefore another objective of the METROL cruise was to examine to what extent this coastal site could be regarded as representative for various seepage locations taking into account the geology of the areas.

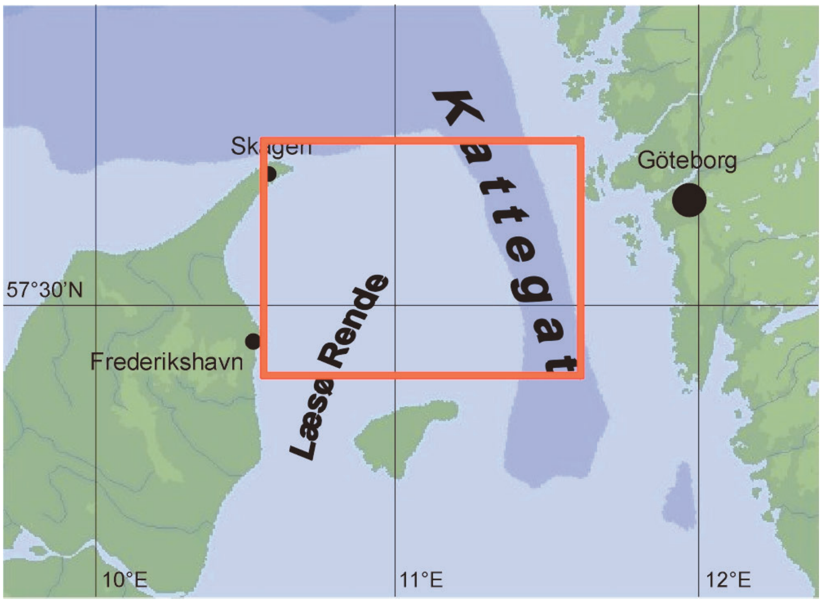

Figure 1. Research area in the Northern Kattegat.

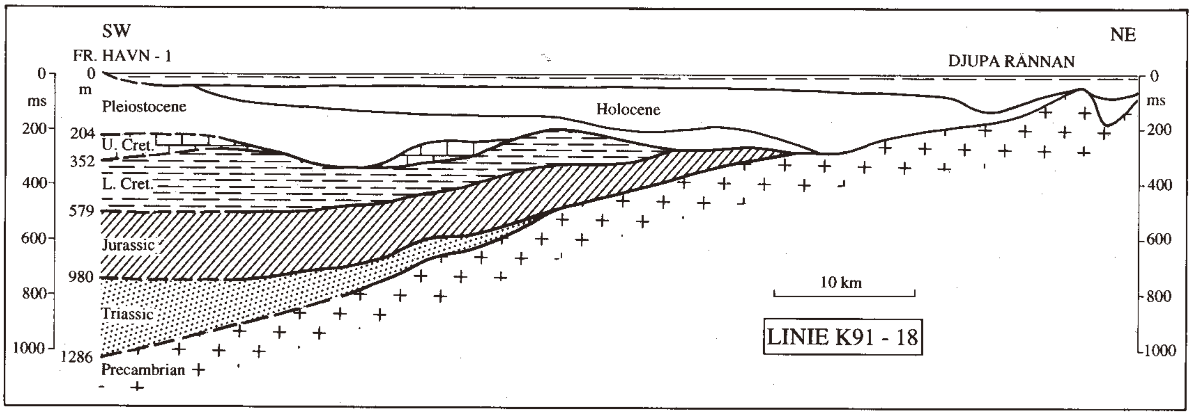

Figure 2. SW-NE geological profile of the northern Kattegat area (from Lykke-Andersen, 1992).

Sediment sampling stations were selected according to several criteria with respect to the objectives of METROL:

Table 2. List of the sediment sampling stations

Area	Station Name	Latitude	Longitude	Water Depth
Læsø Rende	K7	57°24.2' N	10°37.1' E	16 m
Læsø Rende	K8	57°23.4' N	10°37.4' E	15 m
Læsø Rende	K13	57°28.0' N	10°37.7' E	12 m
Læsø Rende-N	K14A	57°25.3' N	10°43.2' E	28 m
Læsø Rende-N	K14B	57°25.4' N	10°53.2' E	28 m
Læsø Rende-N	K14C	57°25.4' N	10°43.7' E	28 m
Læsø Rende-N	K15	57°25.0' N	10°34.3' E	9 m
Kattegat-N	K6	57°50.3' N	11°17.8' E	98 m
Kattegat-N	K9	57°48.4' N	11°03.2' E	47 m
Kattegat-N	K10	57°50.1' N	11°16.7' E	92 m
Kattegat-N	K11	57°50.0' N	11°21.3' E	73 m
Kattegat-N	K12	57°50.2' N	11°21.7' E	73 m

In Læsø Rende southeast of Frederikshavn, organic-rich holocene sediments of varying thickness overlie thick late-glacial deposits of coarser grain size and low organic content.

At Station K7, seismic profiles indicate the presence of gas plumes within the holocene sediment. The gas may ascend from deeper pleistocene deposits as will be revealed by post-cruise ^{14}C-dating. The gas may either penetrate or be retained by the coherent but rather thin holocene sediment. At Station K7 the sulfate-methane interface was located at 210 cmbsf (cm below seafloor). The methane concentration increased from zero to 1.2 mM, corresponding to 1 bar partial pressure, over a depth interval of ca 1.2 m.

Station K8 was situated near K7 but in a uniform area of very shallow gas within the holocene surface deposits. According to the seismic data the gas may reach to within a meter from the sediment surface but there is no clear evidence of gas escape structures. Preliminary methane analyses showed that the sulfate-methane interface is situated at ca 1 mbsf.

Station K9 was situated on a west-east transect between Skagen and the Swedish coast. The sea floor in this northern-most part of Kattegat is a depositional fan. It receives clastic material transported from the large rivers of northwest Europe into the southern North Sea and which is carried by the Jutland current into southern Skagerrak and finally settles east of the northern tip of Jutland. The sediment is holocene mud of tens of meters thickness and most of the area has gas from 4-6 meters sub-seafloor. Station K9 is located in the central part of the gassy area and the rather broad sulfate-methane interface is situated at 90-120 cm depth in the gravity core. The methane concentration increased from steeply from 0.1 to 1.2 mM over a depth interval of <50 cm.

Station K10 was situated in the depositional fan, just west of its front, near the deepest part of the trough along the Swedish coast. The station was chosen for comparison with sediments east and thus outside the depositional fan (Station K6) to show the influence of high holocene sedimentation. The sediment was gassy and acoustically turbid from about 4-6 mbsf. The sulfate-methane transition was situated ca 1 mbsf.

Station K6 was situated just east of the depositional fan, in the deepest part of the Swedish trough. The seismic profiles indicated no free gas but showed a 10-12 m thick layer of holocene sediment overlying late-glacial deposits. This late-glacial sediment was deposited over mounds of unknown nature, possibly basement rock or (according to M. Hovland) diapiric structures of plastic clay driven by entrapped gas. The sulfate-methane interface was situated ca 2 mbsf in accordance with a lower deposition rate of organic-rich sediment and the lack of free gas.

Station K11 and K12 were also situated in the Swedish trough south of K6. The two stations were chosen to demonstrate the effect of a thickening of the holocene layer from ca 10 m to 30 m K11 was cored where there was no visible gas and the holocene layer was ca 15 m thick. There was no detectable methane in the pore water down to 2.5 mbsf.

Station K12 was just some hundred meters away from K11 but situated over gassy sediment starting from 4-6 mbsf. The sulfate-methane interface was situated at 1-1.5 mbsf. Thus, over short horizontal distance with apparently homogeneous holocene sediment there was a great difference in the occurrence of methane gas. The only apparent difference was the depth of the holocene sediment.

Station K14 a, b, and c in Læsø Rende was situated where the depth of the sub-bottom free gas zone varied from less than 1 m to to over 7 m over a relatively short distance ~200 m. Three cores were taken to cover the different depths of the gas zone. The area around the K14 stations is otherwise characterised by a very shallow gas zone.

Station K15 was situated ca. 3 km off the coast of Frederikshavn. Gas plumes in the sandy holocene sediments were clearly seen on the acoustic profiles of the area. The gas plumes originated from the stratified late glacial sediments ca. 4-5 m sub sea-floor.

Station K13 was situated in a sandy area containing carbonate crusts. Gas seeps are known to occur in this area. Several attempts were made to obtain fresh samples of crust including bacterial mats previously observed in a vibro-core sample. The box corer was however not able to hit any crust containing sediment.

Station K18 was situated north of the Hirsholmene Isles 5 km NE of Frederikshavn. Frequent sub-seafloor gas plumes have been observed in the sandy holocene sediment. Less frequently plumes extend up into the water column. CTD samples were collected across one such area, hoping to confirm the presence of elevated methane concentration in the seawater.

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4. Equipment used

4.1 Seismics

- The Side-scan sonar system was an EdgeTech DF-1000 Digital Side-scan Sonar model, 100 kHz and 384 kHz. Data was collected using Triton Elics Isis acquisition software and stored on HP SureStore Optical 2600fx optical disks with simultanious plotting on paper by an OYO GS-612 printer/plotter. The horizontal sweep width of the side scan sonar is 75-100 m giving sea bottom coverage of 150-200 m.
- 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 towfish. The bandwidth of 9.6 kHz (0.4-10 kHz) gives a penetration of 50-500 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, ELAC LAZ 5000, which was connected to the navigation computer.
- 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 50-100 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 North Star 951x DGPS 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.

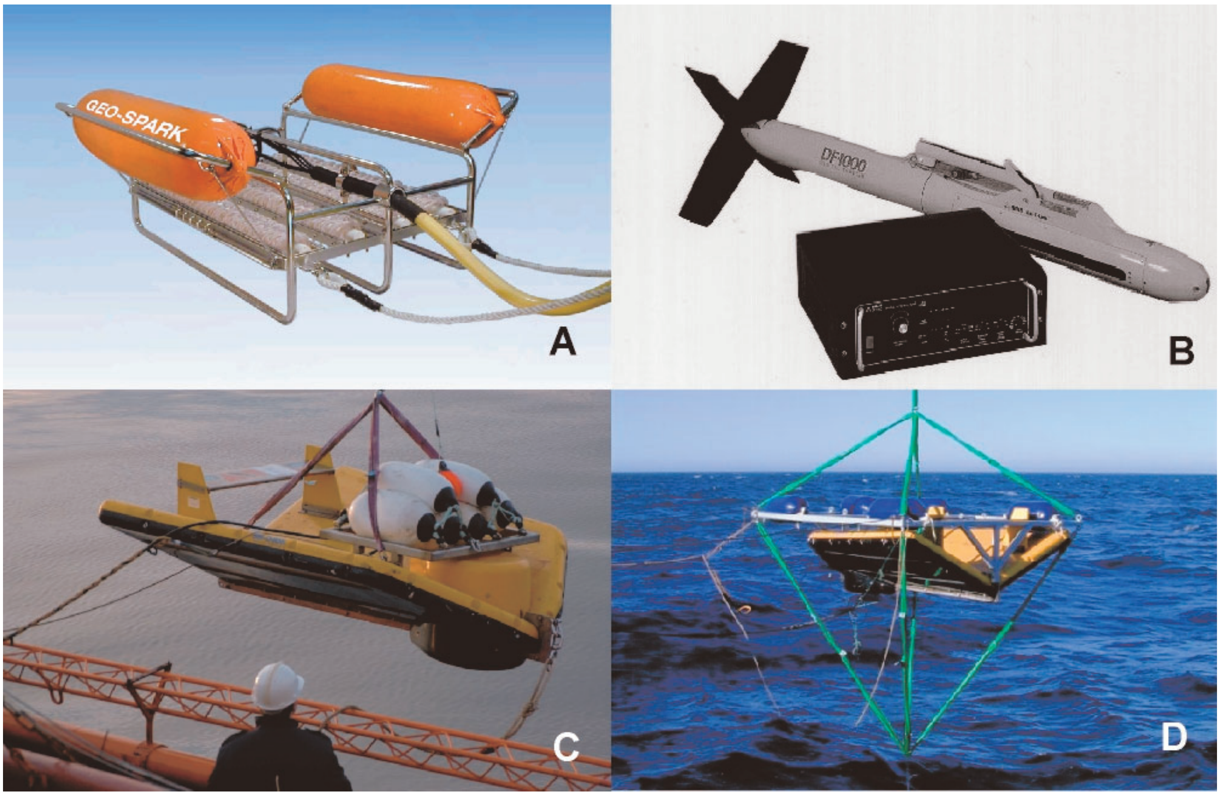

Figure 3: Seismic instruments. A: Single channel GeoSpark 200 system. B: EdgeTech DF-1000 Digital Side-scan Sonar system. C and D: X-Star Full Spectrum Sonar system, X-Star Tow Vehicle Model SB-0408.

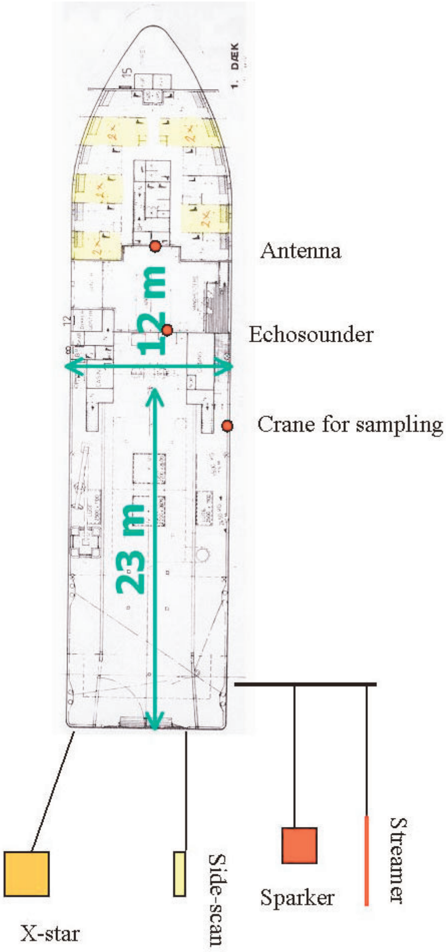

Figure 4: Instrument offsets on Gunnar Thorson. Sparker 13m starboard and 50m behind antenna. Side-scan 2m starboard and 50m behind antenna. X-star 7m port and 55m behind antenna. Echosounder 10m behind antenna

4.2 Sediment sampling gear

- The gravity corer (GC) was used at stations with silt sediments (K6, K7, K8, K9, K10, K11, K12). We used a top weight of approx. 700 kg and 4.25 long core tubes. The sediment cores were 3.1 to 3.9 m long.
- Stations with coarser sediments (K13, K14, K15) were sampled with the vibro corer (VC). This gear consists of a tall rack holding a 6-m long coring tube which is pushed actively into the sediment by a vibrating electric motor. The cores we obtained were 5.5 – 5.8 m long.
- The Rumohr lot (RL) was used for sampling the surface sediments which usually are only incompletely recovered with the long corers GC and VC. The RL consists of a top frame loaded with lead weights (~40 kg) and a PVC-glass core liner of variable length. A lid at the top end closes during bottom contact and seals the core on top during sample recovery. We used 1-m long core liners, and the core lengths obtained from the various stations ranged from 40 – 95 cm. These cores served for the depth calibration of the biogeochemical gradients found in the long cores GC and VC.
- The multi corer (MUC) we used is a special light-weight steel construction with 6 liners that are pushed simultaneously into the sediment. As this instrument did no work reliable, we did not use it regularly.
- The KC HAPS Corer is designed for taking undisturbed samples from hard as well as soft sediments. A cylindrical 136-mm (I.D.) steel tube mounted on a rack is pushed into the sediment by lead weights (68 kg). Lids on top and bottom prevent the core from sliding out of the tube during lift up. The HAPS corer was used at the sandy station K15 where the Rumohr Lot did not penetrate into the coarse sand. We recovered approx. 10 cm long sediment cores, which we subsampled in order to measure sulfate reduction rates.
- The box corer (BC, nick name “Brutalis”) we used was especially designed for sandy sediments. The “box” consisted of a ca. 40-cm wide steel tube which was pushed into the sediment by approx. 500 kg loaded with lead weights on the central column. This BC was deployed at station K13, were it recovered approx. 15 cm long cores. Due to insufficient sealing between the bottom closure and the steel tube, the sandy cores drained out immediately after recovery.

4.3 Water sampling gear

The CTD/rosette was used to sample water at well-defined depth. Twelve bottles each of 15 litres mounted in a rack are slowly lowered into the waters column. A CTD (conductivity, temperature and density monitor) equipped with an oxygen electrode continuously transmits data that is presented graphically on a computer screen. Based on this reading the technician/ scientist determines at which depth the bottles should be closed and water samples collected.

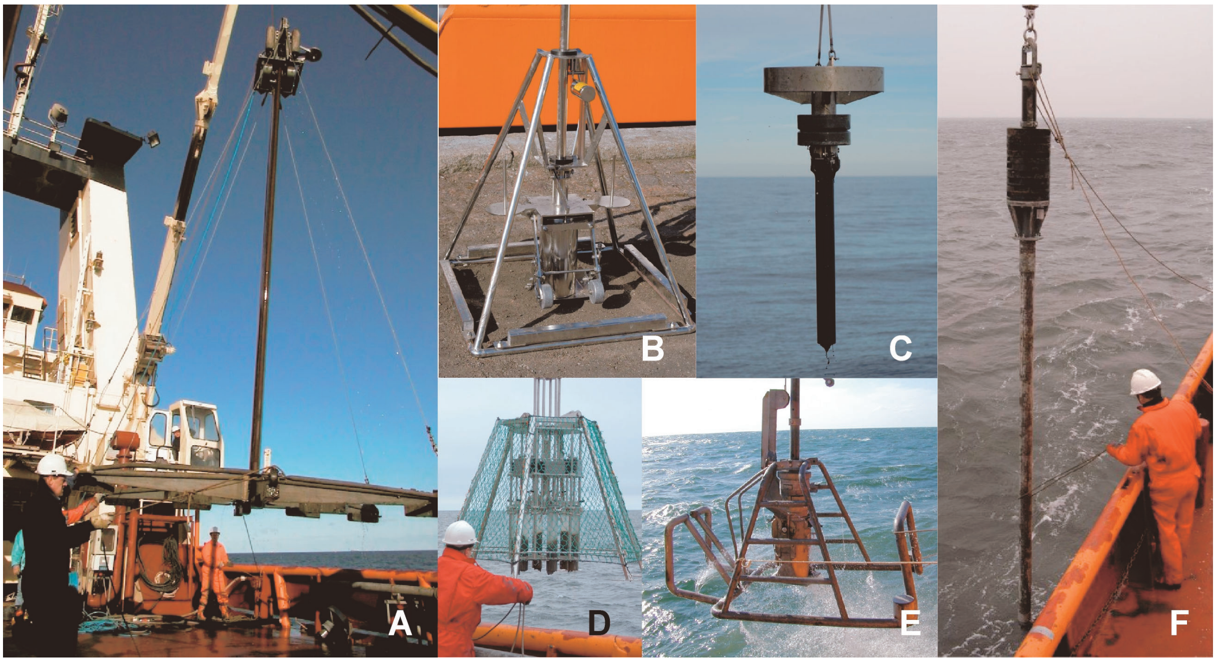

Figure 5: Sediment sampling gear. A: Deployment of the vibro corer. B: HAPS corer partially disassembled, without weights. C: Recovery of the Rumohr lot with core in plexy-glass liner. D: Recovery of the multi corer with sediment cores. E: Box corer “brutalis”; the tube-shaped “box” is closed and contains a sample. F: Deployment of the gravity corer equipped with a 4.25-m long tube.

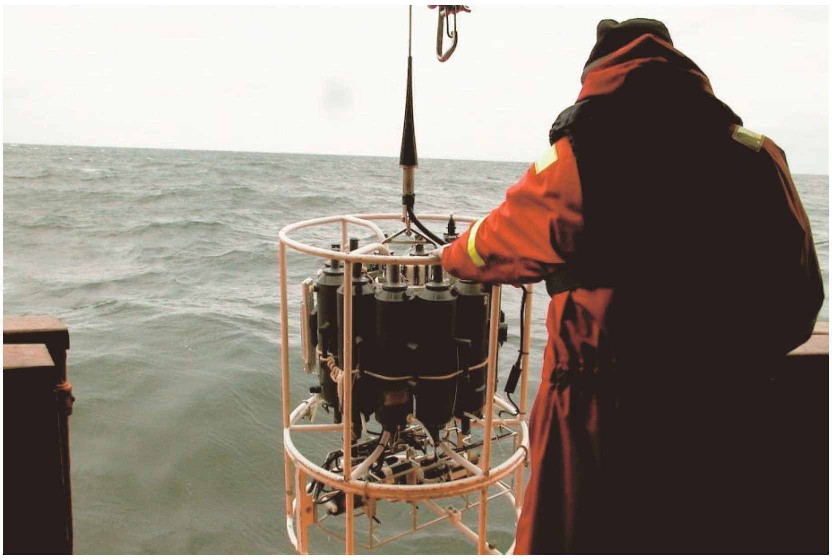

Figure 6. Recovery of the CTD/rosette. The niskin bottles are closed and contain water samples.

5. Narrative

Sunday, 30-03-2003
The day was used to build up the onboard labs, coring instruments and prepare seismic equipment for deployment.

Monday, 31-03-2003
Depart Copenhagen harbour at 0:30 a.m. and arrive at Station K7 ESE of Frederikshavn at 3 p.m. Start sediment coring in semi-rough weather. Weather improves early evening and allows seismic studies during night along a transect starting at K7 (via K1 and K6) towards the Swedish coast.

Tuesday, 01-04-2003
The seismic studies continue until noon steaming SW from the Swedish coast "near" K6. At 1 p.m. sediment coring starts at station K8 (south of K7) and continues until dark. Because of increasing winds seismic studies cannot be performed during night. Activity all day in the lab processing sediment cores from Station K7 and K8 and measuring CH_4. Interpreting the seismic signals in order to chose the right stations for sediment sampling.

Wednesday, 02-04-2003
A long day with calm weather – ideal for gravity corning. Start sediment sampling at 8:30 a.m. W of the Danish/Swedish border at Station K9 (E of Skagen). Continue E to Station K10, K6, K11, and K12 where the last gravity corer is recovered at 8 p.m. Sediment samples slowly but steadily piles up in the lab. Perfect weather for seismic studies. Hence, continued from the "last measurement of Tuesday morning" to the area around Læsø.

Thursday, 03-04-2003
The wind picks up around breakfast and the seismic studies are thus terminated. Sediment sampling is also not possible and Gunnar Thorson returns to Frederikshavn harbour. Activity all day in lab processing sediment cores and measuring CH_4 from all the K-Stations. Ground penetrating radar (GPR) measurements in the area of known coastal gas seeps were carried out during the afternoon (Fig. 7). Approximately 2000 m of georadar-lines were measured in order to detect subsurface depth of the Eemian interglacial clay which is supposed to be the source of the gas.

Friday, 04-04-2003
Leave harbour shortly after breakfast to test new program for seismic equipment. No sediment sampling but there is still a lot of sediment and samples to be processed. Gunnar Thorson returns to Frederikshavn in the evening for exchange of scientific party. The four cruise participants Jørgensen, Lomstein, Parkes and Troest leave the ship and are replaced by the newly arrived Brock, Ferdelman and Hansen (see Tab. 1).

Saturday, 05-04-2003
Sunny sky but really stormy. Not possible to do neither sediment sampling nor seismic studies at sea. Thus the biogeochemists continue with pore water pressing, CH_4 measurements and sectioning sediment. Continued GPR measurements in the area of known coastal gas seeps were carried out. Approximately 2800 m of georadar-lines were measured (Fig. 8). Data from geotechnical borings (5 m deep) located approximately 100 m from the nearest georadar lines were used to interpret the reflections of the georadar profiles. The borings were drilled in 1996 prior to the construction of the highway.

Figure 7. Ground penetrating radar (GPR) measurements performed on shore in the area of known coastal gas seeps south of Frederikshavn.

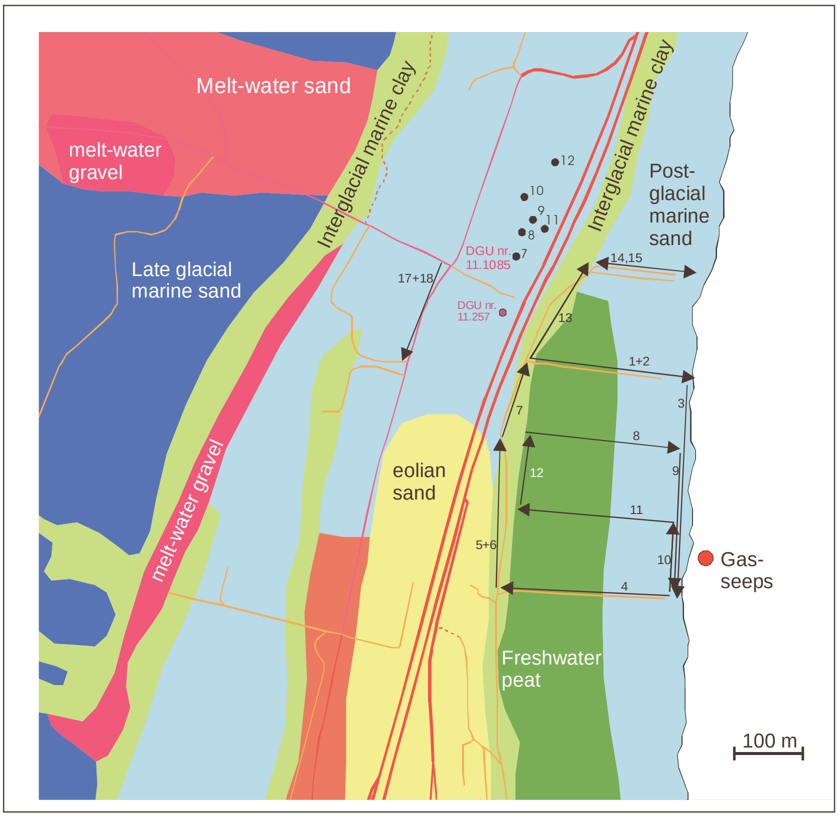

Figure 8. Georadar lines plotted on a sub-surface soil map of the area around the coastal seepage site.

Sunday, 06-04-2003

The strong winds continue and so does the activity in the lab during another day in harbour, while a group of scientists used the opportunity to sample carbonate crusts formed around the coastal gas seeps some 5 km south of Frederikshavn (Fig. 9). Approximately 1 kg of carbonate crust samples were collected on the beach. The samples were however much smaller than the large slabs observed by Dando et al. (1994) around the seeps themselves 10-20 m sea-wards from the beach. Therefore, the samples probably represent fragments of the large slabs that were transported to the beach by the waves. No seepage of gas could be observed on that particular day due to waves and high tide.

Figure 9. Fragments of carbonate crust collected on the beach adjacent to the shallow gas seeps 5 km south of Frederikshavn.

Monday, 07-04-2003

Decreasing winds – leave Frederikshavn in the morning. Arrive at Station K14 W of Frederikshavn at 9:30 a.m. and start vibro coring immediately. Continue to Station K15 (close to the harbour) but unfortunately Gunnar Thorson loses an anchor after the third sediment core has been retrieved from this station. This initially seems to be the end of vibro coring. Seismic studies around Hertha's Flak (midway between Skagen and Læsø) all night. All day sediment cores are being processed in the lab – seems to be a never ending story.

Tuesday, 08-04-2003

Seismic studies continue until after breakfast. Steam to K9 and K10 for sediment sampling all afternoon. Despite the loss of the third anchor, it was managed to obtain a vibro core sample from station K9. Return to Hirsholmene and begin seismic studies around sun set. Still a lot of samples to handle from previous days.

Wednesday, 09.04-2003

Seismic studies terminated shortly before breakfast. Continue sediment sampling at K8 (Rumohr lot) and K13 (box core, SE of Hirsholmene) until noon when strong winds force Gunnar Thorson back to Frederikshavn. Return to position NW of Hirsholmene (K18) late afternoon to sample water above CH_4-seep area. Return to Frederikshavn due to strong winds – stays overnight in harbour. Finish pore water pressing and CH_4 analyses.

Thursday, 10-04-2003

Strong winds – not possible to sample sediment. However, leave harbour to rescue lost anchor at Station K15 – successfully. Return to Frederikshavn where part of the scientific party and equipment leave the ship.

Friday, 11-04-2002

Gunnar Thorson returns to Copenhagen in the morning.

6. Core treatment

6.1 Gravity cores, vibro cores: geochemical parameters, process rates and microbiology

The length of the sediment cores sampled by gravity coring and vibro coring were up to 360 cm and 580 cm, respectively. Immediately after retrieval the core was cut into 1-m long sections. Before the sectioned core liner was capped,

1) sediment was sampled from the top of the sediment for *in situ* CH_4 concentrations
2) temperature was measured
3) pH was measured

The capped sections were stored upright in a cold container at *in situ* temperature until further treatment.

Based on the “rough” *in situ* CH_4-profile (i.e. 1-m interval) it was decided which section(s) should have a more detailed CH_4-profile measured (20-cm intervals). This profile was determined from sediment, which was sampled from the side of the core after little “windows” were carefully cut in the side of the core liner. After sediment sampling these windows were thoroughly closed and sealed with gas-tight tape.

The CH_4 profile obtained from the “window-measurements” was used to locate the sulfate-methane transition zone (SMT) more exactly. The SMT should be positioned at the depth where CH_4 appears with a steep concentration increase (see preliminary results below).

At all stations concentrations of

- CH_4
- SO_4^{2-}
- H_2S

were determined with various depth resolutions, depending on position of the SMT. In and around the SMT, CH_4, SO_4^{2-}, and H_2S were measured with depth-intervals as narrow as 2 cm. Above and below the SMT the depth resolution increased at some station up to 20 cm or more.

Sections subject to detailed sub-sampling were placed horizontally in a cutting rag and the necessary number of 20-cm long Plexiglas core liners were pressed 10 cm into the sediment (Fig. 10). The sediment was extruded from the GC-core liner using a piston until the bottom of the inserted core liners were in line with the rim of the GC core liner and the extruded “lump” of mud was cut of. The subcores were closed with rubber stoppers, gently washed and stored at *in situ* temperature until further treatment.

At two stations (K9 and K15) the sediment sampling was considerably extended. Because of the large amount of samples and parameters to be determined the sediment was sampled from to parallel sediment cores (first and second core, respectively, see Tab. 3). Only CH_4 concentration was measured in both cores in order to be able to position the SMT of the two cores. The analyses performed at Station K9 and K15 are outlined in the table 3.

Table 3. Sub-sampling scheme for detailed analyses of long cores (CG and VC).

	No.	**Analyses**	**Depth intervals resolution**		
			SO_4^{2-} zone	SMT	CH_4 Zone
first core	1	$H^{14}CO_3^{2-}$ methanogenesis	20 cm	2 cm	5 cm
	2	Acetate ^{14}C-methanogenesis	20 cm	2 cm	5 cm
	3	Anaerobic oxidation of methane (AOM)	3*	2 cm	5 cm
	4	Sulfate reduction rate (SRR)	20 cm	2 cm	**No sample**
	5	CH_4	**no sample**	2 cm	
	6	Density/ porosity	5*	2*	5*
	7	Volatile fatty acids	10 cm	2 cm	10 cm
	8	SO_4^{2-}/ H_2S	10 cm	2 cm	10 cm
	9	HCO_3^{2-}	10 cm	2 cm	10 cm

* number of samples in the zone

second core	10	AODC bacterial counts	1st section 5 samples total		
	11	FISH			
	12	Isotopic $\delta^{13}C$ CH_4 & CO_2			
	13	δ D_2O			
	14	Biomarkers Archea lipids	2nd section		
	15	16S methanogens-acetogens	3rd section		
	10	AODC bacterial counts			
	16	Iron / Si	4th section		
	17	CH_4 / SO_4^{2-} diffusion	5th section		
	10	AODC bacterial counts			
	18	CH_4	**none**	10 cm	**None**

Thickness of each section: 5 cm

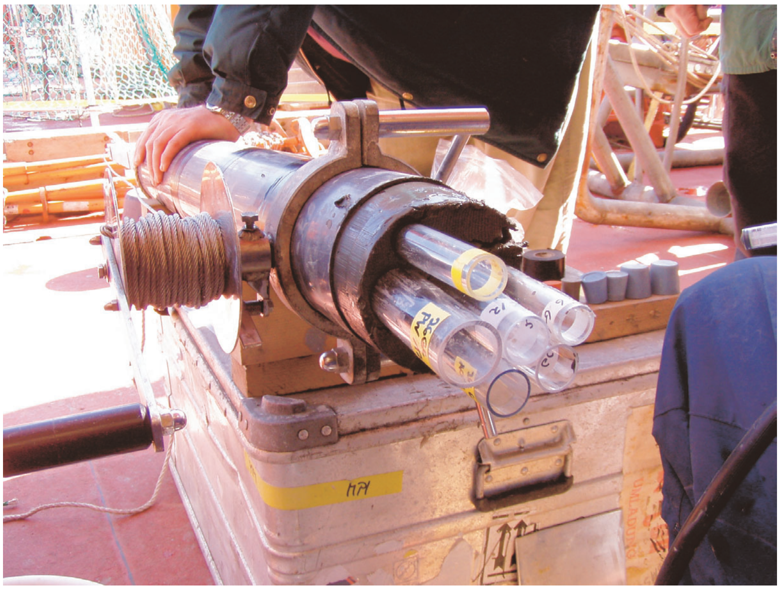

Figure 10. Sub-sampling of the 1-m sections of a gravity core for detailed analyses of geochemical and microbiological parameters and process rate measurements. Core liners of various diameters were pushed from the top into the sediment.

6.2 Gravitiy cores, vibro cores: sedimentological description

The on-board handling of the up to 6-m long geological cores (GC and VC) started with cutting 1-m core sections. The sections were longitudinally split and the cut was documented by digital photography before the sediments were described. For later grain size analyses, macrofossil determination and dating a number of sub-samples were taken.

6.3 Rumohr lot, MUC, and HAPS cores: geochemical parameters, process rate measurements

Cores obtained with the Rumohr lot were used to calibrate the depth range of the long cores obtained with the gravity corer and the vibro corer by comparison of the SO_4^{2-} profiles. A minimum of one Rumohr-lot core was sampled at each sampling location together with the long cores (GC and VC). The Rumohr-lot cores were sub-sampled throughout their entire length in order to measure SO_4^{2-} concentrations: Small core liners (36 cm in diameter) were pushed in from top and extruded together with the respective core section by a piston from below. The 36-cm diameter sub-cores were sampled in 2 to 25-cm depth intervals for pore water pressing and subsequent analyses of the concentrations of SO_4^{2-} and H_2S, porosity and density.

A selected number of Rumohr lot cores was analysed for the distribution of Pb^{210} in order to determine the rate of vertical mixing of the sediment and for analyses of bacterial DNA and FISH. For analyses of Pb^{210}, slices of 2 cm thickness were extruded at the top of the cores and filled into petry dishes. The wholly filled petry dishes were capped with lids and sealed with gas tight tape. For DNA analyses and FISH, samples were obtained from various depth layers with 3-ml and 5-ml syringes.

Sediment cores obtained by the multi corer were treated as described above for the Rumohr lot. As this instrument did not work properly, it was only used in two locations (K8 and K9).

The HAPS corer was used at station K15, were it recovered two approximately 10-cm long cores. The sandy sediments drained immediately after the opening of the corer, however, it was possible to sub-sample one of the two cores from the top with small core liners for measurements of SO_4^{2-} concentrations and SSR.

The box corer was used in an attempt to sample carbonate crusts at site K13. The box was lifted from the cores and the sediment samples were inspected by hand for carbonates. However, carbonate crust were not recovered.

7. On-board analyses

7.1 Seismics

The seismic data types described in section 4 were stored in digital formats and plotted on paper.

A preliminary interpretation of the seismic data was used as background for identifying different types of acoustic signatures indicating methane in the sediments, interpretation of the geological settings and selection of sampling positions. So the general procedure was to survey a seismic grid as a basis for the following sampling. The combination of X-star high resolution and Sparker deeper penetration is the ideal set-up for mapping of the methane gas. However the Sparker profiles turned out to be the best profiles in the present survey area and was mainly used for identification of gas and selection of sampling sites.

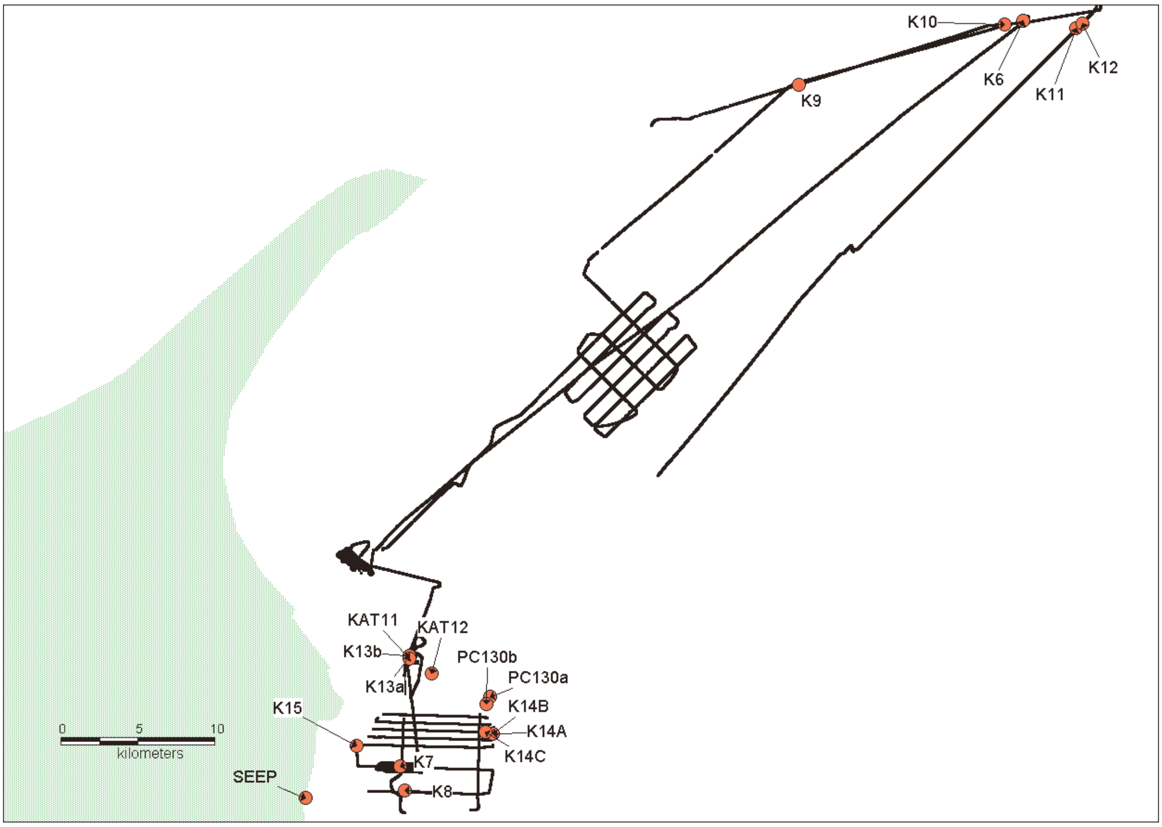

Figure 11. Overview on all seismic lines

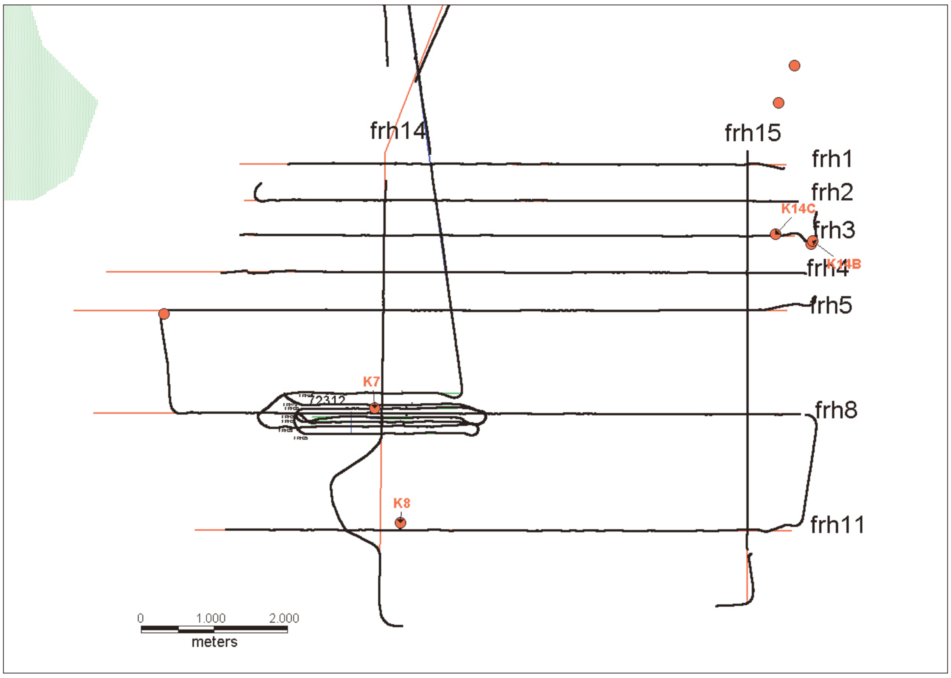

Figure 12. Seismic lines Frederikshavn overview.

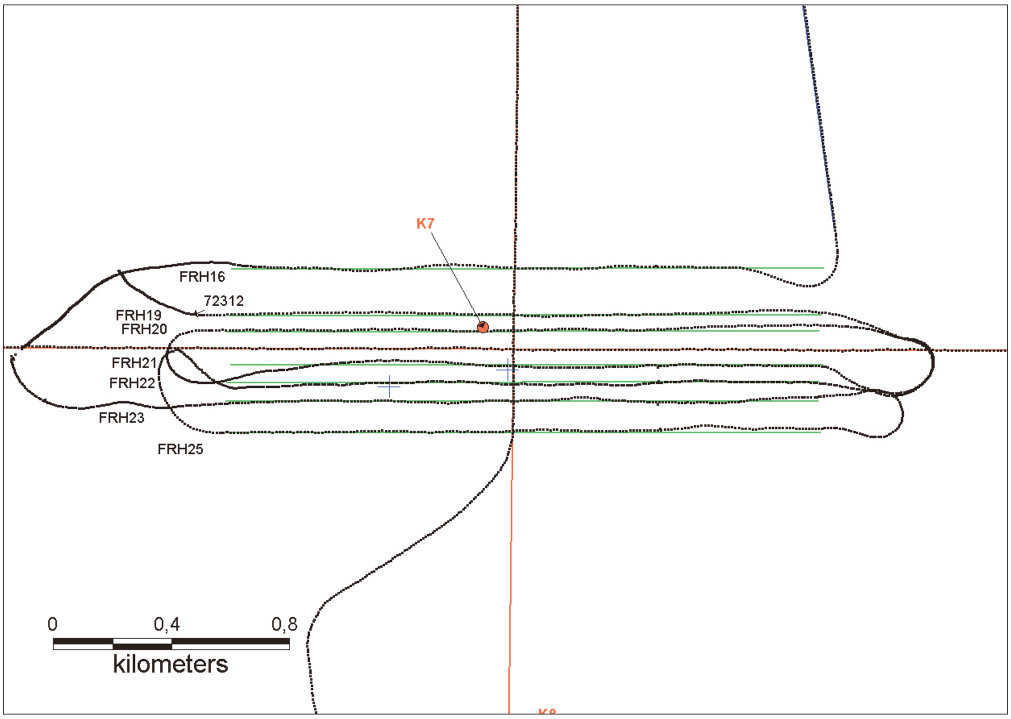

Figure 13. Seismic lines Frederikshavn detailed.

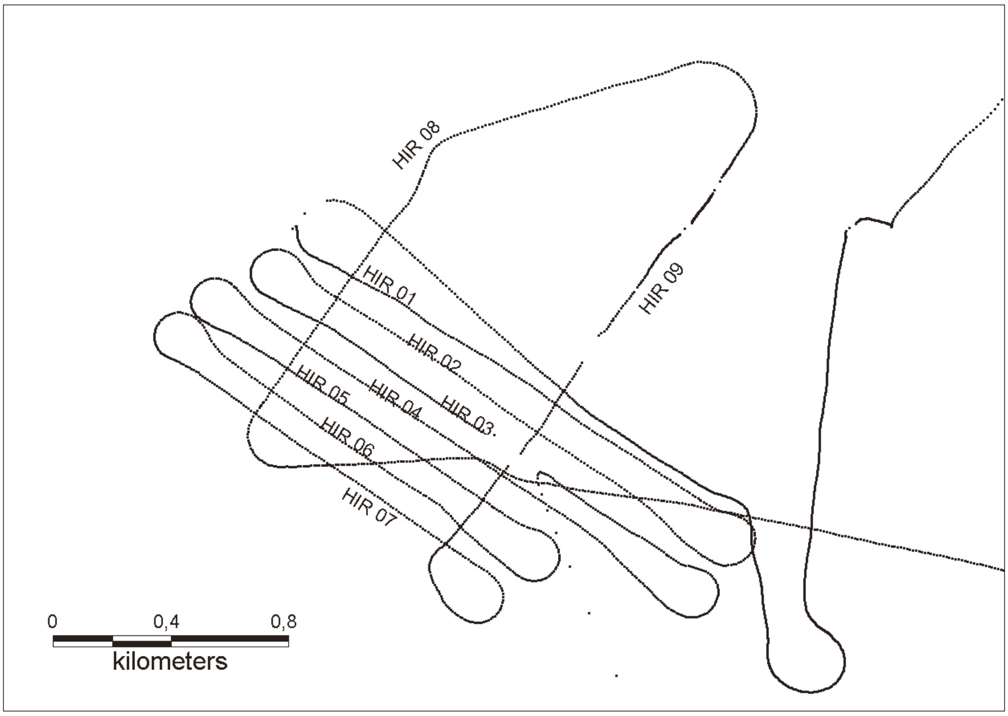

Figure 14. Seismic lines Hirsholmene.

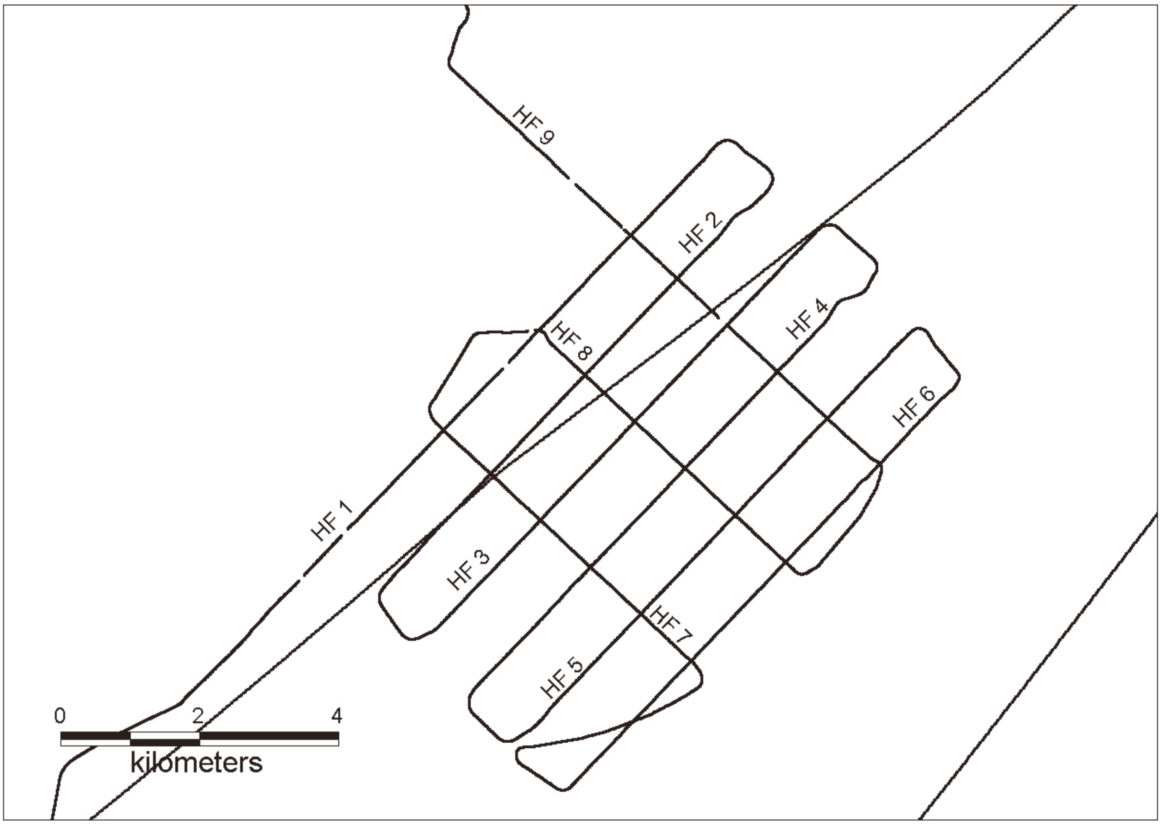

Figure 15. Seismic lines Hertha’s Flak

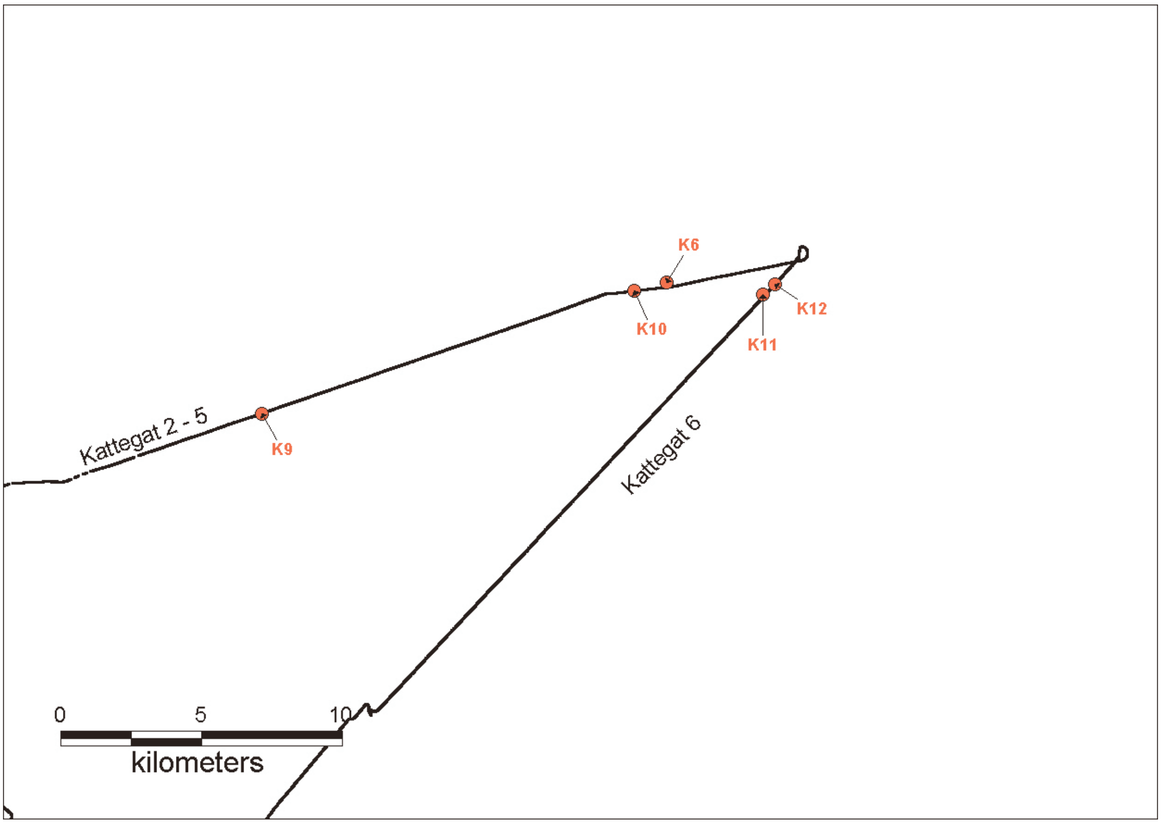

Figure 16. Seismic lines Kattegat 2-6.

7.2 Sediment analyses

CH_4 profiles: Sediments sampled for dissolved methane analyses were processed on board as soon as possible (for depth resolutions see section 6.1 and Tab. 3). 3 ml of sediment sampled with 5-ml syringes were placed in 20-ml serum vials which contained 6 ml of water and 2-3 glass beads. The vials were immediately closed with a rubber stopper and an aluminum crimp seal. The samples were vortexed, left ca 1 h for gas equilibration, and 25 µl of the headspace was taken for methane analysis by gas chromatography using a Varian 3400 gas chromatograph equipped with a splitless injector, a capillary column (30m x 0.544 mm), and a flame ionization detector. N_2 served as carrier gas with a flow rate of 6 ml min^{-1}. Methane elutes at 1.8 min. The methane peak was quantified by comparisons with a 5 point linear calibration curve and corrected for a background.

Pore water pressing for analyses of SO_4^{2-}, H_2S, HCO_3^-, and fatty acids:

A. cores sampled for methane-sulfate transition zone:
Samples for pore water analysis were taken with 36-mm diameter subcores from GCs and RLs in 5-10 cm intervals in the top 2-3 m of the sediment surface. The lower sections of the GCs were sampled every 20 cm.

B. cores sampled for chemical gradients and rates of bacterial processes:
The top 3 m of the cores 26GC and 58VC were sampled with 36-mm diameter subcores. The sampled depth range included the methane-sulfate transition zone. Below 3 m depth the sediment was sampled for pore water in 20 cm intervals.

2 cm of the subcores were squeezed under a pressure of 3 bar N_2 using a pore water squeezing machine (KC Denmark).

- SO_4^{2-}, H_2S: 0.5-3 ml of the pore water from each 2 cm-section were transferred into 1 ml zinc chloride 2 % (w/v) and stored at 4°C.
- Bicarbonate: 1.5 ml porewater from 26GC and 58GC were stored in 20 µl $HgCl_2$ and kept at 7°C.
- Fatty acids: 1-4 ml pore water was filtered (0.2 µm) and stored at 4°C

Sulfate reduction rate: Sediment from 26GC and 58VC was sampled once or twice per meter section and throughout the methane sulfate transition zone using 20 cm subcores (26 mm ID) to determine sulfate reduction rates.
5 µl (400 kBq) $^{35}SO_4^{2-}$ solution were injected into the subcores in 1 cm depth intervals. After incubation at 6°C for 10-12 the bacterial sulfate reduction of each 1 cm-section was stopped in 6 ml zinc acetate 20 % (w/v) and stored frozen for transport to Silkeborg.

Anaerobic oxidation of methane: For the analysis of the rates of AOM, the entire sulfate-methane transition zones of 26GC and 58VC were sampled with 20-cm subcores as described above (see section 6.1). One ore two additional samples were obtained from each of the remaining 1-m core sections. 50 µl $^{14}CH_4$ was injected from the side into each centimeter interval of the subcores. Incubation time was 10-12 h at 6°C. The incubation was stopped by transferring 2-cm slices of the subcores sediments into 25 ml NaOH (2.5%). The sediment was then vortexed until it was completely suspended. The samples were taken to Bremen for rate determination.

Rates of methanogenesis and acetogenesis: Samples (10 cm mini-cores) for measuring rates of bacterial methanogenesis and acetogenesis were taken from gravity core 26GC and vibro-core 58VC. Sampling frequency was one or two per metre except at the methane-sulfate transition zones where the entire length of the 1-metre core was sampled.

Mini-cores were injected at 2 cm intervals with 2 µl of isotope (14-C bicarbonate or 14-C Acetate) and incubated at 6°C for 18 hr (bicarbonate) or 6 hr (acetate). A total of 199 samples were run. Incubations were terminated by extruding the sediments into NaOH (1 M). The samples were returned to Bristol for processing.

Geological description of GC and VC cores: The sedimentological description included determination of sediment type and structures as well as contents of macro fossils and identification of color acording to the Munsell 1998 color charts. Finally, a visual interpretation of depositional environment and stratigraphy was performed.

8. Preliminary results:

8.1 Seismics

Station K15: Plumes of gas are observed in the Holocene sandy sediment which constitutes the upper 5-7 m. The gas derives from the late glacial deposits, below the Holocene (Fig. 15).

Station 14 represents a fairly small area of the Læsø Rende where the sub-bottom depth of gas zone increases from less than 1 m to approximately 6 m.

Stations K6 and K10: K10 is located near the edge of the large shallow gas area. K6 lies just outside this area. The depositional environment appears to have changed at some point during the Holocene.

Stations 11 and 12 illustrate the relationship between free gas formation and thickness of Holocene fine grained sediments

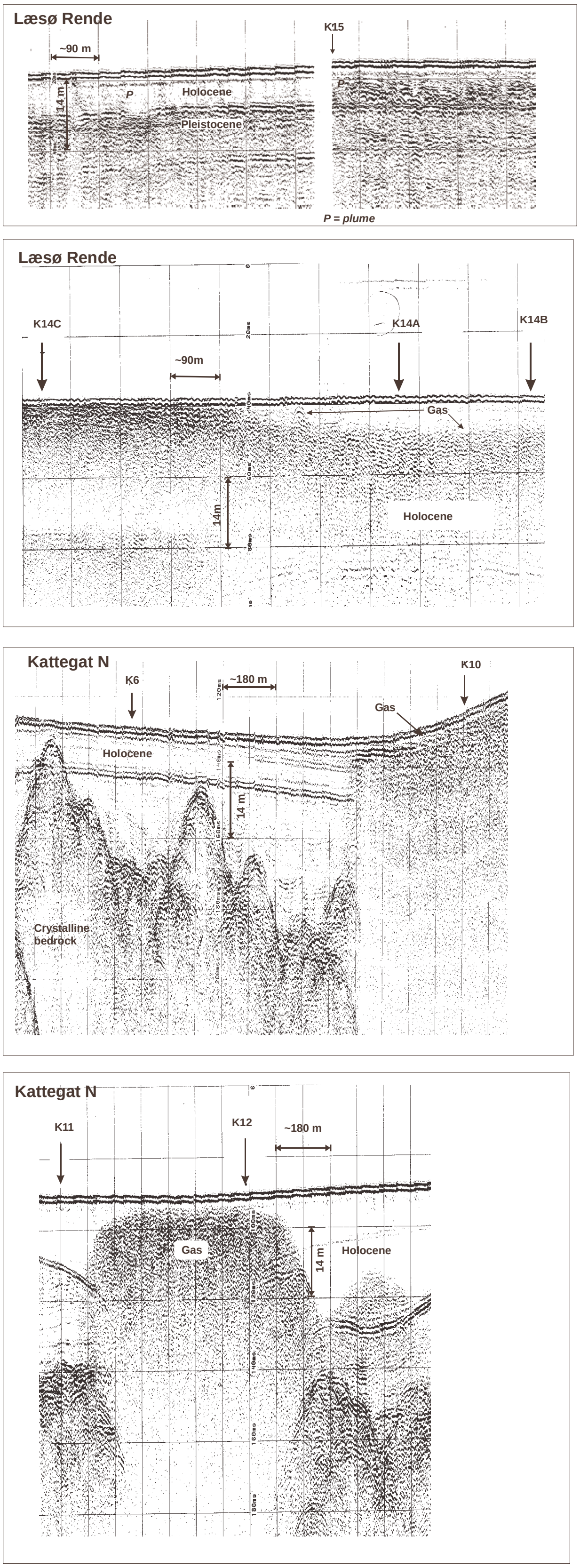

Figure 15. Seismic profiles of the Læsø Rende area and stations in the northern Kattergat. For short descriptions, see text above.

8.2 Sulphate-Methane-transition zone (SMT)

The SMT forms a narrow layer around the depth where the profiles of sulphate and methane concentrations cross. As an example, Figure 15 shows the CH_4 and SO_4^{2-} profiles at the two contrasting locations K9 and K15. In the core 26GC, which was obtained from station K9 in the central northern Kattegat, the SMT was located ca 0.9-1.2 m below the top of the core. The methane profiles of other cores sampled at K9 indicated very different depths for the SMT. In some cases, methane nearly reached the top end of the core, while in other cores methane was detected only below 2-3 m depth. According to the log of the ship positions, the sampling locations of theses cores deviated by several tens of metres, which indicated a heterogeneous depth distribution of methane at K9. The heterogeneity of the distributions of the geochemical parameters at K9 is also supported by the divergent sulphate profiles measured in 26GC and in the Rumohr-lot core 31RL (Fig. 15). In the sandy sediments of K15, dissolved methane occurs only below 3.8 m from the top of the core. The corresponding sulphate profile indicates the SMT between ca 3.8 and 4.1 m below the top of the core.

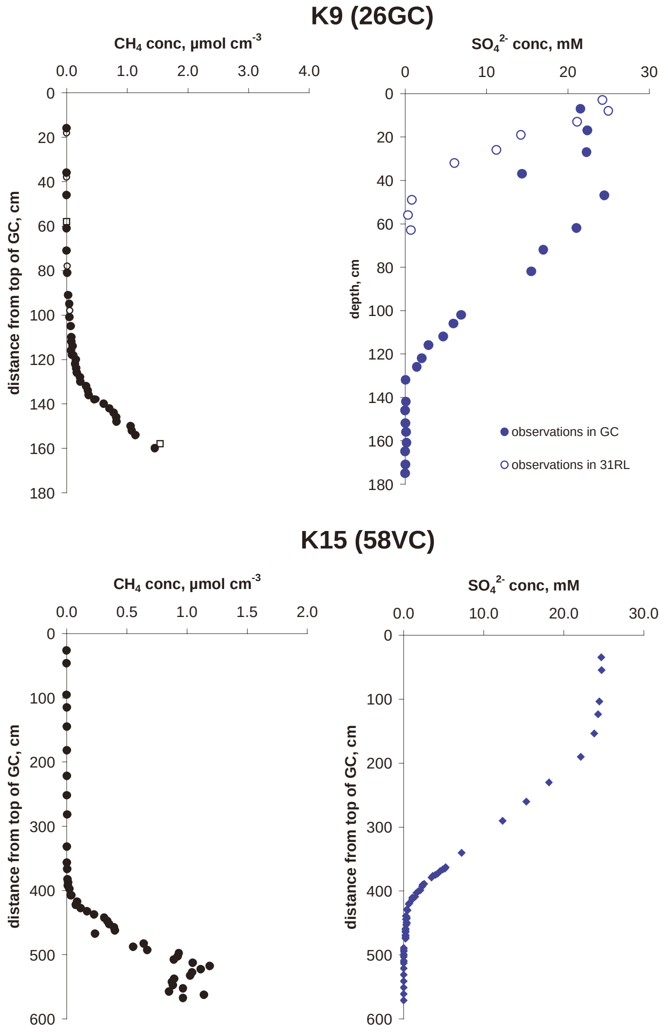

Figure 16. CH_4 and SO_4^{2-} profiles at the two contrasting sampling locations K9 (northern Skagerrak) and K15 (Læsø Rende). The cross points of the CH_4 and SO_4^{2-} profiles mark the depths of the SMT. K9 was sampled with the gravity corer (deployment 26GC), while the sandy sediments at K15 required the use of the vibro corer (deployment 58VC). An additional SO_4^{2-} profile was obtained from a Rumohr-lot core at K9 (31RL).

8.3 Geological description of GC and VC cores

Sedimentological core log Metrol GT03

Core no. 57VC Station K15 **Water depth** 9 m.

Position WGS 84 57°24.9328'N 10°34.2992' E

Samples shells	Sample depth m	Core no. m	Coring depth m	Lithological description	DGU code
		VI 0.00-0.87 V 0.87-1.87 IV 1.87-2.87 III 2.87-3.87	0.00 – 3.80	SAND, very fine, contents of clay, contorted by coring, originally weak lamination with few clay-silt lamina, variations in contents of marine shells from contents to strong contents, about 3.40m large Cardium and Turitella (3-4cm), GEY 1 5/2 greenish grey. Holocene marine.	HS-HL
		II 3.87-4.87 I 4.87-5.87		CLAY-SILT, heterolithic, horizontal lamination, contorted by coring, very few shells marine, below an upper unconformity the uppermost 40 cm flamed with contents of sand balls, GLEY 1 5/2 greenish grey. Late glacial clay	TL

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Most cores, except that of K15 described above, consisted of clayey silts and silty clays. Grain size analyses as well as TOC measurements are currently being performed.

9. List of 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
31.03.2003	Kattegat 1	6366992	597457	6405814	613000	21:08	01:41
01.04.2003	Kattegat 2	6405863	613335	6398123	626438	01:44	05:15
01.04.2003	Kattegat 6	6413742	640979	6398123	626438	05:15	08:18
03.04.2003	FRH 14	6366567	597434	6360466	597517	20:15	21:09
03.04.2003	FRH 15	6360734	601994	6366941	602408	21:42	22:30
03.04.2003	FRH 1	6366745	602913	6366795	596102	22:40	23:30
03.04.2003	FRH 2	6366552	595752	6366263	603022	23:34	00:27
04.04.2003	FRH 3	6366257	603172	6365836	595539	00:28	01:32
04.04.2003	FRH 4	6365295	595145	6365286	603106	01:38	02:32
04.04.2003	FRH 5	6365007	603314	6364801	594610	01:36	03:46
04.04.2003	FRH 8	6363373	594966	6363353	603043	03:49	04:57
04.04.2003	FRH 11	6363353	603043			05:00	
07.04.2003	HF 1	6377753	596351	6394459	612646	23:19	02:36
08.04.2003	HF 2	6394459	612646	6387540	608281	02:39	03:58
08.04.2003	HF 3	6387540	608281	6393266	613787	03:58	04:59
08.04.2003	HF 4	6392958	614454	6386988	609153	05:06	06:14
08.04.2003	HF 5	6386347	608767	6391422	614769	06:15	07:26
08.04.2003	HF 6	6391759	615374	6385433	610391	07:27	08:22
08.04.2003	HF 7	6385371	609797	6390145	608646	08;27	09:26
08.04.2003	HF 8	6390744	608200	6388726	613043	09:33	10:23
08.04.2003	HF 9	6388364	613707			10:29	11:32
08.04.2003	HIR 01	6377228	593552	6376618	594503	21:23	21:35
08.04.2003	HIR 02	6376426	594844	6377063	593653	21:35	21:49
08.04.2003	HIR 03	6377312	593338	6376492	594292	21:49	22:09
08.04.2003	HIR 04	6376256	594650	6377092	593255	22:09	22:27
08.04.2003	HIR 05	6377180	592961	6376493	593937	22:33	22:41
08.04.2003	HIR 06	6376374	594148	6376876	593246	22:43	22:54
08.04.2003	HIR 07	6377036	593058	6376215	593995	22:56	23:11
08.04.2003	HIR 09	6376215	593995	6377014	594349	23:11	23:23
08.04.2003	HIR 08	6377943	594843	6376955	593304	23:41	23:55
08.04.2003	Transit 01	6376713	593161	6375452	599380	23:57	00:48
09.04.2003	Transit 02	6375284	599589	6371118	597809	00:50	01:25
09.04.2003	KOL 1	6370763	597690	6370064	597468	01:27	01:32
09.04.2003	KOL 2	6369883	597642	6370975	597867	01:37	01:45
09.04.2003	KOL 3	6371186	597936	6370982	597953	01:47	01:51
09.04.2003	KOL 3A	6370742	597698	6370008	597623	03:01	03:37
09.04.2003	Transit 03	6369792	597590	6363799	598462	03:39	04:26
09.04.2003	FRH 16	6363623	598311	6363666	596614	04:28	04:40
09.04.2003	FRH 23	6363166	595944	6363666	596614	O5:11	05:31
09.04.2003	FRH 25	6363087	598596	6363097	596509	05:36	05:51
09.04.2003	FRH 22	6363187	596234	6363253	598362	05:53	06:15
09.04.2003	FRH 20	6363227	598579	6363455	596505	06:15	06:38
09.04.2003	FRH 21	6363396	596209	6363308	598365	06:40	07:00
09.04.2003	FRH 19	6363219	598641	6363502	596663	07:03	07;21

10. Complete station list

Date	Area	Station Name	Deploy-ment	Gear	PANGAEA Event Label	Time	Lat.	Long.	Water depth
31.03.2003	Læsø Rende	K7	1GC	Gravity Corer	GT03-1GC	15:11	57°24.204' N	10°37.147' E	16.0m
31.03.2003	Læsø Rende	K7	2GC	Gravity Corer	GT03-2GC	15:58	57°24.203' N	10°37.148' E	16.1m
31.03.2003	Læsø Rende	K7	3GC	Gravity Corer	GT03-3GC	16:35	57°24.205' N	10°37.147' E	16.0m
31.03.2003	Læsø Rende	K7	4RL	Rumohr Lot	GT03-4RL	17:13	57°24.209' N	10°37.143' E	16.0m
31.03.2003	Kattegat-N	-	5SEIS	Seismic gears	-	21:08	see seimsic protocol		
01.04.2003	Læsø Rende	K8	6GC	Gravity Corer	GT03-6GC	12:59	57°23.360' N	10°37.417' E	15m
01.04.2003	Læsø Rende	K8	7GC	Gravity Corer	GT03-7GC	13:57	57°23.360' N	10°37.468' E	15m
01.04.2003	Læsø Rende	K8	8GC	Gravity Corer	GT03-8GC	15:16	57°23.361' N	10°37.477' E	15m
01.04.2003	Læsø Rende	K8	9GC	Gravity Corer	GT03-9GC	16:12	57°23.364' N	10°37.475' E	15m
01.04.2003	Læsø Rende	K8	10GC	Gravity Corer	GT03-10GC	16:41	57°23.368' N	10°37.489' E	15m
01.04.2003	Læsø Rende	K8	11RL	Rumohr Lot	GT03-11RL	17:17	57°23.374' N	10°37.547' E	15m
01.04.2003	Læsø Rende	K8	12MUC	Multi Corer	GT03-12MUC	19:26	57°23.375' N	10°37.517' E	15m
01.04.2003	Læsø Rende	K8	13MUC	Multi Corer	GT03-13MUC	19:46	57°23.373' N	10°37.510' E	15m
01.04.2003	Læsø Rende	K8	14MUC	Multi Corer	GT03-14MUC	19:59	57°23..510' N	10°37.520' E	15m
01.04.2003	Læsø Rende	K8	15RL	Rumohr Lot	GT03-15RL	20:22	57°23.373' N	10°37.357' E	15m
01.04.2003	Læsø Rende	K8	16RL	Rumohr Lot	GT03-16RL	20:27	57°23.374' N	10°37.514' E	15m
01.04.2003	Læsø Rende	K8	17RL	Rumohr Lot	GT03-17RL	20:35	57°23.357' N	10°37.525' E	15m
01.04.2003	Læsø Rende	K8	18RL	Rumohr Lot	GT03-18RL	20:40	57°23.371' N	10°37.561' E	15m
01.04.2003	Læsø Rende	K8	19RL	Rumohr Lot	GT03-19RL	20:46	57°23.372' N	10°37.559' E	15m
01.04.2003	Læsø Rende	K8	20RL	Rumohr Lot	GT03-20RL	20:53	57°23.374' N	10°37.548' E	15m
01.04.2003	Læsø Rende	K8	21RL	Rumohr Lot	GT03-21GT	21:04	57°23.767' N	10°37.534' E	15m
01.04.2003	Læsø Rende	K8	22RL	Rumohr Lot	GT03-22RL	21:09	57°23.375' N	10°37.532' E	15m
01.04.2003	Læsø Rende	K8	25RL	Rumohr Lot	GT03-25RL	21:24	57°23.374' N	10°37.535' E	15m
01.04.2003	Læsø Rende	K8	23RL	Rumohr Lot	GT03-23RL	21:12	57°23.375' N	10°37.534' E	15m
01.04.2003	Læsø Rende	K8	24RL	Rumohr Lot	GT03-24RL	21:12	57°23.375' N	10°37.531' E	15m
02.04.2003	Kattegat-N	K9	26GC	Gravity Corer	GT03-26GC	08:26	57°48.039' N	11°03.175' E	47m
02.04.2003	Kattegat-N	K9	27GC	Gravity Corer	GT03-27GC	08:56	57°48.045' N	11°03.164' E	47m
02.04.2003	Kattegat-N	K9	28GC	Gravity Corer	GT03-28GC	09:59	57°48.021' N	11°03.182' E	47m
02.04.2003	Kattegat-N	K9	29GC	Gravity Corer	GT03-29GC	10:23	57°48.023' N	11°03.187' E	47m
02.04.2003	Kattegat-N	K9	30MUC	Multi Corer	GT03-30MUC	10:46	57°48.015' N	11°03.183' E	47m
02.04.2003	Kattegat-N	K9	31RL	Rumohr Lot	GT03-31RL	11:15	57°48.011' N	11°03.184' E	47m
02.04.2003	Kattegat-N	K10	32GC	Gravity Corer	GT03-32GC	13:35	57°50.146' N	11°16.651' E	92m
02.04.2003	Kattegat-N	K10	33GC	Gravity Corer	GT03-33GC	14:10	57°50.1329' N	11°16.6092' E	92m
02.04.2003	Kattegat-N	K10	34RL	Rumohr Lot	GT03-34RL	14:47	57°50.1355' N	11°16.649' E	92m
02.04.2003	Kattegat-N	K6	35GC	Gravity Corer	GT03-35GC	15:10	57°50.276' N	11°17.8465' E	98m
02.04.2003	Kattegat-N	K6	36GC	Gravity Corer	GT03-36GC	15:57	57°50.2722' N	11°17.8638' E	98m
02.04.2003	Kattegat-N	K6	37GC	Gravity Corer	GT03-37GC	16:44	57°50.286' N	11°17.8520' E	98m
02.04.2003	Kattegat-N	K6	38RL	Rumohr Lot	GT03-38RL	17:21	57°50.2970' N	11°17.9022' E	98m
02.04.2003	Kattegat-N	K6	39RL	Rumohr Lot	GT03-39RL	17:30	57°50.2994' N	11°17.8220' E	98m
02.04.2003	Kattegat-N	K6	40RL	Rumohr Lot	GT03-40Rl	17:40	57°50.2871' N	11°17.8581' E	98m
02.04.2003	Kattegat-N	K11	41GC	Gravity Corer	GT03-41GC	18:35	57°49.9933' N	11°21.2708' E	73m
02.04.2003	Kattegat-N	K11	42RL	Rumohr Lot	GT03-42RL	19:15	57°49.9686' N	11°21.3063' E	70m
02.04.2003	Kattegat-N	K12	43RL	Rumohr Lot	GT03-43RL	19:35	57°50.1781' N	11°21.7095' E	68m
02.04.2003	Kattegat-N	K12	44GC	Gravity Corer	GT03-44GC	19:47	57°50.1723' N	11°21.7126' E	70m
03.04.2003	Frederikshavn	-	45SEIS	Seismic gears	-		see seismic protocol		
07.04.2003	Læsø Rende-N	K14B	46VC	Vibro Corer	GT03-46VC	09:30	57°25.3585' N	10°53.1977' E	28m
07.04.2003	Læsø Rende-N	K14B	47VC	Vibro Corer	GT03-47VC	09:52	57°25.3548' N	10°43.2040' E	28m
07.04.2003	Læsø Rende-N	K14B	48VC	Vibro Corer	GT03-48VC	10:30	57°25.3538' N	10°43.2059' E	28m
07.04.2003	Læsø Rende-N	K14B	49RL	Rumohr Lot	GT03-49RL	10:45	57°25.3630' N	10°43.2200' E	28m
07.04.2003	Læsø Rende-N	K14A	50RL	Rumohr Lot	GT03-50RL	12:27	57°25.3375' N	10°43.1708' E	28m
07.04.2003	Læsø Rende-N	K14A	51VC	Vibro Corer	GT03-51VC	12:42	57°25.3361' N	10°43.1752' E	27.5m
07.04.2003	Læsø Rende-N	K14A	52VC	Vibro Corer	GT03-52VC	13:23	57°25.3392' N	10°43.1683' E	28.4m
07.04.2003	Læsø Rende-N	K14C	53RL	Rumohr Lot	GT03-53RL	14:33	57°25.4137' N	10°43.6927' E	28m
07.04.2003	Læsø Rende-N	K15	54RL	Rumohr Lot	GT03-54RL	15:32	57°24.9355' N	10°34,2985' E	9m
07.04.2003	Læsø Rende-N	K15	55RL	Rumohr Lot	GT03-55RL	15:37	57°24.9355' N	10°34,2985' E	9m
07.04.2003	Læsø Rende-N	K15	56RL	Rumohr Lot	GT03-56RL	15:41	57°24.9355' N	10°34,2985' E	9m
07.04.2003	Læsø Rende-N	K15	57VC	Vibro Corer	GT03-57VC	15:58	57°24.9328' N	10°34.2992' E	9m
07.04.2003	Læsø Rende-N	K15	58VC	Vibro Corer	GT03-58VC	16:33	57°24.9338' N	10°34.3021' E	9.4m
07.04.2003	Læsø Rende-N	K15	59VC	Vibro Corer	GT03-59VC	17:10	57°24.9350' N	10°34.3010' E	9.4m
07.04.2003	Læsø Rende-N	K15	60HAPS	HAPS Corer	GT03-60HAPS	17:25	57°24.9330' N	10°34.3016' E	9.4m
07.04.2003	Læsø Rende-N	K15	61HAPS	HAPS Corer	GT03-61HAPS	17:30	57°24.9328' N	10°34.3016' E	9.4m
07.04.2003	Herta's Flak	-	62SEIS	Seismic gears	-		see seismic protocol		
08.04.2003	Kattegat-N	K9	63GC	Gravity Corer	GT03-63GC	13:47	57°48.0911' N	11°03.1960' E	46m
08.04.2003	Kattegat-N	K9	64GC	Gravity Corer	GT03-64GC	14:05	57°48.0988' N	11°03.1330' E	46m

Date	Area	Station Name	Deploy-ment	Gear	PANGAEA Event Label	Time	Lat.	Long.	Water depth
08.04.2003	Kattegat-N	K9	65GC	Gravity Corer	GT03-65GC	14:19	57°48.1252' N	11°03.1520' E	46m
08.04.2003	Kattegat-N	K9	66GC	Gravity Corer	GT03-66GC	14:32	57°48.1120' N	11°03.1560' E	46m
08.04.2003	Kattegat-N	K9	67GC	Gravity Corer	GT03-67GC	14:45	57°48.0990' N	11°03.1590' E	46m
08.04.2003	Kattegat-N	K9	68RL	Rumohr Lot	GT03-68RL	14:56	57°48.1050' N	11°03.1540' E	46m
08.04.2003	Kattegat-N	K9	69VC	Vibro Corer	GT03-69VC	15:43	57°48.1180' N	11°03.1450' E	46m
08.04.2003	Kattegat-N	K10	70RL	Rumohr Lot	GT03-70RL	16:50	57°50.17' N	11°16.68' E	90m
08.04.2003	Kattegat-N	K10	71RL	Rumohr Lot	GT03-71RL	17:00	57°50.1700' N	11°16.6805' E	90m
08.04.2003	Kattegat-N	K6	72RL	Rumohr Lot	GT03-72RL	17:30	57°50.3060' N	11°17.8680' E	98m
08.04.2003	Hirsholmene	-	73SEIS	Seismic gears	-		see seismic protocol		
09.04.2003	Læsø Rende	K8	74RL	Rumohr Lot	GT03-74RL	08:38	57°23.4183' N	10°37.6206' E	15.5m
09.04.2003	Læsø Rende	K8	75RL	Rumohr Lot	GT03-75RL	08:47	57°23.4153' N	10°37.5773' E	15.5m
09.04.2003	Læsø Rende	K8	76RL	Rumohr Lot	GT03-76RL	08:52	57°23.4159' N	10°37.5892' E	15.5m
09.04.2003	Læsø Rende	K8	77RL	Rumohr Lot	GT03-77RL	08:55	57°23.4152' N	10°37.6011' E	15.5m
09.04.2003	Læsø Rende	K13	78BC	Box Corer	GT03-78BC	10:17	57°28.0433' N	10°37.7234' E	12.5m
09.04.2003	Læsø Rende	K13	79BC	Box Corer	GT03-79BC	10:45	57°28.0533' N	10°37.7403' E	12.5m
09.04.2003	Læsø Rende	K13	80BC	Box Corer	GT03-80BC	11:20	57°28.0644' N	10°37.7326' E	12.6m
09.04.2003	Læsø Rende	K18	81CTD	CTD	GT03-81CTD	16:01	57°30.203' N	10°35.743' E	<10m