MBA Miscellaneous Publications [MBA - 1]

R.R.S. "CHALLENGER"

CRUISE 82

July 12th - July 31st 1991

REPORT

by [P. R. DANDO]

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Contents

Participants

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Rolf Schmaljohann	University of Kiel	Methane oxidation	2
Ingeborg Bussman	University of Kiel	Methane oxidation	2
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Markus Wetzel	University of Hamburg	Meiofauna sampling	1&2
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David Smith	BGS, Edinburgh	Geophysics engineer	1&2
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David Booth	Research Vessel Base	Electronics	1&2
Adrian Fern	Research Vessel Base	Computing	1&2

Equipment

CTD and water-sampling rosette with 1.7 litre bottles
Large box-corer
Kastenlot corer
UMEL Stereo underwater camera system
Simrad EA500 Survey echo-sounder with 10KHz towed and 12.5KHz hull-mounted transducers, HP Paintjet Plotter, Waverly 3710 thermal linescan recorder.
Acoustic velocity metre
BGS Deep-tow boomer, seismic control system, Waverly 3710 thermal linescan recorder and digital recording system.
Waverly side-scan sonar and Waverly 3500 thermal linescan recorder.
Multiple-corer
Jonasson-Olausson corer
Soderberg Drop Sampler

Objectives

Leg 1

1. To locate the source of hydrogen plumes in the Witch Ground Basin by taking water samples with the rosette sampler.
2. To take core samples from the 2 large pockmarks in UK Block 15/25 to obtain *Astomonema* and other samples needed to complete studies on these pockmarks.
3. To re-survey the extent of the shallow gas deposits mapped in 1990

Leg 2

4. To map the distribution of shallow gas and gas seeps in the Skagerrak north of Hirtshals and to study the relationship of the seeps to bottom and sub-bottom topography.
5. To obtain sediment cores from methane-rich and methane-poor sediments in order to compare their biomass, species composition and geochemistry.
6. To collect fauna for stable isotope analysis, for biochemical studies and for electron microscopy.
7. To measure gas concentrations and bacterial activity in the sediments and in the water column.

Narrative

The cruise mobilised at Troon on 10th and 11th July 1991. BGS winches were installed for the side-scan and boomer. A 10' container was installed on the afterdeck, to hold the high voltage equipment. The chemistry laboratory was converted into the geophysics laboratory for this cruise. Gas chromatographs were installed in the general laboratory while the wet laboratory was reserved for glove-bag handling of samples.

12 July . Departure was delayed due to the need to repair the boomer towing block at Ailsa Shipbuilders Ltd. The block had failed under test as a result of being improperly secured. 'Challenger' departed Troon 1455 GMT for the N. Sea. The overall track of the cruise is shown in Figure 1.

13 July. 1230h deployed the BGS deep tow boomer and the Waverly 100KHz sidescan sonar for tests while steaming. Tests were satisfactorily completed by 1415h and the equipment was recovered.

14 July. 0930h stopped to deploy the 10KHz transducer and the transducer on the starboard beam. 1952h fixed Decca error corrections of +0.23 Red, -0.2 Green and -0.42 Purple were applied to the Navigation computer. Bridge navigation for this leg was on Decca chain 6C. 2004h the NW pockmark in the survey area was located. 2200h deployed sound velocity metre in the centre of the pockmark. 2231h commenced deploying deep-tow boomer and side-scan sonar.

15 July 0009h Commenced first geophysics survey line, 5 lines were run overnight, recovering equipment at 0739h. CTD casts and water sampling for dissolved gases using the 0.7 l. rossette sample bottles commenced at 0822h and continued until 1925h. Between unloading and loading the water bottle rosette the Jonasson-Olausson box corer was deployed for collection of meiofauna and macrofauna samples. The boomer and sidescan were deployed again at 1947h. 7 geophysics lines were run overnight.

16 July. 0714h the boomer and sidescan were recovered. Coring and water bottle sampling commenced at 0743h and continued until 1630h. Preparation of the geophysics equipment commenced at 1732 and the gear was deployed at 1809h. 10 geophysics lines were completed before recovery of gear at 0826h on the 17th.

17 July. Coring and water sampling commenced at 1006h and continued until 1830h. A final 3 geophysics lines were run commencing at 1844h and recovering the equipment at 2153h before setting course for Hirtshals.

18 July. The vessel slowed at 1846h for deployment of the 3.5KHz P.E.S. fish over the port quarter and continued at a speed of 5 knots to allow a survey over a known shallow gas area in the western Skagerrak. The survey line was completed and the fish recovered at 2312h.

19 July. Docked at Hirtshals at 0700h. Dr. Judd left the vessel and Dr. Jensen from Helsingør and Dr. Schmaljohann and Ms. Bussman from Kiel

joined for leg 2. A Soderberg sediment gas sampler, on loan from Stockholm University, was loaded. 'Challenger' departed Hirtshals at 2030h for the start of the second leg. The survey area was reached and the sound velocity metre deployed to calibrate the Simrad EA500 echosounder in 400m water depth at 2358h. Station positioning for this leg was based on Decca chain 10B, GPS giving less repeatable positioning for precision coring. GPS positions were computer logged and used to generate the survey track charts.

20 July. An echo sounding profile up slope through the survey area was run, commencing at 0042h and finishing at 0110h. The boomer was deployed at 0119h and 2 survey lines were completed before recovering the boomer at 0706h. The 3.5KHz fish was deployed and coring with the large box corer and Jonasson-Olausson corer commenced at 0954h. Attempts were made to position the corers over gas seeps reported by the Insitut für Meereskunde vessel 'Poseidon' . The water depth range for samples was 323-330m. No seep samples were collected and at 1545h an echosounding and sub-bottom profiling transect along the 5m contour was commenced. No clear indicators of gas seepage, such as indications of bubbles in the water column, were found. The deep tow boomer survey was re-commenced at 2118h and 5 survey lines were completed overnight. At one stage, on survey line 'F', a 360° turn had to be executed before regaining the line due to the presence of fishing vessels.

21 July The boomer was recovered at 0706h. Two echo-sounding lines were run to survey an apparent area of shallow gas outcropping. Box coring started at a shallower site at 0948h. 4 core drops were made at depths of 244-266m before resuming attempts along the 330m contour. The Waverly sidescan was deployed at 1942h and 3 survey lines were completed overnight at a tow speed of approximately 2.5 knots.

22 July Coring operations centered on the 330m contour commenced at 0809. A Kasten core deployment was made to identify the depth of gas-saturated sediment. This was followed by 10 box core deployments. Box-coring finished at 1830h and the boomer was deployed to continue the geophysics survey. 6 survey lines were run.

23 July At 0534h there was a main engine power failure while the boomer was at survey depth. Power was resumed at 0545, fortunately before the instrument had hit the seabed. The survey was terminated and the boomer brought inboard at 0707h. Because of the possibility that this engine shut-down could occur again at any time it was decided not to use the Waverly side-scan for the rest of the cruise because of its near-bottom tow position. The towing depth of the boomer was restricted so that it would not be damaged if there was a repeat occurrence. Box coring, again along the 330m contour, commenced at 0750h. At 1317h a box core was recovered smelling strongly of hydrogen sulphide and with gas bubbling out of the top of the sediment., in half of the core. The 0.5m square corer had part-landed on an area of active gas seepage. Overside operations stopped to allow the scientific party to concentrate fully on the sample. Boomer deployment started at 1852h and 4 lines were completed overnight.

24 July. Box coring recommenced at 0800h in an attempt to obtain a second gas seep sample. Water currents and the imprecise navigation made it difficult to position the corer on the exact position found on the previous day and this was not achieved. At 1443h the first deployment was made of the UMEL stereo camera in an attempt to photograph the seeps. On recovery it was found that the film had failed to advance after the first test frames. The boomer was deployed at 1853h and 8 survey lines were completed overnight. Heavy fishing activity in the survey area caused some course detours and one line had to be aborted.

25 July. Operations with the large box corer restarted at 0836h, again at the 330m site. The first core landed within metres of the previous seep sample and again straddled the edge of a gas seep. Further cores taken during the day were not successful. The coarse steps on the Bridge track plotter made the drop position partly guesswork. Best navigation positions from the computer were not available until the following day. At 1800h the UMEL camera was deployed for the second time. On this occasion the battery failed and the flash did not fire underwater. Boomer operations started at 1854h and continued overnight. 6 survey lines were completed.

26 July. Coring operations started at 0757h. Two large box core sediment samples were collected and used for control measurements. Two CTD casts and water bottle samples for methane were taken around a 'hummock'

discovered during the geophysics survey. The Soderberg sediment gas-sampling corer was rigged and tested. 3 deployments were needed to adjust the valve closure mechanism correctly. A fourth deployment was successful. The boomer survey started again at 1949h and 7 lines were completed overnight.

27 July. After recovering the boomer ,sediment gas sampling commenced with the Soderberg corer which was used to take a further 4 samples before being dismantled. A Kasten core sample was taken to check the gas saturation horizon and further box core samples were collected from the 330m contour. Boomer deployment commenced at 1906h and 7 boomer lines were completed overnight.

28 July. The boomer was recovered at 0706h and the DML multiple corer was rigged for deployment to collect undisturbed surface sediment samples for meiofauna. 4 drops were made in water depths of approximately 330m. 3 box core samples were taken close to the original seep position, two of which contained some gas-saturated mud. Two CTD-rosette samples were taken close to a mud mound found during the geophysics survey.and a successful stereo-camera deployment was made across the seep position which had been cored. A final series of 7 boomer lines were run overnight.

29 July. Analysis of the water samples from the previous day had shown gas concentrations in the water over the bottom hummock. Two camera lowerings were made to photograph the area and two Kasten core samples were taken to examine the gas saturation horizon in the sediment either side of the hummock. The final corer was recovered at 1100h and 'Challenger' set course for Hirtshals, docking at 1355h. The German and Danish scientists left the vessel at Hirtshals and the Soderberg corer was unloaded. 'Challenger' left Hirtshals at 1620 for Great Yarmouth, docking on the 31st.

Data and Results

Leg 1 - Witch Ground Pockmarks

Geophysics and bathymetry (C.P. Brett, D.J. Smith & A. G. Judd)
75 hours shiptime were spent on investigations on a pockmark area on the Witch Ground on this leg. All the geophysical systems worked well and the

calm sea conditions led to high quality data being acquired. The data was recorded as analogue records on Waverly linescan recorders and the boomer data was also recorded digitally for further processing. 25 geophysics lines (Table 2, Figure 2) were completed with the BGS deep tow boomer and sidescan sonar in order to map shallow gas deposits in UK block 15/25. A map of shallow gas layers was produced (Figure 3) during the cruise for comparison with a previous survey to show movement in the upper reservoirs. Sub-surface gas rose to 40m below the seabed under the seeps. The side-scan images enabled individual gas seeps in some of the pockmarks to be counted. The images will be compared with the 1990 data to indicate whether there has been a change in methane seepage.

A bathymetric map of the area was produced showing 4 large pockmarks (Figure 4). More detailed bathymetry of the NW pockmark (D in Figure 4) is shown in Figure 5. Gas plumes were observed from all these pockmarks using the hull-mounted 49KHz transducer. A plume rising from the NW pockmark is shown in Figure 6. The gas plumes were also seen with the Simmrad EA 500 sounder using the 12.5KHz hull-mounted and 10KHz towed transducers but the records were less distinct.

Gas in the water column (S.C.M. O'Hara, S. Niven & L. Taylor)
13 CTD casts with the water sampling rosette were made (Table 2, Figure 7a). On recovery, water was drawn into bottles containing sodium azide as inhibitor in an atmosphere of zero-grade nitrogen. After equilibration on a roller headspace samples were analyzed. Gases were separated on 13X molecular sieve columns and determined using a heated semi-conductor detector for hydrogen and a FID for methane. The vertical profiles of methane and hydrogen concentrations are shown in Figures 8 to 10. This data is plotted in Figures11 & 12 to show the depth variation in methane and hydrogen concentrations along a N-S transect through the survey area. These plots have not been corrected for water movement. There is an approximate correspondence between the regions of high hydrogen and high methane concentrations and the presence of a 'plume' of dissolved gas at 110-130m water depth. This is the depth at which some of the bubble traces disappear from the echo sounder and probably corresponds to a major area of gas solution.

An additional 4 CTD casts were made to investigate a thermocline in the large pockmarks which was observed during the 'Challenger'-70 cruise. No thermocline was found on this occasion, similar profiles were obtained over both the 'Geoteam' and the NW pockmarks (Figure 13).

Sediment sampling (G. Lawson, M. Wetzel)
15 deployments of the Johannasson-Olausson box corer were made in pockmarks and in the surrounding area (Table 2, Figure 7b) for quantitative determination of species composition and biomass of meiofauna and macrofauna. One sample from the base of a small active pockmark (C in Figure 4) was analysed for methane and samples were taken for sulphide and sulphate reduction rate determinations. The measurements made on the core samples are listed in Table 3.

The weather was good for the whole working period which enabled all the objectives for this leg to be achieved.

Leg 2 - Skagerrak Methane Seeps

Geophysics and bathymetry (C.P. Brett, D.J. Smith)
The water depths of the geophysical survey area ranged from 55 to 425m. 53 BGS deep-tow boomer and 4 sidescan lines were completed (Table 4, Figure 14). Weather conditions were good throughout, allowing a detailed survey of bathymetry and the upper horizons of the shallow gas layers to be completed. A bathymetric map of the survey area is shown in Figure 15. The gas blanking was approximately 3m sub-bottom in the shallower part of the area dipping sharply to 50m sub-bottom in deeper water before disappearing at approximately 410m water depth. In the upper few metres of sediment the gas saturation zone was readily detected on the EA500 with both the 10 and 12.5KHz transducers (Figure 16). A number of potential seep areas were noted. The results of the survey will provide a firm foundation for more detailed studies of the area in future years.

No conspicuous gas plumes were observed with any of the echo sounders. Acoustic scattering in the water column was observed on the side scan traces. These were not obvious bubble streams, as seen on the Witch Ground, but were either isolated bubbles or scattered fish.

A typical CTD profile for the deeper part of the survey area is shown in Figure 17.

Mud Mound and Wreck

During the survey an unusual bottom 'hummock' of approximately 15m height was observed on the echo sounder at 58° 3.83'N 9° 39.78'E at a water depth of 360m (Figure 18). This occurred at the position where the sub-surface gas blanking changed from approximately 3m to 50m depth sub-bottom. Two boomer transects of the mound confirmed this. This hummock was considered to be a possible mud volcano caused by gas overpressure. A box core sample from the base of the mound, station 65, contained a peculiar mixture of both stiff and very soft mud. Two water bottle casts were analyzed for methane and showed high values close to the mound. Kasten core samples, stations 112 and 114, taken up-slope and down-slope of the mound showed that methane saturated mud was present just sub-surface. During the final deployment of the UMEL stereo camera over the mound the camera frame snagged an obstruction and on recovery one of the steel strops holding the frame was found to have snapped, the frame was bent, the flash reflectors had ben pulled off and pieces of rusty metal were recovered from the net covering the top of the frame. Photographs showed old bottles and some crates on the seabed and what appeared to be the siderail of a ship.

The Danish Farvandsvæsenet have no knowledge of a wreck in this region. Because of its position over a gas seep there is the possibility that the vessel could have foundered as the result of loss of buoyancy due to a sudden release of a large volume of gas.

Sediment sampling

Sediment coring was largely confined to two areas to investigate the geochemistry and biology of gas seeps. The sample stations are listed in Table 5 and the types of sample taken are listed in Table 6. 34 samples were collected with the large box corer, 18 with the Johannasson-Olausson box corer, 4 with the DML multiple corer,3 with the 2m Kasten corer and 5 with the Soderberg corer. Samples of gas, sediment and fauna were collected for isotope analysis. Vertical and horizontal profiles of methane concentration and oxidation rate were determined onboard. Geochemical depth profiles for 14 cores were determined and quantitative samples were taken for the determination of macro- and meiofauna. 3 cores were collected directly over seeps and had methane bubbles rising from the surface of the core.

Fauna samples (G. Lawson, P. Jensen & M. Wetzel)
Samples of cores were sieved to 500μ for macrofauna and other samples were fixed for meiofauna analysis. Cores were sectioned both horizontally and vertically according to changes in sediment composition.Several cores were dissected to examine burrow structures. Large vertical burrows, up to 40cm long, were formed by hagfish, *Myxine*. Meandering burrows, 2-3cm diametre and penetrating to a depth of more than 60cm, were found in several cores. These were probably due to crustacea but the animals were not captured in any of the cores. It appeared that where methane rose to the surface it did so via animal burrows.

Core 61 had gas bubbling out of one section of the box core. This portion was covered with a 'mat' of the pogonophore *Siboglinum poseidoni*, an animal known to derive its nutrition from endosymbiotic methane-oxidising bacteria. The pogonophore, which penetrated to a sediment depth of approximately 15cm, was absent from the non-seep half of the core. The bivalve *Thyasira sarsi*, another species containing symbiotic bacteria, was also restricted to the seep portion of the core. A similar situation occurred in core 71 where the seep section was confined to an 8cm wide strip along one edge of the box, again only this zone contained numerous pogonophores. In core 105 the seep was confined to one corner of the box sample adjacent to a hagfish burrow. The final seep core, 106, appeared to have caught the very edge of a gas seep. A section of firmer, methane-rich and sulphide-rich mud extended 20cm into the box core from its base but did not reach the surface (Figure 19). It is possible that this intrusion was a result of gas pressure forcing up underlying sediment.

Methane concentrations and methane oxidation rates in the sediment (I. Bussmann, R. Schmaljohann & P. Dando)
It was possible to relate the shallowest "gas" horizons observed using the boomer to strong reflectors, shown in red in Figure 16, on the Simrad EA 500 12.5KHz echosounder and to methane saturated sediment collected with the Kasten corer. The gas blanking was approximately 3m sub-bottom in water depths of 55 to 370m water depth before dipping sharply to 50m sub-bottom and disappearing at approximately

410m water depth. Four Kasten core samples were taken where the gas-saturated sediment appeared to be approaching the surface. All these cores 'fizzed' on deck, the observed sediment depths of outgassing were:-

Station	Water depth (m)	Depth sub-bottom of gas saturation (m)
45	321	1.55
94	305	0.83
112	358	1.35
114	366	0.62

Vertical and horizontal profiles of methane concentration and aerobic oxidation rate, by methane uptake in air, were determined onboard. Additional sediment samples were incubated with $^{14}C\text{-}CH_4$ at 7°C for later determination of total methane oxidation rates. Methane concentration profiles are shown in Figures 20 to 22. Methane oxidation rates are depicted in Figures 23 and 24. In most cores the methane concentration was below 1μmole dm^{-3} sediment in the top 10cm and the aerobic oxidation rate was below 1nmole g^{-1} h^{-1}. Little methane reached the surface due to a combination of impermeable clay and oxidation. Dissection of the cores suggested that where methane did reach the surface, as in cores 61, 71, and 105, old animal burrows and tubes were used as gas escape routes from the underlying clay. This, however, appears to be only part of the explanation since the seep cores ran in a NE-SW line (Figure 25) suggesting underlying stresses.

In the seep part of core 61 the methane oxidation rate was an order of magnitude higher than in the control cores (Figure 24). The oxidation rate was also high surrounding the seep and penetrated deep into the sediment. This was probably due to a circulation of interstitial water induced by the escaping gas bubbles; methane concentrations fell rapidly away from the gas channels. An example of the reduction in methane concentration across a core is shown in Figure 19 or core 106.

Other sediment chemistry (S.C.M. O'Hara, S. Niven, L. Taylor)
Samples from 10cm subcores were pressed under argon to extract interstitial water which was filtered through cellulose acetate filters of 0.2µm porosity. Sediment was sampled at 2cm intervals for the first 10cm and at 5cm intervals thereafter. Sampling intervals were modified if visible discontinuities were observed. Interstitial water was analysed for pH, alkalinity, ammonia and Fe^{++} on board. Samples were derivatized with monobromobimane for later determination of sulphide, sulphite and thiosulphate. Interstitial water was frozen for later determination of total iron and sulphate. Sediment samples were frozen for later determination of water content, organic and total carbon and organic nitrogen. Sulphate reduction rate measurements were made in sealed 4ml samples taken with a cut off syringe and injected with $K_2{}^{35}SO_4$ and incubated at 7°C for 18h before being fixed with zinc acetate under argon. The samples were then extracted with hexane for elemental sulphur. Acid-labile and chromous reducible sulphide determinations were made on the samples at Plymouth. Sulphate reduction rates were considerably enhanced in the methane-saturated sediment and appear to be limited by sulphate concentrations (Figure 26).

Conclusions

The cruise successfully achieved most of its objectives. Unfortunately the hydrogen anomalies found in the water column over the Witch Ground were much smaller than observed in 1990 and their source could not be traced in the time available. However, near-bottom anomalies were found in the area for the third successive year and the distribution maps suggest that one of the smaller pockmarks may be their source. The concentrations observed this year were an order of magnitude above those noted in hydrothermal plumes, for example. Without a submersible or ROV on board for this cruise it was not possible to collect escaping gas. Analysis of samples collected last year from the large 'Geoteam' pockmark (D in Figure 4) with the submersible 'Jago' showed that hydrogen was not present in this gas.

The distribution of subsurface gas concentration in the leg 1 survey area appears similar to that noted when the area was first surveyed, although more detailed analysis of the records is needed. The preliminary results suggest that the upper shallow gas deposits are relatively static in terms of the area covered by them. Sidescan records gave similar gas plume counts to those observed in 1990 suggesting that the number of gas seeps has remained approximately constant. This information is important for calculations on the amount of methane leaving the seabed. Diffusion of gas across the sediment surface appears to have a minor role compared to the escape of gas bubbles.

All the leg 2 objectives were achieved. As a result of this cruise the area of shallow gas in the Skagerrak is known to extend to both deeper and shallower water depths than was previously believed. Calibration of the EA 500 echosounder with the 12.5KHz transducer against the deep-tow boomer records and Kasten corer samples showed that the echo sounder could be used to map the upper horizons of gas saturated sediment. It is probable that the area extends right up to the north Jutland coast. The gas only outcrops, however, in small areas. This makes it difficult to study since dropping the corer onto a seep position requires a number of attempts unless very precise transponder positioning, to within one metre, is available.

The successful seep cores collected were well worth all the effort and provided some fascinating results. At the greater water depth in the Skagerrak it is apparent that greatly enhanced microbial activity and macrofauna biomass is associated with the seeps. Methane oxidation and sulphate reduction rates were at least an order of magnitude greater than that observed at shallower seep sites. Infaunal biomass has yet to be calculated but from the sieved samples it appeared to be 4 to 10-fold higher in sediment from which methane bubbles were issuing. The gas escape also appears to induce water circulation through the sediment and suggest that water and chemical flux measurements should be made at the seep sites to study nutrient re-cycling.

The problem remains as to how to quantify the seep areas and increased benthic production over the whole Skagerrak. The boomer and echo sounder records indicated positions where gas seepage was occuring but could not be used to measure these on an area basis. It is probable that the best approach would be to use a high resolution deep-tow sidescan sonar towed within 30m of the bottom. This should resolve gas bubbles from fish.

Such an instrument is not currently available within NERC. The Waverly sidescan used for some tows on this cruise was at the very limit of its operating range and indicated the likely usefulness of this approach. Further studies are needed to examine how the faunal composition and biomass changes with depth at seep sites on the slope.

In summary: this cruise has greatly extended our knowledge of the biology and geochemistry of methane seeps and suggests that they become increasingly important, in biological terms, at deeper water sites.

List of Tables

Line no.	Day started	Time (GMT)	° N	°E	Day finished	Time (GMT)	° N	°E	Boomer	Layback (m)	Sidescan	Layback (m)
1	15-Jul	0020	58.2821	0.9386	196	0100	58.3267	0.9367	√	175	√	530
2	15-Jul	0129	58.3266	0.9548	196	0219	58.2629	0.9543	√	175	√	530
3	15-Jul	0254	58.2718	0.9382	196	0349	58.3327	0.9402	√	175	√	530
4	15-Jul	0435	58.3232	0.9581	196	0529	58.2611	0.9576	√	180	√	530
5	15-Jul	0632	58.2823	0.9346	196	0704	58.2825	1.0026	√	180	√	530
6	15-Jul	2024	58.2939	0.9483	196	2051	58.3282	0.9480	√	190	√	530
7	15-Jul	2122	58.3254	0.9737	196	2215	58.2655	0.9742	√	190	√	530
8	15-Jul	2252	58.2717	0.9617	196	2341	58.3302	0.9653	√	191	√	535
9	16-Jul	0004	58.3238	0.9814	197	0052	58.2624	0.9767	√	191	√	535
10	16-Jul	0126	58.2734	0.9642	197	0227	58.3316	0.9714	√	190	√	535
11	16-Jul	0336	58.3087	0.9884	197	0403	58.3096	0.9258	√	190	√	535
12	16-Jul	0502	58.3302	0.954	197	0555	58.2664	0.9527	√	190	√	535
13	16-Jul	1926	58.3255	0.9918	197	2022	58.2647	0.9900	√	170	√	535
14	16-Jul	2042	58.2648	0.9716	197	2133	58.3311	0.9714	√	190	√	535
15	16-Jul	2200	58.3253	0.9877	197	2251	58.2663	0.9840	√	190	√	535
16	16-Jul	2315	58.2722	0.9682	198	0004	58.3301	0.9660	√	190	√	535
17	17-Jul	0026	58.3263	0.9834	198	0115	58.2629	0.9845	√	190	√	535
18	17-Jul	0142	58.2702	0.9593	198	0236	58.3291	0.9593	√	190	√	535
19	17-Jul	0256	58.3262	0.977	198	0342	58.2651	0.9746	√	190	√	535
20	17-Jul	0411	58.2667	0.9438	198	0510	58.3299	0.9412	√	190	√	535
21	17-Jul	0547	58.3208	0.9504	198	0634	58.2667	0.9495	√	170	√	535
22	17-Jul	0725	58.2907	0.9252	198	0759	58.2904	1.0010	√	170	√	535
23	17-Jul	1913	58.3013	1.0047	198	1945	58.2897	0.9281	√	205		
24	17-Jul	2019	58.2664	0.9604	198	2037	58.2665	1.0019	√	205		
25	17-Jul	2108	58.2877	1.0002	198	2138	58.2976	0.9305	√	210		

Table 1: Geophysic Survey Lines - Leg 1

STATION LIST LEG 1

Station no.	Date	Time	GPS °N	GPS °E	Decca °N	Decca °E	Depth to bottom	Gear	core length	temp. °C
1	14.7.91	2200	58.3096	0.9581	58°18.64'N	0°57.38'E	170m	sound velocity		
2	15.7.91	0822	58.2798	0.9676	58°16.90'N	0°58.14'E	168m	CTD		
3	15.7.91	1017	58.2829	0.9701	58°16.89'N	0°58.07'E	170m	CTD/water		
4	15.7.91	1157	58.2798	0.9748	58°16.84'N	0°58.35'E	165m	CTD		
5	15.7.91	1257	58.2816	0.9687	58°16.91'N	0°58.15'E	170m	CTD		
6	15.7.91	1452	58.3092	0.9526	58°18.63'N	0°57.20'E	160m	CTD/water		
7	15.7.91	1531	58.2932	0.9579	58°17.60'N	0°57.28'E	151m	CTD/water		
8	15.7.91	1615	58.2929	0.9576	58°17.66'N	0°57.34'E	150m	Olausson corer	35cm	
9	15.7.91	1655	58.2762	0.9564	58°16.60'N	0°57.34'E	152m	Olausson corer	34cm	
10	15.7.91	1733	58.2772	0.9607	58°16.64'N	0°57.55'E	152m	CTD/water		
11	15.7.91	1832	58.2620	0.9567	58°15.76'N	0°57.33'E	151m	CTD/water		
12	15.7.91	1921	58.2646	0.9573	58°15.90'N	0°57.39'E	151m	Olausson corer	35cm	
13	16.7.91	0747	58.3093	0.9582	58°18.60'N	0°57.37'E	167m	Olausson corer	15cm	
14	16.7.91	0840	58.3094	0.9583	58°18.67'N	0°57.38'E	169m	CTD/water		
15	16.7.91	0927	58.3094	0.9587	58°18.60'N	0°57.38'E	170m	Olausson corer	11cm	7.7
16	16.7.91	1004	58.3270	0.9584	58°19.65'N	0°57.39'E	148m	Olausson corer	26cm	7.3
17	16.7.91	1048	58.3281	0.9568	58°19.67'N	0°57.37'E	149m	CTD/water		
18	16.7.91	1217	58.3404	0.9661	58°20.45'N	0°57.83'E	148m	CTD/water		
19	16.7.91	1235	58.3393	0.9695	58°20.36'N	0°58.18'E	148m	Olausson corer	27cm	7.4
20	16.7.91	1326	58.3101	0.9993	58°18.63'N	1°00.01'E	149m	Olausson corer	30cm	7.5
21	16.7.91	1349	58.3084	0.9976	58°18.55'N	0°59.80'E	149m	CTD/water		
22	16.7.91	1445	58.3099	0.9854	58°18.69'N	0°59.02'E	150m	CTD/water		
23	16.7.91	1458	58.3100	0.9838	58°18.65'N	0°58.92'E	150m	Olausson corer	28cm	
24	16.7.91	1536	58.3092	0.9671	58°18.61'N	0°57.94'E	150m	Olausson corer	32cm	7.5
25	16.7.91				58°18.60'N	0°57.93'E	150m	CTD/water		
26	17.7.91	1012	58.2900	0.9755	58°17.44'N	0°58.44'E	157m	Olausson corer	40cm	
27	17.7.91	1226	58.2908	0.9753	58°17.45'N	0°58.44'E	165m	Olausson corer	29cm	7.5
28	17.7.91	1305	58.2899	0.9751	58°17.43'N	0°58.39'E	157m	Olausson corer	50cm	7.6
29	17.7.91	1401	58.2902	0.9755	58°17.44'N	0°58.44'E	165m	Olausson corer	28cm	7.5
30	17.7.91	1454	58.2904	0.9751	58°17.46'N	0°58.40'E	161m	Olausson corer	48cm	7.4
31	17.7.91	1606	58.2895	0.9760	58°17.39'N	0°58.48'E	160m	CTD/water		
32	17.7.91	1825	58.3097	0.9576	58°18.53'N	0°57.37'E	165m	CTD/water		
33	17.7.91	1915	58.3005	1.0000	58°18.55'N	0°57.47'E	170m	CTD	TOTALS	25 DT boomer & sidescan sonar lines
										15 Olausson box cores
										13 CTD casts with water bottles
										4 CTD casts alone
										1 sound velocity meter deployment

Table 2: Station List - Leg 1

Table 3: Core sample measurements - Leg 1

Station no.	Depth to bottom	macrofauna	meiofauna	sulphate reduction	total methane oxidation	aerobic methane oxidation	sediment methane	interstitial water chemistry
8	150m	#	#					
9	152m	#	#					
12	151m	#	#					
13	167m	#	#					
15	170m	#	#					
16	148m	#	#					
19	148m	#						
20	149m	#	#					
23	150m	#						
24	150m	#	#					
26	157m	#	#					
27	165m	#	#	#				#
28	157m	#	#					
29	165m	#						
30	161m	#	#					

Line no.	Day started	Time (GMT)	° N	°E	Day finished	Time (GMT)	° N	°E	Boomer	Layback (m)	Sidescan	Layback (m)
26	20-Jul	0135	58.0140	9.7128	201	0236	58.0708	9.6223	√	various		
27	20-Jul	0251	58.0653	9.6089	201	0401	57.9976	9.7179	√	various		
28	20-Jul	0433	58.0068	9.7134	201	0549	58.0720	9.6115	√	various		
29	20-Jul	2117	58.0117	9.7209	201	2248	58.0787	9.6154	√	various		
30	20-Jul	2302	58.0770	9.6360	202	0022	57.9896	9.7690	√	various		
31	21-Jul	0040	57.9972	9.7782	202	0232	58.0854	9.6394	√	various		
32	21-Jul	0247	58.0750	9.6329	202	0356	58.0088	9.7376	√	various		
33	21-Jul	0411	58.0149	9.7415	202	0554	58.0858	9.6336	√	various		
34	21-Jul	2132	57.9731	9.5744	202	2333	58.0447	9.7377			√	550
35	22-Jul	0046	58.0519	9.7274	203	0204	58.0234	9.6664			√	550
36	22-Jul	0233	58.0322	9.6743	203	0308	58.0475	9.6463			√	550
37	22-Jul	0334	58.0510	9.6564	203	0417	58.0674	9.6939			√	550
38	22-Jul	1950	58.0054	9.7770	203	2122	58.0881	9.6441	√	various		
39	22-Jul	2146	58.0873	9.6590	203	2318	58.0254	9.5088	√	395		
40	23-Jul	0020	58.0581	9.5925	204	0120	57.9994	9.6832	√	various		
41	23-Jul	0139	57.9921	9.6757	204	0256	58.0598	9.5734	√	various		
42	23-Jul	0313	58.0625	9.5948	204	0417	57.9997	9.6900	√	various		
43	23-Jul	0452	58.0027	9.6680	204	0538	58.04?	9.60?	√	various		
44	23-Jul	1916	57.9965	9.6784	204	2026	58.0602	9.5788	√	various		
45	23-Jul	2045	58.0699	9.6009	205	0050	57.8485	9.9328	√	various		
46	24-Jul	0106	57.8578	9.9426	205	0519	58.0696	9.5896	√	various		
47	24-Jul	0542	58.0523	9.5737	205	0644	57.9951	9.6641	√	various		
48	24-Jul	1940	58.0772	9.6242	205	2017	58.0473	9.6743	√	various		
49	24-Jul	2110	58.0825	9.6939	205	2258	58.0170	9.5357	√	242		
50	24-Jul	2356	58.0508	9.5650	206	0038	58.0101	9.6251	√	various		
51	25-Jul	0052	58.0057	9.6139	206	0145	58.0496	9.5460		various		
52	25-Jul	0200	58.0537	9.5663	206	0302	57.9917	9.6640		various		
53	25-Jul	0324	57.9919	9.6430	206	0435	58.0474	9.5508		various		
54	25-Jul	0449	58.0407	9.5431	206	0546	57.9851	9.6297		various		
55	25-Jul	0608	57.9897	9.6121	206	0716	58.0526	9.5092		various		
56	25-Jul	2028	58.0022	9.4936	206	2242	58.0124	9.5175		various		
57	25-Jul	2300	58.0928	9.7298	206	2357	58.0523	9.6439		various		
58	26-Jul	0036	58.0670	9.6532	207	0116	58.0396	9.7269		various		
59	26-Jul	0211	58.0453	9.6739	207	0255	58.0845	9.7622		various		
60	26-Jul	0334	58.1030	9.7152	207	0441	58.0384	9.7874		various		
61	26-Jul	0537	58.0567	9.7868	207	0647	58.0098	9.6809		99		
62	26-Jul	2055	58.0752	9.6132	207	2218	57.9952	9.7424		various		
63	26-Jul	2235	57.9913	9.7255	208	0017	58.0722	9.6051		various		
64	27-Jul	0042	58.0784	9.6389	208	0115	58.0576	9.5874		298		
65	27-Jul	0146	58.0522	9.6317	208	0220	58.0802	9.6096		308		
66	27-Jul	0255	58.0797	9.6493	208	0330	58.0526	9.5894		308		
67	27-Jul	0404	58.0439	9.6366	208	0437	58.0700	9.5956		various		

Table 4: Geophysics Survey Lines - Leg 2

Line no.	Day started	Time (GMT)	° N	°E	Day finished	Time (GMT)	° N	°E	Boomer	Layback (m)	Sidescan	Layback (m)
68	27-Jul	0543	58.0523	9.6255	208	0605	58.0709	9.5983		305		
69	27-Jul	2029	58.0743	9.6133	208	2138	58.0059	9.7249		various		
70	27-Jul	2216	58.0218	9.7805	208	2353	58.0980	9.6616		various		
71	28-Jul	0044	58.0569	9.6424	209	0106	58.0730	9.6781		240		
72	28-Jul	0154	58.0554	9.6355	209	0223	58.0746	9.6819		240		
73	28-Jul	0322	58.0571	9.6533	209	0338	58.0687	9.6787		240		
74	28-Jul	0442	58.0580	9.6521	209	0500	58.0728	9.6862		240		
75	28-Jul	0602	58.0658	9.6594	209	0611	58.0581	9.6703		240		
76	28-Jul	2043			209	2154				various		
77	28-Jul	2155			209	2250				various		
78	28-Jul	2328			210	0225				314		
79	29-Jul	0227			210	0326				various		
80	29-Jul	0328			210	0357				various		
81	29-Jul	0358			210	0505				various		
82	29-Jul	0526			210	0623				various		

Table 4: cont...1

Station no.	Date	Time	GPS °N	GPS °E	Decca °N	Decca °E	Depth to bottom	Gear	core length	temp. °C
35	20.7.91	1008	58.0508	9.6647	58°03.05´N	9°39.87´ E	323m	Large box core	50cm	6.4
36	20.7.91	1253	58.0501	9.6565	58°03.07´N	9°39.42´ E	326m	Olausson corer	55cm	6.4
37	20.7.91	1404	58.0498	9.6561	58°03.06´N	9°39.40´ E	327m	Olausson corer	55cm	6.4
38	20.7.91	1525	58.0495	9.6546	58°03.06´N	9°39.34´ E	327m	Olausson corer		
39	21.7.91	1007	58.0391	9.6873	58°02.39´N	9°41.26´E	266m	Large box core	57cm	6.5
40	21.7.91	1251	58.0322	9.6939	58°01.98´N	9°41.54´E	244m	Olausson corer	52cm	6.6
41	21.7.91	1340	58.0324	9.6960	58°02.00´N	9°41.77´E	249m	Olausson corer	37cm	6.7
42	21.7.91	1509	58.0317	9.6939	58°01.97´N	9°41.46´E	246m	Olausson corer	30cm	
43	21.7.91	1621	58.0523	9.6898	58°03.22´N	9°41.44´E	327m	Olausson corer		
44	21.7.91	1747			58°03.23´N	9°41.44´E	328m	Olausson corer		6.6
45	22.7.91	0836	58.0526	9.6885	58°03.23´N	9°41.40´E	324m	Kasten core	3m	
46	22.7.91	1044	58.0588	9.6771	58°03.59´N	9°40.64´E	335m	Large box corer	57cm	
47	22.7.91	1135	58.0555	9.6703	58°03.40´N	9°40.28´E	334m	Olausson corer	37cm	6.4
48	22.7.91	1228	58.0576	9.6742	58°03.52´N	9°40.48´E	337m	Olausson corer	38cm	6.6
49	22.7.91	1316	58.0559	9.6705	58°03.42´N	9°40.31´E	333m	Large box corer	57cm	6.3
50	22.7.91	1422	58.0532	9.6644	58°03.26´N	9°39.91´E	330m	Large box corer	55cm	
51	22.7.91	1502	58.0516	9.6602	58°03.17´N	9°39.67´E	330m	Olausson corer		6.6
52	22.7.91	1540	58.0506	9.6576	58°03.10´N	9°39.65´E	329m	Large box core	59cm	6.6
53	22.7.91	1618	58.0481	9.6527	58°02.96´N	9°39.23´E	324m	Olausson		
54	22.7.91	1729	58.0505	9.6554	58°03.11´N	9°39.39´E	330m	Large box corer	59-37cm	6.6
55	22.7.91	1821	58.0505	9.6555	58°03.11´N	9°39.38´E	329m	Large box corer	27-31cm	6.5
56	23.7.91	0809	58.0533	9.6588	58°03.24´N	9°39.53´E	333m	Large box corer		
57	23.7.91	0901	58.0529	9.6601	58°03.23´N	9°39.62´E	333m	Large box corer	55cm	
58	23.7.91	0957	58.0533	9.6602	58°03.26´N	9°39.64´E	336m	Large box corer	55cm	
59	23.7.91	1044	59.0534	9.6604	58°03.27´N	9°39.64´E	335m	Large box corer	55cm	
60	23.7.91	1205	58.0538	9.6602	58°03.30´N	9°39.64´E	338m	Large box corer	55cm	
61	23.7.91	1307	58.0525	9.6588	58°03.22´N	9°39.56´E	333m	Large box corer	53cm	
62	24.7.91	0809	58.0522	9.6590	58°03.20´N	9°39.60´E	331m	Large box corer		
63	24.7.91	0846	58.0525	9.6591	58°03.21´N	9°39.58´E	331m	Large box corer		
64	24.7.91	0953	58.0619	9.5508	58°03.78´N	9°39.71´E	358m	Large box corer		
65	24.7.91	1103	58.0635	9.6634	58°03.88´N	9°39.84´E	359m	Large box corer	55cm	6.6
66	24.7.91	1154	58.0522	9.6590	58°03.21´N	9°39.59´E	331m	Large box corer		
67	24.7.91	1245	58.0517	9.6588	58°03.20´N	9°39.60´E	332m	Large box corer		
68	24.7.91	1326	58.0521	9.6589	58°03.21´N	9°39.58´E	331m	Large box corer	55cm	
69	24.7.91	1403	58.0518	9.6577	58°03.21´N	9°39.58´E	332m	Large box corer	55cm	
70	24.7.91	1543-1658						Stereo camera		
71	25.7.91	0851	58.0523	9.6585	58°03.21´N	9°39.56´E	332m	Large box corer	60cm	

Table 5: Station List - Leg 2

Station no.	Date	Time	GPS °N	GPS °E	Decca °N	Decca °E	Depth to bottom	Gear	core length	temp.°C
72	25.7.91	1003	58.0534	9.6602	58°03.22´N	9°39.57´E	333m	Large box corer		
73	25.7.91	1053	58.0521	9.6586	58°03.20´N	9°39.56´E	333m	Large box corer		
74	25.7.91	1144	58.0524	9.6590	58°03.22´N	9°39.57´E	331m	Large box corer		
75	25.7.91	1233	58.0523	9.6597	58°03.22´N	9°39.59´E	332m	Large box corer		
76	25.7.91	1415	58.0520	9.6590	58°03.20´N	9°39.58´E	332m	Large box corer		
77	25.7.91	1453	58.0524	9.6587	58°03.23´N	9°39.56´E	333m	Large box corer		
78	25.7.91	1545	58.0521	9.6593	58°03.21´N	9°39.60´E	332m	Large box corer	55cm	6.4
79	25.7.91	1645	58.0521	9.6593	58°03.22´N	9°39.58´E	331m	Large box corer	55cm	6.4
80	25.7.91	1800	58.0519	9.6594				Stereo camera		
81	26.7.91	0813	58.0515	9.6604	58°03.21´N	9°39.57´E	333m	Large box corer	57cm	6.3
82	26.7.91	0957	58.0537	9.6590	58°03.20´N	9°39.56´E	333m	Large box corer		
83	26.7.91	0956-1010			58°03.22-.19´N	9°36.54-36.52´E		CTD		
84	26.7.91	1057-1125			58°4.70-4.68´N	9°36.59-36.42´E		CTD		
85	26.7.91	1225	58.0630	9.6218	58°03.40´N	9°39.22´E	333m	Soderberg gas corer		
86	26.7.91	1348	58.0526	9.6596	58°03.24´N	9°39.62´E	333m	Soderberg gas corer		
87	26.7.91	1509	58.0521	9.6596	58°03.21´N	9°39.63´E	333m	Olausson corer		
88	26.7.91	1706	58.0526	9.6597	58°03.22´N	9°39.59´E	333m	Soderberg gas corer		
89	26.7.91	1913	58.0521	9.6587	58°03.22´N	9°39.59´E	332m	Soderberg gas corer		
90	27.7.91	0801	58.0522	9.6583	58°03.22´N	9°39.57´E	332m	Soderberg gas corer		
91	27.7.91	0917	58.0517	9.6583	58°03.19´N	9°39.57´E	331m	Soderberg gas corer		
92	27.7.91	1027	58.0519	9.6896	58°03.23´N	9°41.42´E	320m	Soderberg gas corer		
93	27.7.91	1152	58.0521	9.6903	58°03.22´N	9°41.48´E	320m	Soderberg gas corer		
94	27.7.91	1316	58.0525	9.6911	58°03.23´N	9°41.54´E	305m	Kasten core	2m	
95	27.7.91	1505	58.0522	9.6594	58°03.21´N	9°39.70´E	331m	Large box core		
96	27.7.91	1550	58.0529	9.6588	58°03.28´N	9°39.60´E	333m	Olausson corer	50cm	6.3
97	27.7.91	1631	58.0520	9.6584	58°03.22´N	9°39.59´E	333m	Olausson corer	40cm	6.5
98	27.7.91	1722	58.0521	9.6586	58°03.21´N	9°39.61´E	332m	Olausson corer	50cm	6.3
99	27.7.91	1756	58.0520	9.6583	58°03.20´N	9°39.58´E	333m	Olausson corer	55cm	6.5
100	27.7.91	1836	58.0519	9.6572	58°03.23´N	9°39.57´E	333m	Olausson corer		6.5
101	28.7.91	0849	58.0513	9.6576	58°03.20´N	9°39.60´E	333m	Multiple corer		
102	28.7.91	0934	58.0511	9.6564	58°03.20´N	9°39.53´E	333m	Multiple corer		
103	28.7.91	1117	58.0515	9.6571	58°03.23´N	9°39.58´E	332m	Multiple corer		
104	28.7.91	1211	58.0547	9656.0000	58°03.41´N	9°39.53´E	339m	Multiple corer		
105	28.7.91	1312	58.0521	9.6571	58°03.23´N	9°39.81´E	328m	Large box corer	66cm	6.4
106	28.7.91	1404	58.0521	9.6579	58°03.24´N	9°39.57´E	323m	Large box corer	66cm	6.6
107	28.7.91	1557	58.0505	9.6578	58°03.22´N	9°39.55´E	326m	Large box corer	63cm	6.3
108	28.7.91	1651-1726			58°4.11-3.77´N	9°39.72-40.10´E		CTD, water cast		

Table 5: cont...1

Station no.	Date	Time	GPS °N	GPS °E	Decca °N	Decca °E	Depth to bottom	Gear	core length	temp. °C
109	28.7.91	1747-1810			58°4.07´N	9°39.80´E		CTD, water cast		
110	28.7.91	1911-2009			58°3.27-.04´N	9°39.60-.51´E		Stereo camera		
111	29.7.91	0800-0830			58°03.97´N	9°40.06´E		Stereo camera		
112	29.7.91	0911	58.0631	9.6655	58°03.87´N	9°39.98´E	358m	Kasten core	2m	
113	29.7.91	0933-1022			58°03.91-89´N	9°40.19-39.72´E		Stereo camera		
114	29.7.91	1047	58.0646	9.6626	58°03.97´N	9°39.82″E	366m	Kasten core	2m	

TOTALS

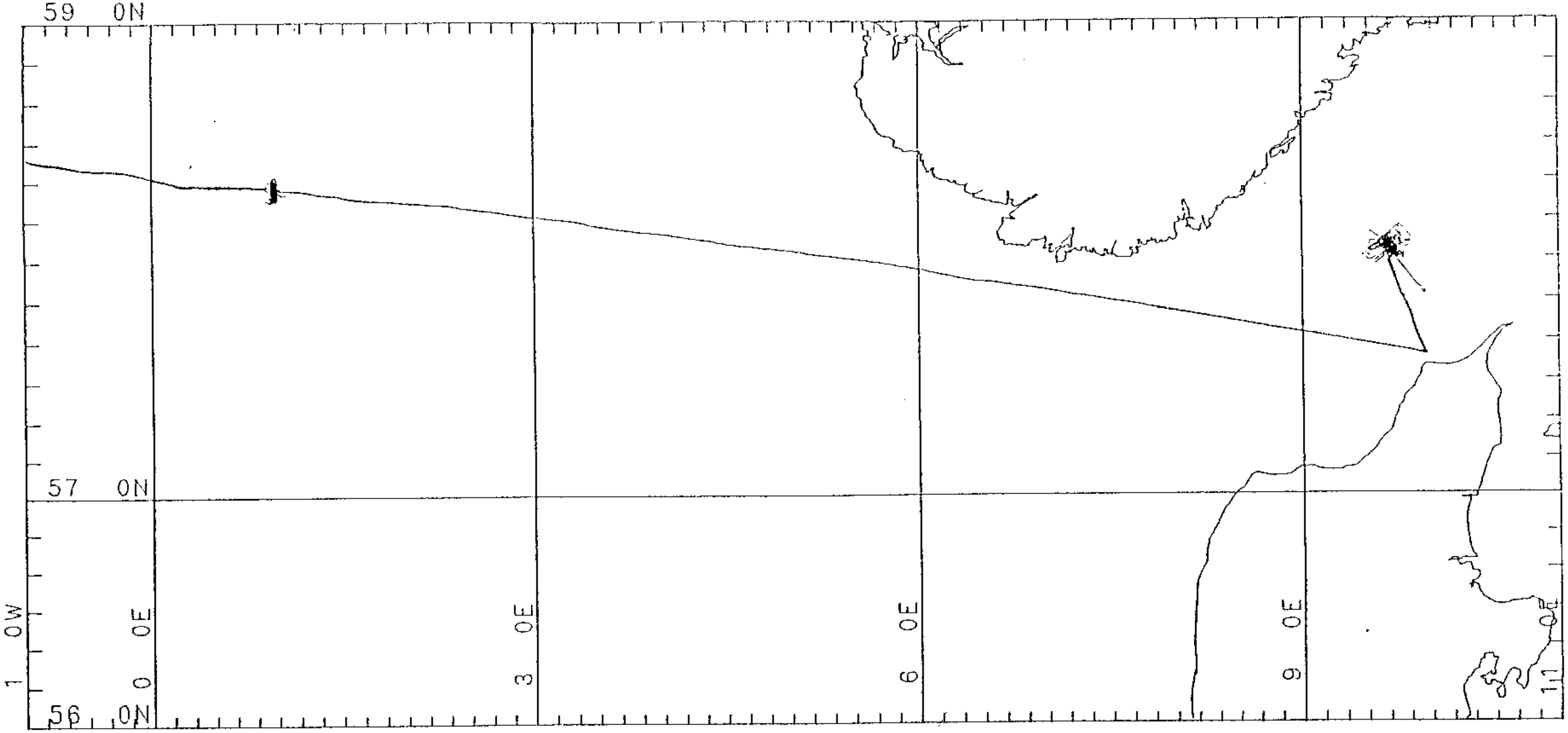
34 samples with the large box corer
18 samples with the Olausson corer
5 multiple corer samples
3 Kasten corer samples
5 Sodergberg corer samples
2 water casts
4 CTD profiles
5 camera deployments
1 acoustic velocity profile

Table 5: cont...2

Table 6: Core sample measurements - Leg 2

Station no.	Depth to bottom	macrofauna	meiofauna	T.O.C and T.I.C	sulphate reduction	total methane oxidation	aerobic methane oxidation	sediment methane	interstitial water chemistry
35	323m	#	#		#	#	#	#	#
37	330m	#							
38	327m	#							
39	266m	#	#		#	#	#	#	#
40	244m	#							
42	246m	#							
43	327m	#							
44	328m	#			#	#	#		#
45	321m				#	#	#	#	#
46	325m	#							
47	334m	#							
49	333m	#							
50	330m	#							
52	329m	#							
53	324m								
54	330m	#							
55	329m		#		#	#	#	#	#
56					#	#	#	#	#
61	333m	#	#	#	#	#	#		#
66		#							
71					#	#	#		#
81	333m				#	#	#		#
94	305m				#			#	
95					#	#	#		#
96	333m	#							
97	333m	#							
98	332m	#							
99	333m	#							
100	333m	#							
102	333m		#						
103	332m		#						
104					#	#	#		#
105		#	#		#	#	#		#
106		#							
107		#							
112	358m				#	#	#		
114	366m				#	#	#		

List of Figures



— Track plotted from bestnav

Figure 1: Challenger-82 Trackplot

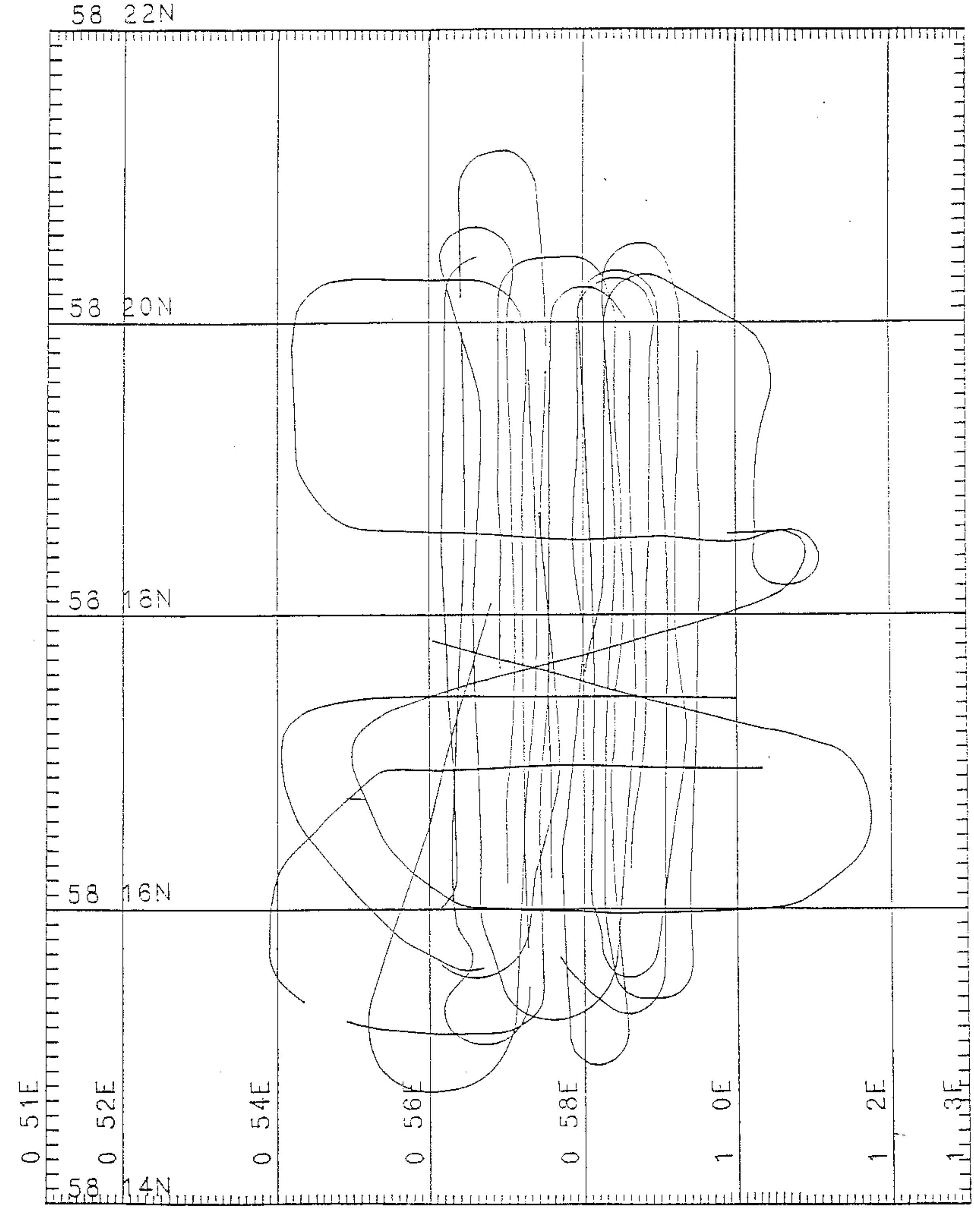


Figure 2: Challenger-82 Geophysical Survey (leg1)

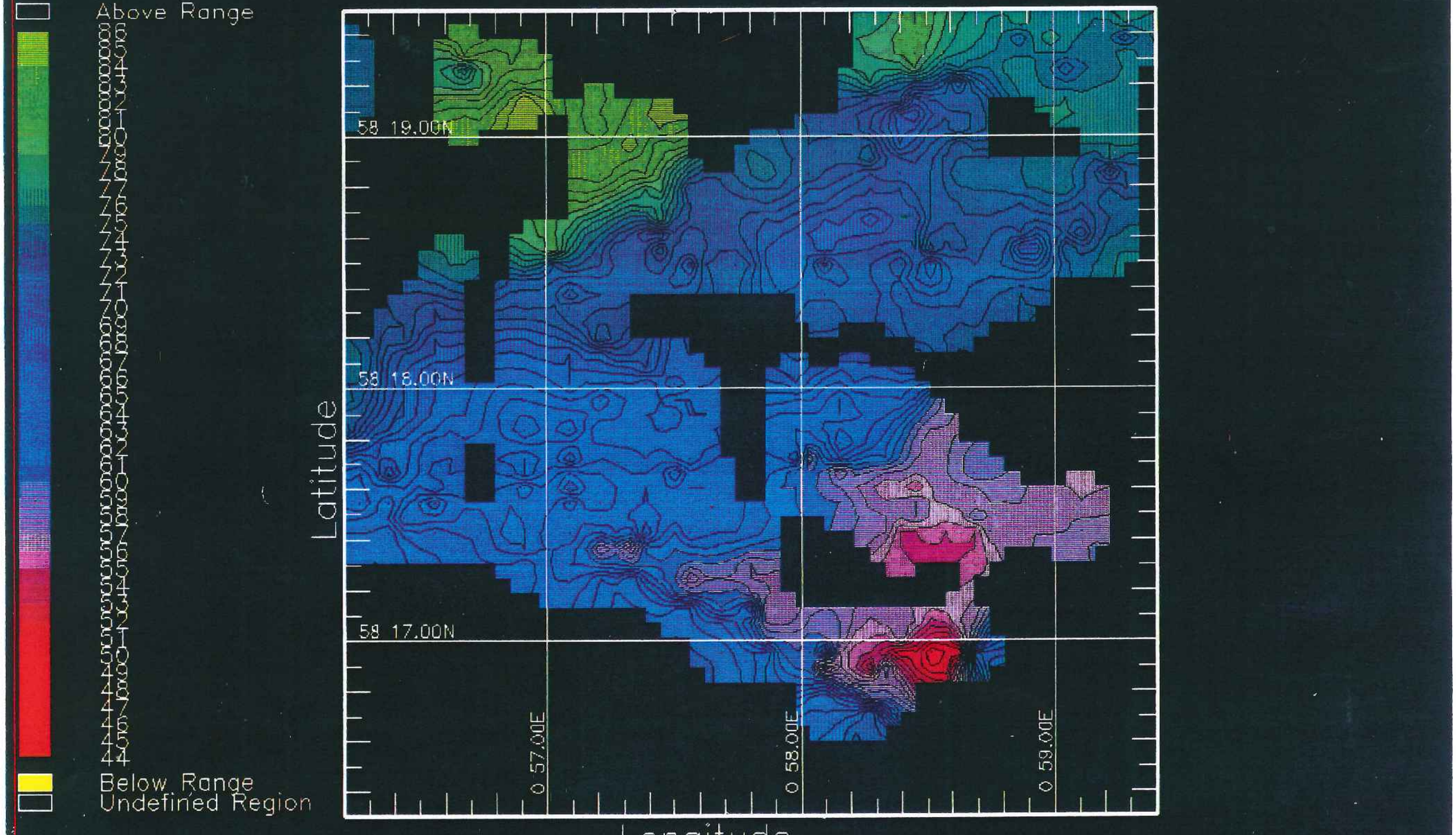


Figure 3: "Challenger 82 (Leg 1) Geophysics Survey Gas depth"
VARIABLE:—Gas depth

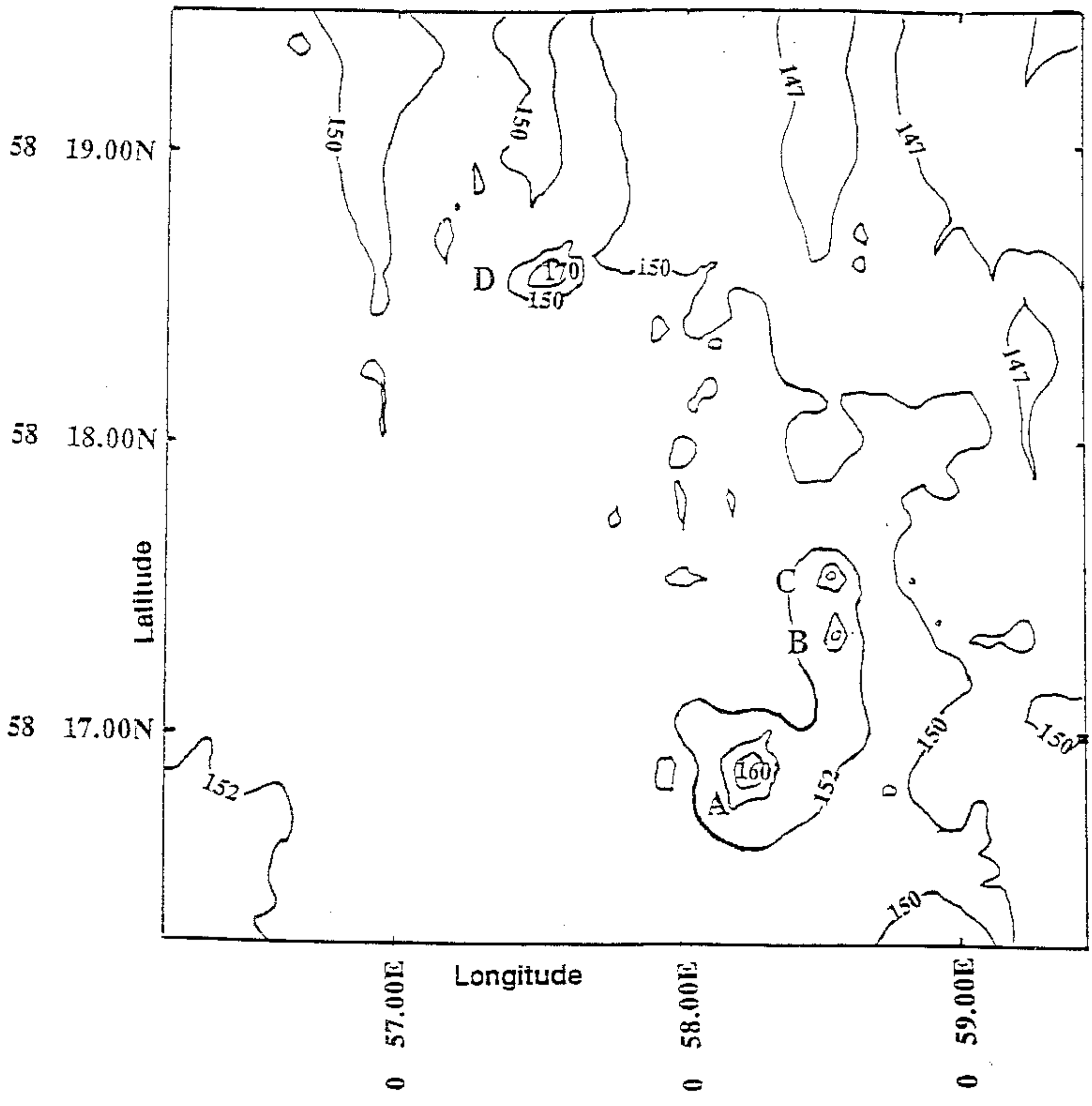


Figure 4: Challenger-82 leg 1 survey area showing pockmarks in the Witchground (A,B,C,D)

Depth (m)

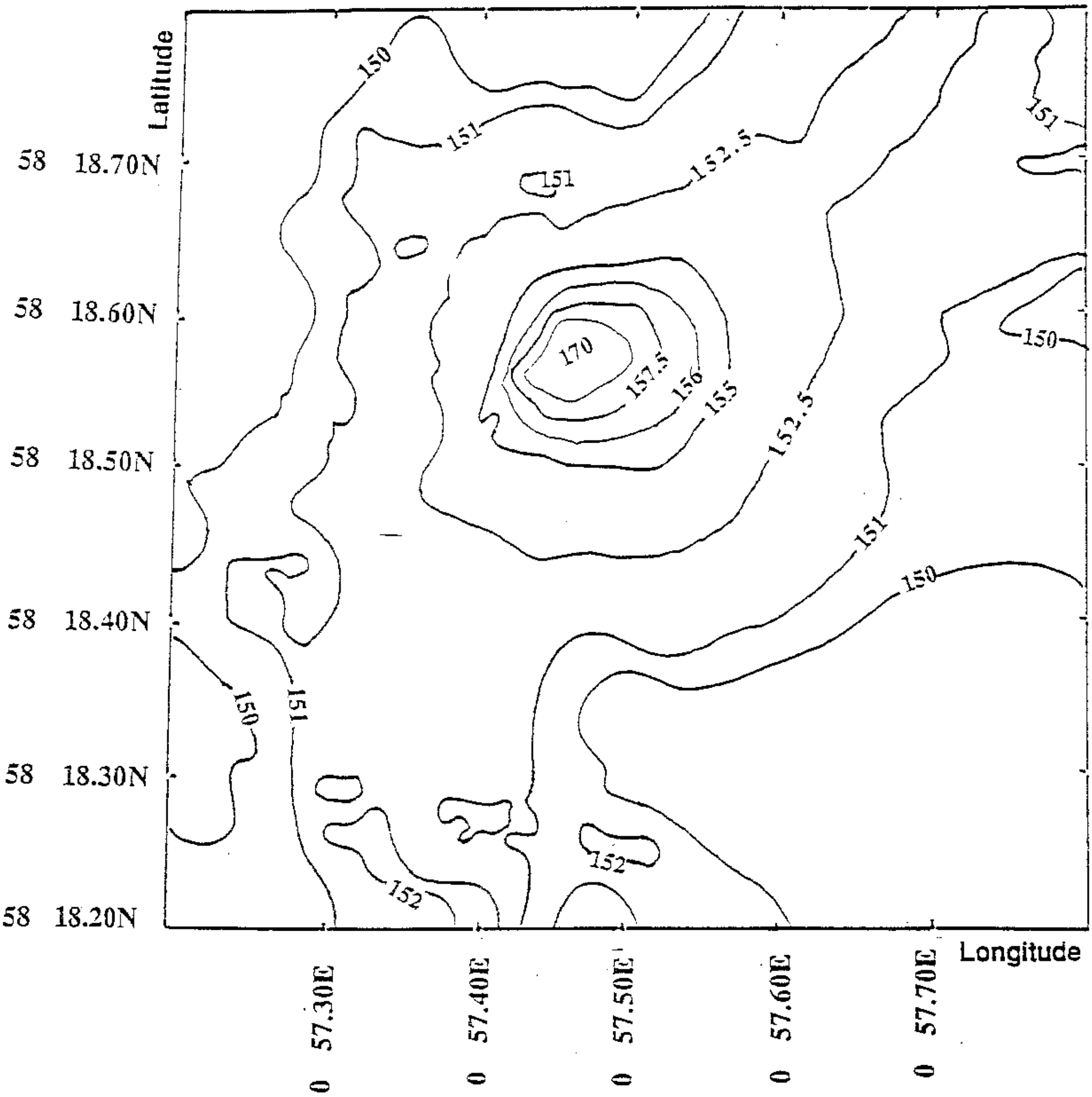


Figure 5: Depth contours of North-West pockmark (metres)

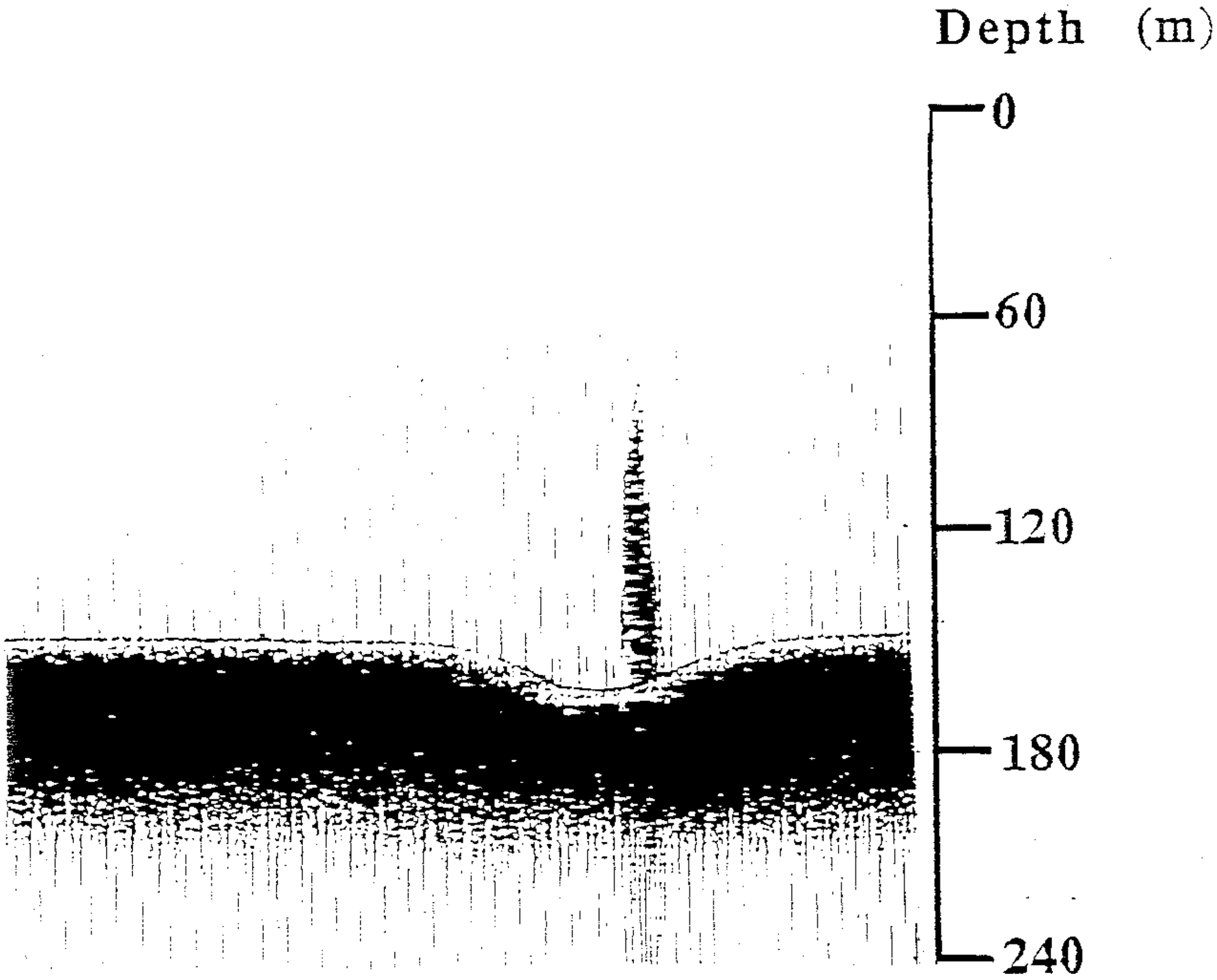


Figure 6: Gas plume rising from North-West pockmark

Figure 7a: Leg 1 Water sampling stations

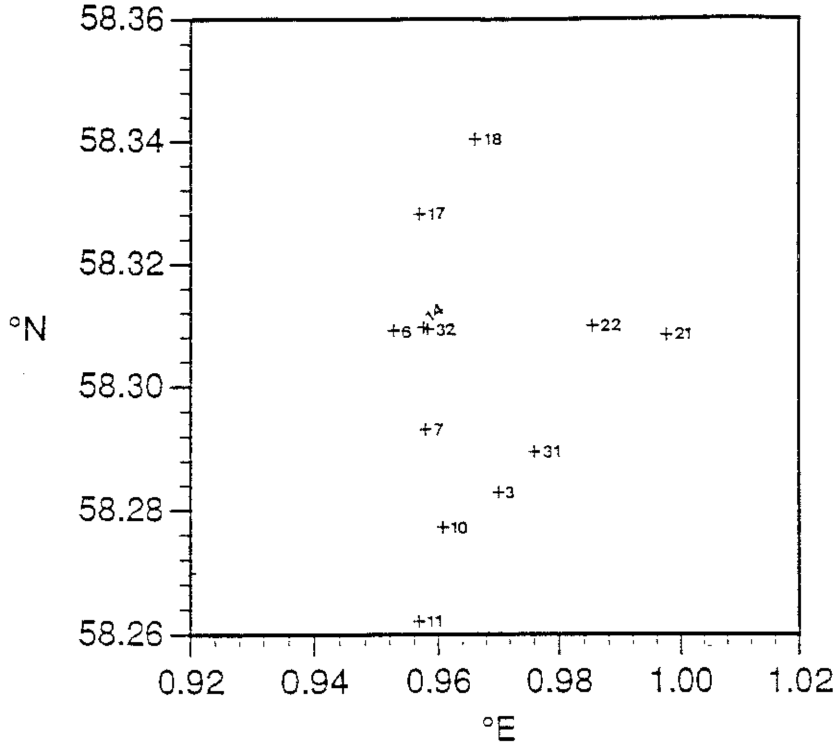


Figure 7b: Leg 1 Box core sampling stations

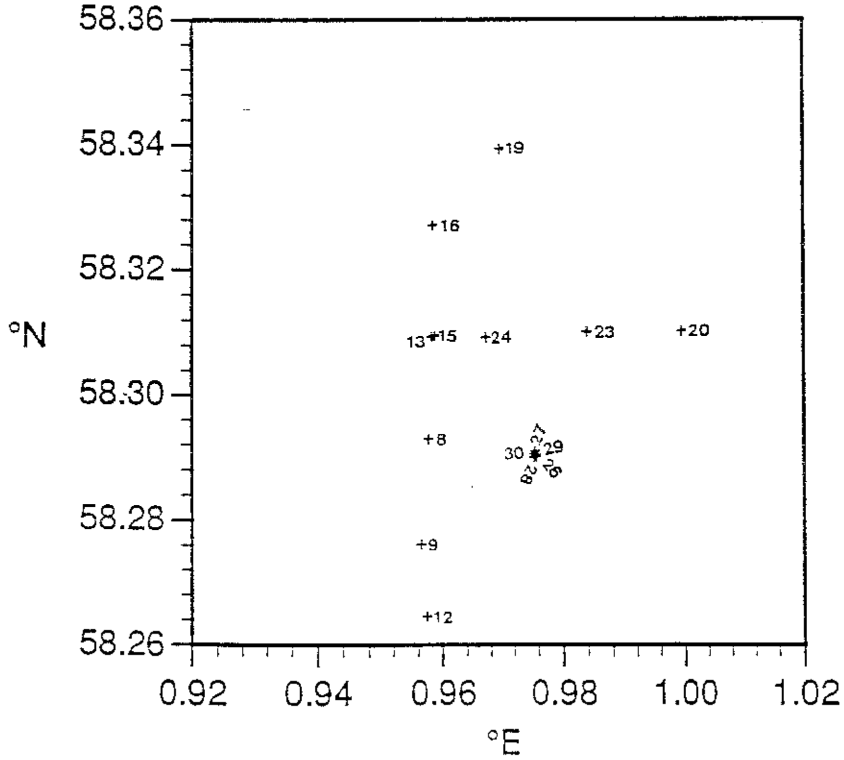


Figure 8: Methane and Hydrogen gas plots for Leg 1 samples

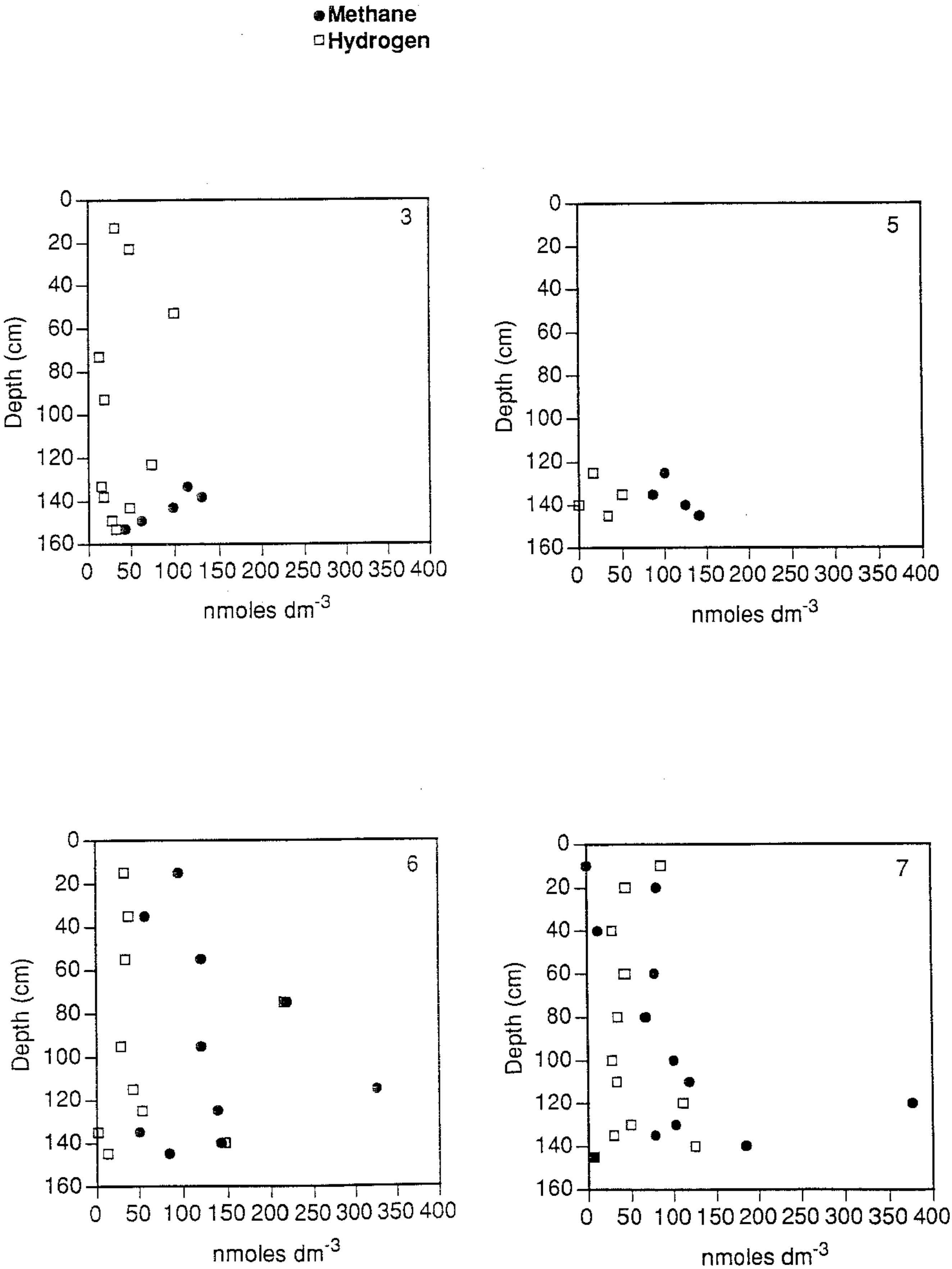


Figure 9: Methane and Hydrogen gas plots for Leg 1 samples

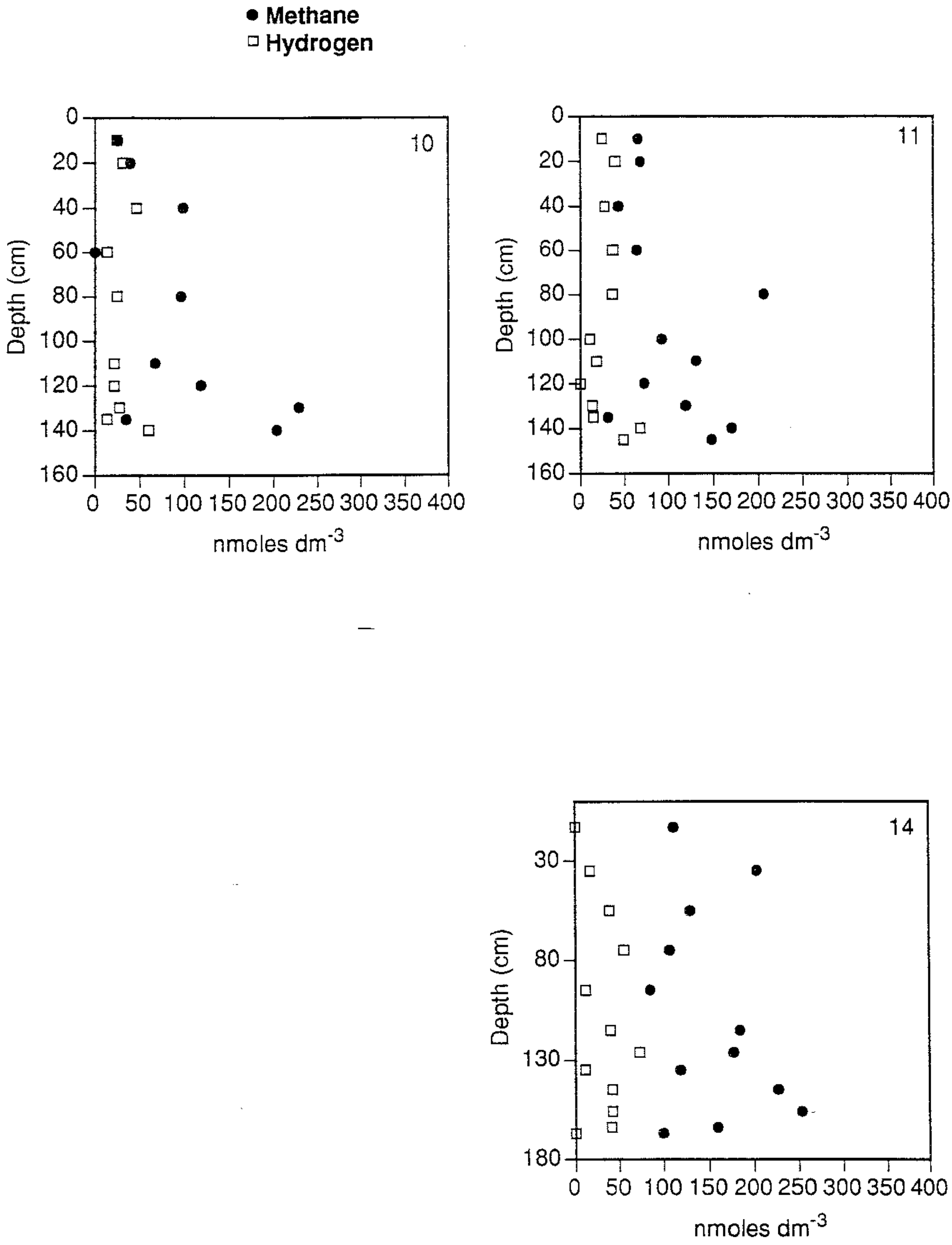


Figure 10: Methane and Hydrogen gas plots for Leg 1 samples

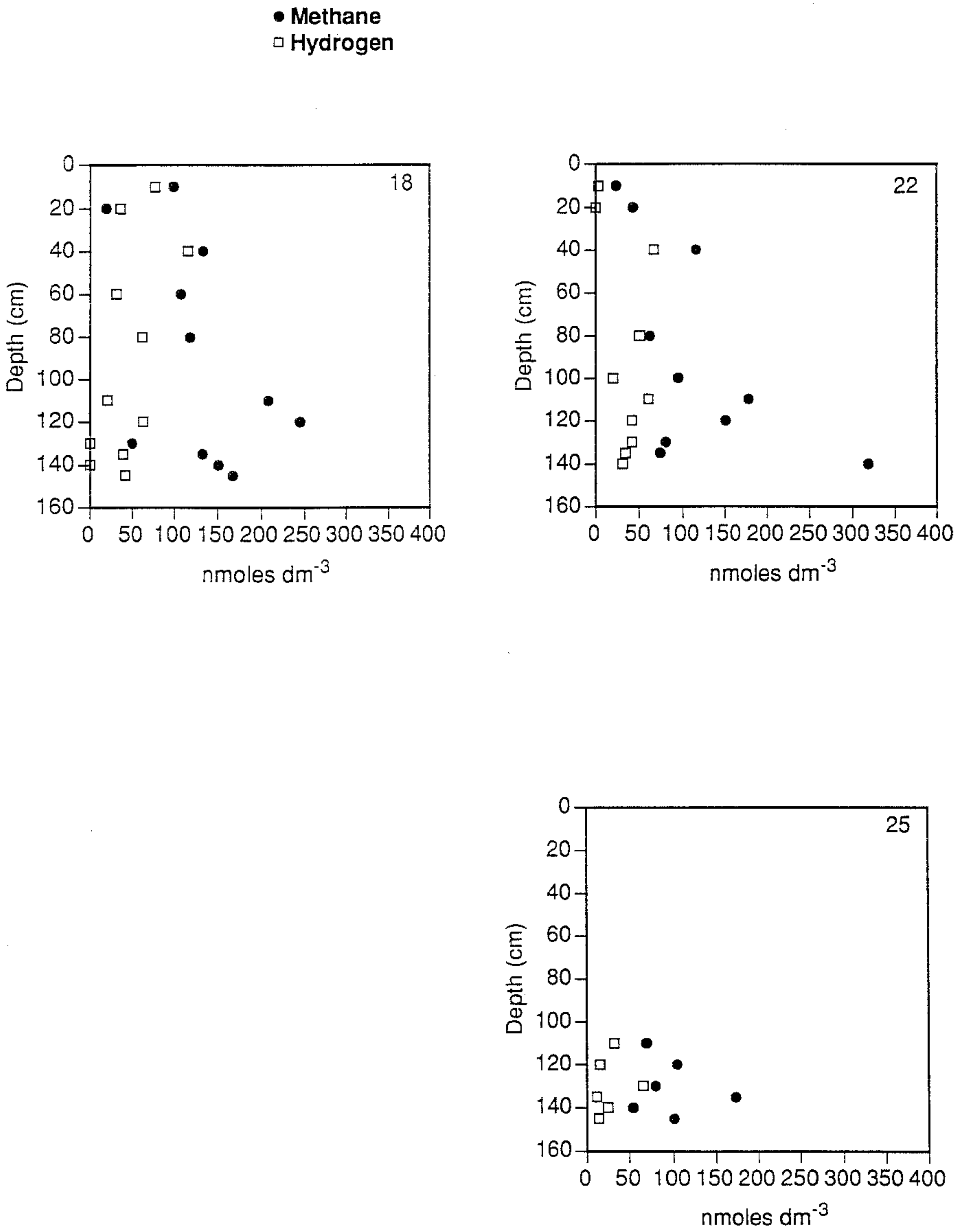


Figure 11: Methane concentration in water column along 0º57 68E, 15.7.91-17.7.91 (nmoles).

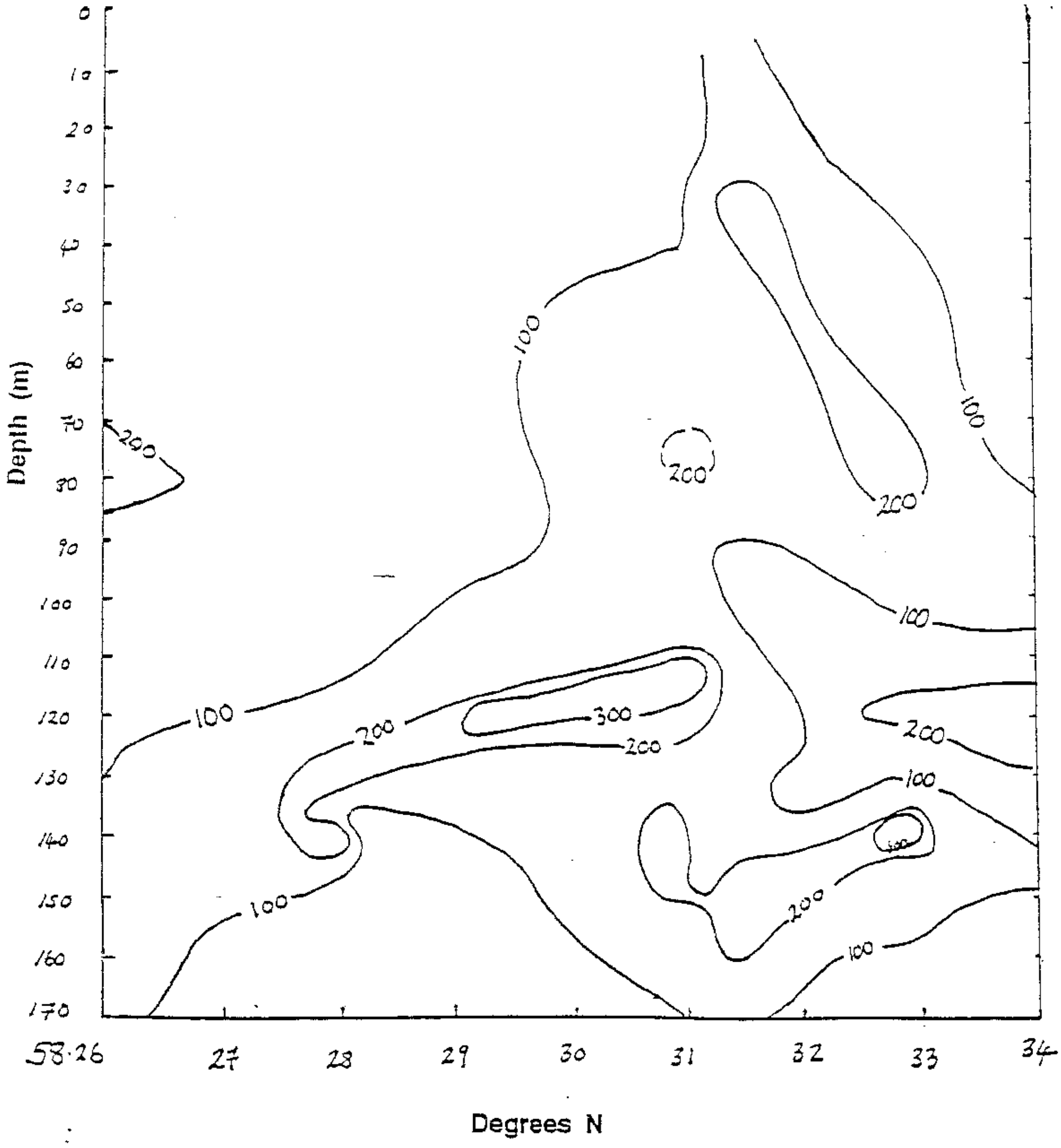
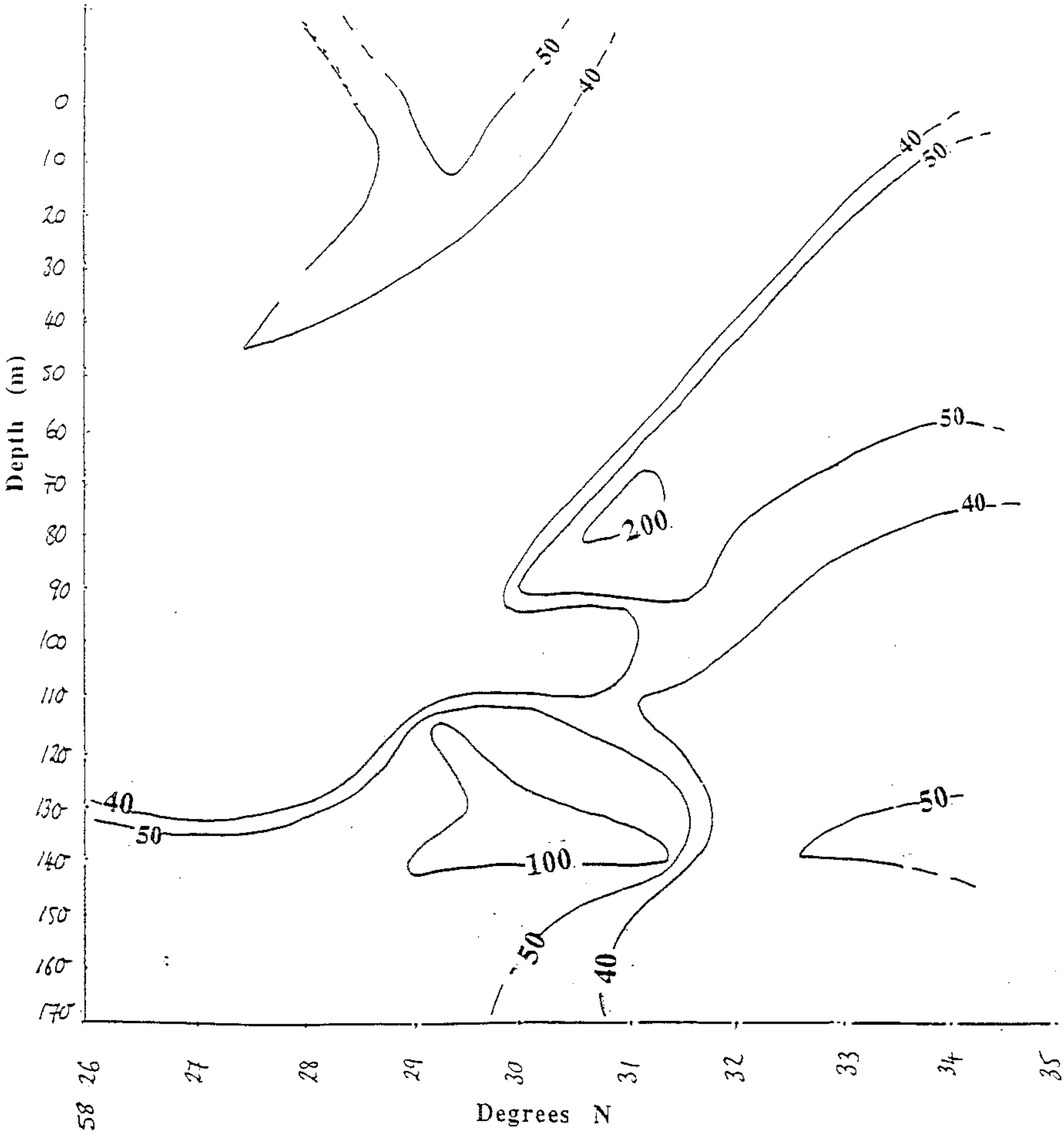


Figure 12: Hydrogen concentration in the water column along 0º57 68E, 15.7.91-17.7.91 (nmoles)



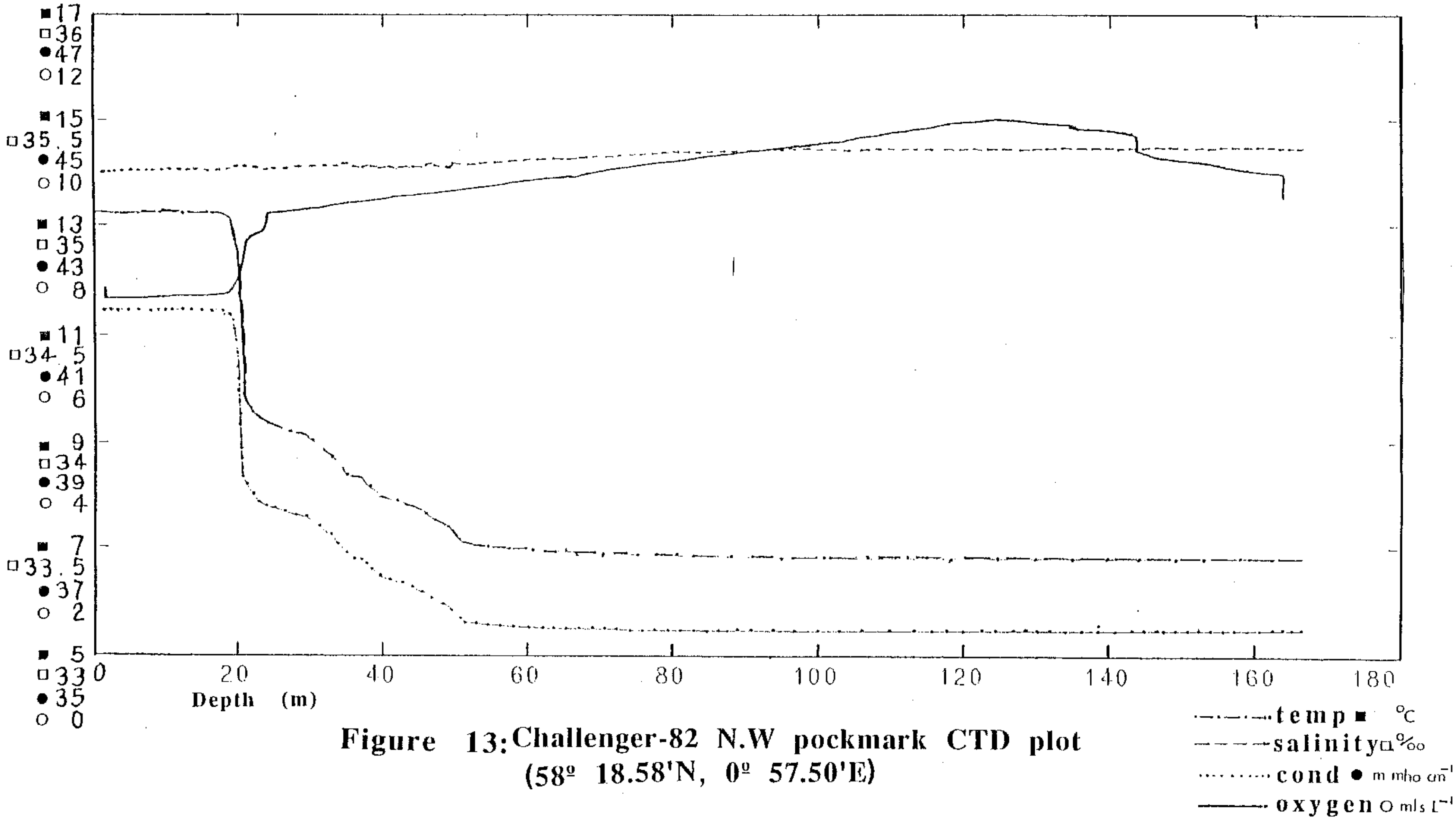


Figure 13: Challenger-82 N.W pockmark CTD plot (58º 18.58'N, 0º 57.50'E)

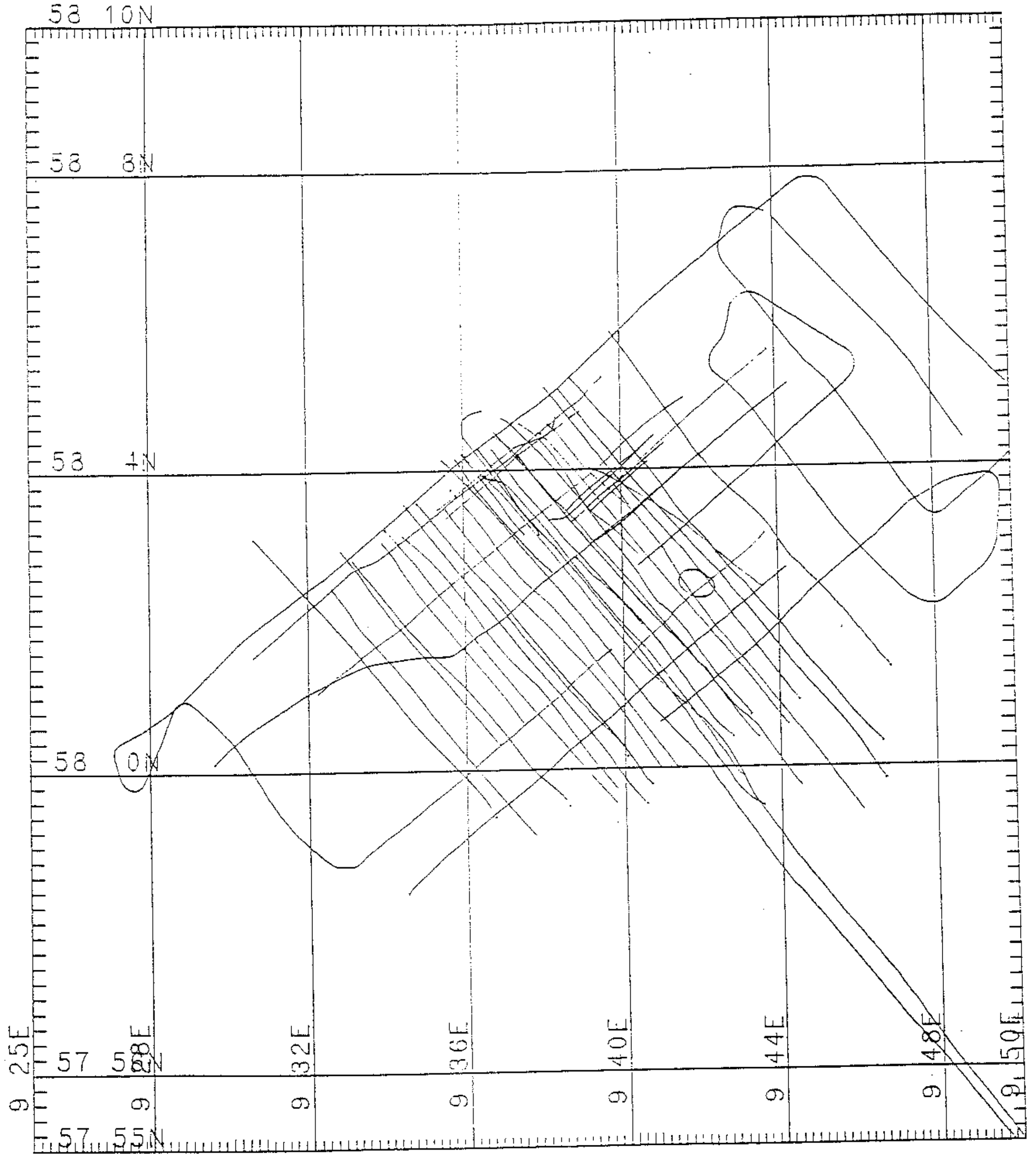


Figure 14: Challenger-82 Geophysical Survey (leg2)

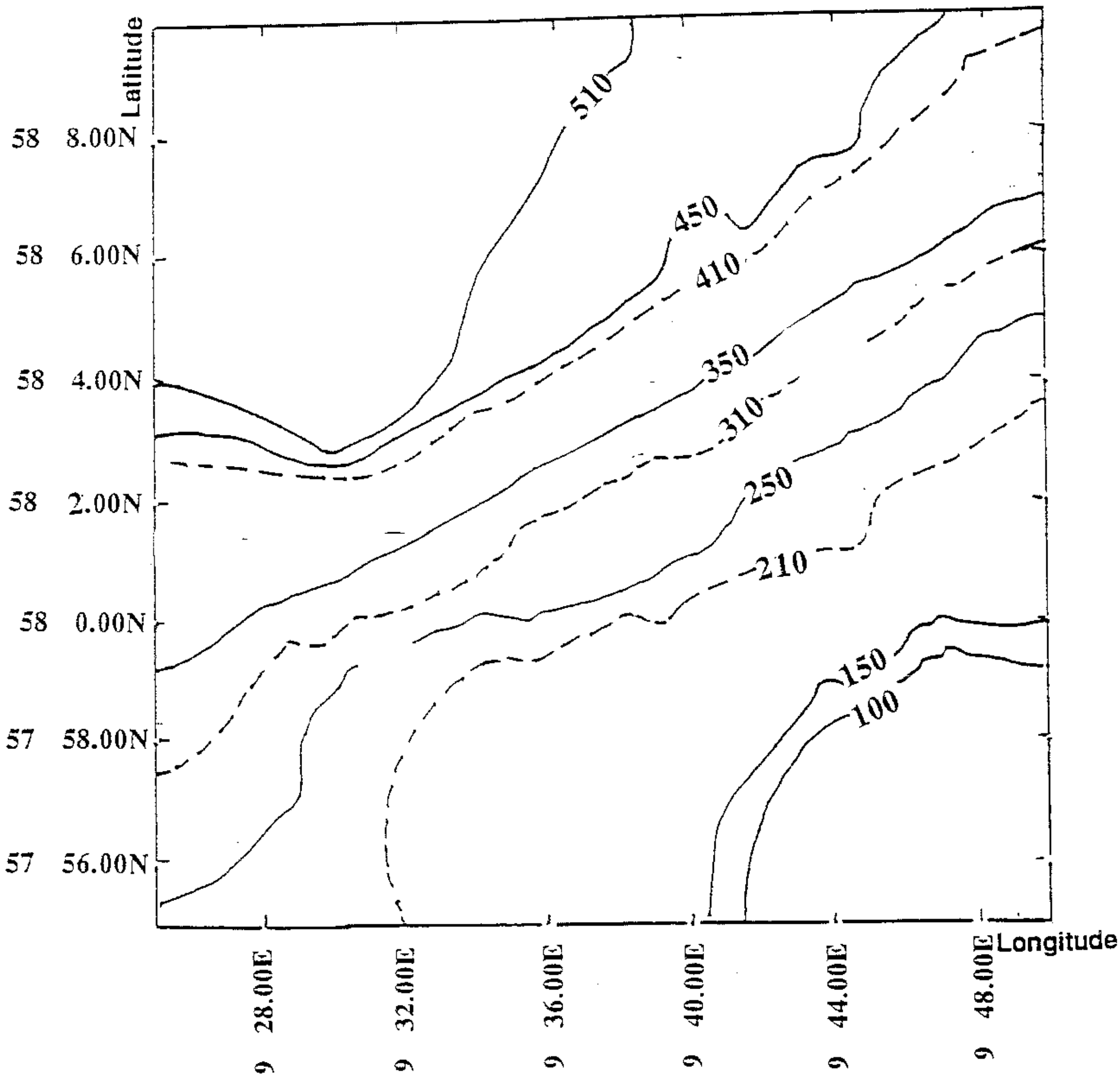


Figure 15: Challenger 82 leg 2 survey area in the Skagerrak

Depth (m)

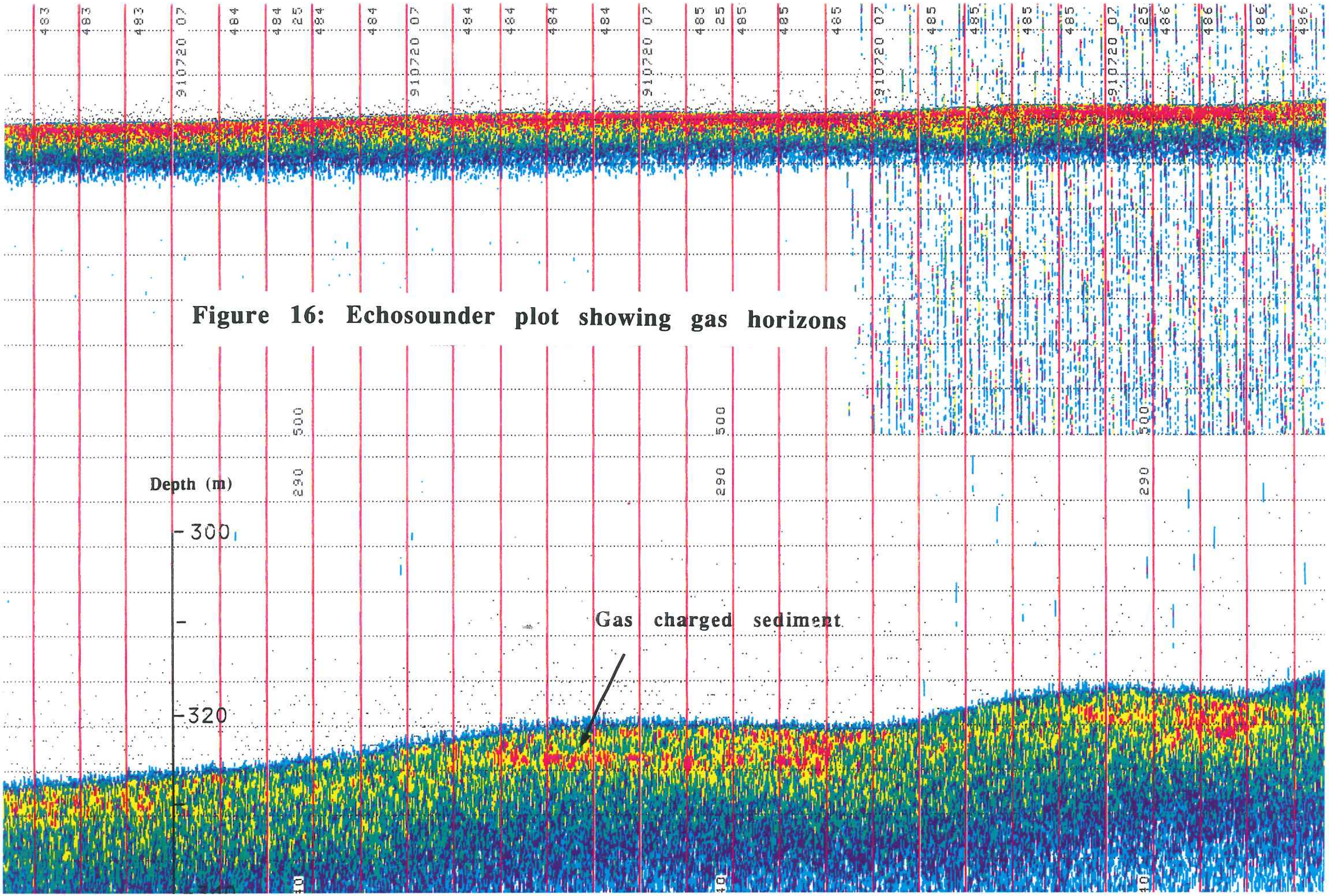


Figure 16: Echosounder plot showing gas horizons

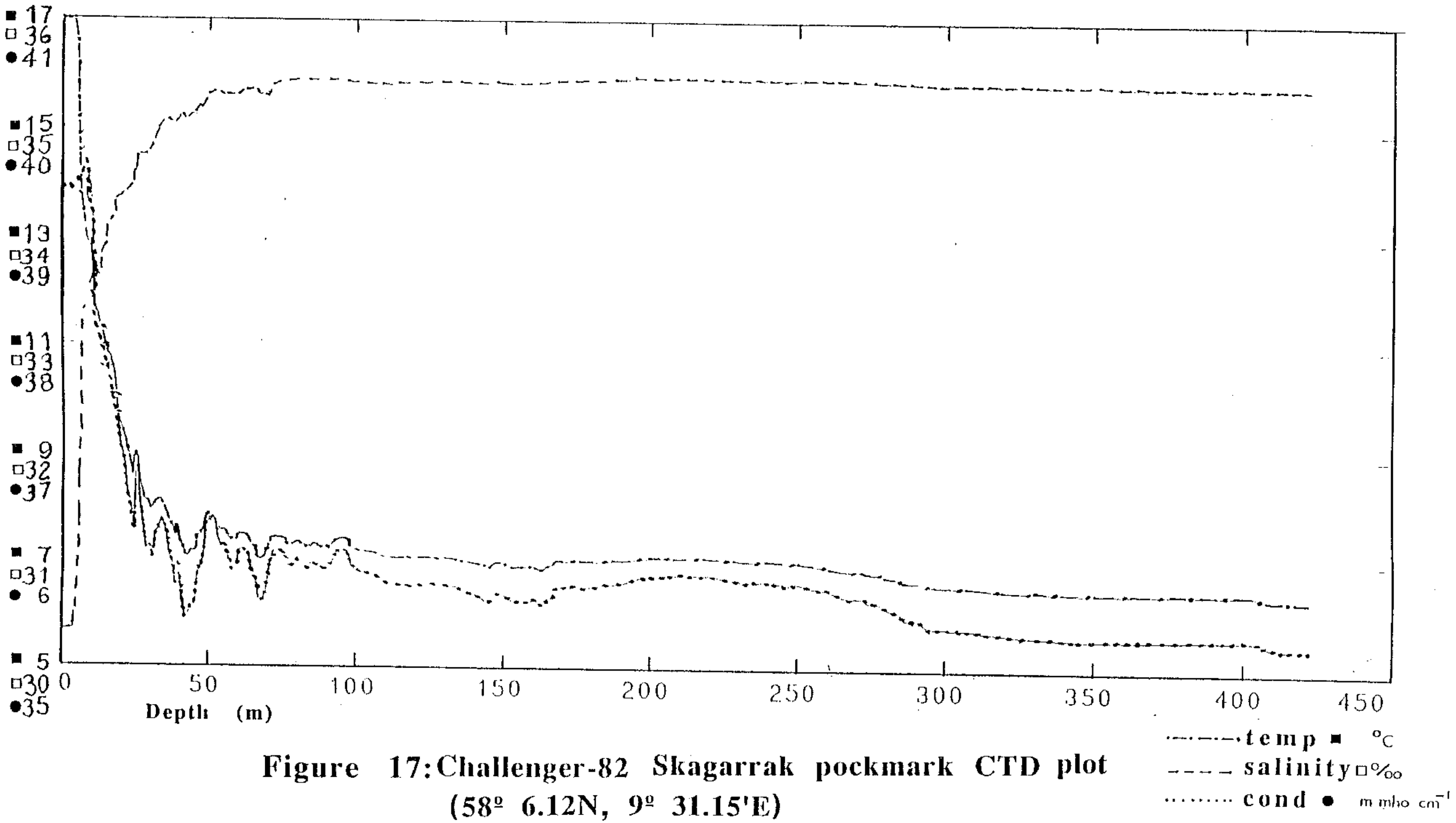


Figure 17: Challenger-82 Skagarrak pockmark CTD plot
(58º 6.12N, 9º 31.15'E)

Figure 18: Mud mound and wreck site record from 49KHz echosounder

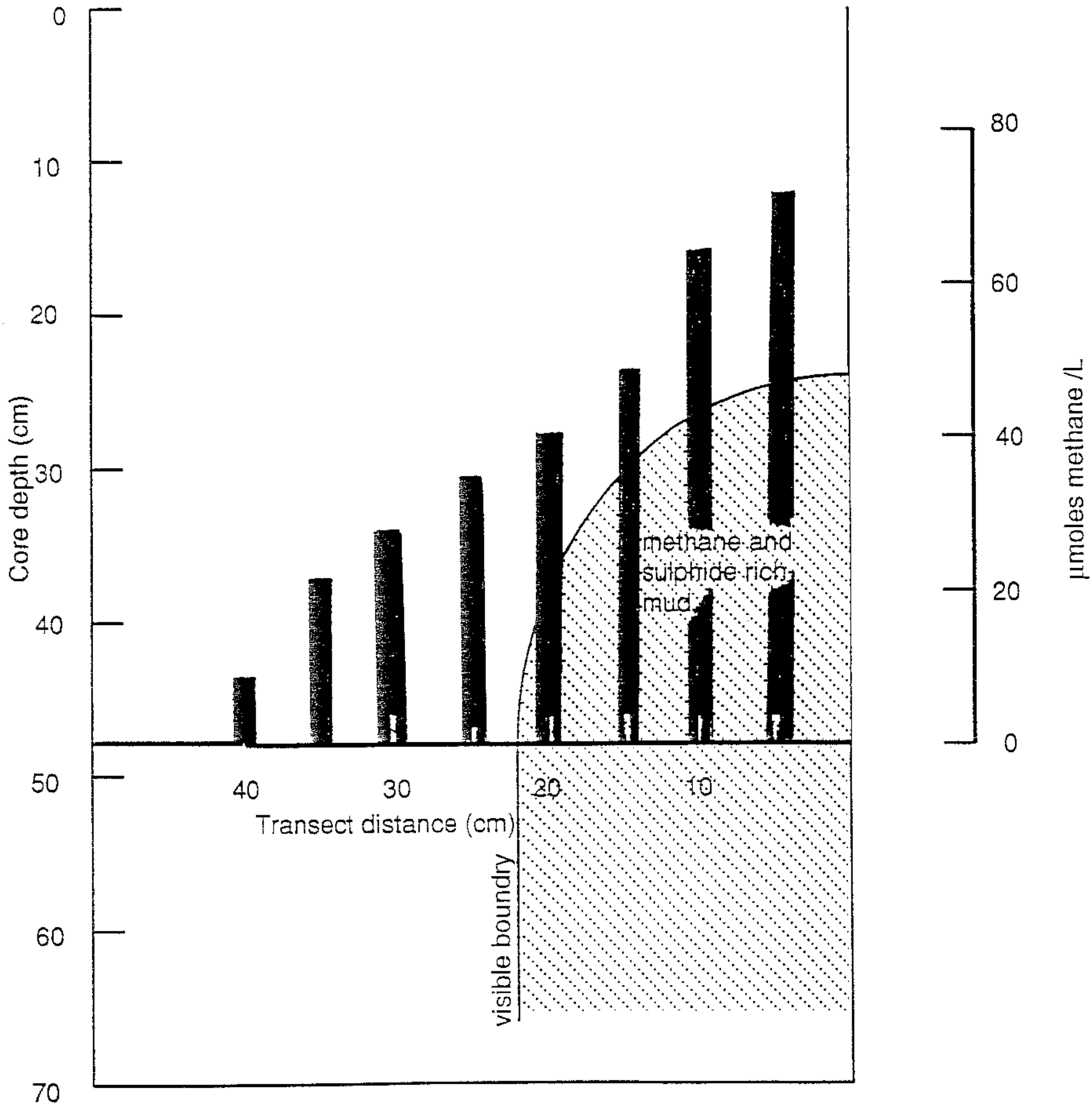


Figure 19: Core 106 transect, exhibiting methane concentration (umoles methane/L)

Figure 20: Methane concentrations (µmoles/L and mmoles/L) in sediment cores

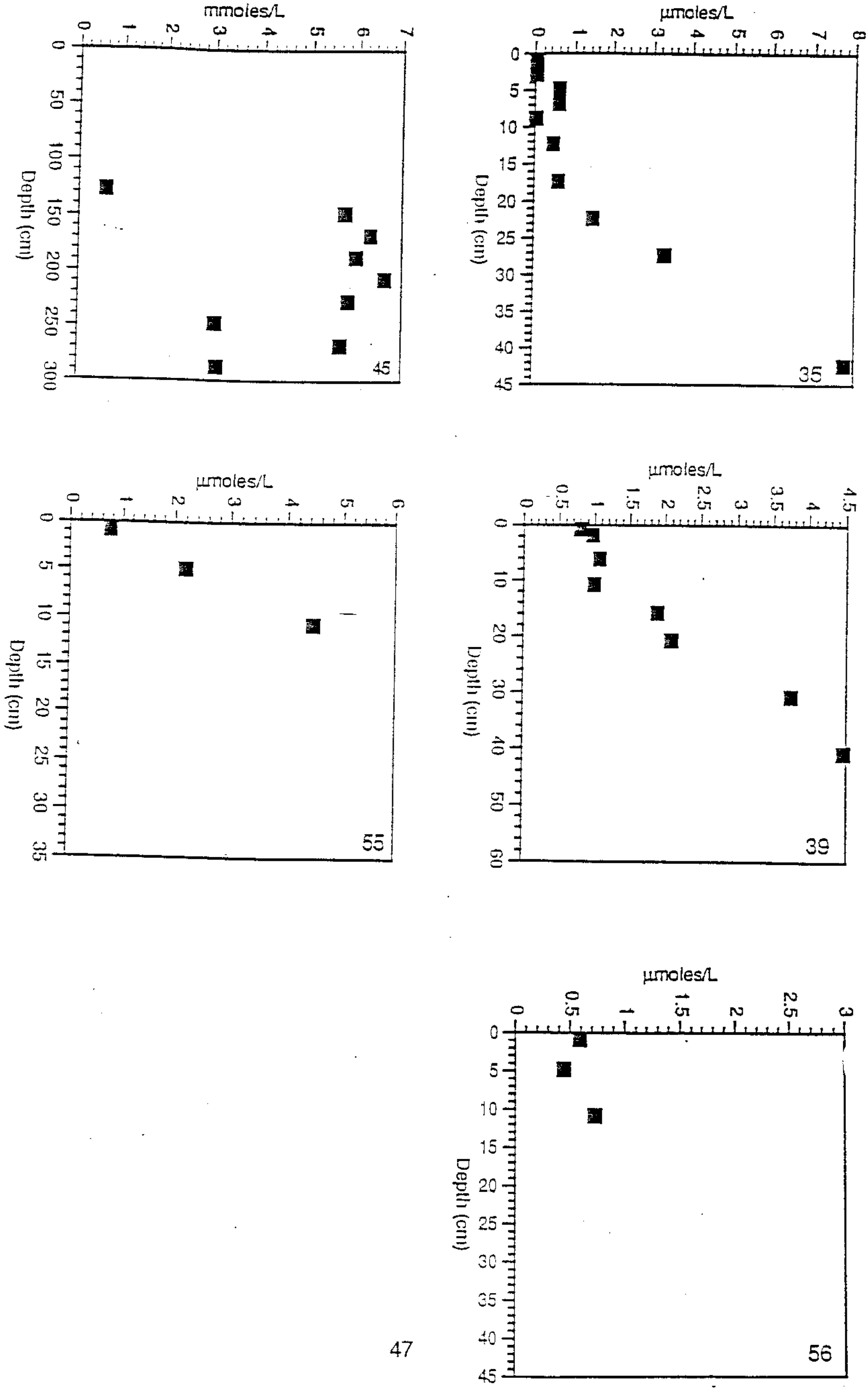


Figure 21: Methane concentrations (µmoles/L and mmoles/L) in sediment cores

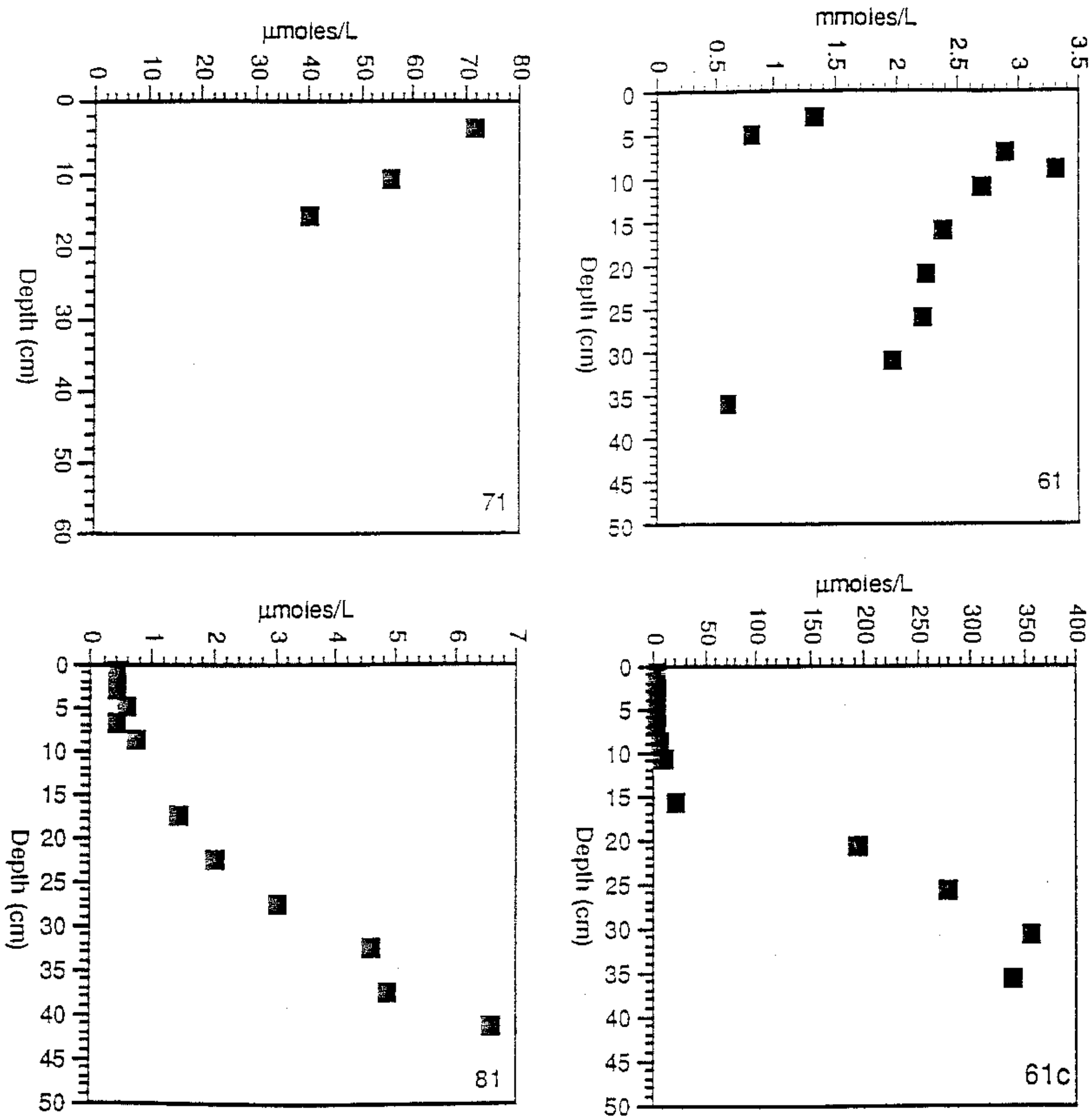


Figure 22: Methane concentrations (µmoles/L) in sediment cores

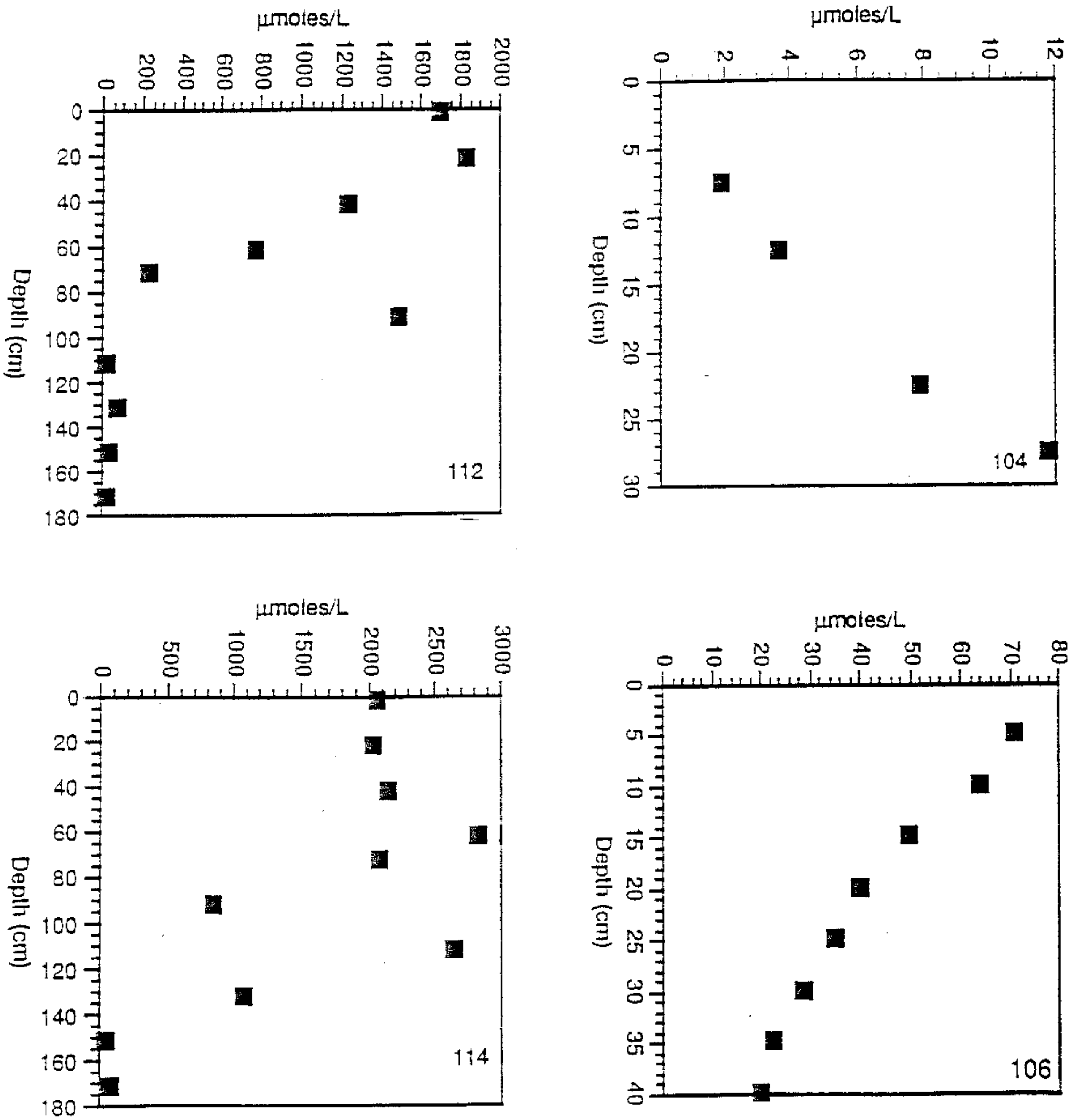


Figure 23: Aerobic methane oxidation rates (nmoles/g wet wt.) in sediment cores (July 1991)

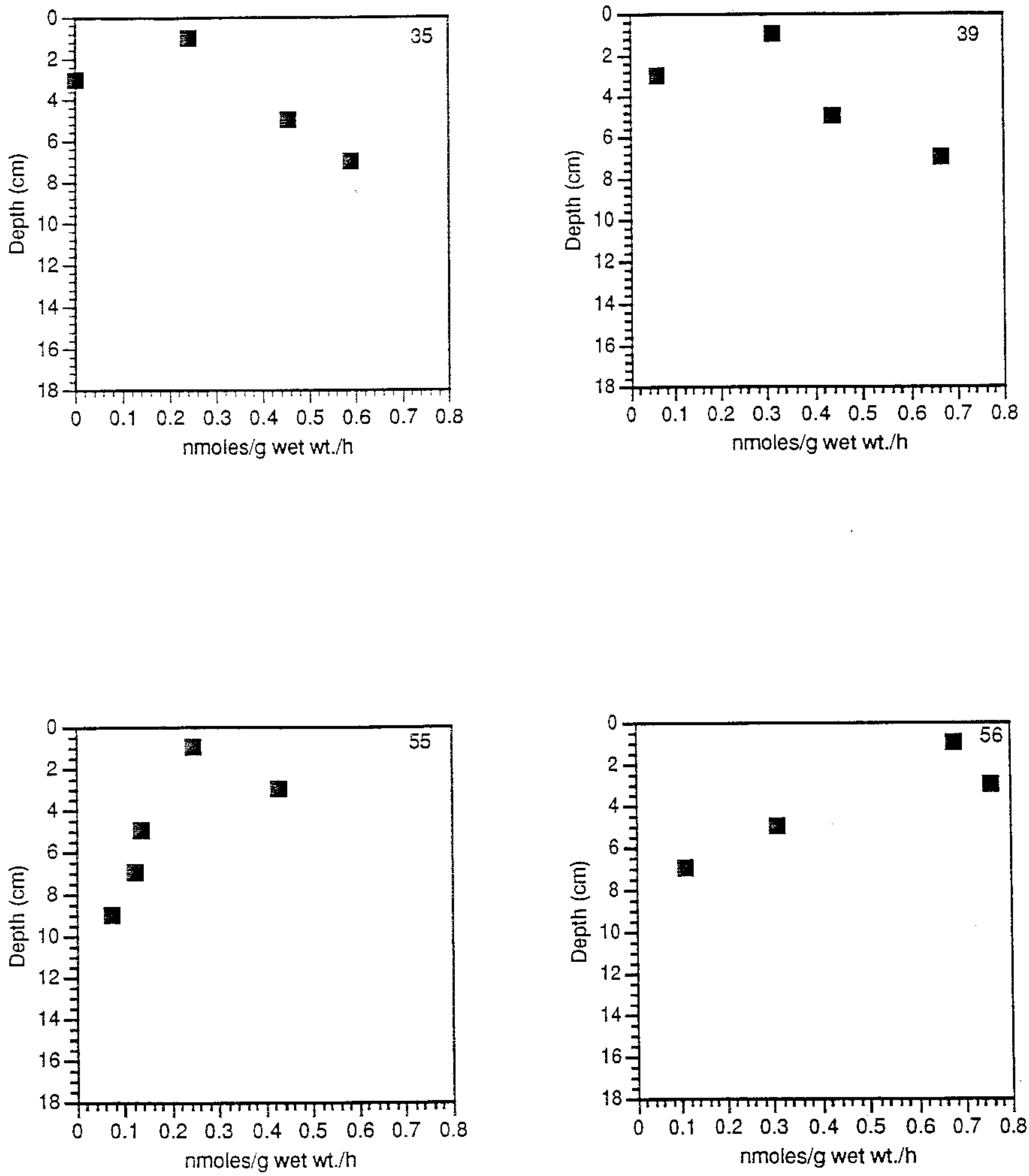


Figure 24: **Aerobic methane oxidation rates (nmoles/g wet wt.), in sediment cores (July 1991).**

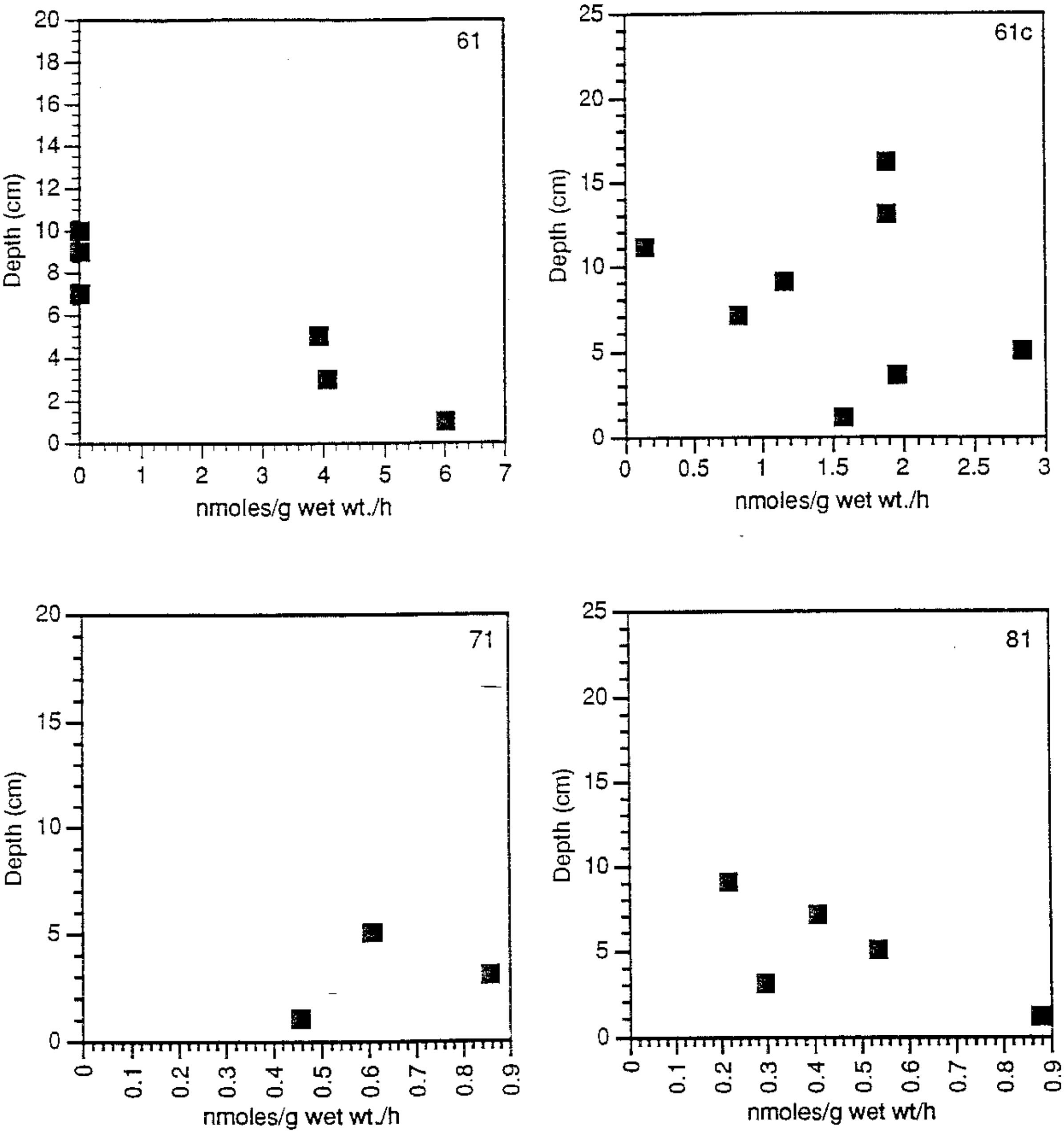
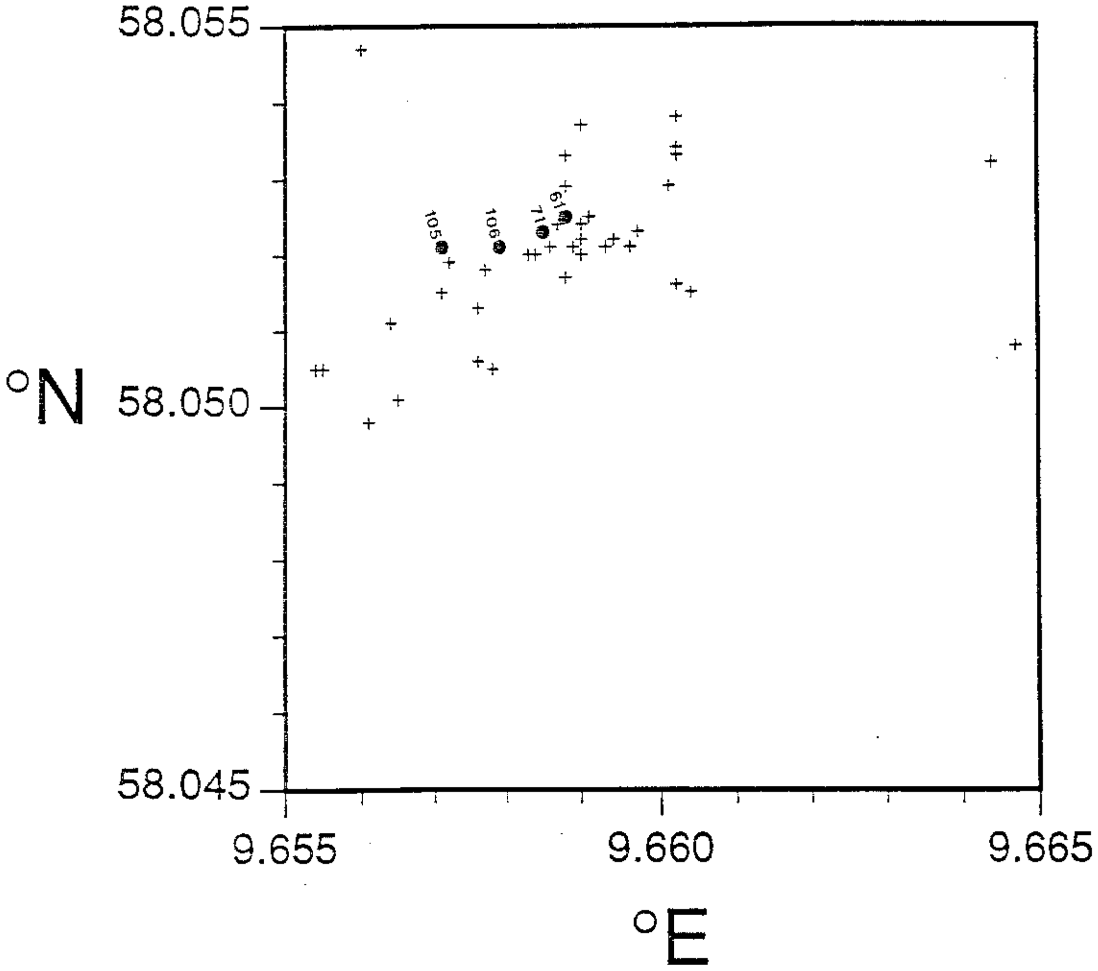


Figure 25: Box core stations in the seep area



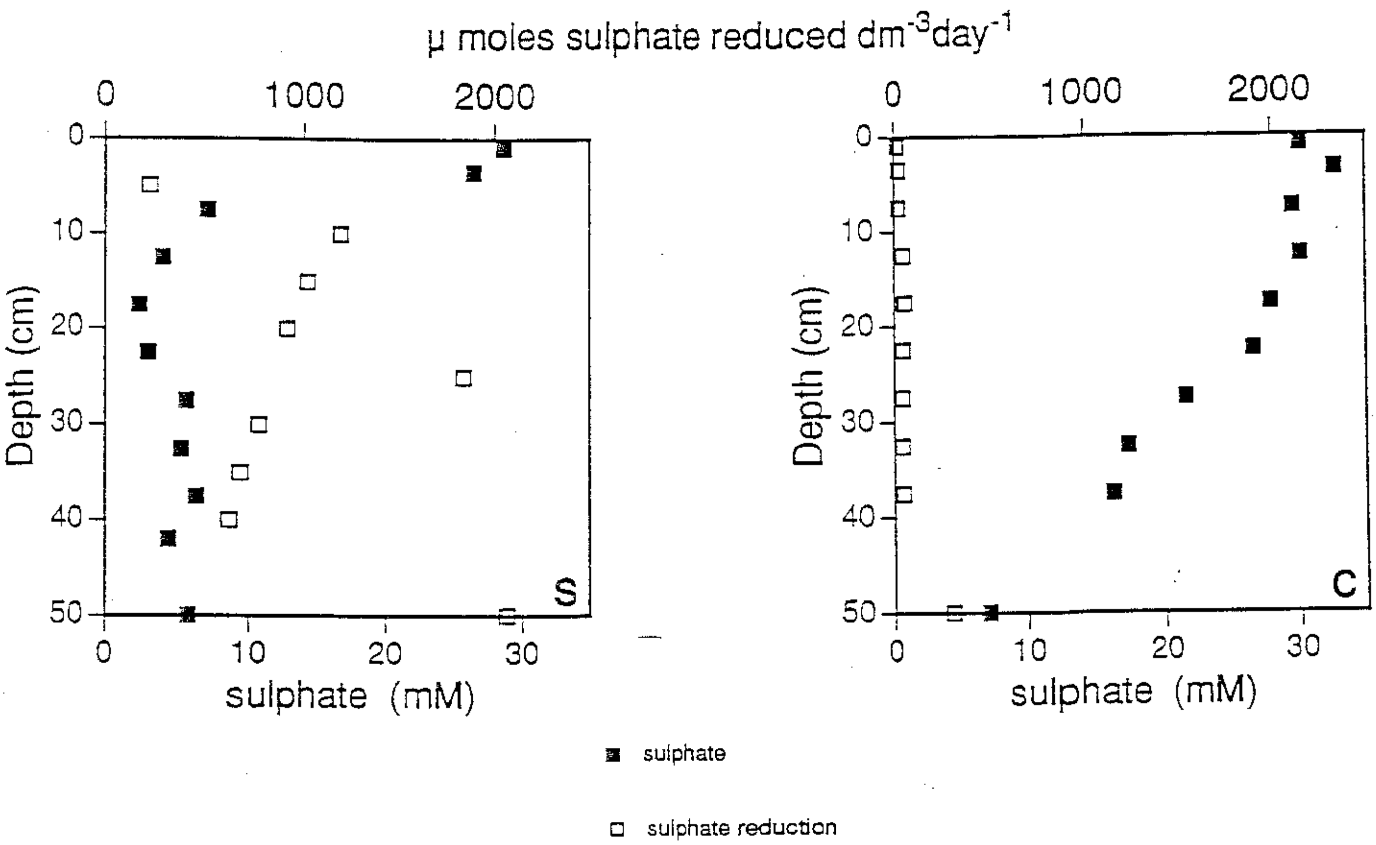


Figure 26: Sulphate concentration and reduction rates from subcores taken 30cm appart within a large box core enclosing part of a gas seep from 330m water depth in the Skagerrak