NORSK POLARINSTITUTT
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CRUISE REPORT

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Anders Solheim[1]
Anders Elverhøi[2]
Espen Sletten Andersen[1,2]
Halvor Jahre[1]

[1] Norwegian Polar Research Institute
P.O.Box 158, N-1330 Oslo Lufthavn, Norway
[2] Department of Geology University of Oslo
P.O.Box 1047, Blindern, N-0316 Oslo 3, Norway

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BACKGROUND AND OBJECTIVES

The marine survey off the west coast of Svalbard forms a part of the European project "Late Cenozoic Evolution of the Polar North Atlantic Margin" (PONAM). PONAM was initiated by the European Science Foundation (ESF) and its main focus is to understand the late Cenozoic climatic shifts. The PONAM studies were planned to be concentrated mainly along two traverses; one across the East Greenland margin through Scoresby Sound, and another from Kong Karls Land across Spitsbergen through Isfjorden and out to the Knipovich Ridge (Fig.1), the so-called "Svalbard Traverse".

Cruise objectives

The main objectives of the cruise were those of PONAM in general. A basic idea is to emphasize the detailed studies of the last glacial-interglacial cycle (i.e. the last 100.000 years), and use this information to extrapolate backwards in time and to study deeper parts of the obtained sedimentary or seismic sections. More specifically, however, the cruise was aimed at obtaining a better understanding of the points listed below.

- Timing, maximum extent, and mechanisms of deglaciation during the last glacial period.
- Glacial erosion of the hinterlands, both during glacial periods and during interglacial/interstadial periods (as the present-day).
- Interglacial deposition of erosional products in the fjord systems, intermediate storage before the next glacial advance.
- Deposition on the shelf and slope during glacials.
- Sedimentary processes on the slope as a function of glacial-interglacial changes.
- Definition of glacial-interglacial cycles and the onset of glaciations in seismic records.
- Accumulation of pollutants in fjord sediments in Spitsbergen.
- General mapping of the distribution and composition of the unlithified sediment cover, and the composition and structure of the uppermost, subcropping bedrock.

While the upper 6 points are strongly PONAM related, the lower two follow from the Norwegian Polar Research Institute (NPRI)'s responsibilities as the federal institution for mapping and research in Norwegian polar regions. The mapping part mostly implies that seismic lines and core stations are planned also with an optimal regional coverage in mind.

Organization

The cruise was part of the regular activities of NPRI, as well as being an integrated part of the European Science Foundation PONAM project. The PONAM program is a joint European project with seven nations (Belgium, Denmark, France,Germany, Norway, Sweden and the United Kingdom) where the main emphasis is on understanding the mechanisms and consequences of the major climatic changes during the Late Cenozoic. The PONAM program focuses on three themes: Theme A, the long term development of the Late Cenozoic environment as reflected in the sediments deposited in the huge sediment fans outside the shelf troughs; Theme B, the last interglacial-glacial cycle; and theme C, the present day sediment transfer from land to the ocean. Themes A and B are being studied from transects across the Greenland margin at Scoresby Sund, and across

Svalbard along its western margin and the Barents Sea at the Bear Island Trough.

By running the cruise as a part of the PONAM program, one could benefit from having national and international cooperation, thereby widening the scope of the studies and subsequent data processing. The cruise was organized as a joint venture between the Norwegian Polar Research Institute, the University of Oslo and the University of Bergen. In addition, there were participants from the University of Tromsø, Woods Hole Oceanographic Institution (USA), the University College of Wales, Aberystwyth (United Kingdom) and the University of Gent (Belgium).

Funding

The cruise was funded mainly by the Norwegian Polar Research Institute, which provided the ship and significant funds for the equipment. From a total budget of approximately NOK 3 mill. NOK 2.5 mill. were provided from NPRI. The University of Bergen, Department of geology, section B, provided three days of ship time and various types of sampling equipment at low cost. Additionally, funds of NOK 0.4 mill. were raised from the Norwegian oil companies Hydro, Statoil and Saga,and the Norwegian Petroleum Directorate. The oil companies funding was part of their support to the Svalbard Traverse project. Finally, funds were provided from the Norwegian Research Council for Science and Humanities (NAVF), in the form of salary for a stipendiate.

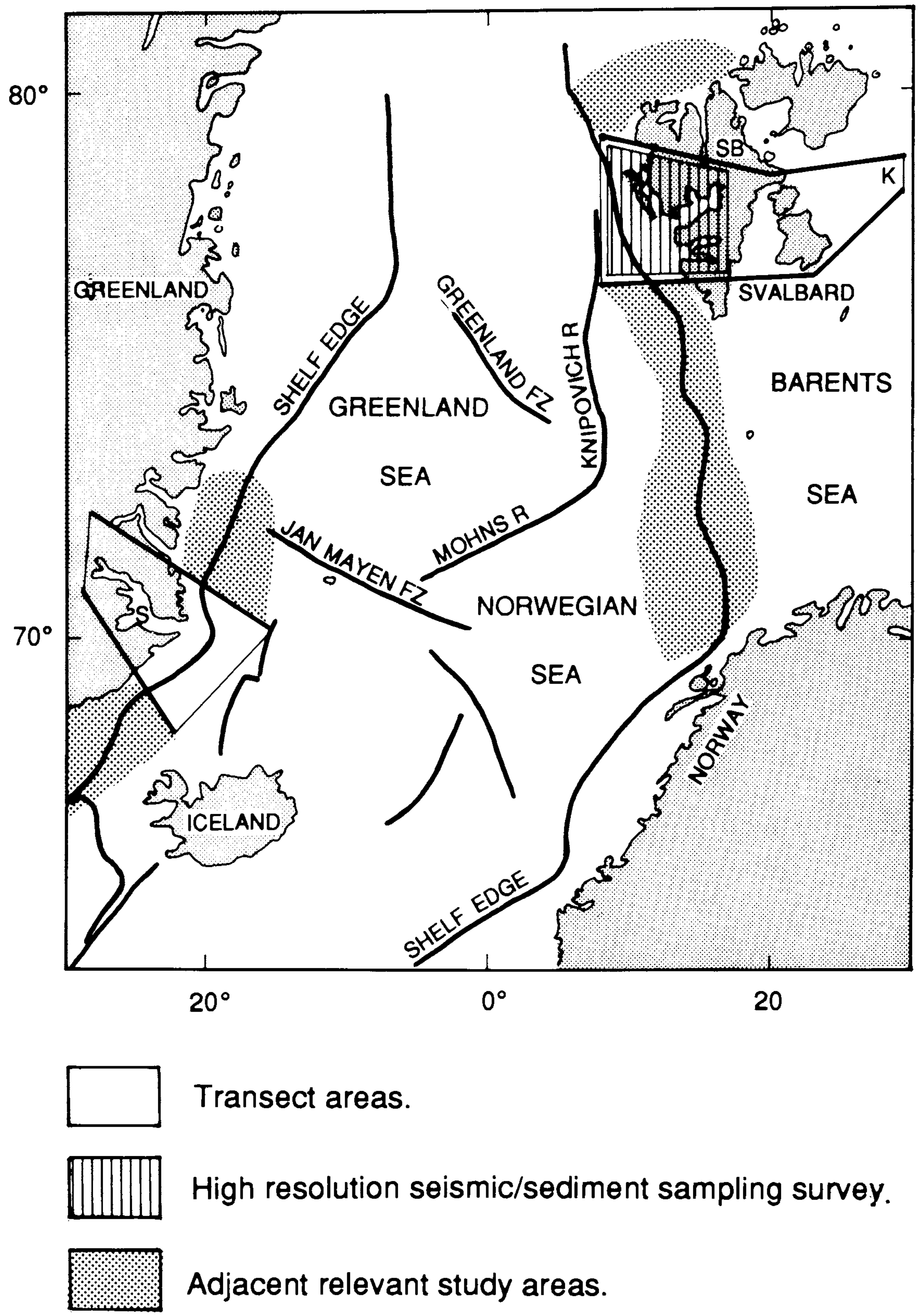

Figure 1. Map of the Norwegian - Greenland Sea, with the study areas on western Svalbard and eastern Greenland indicated. The present study area is marked with vertical pattern. SB - Spitsbergen. K - Kong Karls Land. FZ - Fracture Zone.

Cruise participants

Leg	Name	Institution	Position
1+2	Anders Elverhøi	U.i O.	Co-chief scientist
"	Alf Kr. Nilsen	"	Technician
"	Marit Sørflaten	"	Assistant
"	Ingrid Fossen	"	Assistant
"	Anders Solheim	NPRI	Co-chief scientist
"	Espen S. Andersen	NPRI/U.i O.	Geologist
"	John I. Svendsen	U.i B.	Assistant
1	Earl Young	WHOI	Huntec technician
"	John Milliman	"	Geologist
"	Kris Vanneste	UG	Assistant
2	Bruce Tocher	UA	Palynologist
"	Scott Lehman	WHOI	Geologist
"	Matthias Paetzel	U.i B.	Assistant
"	Tor Kr. Danielsen	U.i T.	Assistant
"	Halvor Jahre	NPRI	Assistant

U.i O.: University of Oslo, Dept. of Geology, P.O.Box 1047, 0316 Oslo, Norway.
NPRI: Norwegian Polar Research Institute, P.O.Box 158, 1330 Oslo Lufthavn, Norway.
U.i B.: University of Bergen, Inst. of Geology, Allegt. 41, 5000 Bergen, Norway.
WHOI: Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA.
UG: State University of Gent, Laboratorium Voor Aardkunde, Krigslaan 281, B-9000 Gent, Belgium.
UA: University College of Wales, Aberystwyth, Institute of Earth Studies, Aberystwyth, SY23 3DB, UK.
U.i T.: University of Tromsø, Institute of Biology and Geology. P.O. Box 3085, 9001 Tromsø, Norway.

Vessel

As part of a joint Norwegian/Russian oceanographic experiment in the northern Barents Sea, the regular NPRI vessel M/S "Lance" had to be used in this region because of ice conditions. An exchange was arranged and instead the research vessel of the University of Bergen, M/S "Håkon Mosby", was used for the present survey. M/S "Håkon Mosby" has a length of 47.5 m and a displacement of 499 reg.ton. Two crews operate the ship. During Leg 1, Captain Røttingen and his crew were on board while Captain Færøy and his crew took over during the port call in Longyearbyen between the two legs. The vessel proved very good for our scientific purposes. This in combination with the excellent cooperation between the ship's crew and the scientific personnel was a main factor in the success of this cruise.

On board laboratory facilities include wet-labs, an electronics lab and sufficient office and storage rooms. The laboratory facilities were facing aft towards the working deck. Even though it is a relatively small ship, the working deck and the laboratories were adequate for our purposes.

Existing data

Several institutions have carried out seismic investigations on the Svalbard Margin. A brief summary of existing data from the present study area includes:

- Single channel work carried out by Lamont-Doherty Geological Observatory (LDGO) in the early seventies (Edholm and Windisch, 1974). The data quality is relatively poor.

- Multichannel data acquired by the German Bundesanstalt für Geowissenschaften und Rohstoffe (Schlüter and Hinz, 1978; Hinz and Schlüter, 1978). A few, mainly east-west running lines cross the study area. The quality is variable, but with poor resolution in the upper parts of the sedimentary section.

- Multichannel data acquired by the Seismological Observatory of the University of Bergen, Norway (SOB) in 1977 and 1981 (Sundvor et al, 1978, 1982; Eiken and Austegard, 1987). Particularly the lines from 1981 are of relatively good quality, but still with inadequate resolution to address late Quaternary problems.

- Multichannel data acquired jointly by SOB and NPRI using the commercial seismic vessel M/V "Mobil Search" in 1987. Four lines running approximately perpendicular to the margin off Bellsund and one tie line along the shelf break, just inside of it, were run with parameters set for high resolution acquisition (Austegard et al, 1987). Despite the fact that only on-board processing has been carried out on these data, the quality is good and the data will be integrated with the data from the present study, as will also parts of the SOB data from 1981. Two of the lines shot during the present survey followed lines shot by the Mobil Search in 1987.

- Two cruises performed jointly by the University of Edinburgh, U.K. and the Dutch Geological Survey in 1987 and 1988, collected high resolution single- and multichannel data mainly in the area to the north of the present study area, but a few lines were also run within the study area. These data are comparable to the data from this cruise, and will also be integrated with the present data set.

- NPRI ran a small combined single channel sparker and 3.5 kHz echo sounder survey in the outer part of Isfjorden in 1987 (Svendsen et al. in prep.), and ran the 3.5 kHz echo sounder further into Isfjorden as well as in Bellsund and Van Mijenfjorden. One sparker line also exists from the latter fjord (Elverhøi & Solheim, 1983).

From the above summary, it is clear that a fair amount of seismic data exists from the study area. When planning the present survey, we have taken most of these data sets into account. Partly we have filled in the pre-existing grid, a few lines have been repeated with the single channel high resolution equipment used in this survey. Several of the older multichannel lines may also serve as tie lines. Despite low resolution, they can be used to tie main sequence boundaries.

Concerning sediments samples, the pre-existing data base is less extensive. One long (8m) piston core was recovered from the inner part of Isfjorden by Lamont Doherty Geological Observatory in 1965 (Elverhøi et al., 1983). Four cores of less than 5 m length were recovered from the inner shelf off Isfjorden during the joint Dutch and U.K. cruise in 1988. During the NPRI cruise in 1987, eight gravity cores, also of less than 5 m length were collected in outer Isfjorden. The cores and some of the seismic results from the latter two cruises have been synthesized by Svendsen et al. (in prep.).

In addition to the data summarized above, long range side scan sonar data using the Sea Marc II were collected during a cruise performed jointly by the U.S. Naval Research Laboratory, the University of Hawaii and the University of Bergen (SOB) in 1989. The main part of the Sea Marc II survey took place in the deep sea, along the Mohn's and Knipovich spreading centers, but a good, almost continuous coverage was obtained of the continental slope outside Isfjorden (Vogt et al. 1990). These investigations continued in the fall of 1990.

PHYSICAL SETTING

Study area

The present survey covered the marine parts of the "Svalbard Traverse", and spanned from the inner parts of Isfjorden and Van Keulenfjorden, across the continental shelf and out to the Knipovich Ridge spreading axis (Figs. 1,2,3). Hence, the cruise covered a wide range of environments; a) relatively deep Arctic fjords, one with a distinct sill (Van Keulenfjorden) and the other without (Isfjorden), both with a significant present-day input of glacially derived sediments from Spitsbergen, b) a narrow continental shelf which probably has been covered by grounded glaciers several times through the Pleistocene and which contains shallow bank areas and deeper, transversely running troughs, c) a continental slope where significant amounts of glacigenic sediments have accumulated during the Plio- and Pleistocene, d) the active spreading center of the Knipovich Ridge, which locally experience overspill of sediments from the margin directly into the axial valley. The water depth within the survey area ranges from less than 50 m in the inner parts of the fjords and close to shore, to 3500 m in the Knipovich spreading axis.

In addition to the main cruise area in the region of the Svalbard Traverse, a small seismic and sampling program was also carried out in Kongsfjorddjupet and the outer part of Kongsfjorden (Fig. 2). This was a joint program with the Woods Hole Oceanographic Institution, to follow up previous investigations in the same region, aimed at understanding the last glacial maximum and deglaciation from northwestern Spitsbergen.

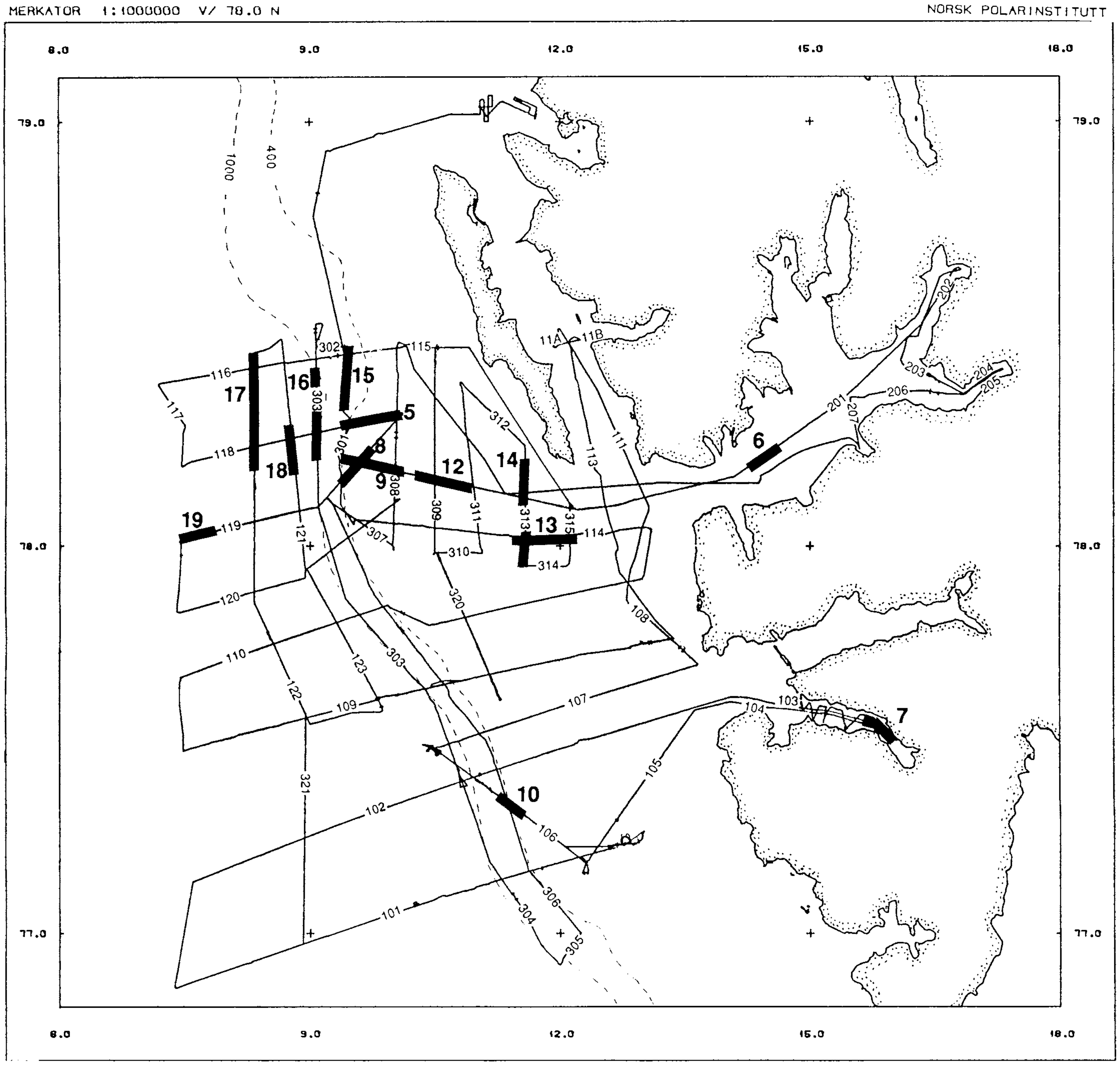

Figure 2. Map showing the seismic lines shot during the cruise. Numbers refer to seismic profiles. Heavy lines with numbers refer to figures used elsewhere in the text. For place names, see Fig.3. See Appendix 1 for more details.

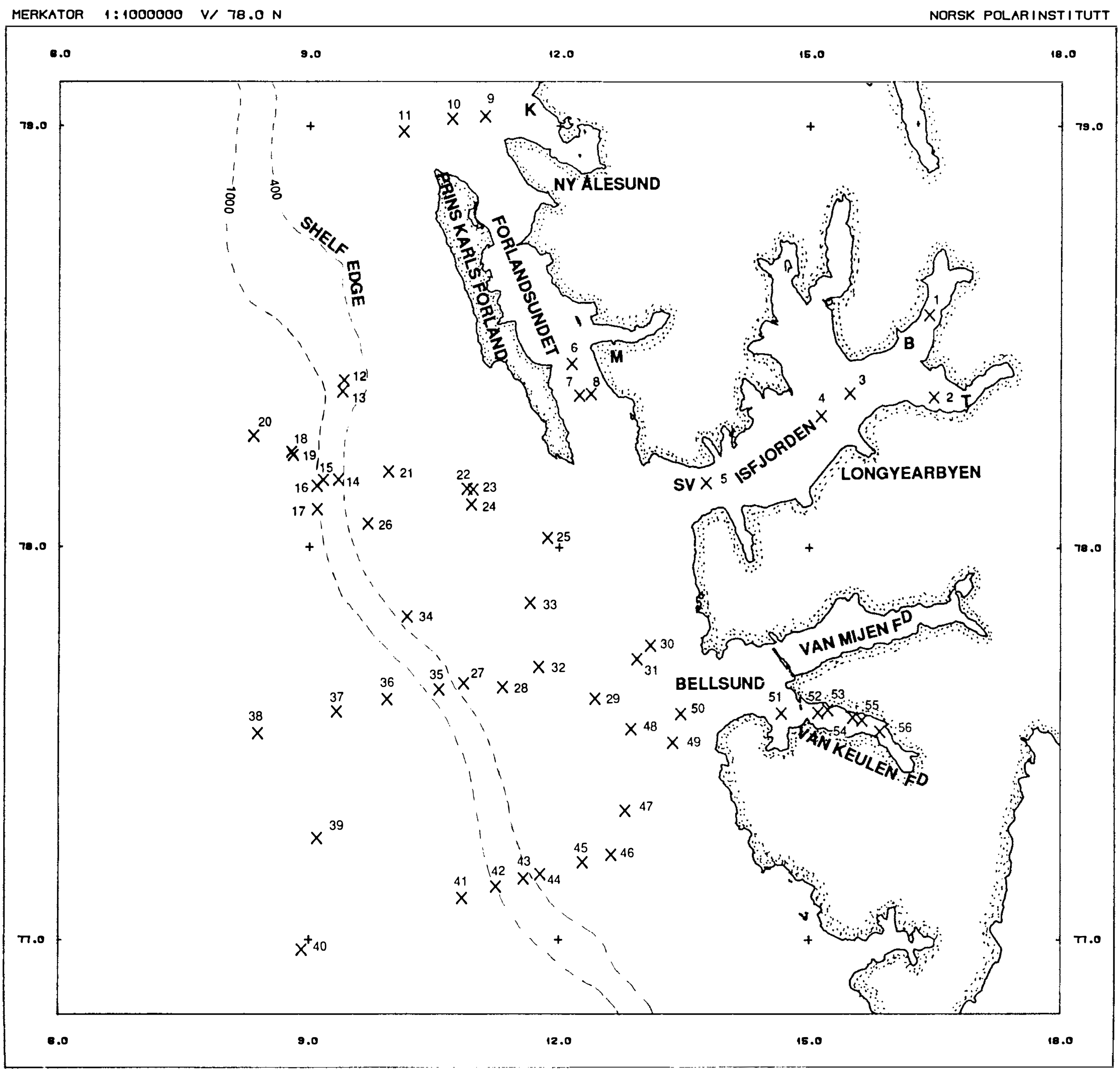

Figure 3. Map showing the locations cored during the cruise. See Appendix for more details.

Legend:

K - Kongsfjorden	SV - Svensksunddjupet	T - Tempelfjorden
M - Müllerodden	B - Billefjorden	

Bedrock geology

Knowledge of the submarine bedrock west of Svalbard is based on geophysical data and extrapolation to the geology of western Svalbard. As the glacigenic, unlithified sediments were the primary goal of the present studies, the underlying bedrock geology will only be summarized very briefly.

The two fjords studied run perpendicular to the main structural strike of Spitsbergen and therefore cross most of the island's Upper Paleozoic, Mesozoic and Tertiary section of sedimentary rocks (Flood et at., 1971). The west coast is dominated by Lower Paleozoic and older metasediments belonging to the Hecla Hoek complex. These crystalline rocks also subcrop on most of the inner shelf, giving rise to high seismic velocities and a highly reflective sea floor in areas where the cover of unlithified sediments is thin (Schlüter and Hinz 1978, Myhre et al. 1982). The outer part of the continental shelf is underlain by thick sequences of low-velocity Tertiary sediments, probably deposited after a shift in plate motion during the lower Oligocene (Malod and Mascle 1975, Myhre et al. 1982, Myhre and Eldholm 1984). The eastern boundary of the sedimentary wedge is formed by the prominent Hornsund Fault Zone. The outer part of the study area is underlain by oceanic basement, but the exact position of the ocean - continent transition is unknown. Most likely it is restricted to a narrow zone of unknown crust under the outer shelf/upper slope (Myhre and Eldholm 1988).

Both the Hecla Hoek rocks and the younger sedimentary rocks along western Svalbard are affected by Tertiary orogenic movements related to plate movements during the opening of the Norwegian - Greenland Sea and the Arctic ocean. The strike of the fold belt is NNW - SSE. Eiken and Austegard (1987) have mapped graben structures on the inner continental shelf that follow this direction and are interpreted to be of Tertiary age. These have widths of up to 15 - 20 km and are filled with up to 4 km of sediments forming layered sequences within the more or less structureless Hecla Hoek rocks.

Fjords

According to previous investigations, the fjords of Svalbard are characterized by a relatively thin (10-20 m) veneer of sediments in their central and outer parts (Elverhøi et al., 1983, Svendsen et al., in prep). Sediment thickness may increase towards the fjord heads, and close to present day ice front thicknesses of 200-300 m have been recorded. However, our knowledge of the sediment distribution is based on a limited amount of data, primarily 3,5 kHz echo sounding profiles (PDR), which are not very useful for recording coarse-grained and compacted sediments such as till deposits. Until now, only Kongsfjorden (Fig. 3) has been studied in some detail.

Sediment coring of the upper 5 m of the fjord sediments has in general shown fine-grained mud with some clasts. Coarse- grained sediments (diamiction), have mainly been found close to the calving ice fronts or on shallow sills where currents have caused winnowing. From the acoustically transparent character in 3,5 kHz echo grams, it seems likely that the rest of the sediments mapped also consists of fine-grained sediment. From the few sparker profiles available, the acoustically transparent sediments seem to be underlain by a veneer of more coarse-grained sediment (till?). The age of the sediments is not well known. Most of the fjords were covered by grounded ice during the Late Weichselian, and the acoustically transparent sediments postdate the ice recession. ^{14}C dating of cores from Isfjorden indicates ice recession of the central fjord basin at about 12.000 years BP, while final ice recession did not occur until 10.000 years BP(Svendsen et al., in prep.).

Continental shelf and slope

The sediment distribution on the shelf is known only from a few seismic lines west of Isfjorden (Svendsen et al., in prep.). As is the case also for the Barents Sea and the Norwegian shelf, a well-defined angular unconformity has been observed, and this is tentatively used to define the boundary between the bedrock and overlying glacigenic sediments. Based on the few seismic lines available, the inner shelf is characterized by a thin (<20m) sediment cover, while the thickness of the glacigenic sediment cover increases significantly towards the shelf edge, to >400 m (Svendsen et al., in prep.). From detailed bathymetric mapping, it appears that ice margin features such as a major end moraine complex may be present in central parts of the shelf (Otha, 1982). The acoustic character of the sediments, with typically internally hummocky structure, suggests repeated glaciations of the region.

Only one high resolution seismic line has so far been published from the slope west of Isfjorden (Boulton, 1990). A major fan complex seems to be present, and, judging from multi-channel surveys, the thickness of the glacigenic sediments may exceed 2 km (Myhre, 1984). Recent long range side scan surveys along the slope seem to indicate a presently quiet sedimentary regime and, in contrast to regions further south along the Norwegian margin, there is no evidence of major slides and/or canyon formation outside Isfjorden (E. Sundvor/P. Vogt, pers. comm. 1990). A major fan complex is also present outside Bellsund (Eiken & Austegard, 1987).

Glacial history

The glacial history of Svalbard and the adjacent shelf has been a matter of long term investigations and disagreement. More than 20 years ago, Swedish geologists proposed the existence of an extensive Late Weichselian ice sheet which covered the entire Svalbard/Barents Sea and extended all the way to the shelf edge (Schytt et al. 1969). Their conclusion was mainly based on raised shore-line data. Later, Boulton (1979a,b) published arguments for a limited Late Weichselian ice cover, located in the central and eastern parts of Svalbard. Based on detailed investigations along Isfjorden and in Bellsund, Mangerud et al. (1987) concluded that the Late Weichselian ice margin extended at least to the present day coastline of Svalbard. Based on seismic data and sediment cores from the outer part of Isfjorden and the adjacent shelf, if now seems likely that the Late Weichselian ice margin was located at a significant distance to the west of the present day coastline (Svendsen et al., in prep.). Based on terrestrial data, the Isfjorden/Bellsund area most likely was ice covered three times during the last ice age (Mangerud and Svendsen, 1990; Mangerud et al., 1990). As shown in Figure 4, it is also evident that the duration of the glaciations have been relatively short, possibly in the range of 10.000 years, which is shorter than what is believed for Scandinavia. The

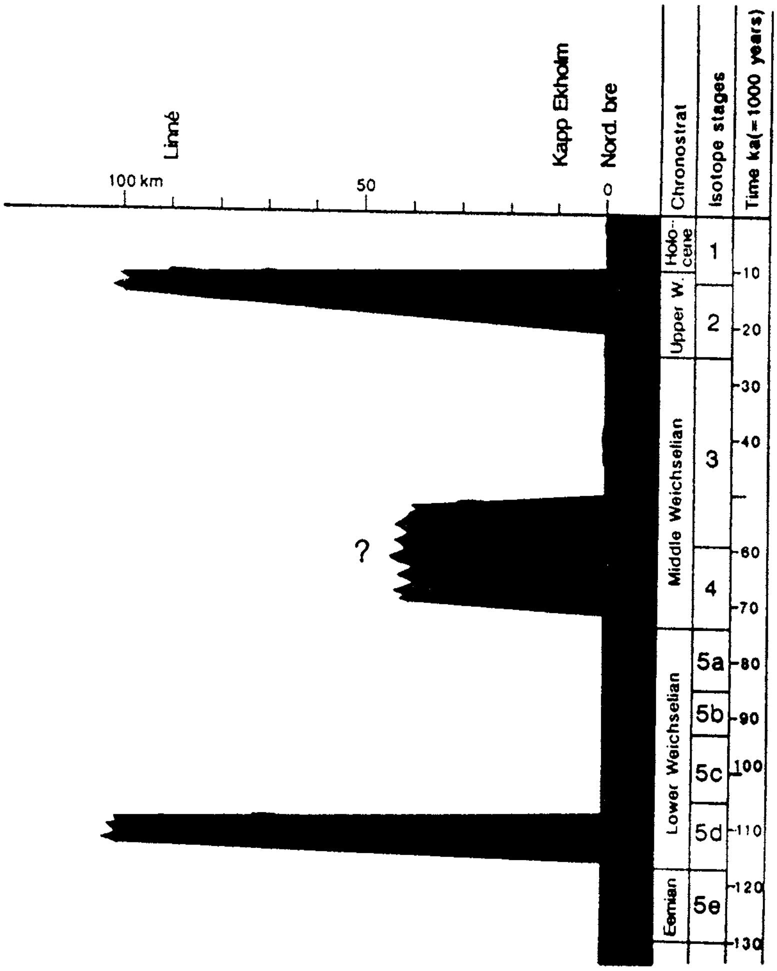

Figure 4. Interpretation of the glacial record from the Weichselian period on Svalbard. The horizontal scale is along a profile from Nordenskiøldbreen in the east, out Billefjorden and Isfjorden, to the coast in the west (from Mangerud & Svendsen, in prep.).

information on older glaciations is very limited, however. From the thick glacigenic sediments on the outer shelf and slope, it is evident that Svalbard/northern Barents Sea has been ice covered repeatedly during the Late Cenozoic, as also suggested from the results of ODP leg 104 at the Vøring Plateau (e.g. Jansen and Sjøholm, in 1991).

METHODS

Navigation

GPS satellite navigation was used throughout the cruise. The shipboard system consisted of a Magnavox MX4102/4200 Transit/GPS receiver, Eiva Navipac logging system and 9-track magnetic tape drives.

GPS was operational most of the day with the exception of a short period, varying from 30 minutes to 2 hours, shortly after midnight. As the system lacked a nuclear oscillator, it would only operate reliably on signals from three or more satellites. Due to a system failure towards the end of the cruise, a new system, Trimble Navigation, GPS Pathfinder Portable Data Logger, was brought on board, and used from 31/7 until the end of the cruise. Data from this system were stored on floppy discs.

Geophysical equipment and procedures

<u>Seismic sources</u>

Texas Instruments sleeve guns. Two 40 cu.inch guns mounted in a frame were used. The distance between the guns was 0.5 m and the tow depth was 2 m. The guns were tuned to fire simultaneously and operated at pressures varying between 120 and 150 kg/cm^2.

Hartley HML sparker system with 9-electrode array.

Additionally, Bolt air guns with chamber volumes varying from 10 to 300 cu.inch (kindly lent to us from Geoteam A/S and the University of Bergen) were available on board, but were not used due to the good functionality and results of the sleeve guns.

<u>Seismic recording</u>

Benthos Mod. 25/50P single channel seismic streamer, with a 7.5 m active section with 50 elements.
Analogue recording on EPC graphic recorders, Mods. 4800, 3200S and 3200. Krohn-Hite band pass filters.
O.R.E. Geopulse Mod. 5210A receiver with TVG and band pass filter.
TSS Mod. 307B TVG amplifier.
Tandberg Mod. 115 analogue tape recorders .

Sonobuoys, military type Mod. AN/SSQ 57, with recording time set to 1 hour and hydrophone depth 60 feet.
Teletron In. Mod. WARX3B, 24 ch. sonobuoy receiver.

Data Response A/S "Draqula" digital acquisition package for seismic recording on PC's. Intermediate storage was carried out on 200 Mb external disks and subsequently dumped on streamer tapes using a second PC and a Tallgrass Technologies tape deck. PC's used were standard IBM compatibles with 80386 processors.

A 16 bit AD board, Data Translation Mod. DT2827, was used for A-D conversion. The data was band pass filtered in the range of 30-900 Hz and amplified prior to sampling at a rate of 0.5 millisecond/sample.

Case Geophysical A/S seismic processing and display package for PC's ("ASAP") was installed on a WYSE 30386 PC and was used for quality control of the data.

Higher frequency equipment

O.R.E. 3.5 kHz echo sounder (PDR), hull mounted, with Mod. 140 transceiver and analogue recording on an EPC Mod. 3200S graphic recorder. With the exception of some periods of technical problems, the PDR was run continuously during both the seismic part (Leg 1) and the coring part (Leg 2) of the cruise.

Huntec Deep Tow System (DTS) Boomer. The system was towed at depths between 20 and 90 m and operated at energies between 240 and 540 J. Both internal and external hydrophones were used, filtered in the pass-bands 600-3000 Hz and 500-3000 Hz, respectively.

O.R.E. Side Scan Sonar system using Mod. 159 towfish with 100 kHz transducers and Mod. 160 transceiver. The cable length of 1800 m limited the use of the side scan system to water depths shallower than 600 m.

Gravity and magnetics

LaCoste & Romberg Sea Gravimeter.
GeoMetrics Mod. G801/803 proton magnetometer.

Both the gravimeter and the magnetometer were set for digital recording, but because of technical difficulties, only analogue strip-chart recording was possible during the cruise. The data were manually digitized and stored on Pc's on board.

Sediment sampling and shipboard laboratory work

Coring sites were chosen from the acoustic records obtained during Leg 1. In addition to the GPS navigation, the 3.5 kHz system was used continuously during the coring leg, and was useful in relocating the chosen sites, or locating better sites in their vicinity.

Four different coring devices were used:

1. Piston corer (9.0 x 0.11 m barrel)
2. Gravity corer (3.0-6.0 x 0.11 m barrel)
3. Plastic gravity corer (4.0 x 0.11 m plastic liner, without steel barrel).
4. Box corer (0.5 x 0.5 x 0.5 m)

Two or more cores were collected from most of the 57 stations. Most often a plastic gravity core was recovered in addition to a long piston core. The core liners were routinely cut in one meter sections, which were capped in both ends, labelled on the top and inside, and stored in an upright position. 21 cores were split, logged and photographed during the cruise. In addition to a visual description involving lithology, structure and colour, simple physical properties were also measured. These include:

- Undrained shear strength (Su), by means of a fall-cone penetrometer.
- P-wave velocity through the length of each sediment section, using a PUNDIT (Portable Ultrasonic Nondestructive Digital Indicating Tester, C.N.S. Instr.,Ltd., England).
- Weighing and sealing of samples for water content and bulk density measurements (only for some cores).

The data were stored on a 30386 PC, and the logs are presented (Appendix 1) using a software package, "LOGGER" from Rock Ware Inc., U.S.A.

Cores up to 8.6 m were recovered by the piston corer, and based on preliminary shipboard studies of core ends, the Eemian interglacial may have been reached at one or two sites. The gravity corer usually gave 3-4 m cores, except in firm shelf sediments, were penetration was less. For the plastic gravity corer, 4 m liners proved to give the best results. A 6 m liner was tried, but seemed to break easily. Besides being quicker to use than the conventional gravity cores, the plastic gravity corer is beneficial in that it can be kept upright on deck until the top is sealed. Hence loss of the surface sediment is avoided.

The box corer provided excellent undisturbed sections of sea floor and the upper 0.5 m of the sediments (Holocene). A clean vertical section was cut in the box core and both this and the surface were photographed. Samples were collected from the box cores in three different ways:

1. 0.11 m core liners (usually 3) were carefully pushed into the sediments, with the help of a vacuum pump.
2. Samples from each 2 cm interval were collected from a few number of box cores, bagged and frozen for later geochemical analyses (heavy metals, organic compounds, Dioxin and ^{210}Pb).
3. The top samples (0-2 cm) were collected and bagged for a palynological and paleontological analyses.

Cores from outer Kongsfjorden are stored at Woods Hole Oceanographic Institution, while the cores from Isfjorden and the Shelf immediately outside Isfjorden are stored at the University of Bergen. One core (NP90-57) was recovered on request by the University of Tromsø, and is being stored and analyzed there. All the remaining cores are stored at NPRI, at 90% humidity and +2-4 degrees Celsius.

FIELD OPERATIONS

Day-by-day summary

Saturday 7/7.
Started loading Håkon Mosby at 14.00 (GMT, which is used throughout this chapter). All equipment present and OK, except the side scan cable. Finished loading at 18.00 and moved from Breivika to Dampskipskaia. Worked with mounting equipment.

Sunday 8/7.
Side scan cable arrived at 01.00. Left Tromsø at approximately 09.00 and headed out the northernmost lead to the open sea, while cleaning deck and mounting the side scan and Huntec winches. Continued mounting equipment. Much work with the side scan-cable. Science-meeting at 21.00.

Monday 9/7.
Transit northwards. Good weather, flat sea. Mounting and testing equipment. Slowed down after dinner and launched the gear across the fan off Storfjordrenna. Sleeve guns gave good data, but the Huntec did not work.

Tuesday 10/7
Continued testing of side scan and the DTS. Side scan had to be reterminated. Started shooting line NP90-101 with sleeve guns and 3.5 kHz, but without the DTS. Various problems with the guns also, so the line was stopped several times (leaks, broken wire etc.). Changed one gun due to (most likely) bad solenoid. Continued shooting from 23.36.

Wednesday 11/7.
Continued shooting line NP90-101, with a few short stops due to air leaks in the hoses. Started line NP90-102 at 18.15, after a power failure on the ship generator. Lost approximately three hours because of the failure. Huntec presumably fixed, waiting to test it at the shelf. Side scan reterminated and also ready to be tested in the water.

Tuesday 12/7.
Continued shooting line NP90-102. Huntec and side scan both working, hence all the acoustic equipment was working. Huntec recording desturbed by noise from the sleeve guns. Line NP90-103 shot in Van Keulenfjorden. Very good 3.5 kHz data. Changed side scan fish from the Ferranti/ORE fish to the University of Bergen fish before line NP90-

104. Line NP90-104 ran out Van Keulenfjorden without the sleeve guns, to improve the Huntec records. Sleeve guns in the water for line NP90-105, but only one gun worked. This resulted in a bad bubble pulse, but still reasonably good results. Side scan worked well, good control on the data due to trawl marks. The weather was cloudy and calm, almost flat sea.

Friday 13/7.
Run lines NP90-105, 106, 107 and the start of 108. Both lines 105 and 106 shot with one gun, due to bad trigger line. Buoys also broke, probably due to high stress caused by the shallow towing depths. Phonecalls to READ in Bergen and to Longyearbyen in order to provide spare parts for the sleeve guns. Some gun problems, but most gear essentially ran well. Weather: cloudy and calm, light wind.

Saturday 14/7.
Finished line NP90-108 and started line NP90-111 northwards towards Forlandssundet, because of possible meeting with the helicopter bringing spare parts for the guns. Huntec, Side scan and PDR worked well, but problems with the sleeve guns. Two firing lines broke, but the guns gave excellent data while working. Ran two short cross-lines (NP90-11A and 11B) in Forlandsundet and towards Müllerneset. Found the two boxes containing spare parts, left by the helicopter on the beach and started line NP90-113 out the sound. Problems with the Huntec, had to be brought for cable termination at about 14.00. All navigation out between 18.10 and 21.00. Weather: cloudy and a bit wind, picking up.

Sunday 15/7.
Continued line NP90-113 and steamed 1 1/2 hours to the start of line 109. All gear except the DTS worked, but still some gun problems. A poor nipple on the air intake caused the air hose to fall off and the guns stopped due to loss of pressure. Missed the shelf break and upper slope because of the gun problems. Made a loop back to the shelf break and reshot the line across the upper slope when the guns were repaired. Obtained good data from then on. Nice side scan data showing iceberg ploughing on the outermost shelf. Weather: cloudy and the wind calmed down again.

Monday 16/7.
Finished line NP90-110 and started NP90-114, through two Dutch core locations from 1988. Everything except the side scan sonar worked well. The side scan towfish stopped working after 10 minutes due to a leak. Tested a sonobuoy, but had problems with the receiver. DTS worked very well after retermination. Broke off line NP90-114 to do two long strike-lines along the slope. Starting line NP90-301 northwards. Weather: cloudy, slight swell, light wind.

Tuesday 17/7.
Finished line NP90-302, shot line NP90-303 and started line NP90-304. Very good sleeve gun data from the fan complex. The 3.5 kHz echo sounder failed around 06.00 due to a broken power supply. The air compressor had a major breakdown on the hydraulic motor at 14.10, and we had to change from the sleeve guns to a 4.5 kJ sparker system. Weather: cloudy and calm.

Wednesday 18/7
Shooting lines NP90-304, 305, 306, 307 and started 308, but used only sparker, gravimeter and magnetometer. The air compressor was fixed at about 22.00, and would be ready for use the next day. Side scan sonar repaired and working fine. Weather: cloudy and calm, 0.5 - 1.0 m waves.

Thursday 19/7.
Shooting lines NP90-308, 310, 311, 313, 314 and 115. Tried different energy levels on the sparker, but ended at 3.6 kJ. Started sleeve gun operations on line NP90-310. Ran the side scan fish into the bottom. Broke the fish, but electronics OK. Changed electronics to the other fish, and the side scan was operational again after two hours. Weather: nice and calm.

Friday 20/7.
Shot lines NP90-201 and 204 in Isfjorden, Billefjorden and Tempelfjorden. Met M/S "Lance" off Isfjorden to receive 3.5 kHz transceiver. Ran line into Isfjorden with everything running. Some problems with one EPC, changed control board. Side scan brought up by an ice floe, and later ran into the block and broke again. Magnetometer taken in at the end of Billefjorden. The weather was beautiful, with a totally flat fjord.

Saturday 21/7.
Lines NP90-205, 206 and 207. Line 205 was running without the sleeve guns to avoid noise on the Huntec records. Pulled in equipment outside Longyearbyen harbor and docked at about 07.00. Changed crew and steamed out the fjord again at about 14.45. Ran Huntec in outer Isfjorden (Svenskesunddjupet) for two hours, and then steamed for the start of the first line on the margin west of Kong Karls Forland. Weather: fair, calm.

Sunday 22/7.
Shot lines NP90-116, 117, 118 and 119 on the outer Isfjorden Fan. GPS problems for short intervals a couple of times. Problems with the 3.5 kHz echo sounder, which was fixed after a couple of hours. Deployed three sonobuoys (2, 3 and 4). Slight problems with sleeve gun firing line twice. Slowed down to 3 knots on the upper slope and got good side scan sonar data down to about 700 m water depth. Weather: cloudy light breeze.

Monday 23/7.
Finished lines NP90-119, 120, 121 and 122. Huntec operations finished after line NP90-121, and packed down. Obtained reasonable good Huntec data down to 1600 m water

depth on line 121. Deployed sonobuoys 5,6 and 7. Sleeve guns up once due to broken air hose. Weather: partly cloudy, mild and calm sea.

Tuesday 24/7.
Finished shooting line NP90-123 at about 08.30 and steamed towards Longyearbyen. Docked at 14.00, and changed part of the scientific crew for the coring leg. Worked on deck and in the labs to prepare for the coring operations. Left Longyearbyen at about 17.00 and arrived at the first station, in outer Billefjorden at 19.00. Spent some time getting the coring equipment ready and, the first gravity core was recovered at 11.00. The 3.5 kHz sounder stopped again and spare parts were ordered from Norway in addition to a complete unit from the University of Tromsø.

Wednesday 25/7.
Changed to 6 m piston corer and continued coring. Catched two cores per station at stations NP90-1, 2 and 3. Laboratory work also started and was running well. Some problems with the piston corer. Changed the length of the trigger wire. Weather was cloudy and calm.

Thursday 26/7.
Continued coring at stations NP90-4,5,6,7 and 8. At station NP90-4, a box-core was specially devoted to geochemical analyses for pollution studies. Stations NP90-6,7 and 8 were located in Forlandsundet, with gravity coring at the two northernmost sites, and piston coring at the southern site. Weather: cloudy, mild and calm.

Friday 27/7.
Shooting seismic line NP90-316 towards the Kongsfjorden area, and cored at stations NP90-9,10 and 11. Did a small seismic survey in outer Kongsfjorden, both for site location and for studies of till ridges. Recovered good cores from outer Kongsfjorddjupet, which penetrated to till. Weather: foggy, flat sea.

Saturday 28/7.
Finished coring in Kongsfjorddjupet and steamed to the core sites at line NP90-301, just at the northern boundary of the fan/slump complex. Recovered 8.3 m in a piston core at station NP90-12 in the stratified sediments outside the slump complex. Shot seismic line NP90-130, as a continuation of line115, towards Prins Karls Forland. Passed over a part of the Hornsund Fault Zone which showed up clearly in the sleeve gun records. Steamed to meet M/S "Sirafjord" in order to receive spare parts for the 3.5 kHz transceiver and for the piston corer. Started shooting line NP90-131 out Isfjordrenna, at about 21.00. Also used side scan sonar. The weather was foggy, flat sea.

Sunday 29/7.
Finished shooting line NP90-131, and continued out to the upper slope and carried out two small side scan surveys at approximately 500 and 1000 m water depth. Observed possible slump scars. Started coring at site NP90-14. Laboratory work (splitting, description, photography, velocity and undrained shear strength) going well. The weather was cloudy, some fog, mild and almost flat sea.

Monday 30/7.
Cored at sites NP90-18, 19 and 20. The ship's GPS system failed at about 11.00. Program stopped for several hours while the technician tried to fix it. Continued coring with combined Loran-C and Transit navigation. This did not work well, but fixes were recorded while at station, so these represent reasonably accurate positions. Contact with the NP officer in Longyearbyen about getting a new GPS receiver on board. Weather still foggy, mild and calm.

Tuesday 31/7.
Cored at sites NP90-21, 22, 23 and 24. These were sites where the exact position is not critical. Steamed to Isfjord radio and picked up Trond Eiken from Norsk Polarinstitutt, who came out from Longyearbyen by helicopter with a new GPS receiver. Mounted and tested the receiver, put Eiken ashore again, and left for the next sites (NP90-25 and 26) which were gravity core stations on the shelf. Started shooting seismic profile NP90-320 at about 22.00, to tie NP90-309 with multichannel line BEL-5 from 1987. The weather was fair, mild and calm.

Wednesday 1/8.
Finished line NP90-320, but found that there had been problems with the logging of GPS navigation, so we did not have good navigation for this line. Continued coring the shelf sites with 3 m gravity corer.

Thursday 2/8.
Coring in deeper water along seismic line NP90-109, with good results by the 9 m piston corer. Plastic gravity cores were split in the lab and gave interesting results for the upper 3-4 m. Stratification and clear differences in the faunal content. Started shooting seismic line NP90-321, as a continuation of line NP90-122, connecting lines NP90-109,-102 and -101. Stopped for piston core site NP90-39, at the cross point with line 102, and completed the shooting of line 321 before starting piston coring along line 101.

Friday 3/8.
Coring along line NP90-101, with good results in deeper water but with numerous problems with the equipment on the shelf. Lost a steel barrel and two cutters and catchers. A rather difficult coring day, but we were still on schedule and had approximately 12 hours left for coring in Van Keulenfjorden.

Saturday 4/8.
Coring in Van Keulenfjorden completed at 11.30. Ran cross profiles back out the fjord and through Bellsund, using the 3.5 kHz echo sounder with excellent results. Good coverage of both cores and PDR records to calculate the sediment budget for this fjord. Spent the rest of the day cleaning up and packing.

Sunday 5/8.
Cruising southwards towards the coring location off Bjørnøyrenna (NP90-57). Continued packing and cleaning up.

Monday 6/8.
Steaming southwards.

Tuesday 7/8.
Unloading the ship. Cruise completed.

Weather conditions

The weather conditions were very good throughout the cruise. The sea was generally calm and there were several days with absolutely flat sea. There was never any need for closing down operations because of weather conditions.

Equipment performance

Navigation

As coring sites during leg 2 were based on the leg 1 acoustic records, precise navigation was considered essential. The shipboard GPS system was mounted just a few days before the start of the cruise, and little experience existed in using the system. The fact that it did not include a nuclear clock and hence needed signals from at least three satellites caused some problems. During leg 1, operations were not stopped, but the navigation is relatively poor for short periods just after midnight. During leg 2, however, coring operations were stopped during intervals when the GPS was out, because of difficulties in holding the ship in position. The logging system also failed on some occasions, and the navigation data were lost for a few short intervals.

Geophysics

Despite some problems with most of the equipment, all units performed well during long intervals between periods of repair and maintenance. Hence the volume of data acquired with each type of equipment was nearly as planned.

The sleeve guns generally performed well, but the towing arrangement cause problems. Due to the shallow tow depth and high shot frequency, the steel frame from which the guns were suspended, was ruptured several times and had to be welded and reinforced. Shackles were worn down and had to be changed several times. Flotation buoys, air hoses and firing/sensor lines broke and had to be replaced several times. New spares were brought to the ship from shore. Clearly an improved towing arrangement would be necessary for continued operations.

The ship's compressor had a major break-down on July 17. After continuous work by the ship's engineer and one crew-member, the compressor was operational again by July 19. This was the only long period without sleeve gun operations during Leg 1. The sparker system was used in this interval, during which lines NP90-303, 304, 305, 306, 307, 208, 310 and 115 were shot. Other gun maintenance rarely took more than one hour. Hence, provided a good towing arrangement, the sleeve guns offer a reliable tool for continuous operations over long periods of time. In case of serious gun problems, complete spares were available.

During Leg 1, the PDR failed several times. Complete transceiver units as well as spare parts were brought in from various sources, the Norwegian Polar Research Institute ship M/S "Lance", The University of Tromsø ship M/S "Johan Ruud" and from Ferranti O.R.E. Because of this a PDR was operational for most of the time during both legs, but the data quality was variable, particularly during Leg 2, at water depths exceeding 1000 m.

The side scan sonar was used in the fjord areas and on the shelf down to approximately 600 m water depth. For two short periods, it was used in deeper water on the slope, when the ship's speed was reduced to 1-2 knots and the towfish lowered to approximately 1000 m. The system had various technical problems when it arrived on board, and extensive maintenance was carried out in the beginning of the cruise. One of the two towfishes had to be reterminated. The winch was manually operated on the aft deck and this usually worked well, except for two incidents, when severe damage was caused to the towfish.

The Huntec Boomer generally performed well after some initial problems. The most severe problem during Huntec operations was the noise created by the sleeve guns. Additionally, the sea floor in most of the shallow shelf area is highly reflective and do not allow much penetration. The system gave good data several places, particularly in the fjords. It was also used with some success down to 1500 m water depth on the slope. However, over much of the shallow part of the study area, the combination of PDR and the sleeve guns provided data that met the cruise objectives.

Coring
An ambitious coring program was scheduled and most of this was carried out successfully. A total of about 300 m of core material was recovered at 57 stations. The cores were up to 8.6 m long. Generally the coring operations went smoothly and were never delayed due to bad weather conditions.

The sampling program was strongly dependent upon the accuracy of the navigation system and the possibility of recognizing the core sites identified from the seismic sections recorded during Leg 1. The recognition of these core locations was done mainly by the GPS system on board and the 3.5 kHz PDR. With the navigation system running there were few problems in identifying the proposed locations, while some delay occurred when the GPS was out of function. This happened during shorter periods, particularly at night time.

In most of the study area the sediments were fine grained and well suited for using the piston corer. The bulk of the material was therefore sampled with this coring device. At some stations the piston corer appeared to have more recovery than penetration seen on the outside of the corer. The possibility of too much recovery caused by the vacuum of the piston ("flow-in") will be carefully examined by x-ray photography. Another possibility concerning the origin of this phenomenon is that the clay in the least consolidated upper part of the sedimentary column did not attach to the outside of the steel barrel, and therefore gave a wrong impression of the degree of penetration. The maximum recovery obtained by the piston corer device was 860 cm and in most cases the piston corer performed well.

The box-corer provided excellent, apparently undisturbed samples of the sea floor and the upper 30-40 cm of the sediments. Good samples were recovered even under very coarse sandy/gravelly bottom conditions and the box corer was used without any problems throughout leg 2.

The gravity corer performed well during the first part of leg 2. In the later part of leg 2, the collar on the steel gravity corer loosened and was lost together with the steel barrel, core cutter and catcher. We had sufficient plastic gravity liners and liners for the piston corer to carry out the remaining parts of the coring program without considerable changes. A redesign of the gravity corer is planned, using screws rather than a collar to couple the barrel to the head.

The plastic gravity corer generally provided good cores. One of its advantages is its light weight and the more easy handling on deck. However one has to consider the bottom conditions while using it. Too pebbly bottom conditions may cause the plastic liner to brake.

General

Despite some problems described above, the planned program was carried out nearly 100%. All the planned seismic lines were run, and coring was carried out at nearly all the proposed sites. The main reasons for this were the excellent weather conditions and the performance of the ship. As there were no days wasted due to bad weather, we had ample time for handling technical problems.

For seismic surveys of this kind and in this type of setting, the sleeve guns appear to be an excellent source. The combination of a sleeve gun array and a 3.5 kHz or related system, offers and adequate source of purposes like the ones during this cruise. The addition of a Huntec Deep Tow System can be beneficial in some settings, particularly in material which is opaque to the 3.5 kHz signal and where the sleeve guns do not offer sufficient resolution. The noise from the sleeve guns made the acquisition of good DTS records a problem during this cruise. Of the other instruments, the hull-mounted 3.5 kHz PDR caused most problems, particularly during leg 2, when it performed poorly at water depths greater than 1000 m. Hence, the acoustic control on some of the core locations may be relatively poor.

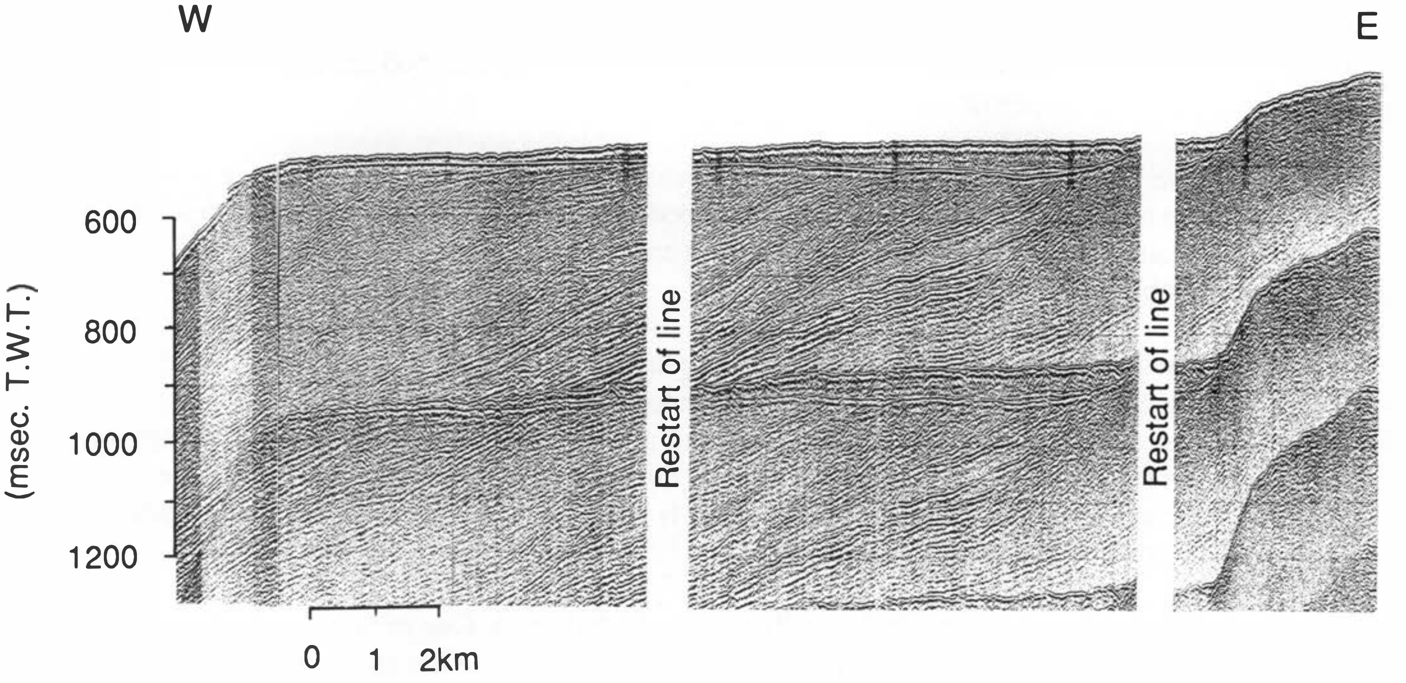

Figure 5. Part of seismic line NP90-118 (sleeve gun). For location, see Fig.2.

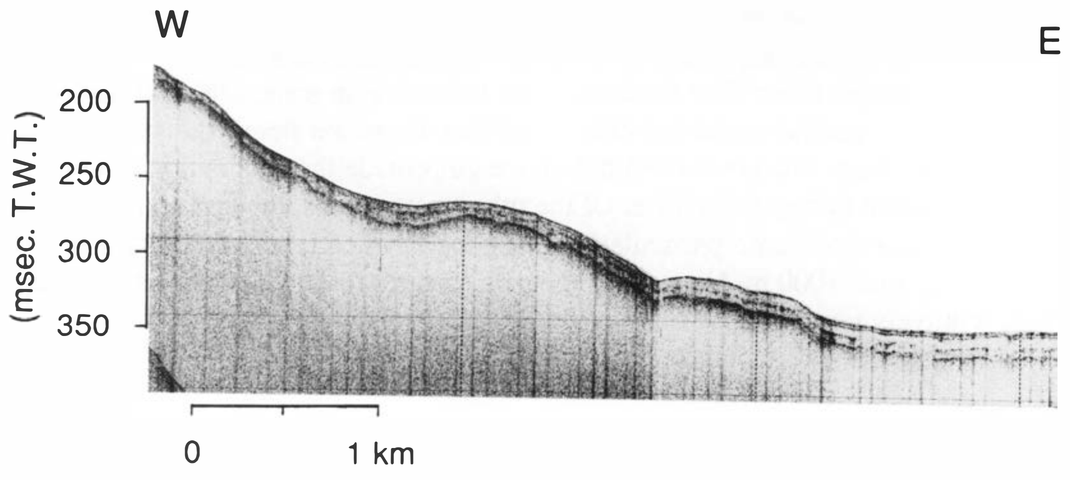

Figure 6. 3.5 kHz PDR profile in line NP90-201 in Isfjorden. For location, see Fig.2.

As a total, the following volume of data was acquired during the cruise:

Seismic lines (sleeve guns & sparker):	2900 km
Huntec Deep Tow Boomer lines:	600 km
Side scan sonar lines:	800 km
No. of sonobuoys:	8
3.5 kHz PDR run continuously.	
No. of stations:	57
No. of piston cores:	38
No. of Gravity cores:	50
No. of box cores:	18
Max recovery:	8.7 m
Total recovery:	300 m

For more details, see tables in appendixes 1,2 and 3 and the core logs in appendix 4.

PRELIMINARY RESULTS

Bedrock geology

At the present stage, the seismic data have not been studied in detail with regard to the bedrock geology. Due to the limited penetration of the relatively small energy source and the multiple problem, the amount of bedrock information is limited. However, several of the lines across the shelf show the distinction between the structureless crystalline basement and the younger sedimentary rocks quite clearly. Hence, the data set may provide additional information for outlining the local sedimentary basins within the Hecla Hoek rocks, as well as outlining the western boundary of the Hecla Hoek complex (i.e. the Hornsund Fault Zone).

On the inner shelf, the eroded bedrock surface forms an unconformity that clearly is the boundary between preglacial and glacial sediments. In the Barents Sea and most other parts of the Norwegian continental shelf, this boundary is well defined by an upper regional unconformity. Approaching the margin in the present study area, this is no longer straightforward. Line NP90-118 (Fig.5) of the present survey presents a good example of the problem. Following the upper unconformity, the thickness of the upper layers decreases to nearly nothing at the shelf break. Because of repeated late Cenozoic glaciations across the shelf, a significant amount of glacigenic sediments must have been transported out and caused shelf progradation. Hence, the preglacial - glacial boundary most likely is situated somewhere in the section further landward from the shelf break, probably as a dipping unconformity.

The problem of defining the base of the glacial sediments is a general problem in all glacial margins. During Ocean Drilling Program (ODP) Leg 119 drilling on the East Antarctic continental shelf, glacier proximal diamictites were drilled more than a hundred meters below the depth where the boundary was defined seismically (Barron, Larsen et al.,1990). This is one of the main bedrock related problems that will be addressed during the work with the "Svalbard Traverse".

Fjord sediments

Isfjorden

The profiles within Isfjorden follow the deeper parts of the fjord (Fig.2), and the sediment thickness towards the fjord walls is therefore not well known. Exceptions are seismic lines running immediately off Longyearbyen and also across the shallow sills into Billefjorden and Tempelfjorden. Fig.6 shows the general pattern of sediment distribution, which is characterized by 10-20 milliseconds two-way reflection time (ms) of acoustically transparent sediments.

In some areas the lower sections of these sediments are faintly stratified. The sleeve gun records show that the thickness of the till deposits, between the bedrock and the acoustically transparent sediments, is generally less than 5 m. The thickness of the acoustically transparent sediment follows the overall fjord morphology as expressed by the bedrock. Towards shallower water the upper sequence becomes acoustically more opaque, and based on previous results (Elverhøi et al., 1983) we attribute this to more coarse-grained sediments. It is also evident that the sediment thickness above the bedrock decreases in the direction of shallower water depths. However, this is not the case towards the fjord heads/present calving ice fronts where the sediment thickness increases significantly. Close to the ice fronts the thickness may exceed 200 m. Somewhat surprisingly, however, the sediment thickness in the central and outer part of Billefjorden is limited to only 5-10 ms. A well-defined basin, where the total sediment thickness may reach 50 ms is located off Longyearbyen. The sediments are characterized by an acoustically well-stratified sequence, and minor faults indicate mass wasting. Previous side scan sonar investigations in the region have also demonstrated sediment redistribution via shutes from the Longyear delta and into the main fjord (Prior et al., 1981).

A local sedimentary basin is also found in the outer part of Isfjorden, in the Svenskesunddjupet trough, where the sediment thickness may reach 200 ms. Whether this magnitude of sediments represents deposits from the last glaciation up to the present or if they also include pre-Late Weichselian deposits, is not known.

Van Keulenfjorden

Van Keulenfjorden is characterized by an outer sill and thus differs from a number of the other "svalbard fjords, which are unsilled. This fjord is smaller than Isfjorden and does not have tributary fjords. The terrestrial material is entirely deposited within the main fjord. At the fjord head, the main glacier of the fjord's drainage basin, Nathorstbreen, expanded significantly into the fjord during the last century, in response to the climatic cooling during the Little Ice Age. Onshore, the position of the former ice front is marked by a hummocky landscape. In the fjord, the maximum glacial extent is marked by a major sediment ridge and fan (Fig.7). As shown in the figure, the thickness of this accumulation is more than 100 ms. The reflector forming the base of the fan (upper surface of the sub-fan stratified sequence) can be followed westwards to where the fan

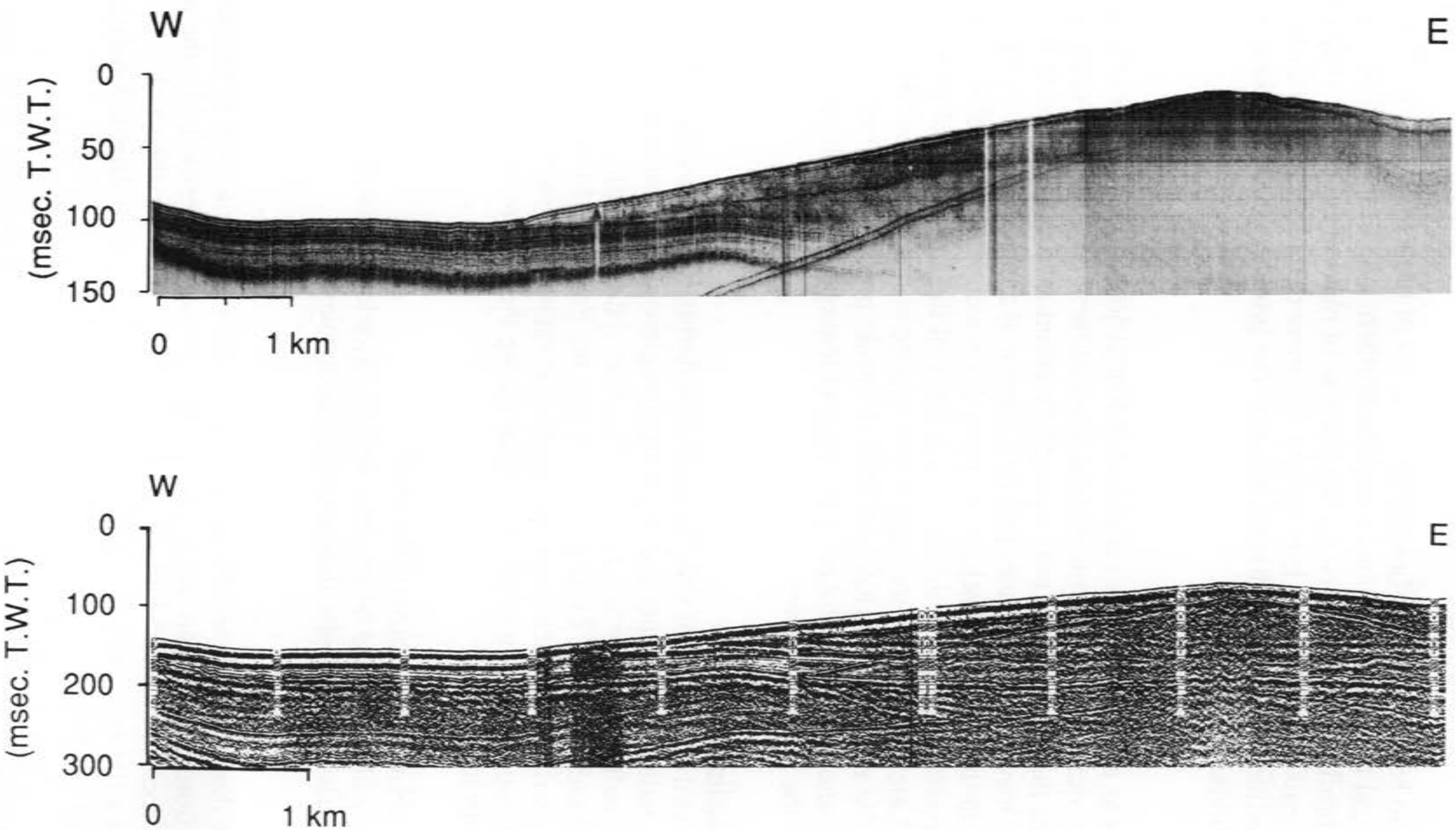

Figure 7. 3.5 kHz PDR (upper) and sleeve gun (lower) profiles from line NP90-103 in Van Keulenfjorden, showing sediment ridge and fan related to the Little Ice Age glacial advance. For location, see Fig.2.

sequence thins out. In this area a long piston core probably recovered sediments below this reflector. If reliable datings can be obtained, we will be able to more exactly date the development of the fan. Through volumetric calculations of the fan, these data will then have a potential for calculation of sediment fluxes during a period of advanced glacier.

Sediments are also brought into the fjord from a number of braided rivers, fed by minor glaciers, and typical fan deltas are found along the northern side of the fjord. A number of cross-section profiles were obtained for the purpose of making an isopach map of the unlithified sediments of entire fjord. It is evident that these delta fans comprises a significant proportion of the total sediment volume. The primary source for these fan deltas are glacifluvial rivers.

Kongsfjorden

A small survey was conducted in the outer part of Kongsfjorden. Piston cores showed the existence of overcompacted diamicton at about 7 m sediment depth. The overcompacted material indicated that the area had been covered by grounded ice, and when compared with preliminary results from the outer part of Isfjorden, it appears that this ice advance may correspond to the Late Weichselian Ice Sheet. Such a conclusion is, however, in contrast to the apparently well established stratigraphy of the adjacent land areas, which suggest that the Late Weichselian ice margin was located east of the cores NP90-9, 10 and 11 (Fig.3). The material from Kongsfjorden is further processed and analyzed at Woods Hole Oceanographic Institution, with the problem of Late Weichselian glacial extend as one of the main objectives.

Summary fjord sediments

The fjords represent an important sink for sediments during interglacial periods. The main part of the sediments is deposited in proximal regions such as outside calving ice fronts and in fan deltas fed by braided rivers. The main sediment input during the present interglacial occurred during the Little Ice Age, while the Early and Middle Holocene have been characterized by much lower sedimentation rates. The lower input during these periods indicates significantly less ice cover than during the present day 60% glacial coverage of the archipelago.

Sediments and seismic structure of the shelf

This description will emphasize on the area outside Isfjorden, which includes the area south of Prins Karls Forland; Isfjordrenna and Isfjordbanken.

Morphology

Isfjordrenna is a dominating morphological feature, defined as a glacially eroded channel running WNW from Isfjorden all the way to the shelf break. It is restricted by the nearly outcropping bedrock to the north and a bank area (Isfjordbanken) to the south. Isfjordbanken is a flat area located between the Isfjordrenna and Bellsund, consisting of glacigenic sediments (see below).

The sea-floor is relatively smooth at water depths above approximately 100-50 ms and below 250-300 ms. In between the sea-floor reflector is clearly undulating, and side scan sonar records have confirmed the presence of iceberg ploughmarks. This regional distribution pattern does also indicate the maximum/minimum size of the icebergs. Iceberg ploughing is therefore most prominent on the western part of Isfjordbanken and on the western rim of Bellsundbanken. There are apparently few or no iceberg ploughmarks north of Isfjordrenna.

Based on bathymetric maps, Ohta (1982) suggested that the ice advanced out on the shelf forming terminal moraines. The conclusions of this years cruise do not fully confirm this. From the seismic data, only one ridge has been defined as a terminal moraine (Fig.8). It is located at the northwesterly part of Isfjordbanken, at the shelf break, with the longest axis slightly oblique to the orientation of the shelf break. At the moment it is not clear whether this is an end moraine or a lateral moraine of an ice stream out Isfjorden.

Near the mouth of Isfjordrenna several depressions (up to 50 ms deep) occur (Fig.9). They are most likely formed by erosion, possibly subglacial.

<u>Regional unconformity (bedrock surface)</u>
The bedrock has played an important role concerning the flow pattern and the erosional force of the ice during periods of advance. Despite the problems of defining the preglacial bedrock surface in the outer parts of the shelf, some comments can be made concerning the interpreted bedrock surface.

The regional unconformity forms a smooth and relatively flat surface in the Isfjordrenna and Isfjordbanken area. In Isfjordrenna bedrock is clearly eroded by ice, and the erosional effect has been greatest in this restricted area (see below). Hence, Isfjordrenna has probably been the location for major ice streams draining parts of the "svalbard/Banks sea ice sheets. There is a distinct break in the gradient of the unconformity surface at the northern flank of Isfjordrenna. North of this change, the surface is shallowing and the relief increases. This shift follows the boundary from sedimentary rocks in the south to Hecla Hoek basement rocks with different competence in the north. Approximately half way out Isfjordrenna this boundary turns north and follows Prins Karls Forland. This may explain why Isfjordrenna makes a northward bend.

A few km west of Bellsund several troughs are cut into the pre-glacial bedrock. In the central part of Bellsundbanken the regional unconformity probably marks the upper boundary of gas blanking. This interpretation is based on a lateral reduction in acoustic impedance between the glacial and the pre-glacial deposits. Shallow gas has also been observed in the sedimentary rocks of Isfjordrenna.

In a few dip-lines it is possible to define the pre-glacial paleo shelf. In the Bellsund area the shelf break has prograded approximately 7 km westwards, while the progradation seems to have been about 10-12 km off Isfjorden. This trend reflects the fact that the sediment flux during glacial periods has been greatest from the Isfjorden drainage system. In one line (NP90-106) the paleo shelf edge is located to the west of the present

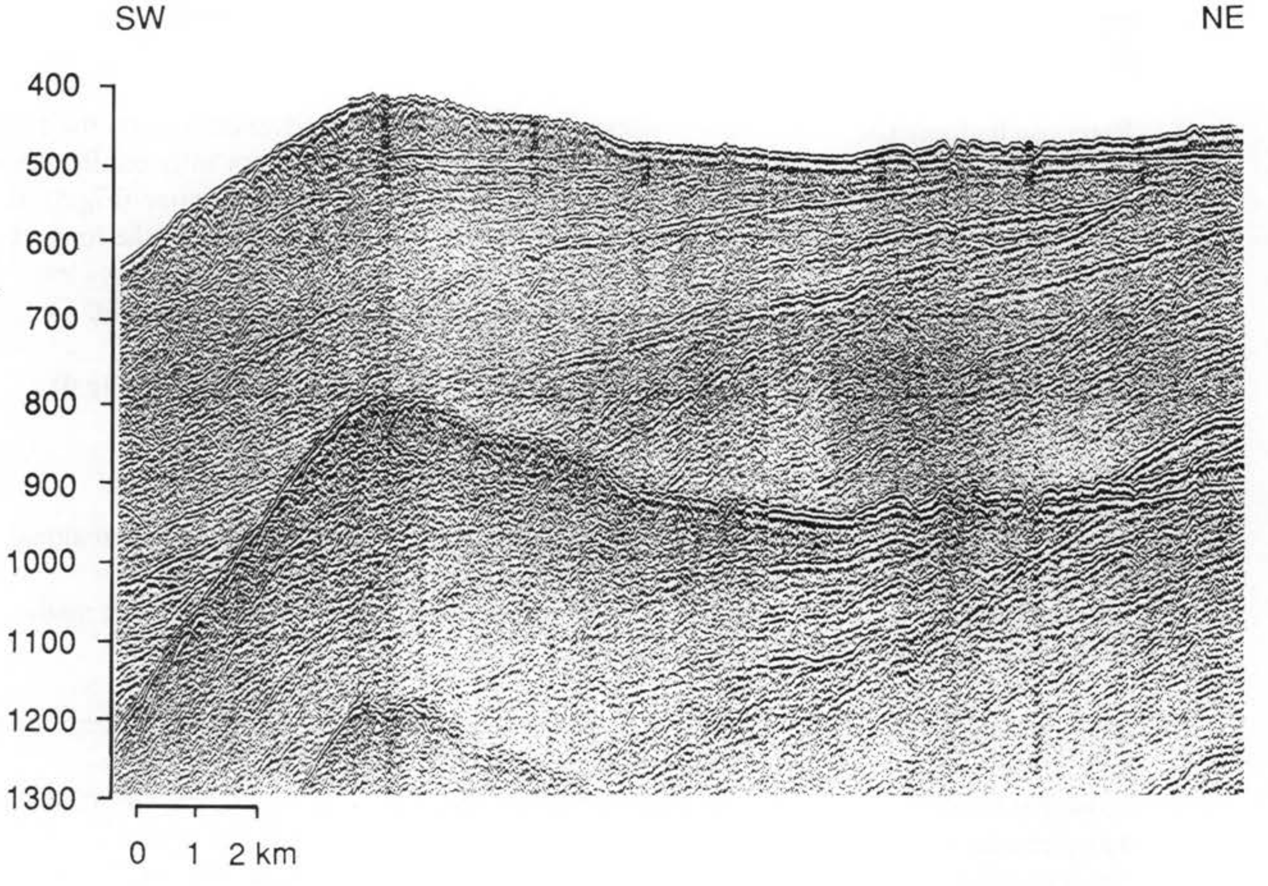

Figure 8. Part of seismic line NP90-119 (sleeve gun), showing (moraine) ridge at the shelf edge. For location, see Fig.2.

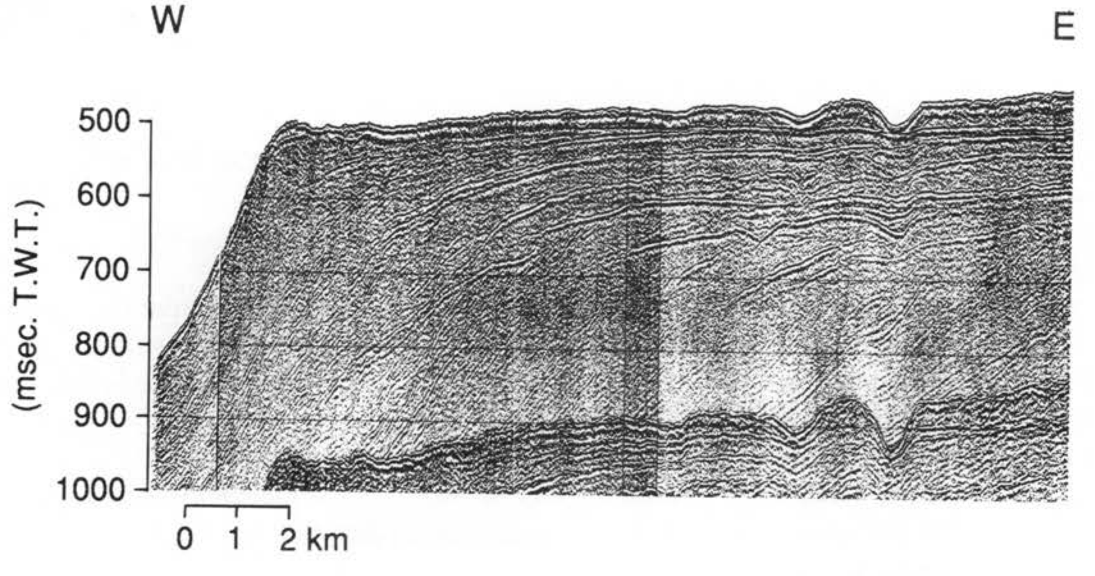

Figure 9. Part of line NP90-131, showing depressions at the sea-floor and buried depressions (approx. 150 ms below the sea-floor). For location, see Fig.2.

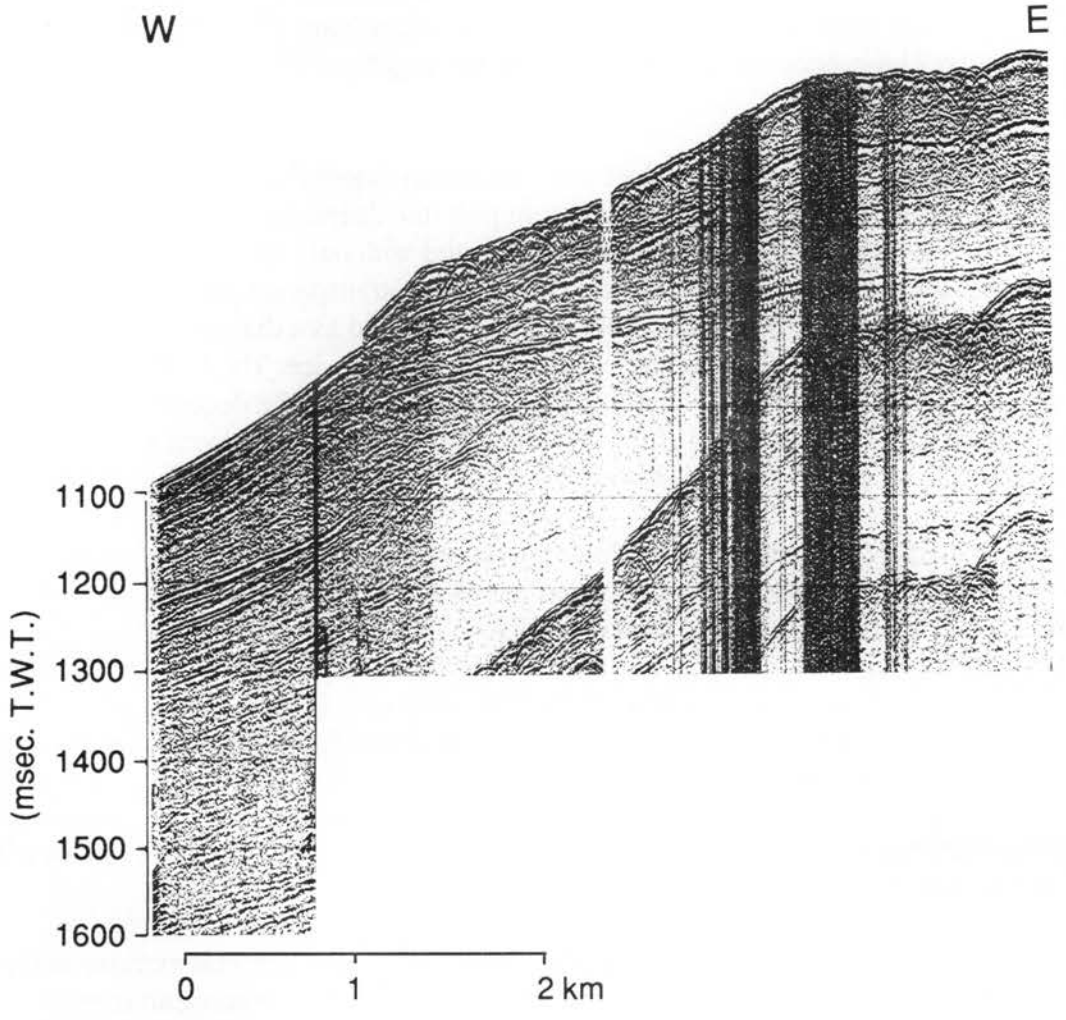

Figure 10. Part of line NP90-106, showing the present shelf edge located to the east of the paleo shelf (unknown age). For location, see Fig.2.

(Fig.10). The relectors in this line, which is not a true dip line, converge seawards, probably due to erosion (mass wasting).

Glacigenic sediments

The thickness of the glacigenic sediments in the nearshore area (<20 km from the coast) and in Forlandsundet does not exceed 10 ms (7.5 - 10 m), and the cover is evenly distributed. The thickness increases steadily towards the shelf break and exceeds 300 ms on the outer shelf (Fig.11).

Multiples and a small source are limiting factors in mapping true glacigenic thicknesses at the shelf break and upper slope. However, multichannel data indicate that the glacigenic thickness may greatly exceed 1 s.

Upper unit/regional reflector

The shelf area south of Prins Karls Forland is covered by a thin unit (10-40 ms) separated from the underlying sequence by a persistent reflector. This reflector probably marks the last glacial advance, since it often cuts older reflectors and is observed under a moraine ridge at the shelf break in the northwesterly part of Isfjordrenna (Fig.8). As no other moraine ridges have been found east of this, the ice may have retreated from the area relatively rapidly.

The unit appears homogenous and does not contain any internal reflectors. In the central part of Isfjordrenna, particularly in the western part (the deepest), approximately 100 ms of possibly late glacial/Holocene sediments are found with only sparse (or non-existent) till material below it. This interpretation is based on the transparent seismic character. In the rest of the investigated area the upper unit is interpreted as a diamicton, probably deposited as a till and/or glacimarine sediments deformed by ice. The Holocene cover is therefore most likely thin throughout the study area, except for the deepest part of Isfjordrenna. The upper unit most likely continues to the north and covers the shallow area south and west of Prins Karls Forland.

The core material confirms the seismic interpretations. Cores from the shelf area demonstrate that the uppermost 1-2 m of sediments consist of homogenous mud in abundance, except for two cores. The first (NP90-33/GC(2)) was collected from the shallow part of Isfjordbanken (Fig.3). It contains approximately 10 cm of compacted till material below a 5 cm thick layer of pebbles. The other core (NP90-21/GC(1)) was recovered from the outer part of Isfjordrenna, in one of the depressions mentioned above. It penetrated homogenous mud containing layers of sandy mud, before it finally went approximately 20 cm down into a slightly overconsolidated gravelly mud, which could possibly represent a dropstone diamicton. The diamicts are probably deposited during the last glacial advance/retreat.

X-ray photographs of a core (NP90-26/GC(1)) obtained on the terminal moraine at the shelf edge show that the uppermost 87 cm of the ridge consist of homogenous mud containing clasts of different sizes. Of two other cores (NP90-23/PC(1) and NP90-24/PC(1)) located in Isfjordrenna, the former includes laminated mud at the top

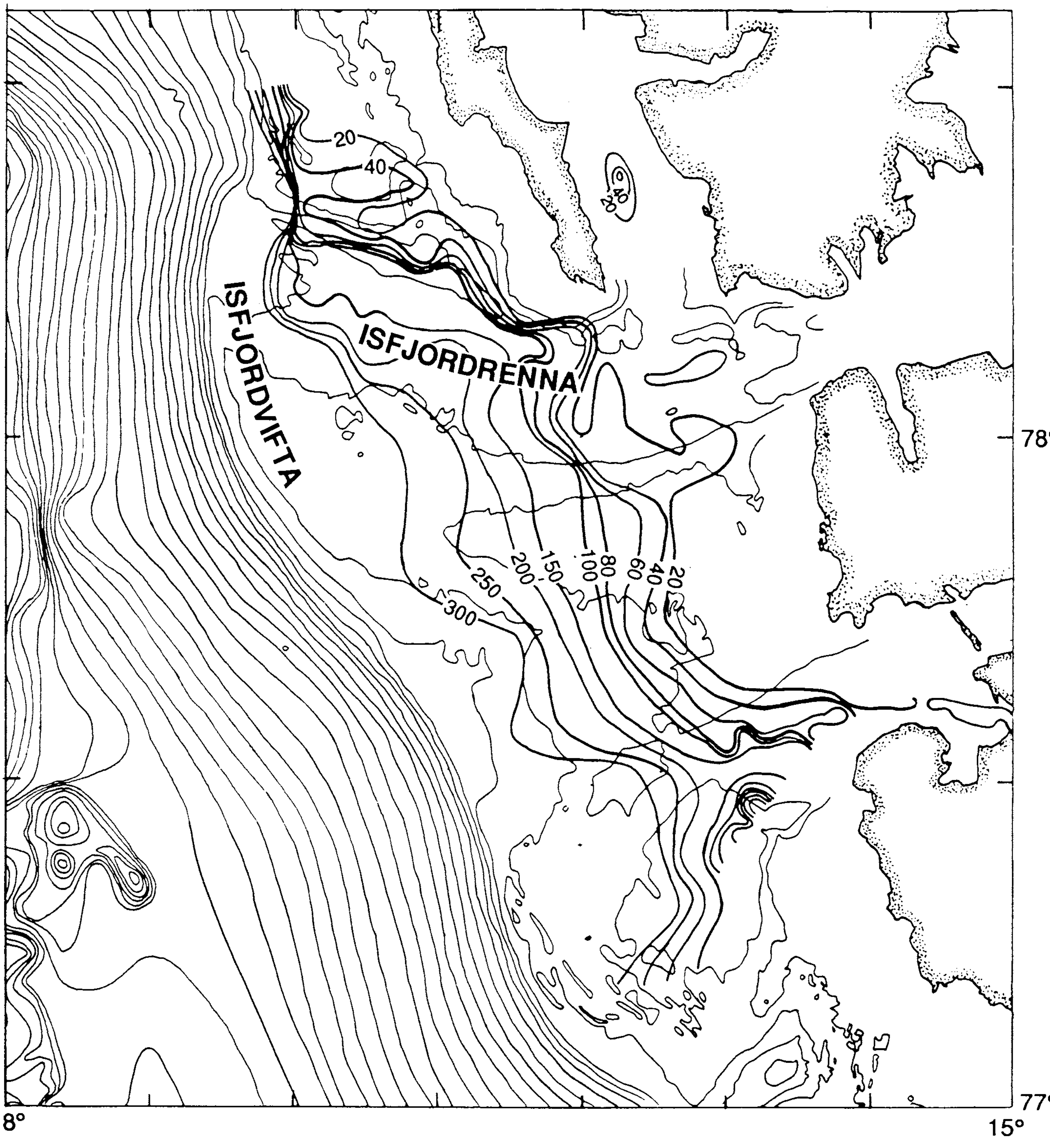

Figure 11. Isopach map of total thickness (in milliseconds, two way reflection time) of the glacigenic sediments on the shelf. See text for discussions on the identification of the preglacial bedrock surface.

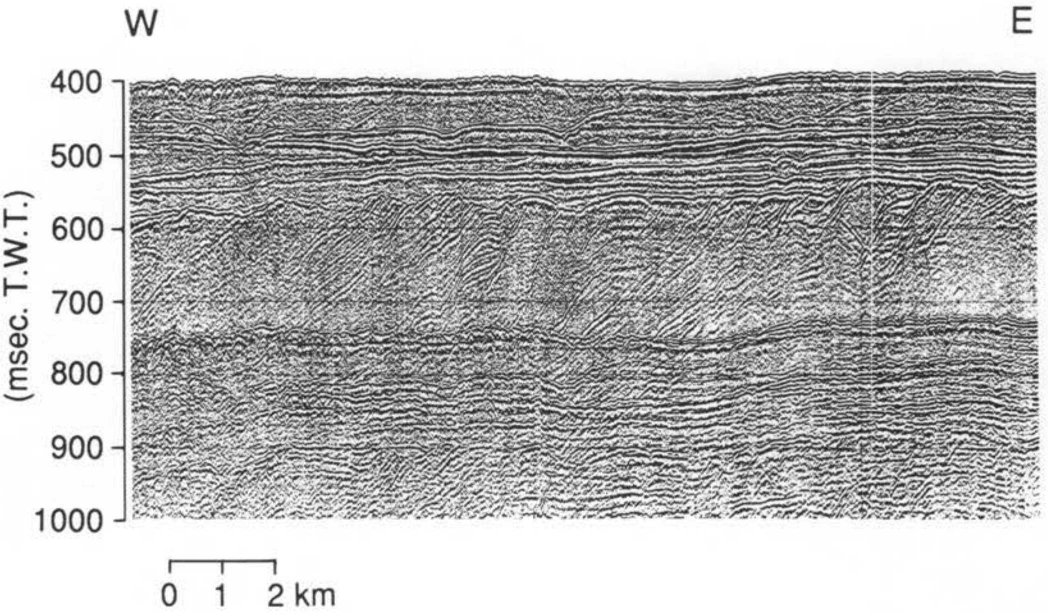

Figure 12. Part of line NP90-131, showing the reflection pattern in central Isfjordrenna. For location, see Fig.2.

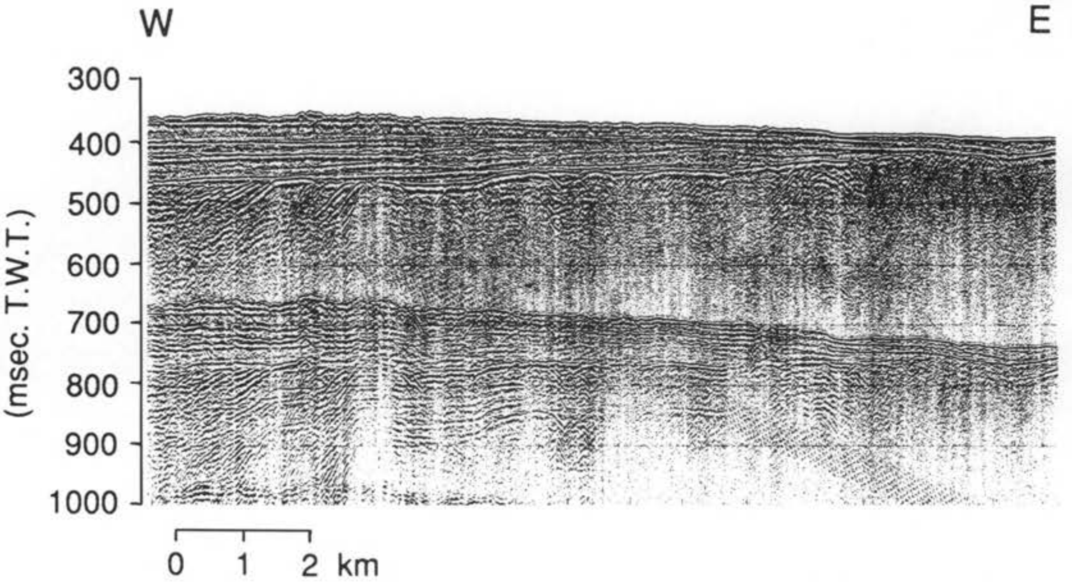

Figure 13. Part of line NP90-114, showing a subparallel seismic reflection pattern. For location, see Fig.2.

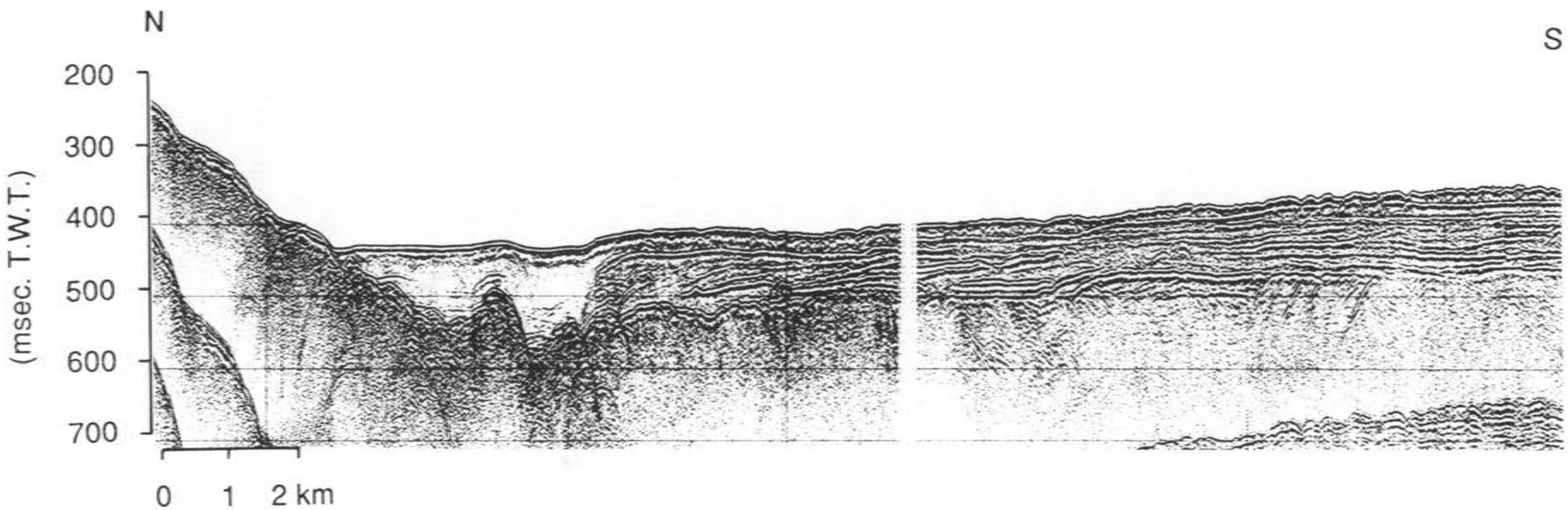

Figure 14. Part of line NP90-313. Note thick acoustically transparent accumulation in the trough and complex reflection pattern towards the south. For location, see Fig.2.

(approximately 20 cm). The rest of the core (20-685 cm) contains homogenous mud with variable content of clasts. The latter core also contains homogenous mud and additionally, several datable bivalves have been observed. Two other cores (NP90-7/GC(1) and NP90-8/PC(2)) acquired in the sound between the Prins Karls Forland and the Spitsbergen contains some laminated mud, but the major part is bioturbated and thus homogenous.

Layered sequence

The sequence between the interpreted bedrock and the upper, homogenous unit is characterized by reflectors of different continuity and amplitude, which may represent ice oscillations. The variable continuity implies that they have been cut by glacial erosion. In the upper part of the sequence (between 50 and 100 ms below the sea-floor), in the western part of the shelf, curving reflectors have been observed, which may be caused by local glacial erosion (Fig.12). The seismic architecture suggests that aggradation has taken place on the central part of the bank area, and that the sediments have prograded in a north-northwesterly direction on the northern part of Isfjordbanken. In addition the sequence reveals progradational structures near the shelf edge, and the shelf edge proper has prograded up to several kilometers by glacial deposition (see above).

The complex seismic configuration is indicated by lines NP90-114 (Fig.13) and NP90-131 (Figs. 9 and 12), both east-west oriented (Fig.2), running along Isfjordbanken and Isfjordrenna, respectively. Line NP90-313 (Fig. 14) runs perpendicular to the two others, from Isfjordbanken across Isfjordrenna and towards Prins Karls Forland. Line NP90-114 reveals strong reflectors which form a more or less subparallel seismic reflection configuration, indicating aggradation rather than progradation. Only in the eastern part of the section the reflectors tend to be truncated (especially by the upper regional reflector). According to this line the whole bank area is built up by glacigenic sediments and does not represent a positive bedrock form. Line NP90-131 forms a contrast to this line. The sequence along this line is built up of numerous reflectors of variable extent. They have been cut by erosion due to a high frequency of ice oscillations. In addition the reflectors dip westwards, indicating progradation in this direction. It is therefore not easy (possible) to tie this line with other areas because of the shift in erosional/depositional mechanisms. The distinct difference in seismic character between the lines indicates that the flow velocity and thus the erosional force has been greater in the Isfjordrenna area than the areas to the north and south.

The internal reflection pattern of line NP90-313 is very similar to the one in line NP90-131, but indicating a progradational/erosional direction to the north (Fig. 14). This configuration gives an impression of a northerly shift of the ice stream location through time.

The continental slope and the deep sea

The bathymetric contours indicate major sediment build-outs outside the main troughs; Isfjordrenna and Bellsunddjupet. The seismic records also confirm that major sediment complexes exist and that the shelf progradation has been greatest in these regions. These fans are formed in response to the enhanced ice flow and glacial erosion in the shelf troughs. As the Isfjorden region is the main area for the "svalbard Traverse", most emphasis has been placed on this region, and the grid density of seismic lines is also greatest here (Fig. 2).

The Isfjorden fan (Isfjordvifta) shows clear boundaries to the inter-fan regions to the north and south. Particularly the northern limitation is sharply defined. Strike-lines at various bathymetric depths along the slope (Figs. 15-17) show the boundary both as a bathymetric feature, and as a boundary between two distinctly different seismic characters and geometries. While the area to the north of the fan complex shows parallel stratification with continuous reflectors throughout the penetrated section, the fan complex shows a much more disturbed character. Internal reflectors are discontinuous, wavy and give a chaotic impression with frequent diffraction patterns. Broad reflecting horizons, consisting of bands of reflectors which individually may be discontinuous, can be followed through the complex (Fig. 16). Between these horizons, the pattern is chaotic. The differences to the surrounding area are also expressed at the sea floor, which is more hummocky on the fan complex.

At present, our interpretation of the seismic structure is that the Isfjorden fan represents numerous relatively small slides and slumps, and that the major part of the complex is deposited through mass wasting. This reflects the enhanced glacial activity in the Isfjordrenna trough. During glacial advances, large sediment volumes have been glacially transported and subsequently deposited at the shelf break and upper slope, which is the outer limit for grounded ice. Rapid deposition caused an unstable sediment configuration that led to numerous small scale slumps and slides. The more continuous reflecting horizons may represent quiet periods, with less slump activity, e.g. interglacials or at least periods when the glacier margin was in a retreated position relative to the shelf edge. However, until more data analyses are carried out, this remains speculative.

The deeper reflecting horizons can seismically be followed to shallow sediment depths to the north of the fan complex (Figs. 15-17). Long piston cores were recovered both on the fan and immediately outside it along seismic line NP90-301 (Fig. 15). Hence, provided adequate material, there is a potential for dating the deeper reflecting horizons, or optimally, the onset of fan formation. This will provide a better background for the discussion of fan development as a consequence of glacial - interglacial variations.

The lack of large slide scars and channel structures both on the present-day surface of the fan complex and at deeper levels, is striking. The lack of these structures is also confirmed by long-range side scan sonar (SeaMarc II) investigations carried out in 1989 (P. Vogt, pers. comm., 1990). To the south of the Isfjorden fan, however, channel structures have been observed both at the surface and deeper in the section. Therefore it appears as rapid deposition and frequent slumping caused by enhanced glacial sedimentation prevent the formation of stable, persistent channel structures.

Individual slumped sediment bodies can be outlined by the deep tow boomer data on the upper slope (Fig.18). The heavy vertical bars on the figure indicate the position of piston cores, both on the assumed slump body proper and immediately to the north of it. The

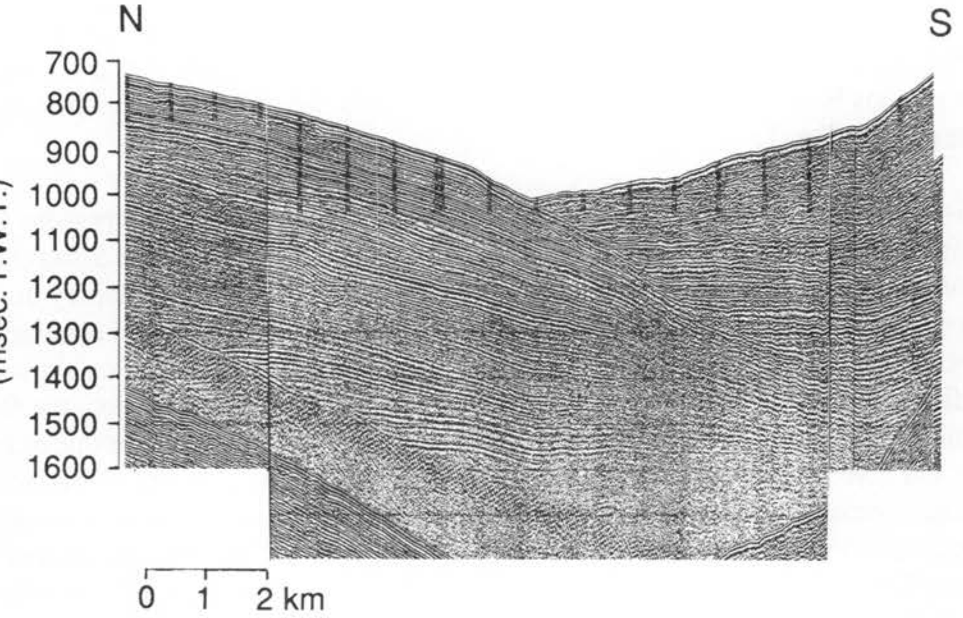

Figure 15. Part of seismic line NP90-301 (sleeve gun), from the upper slope (water depth approx. 670 m). Note the distinct boundary between the layered sequence to the north and the fan complex to the south. For location, see Fig.2.

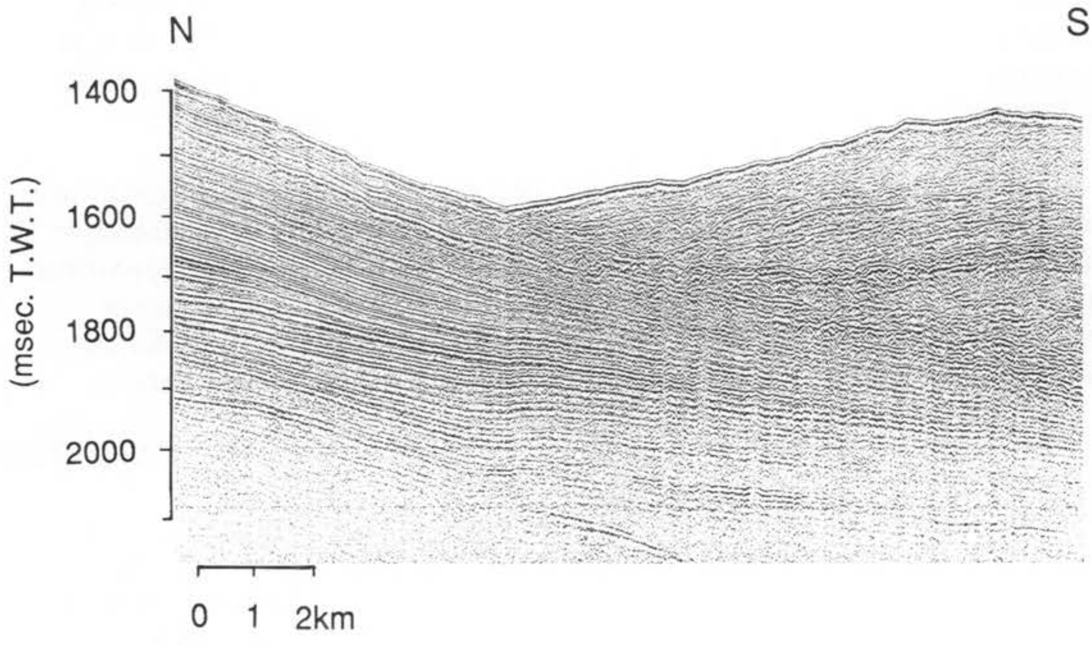

Figure 16. Part of seismic line NP90-303 (sleeve gun) (water depth approx. 1130 m). Note the reflecting horizons between more chaotic sequences in the fan complex to the south. For location, see Fig.2.

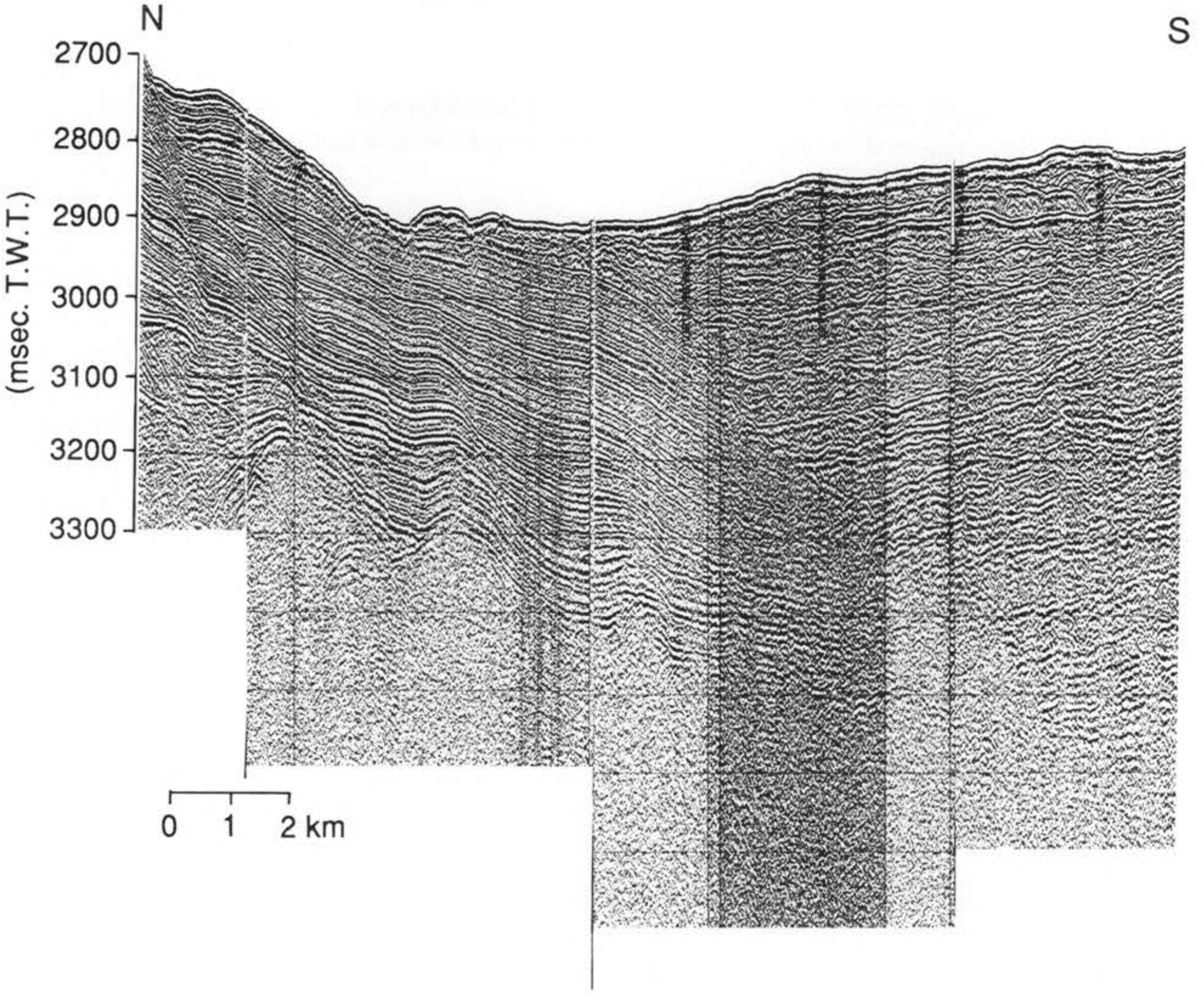

Figure 17. Part of seismic line NP90-122 (sleeve gun) (water depth approx. 2150 m). Note that the reflection configuration of the fan complex in this line is characterized by more continuous reflectors. For location, see Fig.2.

latter hopefully also penetrated to the reflector forming the base of the slump. These and other equivalent cores will be carefully analyzed for geotechnical parameters, lithology and sedimentary structures, in order to better interpret the sedimentary processes active on the slope.

Erosion by contour currents may be important along the slope and rise. Figure 19, from the lower slope shows slope steepening and converging reflectors that may be caused by this process.

Towards the lower slope and the continental rise, the seismically chaotic slump complexes grade into more stratified deposits interpreted as turbidites formed mainly as a result of the slumping on the upper slope. In the southwestern part of the study area, individual reflectors can be followed continuously across a narrow basin developed east of the Knipovich Ridge. Approaching the ridge, individual layers thin towards the axial mountains. In the northern part of the area, however, the lower slope and rise continues directly into the Knipovich Ridge, and the slope sediments, also here apparently developed as turbidites, overspill the axial mountains and deposit in the spreading axis valley proper.

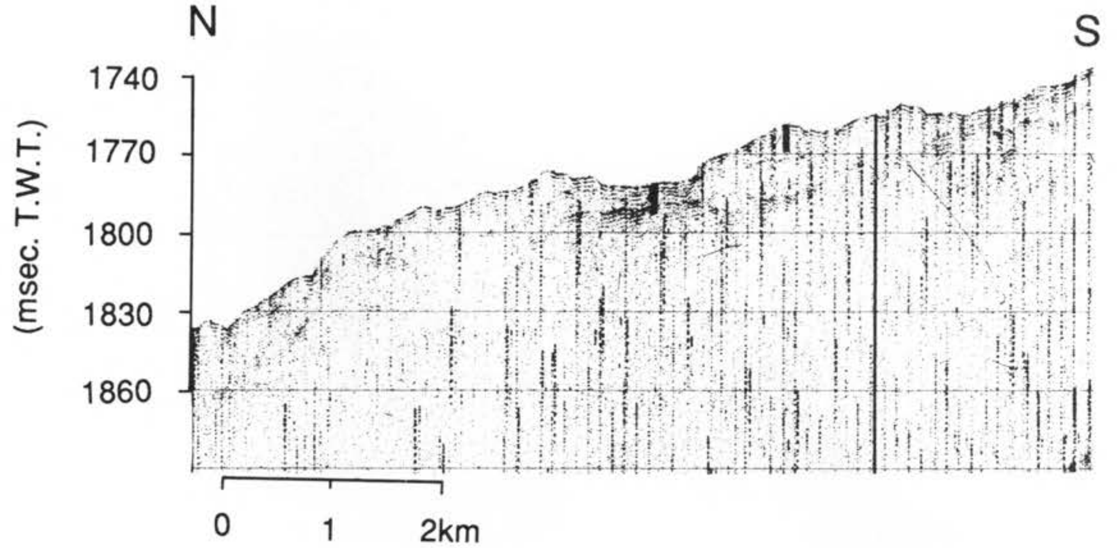

Figure 18. Part of deep tow Huntec Boomer line NP90-121, showing assumed slumped sediment body in the southern half of the profile. Vertical solid bars indicate core locations. For location, see Fig.2.

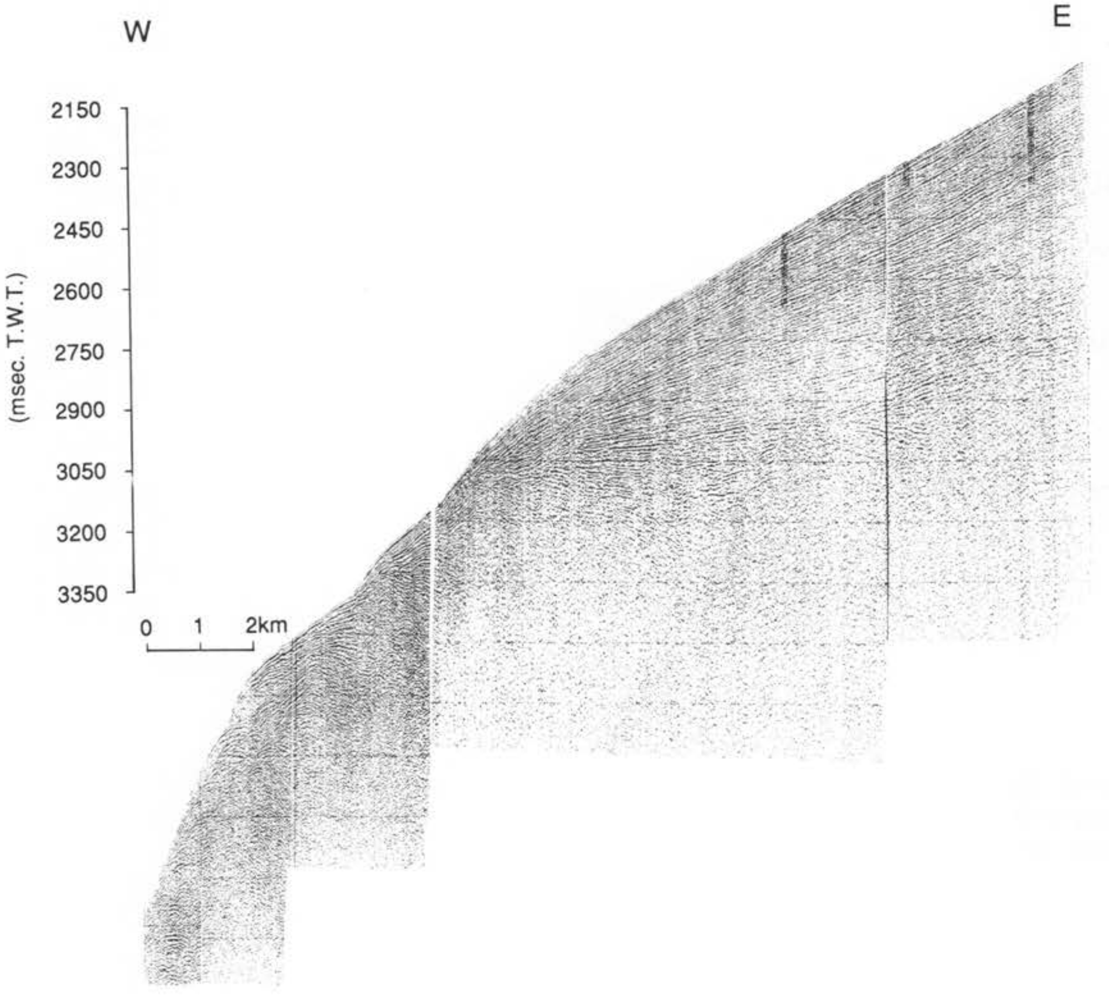

Figure 19. Part of seismic line NP90-119 (sleeve gun), from the lower slope. Morphology and truncated reflectors may be the result of erosion by contour currents. For location, see Fig. 2.

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APPENDIX 1: GEOPHYSICAL PROFILES
APPENDIX 2: SONOBUOYS
APPENDIX 3: SEDIMENT CORES
APPENDIX 4: CORE LOGS

APPENDIX 1

GEOPHYSICAL PROFILES

Abbrevations used in the lines and coring tables:

AIR - Sleeve airguns

SPA - Sparker

SSS - Side scan sonar

PDR - 3.5kHz echosounder

HUN - Huntec Deep-towed boomer

GC - Gravity corer

PGC - Plastic gravity corer

BC - Box corer

PC - Piston corer

Pen - Penetration

Rec - Recovery

		Start of line				End of line			
Line nr.	Type	Date	Time	^{0}N	^{0}E	Date	Time	^{0}N	^{0}E
NP 90 101	AIR	100790	09:45	77^{0}17.83	13^{0}57.99	110790	12:05	76^{0}51.11	07^{0}24.28
102	-	110790	16:15	77^{0}08.10	07^{0}36.16	120790	07:57	77^{0}37.04	14^{0}04.81
103	-	120790	07:57	77^{0}37.04	14^{0}04.36	120790	12:41	77^{0}30.82	15^{0}55.43
105	-	120790	19:30	77^{0}34.95	13^{0}36.82	130790	01:41	77^{0}11.02	12^{0}19.00
106	-	130790	03:30	77^{0}11.19	12^{0}18.07	130790	09:02	77^{0}29.03	10^{0}29.86
107	-	130790	15:04	77^{0}29.31	10^{0}32.61	130790	23:20	77^{0}41.97	13^{0}39.21
108	-	130790	23:21	77^{0}42.03	13^{0}39.41	140790	02:00	77^{0}51.90	12^{0}48.00
109	-	140790	23:20	77^{0}45.92	13^{0}19.79	150790	16:10	77^{0}28.92	07^{0}32.79
110	-	150790	17:55	77^{0}40.28	07^{0}30.62	160790	06:58	77^{0}54.93	12^{0}55.90
111	-	140790	02:29	77^{0}54.70	12^{0}49.50	140790	09:28	78^{0}28.75	12^{0}09.05
11A	-	140790	10:06	78^{0}31.45	12^{0}00.21	140790	10:40	78^{0}29.21	11^{0}55.05
11B	-	140790	10:53	78^{0}29.31	11^{0}58.63	140790	11:54	78^{0}30.57	12^{0}26.17
113	-	140790	14:33	78^{0}29.84	12^{0}06.81	140790	21:49	77^{0}55.98	12^{0}43.05
114	-	160790	08:00	78^{0}02.71	13^{0}04.52	160790	16:50	78^{0}04.00	09^{0}32.57
115	SPA	190790	02:27	78^{0}29.63	10^{0}05.36	190790	03:20	78^{0}29.00	10^{0}29.82

		Start of line				End of line			
Line nr.	Type	Date	Time	^{0}N	^{0}E	Date	Time	^{0}N	^{0}E
NP 90 116	AIR	210790	21:59	78^{0}29.09	10^{0}06.81	220790	04:31	78^{0}24.00	07^{0}11.59
118	-	220790	06:48	78^{0}12.22	07^{0}30.56	220790	15:30	78^{0}19.53	10^{0}06.66
119	-	220790	15:37	78^{0}19.61	10^{0}05.85	220790	23:43	78^{0}00.47	07^{0}27.60
120	-	230790	00:56	77^{0}50.07	07^{0}28.04	230790	03:54	77^{0}55.21	08^{0}56.69
121	-	230790	03:55	77^{0}55.27	08^{0}56.87	230790	10:39	78^{0}30.04	08^{0}39.87
122	-	230790	13:22	78^{0}16.68	08^{0}20.15	230790	22:26	77^{0}33.00	08^{0}59.97
123	-	230790	23:44	77^{0}35.36	09^{0}52.27	240790	06:24	78^{0}07.12	10^{0}04.79
130	-	280790	12.48	78^{0}29.02	10^{0}30.98	280790	13:47	78^{0}29.02	10^{0}54.59
131	-	280790	19:00	78^{0}05.61	10^{0}09.69	290790	02:02	78^{0}13.02	09^{0}18.47
201	-	200790	01:15	78^{0}05.49	12^{0}11.43	200790	05:20	78^{0}09.48	13^{0}44.00
201	-	200790	07:28	78^{0}14.16	14^{0}31.16	200790	14:35	78^{0}38.57	16^{0}40.27
204	-	200790	20:32	78^{0}22.56	16^{0}51.38	200790	21:55	78^{0}26.03	17^{0}19.07
206	-	200790	23:23	78^{0}22.42	16^{0}50.92	210790	03.39	78^{0}18.94	15^{0}03.35
207	-	210790	03:40	78^{0}18.87	15^{0}03.54	210790	05:20	78^{0}15	15^{0}34

Line nr.	Type	Start of line				End of line			
		Date	Time	^{0}N	^{0}E	Date	Time	^{0}N	^{0}E
NP 90 301	AIR	160790	17:30	78^{0}03.98	09^{0}33.02	160790	22:08	78^{0}29.13	09^{0}26.36
302	-	160790	22:23	78^{0}29.08	09^{0}20.17	160790	23:47	78^{0}32.11	09^{0}04.20
303	-	160790	23:49	78^{0}31.96	09^{0}04.23	170790	14.11	77^{0}24.88	10^{0}48.04
304	SPA	170790	19:30	77^{0}25.79	10^{0}46.24	180790	02.33	76^{0}55.00	11^{0}59.80
305	-	180790	02:34	76^{0}54.97	12^{0}OO.19	180790	03.31	77^{0}00.31	12^{0}14.13
306	-	180790	03:32	77^{0}00.73	12^{0}12.23	180790	11:52	77^{0}39.93	10^{0}34.50
306	-	180790	11:58	77^{0}40.09	10^{0}32.94	180790	17:43	78^{0}06.98	09^{0}14.41
307	-	180790	17:56	78^{0}06.94	09^{0}14.42	180790	20:38	77^{0}59.78	10^{0}00.72
308	-	180790	20:59	77^{0}59.83	09^{0}59.99	190790	02:10	78^{0}28.72	10^{0}02.36
309	-	190790	03:22	78^{0}28.92	10^{0}30.49	190790	09:10	77^{0}59.13	10^{0}29.97
310	AIR	190790	09:41	77^{0}58.99	10^{0}36.59	190790	10:44	77^{0}58.84	11^{0}03.34
311	-	190790	10:52	77^{0}59.41	11^{0}03.78	190790	15:40	78^{0}23.90	10^{0}48.00
312	-	190790	15:41	78^{0}24.08	10^{0}48.15	190790	18:05	78^{0}15.06	11^{0}34.89
313	-	190790	18:11	78^{0}14.42	11^{0}35.17	190790	20:50	78^{0}00.38	11^{0}34.91
314	-	190790	21:28	77^{0}56.93	11^{0}33.45	190790	22:50	77^{0}57.33	12^{0}06.60

		Start of line				End of line			
Line nr.	**Type**	**Date**	**Time**	**^{0}N**	**^{0}E**	**Date**	**Time**	**^{0}N**	**^{0}E**
NP 90 315	AIR	190790	22:53	$77^0$57.91	$12^0$0708	200790	00:09	$78^0$04.91	$12^0$0710
316	-	260790	20:00	$78^0$26.80	$09^0$26.01	270790	00:58	$78^0$56.07	$09^0$12.26
317	-	270790	00:58	$78^0$56.13	$09^0$13.23	270790	07:11	$79^0$00.79	$11^0$07.91
319	-	270790	14:36	$79^0$02.69	$11^0$19.14	270790	17:56	$79^0$01.87	$11^0$39.46
320	-	310790	19:38	$78^0$00.?	$10^0$29.89	010890	00:35	$77^0$37.7	$11^0$18.27
321	-	020890	05:25	$77^0$35.10	$08^0$55.02	020890	14.20	$76^0$58.71	$08^0$54.91

		Start of line				End of line			
Line nr.	Type	Date	Time	°N	°E	Date	Time	°N	°E
NP 90 102	SSS	120790	04:19	77°32.00	12°43.37	120790	07:57	77°37.04	14°04.81
103	-	120790	07:58	77°37.04	14°05.26	120790	11:56	77°33.76	15°42.25
104	-	120790	14:35	77°33.45	15°28.97	120790	15:34	77°34.25	15°05.97
105	-	120790	19:31	77°34.88	13°36.66	130790	01:35	77°11.44	12°20.31
107	-	130790	21:40	77°39.54	13°01.02	130790	23:20	77°41.91	13°39.01
108	-	130790	23:21	77°42.03	13°39.41	140790	02:00	77°51.00	12°48.00
109	-	150790	02:52	77°43.56	12°18.12	150790	07:10	77°38.80	10°33.92
110	-	150790	23:40	77°50.39	10°01.71	160790	06:58	77°54.93	12°55.90
111	-	140790	02:29	77°54.70	12°49.50	140790	09:28	78°28.75	12°09.05
11A	-	140790	10:06	78°31.45	12°00.21	140790	10:40	78°29.21	11°55.05
11B	-	140790	10:53	78°29.31	11°58.63	140790	11:50	78°30.52	12°24.79
113	-	140790	14:45	78°28.85	12°07.89	140790	21:40	77°56.70	12°42.34
114	-	160790	07:50	78°02.31	13°06.10	160790	10:00	78°01.91	12°15.51
115	-	190790	02:20	78°29.73	10°03.78	190790	03:20	78°29.00	10°29.82
116	-	210790	19:30	78°10.48	11°13.14	210790	21:55	78°29.16	10°08.33

Line nr.	Type	Start of line				End of line			
		Date	Time	^{0}N	^{0}E	Date	Time	^{0}N	^{0}E
NP 90 131	SSS	280790	19:00	78^{0}0561	12^{0}09.68	290790	02:00	78^{0}13.01	09^{0}18.83
201	-	200790	01:10	78^{0}05.49	12^{0}11.42	200790	10:50	78^{0}24.31	15^{0}37.55
202	-	200790	13:20	78^{0}33.24	16^{0}23.80	200790	17:05	78^{0}33.08	16^{0}22.45
301	-	290790	02:45	78^{0}10.33	09^{0}22.55	290790	03:49	78^{0}07.07	09^{0}21.29
306	-	180790	15:30	77^{0}55.60	09^{0}40.19	180790	17:30	78^{0}05.62	09^{0}17.95
307	-	180790	17:56	78^{0}06.94	09^{0}14.03	180790	20:32	78^{0}00.09	09^{0}59.33
308	-	180790	20:50	77^{0}59.83	09^{0}59.99	190790	02:14	78^{0}28.88	10^{0}02.22
309	-	190790	03:23	78^{0}28.84	10^{0}30.57	190790	09:11	77^{0}59.04	10^{0}29.92
310	-	190790	09:23	77^{0}58.99	10^{0}30.20	190790	10:44	77^{0}58.84	11^{0}03.34
311	-	190790	10:52	77^{0}59.41	11^{0}03.78	190790	15:38	78^{0}23.81	10^{0}48.14
312	-	190790	15:40	78^{0}23.99	10^{0}48.07	190790	18:04	78^{0}15.11	11^{0}34.52
313	-	190790	20:00	78^{0}04.79	11^{0}35.02	190790	21:25	77^{0}57.04	11^{0}34.01
314	-	190790	21:40	77^{0}56.99	11^{0}35.74	190790	22:50	77^{0}57.33	12^{0}06.60
315	-	190790	22:52	77^{0}57.90	12^{0}07.08	200790	00:07	78^{0}04.84	12^{0}07.11
320	-	310790	19:38	78^{0}00.?	10^{0}29.89	310790	23:10	77^{0}52.?	10^{0}44.?
320	-	310790	23:15	77^{0}52.?	10^{0}44.?	010890	10:20	77^{0}42.26	11^{0}46.93

		Start of line				End of line			
Line nr.	**Type**	**Date**	**Time**	**^{0}N**	**^{0}E**	**Date**	**Time**	**^{0}N**	**^{0}E**
NP 90 101	PDR	100790	09:45	77°17.83	13°57.99	110790	12:06	76°51.08	07°23.92
102	-	110790	16:36	77°08.85	07°44.98	120790	07:52	77°37.03	14°02.56
103	-	120790	08:02	77°37.04	14°07.05	120790	12:48	77°30.42	15°55.92
104	-	120790	13:08	77°31.08	15°54.37	120790	19:30	77°34.95	13°36.82
105	-	120790	19:31	77°34.90	13°36.33	130790	01:40	77°11.09	12°19.21
106	-	130790	02:38	77°10.43	12°19.83	130790	09:02	77°29.03	10°29.86
107	-	130790	15:03	77°29.31	10°32.61	130790	23:17	77°41.87	13°38.26
108	-	130790	23:21	77°42.03	13°39.41	140790	02:00	77°51.90	12°48.00
109	-	140790	23:18	77°45.91	13°19.99	150790	07:50	77°39.40	10°34.00
109	-	150790	08:05	77°39.53	10°41.60	150790	16:10	77°28.92	07°32.80
110	-	150790	17:49	77°40.03	07°27.61	160790	06:58	77°54.99	12°56.30
111	-	140790	02:10	77°51.98	12°48.03	140790	10:05	78°31.48	11°59.61
11A	-	140790	10:05	78°31.48	11°59.61	140790	10:40	78°29.21	11°55.05
11B	-	140790	10:53	78°29.35	12°00.00	140790	11:54	78°30.57	12°26.17
113	-	140790	14:33	78°29.84	12°06.81	140790	21:49	77°55.98	12°43.05

		Start of line				End of line			
Line nr.	**Type**	**Date**	**Time**	**^{0}N**	**^{0}E**	**Date**	**Time**	**^{0}N**	**^{0}E**
NP 90 114	PDR	160790	12:50	78^{0}01.87	11^{0}06.72	170790	00:00	78^{0}31.07	09^{0}04.11
114	-	160790	08:12	78^{0}02.79	12^{0}59.39	160790	16:49	78^{0}04.00	09^{0}32.98
116	-	210790	21:55	78^{0}29.16	10^{0}08.33	220790	00.10	78^{0}27.64	09^{0}10.31
118	-	220790	04:00	78^{0}24.44	07^{0}25.31	220790	15:28	78^{0}19.49	10^{0}05.82
119	-	220790	15:37	78^{0}19.61	10^{0}05.85	220790	23:40	78^{0}01.05	07^{0}29.09
120	-	230790	00:50	77^{0}50.00	07^{0}25.21	230790	03:52	77^{0}55.15	08^{0}56.05
121	-	230790	03:53	77^{0}55.17	08^{0}56.37	230790	10:40	78^{0}30.13	08^{0}39.72
12A	-	230790	10:40	78^{0}30.12	08^{0}39.73	230790	14:30	78^{0}10.22	08^{0}20.00
122	-	230790	14:30	78^{0}10.22	08^{0}20.00	230790	22:26	77^{0}33.00	08^{0}59.97
123	-	230790	23:44	77^{0}35.36	09^{0}52.27	240790	00:45	77^{0}41.00	09^{0}38.22
130	-	280790	12:40	78^{0}28.91	10^{0}27.08	280790	14:00	78^{0}12.97	09^{0}18.97
131	-	280790	19:00	78^{0}05.60	12^{0}09.91	290790	02:00	78^{0}12.96	09^{0}18.93
201	-	200790	02:00	78^{0}05.77	12^{0}28.54	200790	15:20	78^{0}39.71	16^{0}48.51
202	-	200790	15:20	78^{0}39.71	16^{0}48.51	200790	18:30	78^{0}27.39	16^{0}05.66
203	-	200790	18:40	78^{0}26.69	16^{0}06.97	200790	20:29	78^{0}22.55	16^{0}50.33

		Start of line				End of line			
Line nr.	Type	Date	Time	^{0}N	^{0}E	Date	Time	^{0}N	^{0}E
NP 90 204	PDR	200790	20.30	78^{0}22.51	16^{0}50.70	200790	21:58	78^{0}25.86	17^{0}18.36
205	-	200790	22:00	78^{0}25.80	17^{0}17.54	200790	23.10	78^{0}22.42	16^{0}50.92
206	-	200790	23:37	78^{0}22.55	16^{0}37.68	210790	03:36	78^{0}19.18	15^{0}03.45
207	-	210790	03:36	78^{0}19.18	15^{0}03.45	210790	05:20	78^{0}15	15^{0}34
208	-	210790	14:19	78^{0}10.61	14^{0}24.47	210790	17:30	78^{0}09.40	13^{0}00.65
301	-	290790	02:00	78^{0}13.00	09^{0}18.64	290790	09:44	78^{0}10.03	09^{0}20.87
302	-	160790	22:08	78^{0}29.14	09^{0}26.36	160790	23:40	78^{0}32.34	09^{0}06.34
303	-	160790	23:48	78^{0}32.04	09^{0}04.24	170790	04:20	78^{0}10.27	09^{0}05.74
307	-	160790	17:31	78^{0}04.04	09^{0}32.68	160790	22:08	78^{0}29.14	09^{0}26.36
316	-	270790	20:20	78^{0}59.72	10^{0}17.88	280790	00:50	78^{0}59.26	10^{0}07.30
317	-	270790	01:00	78^{0}56.15	09^{0}13.75	270790	12:21	79^{0}01.32	11^{0}06.24
319	-	270790	14:40	79^{0}02.58	11^{0}20.50	270790	17:58	79^{0}01.81	11^{0}40.56
320	-	310790	19:38	78^{0}00	10^{0}29.89	010890	07:10	77^{0}40.64	12^{0}45.82

		Start of line				End of line			
Line nr.	**Type**	**Date**	**Time**	**^{0}N**	**^{0}E**	**Date**	**Time**	**^{0}N**	**^{0}E**
NP 90 101	HUN	110790	22:00	77^{0}20.77	10^{0}07.48	120790	00:00	77^{0}24.98	11^{0}03.00
102	-	120790	01:00	77^{0}26.86	11^{0}28.81	120790	07:56	77^{0}37.04	14^{0}04.36
103	-	120790	07:58	77^{0}37.04	14^{0}05.26	120790	11:45	77^{0}34.00	15^{0}37.74
104	-	120790	12:45	77^{0}30.59	15^{0}55.78	120790	19:30	77^{0}34.95	13^{0}36.82
105	-	120790	19:30	77^{0}34.95	13^{0}36.82	130790	03:30	77^{0}11.19	12^{0}18.07
106	-	130790	03:30	77^{0}11.19	12^{0}18.07	130790	09:02	77^{0}29.03	10^{0}29.86
107	-	130790	16:15	77^{0}31.29	11^{0}00.84	130790	21:35	77^{0}39.41	12^{0}58.99
110	-	150790	23:02	77^{0}50.64	09^{0}49.68	160790	04:53	77^{0}52.59	12^{0}01.38
111	-	140790	02:29	77^{0}54.69	12^{0}49.50	140790	10:03	78^{0}31.36	12^{0}00.51
114	-	160790	07:45	78^{0}01.96	13^{0}05.60	160790	16:50	78^{0}03.99	09^{0}32.57
119	-	220790	15:40	78^{0}19.41	10^{0}05.52	220790	19:55	78^{0}06.79	09^{0}09.49
201	-	200790	01:09	78^{0}05.49	12^{0}11.43	200790	15:00	78^{0}39.91	16^{0}45.43
202	-	200790	15:00	78^{0}39.91	16^{0}45.43	200790	18:33	78^{0}27.19	16^{0}05.63
203	-	200790	18:33	78^{0}27.19	16^{0}05.63	200790	20:30	78^{0}22.51	16^{0}50.70
204	-	200790	20:30	78^{0}22.51	16^{0}50.70	200790	22:00	78^{0}25.80	17^{0}17.54

		Start of line				End of line			
Line nr.	Type	Date	Time	^{0}N	^{0}E	Date	Time	^{0}N	^{0}E
NP 90 205	HUN	200790	22:00	78^{0}25.80	17^{0}17.54	200790	23:05	78^{0}22.51	16^{0}52.20
206	-	200790	23:05	78^{0}22.51	16^{0}52.20	210790	03:35	78^{0}19.23	15^{0}03.76
207	-	210790	02:30	78^{0}21.99	15^{0}26.21	210790	05:20	78^{0}15	15^{0}34
208	-	210790	14:31	78^{0}10.05	14^{0}24.43	210790	17:05	78^{0}09.60	13^{0}17.56
301	-	160790	16:55	78^{0}03.72	09^{0}31.75	160790	22:15	78^{0}29.14	09^{0}23.76
302	-	160790	22:10	78^{0}29.18	09^{0}25.91	160790	23:48	78^{0}32.04	09^{0}04.24
303	-	160790	23:40	78^{0}32.34	09^{0}06.34	170790	14:35	77^{0}23.24	10^{0}53.41
306	-	180790	14:30	77^{0}50.85	09^{0}52.85	180790	20:30	78^{0}00.20	09^{0}58.70
307	-	180790	20:50	77^{0}59.83	09^{0}59.99	180790	22:00	78^{0}06.20	10^{0}00.91
310	-	190790	09:51	77^{0}59.01	10^{0}41.56	190790	10:52	77^{0}59.41	11^{0}03.78
311	-	190790	10:52	77^{0}59.41	11^{0}03.78	190790	15:40	78^{0}23.98	10^{0}48.07
312	-	190790	15:40	78^{0}23.98	10^{0}48.07	190790	18:05	78^{0}15.06	11^{0}34.89
313	-	190790	18:05	78^{0}15.06	11^{0}34.89	190790	22:00	77^{0}57.02	11^{0}45.08
314	-	190790	21:29	77^{0}56.70	11^{0}34.55	200790	00:20	78^{0}05.74	12^{0}06.93
11A	-	140790	10:07	78^{0}31.63	11^{0}59.61	140790	10:41	78^{0}29.13	11^{0}54.92

		Start of line				End of line			
Line nr.	**Type**	**Date**	**Time**	**^{0}N**	**^{0}E**	**Date**	**Time**	**^{0}N**	**^{0}E**
NP 90 11B	HUN	140790	10:40	$78^0$29.21	$11^0$55.05	140790	11:54	$78^0$30.57	$12^0$26.17
30C	-	170790	16:45	$77^0$33.90	$11^0$00.10	170790	17:55	$77^0$30.39	$10^0$37.97
30A	-	170790	14:39	$77^0$22.97	$10^0$48.35	170790	16:00	$77^0$29.61	$11^0$08.65
30B	-	170790	15:55	$77^0$29.12	$11^0$09.53	170790	16:45	$77^0$33.90	$11^0$00.10

APPENDIX 2

SONOBUOYS

Sonobuoy number	Date	Time GMT	Latitude °N	Longitude °E
1	220790	06:04	78°15.18	07°28.47
2	220790	16:33	78°16.31	09°51.35
3	230790	07:52	78°15.62	08°47.25
4	230790	13:54	78°13.70	08°19.71
5	230790	19:56	77°46.30	08°31.27
6	260790	20:49	78°30.04	09°22.24
7	280790	22:30	78°09.68	10°40.99
8	020890	12:41	77°08.41	08°59.55

APPENDIX 3

SEDIMENT CORES

Station/Type * Logged on Board	Date	Time	Latitude ^{0}N	Longitude ^{0}E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
* NP90-1/GC(1)	240790	20:55	78^{0}33.90	16^{0}25.42	131	500	400	Brsh.gray pebbly mud in catcher, some sulfide, soft apparently stone free at the top, brsh.gray
-1/PC(1)	--		78^{0}33.88	16^{0}25.68	130	300	248	Stiff at base, gray diamict. core squeezed due to vacuum, pen.into a till? small shell frgmt. at base.
* -2/PC(1)	250790	02:52	78^{0}22.13	16^{0}29.52	43	300	260	Gray pebbly mud at bottom, soft at top.
-2/PC(2)	--	06:24	78^{0}22.13	16^{0}28.85	60	600	400	Gray pebbly mud.
* -3/PC(1)	--	09:04	78^{0}22.77	15^{0}28.72	216	500	300	Some problem with broken nail in catcher.
-3/PC(2)	--	12:32	78^{0}22.78	15^{0}28.54	221	600		Wrong trigger wire length, disgarded
-3/PC(3)	--	14:52	78^{0}22.76	15^{0}28.72	218			Not released
-3/PC(4)	--	15:50	78^{0}22.80	15^{0}28.36	221	300	276	Core releaser a little damaged.
-3/PC(5)	--	19:39	78^{0}22.76	15^{0}28.78	218	550	115	Firm material in catcher, a possibility that catcher was to soft and some material slipped back out again.
-4/GC(1)	--	22:48	78^{0}19.44	15^{0}08.38	279			Close to "Vema-core".
-5/GC(1)	260790	01:52	78^{0}09.08	13^{0}48.25	435			Empty corer.
-5/BC(1)	--	03:17	78^{0}09.58	13^{0}45.91	435		50	Samples for geochemistry.

Station/Type * Logged on Board	Date	Time	Latitude ^{0}N	Longitude ^{0}E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
NP90-6/GC(1)	260790	06:36	$78^0$26.86	$12^0$09.09	216	550	395	Soft, dark mud in core bottom.
* -6/GC(2)	--	07:42	$78^0$26.96	$12^0$09.09	211	350	278	Cutter & catcher packed separately. Lower 30cm of core extruded and packed in small liner.
-7/GC(1)	--	09:32	$78^0$22.40	$12^0$14.30	174	400	364	Gravel on top, soft dark sandy mud in bottom.
* -7/GC(2)	--	10:35	$78^0$22.57	$12^0$14.67	176	300	248	
-7/GC(3)	--	11:45	$78^0$22.55	$12^0$13.48	177	350	260	Sticky clay at bottom, Max.4-5 meter according to echosounding.
* -8/PC(1)	--	13:34	$78^0$15.--	$12^0$24.--	267	600	464	Full penetration(6m) ch. to 9m. Sticky clay at core base. Approx. 5m above a dist. reflector. Radar Nav.
-8/PC(2)	--	15:09	$78^0$22.58	$12^0$22.58	266	800	674	Stiff,gray sticky mud in catcher. Used stiff catcher.
-9/PC(1)	--	07:48	$79^0$01.09	$11^0$06.60	281	600	470	Cutter slightly bent, gray sticky mud in catcher.
-9/PC(2)	--	09:--	$79^0$01.29	$11^0$06.06	279	650		Red diamicton in catcher.
-9/PC(3)	--	12:21	$79^0$01.32	$11^0$06.24	276	700	520	Red till? in catcher again.

Station/Type * Logged on Board	Date	Time	Latitude ^{0}N	Longitude ^{0}E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
NP90-10/BC(1)	270790	19:40	79^{0}01.01	10^{0}42.31	343		50	Full. 3 subcores.
-11/PC(1)	--	21:16	78^{0}59.23	10^{0}07.34	264	500	254	Pink-grey sticky mud with stones in catcher.
-11/PC(2)	--	21:10	78^{0}59.25	10^{0}07.30	264	600		Pink-grey sticky mud in catcher, with stones in cutter. Cutter bent.
-11/PC(3)	280790	00:32	78^{0}59.25	10^{0}07.36	264	550	430	Pink-grey stiff, pebbly mud in bottom.
-12/PC(1)	--	05:29	78^{0}24.47	09^{0}24.88	628	650	830	All sections full(hand-weighted). Top: Gravel,dark grey sandy mud. 150:dark,grey sandy mud. 600:lighter grey sandy mud. 700 & bottom:darker grey sandy mud. Dropstones all through.
* -12/PGC(1	--	07:25	78^{0}24.47	09^{0}24.87	683	600	332	Full penetration, but no mud on lead.
-12/BC(1)	--	09:44	78^{0}24.46	09^{0}24.90	690		50	4 subcores. High content of clasts on the surface. Forams on 96%.
* -13/GC(1)	--	09:47	78^{0}22.23	09^{0}23.95	691	450	120	
-13/PGC(2	--	10:45	78^{0}22.84	09^{0}23.84	696	400	275	Some material fell out at sea surface.

Station/Type * Logged on Board	Date	Time	Latitude ^{0}N	Longitude ^{0}E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
NP90-14/GC(1)	290790	09:09	$78^0$10.03	$09^0$20.84	486	300	204	Nav.error during shooting of line 301? original point 60m to shallow. Cored further west at correct depth. Material is sandy/gravelly in top. Rel.firm,sticky,dark-grey mud in bottom.
-14/BC(1)	--	09:44	$78^0$10.03	$09^0$20.87	484		50	Washed out. Gravelly top lag.
-14/PGC	--	10:35	$78^0$10.04	$09^0$21.10				
* -14/GC(2)	--	11:05	$78^0$10.02	$09^0$21.20	283	250	136	Length+ material in catcher.
-15/BC(1)	--	11:40	$78^0$09.97	$09^0$10.07	596		50	Sand and gravel on top. 4 subsamples.
* -16/GC(1)	--	13:53	$78^0$09.76	$09^0$05.68	974	300	225	Probl. with navigation. Sand & gravel on top.
-16/GC(2)	--	15:03	$78^0$09.73	$09^0$05.71	974	500	239	Sand/gravel on top.
* -17/GC(1)	--	16:30	$78^0$09.09	$09^0$05.58	976	400	150	Sandy/gravelly top. Dark grey sandy mud in bottom.
-17/BC(1)	--	17:17	$78^0$09.08	$09^0$05.57	976		50	Shaken when put on deck. Well bedded.
-17/PC(1)	--	18:55	$78^0$09.09	$09^0$05.58	977	450	735	Note recovery/penetration.
-18/PC(1)	--	21:55	$78^0$14.18	$08^0$47.82	1444	600	630	Wire change due to damage. Catcher wrenched. Sand in bottom. Liner seems not to be entirely filled, upper 1/2 meter destroyed.
-18/BC	--	23:33	$78^0$14.18	$08^0$47.79	1444		50	4 subsamples.

Station/Type * Logged on Board	Date	Time	Latitude ^{0}N	Longitude ^{0}E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
*NP90-18/GC(1)	300790	00:23	78^{0}14.18	08^{0}47.73	1446	450	294	Fine grained mud.
* -19/GC(1)	--	02:56	78^{0}13.67	08^{0}48.29	1431	400	280	Some material fell out 10-20cm.
-19/PC(1)	--	04:14	78^{0}13.70	08^{0}48.17	1427		860	Lots of mud up to 3.5m, but also some on the top of the barrel. Soft some gravel in top and bottom.
-20/PC(1)	--	07:31	78^{0}15.78	08^{0}19.89	2074			Did not trigger
-20/PC(2)	--	17:21	78^{0}16.15	08^{0}19.73	2074		735	Poor navigation, no GPS. Possibly no tape backup.
-20/BC(1)	--	19:02	78^{0}16.09	08^{0}20.06	2070		50	Full corer. Very well preserved surface with large forams.
* -21/GC(1)	--	23:02	78^{0}11.30	09^{0}56.56	322	350	209	Sticky mud in core catcher.
-21/PC(1)	310790	00:00	78^{0}11.24	09^{0}56.11	327	350	543	Very sticky pebbly mud in catcher.
-21/BC	--		78^{0}11.26	09^{0}57.83	293		50	Pebbly surface. Two subsamples.
-22/GC(1)	--	2:25	78^{0}08.7	10^{0}53.45	247	200		Stiff sticky pebbly clay in catcher. The corer probably full at the sea bottom. Loran c nav.
-23/PC(1)	--	03:18	78^{0}08.59	10^{0}57.9	242	500	685	Soft pebbly mud in catcher.
-24/PC(1)	--	05:07	78^{0}06.39	11^{0}56.68	249	400	762	

Station/Type * Logged on Board	Date	Time	Latitude ^0N	Longitude ^0E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
NP90-25/PC(1)	310790	13:17	$78^0 01.31$	$11^0 51.39$	253	550	598	Pebbly mud in the bottom.
* -25/GC(1)	--	13:44	$78^0 01.36$	$11^0 51.23$	254	250	175	Soft pebbly mud in bottom.
-26/GC(1)	--	16:51	$78^0 03.52$	$09^0 42.09$	151	300	87	Olive grey pebble rich sandy mud on top. Mostly pebbles in the bottom.
-26/GC(2)	--	17:46	$78^0 03.50$	$09^0 42.19$	154			Approx. 30m SE of GC(1). Core had some clean sand and gravel-- packed in separat plastic bag.
-27/GC(1)	010890	02:40	$77^0 39.30$	$10^0 50.51$	293			Empty, probably hard bottom.
-27/GC(2)	--	02:55	$77^0 39.32$	$10^0 51.21$	295	250	91	Sticky pebbly mud in bottom. Pebbly surface/lag. Shell fragments at the base. + sample from core base/catcher.
* -28/GC(1)	--	04:19	$77^0 32.41$	$11^0 19.24$	320	250	108	Core split. 3 distinct layers. Olive grey holocene, dark grey,soft and dark grey firm in the bottom.
-29/GC(1)	--	06:06	$77^0 37.17$	$12^0 26.01$	117	200	102	Dark grey mud in bottom. Olive with pebbles in top.
* -29/GC(2)	--	06:30	$77^0 37.19$	$12^0 26.10$	118	100	68	
-30/GC(1)	--	07:48	$77^0 45.27$	$13^0 06.13$	68			Corer clean and empty. Drifting 50m off.
-30/GC(2)	--	07:57	$77^0 45.21$	$13^0 06.22$	69			Empty. Moving to site 31.

Station/Type * Logged on Board	Date	Time	Latitude ^{0}N	Longitude ^{0}E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
NP90-31/GC(1)	010890	08:36	$77^0$43.28	$12^0$56.22	91	100	30	Soft dark grey sediment. Moved to a local through between bedrock outcrops?
-32/GC(1)	--	10:02	$77^0$42.04	$11^0$45.54	167	300	214	Sticky clay in bottom. Stony surface.
* -32/GC(2)	--	12:28	$77^0$42.06	$11^0$45.06	167	300	194	
-33/GC(1)	--	13:33	$77^0$51.34	$11^0$39.02	63	50	20	Corer full at sea floor. Stiff mud in catcher. Gravelly surface.
* -33/GC(2)	--	13:54	$77^0$51.37	$11^0$38.38	63	50	15	Extremely stiff pebbly mud(160-250 KPa, basal till?) in catcher. Gravel on top.
-34/GC(1)	--	13:55	$77^0$49.56	$10^0$10.57	254			Empty, no recovery.
-34/GC(2)	--	14:05	$77^0$49.56	$10^0$10.57	246	100	30	Gravelly mud, shell fragments.
-34/GC(3)	--	14:35	$77^0$49.53	$10^0$10.79	242	5		A few pebbles, stony bottom.
-35/BC(1)	--	15:55	$77^0$38.58	$10^0$33.50	696		50	BC half full. Sandy gravelly surface. Partly washed out in one corner of the corer so there may have been some washing of the finer fraction over the entire surface.
-36/BC(1)	--	17:28	$77^0$37.03	$09^0$56.23	1360		50	4 liners, surface samples.
* -36/PGC(1	--	18:27	$77^0$37.04	$09^0$56.18	1360	400	383	

Station/Type * Logged on Board	Date	Time	Latitude ^{0}N	Longitude ^{0}E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
NP90-36/PC(1)	010890	20:06	77^{0}37.06	09^{0}56.20	1359	900	765	No distinct changes observed downcore in the cut section-levels except for increasing stiffness and darker colour towards the base.
-37/BC(1)	--	22:20	77^{0}35.13	09^{0}19.55	1800		50	Full corer.Soft brown mud at top. 4 Subcores.
-38/BC(1)	020890	00:32	77^{0}31.35	08^{0}23.24	2327	60	50	Foraminifer rich hemipelagic mud in top. At 30cm, ironstained 2-3cm thick sand layer.. 35-55cm laminated mud.
* -38/PGC(1	--	03:16	77^{0}31.10	08^{0}24.02	2326	400	337	Top, brown mud. Bottom, blue grey mud. Wrong longitude? correct is 08^{0}23.02 ^{0}E
-38/PC(1)	--	03:17	77^{0}31.54	08^{0}23.04	2328	700	600	Forams all over the barrel.
-39/PC(1)	--	09:27	77^{0}15.49	09^{0}05.58	2119	850	600	
-40/PC(1)	--	15:30	76^{0}58.28	08^{0}54.54	2254	800	662	
-40/PGC(1	--	17:10	76^{0}58.20	08^{0}54.46	2255			Tried 6m liner but it broke at 3-4m.
-40/BC(1)	--	18:25	76^{0}58.20	08^{0}54.58	2255			
-41/PC(1)	--	21:36	77^{0}06.32	10^{0}50.09	1365	850	842	Upper part(ca.1m) very soft and probably destroyed.
-41/PGC(1	--	22:39	77^{0}06.45	10^{0}49.43	1362		93	Short core, probably full at the bottom. Pebbles at surface.

Station/Type	Date	Time	Latitude	Longitude	Depth	Pen.	Rec.	Comments
* Logged on Board			^{0}N	^{0}E	(m)	(cm)	(cm)	
NP90-42/PGC(1	030890	00:04	77^{0}08.12	11^{0}14.06	1011	400	250	
-42/PC(1)	--	00:54	77^{0}08.21	11^{0}14.46	1011	850	790	Pebbly mud in the bottom.
-43/PC(1)	--	03:30	77^{0}09.35	11^{0}34.38	570	500	820	"Hiatella" shell at the core base. Top 10cm cut off by accident and put in separat plastic bag.
-43/BC(1)	--	04:15	77^{0}09.30	11^{0}34.37	573		50	Surface tilted, may have tilted on the sea floor but also banged around when put on deck.
-44/GC(1)	--	05:34	77^{0}10.16	11^{0}46.38	198		58	
-44/BC(1)	--	06:31	77^{0}10.13	11^{0}46.37	198		50	Well preserved surface.
-45/GC(1)	--	07:36	77^{0}12.08	12^{0}16.58	210		120	Allmost no pullout.
-46/GC(1)	--	10:20	77^{0}13.20	12^{0}37.49	204	204	200	Sticky, pebbly clay in the bottom.
-47/PC(1)	--	11:28	77^{0}22.13	12^{0}47.42	239	650		Collaps of plastic liner, no core.
-47/BC(1)	--	12:00	77^{0}20.09	12^{0}47.50	238		50	Full corer.
-48/GC(1)	--	13:27	77^{0}32.37	12^{0}52.05	142	200	120	Sticky pebbly mud in the catcher. Soft mud at the top.
-49/GC(1)	--	16:09	77^{0}30.37	13^{0}22.02	167			Lost cutter,catcher and sample.

Station/Type * Logged on Board	Date	Time	Latitude ^{0}N	Longitude ^{0}E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
NP90-49/PGC(1	030890	16:45	77^{0}30.35	13^{0}22.04	167	200	171	Corer was by mistake put horisontally in, but the surface looked well preserved.
-50/BC(1)	--	17:47	77^{0}34.54	13^{0}27.57	151		50	Ok sample, 4 sub-cores.
-50/PGC(1	--	18:08	77^{0}34.56	13^{0}27.51	150			The 4 meter plastic liner broke off.
-50/PGC(2	--	19:16	77^{0}34.56	13^{0}27.48	151		118	Let the corer hang 5-6m above bottom to stabilise. Sample fell out when brought to surface, still a recovery of 118cm. Shells in the lower 25cm. of core.
-50/PGC(3	--	20:05	77^{0}34.54	13^{0}27.55	151	250	200	
-51/PC(1)	--	22:02	77^{0}34.52	14^{0}40.43	158			Did not trigger.
-51/PGC(1	--	23:00	77^{0}34.59	14^{0}40.15	157	300	165	Iron stain rich sediments.
-52/PGC(1	040890	00:00	77^{0}35.07	15^{0}06.26	95	300	255	Top and bottom: Iron stained mud.
-52/PC(1)	--	00:34	77^{0}35.06	15^{0}06.41	97	750	740	
-53/PGC(1	--	01:24	77^{0}35.5	15^{0}13.7	104	350	218	Used radar for navigation.

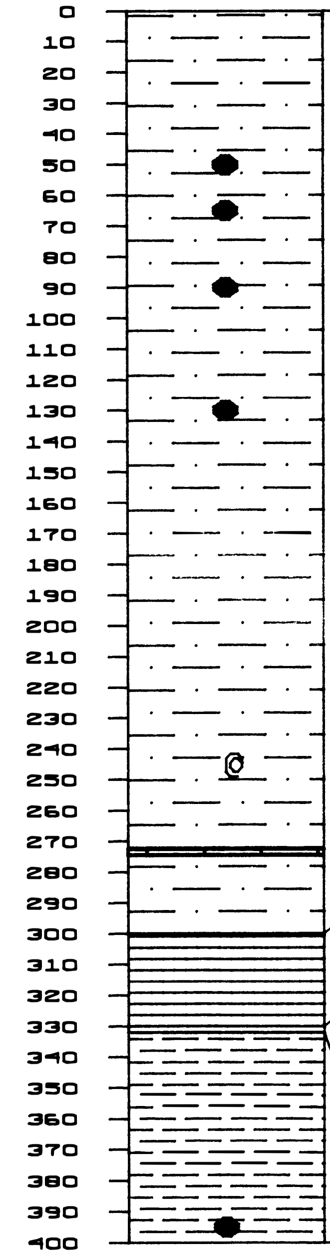
Station/Type * Logged on Board	Date	Time	Latitude ^{0}N	Longitude ^{0}E	Depth (m)	Pen. (cm)	Rec. (cm)	Comments
NP90-54/PC(1)	040890	02:28	77^{0}34.3	15^{0}33.2	64	900	100	Only 1m recovery.
-54/PGC(1	--		77^{0}34.22	15^{0}31.27	66		250	Approx. recovery, foamed before measuring. Top few (2-3)cm. cut off and packed in plastic bag.
-54/PC(2)	--	03:35	77^{0}34.22	15^{0}31.24	65	800	665	Probably not down to reflector.
-54/PC(3)	--	05:16	77^{0}34.22	15^{0}31.27	65	850	694	Check for double marking of pc(2) on this station. Should probably be pc(3).
-55/PC(1)	--	06:48	77^{0}33.58	15^{0}38.09	74	800	797	
-56/PC(1)	--	08:15	77^{0}32.16	15^{0}50.52	32	850	600	Used.
-56/pgc(1	--	09:05	77^{0}32.15	15^{0}50.53	32	400	225	
-57/PC(1)	050890	20:13	71^{0}55.18	14^{0}21.33	1500	900	737	

APPENDIX 4

CORE LOGS

CORE: NP90-1/GC(1) (0-400 cm)

DEPTH (cm) LITHOLOGY



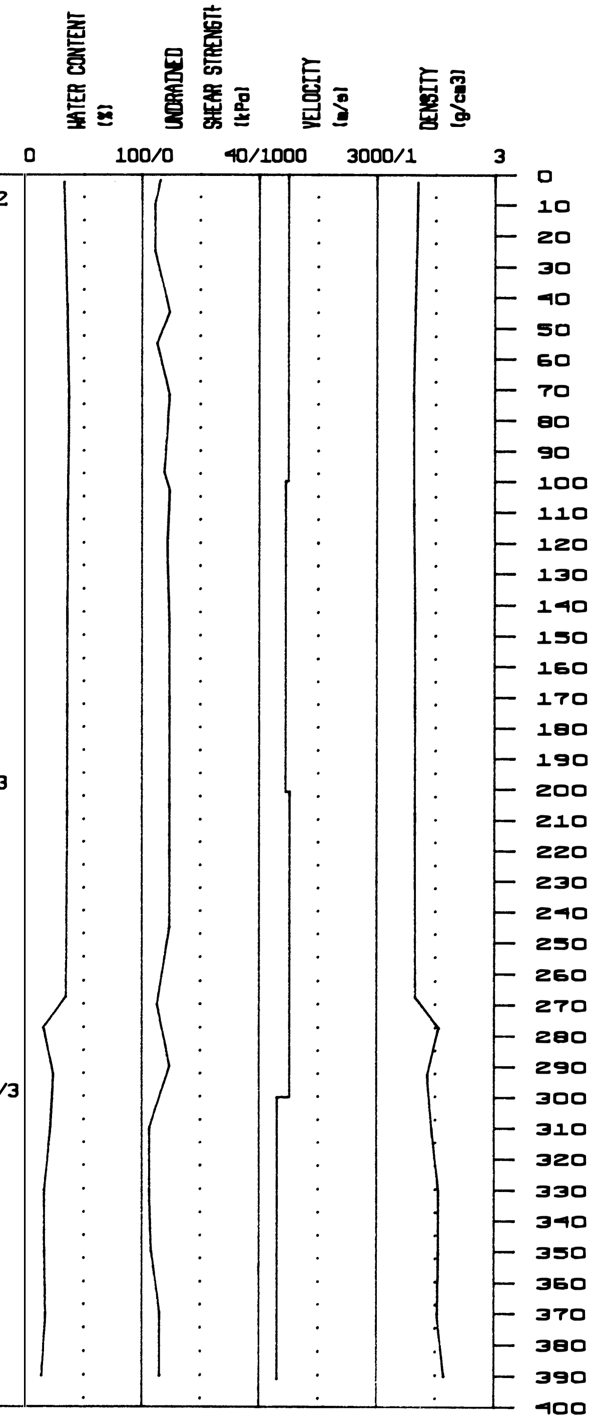
HOMOGENOUS MUD: 0-300 cm
Fine grained greyish brown to pale brown mud with few clasts. Mottled and bioturbated (polycheate worm tubes). Well defined area with low mottling between 53 and 57 cm, increased mottling under 57 cm. Fine mottling between 100 and 123 cm. Increased mottling under 123 cm, with well defined lenticular unmottled patches. Mottling occurs as more discrete layers and patches between 227 and 272 cm. Faint mottling under 272 cm. Pebbles occur between 272 and 274 cm.
(The texture is smeared from 0 to 100 cm and from 180 to 200 cm due to the nylon line)

LAMINATED MUD: 300-330 cm
Mud laminated with sand. Rare small clasts. The lower limit is well defined.

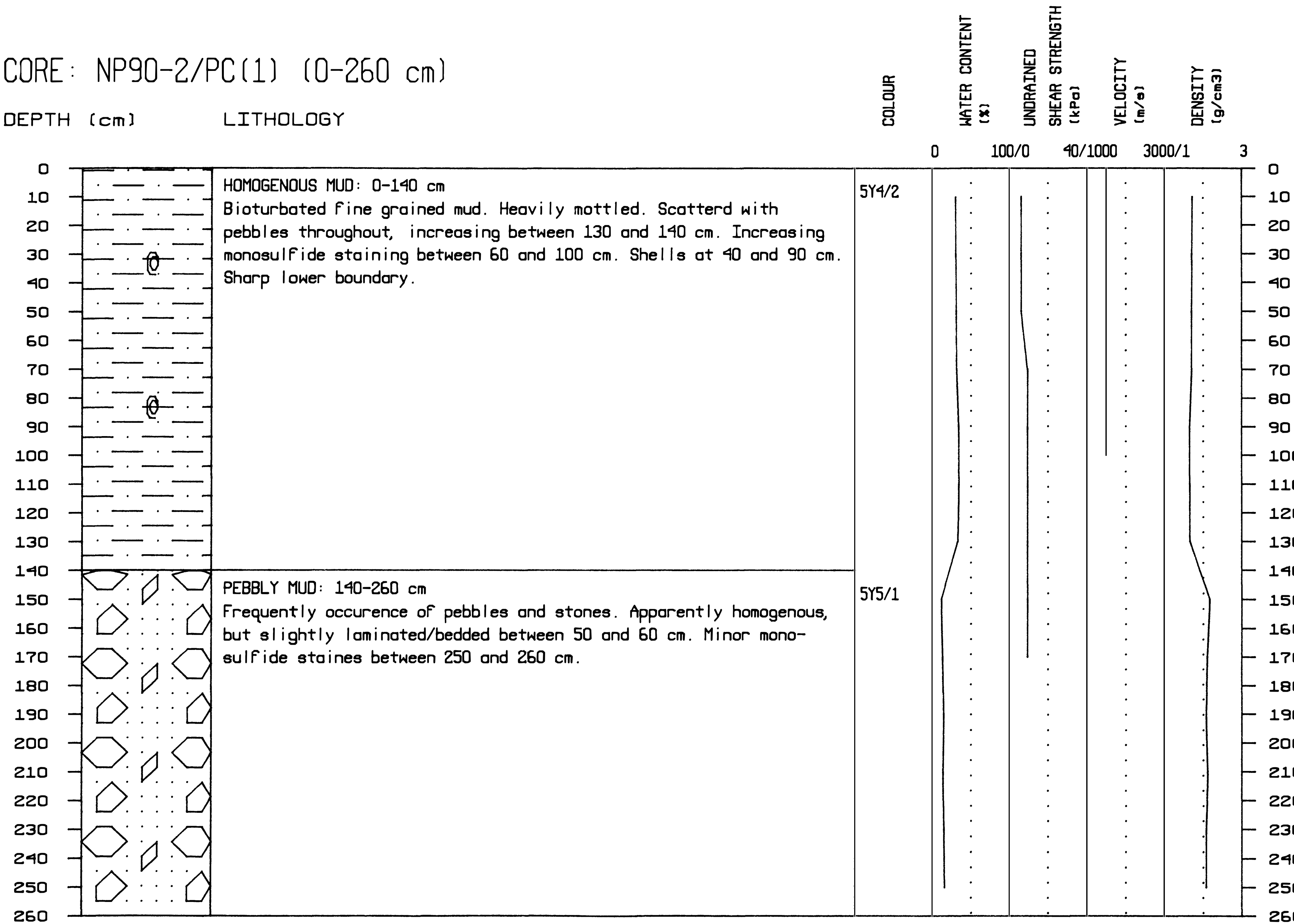
SAND: 330-332 cm
Fine sand layer.

CLAYEY MUD: 332-400 cm
Homogenous mud, with clasts throughout the unit. Large clast at the bottom.

COLOUR: 10YR5/2 (0 cm); 10YR6/3 (200 cm); 7.5YR6/3 (300 cm)

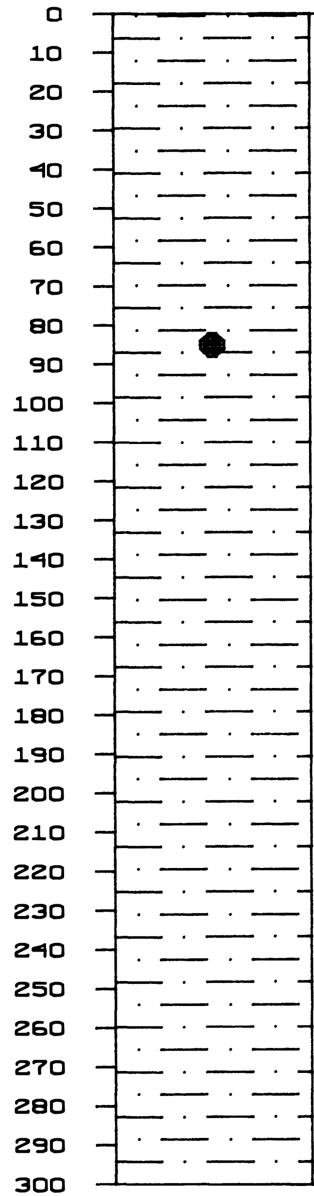


CORE: NP90-2/PC(1) (0-260 cm)



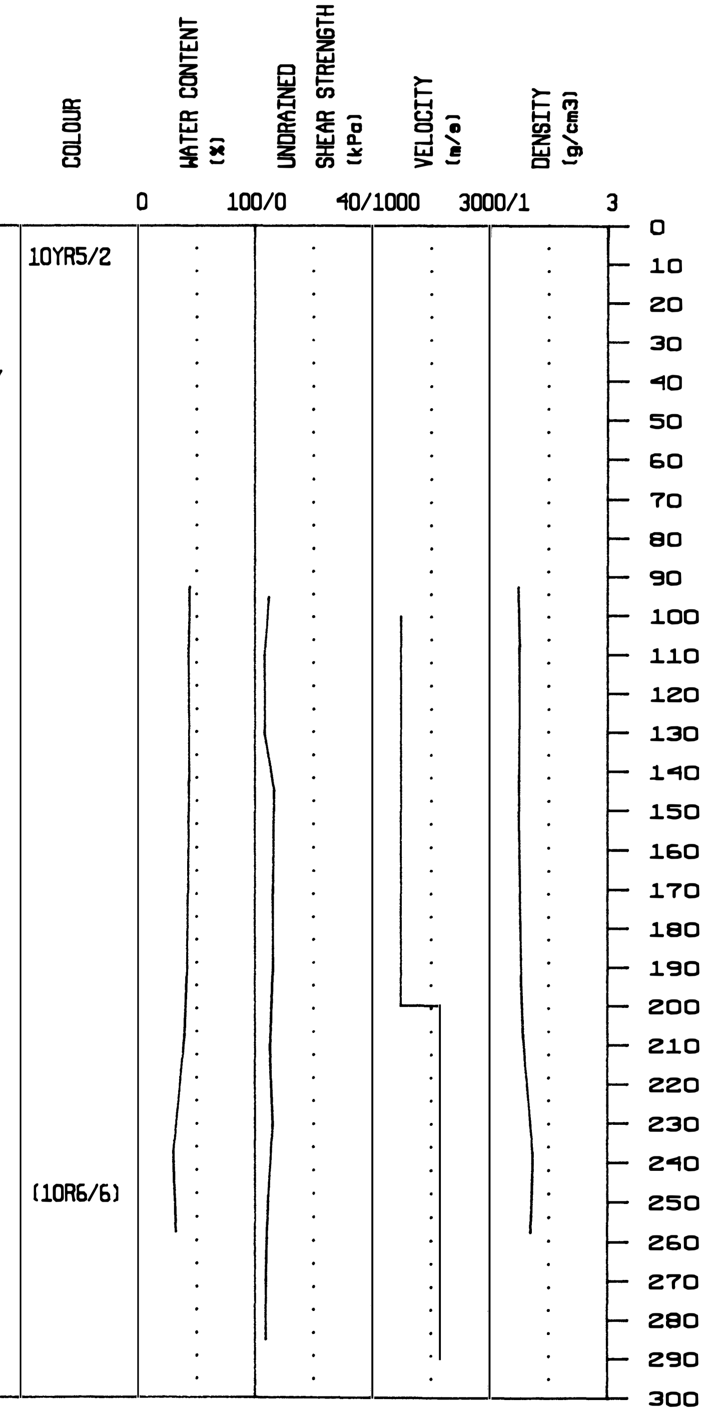
CORE: NP90-3/PC(1) (0-300 cm)

DEPTH (cm) LITHOLOGY

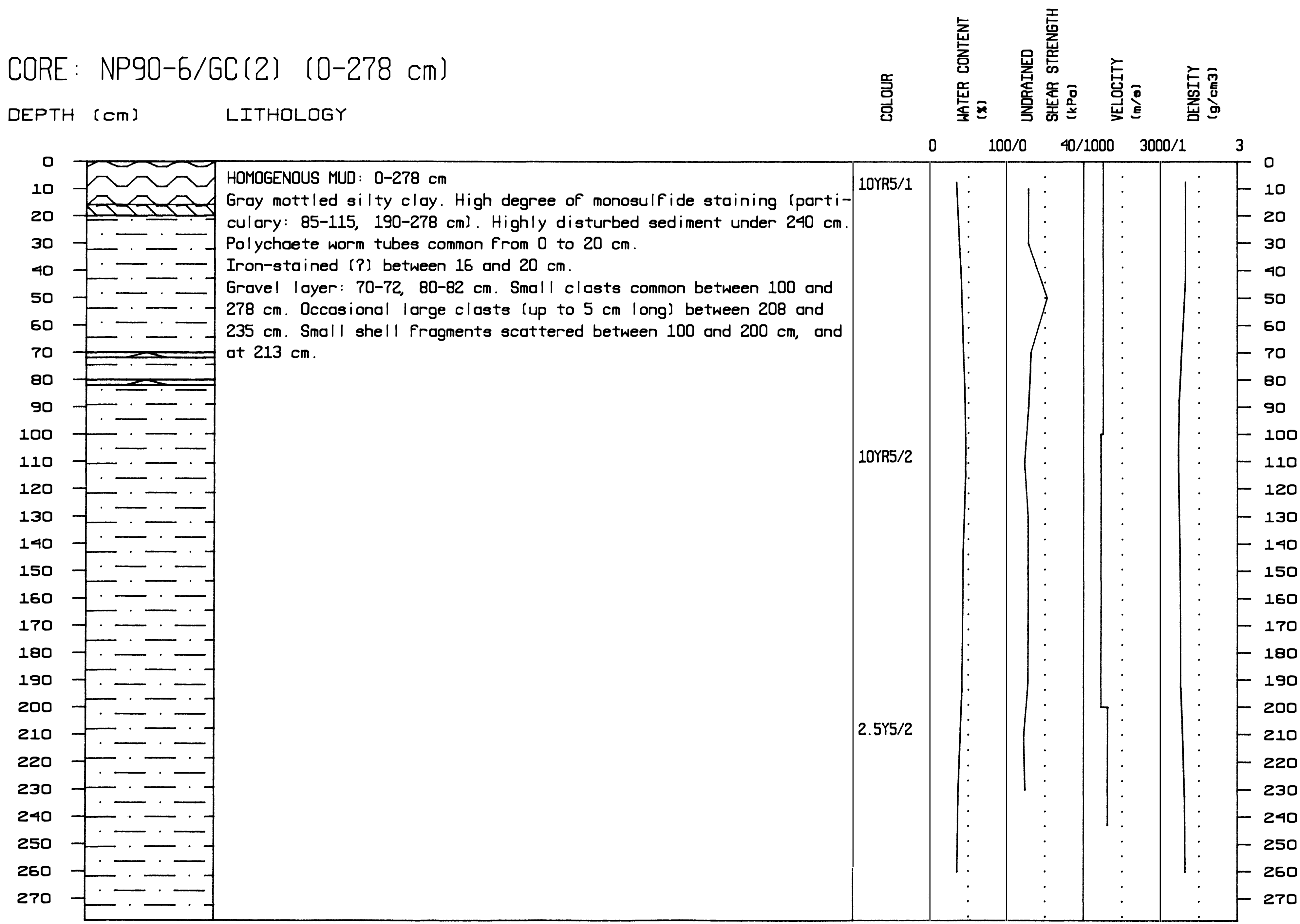


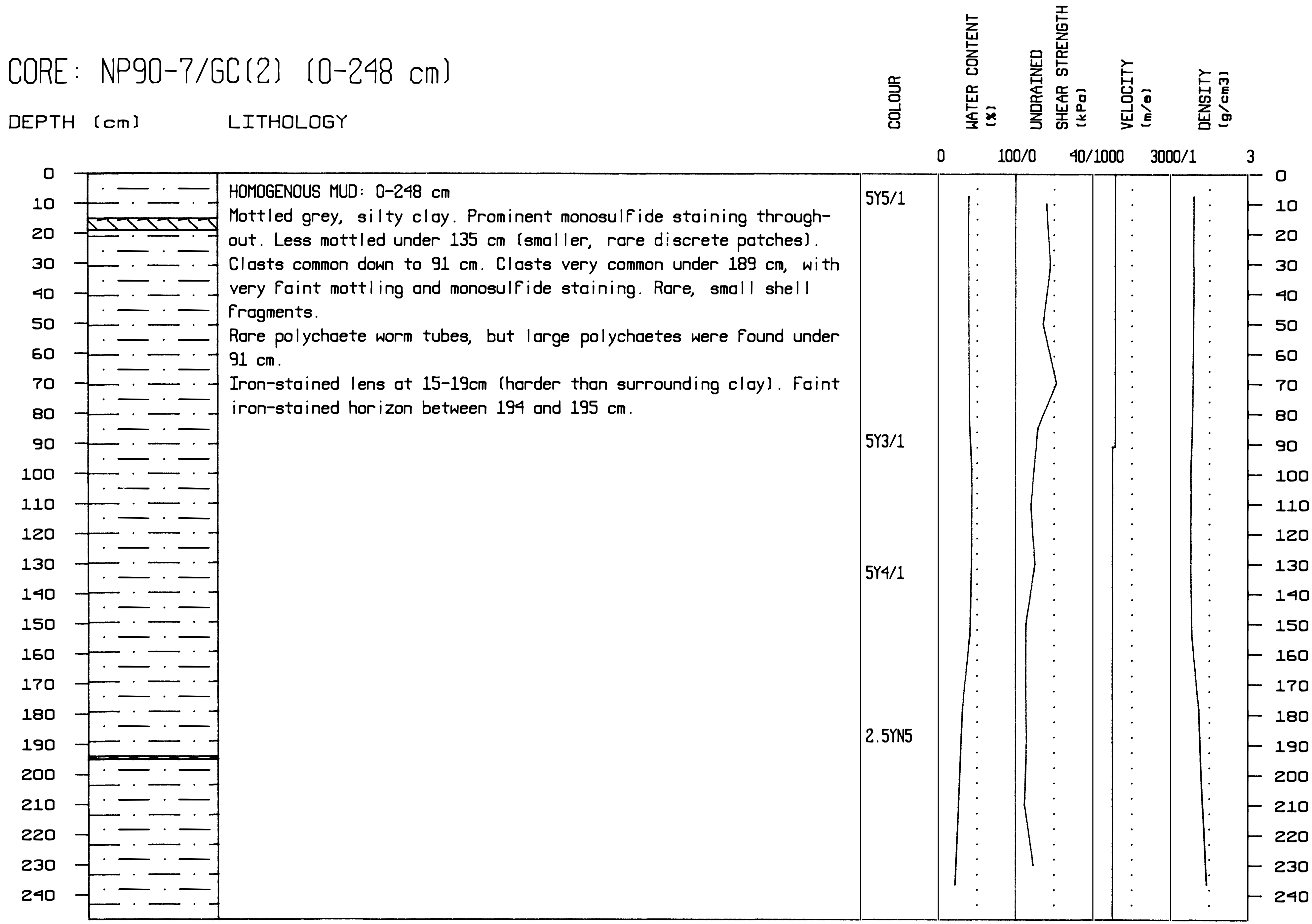
HOMOGENOUS MUD: 0-300 cm

Mottled clay. Highly disturbed at the top (0-10 cm?). Occasional small clasts under 100 cm. Common under 200 cm. Monosulfide staining increases under approximately 120 cm. Heavily mottled, with prominent monosulfide staining between 190 and 220 cm. Lightly mottled under 250 cm, increasing downcore. Impersistent layers of red mud under 250 cm.

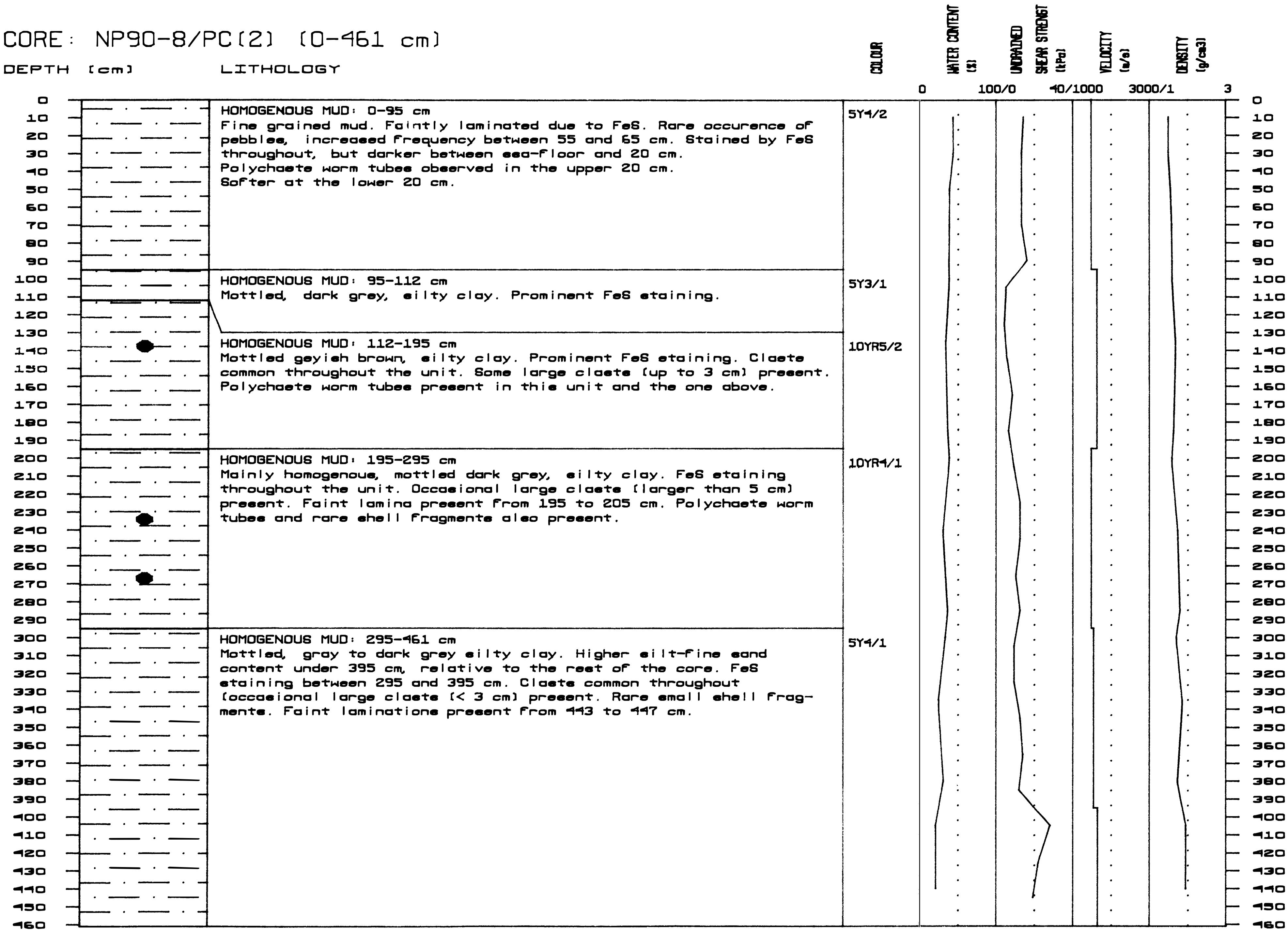


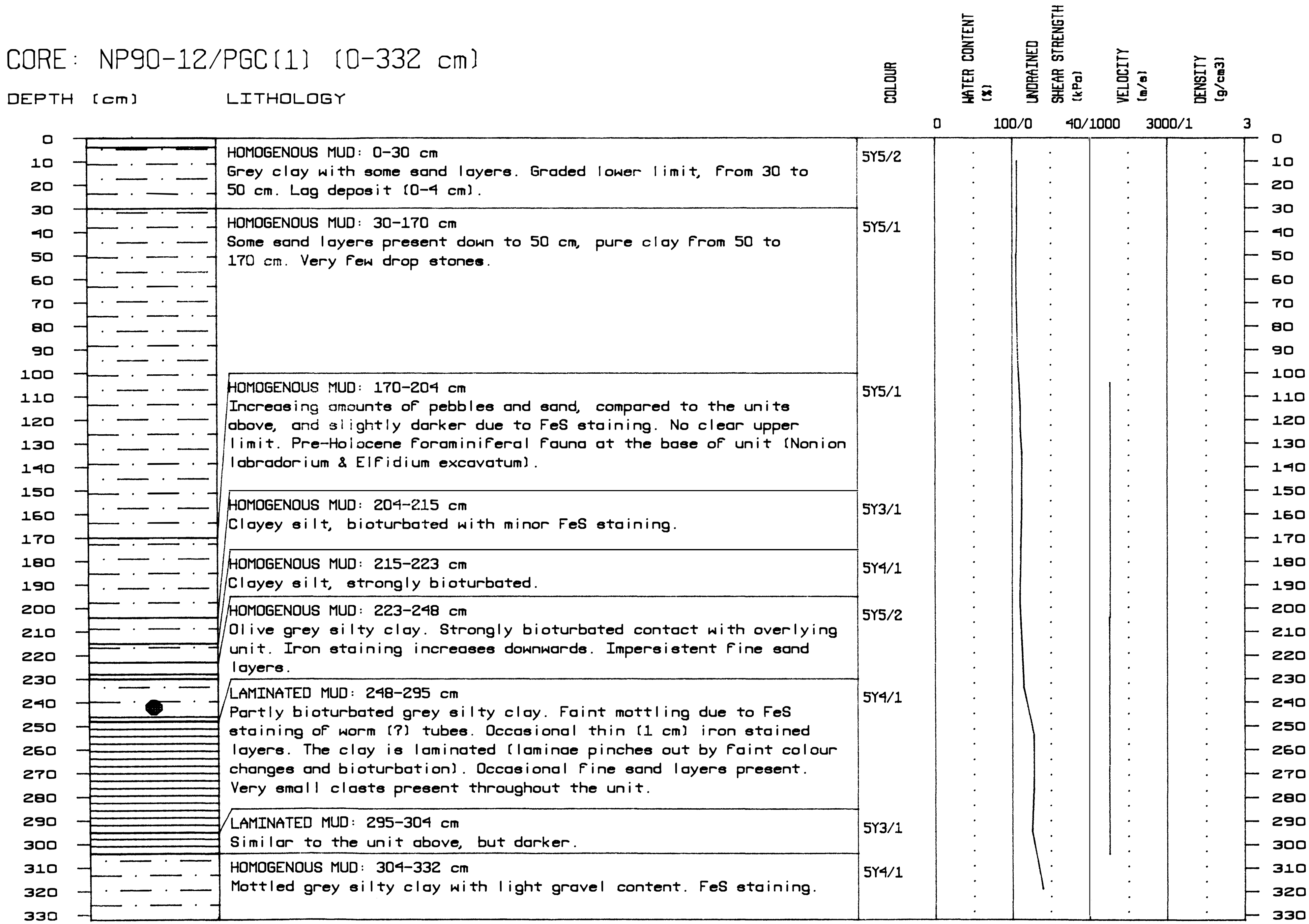
CORE: NP90-6/GC(2) (0-278 cm)

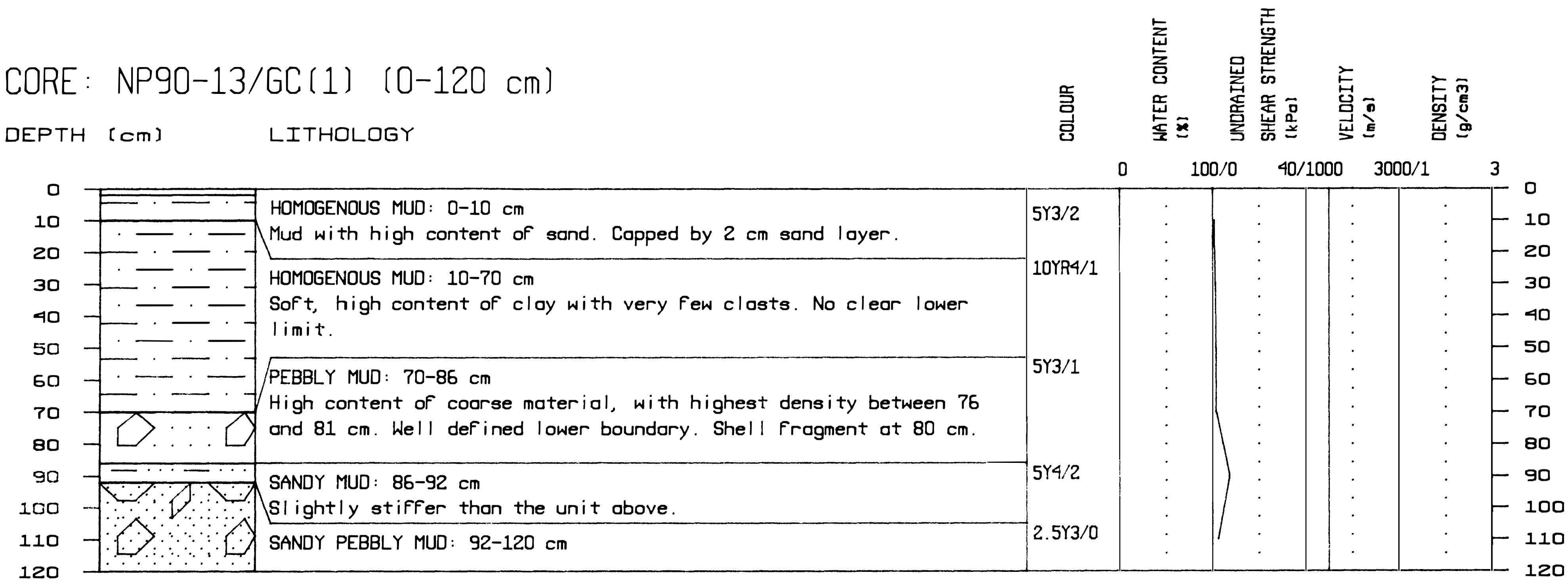



CORE: NP90-7/GC(2) (0-248 cm)
DEPTH (cm)
LITHOLOGY
COLOUR
WATER CONTENT (%)
UNDRAINED SHEAR STRENGTH (kPa)
VELOCITY (m/s)
DENSITY (g/cm3)
0 100/0 40/1000 3000/1 3
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240
HOMOGENOUS MUD: 0-248 cm
Mottled grey, silty clay. Prominent monosulfide staining throughout. Less mottled under 135 cm (smaller, rare discrete patches). Clasts common down to 91 cm. Clasts very common under 189 cm, with very faint mottling and monosulfide staining. Rare, small shell fragments.
Rare polychaete worm tubes, but large polychaetes were found under 91 cm.
Iron-stained lens at 15-19cm (harder than surrounding clay). Faint iron-stained horizon between 194 and 195 cm.
5Y5/1
5Y3/1
5Y4/1
2.5YN5

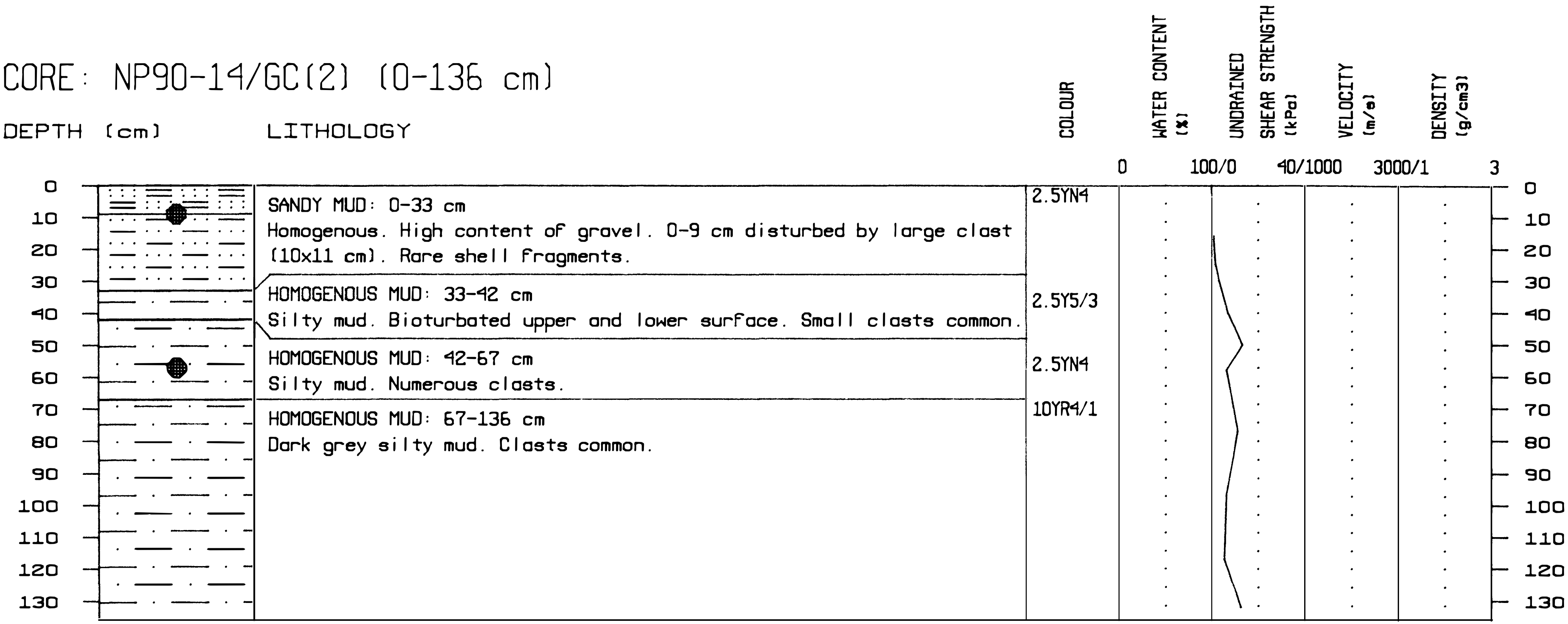
CORE: NP90-8/PC(2) (0-461 cm)



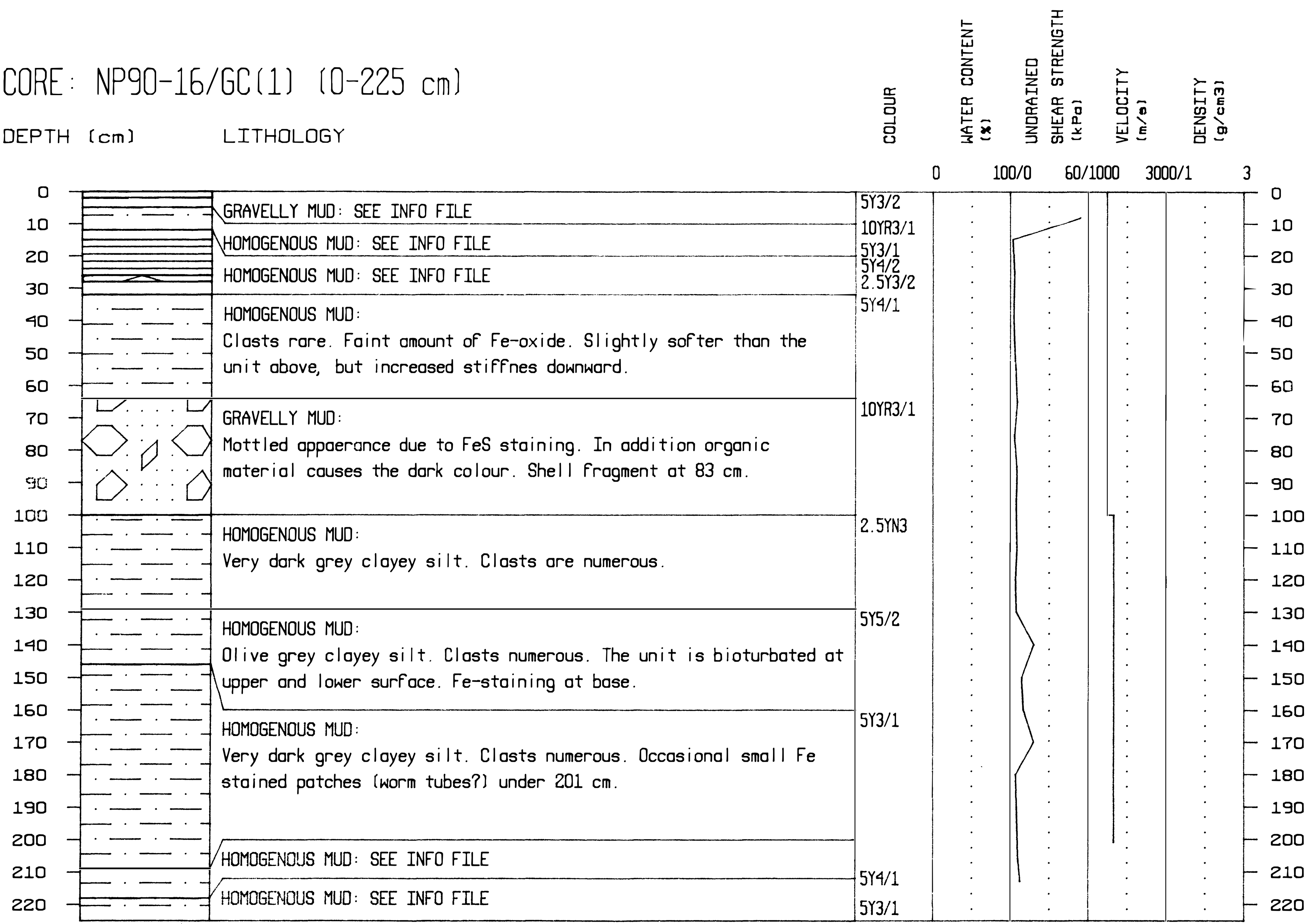

CORE: NP90-12/PGC(1) (0-332 cm)
DEPTH (cm)
LITHOLOGY
COLOUR
WATER CONTENT (%)
UNDRAINED SHEAR STRENGTH (kPa)
VELOCITY (m/s)
DENSITY (g/cm3)
0
100/0
40/1000
3000/1
3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
HOMOGENOUS MUD: 0-30 cm
Grey clay with some sand layers. Graded lower limit, from 30 to 50 cm. Lag deposit (0-4 cm).
5Y5/2
HOMOGENOUS MUD: 30-170 cm
Some sand layers present down to 50 cm, pure clay from 50 to 170 cm. Very few drop stones.
5Y5/1
HOMOGENOUS MUD: 170-204 cm
Increasing amounts of pebbles and sand, compared to the units above, and slightly darker due to FeS staining. No clear upper limit. Pre-Holocene Foraminiferal fauna at the base of unit (Nonion labradorium & Elfidium excavatum).
5Y5/1
HOMOGENOUS MUD: 204-215 cm
Clayey silt, bioturbated with minor FeS staining.
5Y3/1
HOMOGENOUS MUD: 215-223 cm
Clayey silt, strongly bioturbated.
5Y4/1
HOMOGENOUS MUD: 223-248 cm
Olive grey silty clay. Strongly bioturbated contact with overlying unit. Iron staining increases downwards. Impersistent fine sand layers.
5Y5/2
LAMINATED MUD: 248-295 cm
Partly bioturbated grey silty clay. Faint mottling due to FeS staining of worm (?) tubes. Occasional thin (1 cm) iron stained layers. The clay is laminated (laminae pinches out by faint colour changes and bioturbation). Occasional fine sand layers present. Very small clasts present throughout the unit.
5Y4/1
LAMINATED MUD: 295-304 cm
Similar to the unit above, but darker.
5Y3/1
HOMOGENOUS MUD: 304-332 cm
Mottled grey silty clay with light gravel content. FeS staining.
5Y4/1


CORE: NP90-13/GC(1) (0-120 cm)
DEPTH (cm)
LITHOLOGY
HOMOGENOUS MUD: 0-10 cm
Mud with high content of sand. Capped by 2 cm sand layer.
HOMOGENOUS MUD: 10-70 cm
Soft, high content of clay with very few clasts. No clear lower limit.
PEBBLY MUD: 70-86 cm
High content of coarse material, with highest density between 76 and 81 cm. Well defined lower boundary. Shell fragment at 80 cm.
SANDY MUD: 86-92 cm
Slightly stiffer than the unit above.
SANDY PEBBLY MUD: 92-120 cm
COLOUR
5Y3/2
10YR4/1
5Y3/1
5Y4/2
2.5Y3/0
WATER CONTENT (%)
UNDRAINED SHEAR STRENGTH (kPa)
VELOCITY (m/s)
DENSITY (g/cm3)
0
100/0
40/1000
3000/1
3
0
10
20
30
40
50
60
70
80
90
100
110
120

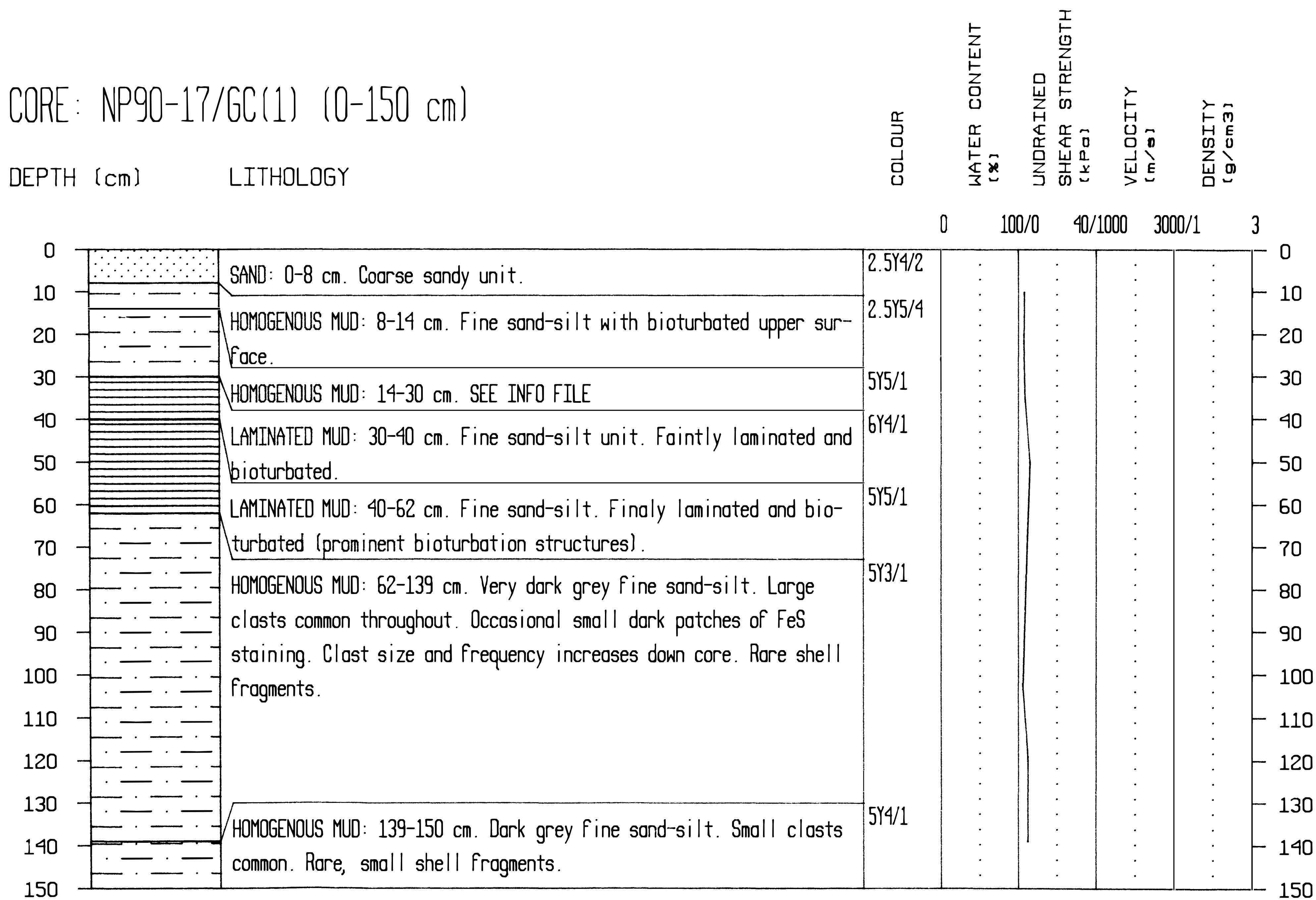
CORE: NP90-14/GC(2) (0-136 cm)



CORE: NP90-16/GC(1) (0-225 cm)

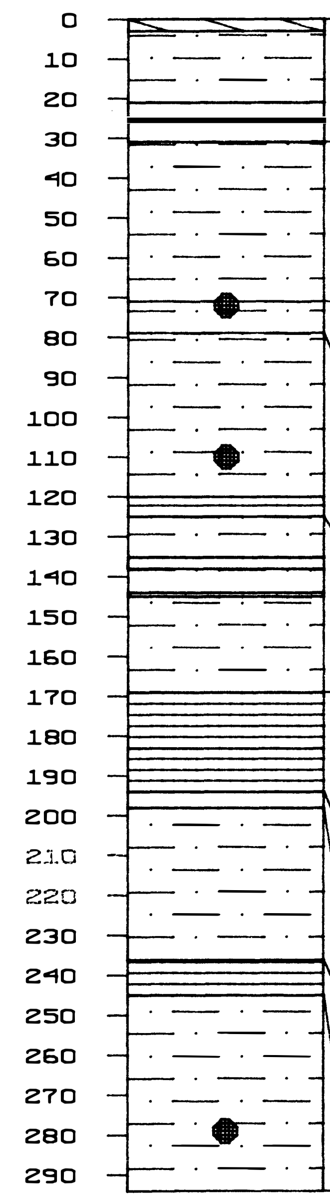


CORE: NP90-17/GC(1) (0-150 cm)

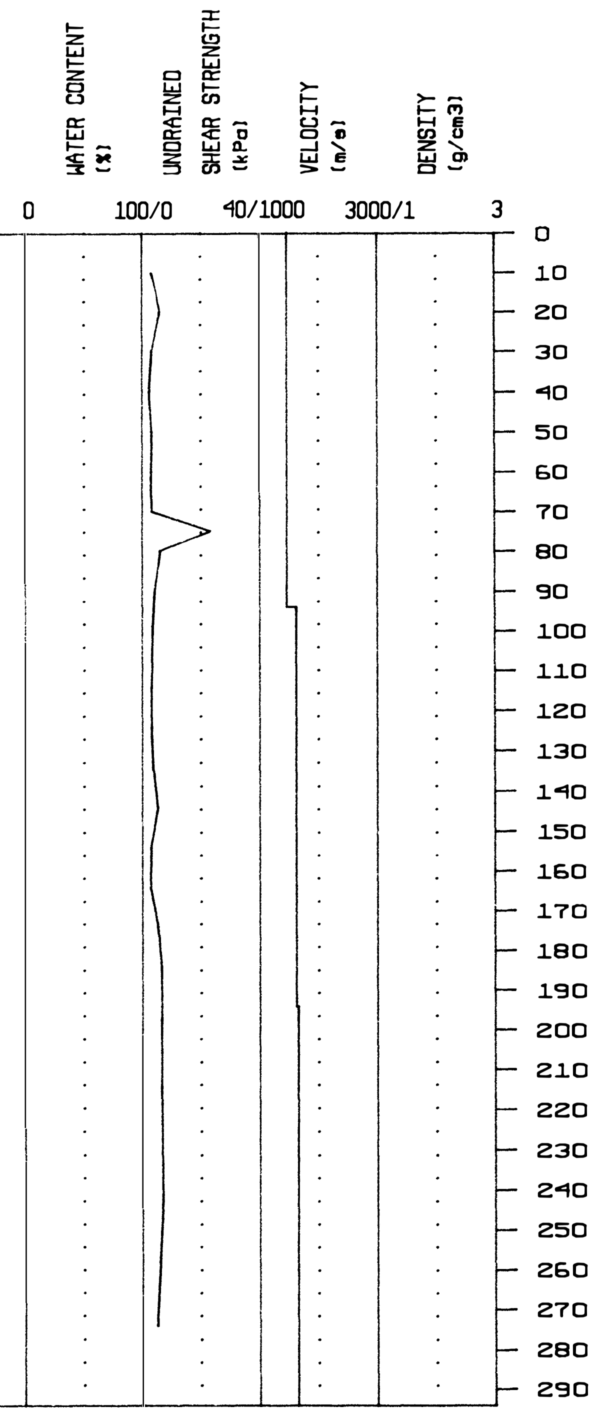


CORE: NP90-18/GC(1) (0-294 cm)

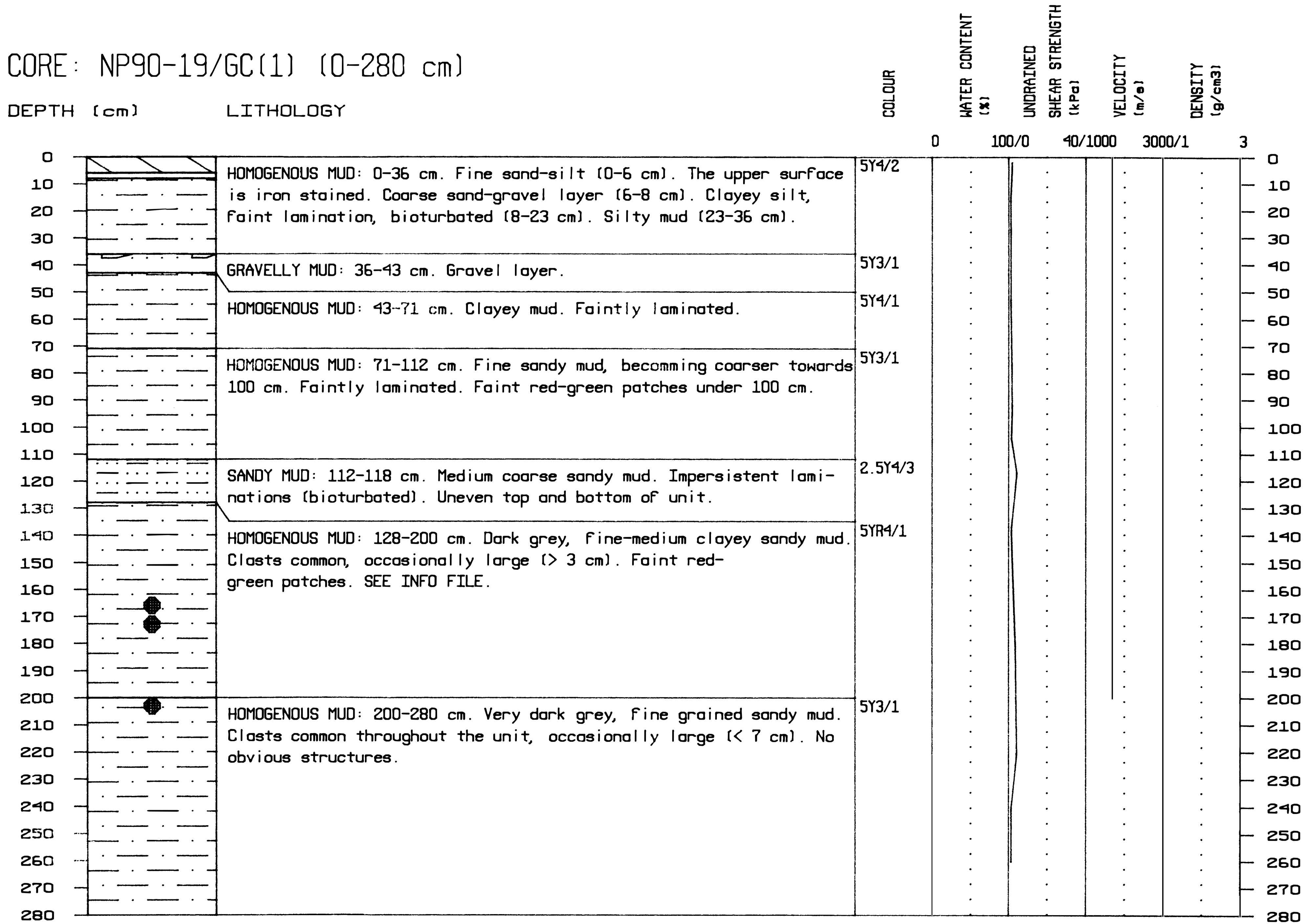
DEPTH (cm) LITHOLOGY



Lithology	Colour
HOMOGENOUS MUD: 0-31 cn. Dark grey, bioturbated mud with few clasts. Rusty brown upper layer, containing Fe oxide. CONTINUES IN INFO FILE.	5Y4/1
HOMOGENOUS MUD: 31-71 cm. Mottled appearance the upper 2-3 cm. Dark grey, but slightly lighter than the unit above. Few clasts present. Dark to very dark grey mud under 45 cm. Increasing appearence of clasts downward (from 55 cm).	5Y4/1 5Y3/1
HOMOGENOUS MUD: 71-79 cm. Dark greyish mud. Slightly stiffer than the unit above. Clasts common.	2.5Y4/2
HOMOGENOUS MUD: 79-125 cm. Very dark grey, softer than the unit above. Clasts in abundance, but decreasing content downcore. Slightly lighter under c. 89 cm. Clast at 104 cm. Laminated from 120 to 125 cm - silt or caused by early diagenetic changes?	5Y3/1
HOMOGENOUS MUD: 125-169 cm. Homogenous to slightly laminated soft mud. Clasts are rare above 138 cm, but more common under. Zones with increased lamination (135-138 & 144-145 cm). Bioturbated lower surface.	5Y4/1
LAMINATED MUD: 169-194 cm. Olive grey. Increased lamination due to FeS staining. Shell at 183 cm. Zone of more tense lamination (FeS) from 183 to 194 cm. The upper surface is clearly bioturbated.	5Y5/2 5Y4/1 5Y5/2
HOMOGENOUS MUD: 194-198 cm. Fine sand-silt. Olive grey, becomming browner towards base. Base is uneven (bioturbated).	5Y4/2
HOMOGENOUS MUD: 198-236 cm. dark grey. Fine sand-silt, common with clasts.	5Y4/1
LAMINATED MUD: 236-245 cm. Olive grey fine sand-silt. Prominent laminations. Sediment becomes browner towards base. The lower surface is uneven due to bioturbation.	5Y4/2
HOMOGENOUS MUD: 245-294 cm. Very dark grey fine sand-silt. Clasts are common. SEE INFO FILE:	5Y3/1

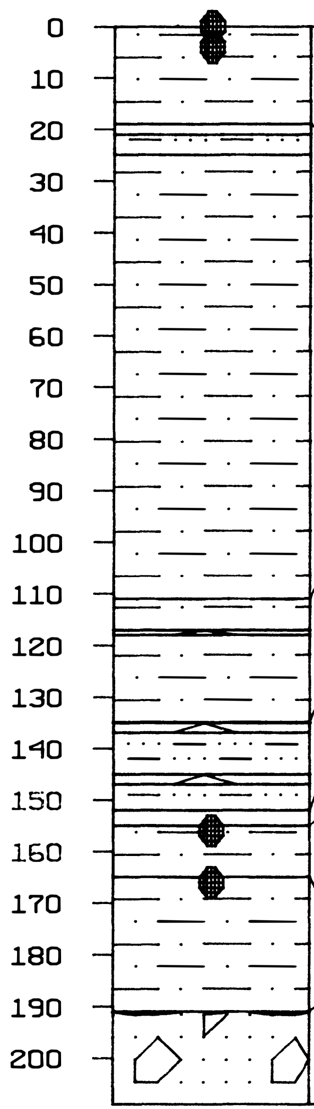


CORE: NP90-19/GC(1) (0-280 cm)

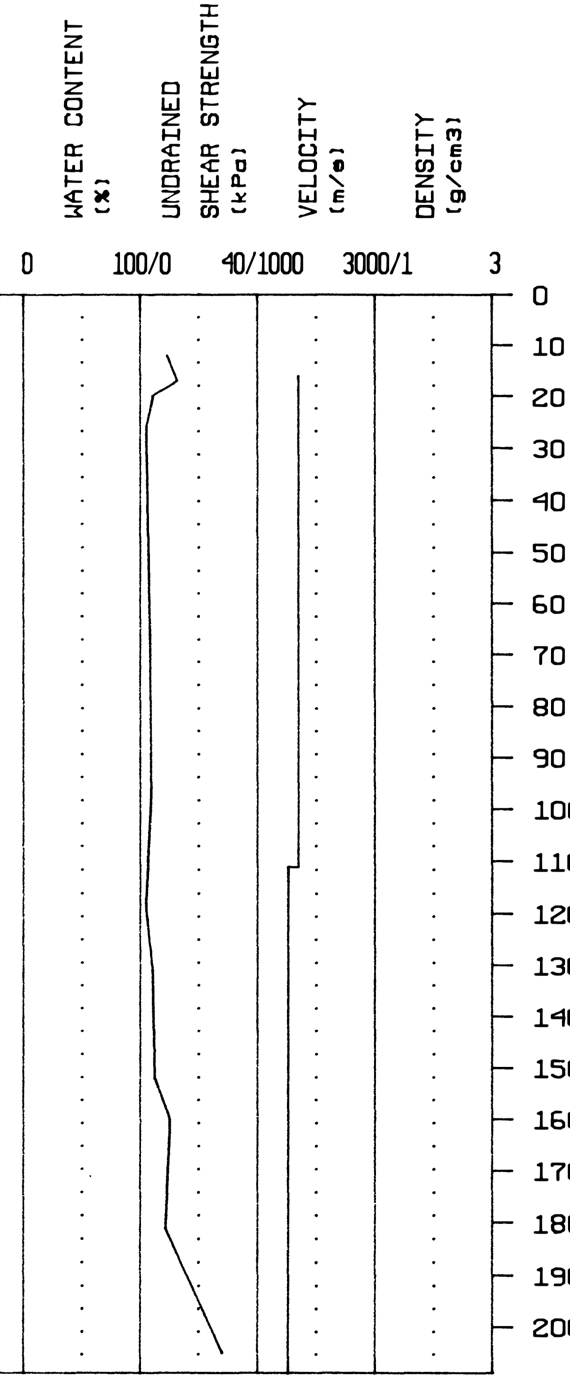


CORE: NP90-21/GC(1) (0-209 cm)

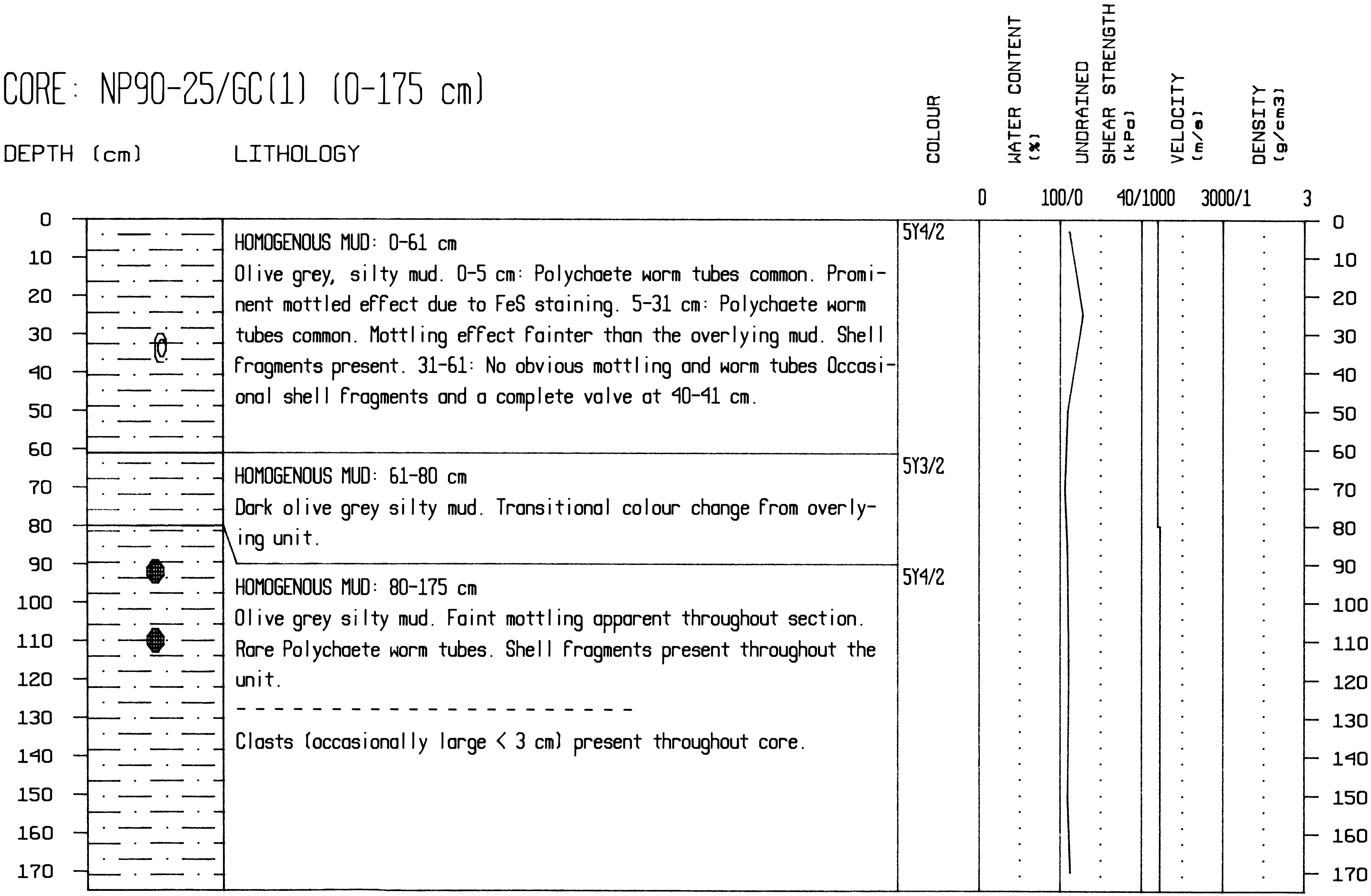
DEPTH (cm) LITHOLOGY



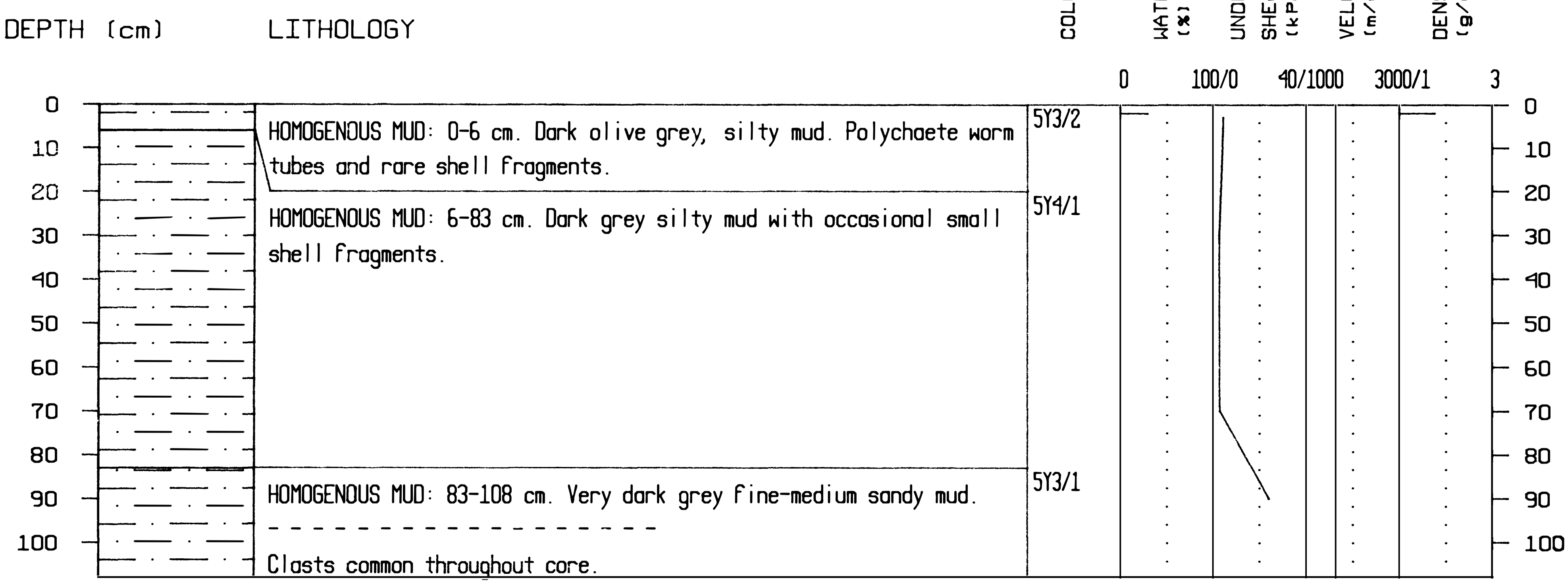
LITHOLOGY	COLOUR
HOMOGENOUS MUD: 0-19 cm. Olive grey, fine sandy silty mud. Large cobbles at top of core (< 7 cm). Clasts common.	5Y4/2
HOMOGENOUS MUD: 19-111 cm. Dark grey silty mud. Thin green fine sandy layer at 21-25 cm. Occasional small mottled patches (FeS). Small clasts common throughout the unit.	5Y4/1
HOMOGENOUS MUD: 111-135 cm. Very dark grey silty mud, with occasional coarse sand-gravel lenses. Faint mottling present (FeS).	5Y3/1
SANDY MUD: 135-152 cm. Very dark grey silty sandy mud. Mottling common at base of unit.	5Y3/1
HOMOGENOUS MUD: 152-155 cm. Dark grey mud.	5Y4/1
HOMOGENOUS MUD: 155-165 cm. Olive brown silty fine sandy mud. Iron stained at base, associated with gravel layer.	2.5Y4/3
HOMOGENOUS MUD: 165-191 cm. Dark grey, fine sandy silty mud.	10YR4/1
GRAVELLY MUD: 191-209 cm. Very dark grey, fine sandy mud, with slightly overconsolidated lens of coarse sand and gravel (till?).	5Y3/1

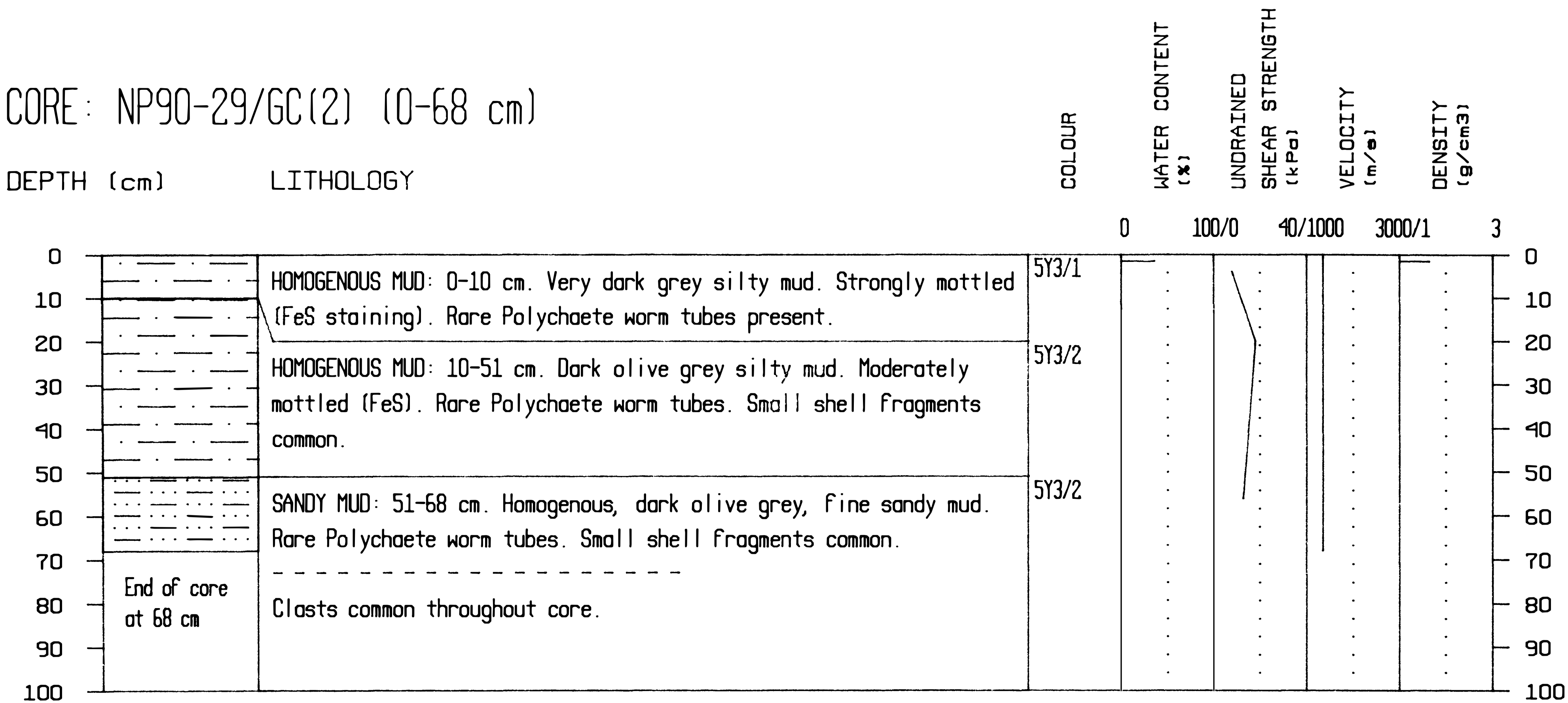


CORE: NP90-25/GC(1) (0-175 cm)



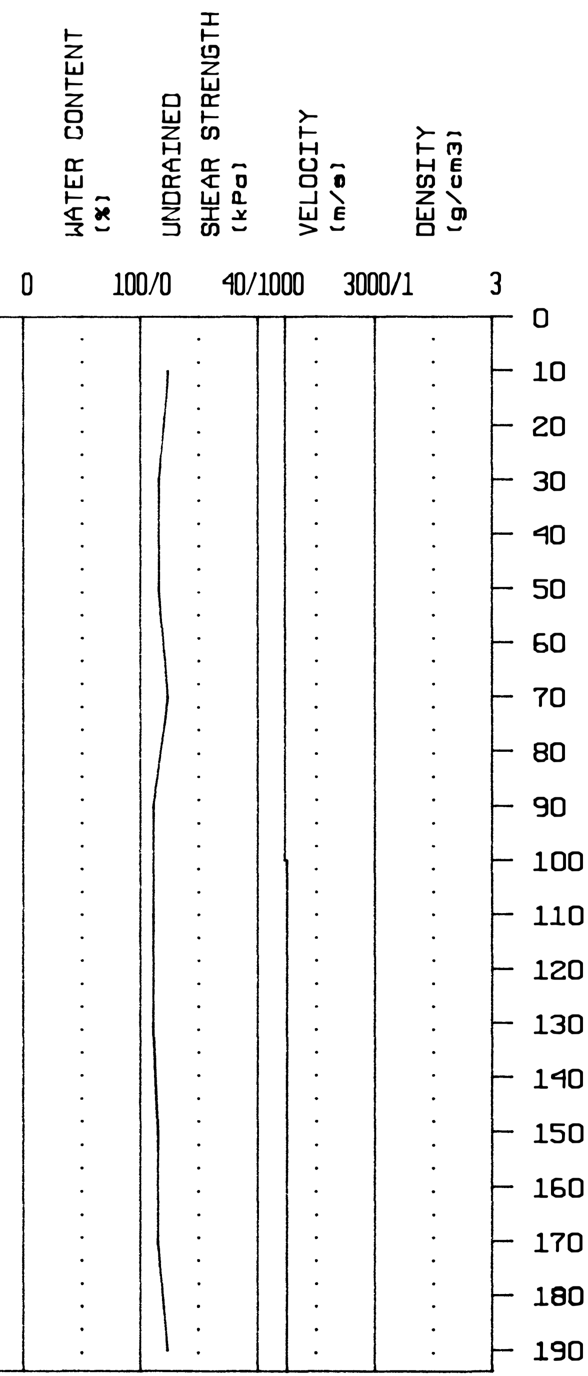
CORE: NP90-28/GC(1) (0-108 cm)



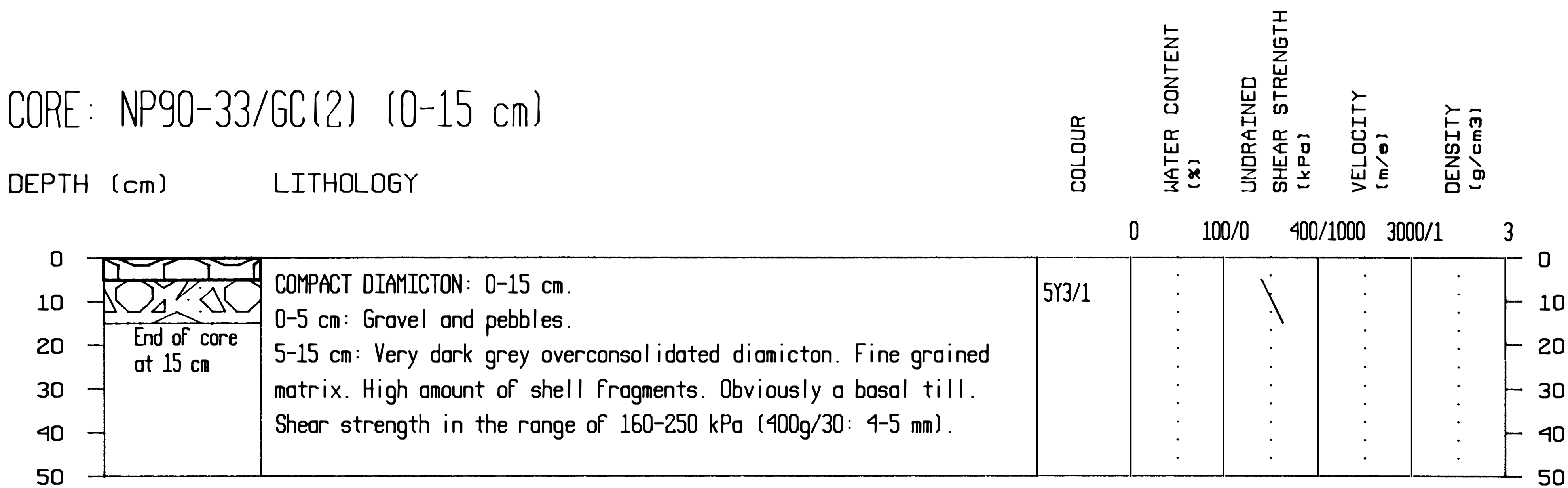

CORE: NP90-29/GC(2) (0-68 cm)
DEPTH (cm)
LITHOLOGY
COLOUR
WATER CONTENT (%)
UNDRAINED SHEAR STRENGTH (kPa)
VELOCITY (m/s)
DENSITY (g/cm3)
0
100/0
40/1000
3000/1
3
0 10 20 30 40 50 60 70 80 90 100
HOMOGENOUS MUD: 0-10 cm. Very dark grey silty mud. Strongly mottled (FeS staining). Rare Polychaete worm tubes present.
HOMOGENOUS MUD: 10-51 cm. Dark olive grey silty mud. Moderately mottled (FeS). Rare Polychaete worm tubes. Small shell fragments common.
SANDY MUD: 51-68 cm. Homogenous, dark olive grey, fine sandy mud. Rare Polychaete worm tubes. Small shell fragments common.
Clasts common throughout core.
End of core at 68 cm
5Y3/1
5Y3/2
5Y3/2

CORE: NP90-32/GC(2) (0-194 cm)

DEPTH (cm)	LITHOLOGY	COLOUR
0-78	HOMOGENOUS MUD: 0-78 cm. Olive grey mud with drop stones present. FeS mottling throughout the unit. Cohesive, probably due to the content of organic material. Transitional lower boundary, from 74 to 78 cm.	5Y4/2
78-100	HOMOGENOUS MUD: 78-100 cm. Grey, clayey mud with patches of FeS. Dropstones present.	5Y4/1
100-156	SANDY MUD: 100-156 cm. Homogenous, dark grey clayey mud with frequent sand grains and gravel. Slightly laminated due to changes in the frequency of sand content. Rare FeS lamina throughout.	5Y4/1
156-194	SILTY MUD: 156-194 cm. Apparently homogenous, dark grey silty mud with frequent occurence of sand and pebbles. Slightly more cohesive than the mud above.	5Y4/1

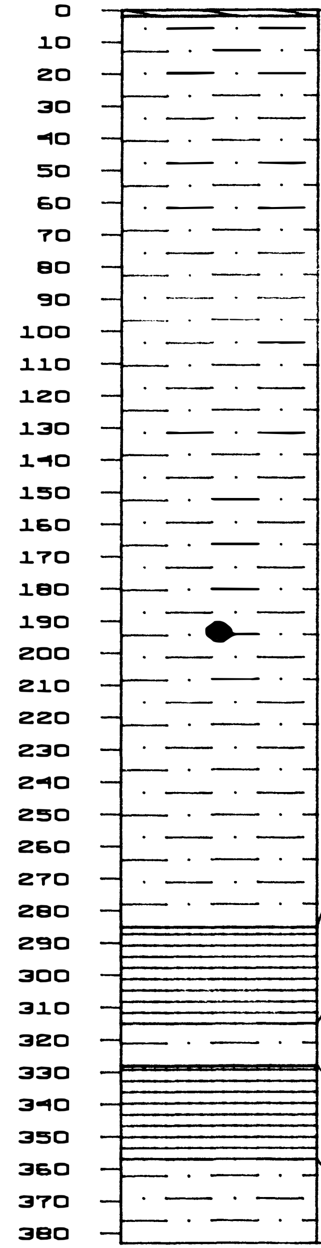


CORE: NP90-33/GC(2) (0-15 cm)



CORE: NP90-36/PGC(1) (0-383 cm)

DEPTH (cm) LITHOLOGY



HOMOGENOUS MUD: 0-285 cm.
Dark grey, silty clayey mud. Faintly laminated. Rare, very small clasts over 85 cm. Occasional clasts under this level. Silty mud (iron-rich) at the top of unit (0-2 cm). Increasing levels of mottling due to FeS staining of polychaete worm tubes from 150 to 285 cm. Darker laminations are marked by small, black spots which may be burrows. Very dark grey clast at 190-197 cm.

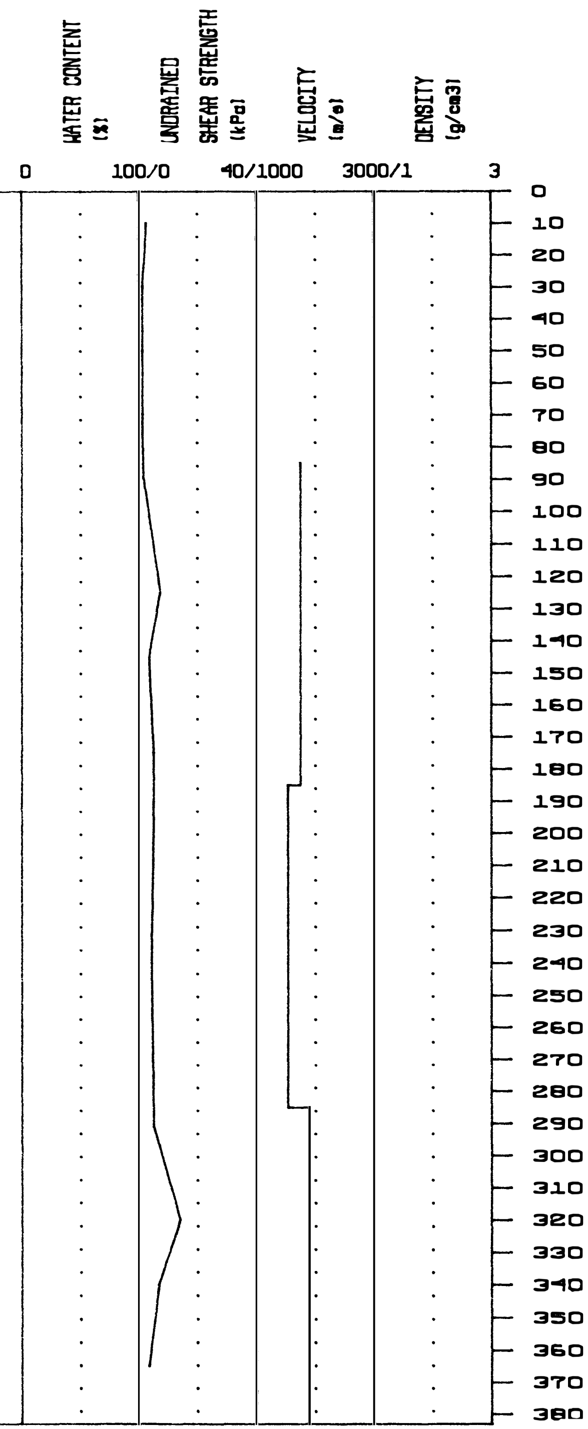
LAMINATED MUD: 285-315 cm. Very dark grey silty mud. Faintly laminated. Small black spots, probably indicate burrows. Polychaete worm tubes common (FeS stained).

HOMOGENOUS MUD: 315-328 cm. Olive grey mud. Bioturbated upper surface. Unit bioturbated throughout. Rusty brown laminae present, particularly towards base.

LAMINATED MUD: 328-357 cm. Dark grey silty mud. Faintly laminated (similar to 285-315). Polychaete worm tubes also present. Small clasts present.

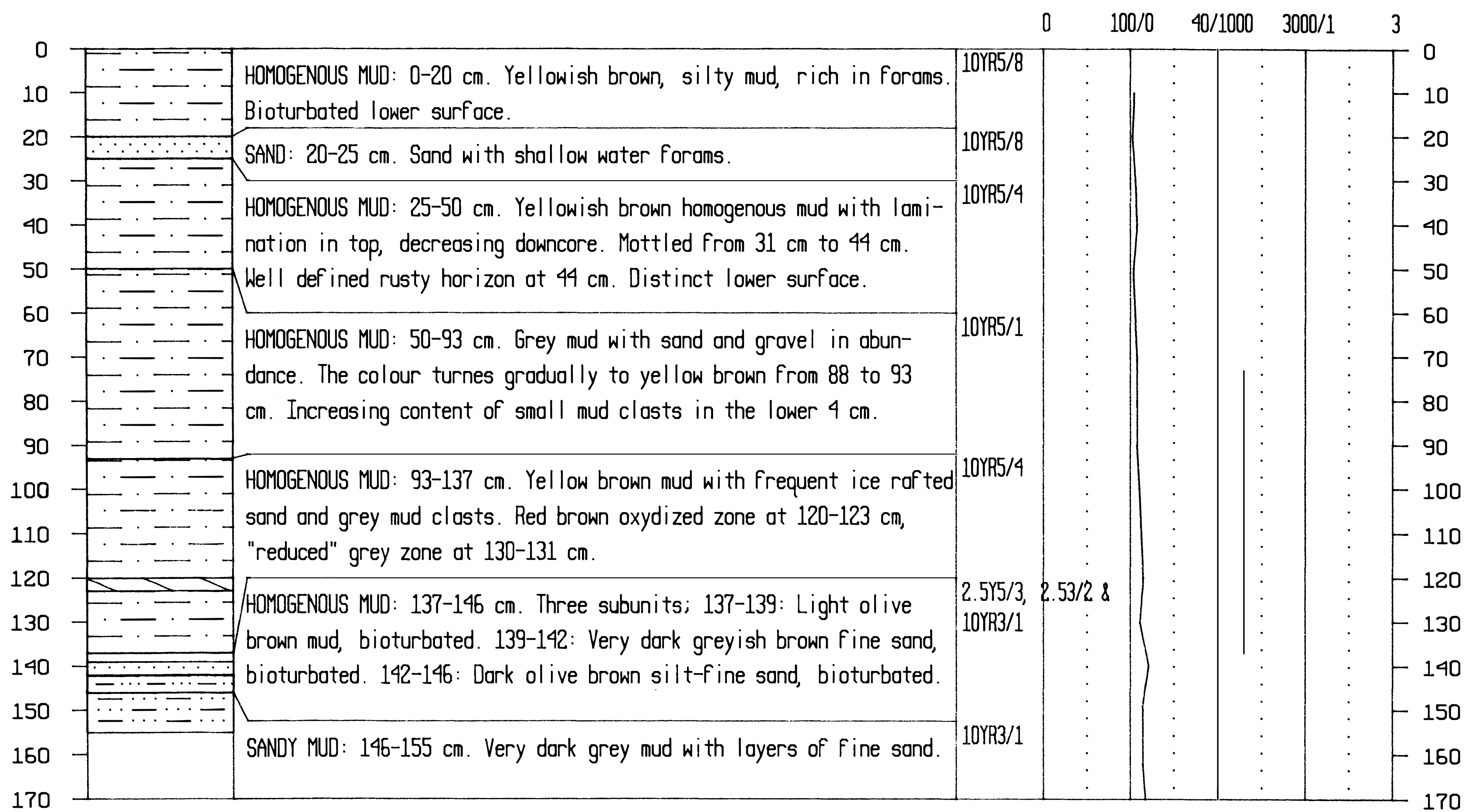
HOMOGENOUS MUD: 357-385 cm. Very dark grey mud with bioturbated upper surface.

COLOUR	Depth (cm)
5Y4/1	0
5Y3/1	285
5Y3/1	315
5Y4/1	328
5Y3/1	357

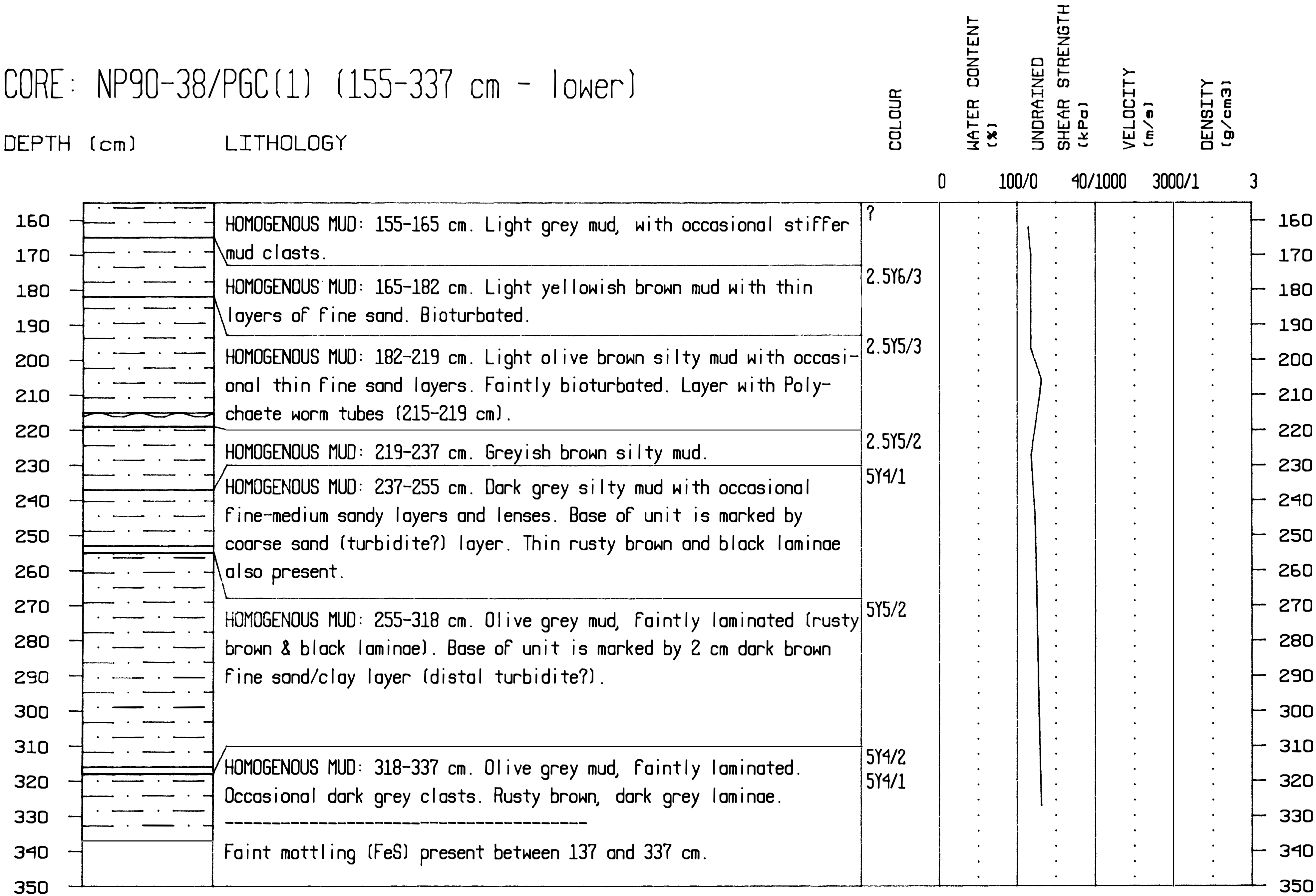


CORE: NP90-38/PGC(1) (0-155 cm - upper)

DEPTH (cm)	LITHOLOGY	COLOUR
0-20	HOMOGENOUS MUD: 0-20 cm. Yellowish brown, silty mud, rich in forams. Bioturbated lower surface.	10YR5/8
20-25	SAND: 20-25 cm. Sand with shallow water forams.	10YR5/8
25-50	HOMOGENOUS MUD: 25-50 cm. Yellowish brown homogenous mud with lamination in top, decreasing downcore. Mottled from 31 cm to 44 cm. Well defined rusty horizon at 44 cm. Distinct lower surface.	10YR5/4
50-93	HOMOGENOUS MUD: 50-93 cm. Grey mud with sand and gravel in abundance. The colour turnes gradually to yellow brown from 88 to 93 cm. Increasing content of small mud clasts in the lower 4 cm.	10YR5/1
93-137	HOMOGENOUS MUD: 93-137 cm. Yellow brown mud with frequent ice rafted sand and grey mud clasts. Red brown oxydized zone at 120-123 cm, "reduced" grey zone at 130-131 cm.	10YR5/4
137-146	HOMOGENOUS MUD: 137-146 cm. Three subunits; 137-139: Light olive brown mud, bioturbated. 139-142: Very dark greyish brown fine sand, bioturbated. 142-146: Dark olive brown silt-fine sand, bioturbated.	2.5Y5/3, 2.53/2 & 10YR3/1
146-155	SANDY MUD: 146-155 cm. Very dark grey mud with layers of fine sand.	10YR3/1



CORE: NP90-38/PGC(1) (155-337 cm - lower)



ISBN 82-90307-85-3