

REPORT

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QUATERNARY SAMPLES COLLECTED AS PART OF
HEAT FLOW MEASUREMENTS BARENTS SEA 1987.

REPORT NO.: 21.3441.00/01/89

AUTHORS:

J. Sættem, H.M. Weiss and D.A. Westgaard

IKU personnel:



IKU

SINTEF GROUP

REPORT

REG. NO.:	ACCESSIBILITY:
89.128	Restricted

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DATE:	NO. OF PAGES:	NO. OF APPENDICES:	PROJECT MANAGER:	SIGN.:
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BP Norway Limited U.A., Elf Aquitaine Norge A/S, Esso Norge a.s, Norsk Agip A/S				

SUMMARY:

Three boreholes were drilled as part of project 21.3431.00 Heat flow measurements Barents Sea 1987. A total of 21 Quaternary samples were recovered in those boreholes.

The samples are collected by hammer - or push - sampling.

The present report gives the result of soil mechanical analyses, sediment description and datings.

KEY WORDS:	
Barents Sea	Shallow drilling
Quaternary	Glacigenic sediments
Soil conditions	Heat flow sites

PREFACE

The present report gives the results of analyses carried out on Quaternary samples collected as part of the IKU project 21.3431 Heat flow measurements Barents Sea 1987 during a combined shallow drilling cruise in the southern Barents Sea in 1987.

The participants of the projects are:

BP Norway Limited U.A.
Elf Aquitaine Norge A/S
Esso Norge a.s
Norsk Agip A/S

The field work was coordinated by Tom Bugge and Joar Sættem and the laboratory work by Joar Sættem. The report is based on contributions from the following IKU personnel:

Field work: T. Berg, T. Bugge, G. Elvebakk, E. Haugane, G. Haugen,
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D.A Westgaard.

Sample description: D.A. Westgaard and J. Sættem.

Laboratory analyses: H. Rendall, H.M. Weiss and D.A. Westgaard.

Foraminifer picking: R. Wilhelmsen.

Drawing: R. Angell-Petersen, B. Fossum, J. Johansen.

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Printing: G. Herje

A study of magnetic properties is carried out by R. Løvlie and K.L. Ellingsen at the University of Bergen, geotechnical laboratory investigations are carried out by the SINTEF Division of Geotechnical Engineering.

H.P. Sejrup at the University of Bergen has been responsible for the amino acid measurements and G. Possnert at the Swedberg Laboratory in Uppsala has done the ^{14}C datings.

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APPENDIX

1 FIELD WORK

1. INTRODUCTION

During a shallow drilling cruise in the Barents Sea in 1987 (Appendix 1) samples were obtained from the Quaternary sediments covering the pre Quaternary rocks in the area. The purpose of this sampling was to determine the thermal conductivity of the sediments and to document the conditions of the drilled formation to provide some regional data on general geotechnical conditions and glacial geology of the area.

The sampling was carried out by a hydraulic pushsampler or a hammersampler. Brief descriptions of the methods are given in Appendix 1. The present report provides documentation of the Quaternary samples and results of various analyses done on this material. Thermal properties is not included but are available through the project: 21.3431 Heat flow measurements Barents Sea 1987.

The report focuses on data documentation, and discussion and interpretation of the results is limited to a few brief comments outlining typical conditions and to some comments related to crossplots of index parameters (Chapter 2).

2. SUMMARY OF MAIN FINDINGS, AND BRIEF COMMENTS ON THE RESULTS

2.1 Physical properties

The 1987 heat flow sites are located in areas with Quaternary thickness varying from 23.3 m to 45 m. The sea bed has typically a rough relief caused by relict iceberg ploughmarks, and frequently numerous small pockmarks occur on the sea bed.

A general sediment description for most of the material would be: "silty, sandy, clay, with scattered fragments of fine gravel". Towards the rockhead the content of gravel tends to increase, and close to the Norwegian coast the samples reflect the provenance from a shield area by a reduced clay content and increase in size and amount of crystalline rock fragments. Nearly all the samples are homogeneous and nonstratified, but a slight fissility is found in a number of the samples. This fissility has a clear primary (real) component, but is often enhanced and deformed by strain related to the sampling.

A number of routine soil mechanical analyses and various other tests have been carried out on these samples. Details of the results are given in Chapter 5.

In Figure 2.1 undrained shear strength (with few exceptions from falling cone tests) from all sites are plotted along a common depth axis. Two straight lines in the plot represent $0.2 - 0.3 \times p_o'$ where p_o' is in situ vertical effective stress. They are based on an average bulk density of 2.03 g/cm^3 . Undrained shear strength is as a rule of thumb generally expected to plot in the vicinity of these lines, and the figure indicates that many of the soil samples represent a sediment that has been overconsolidated - probably by the direct effect from an ice sheet or by previous sediment load which has been eroded away.

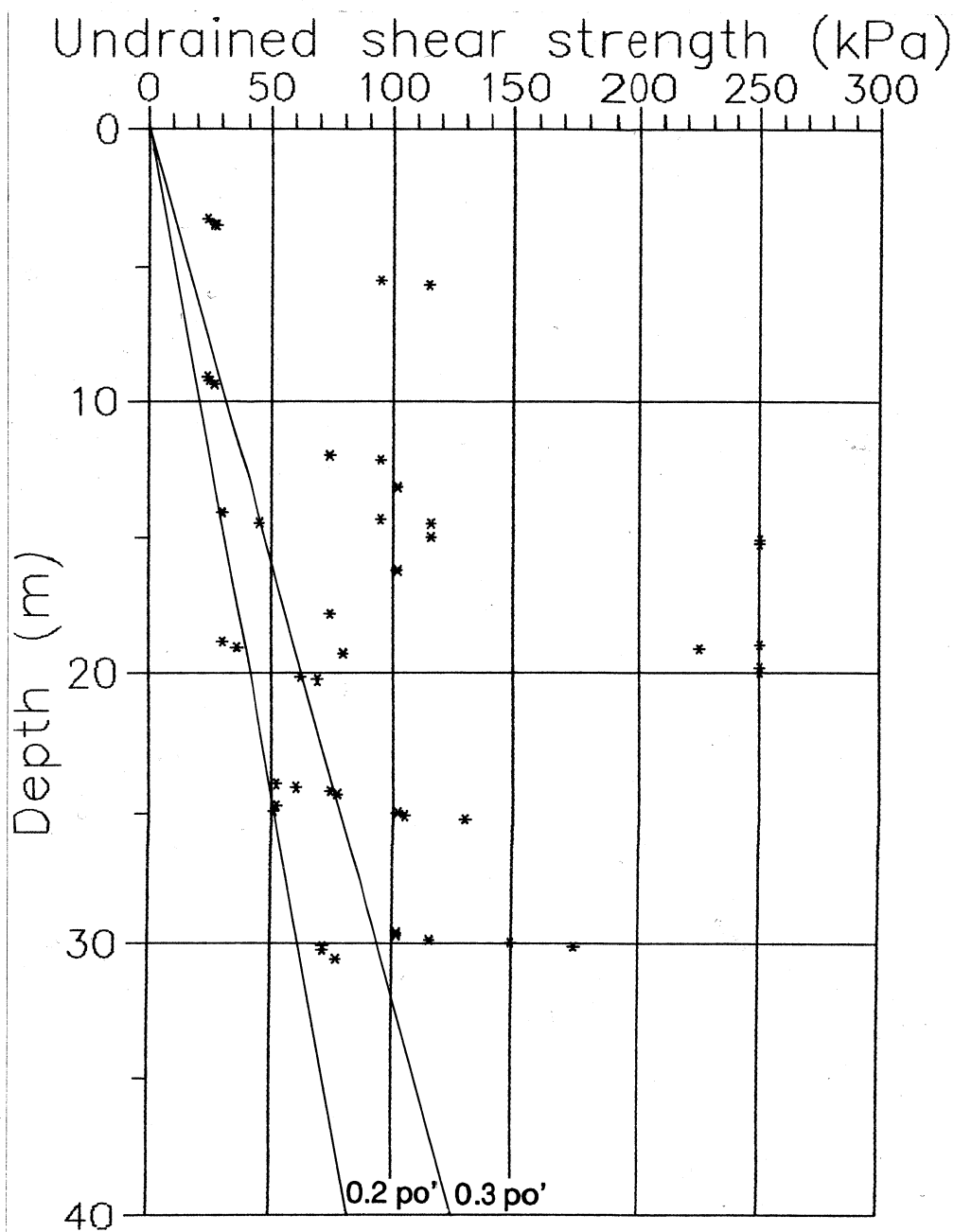


Figure 2.1 Undrained shear strength from all sites plotted along a common depth axis. Straight lines represent $0.2 \times p_0'$ and $0.3 \times p_0'$. All datapoints along $s_u = 250$ kPa are minimum values.

In Figure 2.2 undrained shear strength is plotted versus remoulded shear strength. This plot illustrate the low sensitivity of the clays which compare well with what is found for till and glaciomarine clays elsewhere on the Norwegian continental shelf (e.g. Rokoengen et al 1980; Fig.18). Nearly all samples plot within the "glacial clay" - area in the summarizing diagram of Terzaghi and Peck (1967) and close to the T-line of Boulton and Paul (1976) in the plasticity chart (Figure 2.3). This T-line is, however, not regarded as unique for tills (Sladen and Wrigley 1983).

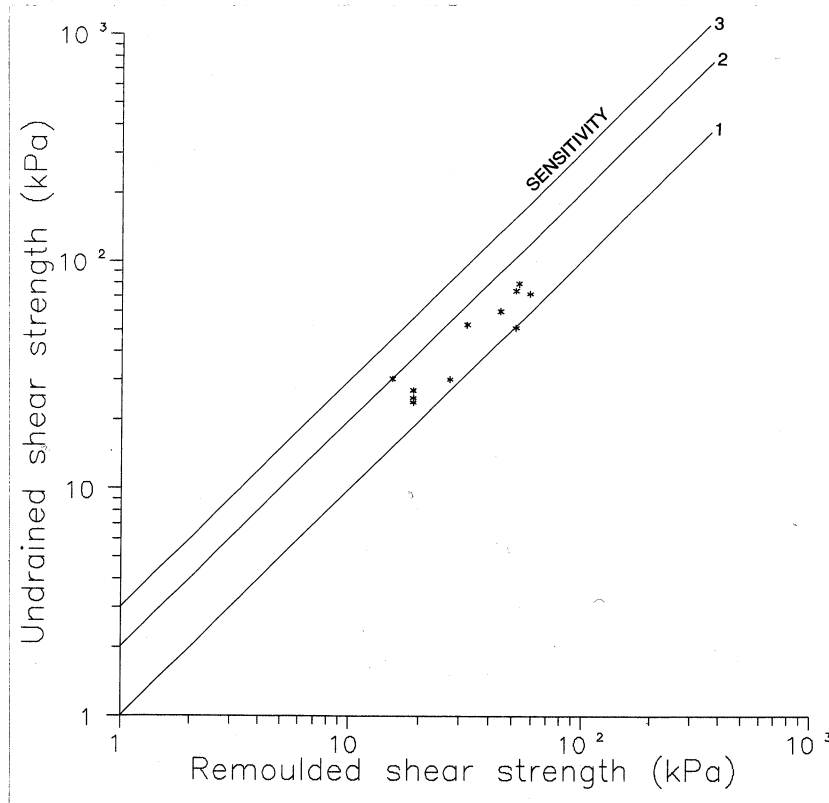


Figure 2.2 Undrained versus remoulded shear strength. Straight lines represent sensitivity values (s_u/s_r) of 1, 2 and 3.

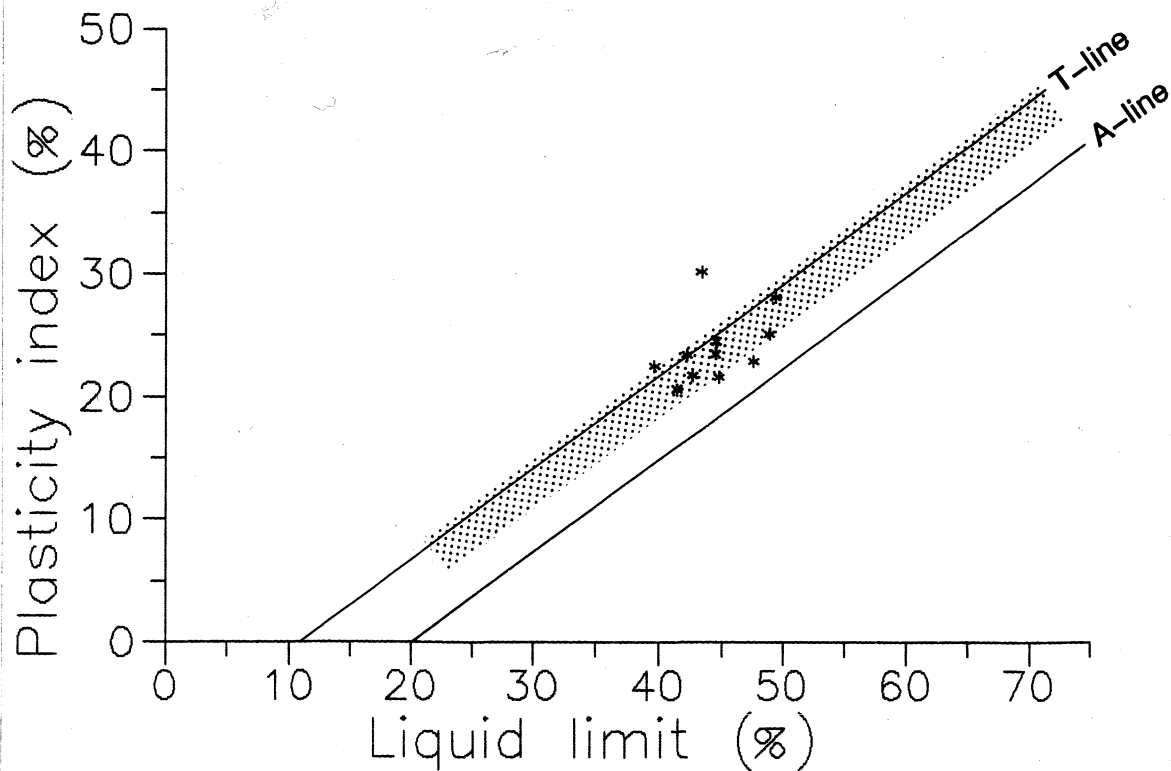


Figure 2.3 Plasticity chart. The A-line is the boundary between sediments of inorganic (above) and organic (below) nature (Casagrande 1948). The T-line is the "till line" of Boulton and Paul (1976).

2.2 Age

^{14}C accellerator mass spectrometry (AMS) measurements on small reworked shell fragments gave two radiocarbon ages of about 39 ka BP and 42 ka BP and one infinite age (Table 5.4). The content of foraminifera in the samples was found to be extremely low, but foraminifera were picked from four samples for amino acid measurements (several hundred gram samples were necessary to obtain sufficient amount of individuals). The results (Table 5.5) indicate a Weichselian or late Weichselian age.

The ages were obtained on small shell fragments which clearly have been mechanically fragmented, most likely by glacial action. The measured foraminifera may probably have been similarly reworked. The dates are therefore maximum ages of the sediments, and probably rather reflect a period/periods of no/moderate glacial activity in the area prior to an event of erosion and sedimentation causing the present sediment distribution pattern.

3. DRILL SITE KEY DATA

3.1 Location of sites

Bentech A/S in Tromsø was operator of the navigation chains in the Barents Sea, and they provided equipment and personnel for positioning of the drilling vessel.

Hyperfix was used as the main system, with Navstar GPS as a backup system during the about 8 hours a day this system provided navigation coverage. The Hyperfix was calibrated using a Syledis navigation chain. This chain has a range of about 100 km, and calibration was done every time the vessel approached the coastal area.

The general survey activity in the area was moderate this year, and the Hyperfix chain was therefore available in range-range mode all the time. We also had access to the same station combination as during the seismic survey. The best possible navigation accuracy was therefore achieved during the whole survey.

The final positions are listed in Table 3.1. and the location of the sites is also shown in Figure 3.1.

Table 3.1. Final position for the heat flow sites.

7227/11-U-01	Shot point	Latitude 72° 01' 15.81" Longitude 27° 29' 59.31"
	300	Northing 7 991 570.4 m Easting 517 219.9 m
7227/11-U-01C	Shot point	Latitude 72° 01' 15.86 Longitude 27° 29' 56.74
	299.9	Northing 7 991 571.9 m Easting 517 195.3 m
7230/08-U-01	Shot point	Latitude 72° 25' 45.59 Longitude 30° 22' 34.38"
	2500	Northing 8 040 236.9 m Easting 613 712.2 m
7230/05-U-05	Shot point	Latitude 72° 42' 07.14" Longitude 30° 22' 32.09"
	604	Northing 8 070 607.9 m Easting 611 981.7 m
7230/05-U-05A	Shot point	Latitude 72° 42' 6 00" Longitude 30° 22' 31.64"
	606.3	Northing 8 070 571.8 m Easting 611 979.5 m

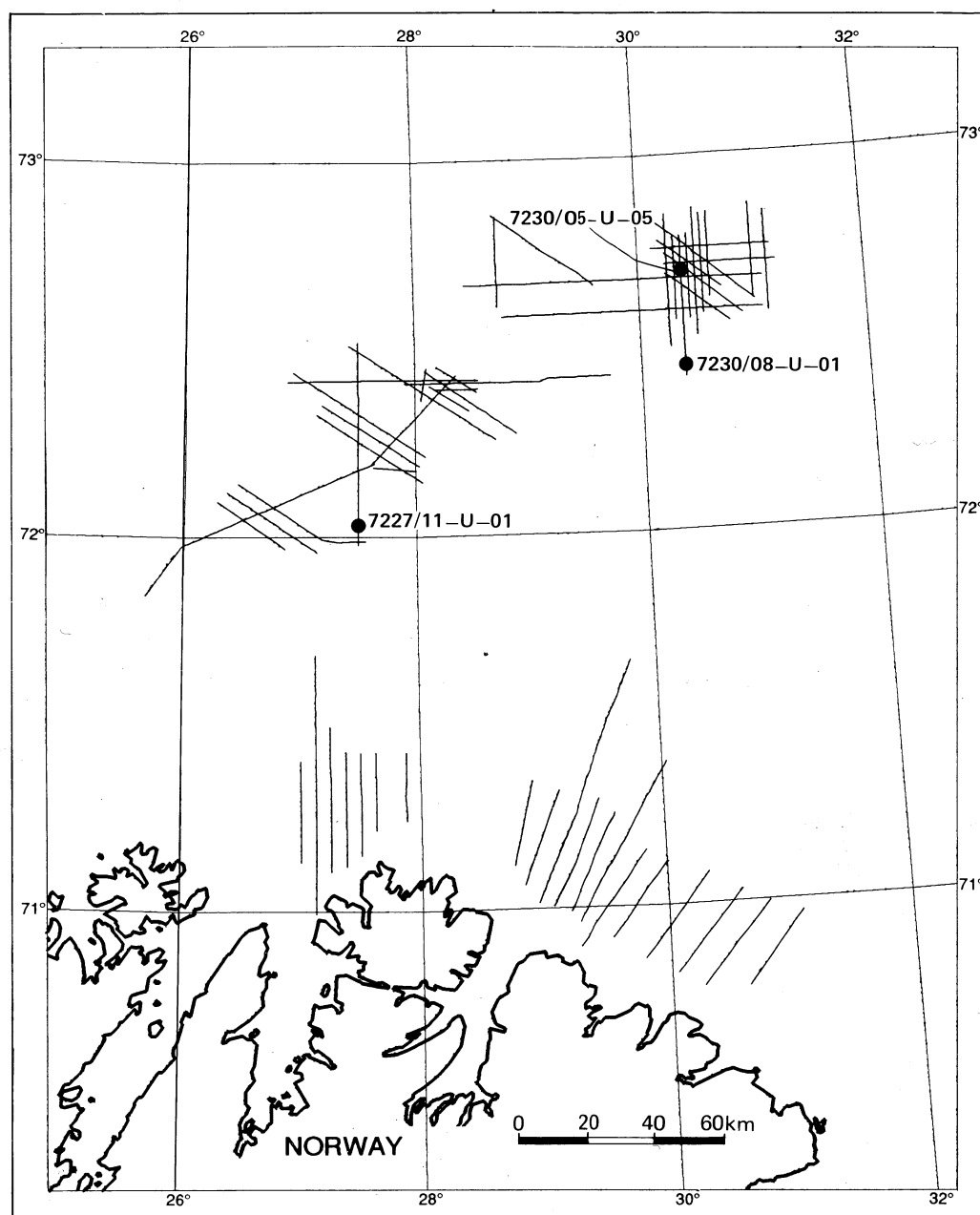


Figure 3.1 Location of the 21.3431.00 - project sites

3.2 Data recovery

Table 3.2 summarizes key data for the boreholes. The recovery of Quaternary samples is given in detail in Table 3.3.

The samples are collected by use of hammersampler, or wip push-sampler. The methods are further described in Appendix 1.

Table 3.2 Key data for all 1987 heat flow sites in the Barents Sea.

Site	Seismic Line	SP	Water depth (m)	Quaternary Thickness (m)	Bedrock coring length (m)	Bedrock Core Recovery		Quaternary samples		Temp. points	TD below seabed (m)
						(m)	% of cored length	no of samp.	Acc.samp. length		
7227/11-U-01	C/D86-6	300	280.5	32.5	-	-		11	4.31	4	13
7227/11-U-01C	C/D86-6	299.9	280.5	32.5	-	-					32.5
7230/08-U-01	IKU-302230-87	2500	283.0	45	-	-		5	0.69	11	29.9
7230/05-U-05	IKU-302230-87	604	286.0	23.3	-	-		3	1.52	5	17.5
7230/05-U-05A	IKU-302230-87	606.4	286.0	23.3	26.4	24.2	91.4	2	0.30		49.7

Table 3.3 Quaternary sample recovery.

Project	Location	Depth	Equipment	Comment
21.3431.00	7227/11-U-01 and -01C	5.50- 5.80	Hammer	Sample from outside core barrel
		13.00-13.40	WIP	
		13.18-13.21	WIP	
		14.17-14.67	WIP	
		16.16-16.36	WIP	
		17.80-17.90	Hammer	
		18.30-18.48	WIP	
		18.80-19.25	WIP	
		19.65-20.33	Hammer	
		24.60-25.39	Hammer	
		29.47-30.25	Hammer	
21.3431.00	7230/08-U-01	14.03-14.54	WIP	
		18.52-19.37	WIP	
		20.00-20.66	WIP	
		23.92-24.62	WIP	
		29.86-30.66	WIP	
21.3431.00	7230/05-U-05	9.00- 9.60	Hammer	
		11.93-12.43	WIP	
		14.90-15.32	WIP	
21.3431.00	7230/05-U-05A	17.00-17.14	Hammer	
		23.50-23.66	Hammer	

4. LABORATORY ANALYSES

4.1 On board procedures

As soon as each sample was retrieved during drilling, it was extruded from the sampling tube and the total length of the sample measured. The sample was then cut in shorter lengths and when possible sound velocity was measured both vertically and horizontally using a portable ultrasonic (100 kHz) non destructive tester, make Pundit. Horizontal and vertical sound velocity in abbreviated V_{hor} and V_{vert} respectively in Table 5.1. The samples collected at the heat flow sites were also subjected to measurement of thermal conductivity.

The samples were then packed and stored. A number of samples chosen for oedometer or triaxial testing were waxed in order to prevent water loss and disturbance. A few samples were also canned and stored in a -80°C freezer for later gas analyses.

4.2 On shore work

4.2.1 Physical properties

In the IKU laboratory the samples have been visually described, photographed and radiographed. Then a suite of standard soil mechanical tests have been performed.

Semiquantitative mineralogical analyses were performed on 15 samples from the heat flow sites. The purpose of this was to be able to carry out, calculation of theoretical thermal conductivity.

Samples for X-ray diffraction analysis were prepared according to the following procedure.

1. The samples were gently crushed in a mortar with ethanol.
2. The whole rock sample were ground in ethanol to a fine powder and sucked onto millipore filters for whole rock analyses.

Radiation: monochromatic $\text{CuK}\alpha$
Voltage: 40 kV
Current: 30 mA
Speed: $2^\circ/\text{minute}$, $2\theta=2^\circ-35^\circ$

The quantification is based on the peak height multiplied by the width of the peak at half maximum and by a weighted factor relative to quartz of the following reflections

Smectite	(Smec):	$(14\text{\AA} - 4.7\text{\AA}) \times 0.35$
Mixed layer minerals	(Mix) :	$10 \text{ to } 14\text{\AA} \times 0.55$
Muscovite/Illite	(Mica):	$10\text{\AA} \times 1.0$ or $10\text{\AA} \times 1.4$ (illite)
Chlorite	(Chl) :	$4.74\text{\AA} \times 3 \times 0.7$
Kaolinite	(Kaol):	$7\text{\AA} \times 0.7 - \text{Chl}$
Quartz	(Qtz) :	$4.26\text{\AA} \times 1$
K-feldspar	(KFsp):	$3.24\text{\AA} \times 0.5$
Plagioclase	(Plag):	$3.19\text{\AA} \times 0.5$
Calcite	(Calc):	$3.04\text{\AA} \times 0.25$
Dolomite	(Dolo):	$2.89\text{\AA} \times 0.20$
Siderite	(Sidr):	$2.79\text{\AA} \times 0.25$
Pyrite	(Pyr) :	$2.71\text{\AA} \times 0.7$

The following routine soil mechanical analyses were carried out in the IKU laboratories.

- water content (w , % of dry sample weight)
- unit weight of soil (γ , kN/m^3)
- undrained shear strength (s_u , kN/m^2)
- remoulded shear strength (s_r , kN/m^2)
- sensitivity (S_u/S_r)

In addition to this some further routine analyses in addition to a number of oedometer and triaxial tests were done at the SINTEF, Division of Geotechnical Engineering. These tests include:

- unit weight of soil (γ , kN/m^3)
- water content (w , % of dry sample weight)
- liquid limit (w_L , %)
- plastic limit (w_p , %)
- plasticity index ($I_p = w_c - w_p$)
- undrained shear strength (s_u)
- grain size distribution

4.2.2 Organic geochemistry (by Hermann Weiss)

Experimental procedures

Headspace gas:

The can was thawed over night and shaken vigorously. Then a septum was attached to the can and a sample of the headspace gas was taken for analysis of C_1 , C_2 , C_3 , $i-C_4$ and C_{5+} hydrocarbons.

This analysis was performed on a Carlo Erba Fractovap 2350 gas chromatograph equipped with a 2 m x 1/8" stainless steel column filled with Porapak Q on Chromosorb using nitrogen as carrier gas. An oven temperature of 150°C was used. After elution of n-butane, the column was back-flushed and C_{5+} compounds were recorded as one peak. A standard gas sample containing methane, ethane, propane, n-butane, n-pentane and n-hexane (100 ppm each) was used for quantification.

The can was then opened and headspace volume, water volume, and sample weight were measured.

Total Organic Carbon:

Bulk samples were crushed in a mortar. Aliquots of the samples were then weighed into Leco crucibles, then treated three times with hot 10% HCl in order to remove carbonate, and finally washed four times with distilled water in order to remove any traces of HCl. The crucibles were then placed on a hot plate (60°C) and dried for 24 hours. The total organic carbon (TOC) content of the dried samples was determined using a Leco CS 244 carbon/sulphur analyser.

The instrument was calibrated using a sediment standard with 2.72% carbon. Calibration and blank runs were carried out every 15th measurement.

The total carbon (TC) content was determined on untreated crushed sediment.

4.2.3 Dating and amino acid measurements

The sediment samples contain very few and small shell fragments. Four fragments of sufficient size for ^{14}C dating by the accelerator method were found. A tentative identification of the fragments are made by E. Thomsen and ^{14}C measurements have been done at the Swedberg Laboratory, Uppsala University.

Identification and picking of foraminifera (*Elphidium excavatum*) for amino acid measurements are done on 13 samples by stud. R. Wilhelmsen, University of Oslo. It was found that the foraminifera content was extremely low and sufficient material (about 100 *Elphidium Excavatum*) was only found in four samples (after sieving 230 - 375 g of sample). Amino acid ratios indicative of age were obtained on foraminifera from boreholes 7230/08-U-01 and 7230/05-U-01. The results are given in Table 5.5 and on the soil boring summary sheets.

4.2.4 Magnetic properties

Magnetic properties were measured at the University of Bergen on 83 samples from 13 locations of the 1987 cruise. The purpose of this was to measure magnetic fabric and paleomagnetic properties for genetic interpretation or chronostratigraphy. The conclusion is, however, that the stress and deformation induced by the sampling seems to disturb the magnetic properties and that the results therefore are difficult to use. These problems will, however, be studied thoroughly as the magnetic property studies has a potential both in chronostratigraphy and maybe also in genetic classification.

5. DATA PRESENTATION

5.1 General comments to data presentation

Chapter 5 gives the results of laboratory analyses of the Quaternary samples. The only exception is the thermal conductivity values measured. This data is available in IKU-Report 21.3431.00/01/88 by participation in that project.

The data presentation is organized as follows:

In chapter 5.2 all test results are given in tables for each type of analysis.

In chapter 5.3 the information is grouped in drill sites. Each subchapter commences with a brief site description. A seismic section across the site is then shown and seismic reflections are shown. (Deep towed boomer and sidescan sonar data are included where they exist). This is followed by a soil boring summary sheet. On this sheet physical properties and age information are plotted. Reflections detected on the seismic profiles are also drawn.

5.2 Test result tables

5.2.1 Soil mechanical data and sound velocities

Table 5.1 shows results from routine soil mechanical analyses and on board measurement of sound velocity of the samples.

Table 5.1 Routine soil mechanical data and sound velocity measured on Quaternary samples (Abbreviations are explained in Sections 4.1 and 4.2.1).

WELL: 7227/11-U-01

DEPTH (m)	w (%)	γ (kN/m ³)	w_L (%)	w_p (%)	I_p (%)	s_u (kN/m ²)	s_r (kN/m ²)	S_t	V_{hor} (m/s)	V_{vert} (m/s)
5.54	19.6	20.5				88.0				
5.57			39.7	17.2	22.5	102.0				
5.71	15.6	21.4								
5.75						115.8			2032	
13.20	23.7					102.1				
14.52	19.8	21.4				115.8				
16.26	26.0					102.1				
17.86	23.5					74.1				
18.98			49.4	21.3	28.1					
19.00	19.2	21.2								
19.06						>250.0				
19.14						225.0			1830	1780
19.78						>250.0				
19.82	17.1	21.5								
20.00						>250.0				
20.06	19.4	20.8	42.7	21.0	21.7	250.0				
20.31									1834	
24.77	23.3	20.5	42.3	18.9	23.4	52.5				
24.96						51.0	51.0	1.0		
25.03	21.9	21.2				102.0				
25.15						150.0			1940	1820
25.30						130.0			1850	1840
29.57			44.6	20.1	24.5					
29.60	23.8	20.8								
29.67						102.1				
29.87	19.9	21.3				115.8				
29.96						150.0				
30.00									1890	1905
30.11						175.0				
30.15									1800	1785

Table 5.1 Continued

WELL: 7230/08-U-01

DEPTH (m)	w (%)	γ (kN/m ³)	w _L (%)	w _p (%)	I _p (%)	s _u (kN/m ²)	s _r (kN/m ²)	s _t	V _{hor} (m/s)	V _{vert} (m/s)
14.08										
14.12	32.6	19.4	48.9	23.8	25.1					
14.13						30.3	27.0	1.12	1721	1650
14.30						94.7				
14.35										
14.36	27.0	20.1				45.0			1630	
14.48										
18.84	34.3	19.0				30.4	15.2	2.0	1674	1638
18.86										
19.08						36.0				
19.12										
19.25	28.1	19.9				79.5	52.5	1.51	1686	1660
19.32										
20.12	31.5	19.3				62.3			1695	1620
20.16										
20.24	28.8	19.9				69.2			1835	1708
20.27						44.1				
20.33	30.9	18.9	43.4	13.2	30.2				1782	1663
20.43						52.5	31.9	1.65	1642	1647
23.98	29.7	19.9				60.3	44.1	1.36		
24.04									1666	1642
24.10	29.2	19.8								
24.19	29.2	20.1								
24.20						74.1	51.0	1.45		
24.24						77.0			1670	1677
24.30	27.5	19.2	47.6	24.7	22.9				1670	1632
24.35										
24.50										
30.07	24.2	20.7				71.6				
30.10										
30.19			41.5	20.9	20.6					
30.22	24.3	20.5								
30.25						71.6	58.4	1.23	1753	2055
30.40									1706	1724
30.58						77.0			1643	1797

Table 5.1 Continued

WELL: 7230/05-U-05

DEPTH (m)	w (%)	γ (kN/m ³)	w_L (%)	w_p (%)	I_p (%)	S_u (kN/m ²)	S_r (kN/m ²)	S_t	V_{hor} (m/s)	V_{vert} (m/s)
9.07	33.6	19.3								
9.12						24.0	18.6	1.3		
9.24	32.8	19.5								
9.26						25.0	18.6	1.3		
9.38	32.4	19.7				27.0	18.6	1.5		
9.50	34.7	18.4	44.8	23.2	21.6	21.1				
12.00	25.7	16.4								
12.07						74.0				
12.18						95.0				
15.01	21.1	22.0				115.8				
15.05									1872	
15.09	18.2	20.8	44.5	21.0	23.5	245.0				
15.10						>250.0				
15.25						>250.0			1888	1787

WELL: 7230/05-U-05A

DEPTH (m)	w (%)	γ (kN/m ³)	w_L (%)	w_p (%)	I_p (%)	S_u (kN/m ²)	S_r (kN/m ²)		V_{hor} (m/s)	V_{vert} (m/s)
17.06	12.8	22.5								

Additional routine analyses and advanced soil mechanical tests are carried out by the SINTEF Division of Geotechnical Engineering. A summary of the results is given in Table 6.2. Symbols and abbreviations used are as follows:

a	=	Coulombian attraction (kN/m^2)
c_v, c_h	=	vertical, horizontal coefficient of consolidation (m^2/year)
m	=	deformation modulus number
p_o'	=	effective overburden pressure (kN/m^2)
p_c'	=	preconsolidation pressure (kN/m^2)
s_u	=	undrained shear strength (kN/m^2)
$\tan \rho$	=	mobilized friction
w	=	water content (%)
w_L	=	liquid limit (%)
w_p	=	plastic limit (%)
ε_f	=	failure strain (%)
γ	=	unit weight of soil (kN/m^3)

Table 5.2 Extract of results from analyses performed at the SINTEF Division of Geotechnical Engineering.

Boring No.	Sample depth m	w %	Index Properties					Soil Description	$\bar{p}_0'$ kN/m ²	Oedometer Tests				Triaxial Tests				Remarks/Sample Quality
			w_L %	w_P %	γ kN/m ³	s_u cone kN/m ²	Clay <2 μ %			$\bar{p}_C'$ kN/m ²	m	c m ² /year	Hor./ Vert.	s_u kN/m ²	a kN/m ²	tan ϕ -	ϵ_f %	
7227/11-U-01	5.50-5.65	19.6	39.7	17.2	20.5	102.0	28.0	Silty Clay. Some gravel grains.	60.2	100- 150	22.9	1.0	V	-	-	-	-	Good.
7227/11-U-01C	20.03-20.14	19.4	42.7	21.0	20.8	250.0	33.1	Clay. Sand and gravel grains.	109.1	550	19.3	1.0	V	-	-	-	-	Good.
7230/05-U-05	9.45-9.60	34.7	44.8	23.2	18.4	21.1	40.4	Clay. Some sand grains.	80.0	p_0' 150	20.0	0.4	V	-	-	-	-	Good.
	15.02-15.17	18.2	44.5	21.0	20.8	245.0	41.4	Clay. Sand grains and sandstone.	163.8	800	16.0 20.3	0.5 3.0	H V	164	50	0.56	6	Good.
7230/08-U-01	20.34-20.49	30.9	43.4	13.2	18.9	44.1	36.5	Clay. Sand and gravel grains.	182.2	250 150	10.9 15.2	1.0 1.2	V H	-	-	-	-	Good.
	24.28-24.43	27.5	47.6	24.7	19.2	77	41.7	Clay. Sand and gravel grains.	224.0	-	-	-	-	32	20	0.33	8	Disturbed.

Grain size distribution analysis has been carried out selected samples by use of the falling drop method.

The percentage of equivalent particle sizes above 0.06 mm, 0.02 mm, 0.006 mm and 0.002 mm have been recorded. The results are given in Figure 5.1 and soil boring summary sheets.

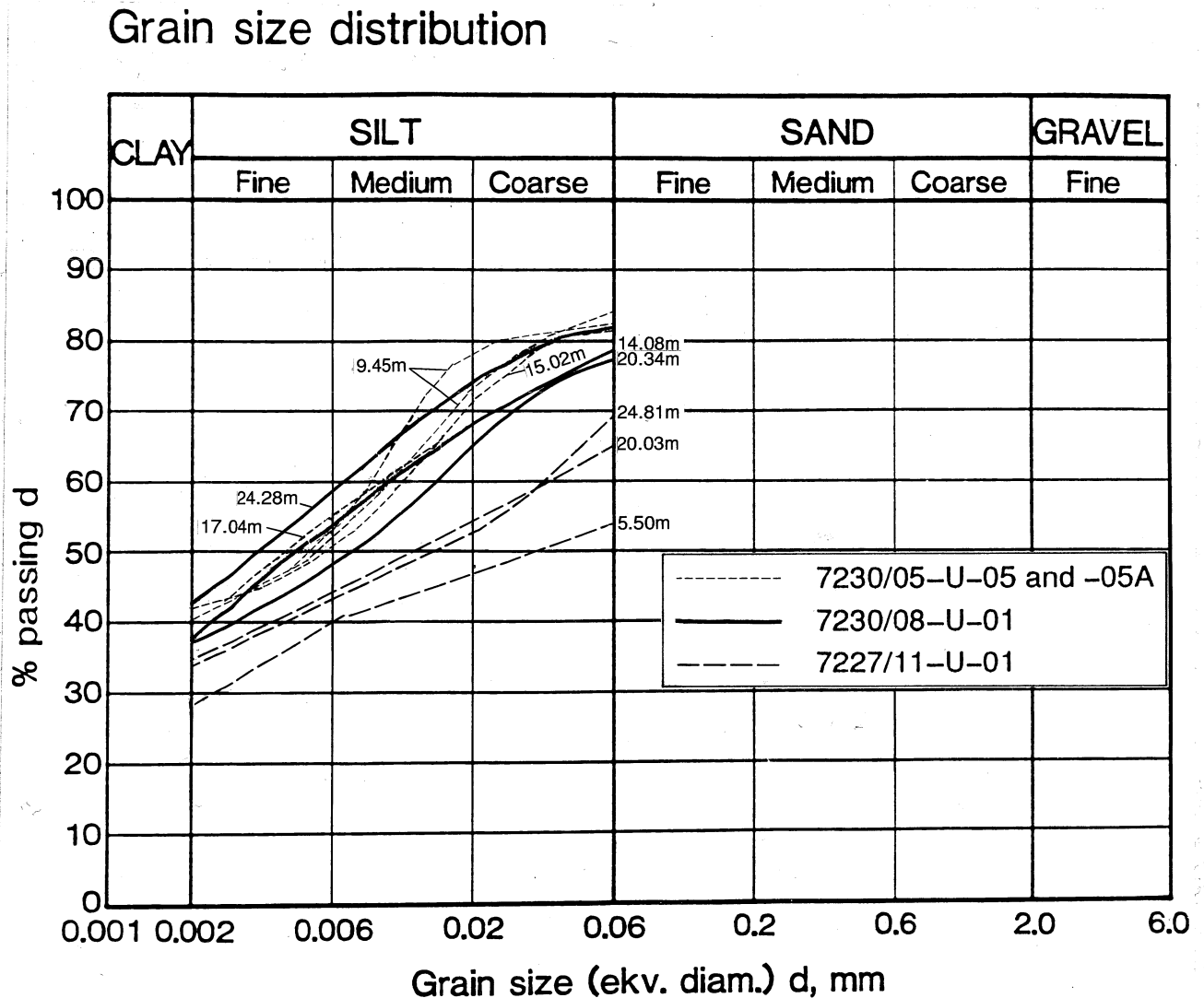


Figure 5.1 Grain size distribution curves. The grain size distribution as a function of depth is also shown in the soil boring summary sheets.

5.2.2 Mineralogy

The results of mineralogical analyses are given in Table 5.3.

Table 5.3 Mineralogical analyses.

	Quartz	K- Feldspar	Plagio- clase	Calcite	Dol/ Ank	Side- rite	Chlorite	Kaolin.	Mica/ Ill	Mx. layer	Smectite	Pyrite
Well 7230/08-U-01												
Depth:												
14.39m	34	19	6	3	2	-	7	5	5	13	5	1
19.32m	23	4	12	-	2	-	4	4	10	21	20	Tr
20.11m	18	6	11	-	-	-	10	6	12	29	8	Tr
24.17m	27	7	15	-	2	-	4	4	12	22	7	1
24.03m	22	3	15	-	2	1	6	2	12	24	13	1
30.07m	39	6	25	2	3	-	4	4	8	7	2	1
30.17m	25	3	14	Tr	1	-	5	5	14	18	14	1
Well 7227/11-U-01												
Depth:												
5.67m	25	2	15	1	1	-	6	4	17	18	10	1
19.03m	30	6	28	1	2	1	4	3	12	10	2	1
19.79m	20	3	24	-	1	-	8	7	13	16	8	1
25.03m	20	3	12	6	2	-	6	3	22	18	8	1
29.87m	21	4	14	2	1	-	7	12	15	17	5	2
Well 7230/05-U-05												
Depth:												
9.24m	20	3	14	-	Tr	-	8	8	20	22	5	1
12.04m	16	5	11	1	-	-	18	12	18	17	10	-
17.12m	35	6	29	1	1	-	3	5	7	8	3	Tr

5.2.3 Datings

Three shell fragments are ^{14}C dated by the accellerator method at the Swedberg Laboratory, Uppsala University, Sweden. Elsebeth Thomsen, University of Tromsø, has tentatively identified the fragments, but because of the fragment size the identification is rather uncertain.

The results are given in Table 5.4.

Table 5.4 ^{14}C -datings and tentative identification of shell fragments.

Site	Depth	Age(v/BP)	Lab.no.	Fragment identification
7227/11-U-01	5.65-5.75m	38640 $\pm$ 1240	Ua-986	Bivalve fragments ?Macoma
7230/08-U-01	20.05m	42420 $\pm$ 1780	Ua-987	Thickwalled bivalve ?Macoma
7227/11-U-01C	17.88m	>45000	Ua-988	Thickwalled bivalve

5.2.4 Micropaleontology and amino acid measurements

the micropaleontological analysis have been limited to a brief scanning of samples and identification and picking of foraminifera for amino acid measurement (elphidium excavatum).

several samples were investigated. the foraminifera content is, however, extremely low, and sufficient material was found only in two samples from the heat flow sites. the foraminifera were typically intact (although fractured do occur) and the surface structure is intact.

the results are given in table 5.5. a possible uncertainty in the results is introduced by the fact that the foraminifera were glued on glass plates during transportation to the laboratory in bergen. according to sejrur (pers.comm.) all the glue has apparently successfully been removed before the analysis. if any of the glue has influenced on the results, it may only result in a too low d-allo/l-iso ratio, as the glue contains no alloisolucine.

Table 5.5 Amino acid measurement results.

Site	Depth (m)	Weight, dry bulk samples	No. of Elph.exc.	Amino acid analysis D-allo/L-iso-ratio	Laboratory reference no.
7227/11-U-01C	29.5 -29.85	375	93	0.064	BAL 1429
7230/05-U-05	9.10- 9.27	327	103	0.035	BAL 1430

5.2.5 Organic geochemistry

The total carbon (TC) and total organic carbon (TOC) content of the Quaternary sediments were determined on 11 samples. The TC contents range from 0.78 to 1.67 wt% and the TOC contents vary between 0.22 and 1.17 wt% of the dry sediment. Both parameters usually show a fair correlation with each other and increase slightly with depth. The inorganic carbon (TC-TOC) is thought to be present in the form of carbonates. Assuming that all calcium carbonate is the only carbonate present in these sediments, the difference between the TC and TOC was expressed in wt% CaCO₃. These values range from 0 to 10.3% and vary independently from the TC and TOC contents.

Only trace concentrations of headspace gas were recorded (< 31 µl/kg dry sediment). Methane is the only hydrocarbon contained in these gases.

Table 5.6 Analysis of total carbon (TC), total organic carbon (TOC) and content of CaCO_3 .

Site	IKU ref. no.	Depth (m)	TC (wt% of dry sediment)	TOC	CaCO_3
7227/11-U-1C	C-7022	19.20-19.25	1.31	1.00	2.59
	C-7023	20.29-20.33	0.78	0.48	2.50
	C-7024	30.19-30.25	1.66	1.10	4.67
7230/05-U-05	C-7026*	11.93-11.96			
	C-7027*)	12.41-12.43	1.67	1.17	4.17
7230/08-U-01	C-7028	14.25-14.29	1.20	0.80	3.34
	C-7029*	18.94-18.96			
	C-7030*)	19.35-19.37	1.07	0.89	1.50
	C-7031	20.64-20.66	1.15	0.90	2.09
	C-7032	24.58-24.62	1.32	0.94	0.38
	C-7033	29.86-30.00	0.93	0.79	1.17

*) Two samples in same can. Sediment was homogenized during shaking prior to headspace analysis.

**) Repeated analyses also gave slightly higher values for TOC than for TC.

Table 5.7 Concentration ($\mu\text{l gas/kg dry rock}$) of C_1 hydrocarbons in headspace gas.

Site	IKU no.	Depth (m)	C1
7227/11-U-01C	C 7022	19.25	13
	C 7023	20.33	21
	C 7024	30.25	31
7230/05-U-05	C 7026	11.96&	15
	C 7027	12.43*)	
7230/-08-U-01	C 7028	12.29	11
	C 7029	18.96&	14
	C 7030	19.37*)	
	C 7031	20.66	15
	C 7032	24.62	15
	C 7033	30.00	5

5.3 DESCRIPTION OF INDIVIDUAL SITES

5.3.1 SITE 7127/11-U-01

Seismic interpretation

Top bedrock was found at 32.5 m during drilling and is interpreted at 36 ms on the seismic record, corresponding to a sound velocity of 1805 m/s. The intra Quaternary reflections are very vague but reflections at about 7 m and 20 m. Apparent acoustic layering on the boomer record is an artefact.

Lithology and mechanical properties

The sediment is a homogeneous silty, sandy clay with gravel fragments. Rock fragments are typically subrounded - subangular and include dominantly finegrained sedimentary rocks. Crystalline rocks occur throughout.

The water content is low throughout and is at or below plasticity limit. The samples at about 19 m and 20 m show a high undrained shear strength decreasing again with depth, and a high effective preconsolidation pressure is recorded in this interval. The quality of the samples at this interval is rated as good, and a "real" local increase in consolidation at this depth could be associated with the process forming the seismic reflection at this level.

Age

An AMS ^{14}C dating at 5.7 m of a shell fragment gave $38\,640 \pm 1240$ BP. The dating is done on a clearly reworked shell fragment, and represents a maximum age of the sediment. Amino acid measurements on foraminifera (*Elphidium excavatum*) from 29.67 m gave a D-allo/ L-iso ratio of 0.064 which possibly represents Early - Middle Weichselian. This may also be a "reworked" age.

LOC. 7227/11-U-01-01C

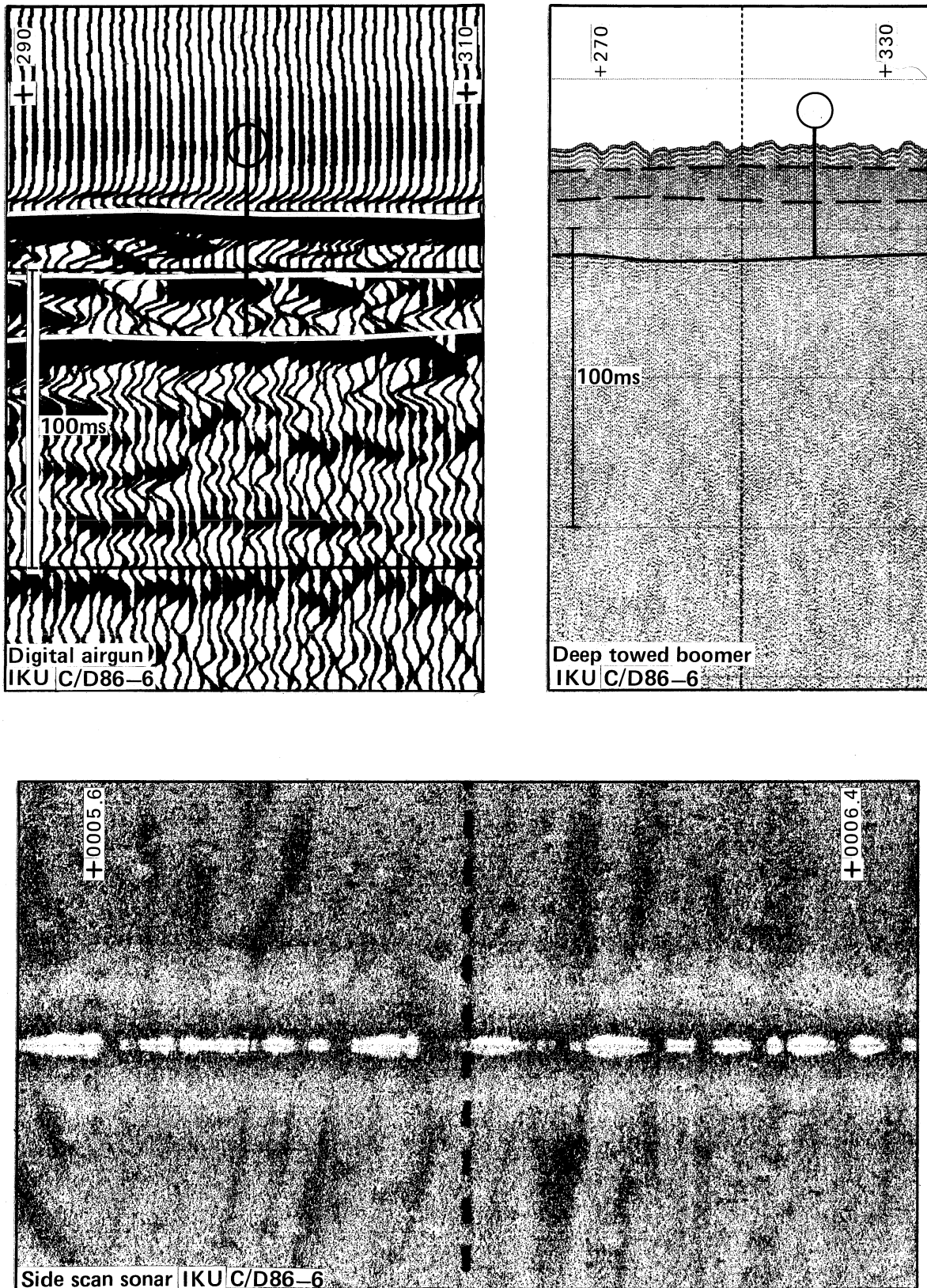


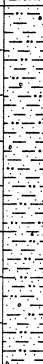
Figure 5.2 Seismic section across site 7227/11-U-01. The figure is continued on the following pages by a soil boring summary sheet, a description sheet and drawings of radiographs for each sample.

IKU SINTEF GROUP		POS.: N E		SEISMIC LINE: C/D 86-6		SP: 300		WATER DEPTH: 280.5 m		SITE: 7227/11-U-01					
UTM ZONE : N E		REFERENCES:		IKU REPORT: 21.3441.00/01/89		ACCESS-ABILITY: RESTRICTED									
NO OF SAMPLES:		Σ SAMPLE LENGTH: 4.21 m		ROCKHEAD: 32.5 m											
DEPTH(m)	LITHO-LOGICAL COLUMN	WATER CONTENT (%)	UNIT WEIGHT (kN/m ³)	S _u ∇-F.CONE (∇=S _p) ○-1 ax ○ ₃ -3 ax kN/m ²	SOUND VELOCITY m/s H _o =HORIZONTAL V=VERTICAL	COLOUMBIAIAN ATTRACTION, a (kN/m ²)	tan φ	PRECONSOLIDATION PRESSURE, p _c ' (kN/m ²)	GRAIN SIZE DISTRIBUTION % < d	DATING	MAGN.	MISC. ANALYSES	SEISMIC REFLECTIONS	COMMENTS	
		20 40 60 80	18 19 20 21 22	100 200 300 400 500	1600 1800 2000	20 30 40 50	2 4 6 8	200 400 600 800	20 40 60 80	14C Amino Acids Other	Polarity + - I F	Stratigraphy Geology Sedimentology Mineralogy XRF (XRD) Thermal Conductivity	(m)	INTERVAL VELOCITY (m/s)	(ms)
10															
20															
30															
40															
50															

		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7227/11 - U - 01		
Equipment Hammer sampler	Water depth 280.5 m	Latitude 72°01'15.81"N	Longitude 27°29'59.31"E	Depth below seabed 5.50 - 5.80 m			
Analytical results	Subsample	m	Lith.	Core description	s_u	s_r	
$w = 19.6\% \quad \gamma = 20.5 \text{ kN/m}^3$ $w_L = 39.7\% \quad w_p = 17.2\%$ $w = 15.6\% \quad \gamma = 21.4 \text{ kN/m}^3$ $V_{SH} = 2032 \text{ m/s}$	Oe	5.50		CLAY, sandy, silty, some gravel (f) Subrounded angular fragments of grey siltstone and metamorphic rocks	5Y - 4/1 Dark grey		
							88.0
							102.0
	Magn. XRD 14C k _r	.70		Shell fragments			
				Crystalline angular pebble, 1.5 cm		115.8	
		5.80					
</							

	Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7227/11 - U - 01		
Equipment WIP sampler	Water depth 280.5 m	Latitude 72°01'15.81"N	Longitude 27°29'59.31"E	Depth below seabed 13.18 - 13.21 m		
Analytical results	Subsample	m	Lith.	Core description	s_u	s_r
w = 23.7%		13.18 13.21	CLAY, silty, some gravel (f) Subangular claystone fragments	5Y - 4/1 Dark grey	102.1	
			Crystalline angular pebble, 1 cm			
Comments: Disturbed sample.			Symbols: K_s = grain size distribution k_t = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) w_L-w_P = liquid and plasticity limits γ = unit weight of soil (kN/m³) V_{SH} = horizontal sound velocity (m/s) V_{SV} = vertical sound velocity (m/s) Oe = oedometer test T = triaxial test TOC = total organic carbon TC = total carbon s_u = undrained shear strength from falling cone test (kN/m²) s_r = remoulded shear strength (kN/m²) Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology			

Site 7227/11-U-01

		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7221/11 - U - 01C	
Equipment WIP sampler		Water depth 280.5 m	Latitude 72°01'15.81"N	Longitude 27°29'59.31"E	Depth below seabed 13.00 - 13.40 m	
Analytical results	Subsample	m	Lith.	Core description	s_u	s_r
		13.00		CLAY, silty, sandy, some gravel (f) Subangular fragments of crystalline rocks and undiff sedimentary rocks	5Y-4/1 Dark grey	
		10				
		20				
		30				
		13.40				

		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7227/11 - U - 01C		
Equipment WIP sampler		Water depth 280.5 m	Latitude 72°01'15.81"N	Longitude 27°29'59.31"E	Depth below seabed 14.17 - 14.67 m		
Analytical results	Subsample	m	Lith.	Core description		s _v	s _r
w = 19.8% γ = 21.4kN/m ³		14.17		CLAY, silty, some sand and gravel (f) Subangular claystone and crystalline rock pebbles		5Y- 4/1 Dark grey	
		27		Subrounded crystalline pebble			
		37					
		47					115.8
		57					
		14.67					
Comments:			Symbols: K _f = grain size distribution K _t = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) w _L -w _P = liquid and plasticity limits γ = unit weight of soil (kN/m ³) V _{SH} = horizontal sound velocity (m/s) V _{SV} = vertical sound velocity (m/s) Oe = oedometer test T = triaxial test TOC = total organic carbon TC = total carbon s _v = undrained shear strength from falling cone test (kN/m ²) s _r = remoulded shear strength Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology				

Site 7227/11-U-01

		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7227/11 - U - 01C	
Equipment WIP sampler	Water depth 280.5 m	Latitude 72°01'15.81"N	Longitude 27°29'59.31"E	Depth below seabed 16.16 - 16.36 m		
Analytical results	Subsample	m	Lith.	Core description	s _u	s _r
w = 26.0%		16.16		CLAY, silty, some gravel (f) Subangular sandstone fragments	5Y - 4/1 Dark grey	
		26				102.1
		16.36		One chert fragment, 2 cm 3 sandstone fragments, ~5 cm, rounded		

		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7227/11 - U - 01C	
Equipment Hammer sampler	Water depth 280.5 m	Latitude 72°01'15.81"N	Longitude 27°29'59.31"E	Depth below seabed 17.80 - 17.90 m		
Analytical results	Subsample	m	Lith.	Core description	s _v	s _r
w = 23.5%	14C	17.80		CLAY, silty, sandy, gravelly (f-m) Subangular fragments of metamorphic rocks and some siltstone/claystone	5Y - 4/1 Dark grey	
		17.90		Chert fragment, 1 cm Shell fragment		74.1
Comments: Shell fragment 17.89 m. 14C (Va - 988): > 45000 BP			Symbols: K _z = grain size distribution k _r = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) w _L -w _P = liquid and plasticity limits γ = unit weight of soil (kN/m³) V _{SH} = horizontal sound velocity (m/s) V _{SV} = vertical sound velocity (m/s) Oe = oedometer test T = triaxial test TOC = total organic carbon TC = total carbon s _v = undrained shear strength from falling cone test (kN/m²) s _r = remoulded shear strength Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology			

Site 7227/11-U-01

		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7227/11 - U - 01	
Equipment WIP sampler	Water depth 280.5 m	Latitude 72°01'15.81"N	Longitude 27°29'59.31"E	Depth below seabed 18.30 - 18.48 m		
Analytical results	Subsample	m	Lith.	Core description	s_u	s_r
$w = 21.4\% \gamma = 21.4\text{kN/m}^3$		18.30	82	CLAY, silty, gravelly (f-m), some sand 5Y - 4/1 Dark grey Crystalline angular/subangular fragments and subangular-rounded clay -and siltstone fragments		
		.40	2			
		18.48	85	Crystalline, angular pebbles		

		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7227/11 - U - 01C	
Equipment WIP sampler	Water depth 280.5 m	Latitude 72°01'15.81"N	Longitude 27°29'59.31"E	Depth below seabed 18.90 - 19.25 m		
Analytical results	Subsample	m	Lith.	Core description	s_u	s_r
$w_L = 49.4\%$ $w_p = 21.3\%$ $w = 19.2\%$ $\gamma = 21.2 \text{ kN/m}^3$ $V_{SH} = 1830 \text{ m/s}$ $V_{SV} = 1780 \text{ m/s}$	Magn. XRD	18.90		CLAY, gravelly (f-m), silty, sandy Angular silt - and claystone fragments Subangular crystalline pebbles CLAY, silty, some sand and gravel (f)	5Y - 4/1 Dark grey	
		19.00		Subangular-subrounded silt, -claystones and some crystalline rocks		250.0
	k_T OG TOC/TC	.10		Crystalline subangular pebble, 2 cm		225.0
		.20				
		19.25				
					</	

Site 7227/11-U-01

Project		Location		
21.3441.00: Quaternary samples Barents Sea 1987		7227/11 - U - 01C		
Equipment	Water depth	Latitude	Longitude	Depth below seabed
Hammer sampler	280.5 m	72°01'15.81"N	27°29'59.31"E	19.65 - 20.33 m
Analytical results	Subsample	m	Lith.	Core description
$w = 17.1\% \gamma = 21.5 \text{ kN/m}^3$ $w = 19.4\% \gamma = 20.8 \text{ kN/m}^3$ $w_L = 42.7\% w_p = 21.0\%$ $V_{sh} = 1834 \text{ m/s}$	Magn.	19.65		CLAY, sandy, silty, some gravel (f) Subrounded-subangular crystalline, sand -silt -and claystone fragments
	TOC/TC			5Y - 4/1 Dark grey
		.75		
	XRD			
		.85		
	K_r	.95		
		20.05		
	Oe K_r			
		.15		
	K_r Magn. OG TOC/TC	.25		
		20.33		
Comments:		Symbols: K_r = grain size distribution K_t = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) w_L - w_p = liquid and plasticity limits γ = unit weight of soil (kN/m ³) V_{sh} = horizontal sound velocity (m/s) V_{sv} = vertical sound velocity (m/s) Oe = oedometer test T = triaxial test TOC = total organic carbon TC = total carbon s_u = undrained shear strength from falling cone test (kN/m ²) s_r = remoulded shear strength Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology		

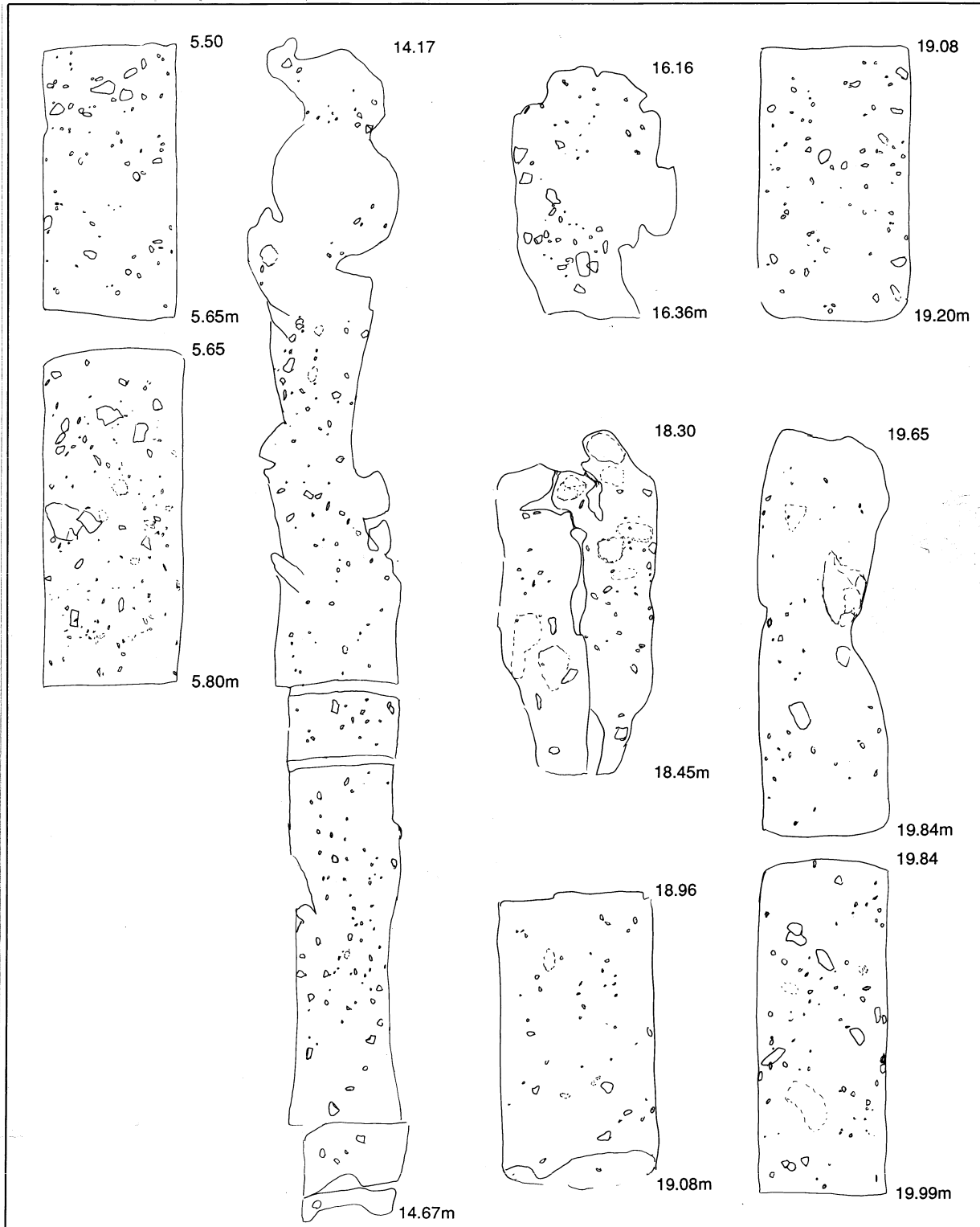
Project		Location		
21.3441.00: Quaternary samples Barents Sea 1987		7227/11 - U - 01C		
Equipment	Water depth	Latitude	Longitude	Depth below seabed
Hammer sampler	280.5 m	72°01'15.81"N	27°29'59.31"E	24.60 - 25.39 m
Analytical results	Subsample	m	Lith.	Core description
$w = 23.3\% \gamma = 20.5 \text{ kN/m}^3$ $w_L = 42.3\% w_p = 18.9\%$ $w = 21.9\% \gamma = 21.2 \text{ kN/m}^3$ $V_{sh} = 1940 \text{ m/s } V_{sv} = 1820 \text{ m/s}$ $V_{sh} = 1850 \text{ m/s } V_{sv} = 1840 \text{ m/s}$		24.60		CLAY, silty, sandy, gravelly (f-m) Subangular fragments of claystone/siltstone, sandstone and crystalline rocks
	Magn.	.70		5Y - 4/1 Dark grey
		.80		
	K_r	.90		
		25.00		Crystalline rounded fragment, 6 cm
	XRD			Siltstone, subangular, 1.5 cm
		.10		
	Magn. k_r			
	Magn.	.20		
	Magn.	.30		
	K_r	25.39		
Comments:		Symbols: K_r = grain size distribution K_t = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) w_L - w_p = liquid and plasticity limits γ = unit weight of soil (kN/m ³) V_{sh} = horizontal sound velocity (m/s) V_{sv} = vertical sound velocity (m/s) Oe = oedometer test T = triaxial test TOC = total organic carbon TC = total carbon s_u = undrained shear strength from falling cone test (kN/m ²) s_r = remoulded shear strength Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology		

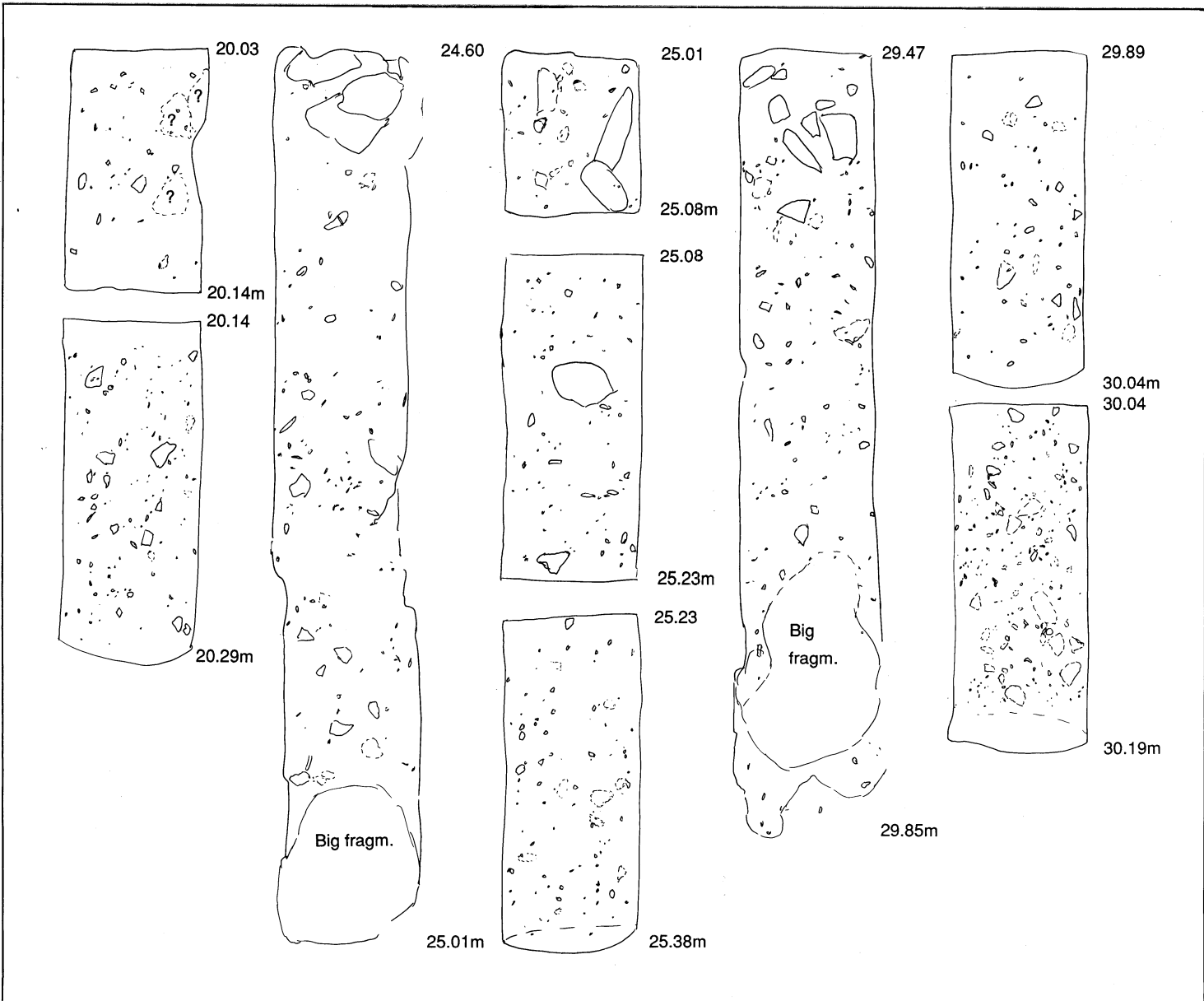
Site 7227/11-U-01

Site 7227/11-U-01

		Project 21.3441.00: Quaternary samples Barents Sea 1987		Location 7227/11 - U - 01C		
Equipment Hammer sampler		Water depth 280.5 m	Latitude 72°01'15.81"N	Longitude 27°29'59.31"E	Depth below seabed 29.47 - 30.25 m	
Analytical results	Subsample	m	Lith.	Core description	s_u	s_v
$w_L = 44.6\%$ $w_p = 20.1\%$ $w = 23.8\%$ $\gamma = 20.8\text{kN/m}^3$	Magn.	29.47	○	CLAY, silty, some sand and gravel (f) Angular silt - and claystones	5Y - 3/1 Very dark grey	
		.57	○	Crystalline subangular pebble, 1 cm		
		.67	○	Crystalline subangular pebbles		102.1
$w = 19.9\%$ $\gamma = 21.3\text{kN/m}^3$	M.Pal.	.77	X	Crystalline subrounded pebble, 7 cm (light biotite gneiss)		
	XRD	.87				115.8
	k_t	.97				150.0
$V_{BH}=1890\text{m/s}$ $V_{SV}=1905\text{m/s}$	Magn.	30.07				
	Magn.					
	k_t					175.0
$V_{BH}=1800\text{m/s}$ $V_{SV}=1785\text{m/s}$	TOC/TC OG	.17				
		30.25				
Comments: MPal, amino acid (BAL 1429): D-allo/L-iso = 0.064 (Elph. exc.)		Symbols: K_s = grain size distribution k_t = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) w_L - w_p = liquid and plasticity limits γ = unit weight of soil (kN/m ³) V_{BH} = horizontal sound velocity (m/s) V_{SV} = vertical sound velocity (m/s) Oe = oedometer test				T = triaxial test TOC = total organic carbon TC = total carbon s_u = undrained shear strength from falling cone test (kN/m ²) s_v = remoulded shear strength Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology

Site 7227/11-U-01





5.3.2 Sites 7230/05-U-05 and -05A

(Data from the two attempts at this site are merged.)

Seismic interpretation

The seismic stratigraphy is similar to site 7230/05-U-02, although the depths to the various reflections are slightly different. At this site an average sound velocity for the Quaternary sediments of 1726 m/s is found by comparing seismic and borehole data.

Lithology and mechanical properties

All samples except one from this site are described as silty clays containing some sand and fine gravel. The subangular - subrounded rock fragments are dominated by claystone, but some few sandstone are seen. As illustrated by the redrawn radiographs the samples are homogeneous and nonstratified. The sample at 17 m is described as a silty sand and has a faint layering.

The reflection 2- level corresponds to a clear soil mechanical boundary. Above the water content is above the plasticity limit and undrained shear vary between approx. 25 kPa and 95 kPa. The large variation in shear strength may be related to local sediment disturbance by the suggested iceberg ploughing which could soften a zone of affected sediments (Lien 1986; Lien and Christophersen 1986). The low sensitivity of the sediments at approx. 9 m (also recorded at other sites in the vicinity) could also be related to such remoulding.

Below reflection 2 the sediments are clearly overconsolidated. The water content is below the plasticity limit and undrained shear strength is more than 100kPa to more than 250kPa.

Age

Amino acid measurements on foraminifera (*Elphidium excavatum*) from approx. 9m gave a D-allo/ L-iso ratio of .035 which probably reflects a Middle to Late Weichselian age.

LOC. 7230/05-U-05-05A

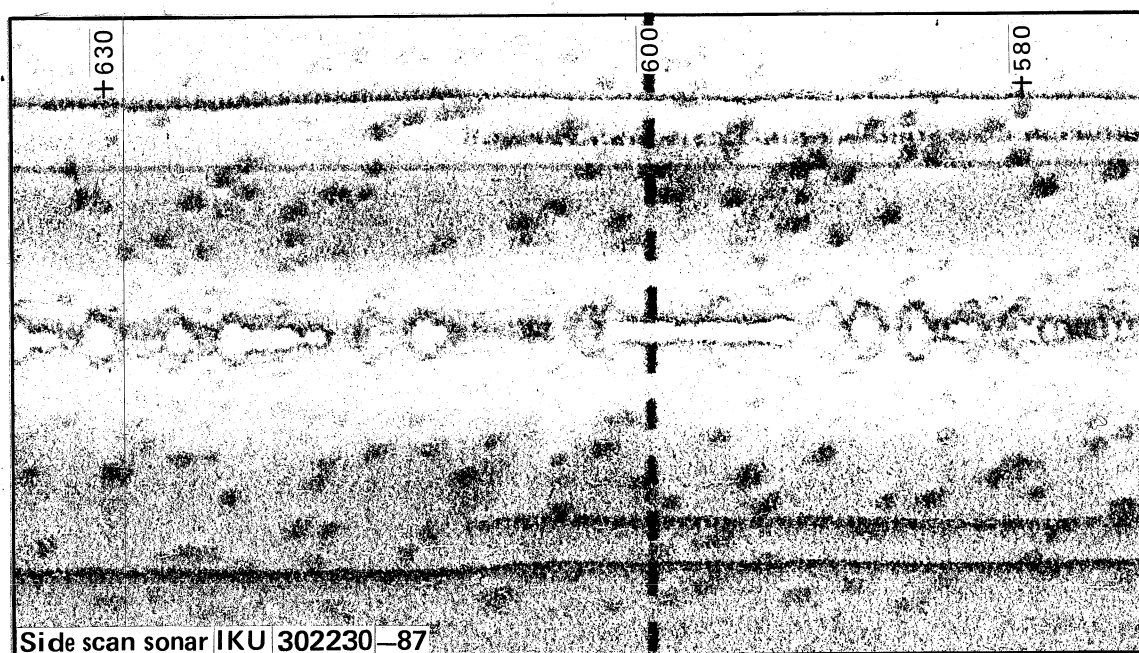
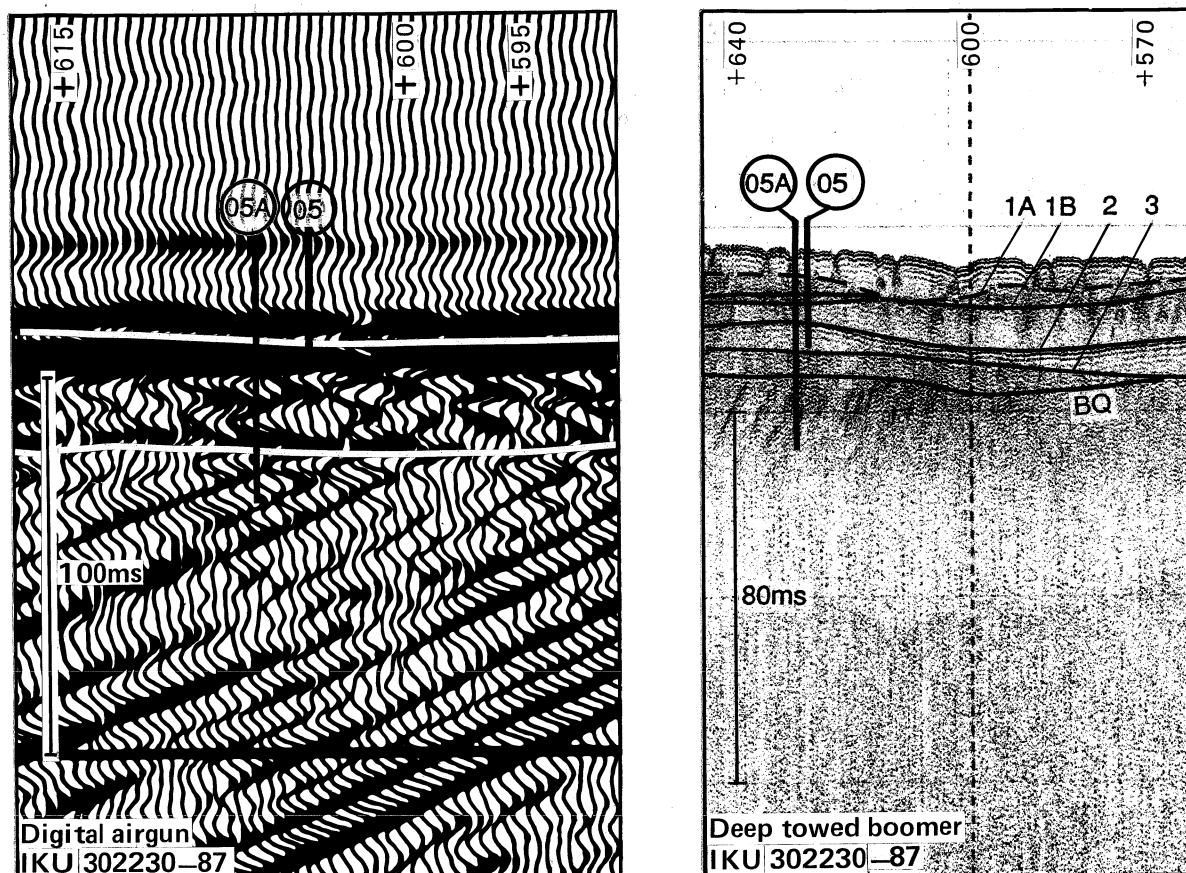


Figure 5.3 Seismic section across site 7230/05-U-05 and -05A. The figure is continued on the following pages by a soil boring summary sheet, a description sheet and drawings of radiographs for each sample.

SINTEF-GRUPPEN
Site 7230/05-U-05

IKU SINTEF-GRUPPEN		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7230/05 - U - 05		
Equipment Hammer sampler		Water depth 286.0 m	Latitude 72°42'07.14"N	Longitude 30°22'32.09"E	Depth below seabed 9.00 - 9.60 m		
Analytical results	Subsample	m	Lith.	Core description	s_u	s_r	
$w = 33.6\% \quad \gamma = 19.3 \text{ kN/m}^3$ $w = 32.8\% \quad \gamma = 19.5 \text{ kN/m}^3$ $w = 32.4\% \quad \gamma = 19.7 \text{ kN/m}^3$ $w = 34.7\% \quad \gamma = 18.4 \text{ kN/m}^3$ $w_L = 44.8\% \quad w_p = 23.2\%$		9.00		CLAY, silty, some sand and gravel (f) Subrounded-subangular claystone fragments	5Y - 4/1 Dark grey		
	MPal.					24.0	18.6
	Magn. XRD					25.0	18.6
						27.0	18.6
	K_f					21.1	
	Oe						
Comments: MPal, amino acid (BAL 1430): D-allo/L-iso=0.035 (Elph. exc.)		Symbols: K_f = grain size distribution T = triaxial test K_t = thermal conductivity TOC = total organic carbon XRD = mineralogy TC = total carbon w = water content (% water of dry sample) s_u = undrained shear strength from falling cone test (kN/m ²) w_L - w_p = liquid and plasticity limits s_r = remoulded shear strength γ = unit weight of soil (kN/m ³) Magn. = magnetic fabric V_{sh} = horizontal sound velocity (m/s) OG = organic geochemistry V_{sv} = vertical sound velocity (m/s) MPal = micropaleontology Oe = oedometer test					

IKU SINTEF-GRUPPEN		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7230/05 - U - 05		
Equipment WIP sampler		Water depth 286.0 m	Latitude 72°42'07.14"N	Longitude 30°22'32.09"E	Depth below seabed 11.93 - 12.43 m		
Analytical results	Subsample	m	Lith.	Core description	s_u	s_r	
$w = 25.7\% \quad \gamma = 16.4 \text{ kN/m}^3$	OG TOC/TC Magn.	11.93		CLAY, silty, some sand and gravel (f) Subangular-subrounded silt - and claystone fragments Subangular fragment claystone, 5 cm	5Y - 4/1 Dark grey		
	XRD	12.03				74.0	
	k_t			Limestone fragment, 3 cm		95.0	
	k_t Magn.			Rounded gravel fragment, 1 cm (Pyrite)			
	TOC/TC OG	12.43					
Comments:		Symbols: K_f = grain size distribution T = triaxial test K_t = thermal conductivity TOC = total organic carbon XRD = mineralogy TC = total carbon w = water content (% water of dry sample) s_u = undrained shear strength from falling cone test (kN/m ²) w_L - w_p = liquid and plasticity limits s_r = remoulded shear strength γ = unit weight of soil (kN/m ³) Magn. = magnetic fabric V_{sh} = horizontal sound velocity (m/s) OG = organic geochemistry V_{sv} = vertical sound velocity (m/s) MPal = micropaleontology Oe = oedometer test					

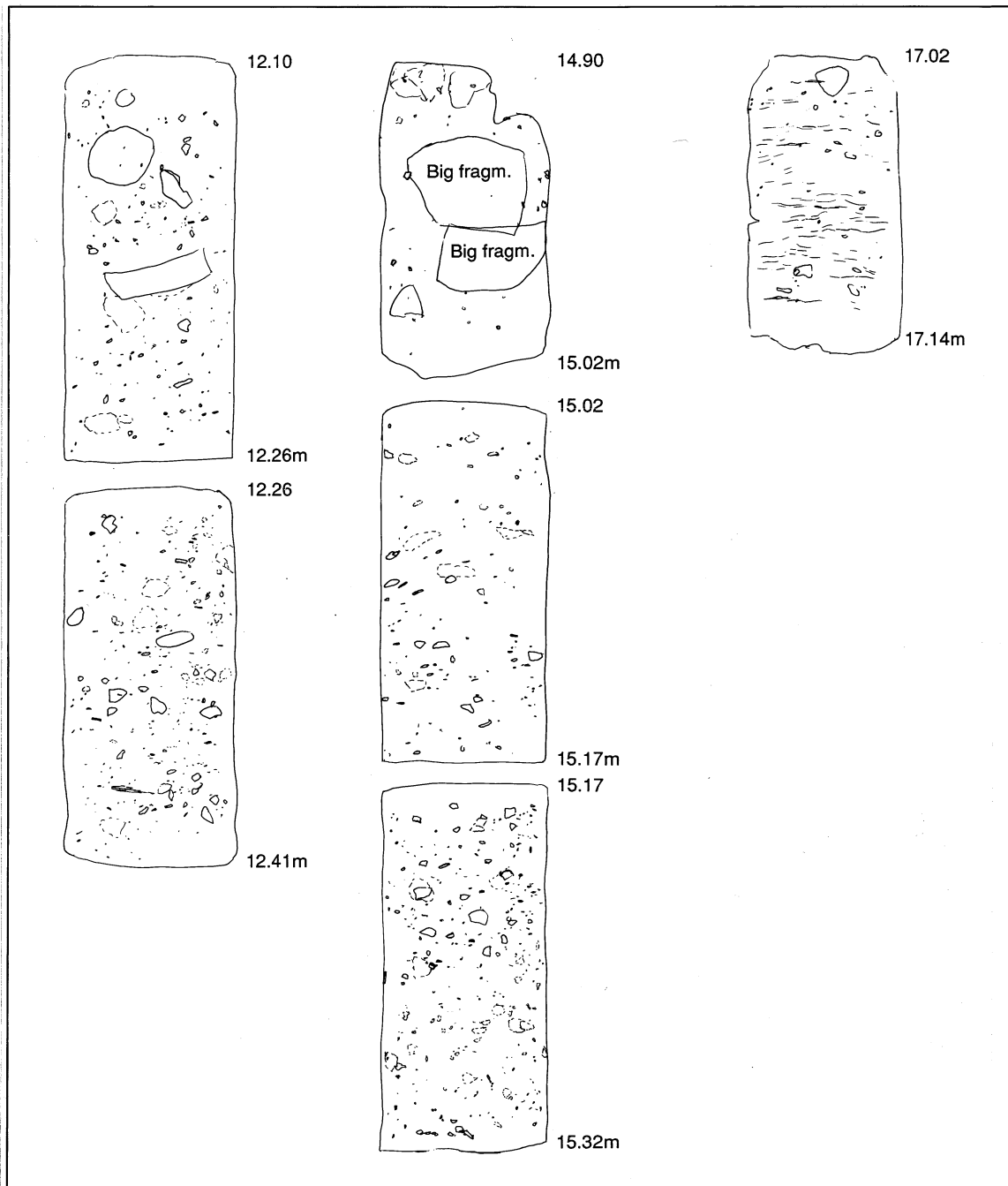
Site 7230/05-U-05

		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7230/05 - U - 05	
Equipment WIP sampler		Water depth 286.0 m	Latitude 72°42'07.14"N	Longitude 30°22'32.09"E	Depth below seabed 14.90 - 15.32 m	
Analytical results	Subsample	m	Lith.	Core description	s _u	s _r
w = 21.1% γ = 22.0kN/m³ V _{BH} = 1872 m/s w = 18.2% γ = 20.8kN/m³ w _L = 44.5% w _p = 21.0% V _{BH} =1888m/s V _{sv} =1787m/s	Magn.	14.90		CLAY, silty, some sand and gravel (f) Subangular silt -and claystone fragments 2 sandstone fragments, 4 cm and 2 cm, subangular Chert ?, 4 cm Red, angular pebble (chert?) Sandstone fragment, subangular	5Y - 3/1 Very dark grey	115.8
	K _t	15.00				245.0
	Oe/T	.10				250.0
	Magn.	.20				250.0
	k _t	.30				
		15.32				

		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7230/05 - U- 05A	
Equipment Hammer sampler		Water depth 286.0 m	Latitude 72°42'06.00"N	Longitude 30°22'31.64"E	Depth below seabed 17.00 - 17.14 m	
Analytical results	Subsample	m	Lith.	Core description	s _u	s _r
w = 12.8% γ = 22.5kN/m³	K _t Magn.	17.00		SAND (f), some silt. Occasional gravel (f) fragments Limestone fragment, 1 cm, subrounded	5Y - 4/1 Dark grey	
	K _u XRD	.10		Thin layer of sand (f)		
		17.14				

Site 7230/05-U-05

Site 7230/05-U-05



5.3.3 Site 7230/08-U-01

Seismic interpretation

The Quaternary sediments are acoustically transparent at this site, and only one Quaternary seismic unit is present. Top bedrock is interpreted at about 45 ms as a subhorizontal reflection both on the digital seismic and on the Deep towed boomer profile. The upper 20 ms of the interpreted bedrock has a chaotic reflection pattern which also has some subhorizontal trends. This may represent a zone of glacial deformation of local bedrock.

Lithology and mechanical properties

All samples comprize silty, sandy, clay with some scattered fine gravel. The lowermost two samples show a very faint horizontal banding which may represent zones of deformation or lamination. With this exception all samples are homogeneous and nonstratified.

Rock fragments are typically subangular to subrounded and comprize mainly claystones - siltstone and some sandstone. Some Crystalline rocks do occur, and are more angular. The watercontent is above the plasticity limit. Undrained shearstrength varies between 30 and 95 kPa. An oedometer test at 20.40 m show a slight overconsolidation, and although there is a considerable scatter in the measured undrained shearstrength it appears that there is a slight overconsolidation at least in the upper part of the borehole.

Age

An AMS 14C - dating on a reworked shell fragment at 20.05 m gave an age of 42 420 $\pm$ 1780 BP. If finite, this is a maximum age of the sampled sediment.

LOC. 7230/08-U-01

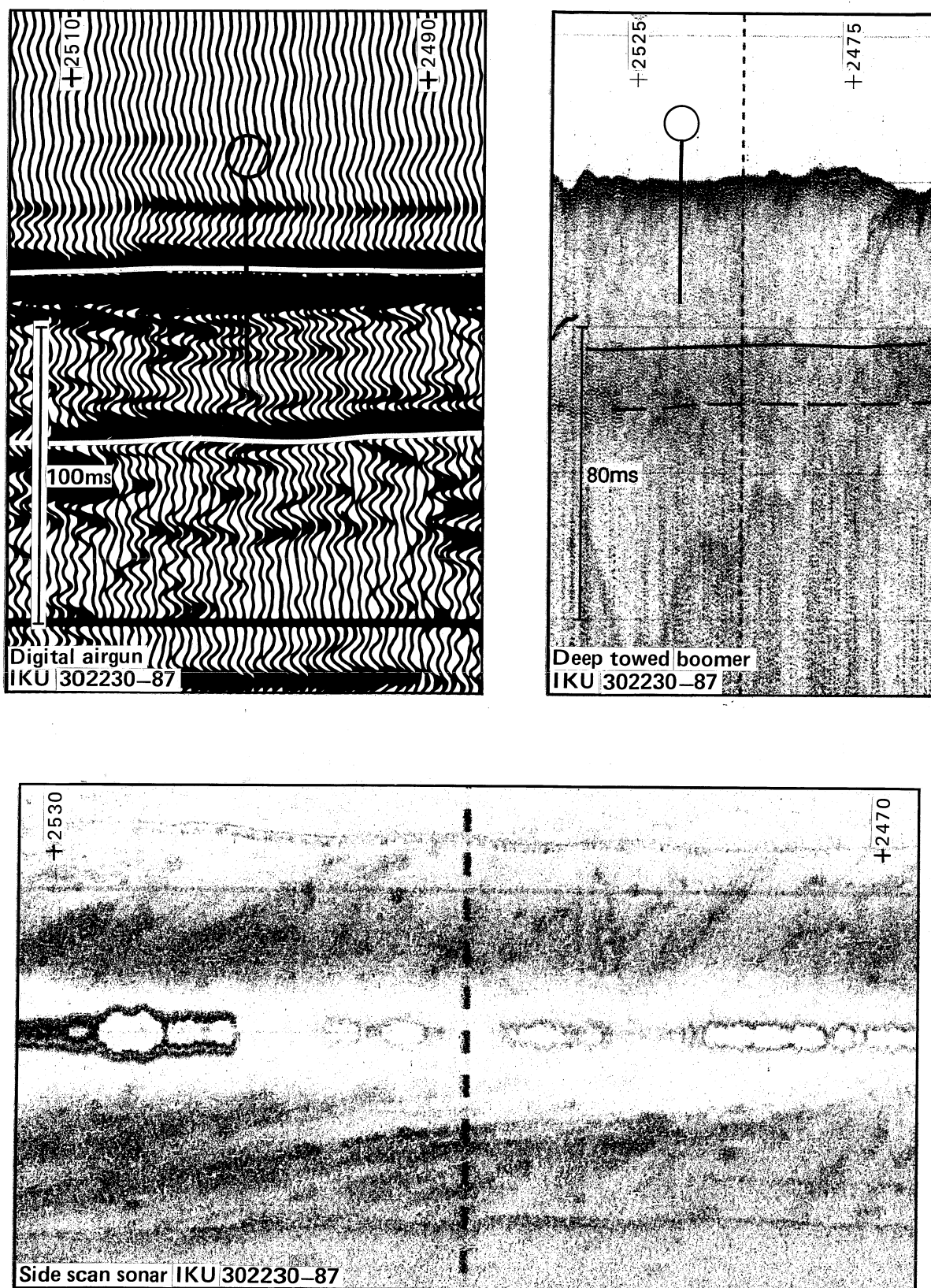
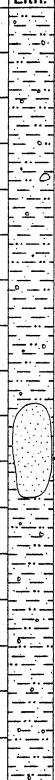


Figure 5.4 Seismic section across site 7230/08-U-01. The figure is continued on the following pages by a soil boring summary sheet, a description sheet, and drawings of radiographs for each sample.

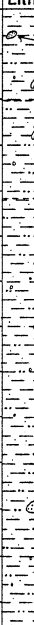
IKU SINTEF GROUP		POS.: N E		SEISMIC LINE: IKU 302230-87		SP: 2500		WATER DEPTH: 283.0 m		SITE: 7230/08-U-01					
UTM ZONE : N E		REFERENCES:		IKU REPORT: 21.3441.00/01/89		ACCESS-ABILITY: RESTRICTED									
NO OF SAMPLES:		Σ SAMPLE LENGTH: 3.52 m		ROCKHEAD: 50 ? m											
DEPTH(m)	LITHO-LOGICAL COLUMN	WATER CONTENT (%)	UNIT WEIGHT (kN/m ³)	S _u ▽-F.CONE (▽=S _p) ⊙-1 ax ⊙ ₃ -3 ax kN/m ²	SOUND VELOCITY m/s H _o =HORIZONTAL V=VERTICAL	COLOUMBIAIAN ATTRACTION, a (kN/m ²)	tan φ	PRECONSOLIDATION PRESSURE, p _c (kN/m ²)	GRAIN SIZE DISTRIBUTION % < d	DATING	MAGN.	MISC. ANALYSES	SEISMIC REFLECTIONS		COMMENTS
													INTERVAL VELOCITY (m/s)	(ms)	
10															
20															
30															
40															
50															
60															
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Project		Location		
21.3441.00: Quaternary samples Barents Sea 1987		7230/08 - U - 01		
Equipment	Water depth	Latitude	Longitude	Depth below seabed
WIP sampler	283.0 m	72°25'45.59"N	30°22'34.38"E	14.03 - 14.54 m
Analytical results	Subsample	m	Lith.	Core description
$w_L = 48.9\%$ $w_p = 23.8\%$	Magn. K_t TOC/TC OG	14.03		CLAY, silty, sandy, some gravel (f) 5Y - 4/1 Dark grey
$w = 32.6\%$ $\gamma = 19.4 \text{ kN/m}^3$		.13		Angular - subrounded fragments of claystone - sandstone and crystalline rocks
$V_{SH} = 1721 \text{ m/s}$ $V_{SV} = 1650 \text{ m/s}$		.23		
$w = 27.0\%$ $\gamma = 20.1 \text{ kN/m}^3$		.33		CLAY, silty, some gravel (f) 5Y - 3/1 Very dark grey
$V_{SH} = 1630 \text{ m/s}$	Magn. k_r	.43		Angular claystone fragments
	Magn. k_r	.54		Siltstone fragment, rounded, 1 cm
Comments:				
Symbols: K_t = grain size distribution k_r = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) $w_L - w_p$ = liquid and plasticity limits γ = unit weight of soil (kN/m^3) V_{SH} = horizontal sound velocity (m/s) V_{SV} = vertical sound velocity (m/s) Oe = oedometer test T = triaxial test TOC = total organic carbon TC = total carbon s_u = undrained shear strength from falling cone test (kN/m^2) s_r = remoulded shear strength Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology				

 IKU BENTEC-GRUPPEN		Project 21.3441.00: Quaternary samples Barents Sea 1987		Location 7230/08 - U - 01				
Equipment WIP sampler		Water depth 283.0 m	Latitude 72°25'45.59"N	Longitude 30°22'34.38"E	Depth below seabed 18.52 - 19.37 m			
Analytical results	Subsample	m	Lith.	Core description	s_u	s_r		
w = 34.3% γ = 19.0kN/m³	Magn.	18.52		CLAY, silty, some sand and gravel (f)	30.4	15.2		
				5Y - 4/1 Dark grey				
				Subrounded - subangular claystone fragment (one crystalline fragment)				
V _{SH} =1674m/s V _{SV} =1638m/s	OG TOC/TC							
w = 28.1% γ = 19.9kN/m³	Magn.	19.02		Sandstone fragment, rounded, ~10 cm	36.0			
V _{SH} =1686m/s V _{SV} =1660m/s	k _T Magn.	.12			79.5	52.5		
w = 28.1% γ = 19.9kN/m³	Magn.	.22						
V _{SH} =1686m/s V _{SV} =1660m/s	XRD TOC/TC OG	.32						
		19.37						
Comments:			Symbols:					
			K _t = grain size distribution T = triaxial test					
			K _r = thermal conductivity TOC = total organic carbon					
			XRD = mineralogy TC = total carbon					
			w = water content (% water of dry sample) s _u = undrained shear strength from falling cone test (kN/m²)					
			w _L -w _P = liquid and plasticity limits s _r = remoulded shear strength					
			γ = unit weight of soil (kN/m³) Magn. = magnetic fabric					
			V _{SH} = horizontal sound velocity (m/s) OG = organic geochemistry					
			V _{SV} = vertical sound velocity (m/s) MPal = micropaleontology					
			Oe = oedometer test					

Site 7230/08-U-01

		Project 21.3441.00: Quaternary samples Barents Sea 1987		Location 7230/08 - U - 01		
Equipment WIP sampler		Water depth 283.0 m	Latitude 72°25'45.59"N	Longitude 30°22'34.38"E	Depth below seabed 20.00 - 20.66 m	
Analytical results	Subsample	m	Lith.	Core description	s _u s _r	
w = 31.5% γ = 19.3kN/m³ V_{SH}=1695m/s V_{SV}=1620m/s w = 28.8% γ = 19.9kN/m³ V_{SH}=1835m/s V_{SV}=1708m/s w = 30.9% γ = 18.9kN/m³ w_L = 43.4% w_p = 13.2% V_{SH}=1782m/s V_{SV}=1663m/s	14 _C	20.00		CLAY, silty, sandy, some gravel (f) Angular claystone fragments (f) Siltstone fragment, rounded Shell fragment	5Y - 4/1 Dark grey	
	Magn. XRD	.10		Rounded - subangular silt -and claystone fragments		62.3
	k _r Magn.	.20		Sandstone fragment, rounded	5Y - 3/1 Very dark grey	
	k _r	.30		Crystalline angular pebble 0.7 cm Limestone fragment, subangular, 1.5 cm Siderite-nodule, 2 cm		69.2
	K _i Oe	.40				44.1
	k _r Magn. TOC/TC OG	.60				
		20.66				
Comments: 20.07 m Shell fragment 14 _C (Va-9879. 42420 ± 1780)			Symbols: K _i = grain size distribution k _r = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) w _L -w _p = liquid and plasticity limits γ = unit weight of soil (kN/m ³) V _{SH} = horizontal sound velocity (m/s) V _{SV} = vertical sound velocity (m/s) Oe = oedometer test T = triaxial test TOC = total organic carbon TC = total carbon s _u = undrained shear strength from falling cone test (kN/m ²) s _r = remoulded shear strength Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology			

		Project 21.3441.00: Quaternary samples Barents Sea 1987		Location 7030/08 - U - 01			
Equipment WIP sampler		Water depth 283.0 m	Latitude 72°25'45.59"N	Longitude 30°22'34.38"E	Depth below seabed 23.92 - 24.62 m		
Analytical results	Subsample	m	Lith.	Core description	s _u	s _r	
w = 29.7% γ = 19.9kN/m³ V _{SH} =1642m/s V _{SV} =1647m/s w = 29.2% γ = 19.8kN/m³ w = 29.2% γ = 20.1kN/m³ V _{SH} =1666m/s V _{SV} =1642m/s w = 27.5% γ = 19.2kN/m³ w _L = 47.6% w _p = 24.7% V _{SH} =1670m/s V _{SV} =1677m/s V _{SH} =1670m/s V _{SV} =1632m/s	Magn. k _T	23.92		CLAY, silty, some sand and gravel (f) Subangular claystone fragments Sandstone fragment, subangular	5Y -4/1 Dark grey	52.5 31.9	
	XRD Magn.	24.02		Crystalline pebble, 0.8 cm CLAY, silty, some gravel Quartzitic pebble, 1.5 cm	Angular claystone fragments (f)		
	k _T	.12		CLAY, silty, sandy, some gravel (f) Subangular claystone fragments		60.3 44.1	
	XRD Magn. k _T TOC/TC	.22				74.1 51.0	
	k _T	.32				77.0	
	T	.42					
	k _T Magn. TOC/TC	.52		Siltstone fragment, rounded, 0.5 cm			
		24.62					
Comments:			Symbols:				
			K _i = grain size distribution K _r = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) w _L -w _p = liquid and plasticity limits γ = unit weight of soil (kN/m³) V _{SH} = horizontal sound velocity (m/s) V _{SV} = vertical sound velocity (m/s) Oe = oedometer test				
			T = triaxial test TOC = total organic carbon TC = total carbon s _u = undrained shear strength from falling cone test (kN/m²) s _r = remoulded shear strength Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology				

Site 7230/08-U-01

Site 7230/08-U-01

IKU SINTEF-GRUPPEN		Project 21.3441.00: Quaternary samples Barents Sea 1987			Location 7230/08 - U - 01	
Equipment WIP sampler		Water depth 283.0 m	Latitude 72°25' 45.59"N	Longitude 30°22' 34.38"E	Depth below seabed 29.86 - 30.66 m	
Analytical results	Subsample	m	Lith.	Core description	s_u	s_r
$w = 24.2\% \quad \gamma = 20.7 \text{ kN/m}^3$ $w_L = 41.5\% \quad w_p = 20.9\%$ $w = 24.3\% \quad \gamma = 20.5 \text{ kN/m}^3$ $V_{SH} = 1753 \text{ m/s} \quad V_{SV} = 2055 \text{ m/s}$ $V_{SH} = 1706 \text{ m/s} \quad V_{SV} = 1724 \text{ m/s}$ $V_{SH} = 1643 \text{ m/s} \quad V_{SV} = 1797 \text{ m/s}$	OG	29.86		CLAY, silty, sandy, some gravel (f)		
	TOC/TC	.96		Subangular fragments of claystone - sandstone		
	Magn.			5Y - 4/1 Dark grey		
	XRD	30.06		Subrounded crystalline pebble, 5 cm		
	k_T					
	Magn.	.16		Crystalline rock fragment, rounded, 4 cm	71.6	
	XRD					
	k_T	.26			71.6	
		.36			58.4	
		.46				
		.56		Siltstone fragment, subrounded, 3 cm		
	k_T					
	Magn.	30.66			77.0	
Comments: 30.29 - 30.52 m disturbed						
Symbols: K_f = grain size distribution k_T = thermal conductivity XRD = mineralogy w = water content (% water of dry sample) $w_L - w_p$ = liquid and plasticity limits γ = unit weight of soil (kN/m³) V_{SH} = horizontal sound velocity (m/s) V_{SV} = vertical sound velocity (m/s) Oe = oedometer test T = triaxial test TOC = total organic carbon TC = total carbon s_u = undrained shear strength from falling cone test (kN/m²) s_r = remoulded shear strength Magn. = magnetic fabric OG = organic geochemistry MPal = micropaleontology						

LOC. 7030/03-U-01

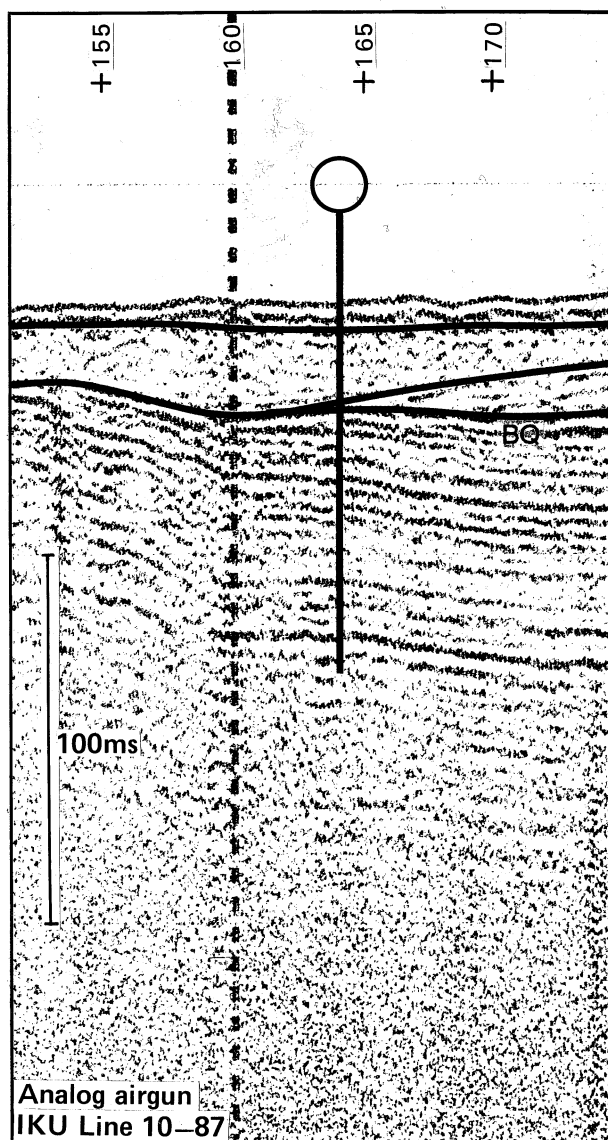
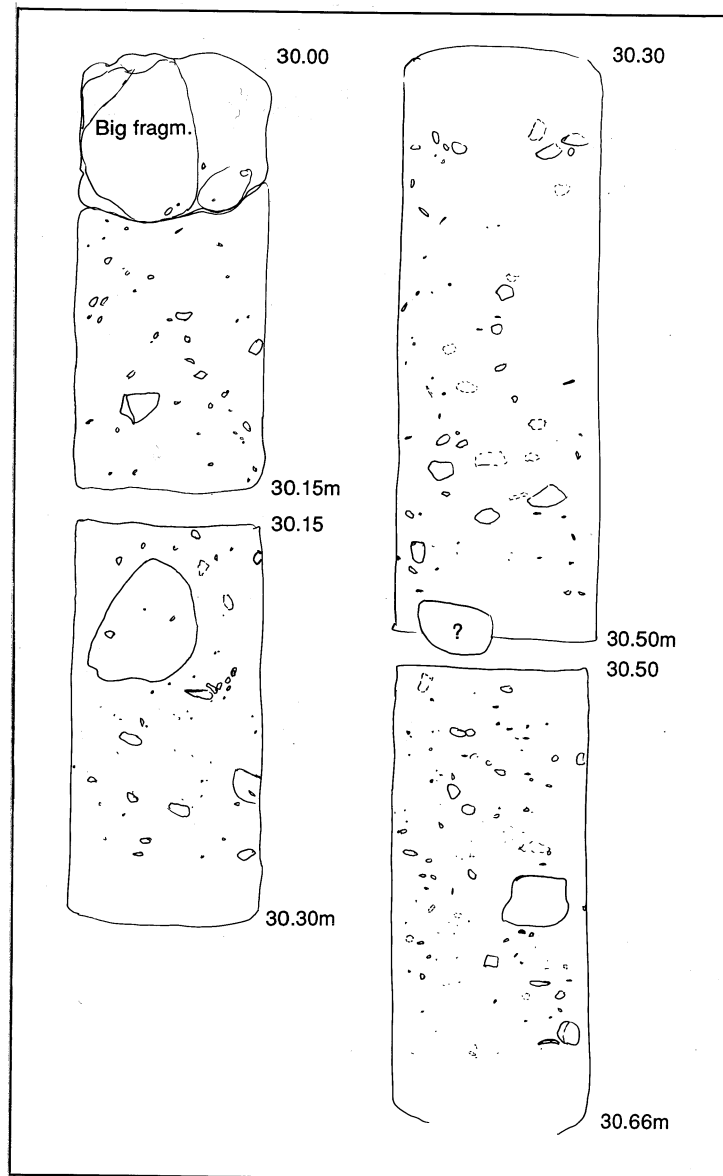


Figure 6.7 Seismic section across site 7030/03-U-01. The figure is continued on the following pages by a soil boring summary sheet, a description sheet and drawings of radiographs for each sample.

Site 7230/08-U-01



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APPENDIX 1

FIELD WORK

A.1 General

The drilling cruise commenced 22.07.87 and lasted until 09.09.87.

The contractor for the drilling operations was Offshore Support Services A/S in Oslo, using the drill ship M/S "Bucentaur" (Figure A.1.1). As bed-rock coring machine the DB 1500S from Diamant Boart, Belgium/Norway was used, and Dia-Team, Norway provided diamond drilling staff. This equipment was used in the continuation of borehole 7230/05-U-05 after completion of heat flow measurement.



Figure A.1.1 The drill ship M/S "Bucentaur".

A.2 Technical Data

Drill ship M/S "Bucentaur".

Length over all	78.07 m
Breadth moulded	16.00 m
Draft fully loaded	5.55 m
Displacement	4.470 tonnes
Gross register tonnage, international	2.768 tonnes

Main engine: Four Wärtsilä diesels, type Vasa 8R22HE, each driving a van Kaick generator of 1200 kW at 1200 RPM, 600V/60 periods AC.

Propulsion units: Two azimuthing thrusters with CP propeller in nozzle, make Liaaen.

Bow thrusters: Two tunnel thrusters with CP propeller, make KaMeWa.

Dynamic positioning system: One GEC simplex system with GEC-Elliott 2050 computer, video display and joystick. Positioning reference by deep water tautwire system and by Simrad HPR T209 hydro-acoustic system.

Hard-tie winch: One Ingersoll Rand, max pull 10,000 lbs, with auto. Failsafe brake.

Elevator: Wirth, type special pipe pick-up chuck, suitable for 5 1/2" F.H. joints.

Slips: Wirth power slips type B12, with inserts for 5" pipe.

Heavy lift winch: One winch make Pusnes, capacity on single drum 2 lengths each 1200 m wire 36 mm dia. Braking force 90 tonn.

Mud system: Complete dry mud system with mud mixing equipment mud storage, and mud pumps (three X: WIRTH TPK 51/2" x 51/2", 84 HP hydraulic motor, capacity 1600 l/min at 20 bar).

Main drill string

Drill pipe: 2000 m of API-5" Grade E, range II, 19.51 lbs/ft with 51/2" tool joints, 4" I.D.

Drill collars: Sixteen, each 5 m long, 7" O.D. and 4" I.D. with 51/2" tool joints.

Diamond core drill system Drilling machine: DBH 1500S electro/hydraulic drill.

Spindle opening: 127 mm

Rotating speed: Max 900 rpm.

Drill string: Wireline HP Heavy duty rods O.D. 88.9 mm, mI.D. 70 mm, length 10 ft, weight 38 kg. Back-up NR Heavy duty wire line drill rods, O.D. 69.9 mm, I.D. 60.3 mm.

Core barrels: Triple tube, 10 ft with split tube.

Core diameters: HR triple tube 54.2 mm, NR triple tube 38.1 mm.

Drilling capacities: HR-1000 m, NT 1500 m.

Seabed template: Fugro SEACLAM with hydraulic pipe clamping system, inclinometers and underwater Tv camera.

A.3 Standard drilling operation (Figure A.1.2)

- (a) M/S "Bucentaur" moves onto position and sets the dynamic positioning system (D.P.) in operation.
- (b) Seabed re-entry template is lowered to the seabed, and constant tension is applied to the template cables via the template heave compensation system.
- (c) The 5" drill pipe with open centre bit is lowered on a guided template cable rider to the seabed.
- (d) The Quaternary overburden is penetrated until the drillbit is drilled into rockhead. Samples of Quaternary sediments are recovered during drilling.
- (e) The powerswivel heave compensator is then set to give the chosen bit weight on the API string (often slightly in excess of the maximum weight that may be required by the diamond core bit used for the coring), and the 5" drill string is clamped to the seabed template.
- (f) The piggyback coring wireline core barrel is then run into the hole.
- (g) Core drilling commences, with length of each run being determined by the length of the inner tube (3.05 m), or by the drilling conditions. Coring continues for 1-2 days. Typical production rates are 1.5-3.0 m/h.
- (h) The coring pipe and subsequently the 5" drill pipe are pulled and stored on the deck. The seabed template is hoisted into the moonpool, D.P. is disengaged and the vessel proceeds to the next location.

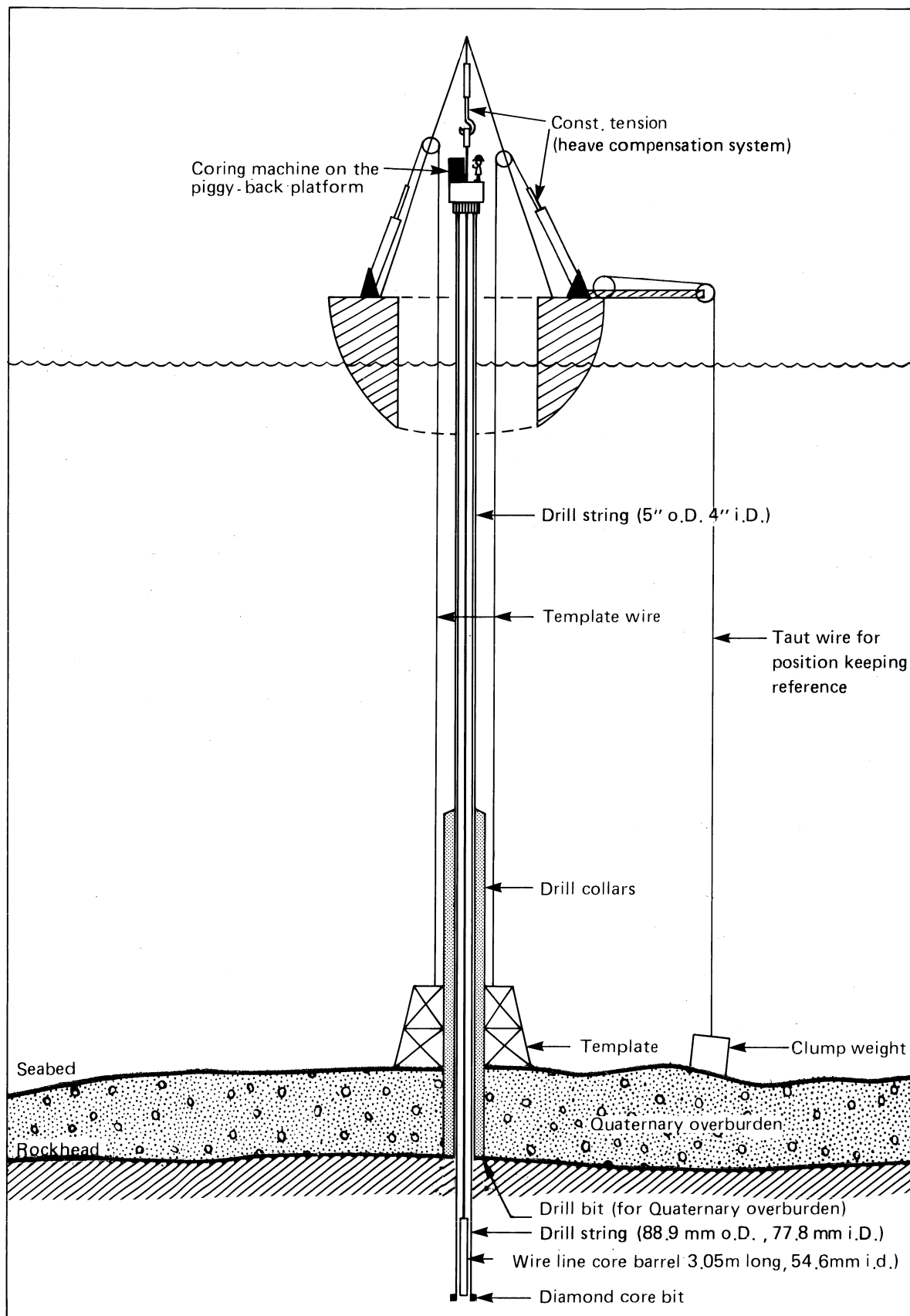


Figure A.1.2 Sketch showing the drilling operation for M/S "Bucentaur".

Two types of standard soil sampling equipment were used in addition to the piggyback coring. These were: The Fugro Wip sampler and a hammersampler. These two systems were combined with 3 inch and 2 inch steel sampling tubes, respectively.

The Wip system comprises a hydraulically operated jack that is lowered down inside the drill string and latched with the sampling tube cutter at drill bit level. The sampling tube is then pushed down into undisturbed sediments and cuts a cylindrical sample.

The hammersampler is mechanically operated from a winch on the main deck and comprises a load that can move freely a certain distance up and down along a shaft which on the lower end is connected to the tube. During sampling the load is pulled up and allowed to drop freely down about 10-30 times and by this the sampling tube is hammered into the sediment.

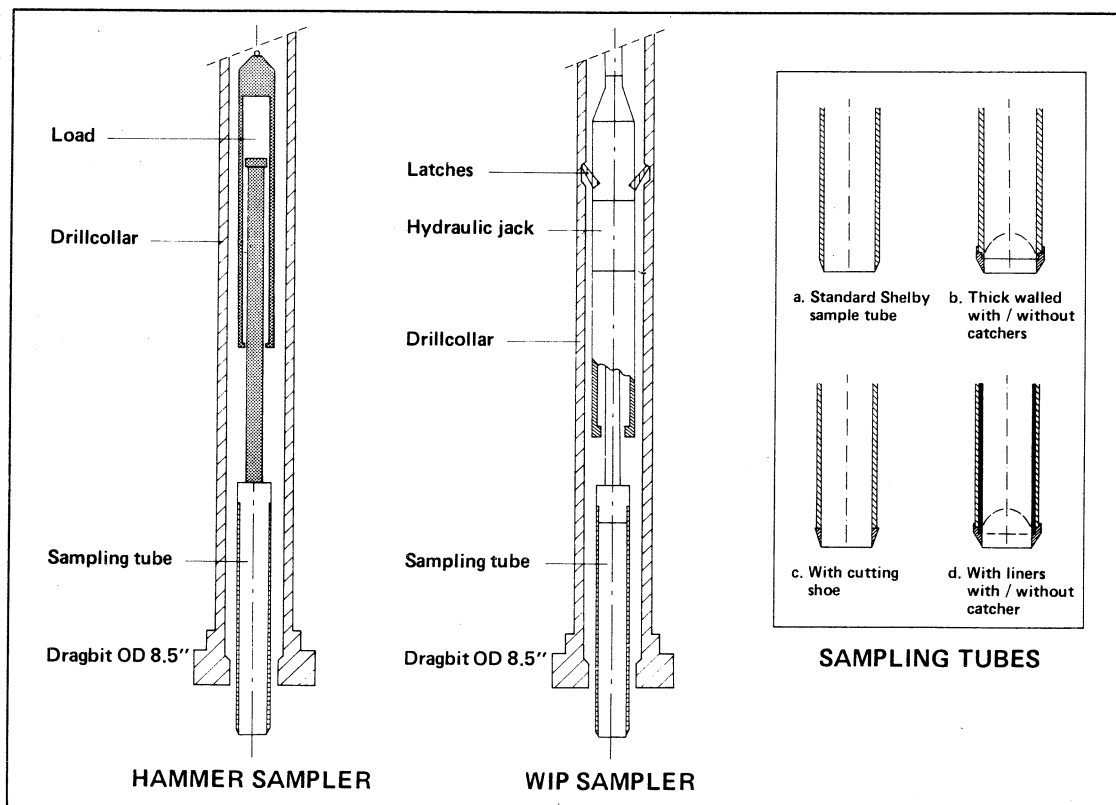


Figure A.1.3 Hammer sampler and wip sampler.