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A COLLECTION OF OCEANOGRAPHIC AND GEOACOUSTIC DATA IN VESTFJORDEN - OBTAINED FROM THE MILOC SURVEY ROCKY ROAD

JENSERUD, Trond

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Director of Research

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8) ABSTRACT

A brief overview of oceanographic and geoacoustic data from the Vestfjorden area is given. The overview is based on data collected during the MILOC survey Rocky Road, which took place during 1992-95.

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CONTENTS

A COLLECTION OF OCEANOGRAPHIC AND GEOACOUSTIC DATA IN VESTFJORDEN - OBTAINED FROM THE MILOC SURVEY ROCKY ROAD.

1 INTRODUCTION

In this note I provide some information about the oceanographic conditions and geoacoustic properties of the Vestfjord region (Norway). The information is based on the Environmental ASW guide for the Vestfjord [1] and data collected during the NATO MILOC survey ROCKY ROAD [2], [3], [4] and [5].

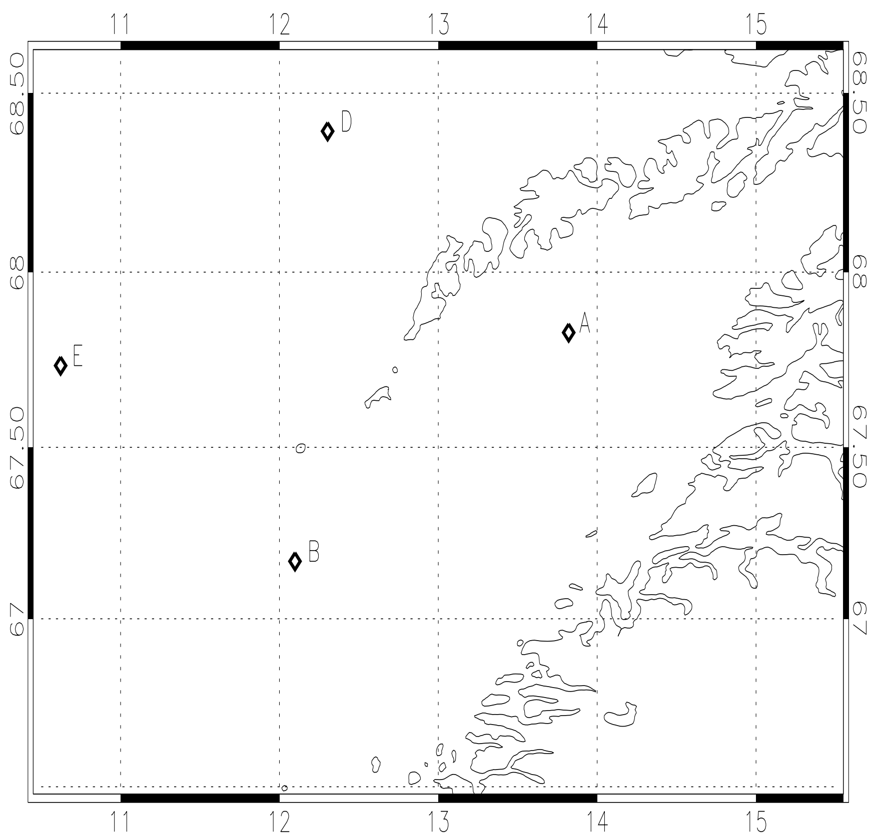

Figure 1.1: The Vestfjord area and the location of tracks for geoacoustic measurements in Rocky Rock

Table 1 shows the locations of some of the tracks for acoustic and oceanographic measurements which were carried out during the Rocky Road survey.

Track A-B is along the axis of Vestfjorden. The track is characterized by almost constant water depth and complex oceanography. Track D-E is along the shallow water shelf outside Vestfjorden. The water depth is relatively constant also in this region, the oceanography is less complex and the sediments are harder than inside the fjord.

Station	Latitude	Longitude	Water depth (m)
A	$67^o49'44''$	$13^o49'15''$	260
B	$67^o10'08''$	$12^o05'52''$	260
C	$68^o23'41''$	$12^o18'12''$	130
D	$67^o44'05''$	$10^o37'21''$	180

Table 1.1: Locations of Rocky Rock stations A, B, C and D

2 OCEANOGRAPHY

The Vestfjord is located on the northwestern Norwegian coast. Figure 2.1 shows a map of the Vestfjord and the Lofoten islands. The principal currents that determine the oceanographic structure in the region are indicated in the figure. The Vestfjord is about 200 km in length, with a width varying from 70km at the seaward end narrowing to about 20 km. The majority of the region has a water depth between 100 m and 300 m, with steeper topography on the eastern side than on the western. There is a shallow sill, rising to about 250 m at the entrance. The largest depths, more than 500 m, is found in the inner parts of the fjord. The outer shelf to the west of Vestfjorden is shallow with relatively constant depth.

There are three main contributions to the water structure in Vestfjorden: The Norwegian Coastal Current (NCC), the Norwegian Atlantic Current (NAC) and freshwater runoff from adjacent fjords. The NCC consistes of a wedge of coastal water (less than 35 ppt salinity) extending out from the shore. The NCC is narrow and shallow, occupying the upper 50-100 m. In shelf regions deeper than this, the NCC lies on top of the denser, more saline waters of the NAC. NCC is highly variable in volume and composition.

Horizontal sections at 20 m depth, Figs. 2.2 and 2.3, show the extension and composition of the coastal current in May and October. The figures indicate a temperature front in the outer part of the fjord.

The water in the upper layers in Vestfjorden originates mainly from the NCC, while the deeper water is formed by the NAC. Tidal effects and winds also play an important role in determining the circulation and mixing in Vestfjorden.

At the outer shelf, to the west of Vestfjorden, the water structure is dominated by the strongly meandering NAC at its western boundary with the colder, fresher Norwegian Sea Deep Water (NSDW), see Figure 2.3. The shelf water itself is expected to be a mixture of NCC and the mixed water flowing out of Vestfjorden.

The oceanographic variability in the area is indicated in Fig. 2.4 which shows all profiles collected during a so-called synoptic survey in the period 2-4 May 1995.

Figure 2.5, 2.6 and 2.7 show profiles of temperature and salinity along the fjord axis in May and October 1995. There is considerable variability along the track.

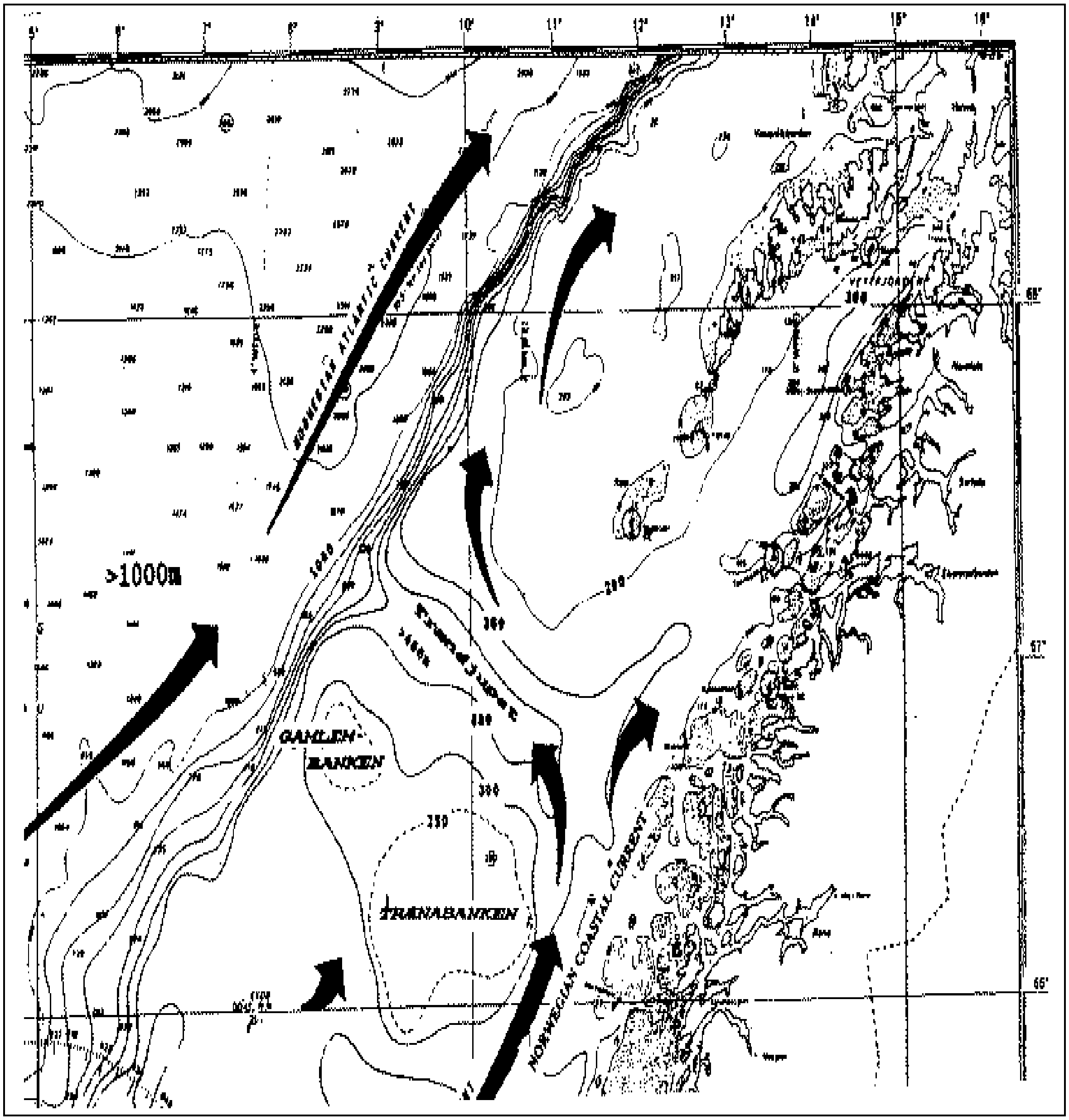

Figure 2.1: The principal currents in Vestfjorden and Lofoten islands

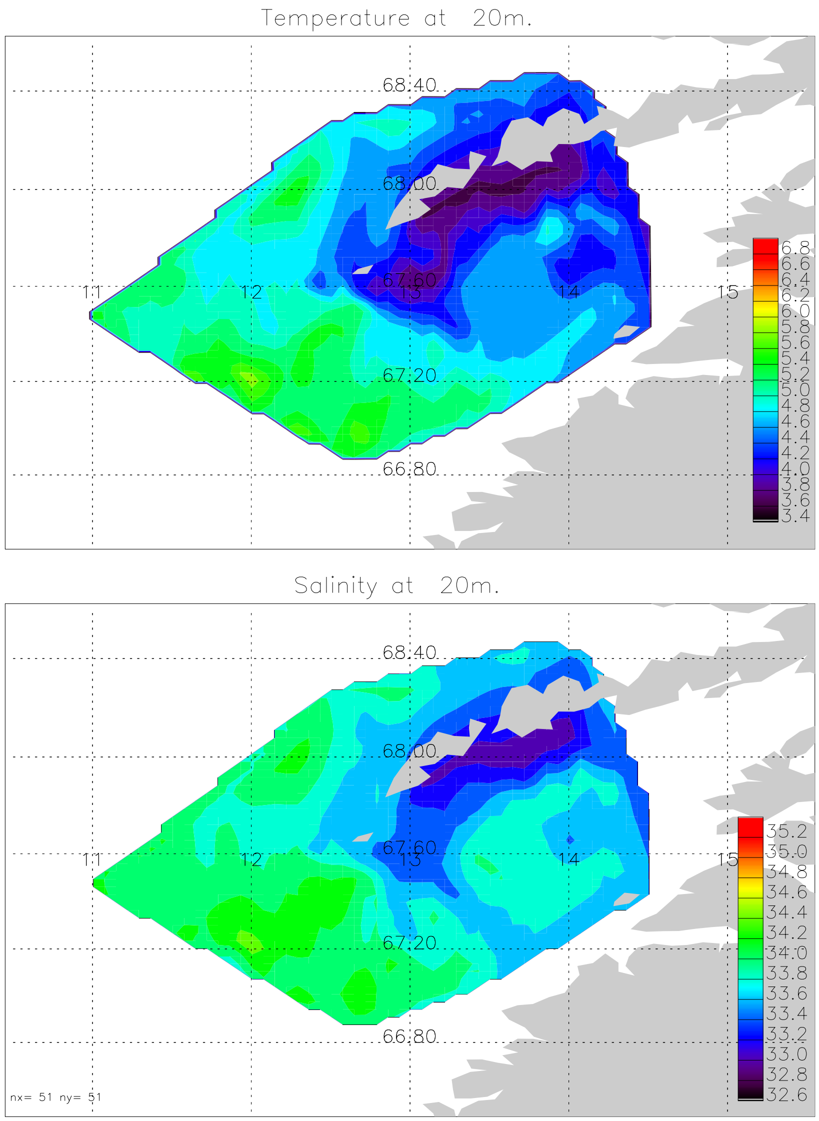

Figure 2.2: Rocky Road synoptic survey May 1995. Temperature and salinity at 20m depth.

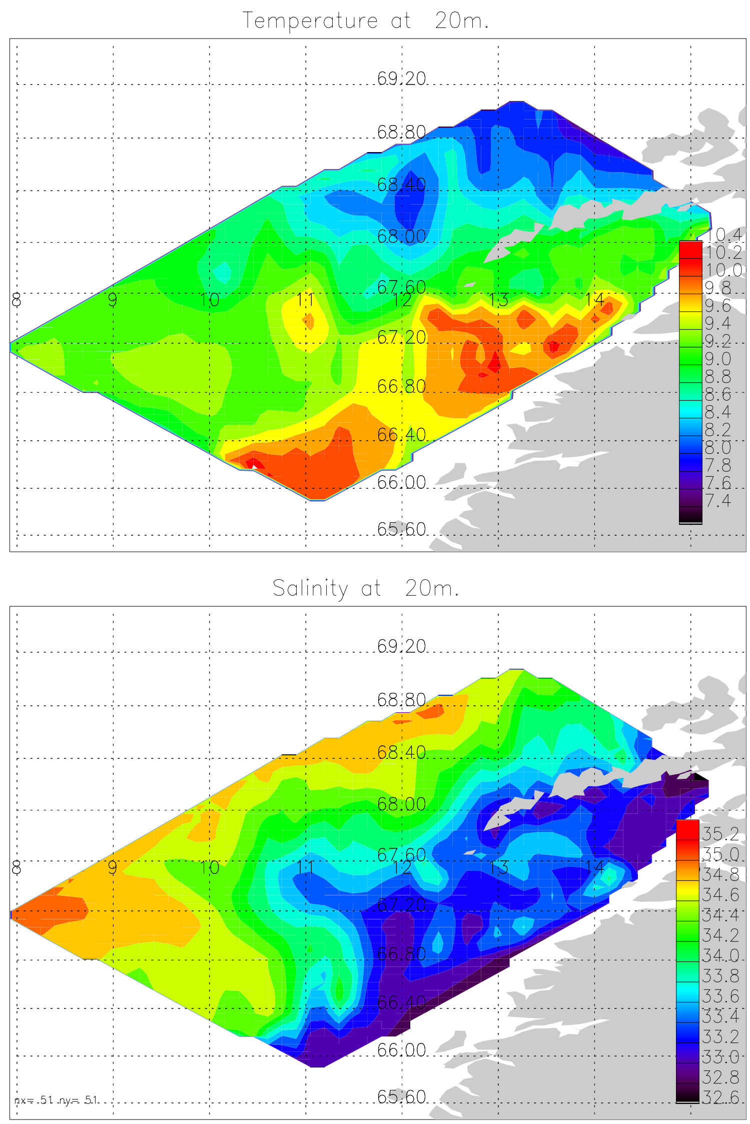

Figure 2.3: Rocky Road synoptic survey October 1993. Temperature and salinity at 20m depth.

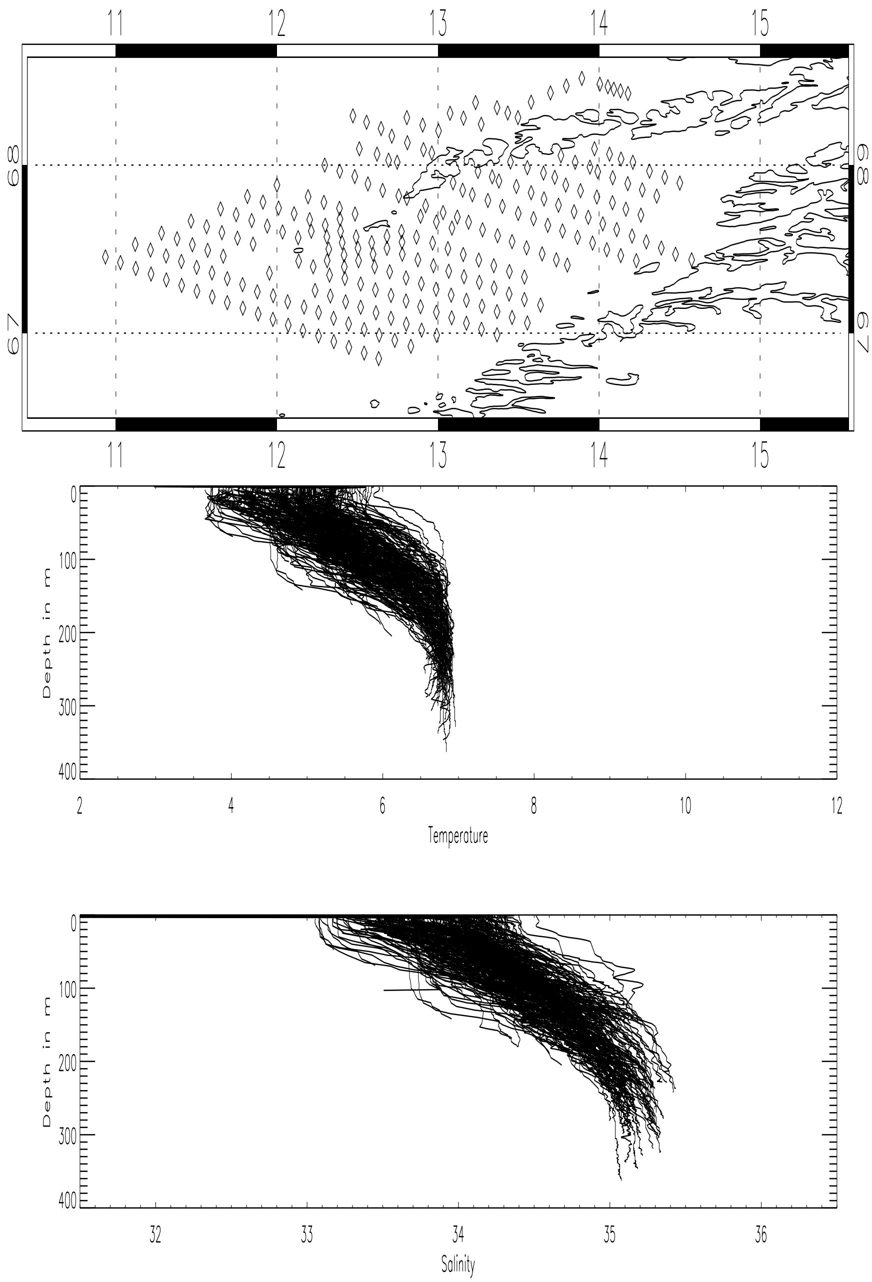

Figure 2.4: All profiles collected during Rocky Road synoptic survey 2-4 May 1995. Upper panel shows the locations of the CTD casts

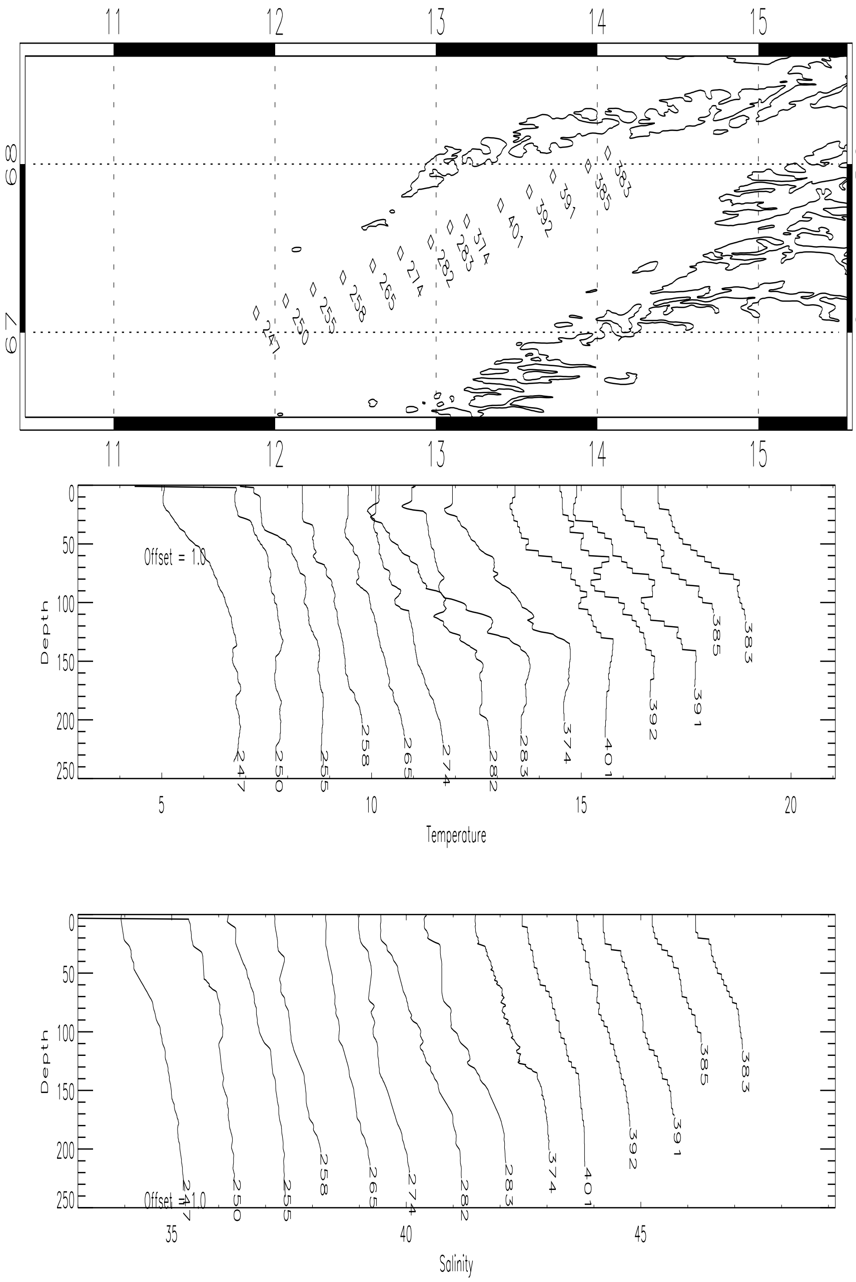

Figure 2.5: Rocky Road synoptic survey May 1995

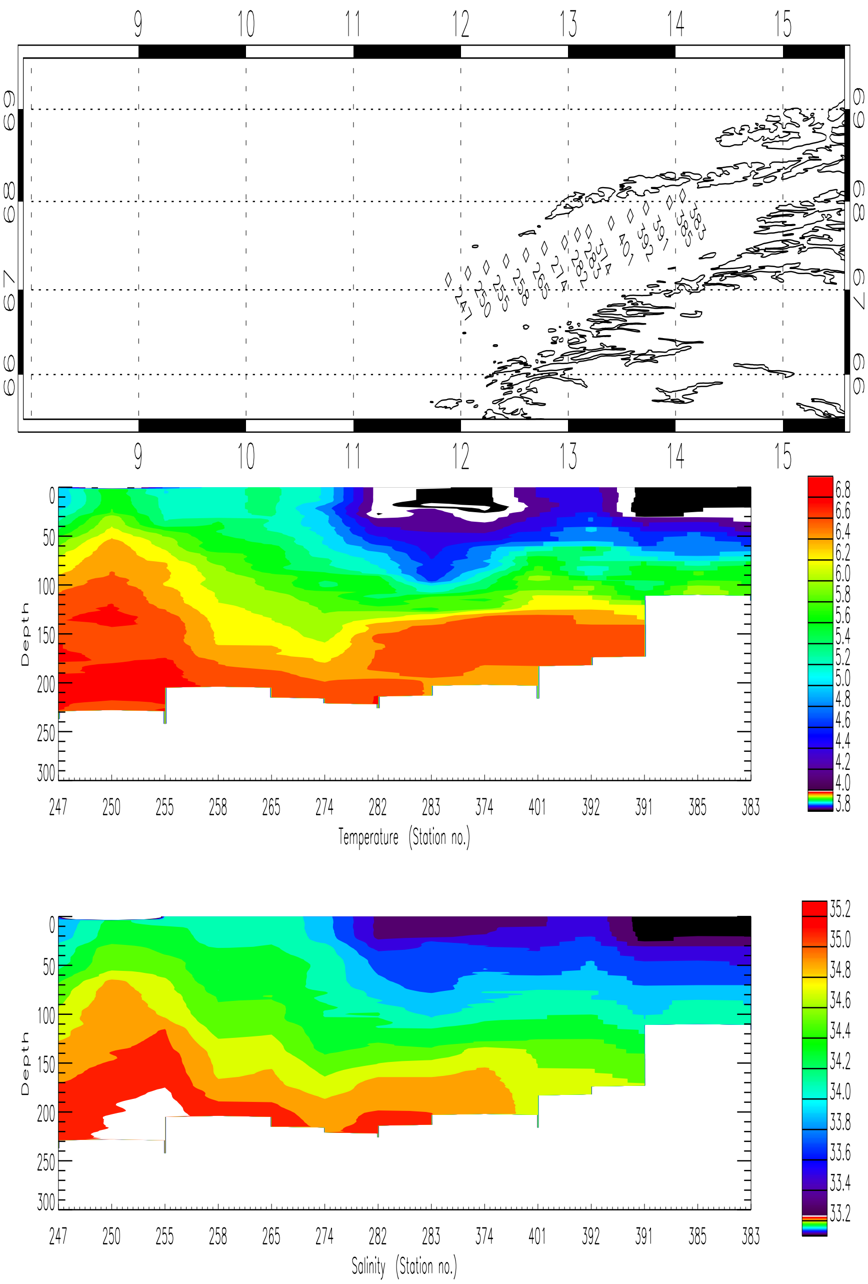

Figure 2.6: Rocky Road synoptic survey May 1995

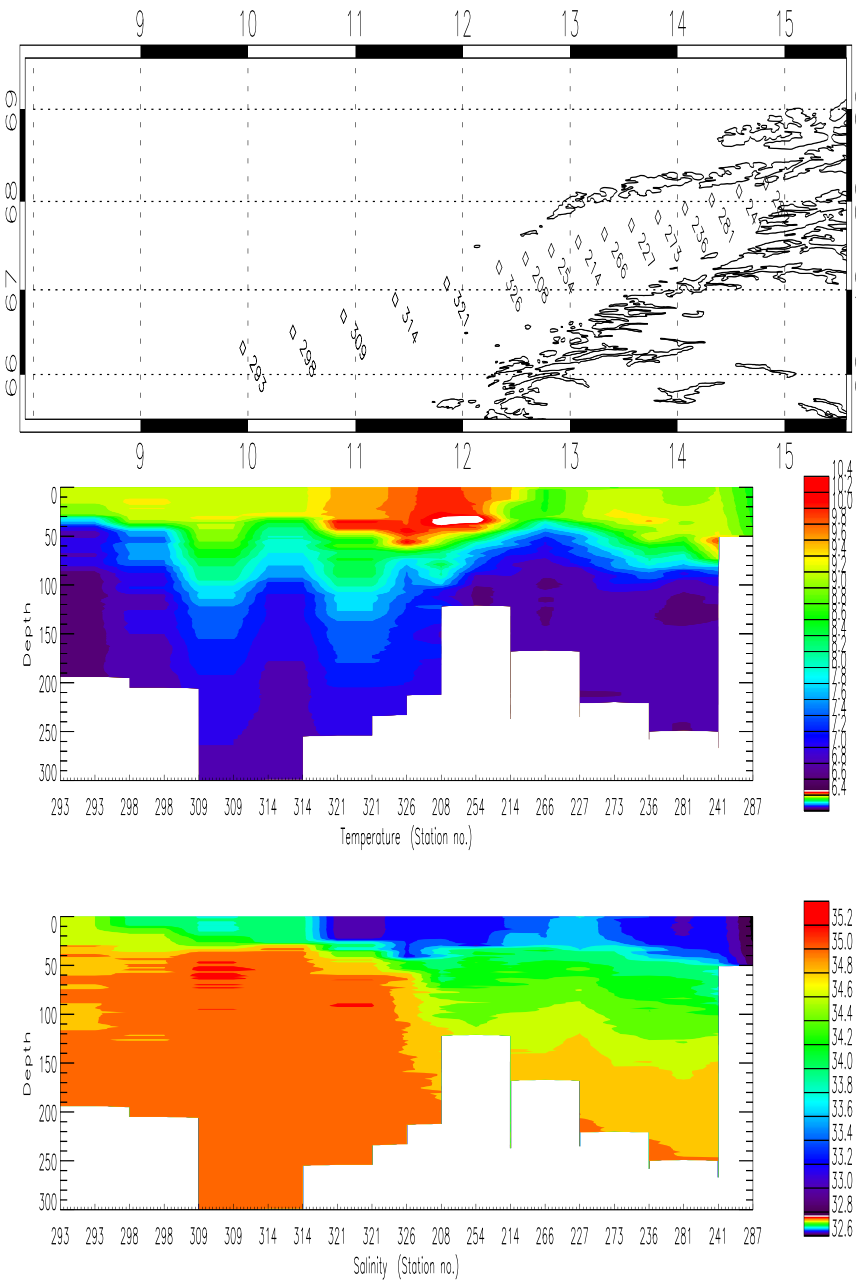

Figure 2.7: Rocky Road synoptic survey October 1993

3 GEOACOUSTIC PARAMETERS

The following description and map are taken from [1]. ”Figure 3.1 shows the distribution of surface sediment types in Vestfjorden. Unconsolidated sediment on the Norwegian continental shelf contains a predominance of material which resulted from erosion associated with past glaciation. This material consists of large quantities of boulders, cobbles, gravel, sand and silt. Distribution of these sediments varies considerably in areal extent and vertically within the sedimentary section. Thus, the composition of the surface sediment is not necessarily indicative of the underlying material. Along the inner shelf to depths of about 180 m, boulder and gravel deposits are those left behind when the last glaciers receded. Deeper portions (180 to 250 m) of Vestfjord are covered by cobbles, gravel and sand, the result of flushing action by currents which act to sweep away finer sediments. Small, isolated basins on the shelf, deeper than 270 m, are presently being filled with fine silt and clay.

The predominantly silty sediments covering broad expanses of the shelf often contain some sand, especially over shallower portions of Trænabanken. The unconsolidated sediments covering the shelf are underlain by older hard rocks. These form an abrupt discontinuity with the sediments above, and constitute a major change in density and velocity characteristics.”

Maps of top layer sediment distribution are also available from NTNF [6]. The NTNF sediment map of Figure 3.2 shows considerable discrepancies from the sediment map of Figure 3.1.

The seafloor studies conducted during ROCKY ROAD included boomer and sparker measurements as well as seabed coring. Side-scan sonar was also deployed at several locations. Seismic profiles gave a rough picture of the layering, but no detailed information on sound speed profile and attenuation. Cores provided information on sound speed and density in the upper 0.5-2.0m of the sediment, see Section 4 and Appendix A. The cores both in Vestfjorden and on the continental shelf showed high variability such that it was not possible to deduce reliable seabed acoustic parameters from these measurements. The modelling studies (2) concluded that inverse modelling is a more reliable means of obtaining geoacoustic parameters for the area.

Three different propagation models were used for acoustic modelling at tracks A-B and D-E: the normal mode model C-SNAP [3], the ray model MOCCASIN [4] and the ray model ALMOST. Below we provide the bottom parameters used by the models.

Track A-B is inside Vestfjorden. The water depth is approximately 250 m along the entire track. Side-scan images showed rocks and glacial scouring. Two general orientations of these scourings are present: along the fjord axis, and perpendicular to the mainland coast.

The C-SNAP model. For C-SNAP the sea surface and the seafloor roughness were determined in order to obtain good model-data agreement at higher frequencies. Both in Vestfjorden and on the shelf good modelling results were obtained with a homogeneous bottom. The geoacoustic parameters adopted for the modelling by C-SNAP are given in Table 3.1. These parameters indicate a hard sand/gravel bottom.

Sound speed	1800	m/s
Gradient	0.0	m/s/m
Attenuation	0.3	dB/λ
Density	2.0	g/cm^3
RMS roughness	0.5	m

Table 3.1: Geoacoustic parameters for Vestfjorden [3]. Track A-B.

Note that the sediment map of Figure 3.1 indicates a softer bottom than was obtained by matching C-SNAP model predictions to measurements. Acoustic model runs showed little effect by using actual bathymetry, hence a flat, homogeneous bottom was used for the acoustic modelling.

The MOCCASIN model. For modelling with the MOCCASIN model, the actual bathymetry was used. For the MOCCASIN model a bottom class ranging from 1 (soft) to 10 (hard) specifies the bottom type, see Table B.2. For track A-B bottom classes has been taken from the sediment map of Figure 3.1, resulting in MOCCASIN bottom classes between 4 and 7. The model-data comparison showed good agreement for lower frequencies. The sound speeds and densities corresponding to the MOCCASIN bottom classes can be found from Tables B.2 and B.1. These values indicate a softer bottom than was used for the normal mode model.

The ALMOST model. For the ALMOST model the bottom parameters were taken from seabed core data, Section 4. The sound velocities obtained from cores are lower than the values that are obtained from the sediment map of Figure 3.1, using Tables B.2 and B.1. Model results show that the transmission loss resulting from using core data for the bottom parameters are too low. This indicates that the sound velocities obtained from the cores are too low.

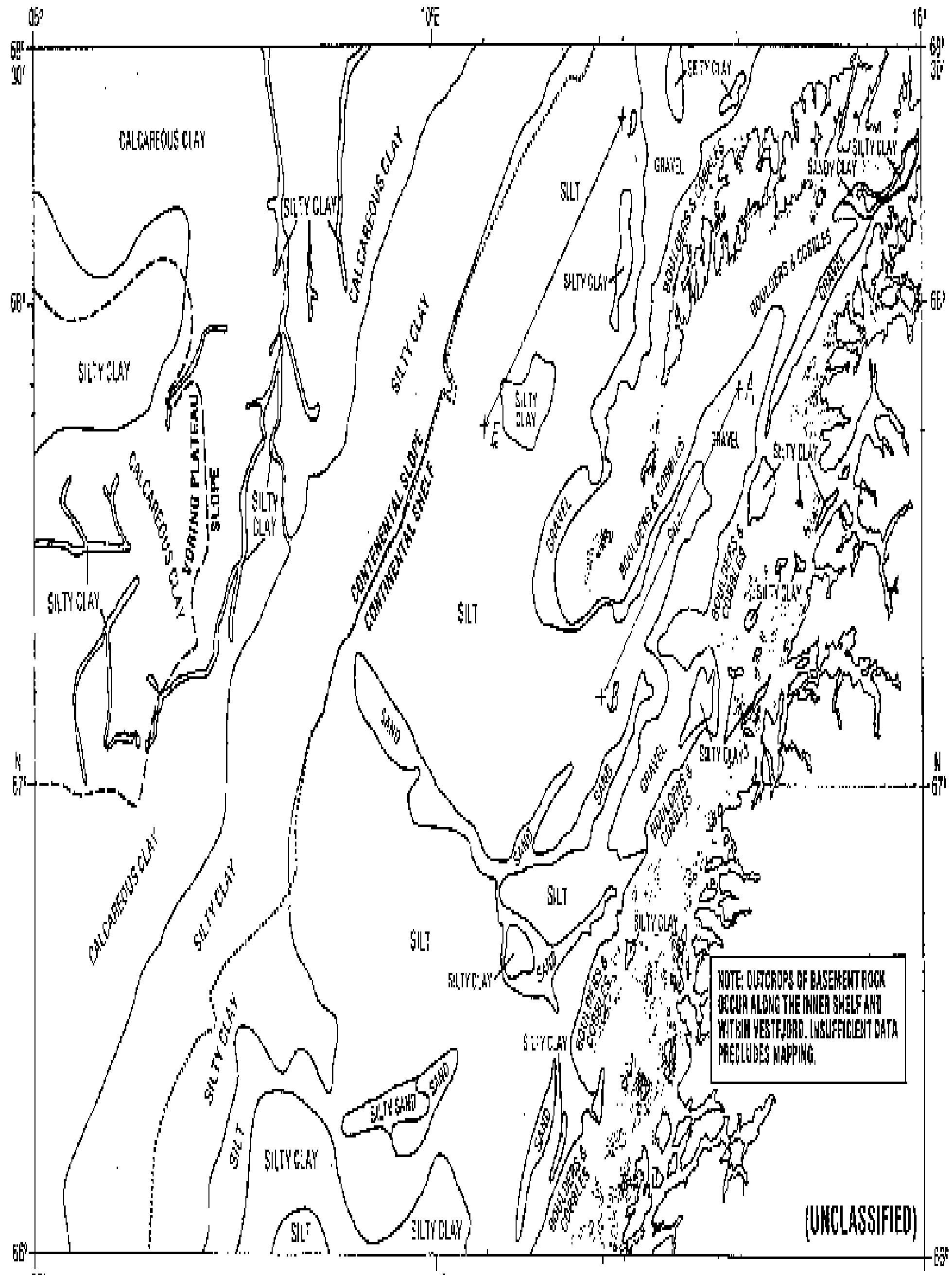

Figure 3.1: Surface sediment type of Vestfjord and the Vøring platau.

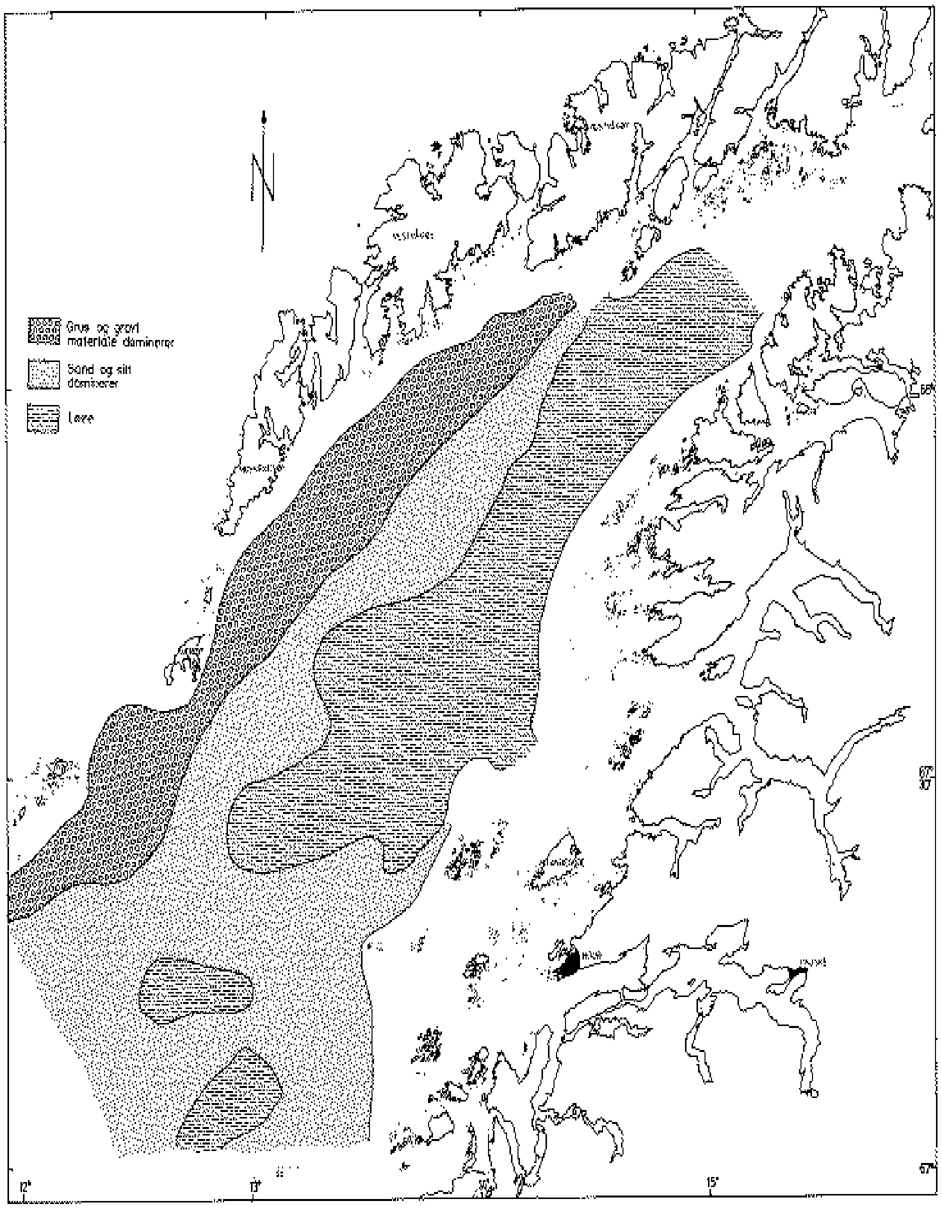

Figure 3.2: Surface sediment type of the Vestfjord area. Data compiled by NTNF.

4 CORES

Sediment cores were collected by R/V Alliance, and kindly provided by Dr. T. Akal of SACLANTCEN.

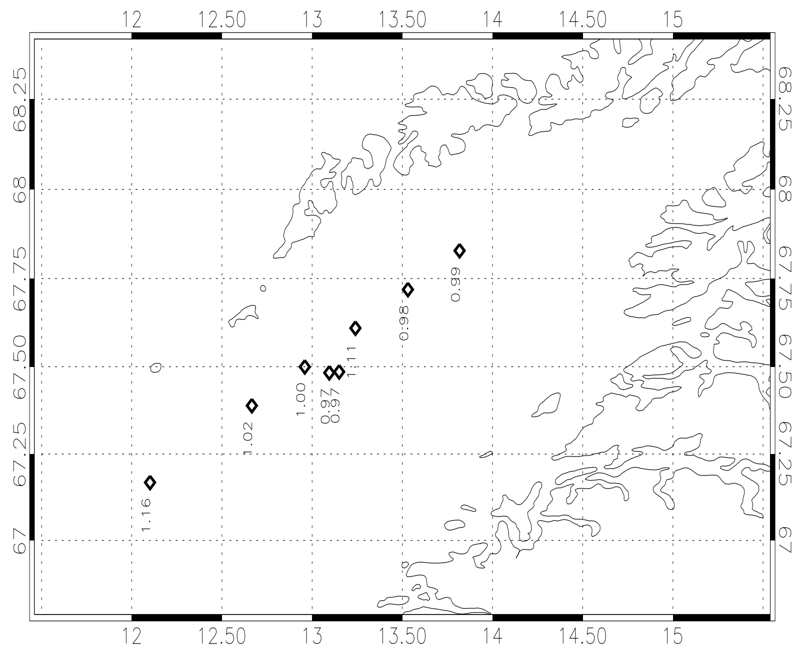

Figure 4.1: Surface sediments V_p ratio.

Lat	Lon	V_p ratio
67.4855	13.1497	0.974
67.4828	13.0950	0.974
67.4997	12.9592	0.997
67.6097	13.2400	1.110
67.7189	13.5311	0.981
67.8283	13.8175	0.991
67.1678	12.1014	1.164
67.3889	12.6658	1.020

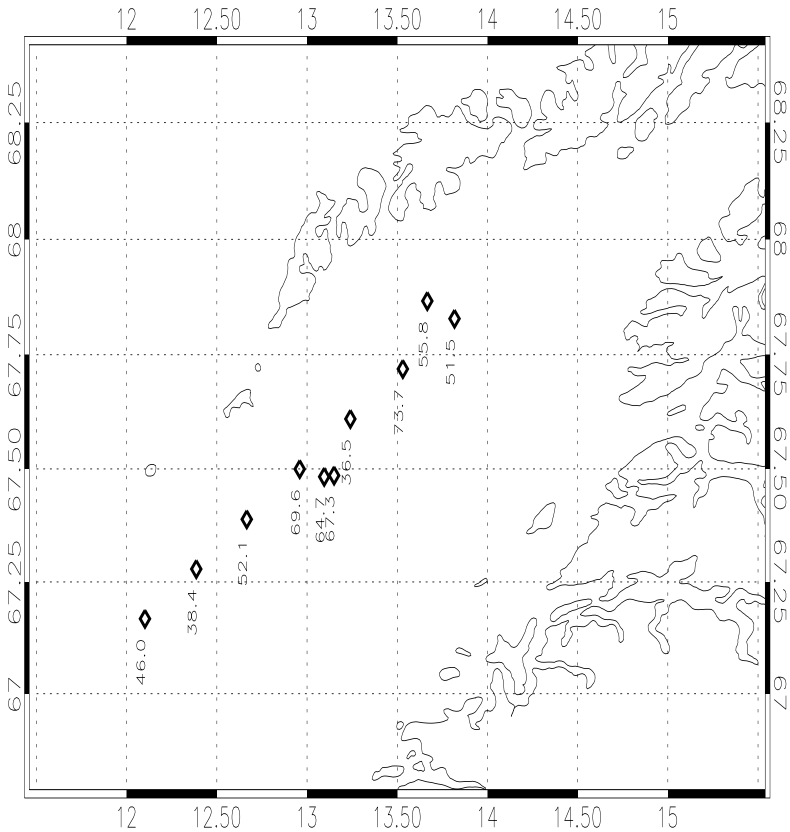

Figure 4.2: Surface sediments porosity (%).

Lat	Lon	Porosity (%)
67.4997	12.9592	69.60
67.6097	13.2400	36.51
67.7189	13.5311	73.66
67.8283	13.8175	51.50
67.1678	12.1014	45.99
67.2786	12.3858	38.37
67.3889	12.6658	52.13
67.4855	13.1497	67.34
67.4828	13.0950	64.72
67.8281	13.8189	69.05
67.8667	13.6667	55.78

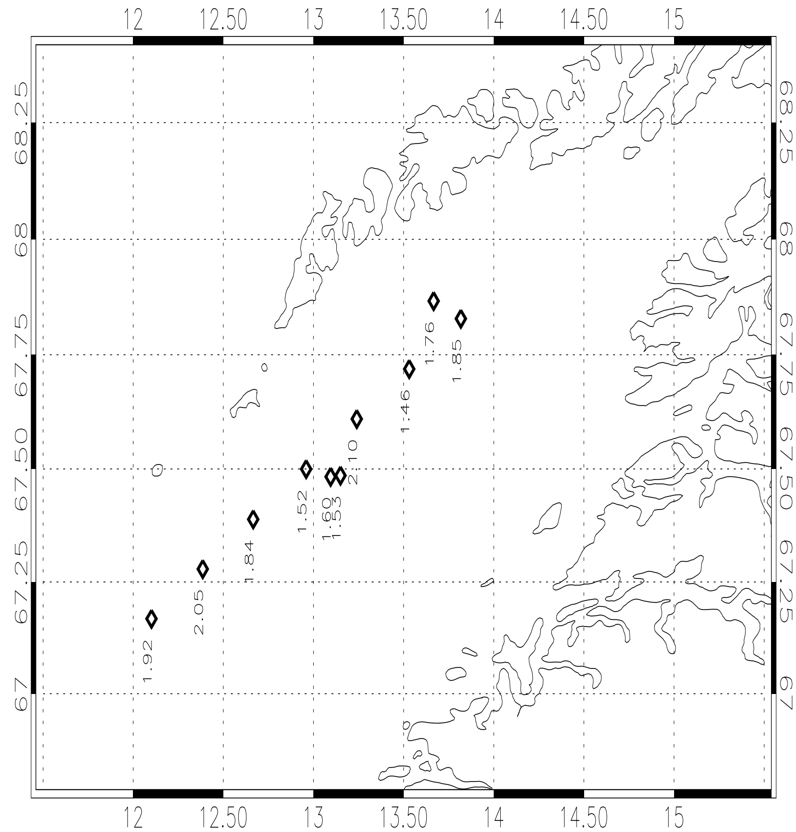

Figure 4.3: Surface sediments wet density (g/cm^3).

Lat	Lon	Wet density (g/cm^3)
67.4997	12.9592	1.52
67.6097	13.2400	2.10
67.7189	13.5311	1.46
67.8283	13.8175	1.85
67.1678	12.1014	1.92
67.2786	12.3858	2.05
67.3889	12.6658	1.84
67.4855	13.1497	1.53
67.4828	13.0950	1.60
67.8281	13.8189	1.46
67.8667	13.6667	1.76

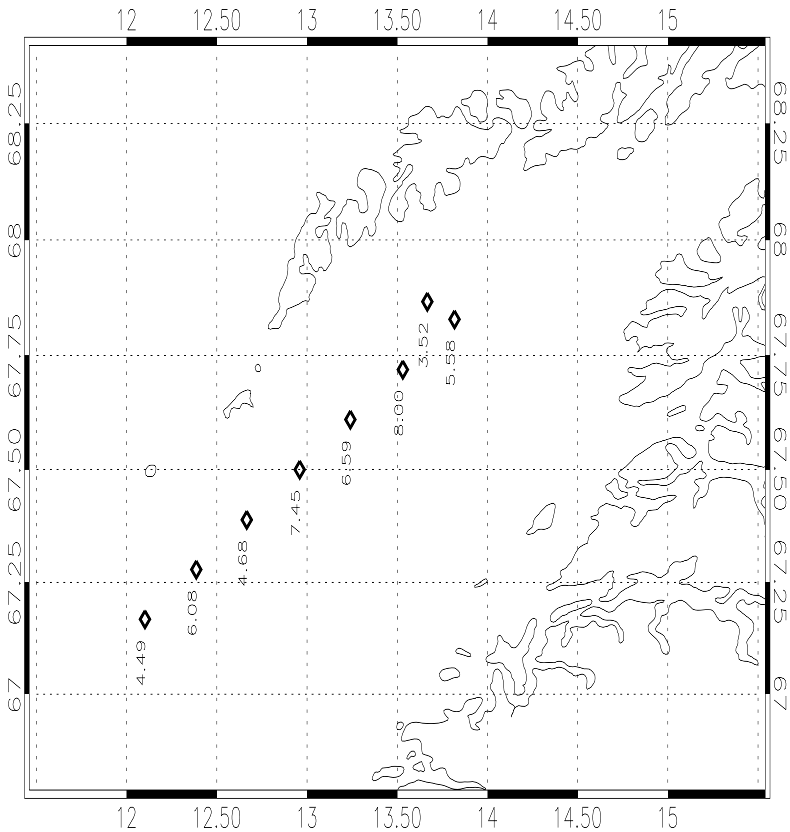

Figure 4.4: Surface sediments mean grain size (Φ).

Lat	Lon	Mean grain size (Φ)
67.4997	12.9592	7.45
67.6097	13.2400	6.59
67.7189	13.5311	8.00
67.8283	13.8175	5.58
67.1678	12.1014	4.49
67.2786	12.3858	6.08
67.3889	12.6658	4.66
67.8281	13.8189	7.71
67.8667	13.6667	3.52

5 BACKSCATTER

During the MILOC survey Rocky Road FWG measured the angle dependent backscattering strength of the sea bed in the Vestfjord area [7]. Measurements were carried out at one location in **inner Vestfjord for t**he frequencies 400 Hz and 1100 Hz.

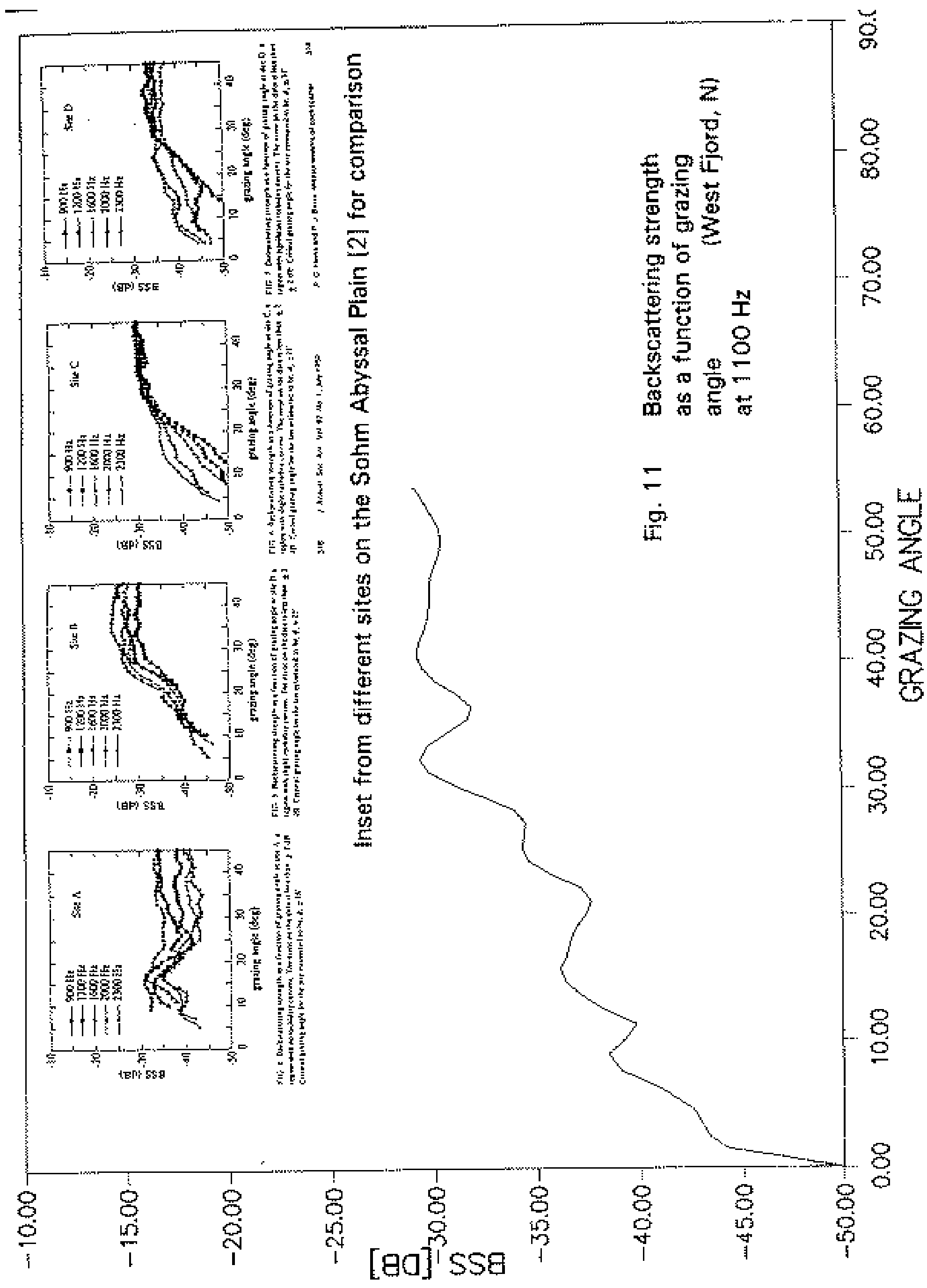

Figure 5.1: Backscattering strength at 1100 Hz ([7])

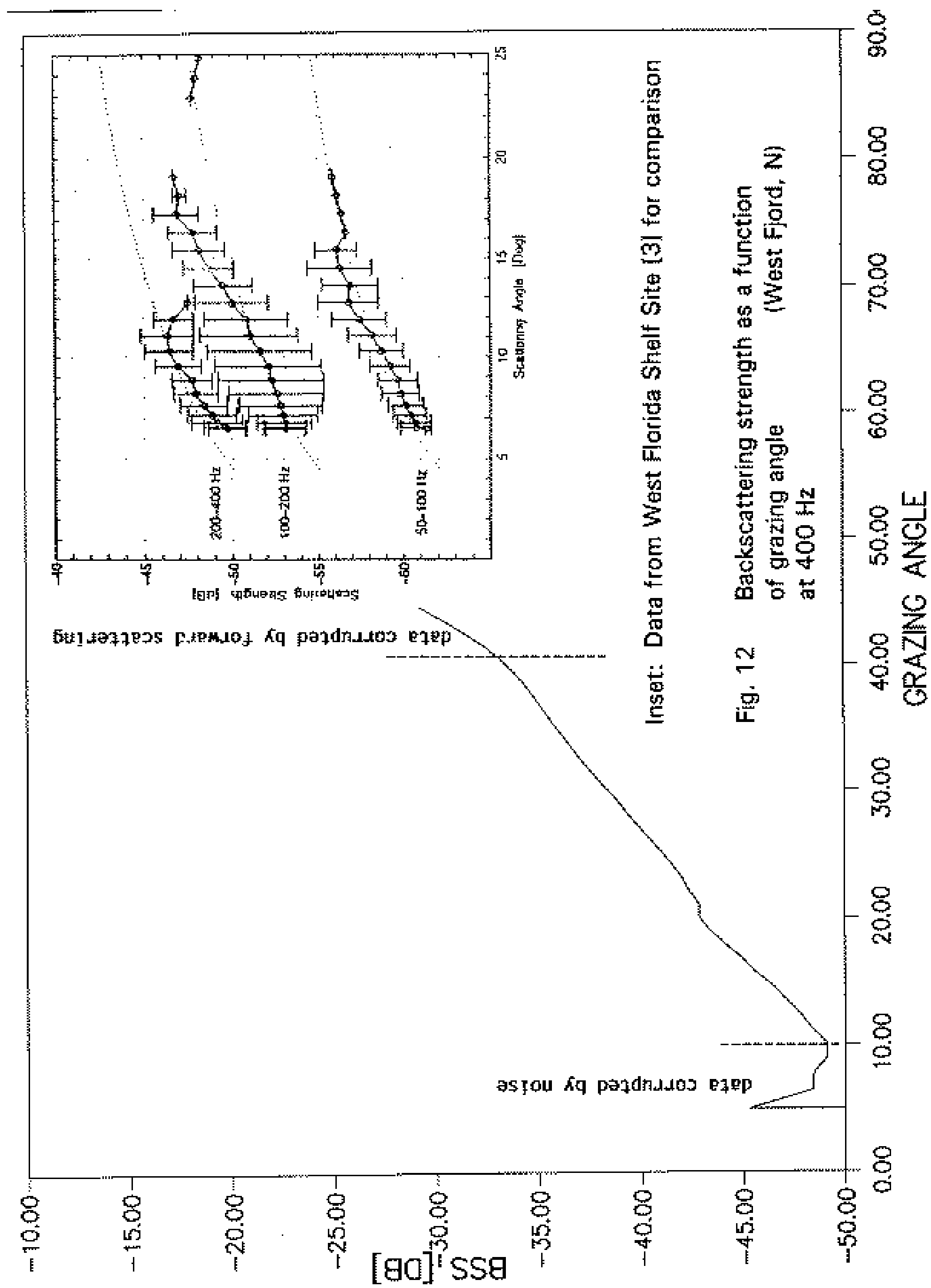

Figure 5.2: Backscattering strength at 400 Hz ([7])

A CORE PROFILES

In this Appendix the core profiles are given. The cores were collected by R/V Alliance, analyzed by SACLANTCEN and provided by dr. T. Akal.

As the cores are relatively shallow, the validity of the geoacoustic parameters obtained can be questioned. Especially for use at low frequencies.

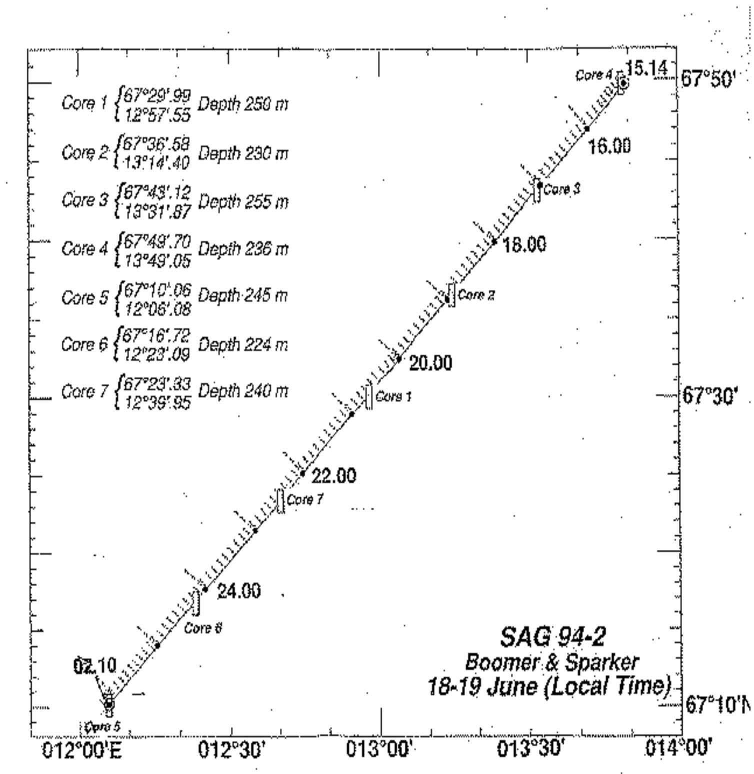

Figure A.1: Location of cores

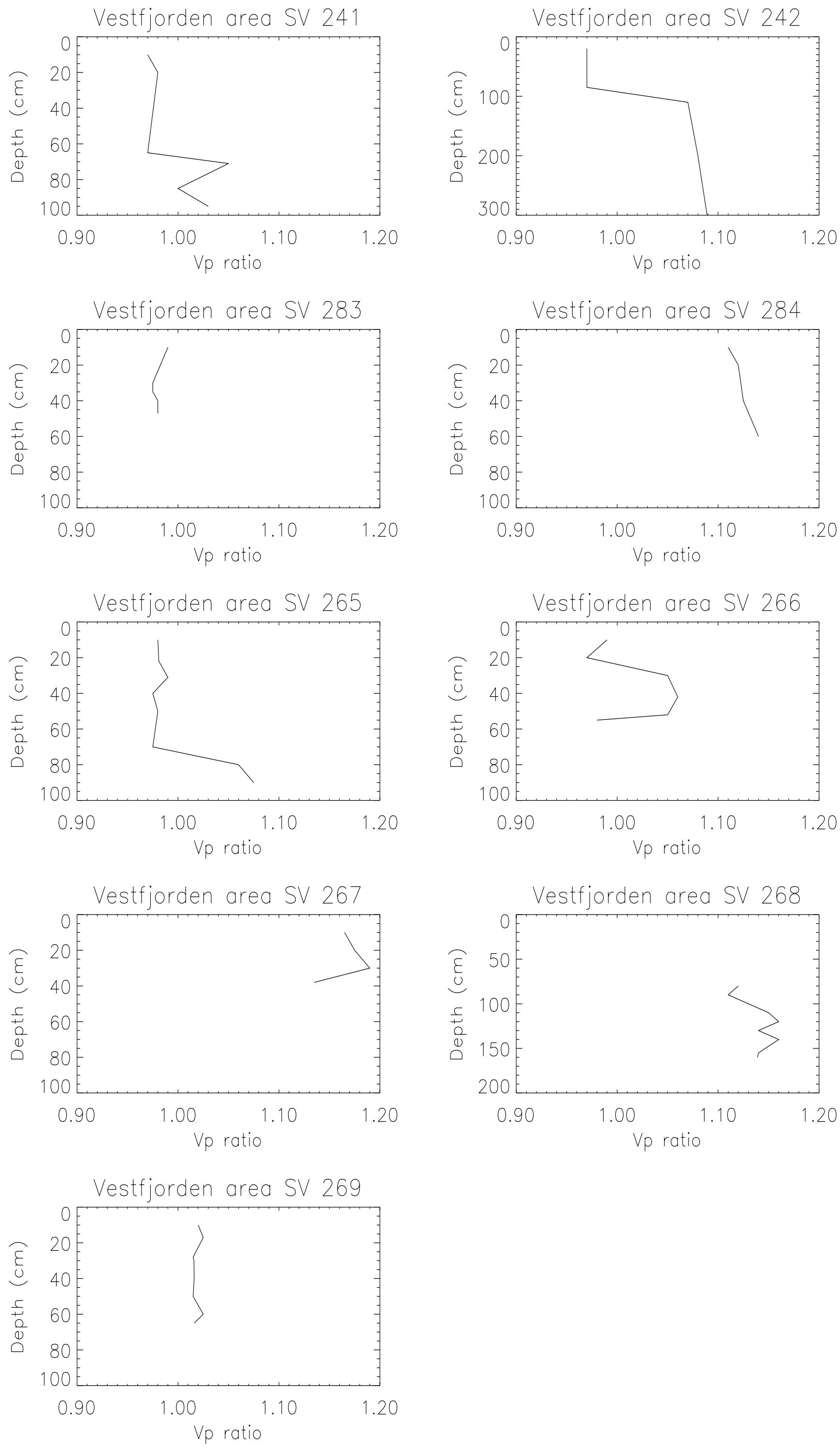

Figure A.2: V_p ratio.

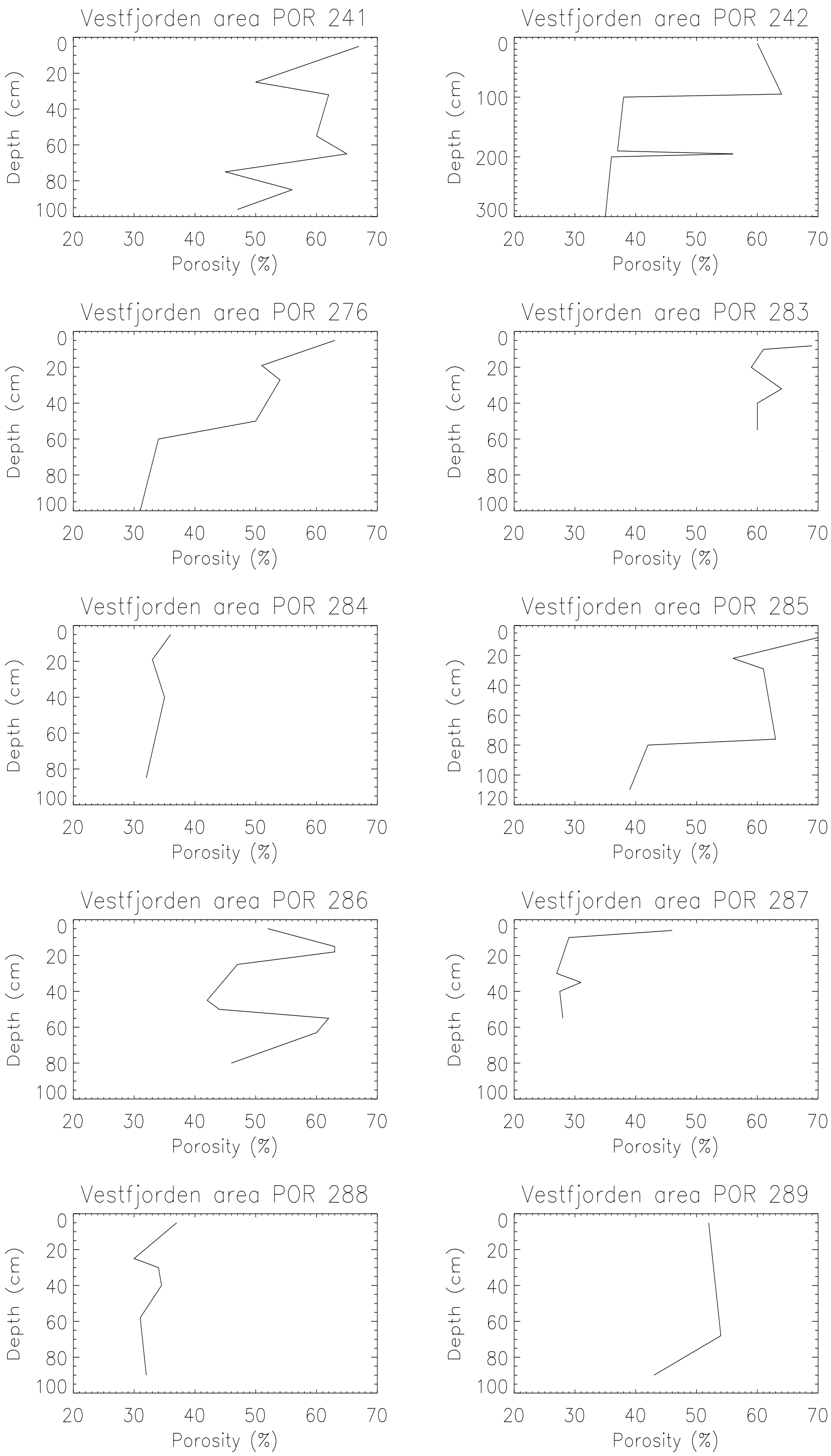

Figure A.3: Porosity (%).

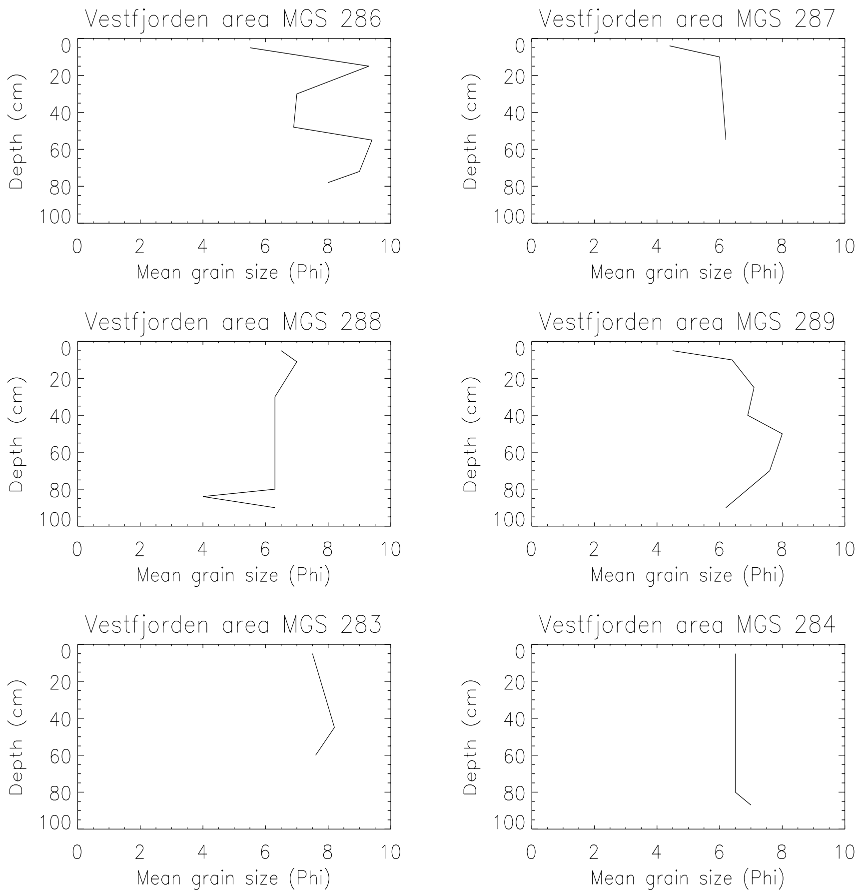

Figure A.4: Mean grain size (Φ).

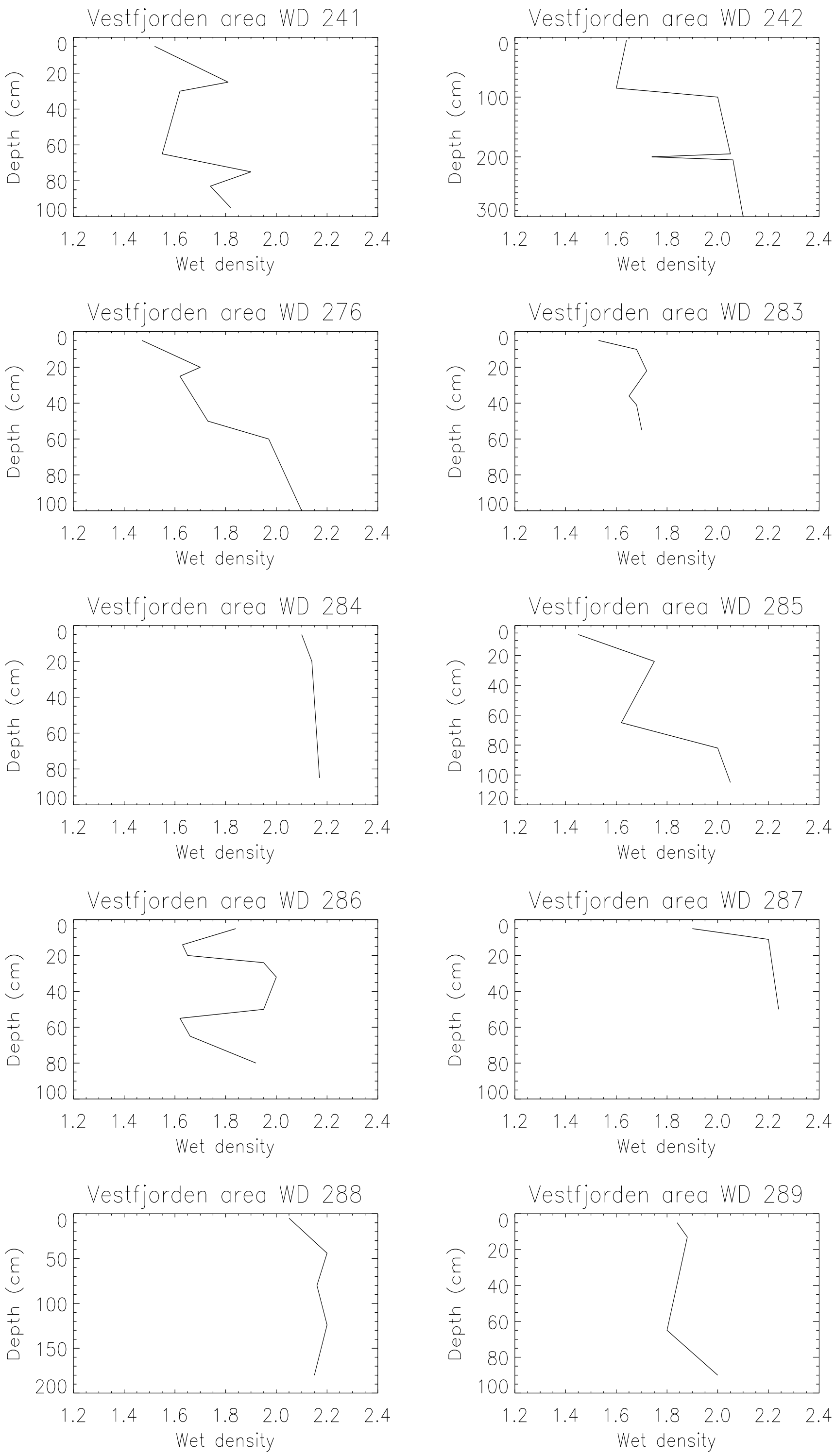

Figure A.5: Wet density (g/cm^3).

B SOME GEOACOUSTIC PROPERTIES OF SEDIMENTS

Unconsolidated sediment category	Surface P-wave velocity (m/s)	Density (g/cm^3)	Mean layer P-wave velocity (m/s)
Silty clay	1510	1.54	131
Sand-silt-clay	1575	1.74	187
Sandy silt	1664	1.77	264
Silty sand	1640	1.88	243
Sand/gravel	1734	2.10	324

Table B.1: Geoacoustic parameters for unconsolidated surface sediments in the Barents sea [8].

Sediment	MOCCASIN	NISSM II		MGS
category	Nr	Nr	Porosity	Nr
Rock, gravel	10	9	0.30	1
Coarse sand	9	8	0.39	
Mid sand	8	7	0.47	2
Fine sand	7	6	0.55	
Silty sand	6	5	0.61	3
Sandy silt	5	4	0.71	
Silt	4	3	0.81	4
Clayey silt	3	2	0.87	
Silty clay	2			5
Clay, mud, ooze	1	1	0.39	6,7,8,9

Table B.2: Relation of different bottom classes: MOCCASIN, NISSM II and MGS [9].

	Sediment category	Grain size (mm)	Φ
	Boulder		
G		256	-8
R	Cobble		
A		64	-6
V	Pebble		
E		4	-2
L	Granules		
		2.00	-1.0
	Very Coarse		
		1.00	0.0
S	Coarse		
A		0.50	1.0
N	Medium		
D		0.25	2.0
	Fine		
		0.125	3.0
	Very Fine		
		0.0625	4.0
S	Coarse		
I		0.031	5.0
L	Medium		
T		0.0156	6.0
	Fine		
		0.0078	7.0
	Very Fine		
		0.0039	8.0
	Coarse		
		0.0020	9.0
C	Medium		
L		0.00098	10.0
A	Fine		
Y		0.00049	11.0
	Very Fine		
		0.00024	12.0
	Colloids		
		0.00006	14.0

Table B.3: Grain size scales and conversion table for diameter expressed in millimeters and $\Phi = -log_2(\textit{diameter in mm})$.

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