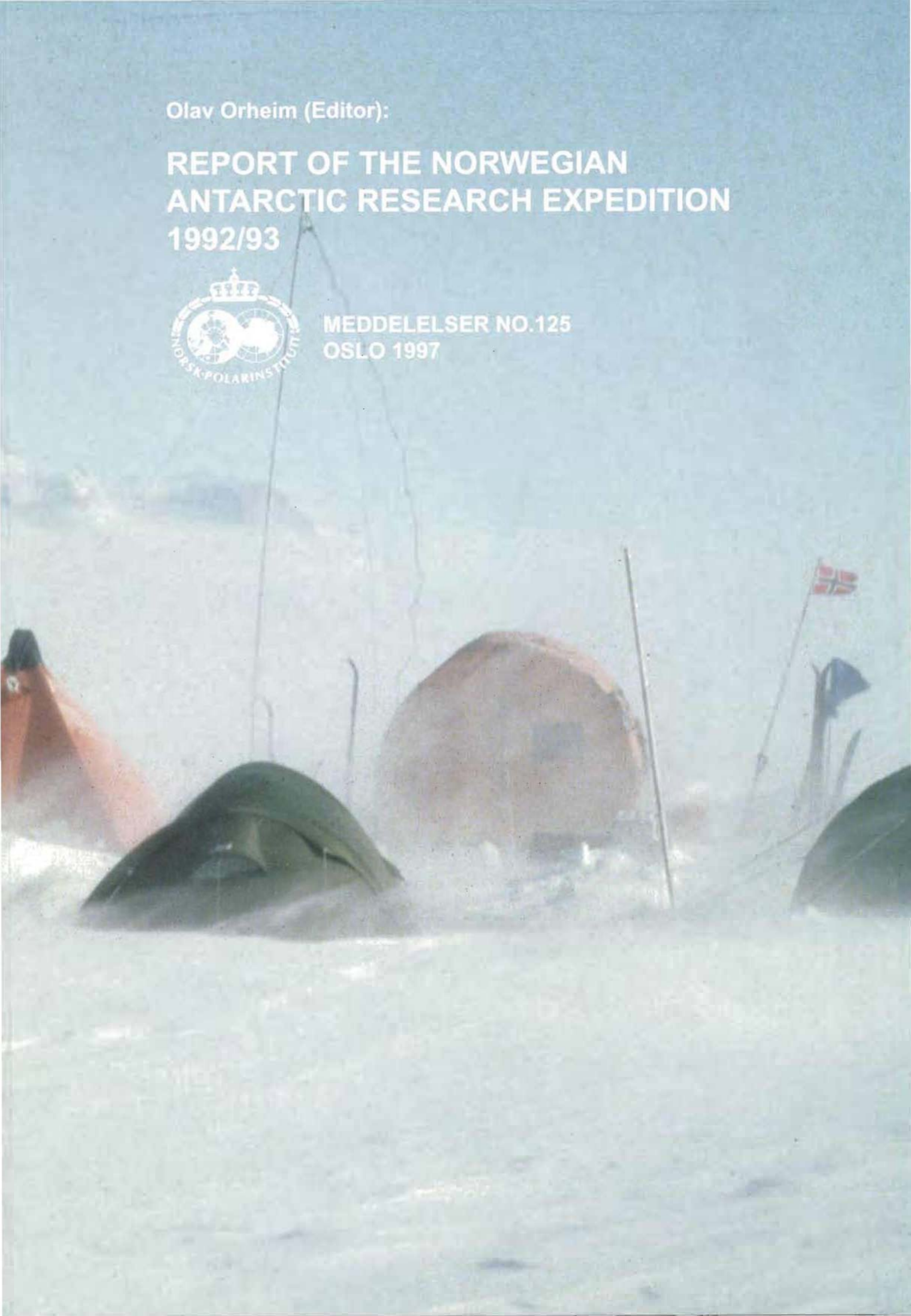

Olav Orheim (Editor):

REPORT OF THE NORWEGIAN ANTARCTIC RESEARCH EXPEDITION 1992/93

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REPORT OF THE NORWEGIAN ANTARCTIC RESEARCH EXPEDITION 1992/93

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Oslo 1997

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Cover: The glaciologists' camp in Jutulstraumen, Antarctica, during NARE 1992/93. Photo: Jan Gunnar Winther
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ORNITHOLOGY

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PREFACE

This volume contains reports from the research programmes conducted during the Norwegian Antarctic Research Expedition (NARE) 1992/93. This was also the logistic vehicle for the Nordic Antarctic Research Programme (NARP) that season. Included are also brief descriptions of the other Nordic programmes.

All the manuscripts in this volume were completed in their present form by summer/autumn 1993. Three events then combined to cause the long delay before publication: 1. the Parliamentary decision to move Norsk Polarinstitutt from Oslo to Tromsø introduced numerous new tasks which caused backlog in ongoing work; 2. the editor's new position as Managing Director of the Norwegian Polar Institute left less time for the editorial work connected with this volume; and 3. a computer crash resulted in the loss of parts of the manuscript file with incomplete backup.

Despite this delay we have decided to publish the report in the form it was completed in 1994. The report contains numerous articles which give accounts of field work done, and which will not be available elsewhere in the literature. It should be recognized, however, that many programme results are likely to have been published elsewhere already, which will make the present tentative conclusions of less relevance. This is not the fault of the authors, but solely the responsibility of the editor.

The authors are listed under the institutions they worked at in 1993, but with today's addresses of the institutions.

Oslo, November 1997
Olav Orheim
Editor

OLAV ORHEIM*:

GENERAL REPORT OF THE EXPEDITION

INTRODUCTION

The Norwegian Antarctic Research Expedition (NARE) 1992/93 comprised the largest number of scientists on any Norwegian Antarctic expedition. It involved altogether 120 persons, including 63 scientists and technicians. Of these 42 where from Norway, ten from Sweden, seven from Finland, five from the Netherlands, and one each from Denmark and Canada. The expedition was the logistic vehicle for Nordic Antarctic cooperation, organized between Finland, Norway, and Sweden, with the countries having rotating responsibility for the transport to/from Antarctica. This joint programme is named The Nordic Antarctic Research Programme (NARP). This article describes the NARE/NARP logistics, but the list of scientists and their programmes include only NARE particpants.

The expedition was organized and led by Norsk Polarinstitutt (NP). Expedition planning began over one year before departure, and included both Nordic planning meetings, and planning meetings in individual countries and within science groups. The 17 scientific programmes of Norwegian origin carried out on the expedition were selected from proposals submitted by a wide variety of Norwegian research communities. The selection was decided, after use of international referees, by a nine-person committee appointed by Nasjonalkomiteen for Miljøvernforskning (The National Committee for Environmental Research) in cooperation with NP.

The extent of marine programmes, and the number of scientific personnel to be transported, meant that two ships were needed for NARE 1992/93. These were the 60m long government-owned research vessel R/V *Lance*, and the 50m long chartered vessel M/V *Polarbjørn* (Figs. 1 and 2). Both carried out transport of both personnel and equipment for land-based groups, and various types of marine research, mainly in the Weddell Sea (Fig. 3). *Lance* was primarily used for research within the fields of physical and chemical oceanography, glaciology including sea ice, and marine geology. *Polarbjørn* was used mainly for marine biological research.

Various modifications were done to *Lance* to make the ship more suitable for conducting research on long-lasting Antarctic expeditions. This included improvements to the three existing laboratories, and installation of computer network and additional accommodation. Lance is the ship used by NP for the annual expeditions to Svalbard (Spitsbergen) and was already well equipped for marine research. However, three containers, for oceanography and marine geological/geophysical research, were also installed. Six containers with marine biological research facilities, and four additional accommodation modules were installed on *Polarbjørn*.

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Fig.1. R/V *Lance* at Prinsesse Astrid kyst, an area for flights to/from Troll. Photo: J.-G. Winther.

The landbased activities were centered around Troll Station which is located at 72°00.7'S, 2°32.3'E, at Grjotlia, Jutulsessen, at 1290 m elevation (Fig. 4). It was established on 1 February 1990, and is constructed to be used for winter operation. So far, however, it has only been used in the Antarctic summer season. A new garage/laboratory was added this season. Also established this season was Tor Station, an auxiliary station located at 71°53.4'S, 5°09.6'E, at Svarthamaren, Mühlig-Hofmannfjella, at 1625 m elevation. It had been used as refuge and base camp for ornithologists from 1985 to 1992, and was now expanded by a garage/laboratory building.

The expedition also established field camps at Jutulstraumen and on the Ronne Ice Shelf.

Two Ecureil AS 350B were operated from Troll Station and the ships throughout the expedition and flew a total of 290 hours. Two BV 206 Hägglund band wagons were used to transport about 50 tons of cargo from the ice front to the Troll and the Tor stations. One was stationed at Troll Station, and one at Tor Station, at the end of the season. Seven skidoos were also used by field parties for inland transport.

Fig. 2. M/S *Polarbjørn* by Rampen. Photo: J.-G. Winther.

NORWEGIAN PROGRAMMES AND PARTICIPANTS

The main emphasis in the Norwegian research on this expedition was on environmental issues, which has also been the case for other Norwegian Antarctic expeditions in recent years. The major research programmes concerned the coupling between the the floating ice shelf and the ocean, the paleoclimate history as revealed by sea bed samples, and the marine ecosystem, including sea birds. Other studies included ice stream glaciology and sea ice studies, topographic mapping, and industrial archaeology on South Georgia Island. The investigators and title of their projects, and some information on equipment used, are listed below.

Expedition leadership:

Expedition leader:	Olav Orheim
Deputy leader and station leader:	Jan Erling Haugland
Chief scientists onboard *Polarbjørn*:	Egil Sakshaug, Arnoldus S. Blix
Chief scientist onboard *Lance*:	Tor Gammelsrød.

NARE scientists, disciplines and affiliations

At Troll Station:

Jon Ove Hagen	Glaciology	Norsk Polarinstitutt
Kjetil Melvold	"	"
Øyvind A. Høydal	"	"
Jan Gunnar Winther	"	SINTEF
Henrik Højmark Thomsen	"	Grønl. Geol.Unders.
Trond Eiken	Geodesy	Norsk Polarinst.
Bjørn Lytskjold	"	"
Bjørn Barstad	"	"
Halvor Bævre	Medical doctor	Gjøvik Fylk.sykeh.
Frode N. Bye	Environmental research	Norsk Polarinstitutt

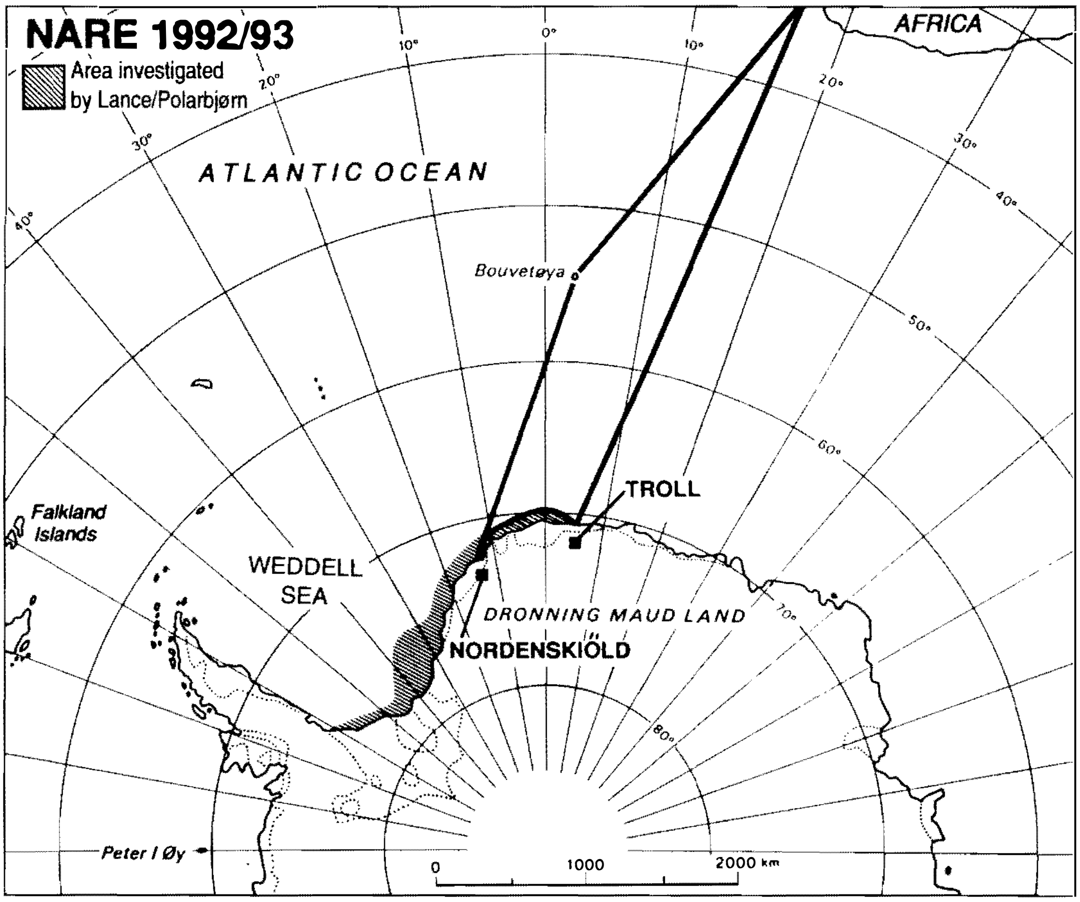

Fig. 3. Main sailing route and work area (dashed) of the Norwegian Antarctic Research Expedition 1992/93.

At Tor Station:

Bernt Erik Sæther	Ornithology	NINA
Reidar Andersen	"	"
Torkild Tverraa	"	Univ. Tromsø
Terje Bøe	"	Fylkesm. Nordland

At* Polarbjørn *II cruise:

Egil Sakshaug	Marine biology	Univ. Trondheim
Runar Dalløkken	"	"
Svein Kristiansen	"	Univ. Oslo
Erik Syvertsen	"	"
Tove Farbrot	"	"
Cecilie Hellum	"	Norges Fiskerihøgskole
Inger J. Andreassen	"	"
Sverre Myklestad	"	Univ. Trondheim
Knut Yngve Børsheim	"	"
Stig Falk Petersen	"	Akvaplan/NIVA
Ole Jørgen Lønne	"	Norges Fiskerihøgskole
Øistein Skagseth	Oceanography	Univ. Bergen

At* Polarbjørn *III cruise

Arnoldus S. Blix	Marine biology	Univ. Tromsø
Erling Sverre Nordøy	"	"

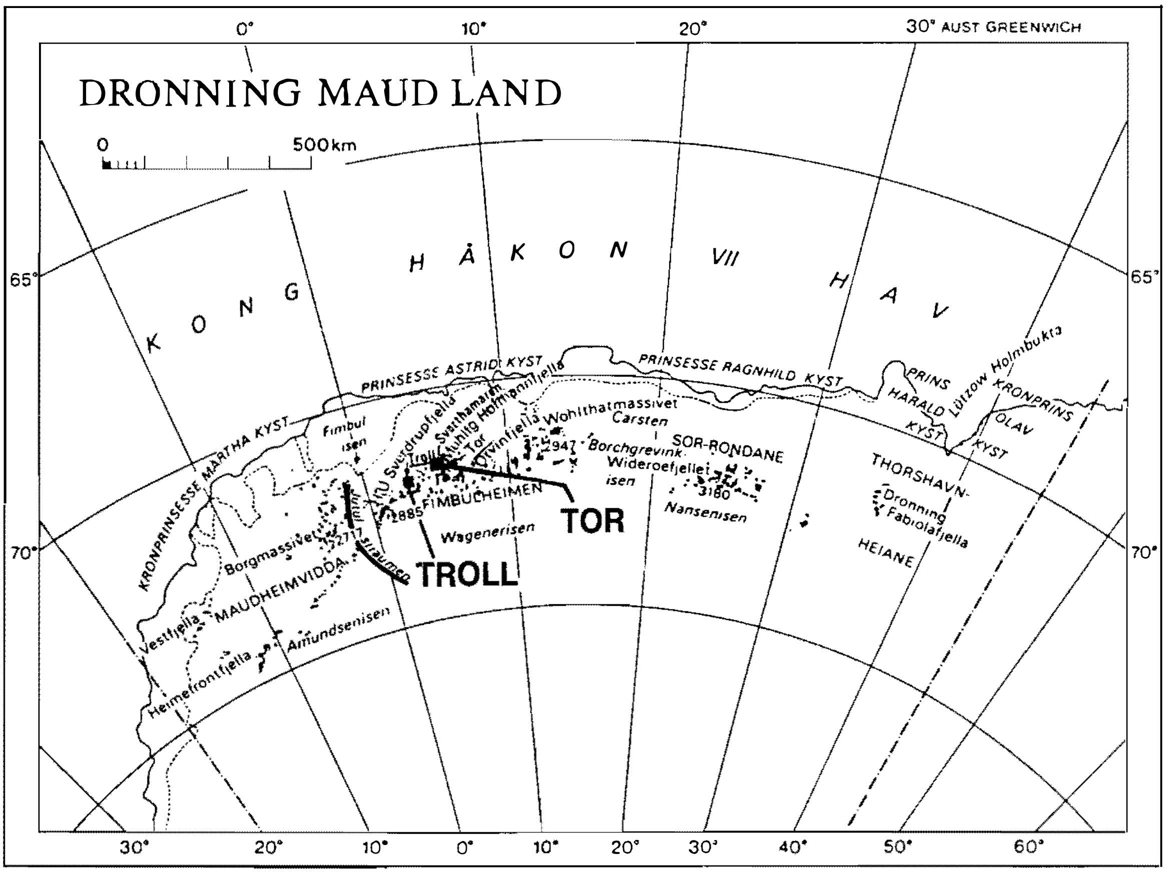

Fig. 4. Locations (underlined) of Troll and Tor stations, and of Jutulstraumen, site of various glaciology programmes.

At* Lance*:

Olav Orheim	Glaciology	Norsk Polarinst.
Svein Østerhus	"	Univ. Bergen
Tor Gammelsrød	Oceanography	"
Steinar Myking	"	"
Ole Anders Nøst	"	"
Terje Brinck Løyning	Sea ice	Norsk Polarinst.
Carl Fredrik Forsberg	Marine geology	"
Alf Kr. Nilsen	"	Univ. Oslo
Pekka Kiviranta	"	Selantic Industries
Bill Austin	"	Univ. Bergen
Espen Sletten Andersen	"	Univ. Oslo

At South Georgia:

Bjørn L. Basberg	Industrial archaeol.	Trondheim Øk. Høysk.
Gustav Rossnes	"	Fylkeskultur. Akershus

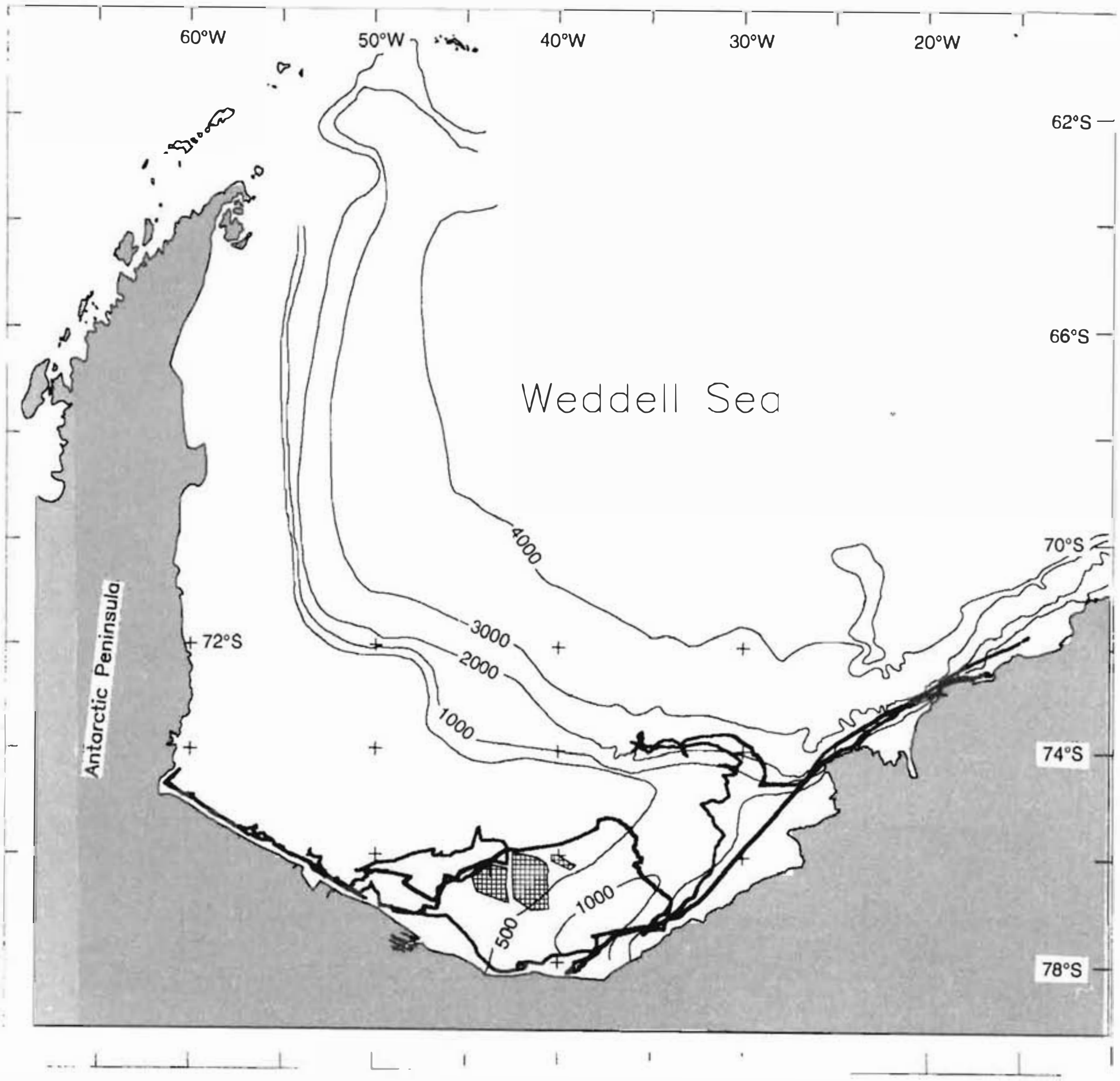

Fig. 5. Sailing route of *Lance* in southern Weddell Sea.

PLANNED NORWEGIAN RESEARCH PROGRAMMES AND EQUIPMENT

(See articles elsewhere in this volume for descriptions of field work carried out in 1992/93 by NARE and NARP participants)

At and around Troll Station:

***Investigators and programmes*:**

Hagen, Thomsen, Melvold, Winther: Studies of mass balance and dynamics of Jutulstraumen Ice Stream.

Høydal: Study of velocity, mass flow and deformation in Jutulstraumen.

Eiken, Lytskjold, Barstad: Geodetic and topographic work in central Dronning Maud Land.

Bye: Sampling of lichens, algae and invertebrates, and estimating numbers of Antarctic Petrels, for environmental monitoring.

Scientific equipment:

6 Ashtech XII dual frequency GPS-receivers
2 Ashtech P12
2 Wild T2000 and 1 Wild T2 Theodolites
1 Wild DI3000 electro-optic distancer
1 AGA Geodimeter 6000 electro-optic distancer
1 spectrometer for reflection studies
2 PICO 30-m corers
1 automatic weather station

At Tor Station:

Investigators and programmes:

Sæther, Andersen, Bøe, Tverraa: Demographic and other studies of the colonies of Antarctic Petrel, Snow Petrel and South Polar Skua.

At *Polarbjørn*:

Investigators and programmes:

Sakshaug, Dalløkken: Photobiological studies in the Antarctic Ocean.

Kristiansen, Syvertsen, Farbrot: Nitrogen uptake and growth of Antarctic ice algae and phytoplankton.

Andreassen, Hellum: Sedimentation of particles in the Antarctic Ocean.

Myklestad, Børsheim: Occurrence and dynamics of dissolved organic carbon in the Antarctic Ocean.

Falk-Petersen, Aarseth: The place of Antarctic krill in the food web

Lønne: Biology of Antarctic Ice fauna.

Blix, Nordhøy: Distribution and food consumption of crabeater seals off Dronning Maud Land and of southern fur seals at Bouvetøya.

Scientific equipment on* Polarbjørn *included the following:

Neil Brown CTD-system, with rosette water sampling
1 photo-biological rig, with CTD, spectroradiometer and fluorometer
1 Li-cor spectroradiometer
1 organic-carbon analyser
1 scintillation counter
3 winches
5 container laboratories, with various equipment for marine biological studies.

At Ronne Ice Shelf:

Investigators and programmes:

Orheim, Østerhus, Eiken, Melvold, Thomsen, Winther: Studies of ice-ocean interaction underneath Filchner- Ronne ice shelf.

Scientific equipment included the following:

Hot-water drilling system for ice shelf penetration
2 instrument-rigs for ice shelf/ocean investigations, each consisting of
3 current meters, 8 salinity sensors, 19 thermistors, DSU, and 2 ARGOS transmitters
1 ME mini CTD, with winch
1 Sensordata mini CTD
3 specially constructed bottles for water sampling through drill hole

At *Lance*:

Investigators and programmes:

Gammelsrød, Myking, Nøst, Skagseth: Bottom water production and ice shelf melting in the Southern Weddell Sea.

Forsberg, Nilsen, Kiviranta, Austin, Andersen: Marine geological studies in the Southeastern Weddell Sea.

Løyning: Ice production and convection in the Southern Weddell Sea.

Scientific equipment at* Lance *include the following:

Guildline portasal salinometer
1 Neil Brown EG&G CTD
1 Seabird CTD
1 ME mini CTD1 SACM EG&G current profiler
1 Simtronic UCM-50 current profiler
1 Sensordata STD
2 General Oceanic rosette samplers, 2 and 10 *l* bottles
9 current meter moorings, including 20 Aanderaa RCM4/5/7 current meters
3 Aanderaa WLR water level recorders, and 9 Oceano acoustic releases
3 CMI upward-looking sonars, with mooring rigs and 3 acoustic releases
4 CMI ARGOS data collecting platforms
1 box corer
1 piston corer for up to 12 m long cores
2 gravity corers
1 Selcore percussion corer for up to 21 m long cores4 sleeve guns, with 3 compressors
3 winches
4 permanent laboratories
2 container laboratories

At South Georgia:

Investigators and programmes:

Basberg, Rossnes: Industrial archaeology in South Georgia - part II.

MAIN EVENTS

(See Appendix for the itineraries of the two ships)

Polarbjørn departed from Cape Town on 9 December 1992, with 30 passengers. These included one Swedish air chemist who had conducted measurements all the way from Bergen, and two media personnel. These were to follow the ship back to Cape Town, while the remainder were to work ashore in Dronning Maud Land.

Seven persons with equipment were first transported to the Swedish Station Svea. This involved about 30 flying hours because of the 300 km long helicopter flights, and was carried out on 22 and 23 December, in mostly favourable flying weather.

On the following day three German overwinterers were fetched from Neumayer, to be northward bound with *Polarbjørn.*

Off-loading of the 20-person group for Troll and Tor started on 26 December, and the ornithologists were established at Tor already the following day. The South African ship *Agulhas* arrived as planned, and the heaviest equipment, including two Hägglund bandwagons, was flown onto the ice shelf by their Puma helicopters. All equipment was ashore on the ice shelf by 28 December, when *Polarbjørn* headed for Cape Town.

All personnel and the first overland transport of equipment was at Troll by 1 January, with the bandwagons having needed 60 hours travelling time because of very soft snow conditions. The glaciologists and topographers had all started their field work by the following day

Lance departed Cape Town on 5 January with 23 passengers. The two ships passed each other some hours south of Cape Town, where *Polarbjørn* arrived on the following day. *Lance* arrived off-shore Troll on 17 January, and it was planned then to close down Tor and Troll for the season. Bad flying weather prevented transport of personnel from Troll, and after a week of waiting interspersed with marine geological research and instrument testing it was decided to transport the 17 persons out by a bandwagon. This entailed that two of them would have to drive back to Troll, store the bandwagon in the garage and close down the station, and then be retrieved later. The overland group reached the ice front on 25 January, but not until 28 January was the flying weather such that all personnel, cargo, and the helicopters had been brought to the two ships.

Polarbjørn departed Cape Town on 8 January with 18 marine biologists, and conducted research around Bouvetøya before joining *Lance* on 20 January. They continued their marine biological studies in the pack ice until 30 January, of which one week was spent bound in heavy-pressured ice. On 25 January the first mate onboard had a spontaneously punctured lung. Fortunately the expedition doctor, who was on the ice shelf, reached the patient within a couple of hours. The patient was two days later transported to SANAE, where X-ray facilities were available, and where he convalesced until he went north with *Polarbjørn* on 1 February.

Lance brought one German passenger to Neumayer on 30 January, and conducted thereafter research in southern Weddell Sea until 23 February (Fig. 5). This included physical and chemical oceanography, marine geology, and sea ice studies. A group of 11 worked on the Ronne Ice Shelf from 5-14 February for sub-ice shelf studies.

On 11February Lance was in its westernmost position, 74°41'S, 61°21'W. This was the first time a Norwegian expedition had managed to conduct research along the front of the Ronne Ice Shelf. This area was reached by following narrow leads in multiyear ice between Berkner Island and the large grounded icebergs 100 km to the north-east, while the northbound voyage passed west and north of the icebergs, passing also ex-Druzhnaya Station. Lance was also further south (78°11'S) then any previous Norwegian expedition, as a result of the changed coastline caused by the large break-offs from the Filchner Ice Shelf.

Polarbjørn picked up three German passengers from Neumayer on 1 February, and headed then for Cape Town, and arrived there on 10 February. It sailed south again the next day, with two passengers. They conducted seal research in the pack ice, and passed by SANAE to pick up four South Africans and the two Norwegians that had been at Troll, before both ships met by Rampen on 24 February. Poor flying weather caused two days of waiting before the seven-person Swedish/Dutch party was retrieved. In the meantime Lance sailed to Neumayer so that our doctor could help the German doctor with an injury he had sustained. Finally 15 Germans were picked up for northbound return by Polarbjørn.

Both ships arrived Cape Town on 8 March, where all personnel went ashore, and they returned to Norway on 2 April.

RESULTS

Preliminary results of the expedition are reported elsewhere in this volume. In general the flying weather was considerably less favourable than we have experienced in recent years. This, combined with difficult driving conditions, means that some of the land programmes, especially those of the topographers, achieved less than planned. The marine biologists were very satisfied with the results obtained on the two Polarbjørn cruises dedicated to their research. The long delays at Lance at the start of the field programmes meant that some disciplines did not get as much field time as planned. This affected especially the glaciologists working at Ronne Ice Shelf, which only had one week of working time instead of planned four weeks. To a smaller extent it also affected the marine geologists. The marine scientists, however, had much compensation through the results obtained in the almost unstudied south-western sector of the Weddell Sea.

CONCLUSIONS

This was the first fully integrated Nordic expedition, with logistics provided by one Nordic country. The experience shows that this requires some additional planning over that of national efforts, but the pre-expedition planning and bureaucracy was not even the double of that of NARE 1989/90. This was a Norwegian expedition which was 3/4 of the size of NARP 1992/93, but in many other ways similar. Thus the increased pre-expedition work is small compared to the considerable savings per scientists that can be obtained by the three nationals pooling their logistic resources.

APPENDIX

SHIP ITINERARIES (see also Figs. 3 and 5):

M/V *Polarbjørn*:

Departure Bergen	12 Nov. 1992
Arrival Cape Town	9 Dec.
Departure Cape Town	10 Dec.
Arrival Rampen, offloading Swedish/Dutch group	22 Dec
Arr. Prinsesse. Astrid Kyst, off-loading Norwegian land party	26 Dec.
Departure loading area	28 Dec.
Arrival Cape Town	6 Jan. 1993
Departure Cape Town	8 Jan.
Departure Prinsesse Astrid Kyst	30 Jan
Departure Neumayer	1 Feb.
Arrival Cape Town	10 Feb.
Departure Cape Town	11 Feb.
Arrival Rampen	24 Feb.
Departure Rampen	26 Feb.
Arrival Cape Town	8 March
Departure Cape Town	9 March
Arrival Bergen	2 April 1993

R/V *Lance*:

Departure Oslo	10 Dec. 1992
Arrival Cape Town	3 Jan. 1993
Departure Cape Town	5 Jan.
Arrival Prinsesse Astrid Kyst	16 Jan.
Departure Prinsesse Astrid Kyst	29 Jan.
Marine programmes, Weddell Sea	31 Jan. - 23 Feb.
Arrival Rampen	23 Feb.
Arrival Neumayer	25 Feb.
Departure Neumayer	27 Feb.
Arrival Cape Town	8 March
Departure Cape Town	10 March
Arrival Oslo	2 April

JAN ERLING HAUGLAND*:

BUILDING IMPROVEMENT AND MAINTENANCE CONSTRUCTION DURING THE NORWEGIAN ANTARCTIC EXPEDITION 1992-93

DESCRIPTION

A permanent research station was established in Jutulsessen, Dronning Maud Land, in 1989/90, at S72°00.7' E2°32.3', and at 1290 m elevation. The station, which was named *Troll*, consisted initially of a main building and a shed/generator room. The main building contains a communications room, five double bedrooms, a shower, WC, storage room, and a room designated as a sauna. In addition, there is a kitchen, and an office/lounge. The main building can be heated both by electricity and by petroleum. The source of energy is a main diesel generator, which was supplemented in the 1992/93 season with a reserve diesel generator for emergency electricity.

The following work was planned and accomplished at Troll in the season 1992/93:

- Permanent completion of installation of the electrical wiring system in the main building and installation of a HF and VHF radio base station.
- A new building was erected as a combined workshop/garage and emergency station to be used in case of damage to the main building. The new building, 3.5 m x 9 m x 3 m, was constructed of fully insulated steel wall sections.
- At the end of the expedition, one snow-track vehicle (Hägglund's BV206) was stored in the new building.

The station Troll now consists of one main building, one emergency building, a generator shed, and a single Fiberglas igloo.

In the vicinity of Svarthamaren, an ornithological research site, an auxiliary station, *Tor*, was constructed at position 71°53.2'S, 5°09.3'E at 1625 m elevation. The building has the same design and size as the emergency station/garage at Troll station. The interior is designed as a work room and is generated by electricity and petroleum. It has a complete electrical system and a small, 5 kW diesel generator as electricity source. Stored in this building is one Hägglund BV206 snow-track vehicle. Small depots of Jet A-1 fuel and considerable provisions of dried food rations are stored in the Troll and Tor areas.

Waste not retrograded with the last transport of the season, was stored and sealed in barrels which will be transported from the station upon start of the next Antarctic research season.

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EGIL SAKSHAUG[1]:

CRUISE REPORT POLARBJØRN II, NARE 1992-93
(Marine Biology Cruise)

INTRODUCTION

This report gives information about stations visited and work/sampling/analyses carried out on board the *Polarbjørn* Leg II as part of NARE 1992/93.

The cruise started on Friday 8 January from Cape Town, two days delayed due to late incoming ship, and ended on Wednesday 10 February, a delay of four days relative to schedule.

Final preparations for sampling/analyses began on 13 January and the first station was taken on 14 January a little north of Bouvetøya. Problems arouse immediately when neither the CTD nor the bio-optical rig would work. Luckily, it was possible to repair the CTD to function for the remaining part of the cruise; the bio-optical rig, however, could not be repaired so that the total output was one profile at the very first station. Therefore, it was impossible to generally produce vertical profiles of spectral irradiance and chlorophyll fluorescence; the latter would have been most helpful in selecting sampling depths.

Fair weather from Bouvetøya and south to the ice shelf ensured good conditions for work in the next eight days and a high number of stations were taken. The ice edge was reached on 19 January and an open lead between the ice shelf and the sea ice was reached on the evening of 21 January. Comprehensive ice stations were taken on 19-23 January.

In the evening of 23 January the winds shifted from weak westerly to strong easterly, causing the vessel to be locked in the ice. It remained locked-in until the evening of 30 January. A hurricane passed, and most of the time the ice held the vessel in such a tight grip that it was impossible to lower equipment into the water. The vessel in this condition, however, became a sturdy platform that permitted delicate microscopy to be performed and the operation of instruments that were difficult to run in open seas. For instance, analysis of dissolved organic carbon could be run as in a land-based laboratory. During this period the scientific party from the Troll base was taken on board by helicopter. After the ship got out of the ice, additional sampling was carried out on the way towards the Neumayer Base and Bouvetøya; work was concluded on 7 February.

Polarbjørn II was the first Norwegian dedicated marine biological cruise ever to Antarctica, and the experiences acquired may be of value for the planning of future expeditions. The duration of the cruise was obviously too short, considering that the journey from Cape Town and back took a good 18 days in net terms, and that *force majeure* events such as

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freezing-in in the ice may happen on any Antarctic cruise. The ideal length of a marine biological cruise would presumably be around six weeks.

It should also be considered if at least one future cruise should take place one month earlier. In the high summer season of January, the spring blooming of phytoplankton was apparently over and we could only study typical summer situations with minute standing stocks. It should be added that the bulk of past investigations by other nations also has been carried out in January-February so that there is a deficit of studies during the early half of the growth season.

The investigated waters were characterised by the absence of krill swarms. Although the sampling equipment was far from ideal for sampling krill quantitatively, it is evident that krill stocks were small, partly minute, whether waters were open or ice-filled. On the other hand copepod stocks were large. This may not be surprising to seasoned Antarctic investigators who know well that krill stocks tend to be restricted to large but few swarms which one either hits or misses. It raises, however, questions to which extent birds, for instance at Svarthamaren, and seals living in the ice near the shelf, consume copepods in addition to krill. This question intimately ties the marine biological investigations of NARE to the investigations of feeding habits of seals and birds. Possibly krill swarms had been there before the cruise and would perhaps come back again. In any case it seems pertinent to give a high priority to investigations of copepods in future investigations of zooplankton - their biology is generally less known than that of krill, and their productivity in the Antarctic Ocean is certainly several-fold higher than that of krill.

Polarbjørn proved to be quite adequate albeit not ideal for marine biological studies. The system with laboratory containers on the shelter deck functioned very well. Containers on the upper deck, however, have to be more sturdy and watertight than wooden huts which were frequently exposed to swells at times preventing access, and the excessive moisture causing temporary shutdowns of the electronic equipment. An incident which might have caused serious trouble happened when two containers by accident were dropped about 0.5 m during loading. Luckily they contained no sensitive equipment. It might be useful for future scientific parties to invest in sturdy containers which are tailor-made for each purpose on future cruises.

The 220V/50 Hz current on board was largely unusable because the generator produced currents so variable that lights virtually blinked. Luckily, nearly all equipment could be used with the standard current on board, i.e.220V/60Hz. Moreover, vibrations from the main engine when running at full speed hindered microscopy and filtration. Vibrations also caused instrument problems with respect to analysis of dissolved organic carbon.

A serious problem which limited the number of experiments carried out was that the pump system furnishing cooling water to deck incubators and other experimental equipment did not work satisfactorily in the ice or while the ship was running. Finally, it would have been an advantage to have a deep-water echosounder. We had to estimate depths on the basis of rather crude maps.

Altogether the cruise went smoothly in spite of the problems mentioned above. This is more than anything due to the extreme helpfulness and inventiveness of the crew of *Polarbjørn*. We know of no cruise where the service by the crew has been more excellent. This and the fact that the scientific party had earlier field experience made the difference between success and failure. Moreover, the Finnish and Norwegian research teams fit excellently together, scientifically as well as otherwise.

PARTICPANTS

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POLARBJØRN CRUISE II - JANUARY 1993, ANTARCTIC OCEAN

Station information

(Depths, Z, are approximate, on basis of map readings)

St. 1. 14 January, 1530-2245 GMT
53°06'S, 04°15'E
Z = 3000 m
Cloudy/hazy 10
Wind 10 m s^{-1}
Biooptical rig 1540-1615 h, data to 150 m, aborted
CTD aborted
30-1 Niskins, 20 m, 5 m, 1630-1800 h
Phytoplankton water and net samples

St. 2. 15 January, 0545-1100 GMT
54°20'S, 03°22'E
Z = 550 m, north-east of Bouvetøya Island
Filtered samples infested by minerogeneous particles
Cloudy 10, sleet
Wind 15 m s^{-1}
30-1 Niskins, 30 m, 50 m: 0600-0700 h; 300 m: 0930-1045 h
Phytoplankton water and net samples

(Stations 3-13: Wind < 5 m s^{-1})

St. 3. 15 January, 1500-1530 GMT
55°00'S, 03°11'E
Z = 2600 m
WP-2 (Copepod) haul
Phytoplankton water and net samples

St. 4. 15 January, 2050-2105 GMT
56°00'S, 03°22'E
Z = 3200 m
WP-2 (Copepod) haul
Phytoplankton water and net samples

St. 5. 16 January, 0255-0310 GMT
57°00'S, 03°33'E
Z = 3800 m
WP-2 (Copepod) haul

St. 6. 16 January, 0850-0905 GMT
58°00'S, 03°00'E
Z = 5000 m
WP-2 (Copepod) haul
Phytoplankton water and net samples

St. 7. 16 January, 1440-1505 GMT
59°00'S, 03°34'E
Z = 5200 m
Light profile (PAR)
WP-2 (Copepod) haul
30-1 Niskin, 20 m
Phytoplankton water and net samples

St. 8. 16 January, 2035-2057 GMT
60°00'S, 03°38'E
Z = 5300 m
WP-2 (Copepod) haul
Phytoplankton water and net samples

St. 9. 17 January, 0215-0245 GMT
61°00'S, 03°45'E
Z = 5400 m
WP-2 (Copepod) haul

St. 10. 17 January, 0800-0822 GMT
62°00'S, 03°50'E
Z = 5000 m
WP-2 (Copepod) haul
Phytoplankton water and net samples

St. 11. 17 January, 1335-1400 GMT
63°00'S, 03°58'E
Z = 5000 m
WP-2 (Copepod) haul
30-1 Niskin, 20 m

St. 12. 17 January, 1920-1955 GMT
64°00'S, 04°07'E
Z = 4600 m
30-1 Niskin, 20 m
WP-2 (Copepod) haul
Phytoplankton water and net samples

St. 13. 18 January, 0105-0135 GMT
65°00'S, 04°15'E
Z = 4400 m
WP-2 (Copepod) haul
30-1 Niskin, 20 m

St. 14. 18 January, 0900-1850 GMT
66°27'S, 04°29'E
Z = 4000 m
Lightly cloudy, 9-10
Wind 5 m s^{-1}
CTD-cast + rosette 0-200 m (100 m, 200 m): 0920-0935 h
30-1 Niskins, 20 m, 50 m: 0945-1030 h
CTD-cast + rosette 0-100 m (80 m, 90 m): 1000-1015 h
CTD-cast + rosette 0-3560 m (500 m, 1000 m, 2000 m, 2800 m, 3560 m): 1100-1340 h
Light measurements, spectral, 1415-1430 h
Light profile (PAR), 1030-1645 h
WP-3 haul, 1440-1520 h
Tucker trawl haul, 1530-1850 h
Phytoplankton water and net samples

St. 15. 18 January, 2120-2150 GMT
67°00'S, 04°41'E
Z = 4100 m
WP-3 haul
Phytoplankton water and net samples

St. 16. 19 January 0750-0930 GMT
69°00'S, 04°14'E
Z = 2700 m
Sunny, cloudiness 0-2
Wind 3 m s^{-1}
30-1 Niskin, 20 m, 0750-0810 h
2 WP-3 hauls, 0810-0900 h
Light measurement, spectral, 0900-0930 h
Phytoplankton and water samples

Note: Ice edge passed 1 h before St. 17

St. 17. 19 January 1205-1420 GMT
69°28'S, 04°09'E
about 6 n.m. south of ice edge
Z = 1800 m
Lightly cloudy, 10
Wind 3 m^{-1}
Ice cover 3/10
2 WP-3 hauls, 1210-1235 h
30-1 Niskin, 20 m, 1235-1255 h
Light measurement, spectral, 1300-1330 h
Light profile (PAR), 1450-1510 h
Tucker trawl haul, 1350-1420 h
Phytoplankton and water samples

St. 18. 19 January 1700 - 20 January 1340 GMT
In beginning: 69°38'S, 03°54'E
Drifting 9 n.m SSW until end of station
30-45 n.m. south of ice edge
Z = 1100 m
19 Jan.: Cloudy 10, 20 Jan.: Light clouds or haze 10
Wind 0 m s^{-1}
Ice cover 9/10
Sediment trap out 19 Jan 1930, in 20 Jan 1340 h
Diving, 1935-2135 h 19 Jan
CTD + rosette 0-200 m (10 m, 30 m, 40 m, 75 m, 200 m), 0645-0710 h 20 Jan
CTD + rosette 0-1000 m (300 m, 500 m, 750 m, 1005 m)0750-0835 h, 20 Jan
30-1 Niskin, 20 m, 50 m, 100 m, 0900-0945 h, 20 Jan
WP-3 haul, 1000-1100 h, 20 Jan
Phytoplankton water and net samples
Ice sampling, light measurement (PAR) in infiltration layer, 1100-1230 h, 20 Jan

St. 19. 20 January 2100 - 21 January 1320 GMT
2100 h: 69°50.6'S, 04°19.7'E
0800 h: 69°46.6'S, 04°27'E
1200 h: 69°45'S, 04°27'E
30-45 n.m. south of ice edge, near 1st rendevouz with *Lance*
Z = 1100 m
Cloudy 10
Wind 0-2 m s^{-1}
Ice cover 9/10
Sediment trap, 100 m, 20 Jan. 2100 - 21 Jan. 1150 h
CTD + rosette 0-100 m (15 m, 25 m, 35 m, 50 m, 75 m), 0630-0702 h
CTD + rosette 0-1000 m (50 m, 100 m, 200 m, 500 m, 1000 m), 0730-0845 h
30-1 Niskin, 20 m, 0900-0915 h
WP-2 haul, 0945-1015 h
2 -WP-3 hauls, 0915-0945 h

30-1 Niskin, 20 m, 1250-1320 h
Phytoplankton and water samples
Ice sampling incl. diving, light measurement (PAR)
in infiltration layer, 21 Jan 0900-1100

St. 20. 21 January 2050-2200 GMT
70°06'S, 04°37'E
Open water, calm, 1/2 n.m. south of ice belt,
4-5 n.m from ice shelf
Cloudiness 9
Wind 0 m s^{-1}
WP-3 haul
Tucker trawl haul

St. 21. 21 January 2340 - 23 January 1630 GMT
0800 h, 22 Jan: 70°06.6'S, 04°45.9'E
1200 h, 22 Jan: 70°06.4'S, 04°42,2'E
1630 h, 23 Jan: 70°05.9'S, 04°27.8'E
2-3 n.m north of southern edge of ice layer, 7-8 n.m from ice shelf
Ice cover 9/10
Z = 500-800 m
22 Jan cloudy 7, with sun. Wind 2-3 m s^{-1}
23 Jan cloudy 10. Wind 6 m s^{-1}.
Sediment trap, 100 m, 22 Jan 0745 h - 23 Jan 1620 h
Amphipod cage, xxx m, 22 Jan 0915-1315 h
CTD + rosette 22 Jan, 18-538 m, 1425-1500 h
CTD + rosette 23 Jan, 0-494 m (205 m, 285 m, 400 m, 491 m): 1315-1405 h
30-1 Niskins, 20 m, 50 m, 100 m, 22 Jan 1210-1240 h
30-1 Niskins, 20 m, 50 m, 100 m, 23 Jan 0830-0900 h
Light profile (PAR): 22 Jan 1500-1515, 23 Jan 1450-1515 h
WP-3 haul 22 Jan 1000-1100 h; 23 Jan 1000-1100 h
Phytoplankton water and net samples

Ice sampling, diving, 22 Jan 0900-1115 h (Flak 1, 2), 1550-1730 h (Flak 3), 1930-2000 h (Flak 4), 23 Jan 0940-1300 h (Flak 5, 6), 1500-1730 h (Flak 7)

Additional ice sampling at St 21: 24 Jan 1630-1730 h (includes light measurement PAR in infiltration layer); 26 Jan 1630-1730.

Ship locked into ice near ice shelf and St 21: 24-30 January
1930 GMT.
Samples collected during this period are collectively termed
Station 22.
Position 70°08'S, 04°25'E
Z = 300 m

St. 22. 24-30 January 1930 GMT
28 January, 1400-1600 GMT
Light clouds, 9. Wind 8-10 m s^{-1}
WP-3 hauls
Ice samples: 24 Jan 1600-1700 h, cloudiness 10. Wind 10-15 m s^{-1}
26 Jan 1600-1700 h, cloudiness 10. Wind 25-40 m s^{-1}
29 Jan 1600-1700 h, cloudiness 10. Wind 10-15 m s^{-1}
30-1 Niskin, 20 m, 30 Jan 1145-1215 h, sunny, no clouds
WP-3 hauls, 30 Jan 0900-1000 h

St. 23. 31 January 1050-1130 GMT
69°03'S, 00°35'E
Wind < 5 m s^{-1}, cloudiness 10

At outer ice edge, ice cover < 1/10
Light profile (PAR)
30-1 Niskin, 20 m, 1200-1230 h

St. 24. 1 February 1000-1330 GMT
70°27'S, 07°53'W
No ice
off Neumayer Base
30-1 Niskin, 20 m
WP-3 haul
+ Tucker trawl haul (1930-2000 h, 69°25'S, 06°40'W)

St. 25. 2 February 1930-2015 GMT
65°02'S, 02°33'W
WP-3 hauls

INGER ANDREASSEN* & PAUL WASSMANN*:

VERTICAL FLUX OF PHYTOPLANKTON AND ORGANIC MATTER FROM THE EUPHOTIC ZONE IN ANTARCTIC ENVIRONMENT

INTRODUCTION

Spatial and temporal patterns in the flux of sinking organic matter are central to the understanding of elemental dynamics and foodwebs in the ocean. Sedimentation removes suspended biomass from the water column and represents at the same time an input of energy to the benthos. Sediment traps are powerful tools in furthering our understanding of the dynamics of pelagic systems. They not only collect the material settling out of the upper layer, but also demonstrate which types of suspended particles do not sink out, or do so only rarely.

The goal of this project is to estimate the vertical flux of the biogenic elements of carbon, nitrogen and silica and compare this to the water masses over the trap. We also want to find out what kind of particles (phytoplankton, fecal pellets, detritus) fall out and link this to the structure of the pelagic community and the ice community in the area.

METHOD

A TECNICAP PPS sediment trap was attached and deployed from the ice and drifted along with it during the sampling period. The trap is cylindrical with a conical bottom leading to a 270 ml sampling bottle. After recovery the trap was placed on deck an drained from the top for one hours to prevent resuspension of the material in the sampling bottle. The depth of deployment was 100 m at all stations, and the duration of deployment was 15-34 hours. The sedimented material was diluted to a known volume and split with a bird pipette. Samples for DW, particulate organic carbon, particulate organic nitrogen, lipid (see Falk-Pettersen & Lønne 1994), Chl a and pigment analyses were filtered by means of Wathman GF/F filters. Samples for biogenic silica were filtered on 1.0 µm Nucleopore filters. The rest of the samples were fixed with buffered formalin to an end concentration of about 4% and stored for later microscopic examination of plankton and fecal material. All analyses, except for Chl a determination and pigment analyses, will be done at home.

At all stations the water column was sampled for the same parameters (for Chl a, lipid and pigment, see other authors) as the sediment trap. Water samples were taken from the CTD rosette and the Niskin bottles, and 1-2 l was filtered for each parameter.

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Stations and depths sampled for POC; PON; PSi and DW

ST 14	ST 18	ST 19	ST 21 a,b
20 m	10 m	15 m	20 m
50 m	20 m	20 m	50 m
80 m	30 m	35 m	100 m
90 m	40 m	50 m	
200 m	50 m	100 m	
	75 m	200 m	
	100 m		
	200 m		

PRELIMINARY RESULTS

We had a total of three deployments of the trap in the pack ice. Ice conditions were fairly the same in all three areas. At the first deployment the trap was unfortunately not satisfactorily closed causing the water in the trap funnel to leak out during recovering. This may have lead to a loss of the trapped material, and an underestimation of the vertical flux of this station.

Analyses of Chl a and pigment and qualitative microscopy were carried out on the ship.

Station	Duration	mg Chl a sedimented m^{-2} d^{-1}
18 (trap I)	19.5 h	0.31
19 (trap II)	15.0 h	2.34
20 (trap III)	34.0 h	0.57

The first trap was almost completely dominated by fecal material, mainly long strings of Euphausian fecal pellet. Very little identifiable phytoplankton material was found in the trap material at this station. Euphausian fecal pellets were also dominant in trap II, but together with phytoplankton material. In trap III fecal pellets of copepods seemed to be the only type of fecal pellets present. Trap II and III were similar with regard to the species of phytoplankton found, but trap II had more empty frustles and detritus than trap III. The main species were *Phaeocystis* sp., *Corethron* sp and unidentified foraminifera.

REFERENCES

Falk-Pettersen, S. & Lønne O. J. 1997: Zooplankton in the marginal ice zone off Dronning Maud Land - population structure and relationship. Pp. 29-36 in Orheim, O. (Ed.): Norwegian Antarctic Research Expedition (NARE) 1992/93- *Norsk Polarinstitutt Meddelelser No. 125* (this volume).

STIG FALK-PETERSEN[1] & OLE JØRGEN LØNNE[2]:

ZOOPLANKTON IN THE MARGINAL ICE ZONE OFF DRONNING MAUD LAND - POPULATION STRUCTURE AND TROPHIC RELATIONSHIP

INTRODUCTION

In Antarctic waters zooplankton, including krill, form an important linkage between phytoplankton, ice algae and top predators such as marine mammals and birds. There is, however, a lack of information about the trophic In Antarctic waters zooplankton, including krill, form an important linkage relationships and energy transfer from the primary producers to the different zooplankton species in Antarctic waters (Conover & Huntley 1991). Little is also known about to what extent the flora associated with the lower surface of the ice is utilized by krill (Daly & Macaulay 1983).

The food chain can be studied in detail by the use of biochemical markers such as lipids (Sargent & Whittle 1981) and by stomach analyses. Studies of numerous species of marine algae and animals have established that lipid class and fatty acid composition are characteristic for species or groups of species (Falk-Petersen et al. 1990). In this investigation, a main goal is to characterise the lipid composition and to identify the stomach content of the most conspicious members of the ice and water communities to study the energy transfer between trophic levels. Community structure and population characteristics will be determined and discussed in relation to the lipid composition to shed light over the life cycle strategies of the investigated zooplankton species. Data on species composition and energy level of zooplankton which is important as food for the Antarctic birds in this area, will also be made available.

THE PROGRAMME

The investigation and the field sampling were performed in cooperation with dr. Ole Jørgen Lønne, University of Tromsø. He did the SCUBA-diving and will also be responsible for the stomach analyses. Tucker-trawl (TT) and WP-3-net hauls were taken by Lønne and Falk-Petersen.

On each station hauls were taken both for the Finnish group and to this investigation. Water samples for phytoplankton lipid chemistry were taken from the 20m depth by the use of 30l Niskin bottles and filtered by Cecilie Hellum, University of Tromsø. The sampling on ice was conducted by a team consisting of Cecilie Hellum and Ole Jørgen Lønne, University of Tromsø; Svein Kristiansen, Erik Syvertsen and Tove Farboth, University of Oslo; and Stig Falk-Petersen, Akvaplan-niva. Sediment-trap samples were taken by Inger Andreassen, University of Tromsø. Øystein Skagseth, University of Bergen, obtained the CTD data.

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Table 1.

Station #	Sampling gear	# of replicates	depth range
14			
	Tucker-trawl	4	200-0m
	WP-3 haul	1	200-0m
15			
	WP-3 haul	2	200-0m
16			
	2ol-Niskin	1	20m
	WP-3 haul	2	200-0m
17			
	Tucker-trawl	1	
	20l-Niskin	1	20m
	WP-3 haul	1	200-0m
18			
	20l-Niskin	1	20m
	WP-3 haul	2	200-0m
	Diving	1	5-0m
	ice-collection	1	0m
19			
	20l-Niskin	1	20m
	WP-3 haul	1	200-0
	Diving	1	5-0m
	ice-collection	1	0m
	Sediment trap	1	100m
20			
	Tucker-trawl	1	
21			
	WP-3 haul	2	200-0m
	WP-3 haul	1	300-0m
	Diving	6	5-0m
	Ice collection	3	0m
	Sediment-trap	1	100m

Table 2

	Station #	14	16	17	18	19	21	21	21	21	21	21	21
	Floe #							1	2	3a,b	4	5	6
Zooplankton	population dynamics		●	●	●	●	●						
Zooplankton	growth parameters	●	●	●	●	●	●						
Zooplankton	body composition	●	●	●	●	●	●						
Zooplankton	lipid chemistry	●	●	●	●	●	●						
Zooplankton	stomach content	●	●	●	●	●	●						
Phytoplankton	lipid chenistry	●	●	●	●	●	●						
Phytoplankton	species composition	●	●	●	●	●	●						
Ice fauna	population dynamics				●	●			●	●	●	●	
Ice fauna	growth parameters				●	●			●	●	●	●	
Ice fauna	body composition				●	●			●		●		
Ice fauna	lipid chemistry								●	●	●		
Ice fauna	stomach content								●	●	●	●	
Ice algae	lipid chemistry				●	●		●	●	●			●
Ice algae	species composition				●	●		●	●	●			●
Sedim. trap cont.	lipid chemistry					●		●					

Table 3
Ice conditions

Station #	17	18	19	20	21
Total ice cover	2-3/10	7-9/10	7-9/10	0/0	9/10
Primary ice category					
age	old-FYI	old-FYI	old-FYI	open water close to the ice-shelf	old-FYI
average floe size	30-50m	50m	50-100m		50-100m
ice thickness	N/A	1-2 m	1-2m		3-5m
sno cover	N/A	50-70 cm	50-70 cm		50-70 cm
Secondary ice category	N/O	N/O	N/O		
age					young-FYI
average floe size					50m
ice thickness					70 cm
sno cover					20 cm

FYI= First-Year ice, N/A= Not Available, N/O= Not Observed

METHODS AND STUDY AREA

The study area

The investigation was conducted in the Lazarev Sea off Dronning Maud Land between 66°S and 70°S. A total of six stations were sampled, two in open waters and four inside the pack-ice.

Zooplankton and ice fauna

Zooplankton were sampled with a Tucker Trawl (TT) fitted with a 0.5mm mesh net and a with a 1mm mesh WP-3 net. Net hauls were taken in the upper 200 m. Ice fauna was sampled by SCUBA-divers and the animals caught by a 0.35 mm hand net. Video recordings were taken of the under ice fauna and flora using a Sony video 8.

Animals for population and community analyses were sub-sampled using a 1 litre jar and stored on formaline for further analyses. Approximately ten animals of the most conspicuous species in each haul were picked out and stored separately on formaline for stomach analyses. Five to 20 live animals were individually picked from the sample for later body content analysis. They were rinsed in filtered sea water, identified and carefully packed in single layers in small plastic bags and frozen in a bio-freezer at -80°C. Zooplankters sampled for lipid analysis were picked out individually and immidiately dropped into chloroform:methanol (2:1, v/v) contained in v-vials with a Teflon cap. The samples were stored in a freezer at -80°C.

Algae

Microalgae from the infiltration layer were sampled from holes digged in the snow at the outer edge of the ice floes. Ice and snow was filtered from the water before further treatment of the samples.

Ice algae from the bottom layer of floes were sampled by SCUBA-divers using a small suction pump (Lønne 1988).

Phytoplankton from the water-coloumn was sampled with a 30 l Niskin bottle at 20 m depth. The samples were filtered by means of Whatman GF/F filters and immediately transferred to glass vials containing chloroform : methanol (2:1, v/v) and stored at -80°C for later lipid analysis. Samples for determination of phytoplankton and ice algal composition were taken both by Hellum and Syvertsen on all stations and will be made available for this project.

THE SAMPLING PROGRAMME AND PRELIMINARY RESULTS

The station list and parameters sampled are shown in Tables 1 and 2. Ice cover, age of the ice, floe size, ice thickness and ice cover are given in Table 3.

Station 14, 18.12.93

This was an open water station with a total depth of approximately 4000 m. The upper 20 m is characterised by warm (0.5 to 1.0°C) and moderate saline waters (33.9), while the water masses between 30 m and 100 m is cold (-1.7°C) and slightly more saline.

A total of four TT and one WP-3 hauls were taken. Four of the hauls were aborted due to heavy clogging of the net by phytoplankton. Samples of *Calanus propinquus* and *Thysanoessa macrura* were stored for further analyses of body composition, growth parameters and lipid chemistry. Three litres of water taken at 20 m depth were filtered for later for lipid analysis of the phytoplankton.

Station 15, 18.01.93
This station was in open water with a total depth of 4100 m. A WP-3 net haul was taken for the Finnish group.

Station 16, 19.01.93
This station was in open water with a total depth of approximately 2700 m. It was about 10 nm from the ice edge. No CTD-data were available from this station due to technical problems.

Two WP-3 hauls were taken and samples of *Calanus propinquus, Calanoides acutus* and *Thysanoessa macrura* were stored for later analyses of body composition, growth parameters and lipid chemistry. A sub-sample for population analysis was stored on formaline. 1.9 l of water was filtered and stored for lipid analysis of the phytoplankton.

Station 17, 19.01.93
This station was in the marginal ice zone approximately 6 nm from the ice edge. Water-depth was approximately 1800 m. The ice cover was light, 2-3/10, and characterised by old first-year ice floes with diameters of 30 m - 50 m.

One WP-3 and one TT haul were taken. A sub-sample for population studies was taken from the WP-3 net haul and stored in formaline. Samples of *Calanus propinquus, Calanoides acutus* and *Thysanoessa macrura* were stored for body composition, growth parameters, and lipid analyses. All krill found were picked out for different analysis. The larger krill had distinct green guts.

Two litres of water were filtered and stored in the bio-freezer for analysis of the phytoplankton lipids.

Station 18, 19.01.93
The station was in moderate to heavy pack ice (7-9/10) with a total water depth of 1100 m. Floes with a diameter of approximately 50 m, thickness of 1-2 m and a snow cover of 50-70 cm were most common. The ice was characterized as old first-year ice. The CTD-profile showed a thin, low salinity (33.5) upper layer of approximately 10 m. The temperature in the upper 300 m is approximately -1.7°C and the salinity between 34.1 and 34.5.

One WP-3 haul and ice fauna sampling by diving and collection of ice algae from the infiltration layer were carried out. From the WP-3 haul *Calanus propinquus* and *Calanoides acutus* were sampled for analyses of body composition, growth parameters, lipid chemistry and population parameters. The under-ice fauna and flora were very poor and only two krill (*Euphausia crystallorophias*) and two amphipods were collected. They were frozen for analysis of the body composition. Samples of phytoplankton (2 l) from 20m depth and ice algae (230 ml) from the infiltration layer were filtered and stored for analysis of the lipid composition.

Station 19 20.01.93
This station was in moderate to heavy pack ice (7-9/10) with a water-depth depth of 1100 m. The ice was characterised by old first year ice. The floes had a typical diameter of 50-100 m, thickness of 1-2 m and a snow cover of 50-70 cm. The CTD-profile showed a distinct upper 10 m layer with a temperature of -1.7°C and a

salinity of 33.8. The water masses between 30 m and 300 m had a temperature between -1.5°C and -1.9°C and salinities between 34.1 and 34.3.

One WP-3 haul was taken in addition to ice fauna and ice algal samples from the infiltration layer. Samples were also taken from the Niskin bottle and from an overnight sediment trap of 100 m depth. From the WP-3 net a subsample was collected for population studies *Calanus propinquus* and *Calanoides acutus* were sampled for analysis of growth parameters, body composition and lipids. The under ice flora and fauna were poor and only three *Euphausia crystalorophias* were found. One sample (50 ml) from the sediment trap, two samples (50 and 80 ml) of ice algae from the infiltration layer, and one sample of phytoplankton (2 l) from the 20 m Niskin bottle were filtered for lipid analysis.

Station 20. 21.01.93
One TT-haul was taken in an open lead near the shelf. The haul was very poor and no samples taken.

Station 21. 21-23.01.93
Heavy pack ice (9/10) dominated on this station with a water-depth of 500 m to 800 m. The ice in this area consisted of both young and old first year ice. The old ice had a typical floe size of 50-100 m, a thickness of 3 m to 5 m and a snow cover of 50-70 cm. The young ice was much thinner (70 cm) with a snow cover of only 20 cm. The CTD-profile showed that the upper 30 m form a layer with a salinity of 33.7 and a temperature of 1.6°C. Between 50 and 300 m there was a slow but steady increase in salinity from 34.0 to 34.3 and decrease in temperature from -1.7°C to -1.9°C.

Investigations on this station were mainly concentrated on the ice fauna and flora, but from the 2 WP-3 hauls samples were taken for population studies and of *Calanus propinquus* and *Calanoides acutus* for analyses of body content, growth parameters and lipids. A sediment trap sample (50 ml) from 100 m were filtered and stored for lipid analysis.

Station 21, floe 3
Ice algae from the infiltration layer were filtered (100 ml) and stored for lipid analysis.

Station 21, floe 4
Moderate amounts of ice algae were recorded in domes and small holes under the ice. Amphipods were sampled by diving and stored for species identification and for analysis of the body content and lipid chemistry. A total of eleven small and one large amphipods were collected. The small amphipods were sitting on the ice and in small cracks and cavities. Ice algae from the infiltration layer were collected and 200 ml filtered and stored for lipid analysis.

Station 21, floe 5
Ice algae from the infiltration layer were filtered (15 ml) and stored for lipid analyses.

Station 21, floe 6
This floe was 1-1.5 m thick and had a relatively rich under-ice algal cover. Swarms of grazing krill were associated with the bottom layer of algae. The krill, *Euphausia crystallorophias,* was sampled for analysis of growth parameters, body content and lipid chemistry.

Station 21, floe 7
Ice fauna were sampled. Eleven amphipods were collected for species identification and body content analysis. The under-ice flora was poor and no algae were recorded.

Station 21, floe 8
Euphausia crystalorophias were sampled by diving and stored on formaline for stomach analyses. Video recordings of grazing krill were taken.

Station 21, floe 11
Under-ice algae were sampled by diving and a 100 ml sample filtered for lipid analysis.

Station 22. 28.01.93.
This station was in very heavy pack ice (10/10) with a water-depth of about 300 m. Three WP-3 hauls were taken and samples of *Euphausia crystalorophias, Calanus propinquus, Calanoides acutus* and an unidenified amphipod (probably *Orchomone plebs*) were taken for analysis of growth parameters, body composition and lipids.

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CECILIE HELLUM VON QUILLFELDT*:

ICE ALGAE AND PHYTOPLANKTON COMPOSITION IN THE WEDDELL SEA: INTERACTIONS WITH DIFFERENT ENVIRONMENTAL FACTORS

INTENTION

- To study the influence of ice, distance from land and hydrographical conditions on the development of phytoplankton in a part of the water column.
- To increase the knowledge about the relationship between ice and the water column near the ice with regard to the origin and fate of the cells in the ice.
- To study intraspecific variation in growth habitat and size, life stage and abundance (relative and absolute) of ice-related species.
- To study which algal species may be selectively grazed by zooplankton.
- To compare species composition of phytoplankton and ice algae in the Arctic and Antarctic.

INTRODUCTION

The pattern of seasonal variation in phytoplankton standing crop and production is of fundamental significance to the marine ecosystem. The availability of phytoplankton determines the ecology of both benthic and pelagic herbivores, and this influences animals in the higher levels of the food web (Clark et al. 1988). Changes in light levels have been shown to be a major controlling factor in the diversity of phytoplankton (Perrin et al. 1987). In addition, water temperature, salinity and nutrients, all of which exhibit seasonal fluctuation, have been shown to have considerable effect on the phytoplankton and ice algal abundance and species composition (Horner 1977; Legendre et al. 1981).

The ice algal assemblages can be divided into different types of assemblages: Infiltration assemblage (seawater infiltrated snow-ice interface), pool assemblage (pools on the ice surface), band assemblage (bottom ice algal layers frozen into the ice), brine channel assemblage (in brine channels and cracks), interstitial assemblage (between ice crystals and platelets), and sub-ice assemblage (mats and/or strands loosely attached to the under-surface of the ice) (Horner et al. 1988).

It is difficult to compare the species present in the sea ice and water column in the Arctic and the Antarctic because adequate floristic studies are lacking. Pennate diatoms are the most abundant groups in the ice in both polar regions. The ice acts as an inverted benthic environment and the species present are often benthic forms. Only a few centric diatoms are commonly found in the ice (except for the marginal ice zones), with more centric species occurring in the Antarctic than in the Arctic (Horner 1985). In both polar regions where marginal ice zones have been studied, centric diatoms are dominant in the ice and water column, but it is not known whether the diatoms from ice in these areas actually grow in the sea ice (Horner 1985).

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Table 1. Net samples from running water

1. Start:	58°54' S 3°34' E	End:	59°14' S 3°32' E	16.01.93 14.00-15.00
2. Start:	62°19' S 3°53' E	End:	62°36' S 3°54' E	17.01.93 10.00-11.00
3. Start:	St.16	End:	69°15' S 4°12' E	19.01.93 09.30-10.30
4. Start:	St. 23	End:	68°59' S 4°29' W	31.01.93 11.30-12.30
5. Start:	68°50' S 4°11' W	End:	68°43' S 4°13' W	31.01.93 22.00-23.00
6. Start:	70°17' S 8°11' W	End:	70°27' S 8°12' W	01.02.93 09.45-10.45
7. Start:	69°04' S 6°21' W	End:	68°52' S 6°11' W	01.02.93 22.00-23.00
8. Start:	66°40' S 4°16' W	End:	66°30' S 4°06' W	02.02.93 10.00-11.00
9. Start:	64°41' S 2°19' W	End:	64°31' S 2°10' W	02.02.93 21.45-22.45
10. Start:	59°18' S 2°11' E	End:	59°07' S 2°21' E	04.02.93 09.30-10.30
11. Start:	57°08' S 3°55' E	End:	56°57' S 4°05' E	04.02.93 21.30-22.30
12. Start:	54°58' S 5°49' E	End:	54°47' S 5°57' E	05.02.93 10.00-11.00

Table 2. Sampling survey (number of samples)

	Ice filled areas	**Ice free areas**
Net samples (vertical)	3	4
Net samples (running water)	3	13
Infiltration layer	5	
Melted ice	3	
Underside of ice	3	
Water samples	14	22

Critical examinations of the species composition of Antarctic diatoms show the problems encountered by scientists who have made an attempt to identify the diatoms involved. Diatoms are often referred to genus or given names of similar species living in temperate or Arctic seas, sometimes correctly but more often not. Several Antarctic diatoms have repeatedly been described because polymorphic stages of a single organism have not been recognised. Life histories are poorly known (Fryxell 1989). Examinations of ice diatom and phytoplankton communities by the use of modern techniques will therefore be most important to obtain information not only on the species composition and relationship between the species, but also to understand the specific ecological and physiological attributes of the Antarctic ice communities.

METHODS

Phytoplankton samples were collected in both ice-covered and open water by vertical net hauls (25µm) and with Niskin sampling bottles (sampling depths: 0 m, 20 m, and 50 m). Net samples were also taken from the running sea water on board the ship. This sampling lasted for about one hour, once or twice every day when the ship was cruising between Bouvetøya and the Antarctic Continent (both directions).

Ice algae from the underside of the ice were collected by divers using a special designed pump connected to a net with mesh size of 25 µm. On some occasions a special piston sucking algae from small depressions in the ice was used. The phytoplankton and ice algal samples were preserved in a mixture of formaldehyde and acetic acid or neutralised formaldehyde.

Pieces of coloured ice, floating between the ice floes were sometimes collected and melted. Samples from the infiltration layer were taken by digging from the surface of the ice floe and then sampled in bottles.

The net and ice algal samples will be cleaned (Simonsen 1974) to provide material for relative abundance and identification. The water samples will be counted in an inverted microscope (Hasle 1978) to provide estimates of absolute abundance. Water samples and net samples provide different kinds of information: Water samples of one litre or less are dominated by the smaller, more ubiquitous nanoplankton (Weber & El-Sayed 1987; Brandini & Kutner 1986), while net hauls concentrate the larger and rarer net-plankton which is more likely to show spatial variation and contain more heavily silicified species expected to be in the sediment. Net hauls also integrate collections over a larger volume of the water column (Fryxell 1989). Water samples may not capture net plankton in sufficient quantity to provide reliable counts. Relative abundance of net plankton can be informative, but will be difficult to interpret.

PRELIMINARY RESULTS

In spite of occurrence of some widely distributed species there appeared to be some more-or-less distinct assemblages. However, there was a close similarity in algal species composition between some of the sea ice samples and different planktonic communities, but the relative abundance of species sometimes differed considerably. Early in the cruise the net samples were dominated by large diatoms such as *Chaetoceros criophilum*, *Thalassiothrix antarctica* and sometimes *Corethron criophilum.* Different *Pseudonitzschia* species were relatively abundant in almost every net sample and *Fragilariopsis kergulensis* in some of them. *Cylindrotheca closterium* was also common in several of the net hauls and was dominating one of the samples of melted ice. One of the samples from depressions in the ice consisted of typical ice algae such as *Nitzschia stellata* and different *Pleurosigma*, *Gyrosigma* and *Entemoneis* species. Dark brown threads of *Berkelya* were also found here. *Phaeocystis pouchetii* was the dominant species in most of the samples from the infiltration layer, but this often differed from the water column in the same area. This shows that differential growth in the infiltration layer can change relative abundance.

Big mats of algae on the underside of the ice were not found due to the time of the year. We saw only remains from this. This was different from what we found during NARE 89/90 (Gulliksen et al. 1990). Then there were several types of ice algae assemblages on the underside of the ice and long strands of algae, often dominated by the species *Entemoneis* sp. hanging into the water column. But this was just found on floes which had not drifted too much and with little melting, if at all.

Several of the species found have to be studied in more detail to sort out whether they belong to one or more species, and some new ones should also be described.

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SVEIN KRISTIANSEN*, ERIK E. SYVERTSEN* & TOVE FARBROT*:

ICE ALGAE AND PHYTOPLANKTON COMPOSITION IN THE WEDDELL SEA: INTERACTIONS, PRODUCTION AND NITROGEN UPTAKE

Samples collected by this project are given in Tables 1 & 2. Detailed information about the samples collected in the infiltration layer are given in Table 3.

Sampling
The rosette sampler was used to sample depth profiles of nutrients. The other samples from the water column were collected using 30-l Niskins. Samples from the infiltration layer (interface between ice and snow flooded with sea water) were collected by digging into the layer from above. Nutrients were measured on undiluted ice-free samples. Biomass samples containing ice were diluted (10x) with filtered (GF/F) sea water.

Irradiance (PAR)
Profiles in the water column were measured using LI-COR Data Logger (LI-1000) and Underwater Spherical Quantum Sensor (LI-193SA). Irradiance in the infiltration layer were measured using Biospherical Integrating Quantum Scalar Irradiance Meter (QSI-140B).

Nutrients
Ammonium and urea were measured 2-5 h after sampling using standard methods. The total nitrogen samples were digested on board, frozen and will be analysed in Oslo. Nitrate, nitrite, phosphate and "silicate" will be measured on frozen samples in Oslo.

Biomass
Chlorophyll was measured by Mika Raateoja (ethanol-extracts).

Cellular lipids and Fe
Lipids will be measured at the University of Bristol (dr. M. Conte) and Fe at IMP, University of Bergen (M. Heldal).

Nitrogen uptake rates
Uptake rates of nitrate, nitrite, ammonium, urea, and a mixture of amino acids were measured using the stabile isotope N-15 (Kristiansen & Paasche 1989)

Regeneration
Regeneration of ammonium by microzooplankton was measured using the stabile isotope N-15 (Kristiansen & Paasche 1989).

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Table 1. Samples collected during NARE 92/93 (Polarbjørn II)

Date	St. #	Floe# old	Floe# new	Depth/m from edge	S o/oo	PAR	Nutrients	Ammonium µM	Urea-N µM	Uptake	Species	Additional exp & samples
14-jan	1			20	x		x	0.43	0.2	A,N,Ni,U	Q,Net	Frac
14-jan	1			50			x	0.53	0.2			
15-jan	2			20	x		x	0.37	0.1	A,N,Ni,U	Q,Net	Frac
15-jan	2			50	x		x	0.44	0.3			
15-jan	2			400	x		x	<0.03	<0.1			
16-jan	7			20	x	Profile	x					
17-jan	11			20	x		x				Q,Net	
17-jan	12			20	x		x					
18-jan	13			20	x		x					
18-jan	14			20		Profile	x	0.40	0.1	A,N,Ni,U,Aa	Q,Net	Fe-add, Remin tot & <63
18-jan	14			50			x	0.52	0.1	A,N,Ni,U		
18-jan	14			80			x	0.26	0.1			
18-jan	14			90			x	0.20				
18-jan	14			100			x	0.30	0.1			
18-jan	14			200			x	0.34	0.2			
18-jan	14			500			x	0.49	0.3			
18-jan	14			1000			x	0.34	0.2			
18-jan	14			2000			x	0.47	0.2			
18-jan	14			2800			x	0.07	0.3			
18-jan	14			3560			x	0.06	<0.1			
18-jan	15			20	x		x					
19-jan	16			20	x		x				Q,Net	
19-jan	17			20	x	Profile	x	0.29	<0.1	A,N,Ni,U,Aa	Q,Net	Frac
20-jan	18			20	x		x	0.92	0.2	A,N,Ni,U,Aa	Q,Net	Frac
20-jan	18-ice	A	1	0.1	x	x&12h	x	1.14	1.0		Q,Net	
20-jan	18-ice	A	1	1	x	x	x	1.38	2.5		Q	
20-jan	18-ice	A	1	2	x	x	x	0.90	0.7		Q	
20-jan	18-ice	A	1	4	x	x	x	0.66	0.5		Q	
20-jan	18-ice	A	1	6	x	x	x	0.61	0.5		Q	
21-jan	19			15			x	0.39				
21-jan	19			20			x	0.93	<0.1	A,N,Ni,U	Q	
21-jan	19			25			x	1.27				
21-jan	19			35			x	1.00				

		Floc#	Floc#	Depth/m				Ammonium	Urea-N			Additional
Date	St. #	old	new	from edge	S o/oo	PAR	Nutrients	µM	µM	Uptake	Species	exp & samples
21-jan	19			50			x	0.82				
21-jan	19			75			x	0.74				
21-jan	19			100			x	0.46				
21-jan	19			200			x	0.25				
21-jan	19			500			x	0.22				
21-jan	19-ice	B	2	0.1	x	x	x	0.80	0.3		Q,Net,S	Fe,Lipid
21-jan	19-ice	B	2	1	x	x	x	1.12	0.6		Q	Fe,Lipid
21-jan	19-ice	B	2	2	x	x	x	0.44	0.2		Q	Fe,Lipid
21-jan	19-ice	B	2	4	x	x	x	0.94	0.4		Q	Fe,Lipid
21-jan	19-ice	B	2	10	x	x	x	0.54	0.2		Q	Fe,Lipid
22-jan	21			2[illegible]		Profile	x	0.59	0.1	A,N,U	Q,Net	
22-jan	21-ice	1	3	0.1	x	x	x	0.67	1.4		Q,Net	
22-jan	21-ice	2	4	0.1	x	x	x	0.60	0.5		Q,Net,S	
22-jan	21-ice	3	5	0.1	x	x&30h	x	0.40	0.2	A,N,Ni,U,Aa	Q,Net	Light,Fe,Lipid
22-jan	21-ice	3	5	2	x	x	x	0.42	0.6		Q	Fe,Lipid
22-jan	21-ice	3	5	4	x	x	x	0.34	0.5		Q	Fe,Lipid
22-jan	21-ice	4	6	0.1							Q,Net,S	
22-jan	21-ice	5	7	0.1							Q,Net,S	
22-jan	21-ice	Blue ice					x	2.87	8.1			
23-jan	21-ice	7	10	0.1	x	x & Profile	x	0.46	0.4	A,N,Ni,U,Aa	Q,Net	Fe,Lipid
23-jan	21-ice	7	10	1	x	x	x	0.57	<0.1		Q	Fe,Lipid
23-jan	21-ice	7	10	2	x	x	x	0.47	0.4		Q	Fe,Lipid
24-jan	22-ice	9	12	0.1	x	x	x	0.63	0.3	A,N,U	Q	Light,Growth
26-jan	22-ice	10	13	0	x		x	0.45	0.9	A,N,U	Q	O2-Prod
27-jan	22-ice	Blue ice			x		x	2.44	5.2			
29-jan	22-ice	11	14	0.1	x	x	x	1.03	0.8	A,N,Ni,U,Aa	Q	Light,Inhib,O2-Prod
30-jan	22			20	x		x	0.70	0.3	A,N	Q	Remin tot
31-jan	23			20	x	x & Profile	x	1.27	0.6	A,N,U,Aa	Q	Remin tot & <63

Abbreviations:

x: Sample to be analyzed

A,N,Ni,U,Aa: Ammonium, nitrate, nitrite, urea, amino acids

Q,Net,S: Quantitative and net samples from water column and infiltration, sub-ice

Fe, Lipid, Growth, Prod, Remin, Light, Inhib, Frac, Fe-add: Cellular iron and lipid, ice algae growth and grazing, O2-production, Regeneration of ammonium by total sample and <63µm fraction, Uptake vs. irradiance exp., Inhibitor exp., Fractionation exp., Fe-addition exp.

Table 2	Additional experiments and samples
Experiment/sample	Station
Excretion of dissolved organic nitrogen by macrozooplankton	14, 19, 21, 22
Net samples	Neumayer, Cape Town

Table 3. Infiltration layer sampled during NARE 92/93 (Polarbjørn II)

Date	Station #	Floe # old	Floe # new	Sampl. time	m from edge	Snow cm	filtr.layer cm	Irradiance infilt.layer. µmol/m2/s)	Irradiance now surface µmol/m2/s)	irradiance nfilt.layer.	Chl.a (µg/l)
20-Jan	**18-ice**	**A**	**1**	**12**	**0,1**	**60**	**25**	0	3507	0	11,8
20-Jan	**18-ice**	**A**	**1**	**12**	**1**	**60**	**10**	0		0	5,3
20-Jan	**18-ice**	**A**	**1**	**12**	**2**	**65**	**15**	0		0	3,4
20-Jan	**18-ice**	**A**	**1**	**12**	**4**	**80**	**35**	0		0	1,3
20-Jan	**18-ice**	**A**	**1**	**12**	**6**	**72**	**22**	0		0	1,6
21-Jan	19-ice	B	2	10	0,1	50	25	500	3352	15	24,5
21-Jan	**19-ice**	**B**	**2**	**10**	**1**	**50**	**25**	0		0	31
21-Jan	**19-ice**	**B**	**2**	**10**	**2**	**50**	**15**	0		0	49,7
21-Jan	**19-ice**	**B**	**2**	**10**	**4**	**50**	**15**	0		0	25,9
21-Jan	**19-ice**	**B**	**2**	**10**	**10**	**60**	**25**	0		0	2,7
22-Jan	21-ice	1	3	9	0,1	65	20	0	3996	0	
22-Jan	21-ice	2	4	10	0,1	65	10	0	4743	0	
22-Jan	**21-ice**	**3**	**5**	**15**	**0,1**	**65**	**15**	0	3969	0	12,2
22-Jan	**21-ice**	**3**	**5**	**15**	**2**	**70**	**10**	0		0	4,5
22-Jan	**21-ice**	**3**	**5**	**15**	**4**	**80**	**15**	0		0	10,4
22-Jan	21-ice	4	6	16	0,1	40	25				
22-Jan	21-ice	5	7	16	0,1	50	20				
23-Jan	21-ice	7	10	15	0,1	60	25	0	3750	0	6,2
23-Jan	21-ice	7	10	15	1	50	20	0		0	17,3
23-Jan	21-ice	7	10	15	2	50	25	0		0	3,1
24-Jan	22-ice	9	12	17	0,1	30	15	0	2013	0	13,6
26-Jan	22-ice	10	13	17	0	0	10				
29-Jan	22-ice	11	14	16	0,1	10	10	0	3519	0	13,1

Biomass samples in bold face have diluted (100 ml sample to 1000 ml using GF/F-filtered seawater)

Chlorophyll concentrations have been corrected for the dilution (values from Mika)

Ice algal growth and grazing

A dilution method was used to estimate growth and grazing (Landry & Hassett 1982).

Ice algae O_2 production

Measured production of O_2 in light and dark bottles after 24h incubation.

Inhibitor experiments

Chloramphenicol and cycloheximide were used in an attempt to separate between heterotrophic and autotrophic nitrogen uptake.

Fractionation

1.0 µm polycarbonate filters were used to separate between nitrogen uptake in the <1.0 µm fraction ("bacteria") and the >1.0 µm fraction ("algae").

Fe-addition

Fe was added to study short term effects of Fe on the nitrogen uptake rates.

Excretion

Excretion of total nitrogen and urea from macro-zooplankton were measured in experiments conducted by Jan-Erik Bruun.

Diatom taxonomy

Net samples from nearly all stations plus two samples each day from Neumayer to Cape Town. Samples from infiltration layers and sub-ice assemblages. Altogether c. 200 samples. Preparation began on board, but the main part of the work will be done in Oslo.

Interaction ice assemblages/plankton

Species composition in plankton and the two different ice algal assemblages (infiltration and sub-ice) observed were completely different. There thus seems to be no interaction at this time of the year.

Selective grazing

Gut content of c. 250 animals (krill, amphipods and copepods) will be analysed in Oslo and compared to the species composition in ice and plankton assemblages (Coop. O.J. Lønne).

Lipids

Samples have been collected to study lipids in algae and zooplankton (S. Falk-Petersen); the results will be compared to the species composition and physiological status of the algae.

Organic components in sea ice

E. Fogelquist (Sweden/Lance cruise) has found interesting and unknown organic components in the infiltration layer. These finds will be compared to the species composition of the algae in the ice, and further cooperation will take place based on algal cultures.

Growth and uptake experiments in the lab

A number of crude cultures was started on board and will be brought back to Oslo. If the transport back is successful, colonial cultures will be isolated for further experiments in the lab. (Coop. E. Sakshaug).

GENERAL COMMENTS

For sampling stations, etc., see tables. In addition there will be c. 20 net samples from the section Neumayer-Cape Town. Most of the samples have to be worked up in preliminary concentrations of ammonium and urea are given in Tables 1 and 2.

We had our laboratory in a container ("letthus") on the shelter deck. After having the power system (220 V) repaired in Cape Town (could have cause a lot of damage), the laboratory functioned very well. We were able to fulfil most of our objectives for the nitrogen part of this project. The crew was very helpful, and often made the impossible possible.

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SVERRE MYKLESTAD* & KNUT YNGVE BØRSHEIM*:

PHYTOPLANKTON CELLULAR AND EXTRACELLULAR PRODUCTION AND DOC TURNOVER

The following table shows data collected, sampling carried out and experiments performed during the expedition January/February 1993.

Polarbjørn Cruise II, January 1993, Antarctic Ocean. List of samples and analyses

BY K.Y. BØRSHEIM

Codes:	**Bac:**	Samples fixed for the counting of bacteria by DAPI, and bacteria and viruses in the TEM.
	DAPI:	Counting of bacteria on board after staining with DAPI
	Thym:	Thymidine incorporation incubation for the measurement of bacterial production.
	DOC:	On board analysis of Dissolved Organic Matter by high temperature catalytic combustion

		Bac	DAPI	Thym	DOC
St.1. 14 January, 1530-2245 GMT	20m	+		+	
	50m	+		+	
St.2. 15 January, 0545-1100 GMT	20m	+			
	50m	+		+	
	400m	+		+	
St.6. 16 January, 0850-0905 GMT	20m	+		+	
	Ice algae	+			
St.14. 18 January, 0900-1850 GMT	100m	+		+	
	200m	+		+	
	80m	+			
	90m	+			
	1000	+		+	
	3560	+		+	
Ice sampling incl. diving	Snow	+		+	
	Ice algae	+		+	
St.21. 21 January 2340	Snow	+	+	+	+
January 1630 GMT	Ice-algae	+	+		+
	20m	+		+	+
St.22. 22 January	20m	+		+	+
	Ice algae	+		+	+
St.22. 23 January	20m	+	+		+
	50m	+	+		+
	100m	+	+		+
	205m	+	+		+
	285m	+	+		+
	400m	+	+		+
	491m	+	+		
St.22. 23 January 1129	Snow	+	+		+
	Ice algae	+	+		+
St.23. 31 January 2340	20m	+		+	+
St.24. 1 February	20m	+		+	+

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The following tables show data collected, sampling carried out and experiments performed - By Sverre Myklestad

		Depth (m)	Extracellular				Cellular						
Date	Station	Type water	DOC	Amino acid	Carboh	Protein	C/N	Carboh	F. amino	P	TOC	^{14}C-incorp	Comment
14 jan	1	20 op.w	x	x	x	x	x	x	x	x	x	-	
"	"	50 op.w	x	x	x	x	x	x	x	x	x	-	
15 jan	2	20 op.w	x	x	x	x	x	x	x	x	x	-	
"	"	50 op.w	x	x	x	x	x	x	x	x	x	-	
"	"	400 op.w	x	x	x	x	-	-	-	-	x	-	
"	"	20 < 1µ	-	-	-	-	x	-	-	-	x	-	
16 jan	7	20 op.w	x	-	-	-	-	-	-	-	x	-	
17 jan	11	20 op.w	x	x	x	x	-	-	-	-	x	-	
18 jan	14	20 op.w	x	x	x	x	x	x	x	-	x	-	
"	"	50 op.w	x	x	x	x	-	x	x	-	x	-	
"	"	90 op.w	x	x	x	-	-	-	x	-	x	-	
"	"	100 op.w	x	x	x	x	x	x	x	-	x	-	
"	"	200 op.w	x	x	x	x	-	x	x	-	x	-	
"	"	500 op.w	x	x	x	x	-	-	-	-	x	-	
"	"	1000 op.w	x	x	x	x	-	x	x	-	x	-	
"	"	2000 op.w	x	x	x	-	-	-	-	-	x	-	
"	"	2800 op.w	x	x	x	-	-	-	-	-	-	-	
"	"	3600 op.w	x	x	x	-	-	-	-	-	-	-	
19 jan	16	20 op.w	x	x	x	x	x	x	x	x	-	x	
"	"	Net plankto	-	-	-	-	x	x	x	x	-	-	
"	"	< 63 µ	-	-	-	-	x	-	-	-	-	-	
19 jan	17	20 in ice	x	x	x	x	x	x	x	x	-	-	
20 jan	18	20 in ice	x	x	x	x	x	x	-	-	x	-	
"	"	50 in ice	x	x	x	x	x	x	x	-	x	-	
"	"	100 in ice	x	x	x	x	-	-	-	-	-	-	
"	"	200 in ice	x	x	x	x	-	-	-	-	-	-	
"	"	300 in ice	x	x	x	x	-	-	-	-	-	-	
"	"	500 in ice	x	x	x	x	-	x	x	-	-	-	
"	"	750 in ice	x	x	x	-	-	-	-	-	-	-	
"	"	1000 in ice	x	x	x	-	-	-	-	-	-	-	

		Depth (m)	Extracellular				Cellular						
Date	Station	Type water	DOC	Amino acid	Carboh	Protein	C/N	Carboh	F. amino	P	TOC	^{14}C-incorp	Comment
21 jan	19	20 in ice	x	x	x	x	x	x	x	-	x	x	
"	"	Net plankto	-	-	-	-	x	x	x	x	-	-	
"	"	ice algae ES	-	-	-	-	x	x	-	-	-	-	
"	"	ice algae SK	-	-	x	-	x	x	x	x	-	-	
"	"	SK < 10 µ	-	-	-	-	x	-	-	-	-	-	
"	"	SK < 1 µ	-	-	-	-	x	-	-	-	-	-	
22 jan	21	20 in ice	x	x	x	x	x	x	x	-	x	x	
"	"	50 in ice	x	x	x	x	-	x	x	-	-	-	
"	"	100 in ice	x	x	x	x	-	x	x	-	-	-	
"	"	ice algae SK	x	x	x	-	x	x	x	-	-	x	
23 jan	"	20 in ice	x	x	x	x	x	x	x	-	x	-	
"	"	50 in ice	x	x	x	x	x	x	-	-		-	
"	"	100 in ice	x	x	x	x	x	x	x	-	-	-	
"	"	205 in ice	x	x	x	-	-	-	-	-	-	-	
"	"	285 in ice	x	x	x	-	-	-	-	-	-	-	
"	"	400 in ice	x	x	x	-	-	-	-	-	-	-	
"	"	491 in ice	x	x	x	-	-	-	-	-	-	-	
"	"	Ice algae Floe 7, 0 m	x	x	x	-	x	x	x	-	-	x	
"	"	Ice algae Floe 7, 1 m	-	-	-	-	x	-	-	-	-	-	
"	"	Ice algae Floe 7, 2 m	-	-	-	-	x	-	-	-	-	-	
"	"	Ice algae Floe 7, Lønne 3	x	-	-	-	x	x	x	-	-	-	
24 jan	22	Ice algae Floe 8, 0 m	x	x	x	-	x	x	x	-	-	x	
"	"	"	x	-	x	-	x	x	-	-	-	-	E - 6
"	"	"	x	-	x	-	x	-	-	-	-	-	"

Date	Station	Depth (m) Type water	Extracellular DOC	Amino acid	Carboh	Protein	Cellular C/N	Carboh	F. amino	P	TOC	^{14}C-incorp	Comment
26 jan	22	ice algae SK	x	x	x	-	x	x	x	-	-	x	lipid s.
27 jan	"	"	x	x	x	x	x	x	-	-	-	-	E - 7
"	"	Ice algae Floe 7, 0 m	x	x	x	-	x	x	-	-	-	-	E - 6
29 jan	"	Ice algae Floe 10	-	-	-	-	x	x	-	-	-	-	
30 jan	"	20 in ice	x	x	x	x	x	x	x	x	-	x	
"	"	"	x	x	x	-	x	x	-	-	-	-	E - 8, 8
"	"	"	x	-	x	-	x	x	-	-	-	-	E - 8, 11
"	"	"	x	-	x	x	x	-	-	-	-	-	E - 8, 18
"	"	"	x	x	x	x	x	x	-	-	-	-	E - 8, 24
31 jan	23	20 in ice	x	x	x	x	x	x	x	x	-	-	
"	"	20 < 63 µ	-	-	-	-	x	-	-	-	-	-	
1 feb	24	20 m	x	x	x	-	x	x	-	-	-	x	

EGIL SAKSHAUG[1] & RUNAR DALLØKKEN[1]:

PHOTOBIOLOGICAL INVESTIGATIONS IN THE ANTARCTIC OCEAN

OBJECTIVES, METHODS

This project comprises measurements of submarine light and absorption of light by total particles and phytoplankton alone. The measurements are inputs in mathematical models which describe the submarine light field and the primary productivity of algae. The data are important also in the context of calibration of satellite sensors for "ocean colour". Antarctic open waters are of particular interest in optical terms because they may be among the "bluest" and lowest in chlorophyll content anywhere.

The measurements of the submarine light field are carried out with a profiling MER-1032 bio-optical rig (Biospheric Instruments, San Diego) which has a CTD, a sensor for stimulated chlorophyll fluorescence, and a spectroradiometer with 13 wavelength channels for downwelling irradiance, eight for upwelling irradiance, and eight for upwelling radiance.

After having been lowered down to 150 m at the very first station, the rig stopped communicating, and it was impossible, in spite of several attempts, to repair it on board. The rig will be examined in Trondheim, however, and it is likely that it has to be sent to San Diego for repair. This has to be done in February or March as it is to be used on cruises again in April.

This instrument failure restricted our optical profiles to one, albeit a good one, in blue water at Station 1. Moreover, the scientific party onboard also lost the possibility to choose sampling depths according to chlorophyll fluorescence profiles. Some spectral data were had with a Li-Cor spectroradiometer which we coupled to a "Mini-CTD". This spectroradiometer, however, is not constructed for profiling, and data were of limited quality because of the lack of a calibrating deck sensor.

Data for surface irradiance were collected, however; these data were in terms of Photosynthetically Active Radiation (400-700 nm) and not spectral. Emphasis was instead put on the acquiring spectra for absorption of light by particles and algae. The absorption by all particulate is done by wavelength-scanning in a spectrophotometer of particulate collected on Whatman GF/F glass fibre filters. An estimate of non-algal absorption of light is had by rinsing the sample on the filter with methanol. This effectively removes the chloroplast pigments. By subtracting the latter spectrum from the former, a fair estimate of the light absorbed exclusively by algae can be produced.

Light absorption data for particulate matter in the sea are commonly normalised to chlorophyll a [m^2 (mg Chla)$^{-1}$]. Therefore concentrations of chlorophyll a in the water have been determined. For these analyses ice-cold 100% acetone was used as extractant; extraction time was 24 hours. Readings were made in a spectrophotometer, at 664, 647 and 630 nm. Complete spectra of extracts were stored for later analysis.

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Because the optical equipment failed massively it was not possible to analyse the submarine light field in the context of absorption of light by particulate material. Viewed in isolation, there is no basis for publishing these data, either. The data, however, will be used as a supplement to a large data base acquired from the northern waters in the last two years. This data base is being used for a doctoral thesis by Runar Dalløkken.

Data were collected as follows (both Chla-specific absorption of light and chlorophyll a):

St. 1.	30-1 Niskins:	20 m: 0.19	50 m: 0.265	mg	Chla m^{-3}
St. 2.	30-1 Niskins:	20 m: 0.47	50 m: 0.44	"	"
St. 14.	30-1 Niskins:	20 m: 0.54	50 m: 0.50	"	"
St. 17.	30-1 Niskins:	20 m: 1.48		"	"
St. 18.	Rosette:	10 m: 2.30		"	"

Sediment trap samples:

St. 18.	105 mg Chla m^{-3}
St. 19.	183 "
St. 21.	201 "

Ice samples:

St. 19.		56,5 mg Chla m^{-3}
St. 21:	Flak 1:	27.2 mg Chla m^{-3}
	Flak 2:	14.8 "
	Flak 7:	23.0 "

JAN-ERIK BRUUN[1]:

QUANTIFICATION OF ASSIMILATION EFFICIENCY, RESPIRATION AND AMMONIA EXCRETION OF ANTARCTIC COPEPODS

OBJECTIVES

Two dominant herbivorous copepods, *Calanoides acutus* and *Calanus propinquus*, were picked out from net samples (WP-3) taken from the open sea and ice covered areas of the Antarctic during the period 18.1. - 14.2.93. A set of simultaneous incubations to measure assimilation, oxygen uptake and ammonia excretion was performed seven times on *C. acutus* and four times on *C. propinquus*.

METHODS

The *assimilation efficiency* of copepods was measured using two parallel methods; the first based on destruction of chlorophyll during gut passage and the second on the loss of particulate organic carbon (POC) caused by the animals during the incubation. The particles from each sample were collected on filters for carbon content measurements at the FIMR later on.

The *respiration* (oxygen consumption) was determined from incubated samples using a Micro-Winkler Video-titrator on board. The final results will be calculated later on.

Parallel to the respiration measurements the copepods were kept in the same conditions for the determination of *ammonia excretion*. The analysing procedure was made spectrophotometrically and the final calculations shall be performed later on.

During the incubations the experimental bottles were kept in dim (red) light in a temperature of -0.5°C.

From each set of incubations 30-50 animals were collected for carbon content and dry weight measurements to be made at FIMR after the cruise.

The experimental animals were collected at Stations 14, 16, 19, 20, 21 (2 exp.), 22 (3 exp.) and 25 (2 exp.).

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JAN-ERIK BRUUN[1]:

DISTRIBUTION AND ABUNDANCE PATTERNS OF ANTARCTIC SEABIRDS

During the *Polarbjørn* expedition (9 Jan. to 11 Feb. 1993) the seabirds were determined to species and counted from Cape Town to the sea area off northern Dronning Maud Land and back to Cape Town.

Three times per day, in the morning, at noon and in the late afternoon, when the ship was moving ahead, standard counts of 15 min. were carried out to obtain estimates at species level of the abundance of birds. During each count the position, weather conditions, roughness of the sea and vicinity of ice were registered. At the end of each day total counts of observed species were noted.

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HARRI KUOSA[1]:

STUDIES ON PROTOZOA

OBJECTIVES AND METHODS

1. The biomass of the most important groups of protozoa (aplasticid nano-flagellates, aplasticid dinoflagellates and ciliates) will be estimated with epifluor-escence microscopy. Prepared specimens stained with a fluorescence compound, proflavine, were made on board. Microscopy appeared to be rather difficult to do when the engines of Polarbjørn were on. Thus the actual counting and cell studies on protozoa were divided into two entities: biomass estimates; and volume measurements which will be done in Helsinki.

2. The growth rate experiments were done by fractionation. The predators of protozoa were screened from the sample with a 100µm net, and the net increase of cell number of ciliates and dinoflagellates was followed during six days. During the cruise eleven experiments were conducted. Again, prepared specimens were made on board, but microscopy will be done later in Helsinki.

All samples were taken from the 30-1 Niskins. The following stations were sampled:

1. Biomass estimates:
   St. 1 (20 and 50 m), St. 2 (20 and 50 m), St. 7 (20 m), St. 14 (20 m),
   St. 17 (20 m), St. 18 (20 and 50 m), St. 19 (20 m),
   St. 21 (20, 50 and 100 m, samples on 22 Jan) and
   St. 23 (20 m);
   ice floes #1, 2, 5, 10 & 14.

2. Growth rate experiments (all from 20 m):
   Stations 1, 2, 7, 14, 17, 19, 21 (sample on 23 Jan) and 23.
   In addition three experiments from infiltration community were done:
   ice floes #1, 5 & 10.

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ANNE HEINÄNEN[1]:

ACTIVITIES DURING THE POLARBJØRN LEG II

STUDIES MADE BY USING PUMP WATER FROM 3 M DEPTH

A. Patchiness of bacterioplankton

Parameter	*Method*
Bacterial activity	Tritiated thymidine incorporation (later TTI)
Cell numbers	Epifluorescence microscopy (later AO)
Cell volume	AO

Study areas:
1. 58.21S, 03.16E - 55.47S, 03.20E
   15.01.1993
   TTI
2. 58.21S, 03,38E - 59.28S, 03.40E
   16.01.1993
   TTI, AO
3. 62.29S, 04.00E - 63.39S, 04.00E
   17.01.1993
   TTI, AO
4. 69.01S, 04.21E - 69.39S, 04.00E
   19.01.1993
   TTI, AO
5. 69.18S, 01.16E - 68.57S, 00.45W
   31.01.1993
   TTI, AO
6. 70.09S, 07.31W - 69.55S, 07.03W
   01.02.1993
   TTI. AO
7. 66.15S, 03.45W - 65.45S, 03.24W
   02.02.1993
   TTI, AO

B. Saturation level of bacterial thymidine uptake from 8 “stations”

C. 3 Heat shock experiments of bacterioplankton (TTI)

In cooperation with Eila Lahdes.

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EILA LAHDES[1]:

COLD ADAPTATIONS IN POLAR AND BALTIC CRUSTACEANS

TEMPORARY REPORT

The purpose of the study was by using the Antarctic krill, *Euphausia superba*, and the amphipod, *Orchomene plebs*: 1. to measure the critical thermal maximum (CTMax) and upper lethal temperature with and without acclimation; 2. to expose the animals in sublethal temperatures in order to discover the possible induction of heat shock proteins; and 3. to measure the characteristics of cellular membranes by analysing the membrane fluidity, membrane lipids, some membrane enzymes (ATP-ases) and by electron microscope images. Analyses in item 3 and the protein analyses from item 2 were made in the laboratories in Finland. The same parameters are planned for measurements of some Baltic crustaceans for comparison between organisms of two cold seas.

Due to the total failure in catching krill or amphipodes the Antarctic part of the research plan will be cancelled. The good catch of copepods allowed some work to be done with two dominant species, *Calanoides acutus* and *Calanus propinquus*. The testing mainly consisted of the determination of the acute thermal toxicity of these species. The analysing of membrane parameters remain open because the methods are developed for another type of material. In all, the work done will not compensate for the original plan.

The echo sounding equipment might have helped in finding the krill and suitable sea beds for catching the amphipodes. But the delay in schedule did not allow enough time for the trawling, and entrappment in the ice prevented search of new sea bed localities.

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SAMPLING AND TESTING SUMMARY
Thermal tolerance and membrane characteristics of some Antarctic crustaceans

Sampling		Testing		
Date	Station	Testing	Species	Tests and analyses
19.1	17	19.1	*C. propinquus*	Prelim. acute toler. at -1°C - +14°C freezing of samples
20.1	18	20.1	*C. propinquus*	Prelim. acute tolerance at +14°C
20.1	19	21.1	*C. propinquus*	+16, 18°C
21.1	21	21.1	*C. propinquus*	+14, 16, 18°C
21.1	21	21-22.1	*C. propinquus*	12 h at +14°C
21.1	21	22-23.1	*C. acutus*	12 h at +14°C
23.1	21	23.1	*C. acutus*	+14, 16, 18°C
23.1	21	23-24.1	*C. acutus*	12 h at +14°C
23.1	21	24-25.1	*C. acutus*	12 h at +14°C
Pump water	22	26-29.1 tests on bacterial production in raised temperatures in cooperation with Anne Heinänen		
28.1	22	29-30.1	*C. acutus*	12 h at +16°C
30.1	22	30-31.1	*C. acutus*	12 h at +15°C
30.1	22	1.2	*C. acutus*	Heat shock 2 & 4 h
1.2	25	5.2	*C. acutus*	Samples for fluidity measurements

JUHA-MARKKU LEPPÄNEN[1] & MIKA RAATEOJA[1]:

MEASURING THE SPATIAL AND TEMPORAL DISTRIBUTION OF PHYTOPLANKTON IN THE SOUTHERN OCEAN IN JANUARY - FEBRUARY 1993 USING A FLOW-THROUGH-ANALYZER

ABSTRACT

The spatial and temporal distribution of phytoplankton chlorophyll-a was investigated in the Atlantic Ocean sector, 10°W, 15°E, along a latitudinal gradient 40°S to 70°S in the Southern Ocean (Fig. 1). The measurements were carried out in the period 8 January - 10 February 1993 using an unattended flow-through analyzer on board the research vessel M/V Polarbjørn. In vivo fluorescence, temperature and salinity were recorded at a depth of 3 metres every 30 seconds while the ship was moving. Consequently the distance between two subsequent observations was 150-200 metres.

Chlorophyll samples were taken from the water in order to calibrate the fluorescence data. From the samples total chlorophyll-a, <2µm and <20µm fractions were measured (Table 1). The measurements were made according to Helcom Guidelines (Baltic Marine Environment Protection Commission 1988). 96% ethanol was used as an extract liquid and the filter was Whatman GF/F.

A vertical chlorophyll profile was taken from most of the CTD-stations and chlorophyll from the icesamples was measured.

The highest *in vivo* fluorescence values (corresponding to 8-9 µg/l chlorophyll-a concentration) were observed in the coastal regions of Antarctica (Figs. 2 and 3). An area with high primary production (chl.a 0.7-6.7 µg/l with median 2.8 µg/l) extended about 250 km off the coast. Outside the coastal area chl-a was always under 1.8 µg/l with median 0.6 µg/l.

REFERENCES

Guidelines for the Baltic Monitoring Programme for the Third Stage, 1988: Part D. Biological determinants. *Baltic Sea Environment Proceedings No. 27 D*. Baltic Marine Environment Protection Commission - Helsinki Commission.

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[1] Finnish Institute of Marine Research, P.O. Box 33, SF-00931, Helsinki, Finland.

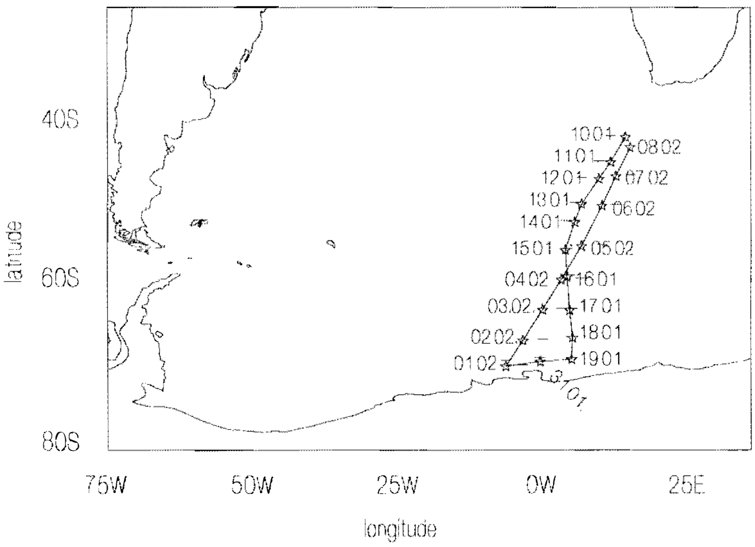

Fig. 1 The route map and daily positions of the cruise.

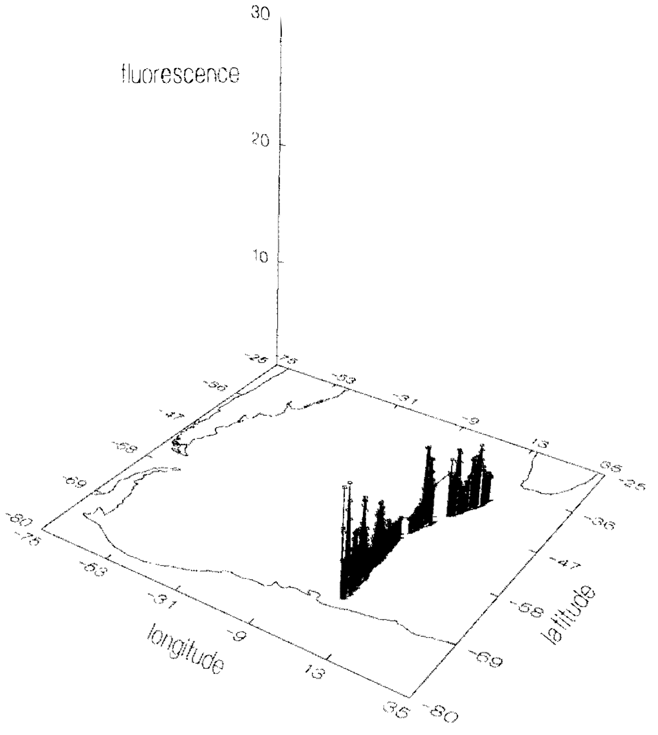

Fig. 2 *In vivo* fluorescence along a transect from South Africa to Antarctica.

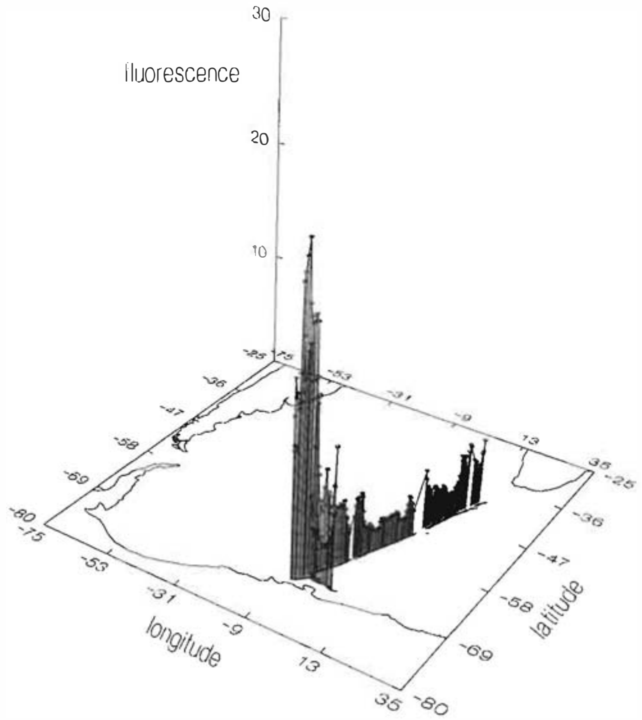

Fig. 3 *In vivo* fluorescence along a transect from Antarctica to South Africa.

Table 1. A station list. Total chl-*a*, <2μ fraction and <20μ fraction: x=sample has been taken. Vertical samples: values show the depths of separate samples (m). Ice samples: values show the distance from the edge of an ice float (m).

date	lat	lon	tot. chl-*a*	<2u fraction	<20u fraction	vertical samples	ice samples
10.01	-39*58'	14*25'	x	x	x		
	-40*34'	13*58'	x				
	-42*00'	13*32'	x	x	x		
11.01	-43*50'	11.32'	x	x	x		
	-44*28'	10*52'	x				
	-44*58'	10*19'	x	x	x		
13.01	-48*40'	6*33'	x				
	-49*07'	6*17'	x	x	x		
	-49*38'	5*59'	x				
14.01	-52*01'	4*48'	x	x	x		
	-52*37'	4*28'	x				
			x	x	x		
15.01	-54*19'	3*25'	x	x	x		
	-54*32'	3*14'	x				
	-55*05'	3*16'	x	x	x		

16.01	-57*56'	3*37'	x	x	x		
	-58*35'	3*39'	x				
	-59*07'	3*39'	x	x	x		
17.01	-62*21'	3*59'	x	x	x		
	-62*50'	4*03'	x				
	-63*23'	4*07'	x	x	x		
date	lat	lon	tot. chl-*a*	<2u	<20u	vertical	ice
				fraction	fraction	samples	samples
18.01	-66*19'	4*34'	x	x	x		
	-66*27'	4*36'				20	
						50	
						80	
						90	
						100	
						200	
						500	
						1000	
						2000	
						2800	
						3560	
19.01	-69*04'	4*21'	x	x	x		
			x				
	-69*37'	4*02'	x	x	x		
20.01	-69*48'	3*49'				10	0
						30	1
						40	2
						75	4
						200	6
						300	
						500	
						750	
						1000	
21.01	-69*46'	4*33'				0	0
						15	1
						25	2
						35	4
						50	10
						75	
						100	
						200	
						500	
22.01	-70*07'	4*46'				12	0
						23	2
						50	4
						101	
						149	
						196	
						245	
						348	
						425	
						538	

23.01	-70*06'	4*33'					0
							1
							2
24.01	-70*08'	4*35'					0
29.01	-70*08'	4*31'					0
31.01	-69*23'	1*44'	x	x	x		
	-69*02'	24'	x				
	-69*02'	-1*33'	x	x	x		

date	lat	lon	tot. chl-*a*	<2u fraction	<20u fraction	vertical samples	ice samples
	-69*55'	-3*56'	x				
01.02	-70*05'	-7*19'	x	x	x		
	-70*34'	-8*02'	x				
	-69*44'	-6*52'	x	x	x		
02.02	-66*58'	-4*25'	x	x	x		
	-66*22'	-3*52'	x				
	-65*43'	-3*13'	x	x	x		
03.02	-62*35'	-35'	x	x	x		
	-62*00'	-01'	x				
04.02	-59*31'	2*06'	x	x	x		
	-58*50'	2*43'	x				
	-58*03'	3*22'	x	x	x		
05.02	-55*07'	5*49'	x	x	x		
	-54*27'	6*17'	x				
06.02	-50*56'	8*44'	x	x	x		
	-50*27'	9*05'	x				
	-49*43'	9*33'	x	x	x		
07.02	-46*28'	11*38'	x	x	x		
	-45*54'	12*02'	x				
	-45*29'	12*19'	x	x	x		

ILPPO VUORINEN[1], JARI HÄNNINEN[1], ERIK BONSDORFF[2], BEN BOORMANN [3] & MARTIN V. ANGEL[3]:

TESTING THE CASCADING TROPHIC INTERACTION THEORY IN THE SOUTHERN OCEAN

INTRODUCTION

The purpose of the study is to test the Cascading trophic interaction theory in an oceanic environment. This theory predicts that changes in numbers of top-predators of an aquatic food web should cause changes cascading down to the lower trophic levels. In this study the theory will be tested for the first time in an oceanic environment.

The connection to Southern Ocean is whaling in the late 1920s and the decline in the large rorqual whales stocks because of this. The whales are the top-predators in the Southern Ocean. So, the aim of this study is to verify possible effects upon different levels of the food web in the Southern Ocean caused by the decimation of whales.

Our interests are four species from different size groups of Copepods (zooplankton), which compete for food with krill, the most important food of the rorqual whales. Because of the decline in the whale stocks the possible surplus of krill has led to (again possible) changes in relative abundance of these Copepod species. Krill, as a stronger competitor for the food, is able to outdo the smaller competitors. This should lead to a decline in the Copepods.

METHODS

A WP-2 net (mesh size 200 µm) was used to collect Copepods as vertical hauls from 200 metres to surface, at least, this was the original purpose. Because of drifting of the ship the hauls were more or less oblique and this made the depth determination difficult. I solved the problem by lengthening the wire to 250 metres. We calculated that this was enough for the net to reach a depth of 200 metres, if the angle of the wire was not more than 37°. The species are most abundant at 200 metres depths. The hauling speed was not more than 0.5 metres/second, but since the winch lacked speedometer, this was difficult to control. The sample was stored in buffered formalin (4%) for later counting. The number of stations (list below) was 12 and collection of samples started from latitude 55°S and continued on every full latitude (approximately) until 66°S, which was the last station. The time used for hauling at each station varied, but was always less than 30 minutes.

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STATION LIST

1. Name: St. 3. (PB1, in my own list)
   Date: 15.1.93
   Time: 15.00-15.30 GMT
   Position: 55°00,2'S - 3°17,3'E

2. Name: St. 4. (PB2)
   Date: 15.1.93
   Time: 20.50-21.05 GMT
   Position: 56°00,6'S - 3°22,9'E

3. Name: St. 5. (PB3)
   Date: 16.1.93
   Time: 02.55-03.10 GMT
   Position: 57°00,0'S - 3°33.3'E

4. Name: St. 6 (PB4)
   Date: 16.1.93
   Time: 08.50-09.05 GMT
   Position: 58°00,6'S - 3°36,6'E

5. Name: St. 7 (PB5)
   Date: 16.1.93
   Time: 14.40-15.05 GMT
   Position: 59°00,6'S - 3°39,5'E

6. Name: St. 8 (PB6)
   Date: 16.1.93
   Time: 20.35-20.57
   Position: 60°00,6'S - 3°44,2'E

7. Name: St. 9 (PB7)
   Date: 17.1.93
   Time: 02.15-02.45 GMT
   Position: 61°00,5'S - 3°50,5'E

8. Name: St. 10 (PB8)
   Date: 17.1.93
   Time: 08.00-08.22 GMT
   Position: 62°00,5'S-3°56,4'E

9. Name: St. 11 (PB9)
   Date: 17.1.93
   Time: 13.35-14.00 GMT
   Position: 63°07,1'S - 4°04,4'E

10. Name: St. 12 (PB10)
    Date: 17.1.93
    Time: 19.20-19.55 GMT
    Position: 64°00,4'S - 4°13,2'E

11. Name: St. 13 (PB11)
Date: 18.1.93
Time: 01.05-01.35 GMT
Position: 65°01,1'S - 4°21,3'E

12. Name: St. 14 (PB12)
Date: 18.1.93
Time: 14.55-15.15 GMT
Position: 66°30,4'S - 4°27,4'E

ERLING S. NORDØY & ARNOLDUS SCHYTTE BLIX*:

DISTRIBUTION AND FOOD CONSUMPTION OF CRABEATER SEALS OFF DRONNING MAUD LAND

BACKGROUND

The effects of changes in prey abundance on the population dynamics of bird and mammals which seasonally occupy the Antarctic pack ice, is pointed out as an important research topic in *Perspectives for Norwegian Antarctic Research*.

With a conservative population estimate of about 15 million individuals (30-40 million is not unlikely) the crabeater seal (*Lobodon carcinophagus*) is the most abundant seal species in the world (Gilbert & Erickson 1977; Laws 1984). Therefore, knowledge of both abundance, annual distribution and food consumption of crabeater seals, being particularly numerous off Dronning Maud Land, is of great importance since this species is supposed to prey primarily on krill (Øritsland 1977; Klages & Cockcroft 1990). Assuming that 15 million crabeater seals eat only krill this would imply an annual food consumption in the order of 40 million metric tons by this species alone.

Assessment of the ecological role of the crabeater seal in the waters off Dronning Maud Land depends to a large extent on knowledge of population size, annual distribution of the species and their choice of prey at different times of the year. From these parameters food consumption can be estimated on the basis of known physiological parameters. Due to logistical difficulties, particularly during the winter season, it is unlikely that adequate information on diet composition can be obtained from stomach content analysis.

Recently, the development of satellite telemetry made it possible to obtain substantial information on the seasonal distribution and diving behaviour of marine mammals. This method has been employed with success on e.g. hooded seals (*Cystophora cristata*) (Folkow & Blix 1991).

An important physiological parameter when calculating food consumption of crabeater seals, is the digestibility of prey. Very little information exists with regard to the digestibility of the major prey item of crabeater seals, krill. Fadely et al. (1990) have developed a method using dietary manganese as a chemical marker for determining energy assimilation from the food in marine mammals. This method requires that fresh samples of food and feces are available.

OBJECTIVES

1. To determine the seasonal movements and distribution of crabeater seals off Dronning Maud Land. For this purpose eight crabeater seals were to be caught alive for attachment of satellite platform transmitter terminals (PTTs) attached.

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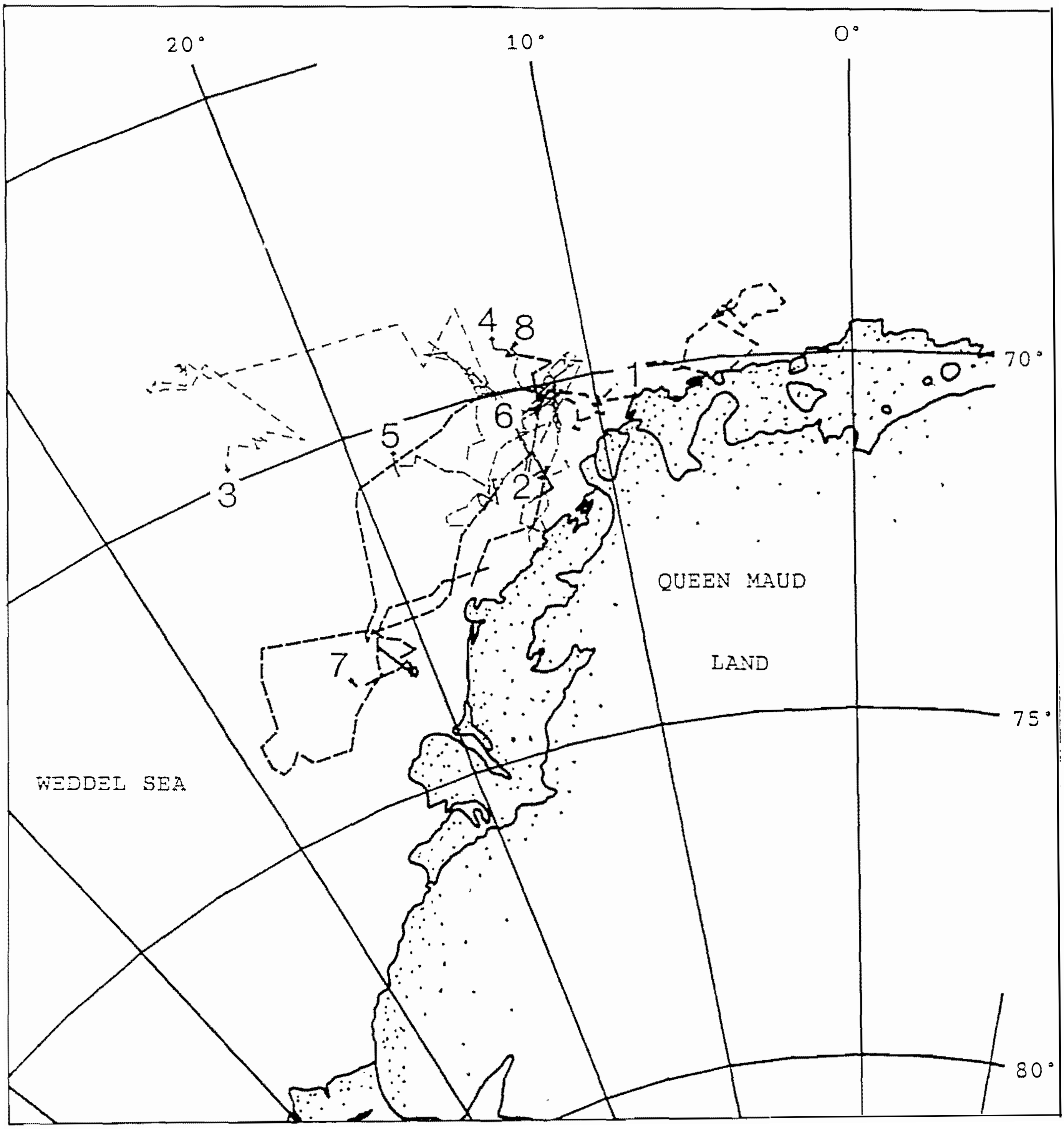

Fig.1. Map showing the gross movement of 8 adult crabeater seals which were equipped with satellite PTT's in the pack ice off the coast of Dronning Maud Land, February 1993. Last updated location (15 April 1993, except for AA2 which was lost on 2 March) is shown by numbers.

After the animals have been released these PPTs will give daily locations for a period extending at its maximum until next moulting in January 1994. The PTTs were moreover equipped with time-depth recorders providing continuous information on diving profiles. The diving profiles and locations will later be coupled with information on the prey destribution in the area.

2. To determine the digestibility of krill in crabeater seals. A number of crabeater seals which had recently eaten krill was therefore planned to be killed for collection of stomach and colon contents. Samples will be analysed for energy and manganese content.

3. To determine the level of environmental pollutants in crabeater seals. A set of samples (blood, heart, kidney, liver, blubber and muscle) was to be taken from each killed animal.

FIELD WORK ON CRABEATER SEALS

On 21 and 24 February 1993, eight adult crabeater seals (*Lobodon carcinophagus*) were collected alive to have satellite platform transmitter terminals (PTT) (Wildlife Computers) with time depth recorders attached. All animals had recently completed moulting. Position of catch, sex, weight and position of release are given in Table 1.

Table 1.

No	Sex*	Weight (kg)	Date of release	Pos. of release (S W)
AA1	F	210	22.2.93	70°07' 6°52'
AA2	F	210	"	71°10' 11°45'
AA3	F	220	"	71°23' 12°29'
AA4	M	170	"	71°41' 12°39'
AA5	M	175	"	71°52' 13°11'
AA6	M	200	"	72°08' 14°05'
AA7	M	125	24.2.93	72°20' 11°54'
AA8	M	150	26.2.93	72°28' 16°36'

* F = female, M = male

Seven adult crabeater seals (five males and two females) were killed at position 70°25'S, 8°10'W on 27 February. Stomach and colon with contents were immediately collected for later studies of energy assimilation from the krill diet. Blood samples and 200 g samples of liver, muscle, kidney, heart and blubber were sampled for studies of environmental pollutants.

PRELIMINARY RESULTS

Transmissions were obtained from all eight crabeater seals during the first week after release. One transmitter (AA2) became silent after seven days, while the remaining seven were still transmitting on 15 April. Fig.1 shows the tracking pattern of the eight crabeater seals.

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BERNT-ERIK SÆTHER*, REIDAR ANDERSEN*, TORKILD TVERAA* & TERJE BØ*:

ORNITHOLOGICAL INVESTIGATIONS IN SVARTHAMAREN DURING THE SUMMER 1992/1993

INTRODUCTION

The ornithological investigations in Svarthamaren during the austral summer 1992/1993 were a continuation of the studies initiated in 1989/1990 (Sæther et al. 1990) which were followed up with the visit in 1991/1992. The purpose of the study is:

- to monitor longterm changes in demographic characteristics of the breeding populations of the Antarctic Petrel and South Polar Skua at Svarthamaren, and
- to identify the factors that determine individual variations in breeding success of those two species.

ANTARCTIC PETREL

Population census

On NARE 1991/1992 a permanent grid system covering the breeding colony of the Antarctic Petrel was established in order to monitor fluctuations in population size (Lorentsen et al. 1993). The number of breeding pairs in these plots was censused on 19 January 1993.

No statistical evaluation of changes in the number of breeding birds has yet been performed. However, the number of breeding pairs recorded by the census in 1993 is likely to be smaller than in 1992. This is due to the fact that several plots were covered with snow in 1992 and were therefore not useful as breeding sites, and had a lower number of breeding individuals present.

Demographic studies

An important aspect of the demographic studies of the Antarctic Petrel is to estimate the adult survival rate. In order to estimate this parameter, four permanent study plots, each 9 m x 15 m, were established on NARE 1992/93 (see Lorentsen et al. 1993 for a detailed description). In these plots all breeding adults were colour-ringed. Much effort was put into the determination of the returning rate of these individuals. From the start of the field-work on 27 December until the end on 24 January, the plots were visited daily and previously ringed birds that had arrived were captured. In addition, all new breeding birds were banded.

Unfortunately, these studies were heavily affected by the weather. A snowfall at the time of hatching covered the breeding colony with 15-20 cm snow. When the snow melted, the water washed out a large number of nests or filled up the nestcups. The breeding success therefore became very low.

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Experimental studies on regulation of reproductive investment

Two experiments were conducted to show how the Antarctic Petrel parents regulate the investment in their offspring. Two, not mutually exclusive, hypotheses have been made:

1. Drent & Daan (1980) argued that the amount of investment into the offspring should not exceed a maximum working load, estimated by them to be four times the basal metabolic rate.
2. Several authors have argued (see Clutton-Brock 1991) that among long-lived birds some critical lower level of body condition exists where the parent will leave their offspring instead of making a further investment which will reduce the probability of their own future survival.

These hypotheses were tested by establishing two experimental groups. In one group the egg was replaced at regular intervals by a cold egg that had to be warmed up by the incubator. This increased the cost of incubation and thereby the daily working load. In the other group one parent was removed just as it was replaced by the other adult. These individuals were used for environmental pollutant studies. The weight decrease of the remaining incubating adult was checked. By this experimental set-up we were able to test whether the body condition differed in the two groups. If no variation was found, the existence of a lower threshold of body condition would be supported. If the body condition of the pairs with single parents became lower, this would support the maximum working load hypothesis.

The experiments were conducted as planned. The only problem was that the poor weather caused a reduction in the sample sizes at the end of the experimental period. The results support the previous results of Andersen et al. (1993) and Sæther et al. (1993), showing that the Antarctic Petrel is resource limited during the breeding season.

SOUTH POLAR SKUA

The population at Svarthamaren was censused and the territorial position of each colour-ringed individual mapped. In addition, several unringed territorial birds were caught and given a unique combination of colour-rings.

Ten pairs were supplementary fed after the hatching of the chicks. However, the heavy snowfall reduced the sample sizes, and prevented further statistical tests of differences in growth rate between the supplemented fed- and control chicks. In order to get basic background data for next year's studies activity budgets for South Polar Skuas were set up.

Four territorial skuas were equipped with small satellite transmitters weighing 65 g, supplied by Microwave Telemetry Inc. Three birds were localized during a five-month period.

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BJØRN BARSTAD*, TROND EIKEN* & BJØRN LYTSKJOLD*:

GEODETIC AND TOPOGRAPHIC WORK

BACKGROUND

On the two previous NARE expeditions, in 1984/85 and 1989/90, the geodetic/topographic programmes have been a combination of precise geodetic measurements and the measurement of photogrammetric reference points and ground control points for rectification of satellite images. The measurements covered H.U. Sverdrupfjella and Gjelsvikfjella, between Sørhausane (72°44'S - 0°15'E) in the southwest, and Svarthamaren (71°53'S - 5°10'E) in the east. The geodetic measurements were carried out using conventional and satellite based surveying.

The old trigonometric nets in this part of Dronning Maud Land were very sparse. The network in H.U. Sverdrupfjella and westwards was measured during the Norwegian-British-Swedish Antarctic Expedition, 1949-52. The net from Gjelsvikfjella to the east of the already covered area was measured during the Norwegian Antarctic Expedition, 1956-60.

The maps in the area were compiled in the early 1960s at the scale of 1:100,000 and published at the scale of 1:250,000. The mapping was concentrated to the rock outcrops. Approximate contour lines were drawn on the ice, however, the geomorphic content in the ice covered areas is very sparse on these maps. New technology has enabled mapping from single satellite images, and even if extraction of heights is not possible, a lot of information in the ice areas can be extracted from the rectified images. Five satellite image maps have been compiled and published based on the measurements of NARE 1984/85 and 1989/90, these are H5S, H6S, J5S, J6S in the main map series, and Jutulsessen at the scale of 1:100,000. LANDSAT TM are the main image source, but LANDSAT MSS and SPOT images are also used. The image maps are printed in four colours, with some additional information from the topographic maps.

The research station Troll, built during NARE 1989/90, is situated in Jutulsessen, one of the main research areas of the Norwegian expeditions. In addition to the existing topographic maps of the area, a satellite image map at the scale of 1:100,000 was compiled in 1992. A topographic map on a larger scale is also desired, and new aerial photographs for this purpose were to be collected in the 1989/90 season, but this was cancelled due to technical problems with the helicopter. A new photo coverage was therefore still desirable. A triangulation network covering the northern part of Jutulsessen as well as several photogrammetric reference points were established on the last expedition.

During NARE 1989/90 a group of glaciologists attempted to drill a hole through the ice shelf in the area where Jutulstraumen flows into Fimbulisen, in order to put oceanographic instruments into the sea beneath the ice. In connection with their work, they required exact velocity and strain rates for the ice stream. A network of stakes

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was established on the ice, and was measured twice during the field season with GPS-measurements. The GPS-technique represents a new and revolutionary way of conducting measurements on the large ice streams.

A glaciology/oceanography group (Orheim et al. 1990) put out oceanographic equipment in Jutulgryta in 1989/90 and collected it in 1991/92. Jutulgryta is a very characteristic shear zone on the east side of Jutulstraumen on Fimbulisen. Large crevasses are formed in this shear zone, and as this is on the ice shelf, they open up for the sea to surface enabling tidal measurements. In the 1991/92 season a tide gauge was running for 30 days in Jutulgryta (Østerhus & Orheim 1994), and a new tidal measurement with a connection to a reference point on solid rock would be a unique possibility to establish a height reference in the mountains.

OBJECTIVES

The geodetic/topographic programme on NARE 1992/93 had six main objectives.

1. To extend the existing precise trigonometric network between Sørhausane and Svarthamaren to the west and to the east, establishing a coherent network with high accuracy. Priority should be put on the areas west of Jutulstraumen (at 1°W), as far west as possible, and east of Svarthamaren, between 6° and 9°East.
2. To measure reference points for satellite image rectification in order to compile five to seven new satellite image maps. The main areas were the same as for the trigonometric network, but additionally some reference points should be measured along the coast and in Hellehallet between the mountains and the coast line. This area, covered by the map sheets H4 and J4, was given first priority as it has never been mapped with any quality, and because the transportation route between Troll and the main ship landing spot at the ice barrier runs here. Second priority was given to the area covered by the three sheets G5, G6 and G7 over a part of Jutulstraumen. Also the area east of 6°E covered by the map sheets K5 and K6 should be measured, but this area had the lowest priority.
3. To expand the detailed triangulation net in Jutulsessen in order to collect additional reference points for photogrammetric compilation of a new map at the scale of 1:50,000. The measurements should especially cover the southern part of Jutulsessen which was not covered on the last expedition.
4. To photograph Jutulsessen from helicopter for photogrammetric map compilation at the scale of 1:50 000.
5. To set out a tide gauge in Jutulgryta and perform measurements in order to transfer the mean sea level to the Troll geodetic reference point.
6. To measure a stake network set out by the glaciologists working in Jutulstraumen.The stakes should be measured with a time spacing of at least two weeks in order to give the best estimates of velocity and strain in the ice-flow.

WORK DONE

The successful use of GPS-measurements on the last expedition made it an easy decision to go for the same method and equipment on this year's expedition. Until NARE 1989/90 our experience with GPS was quite sparse, but as we have gained more experience, we have found that GPS should be used whenever possible and when efficient to use over other methods. We brought a total of 8 Ashtech XII dual frequency twelve-channel GPS receivers, of which two were equipped to measure the P-code on both the L1 and L2 frequencies. The remaining six were using squaring techniques to measure the L2 frequency.

The Ashtech receivers are "all in sky" receivers, and collect data from up to twelve satellites simultaneously. The receivers were usually set to log data at 20 second epochs. The Ashtech receivers have 1 Mb RAM, storing more than 12 hours of measurements with five satellites continuously and 20 second epochs. Data storage was therefore no problem for the standard baseline measurements, but for the kinematic measurements higher recording intervals were desirable, and thus more memory would be advantageous. The recorded data were transferred daily to a computer. We had our base at Troll and downloaded the data and made the computations there. Processing of the GPS-data was done with the Ashtech software GPPS (GPS Post Processing System) using portable 486-50 MHz computers which completes an average baseline processing in about five minutes.

The weather this season was very unfavourable in our working area. Only six days were complete working days without any weather restrictions, but another ten days could be used for work in limited areas. The bad weather resulted in much less work done than we had hoped, but thanks to the efficient use of the helicopters on fine days we managed to carry out some of the planned work.

Geodetic network observations

The GPS measurements in H.U. Sverdrupfjella on the 1989/90 expedition were made with one receiver stationary in the reference point at Troll, and the two remaining receivers occupying different sites. The measurements were mostly laid out as triangles connected to each other with common sides from Troll to the different points in order to establish a net suitable for adjustment. We considered this network to be sufficiently tied up to the reference point at Troll, thereby being able to use the western points in H.U. Sverdrupfjella as references for the extension of the network.

The measurements this year were laid out as vectors in a network of triangles, without the connecting vector from each point to one specific reference point. On a typical day we started with two or three receivers at previously measured sites, and the others at new ones. After approximately three hours the first ones were moved to new sites where they collected data for another three hours. Fig. 1 shows schematically how the measurements were performed. Typically six receivers were operated in each session. We mostly had two measuring crews, often using two helicopters, being able to bring more than four receivers in each. Handling more than three receivers per crew, though, is not very practical as much time is spent moving between and establishing the sites. We collected data for three to four hours even if a reduction of the observation time would have increased the number of measured points.

One new point was established at Holane in H.U. Sverdrupfjella extending the network to the north, and enabling a better connection to the new net to the west of Jutulstraumen. A few additional vectors were measured to strengthen the network in H.U. Sverdrupfjella. A total of 41 vectors connect nine newly established points west of Jutulstraumen covering Ahlmann-ryggen, Borgmassivet and a single point in Neumayerskarvet, to three points in H.U. Sverdrupfjella (Fig.2). The vectors vary in length from 41 to 142 km. The vectors were processed using the L1 frequency (single frequency), and a free network adjustment as well as an adjustment with the old points in H.U. Sverdrupfjella fixed has been made. The average scale error in the free adjustment was 0.6 ppm. Connecting the network to the points in H.U. Sverdrupfjella gave a considerable increase in scale error, probably caused by a scale difference to the old net. An adjustment including both the new and old measurements will be performed. Solutions using both L1 and L2 frequencies have been processed too, with approximately the same results as single frequency results. It seems that there has been very little ionospheric activity during our stay, giving measurements with little noise and good single frequency solutions even on distances exceeding 100 km.

To the east of Troll we had four reference points measured with the Transit satellite system (NNNS) in 1984/85, and about ten other points in a net of distances and bearings measured the same season. Due to bad weather conditions in the high priority areas to the north and to the west, we had the opportunity on some days to work to the east of Troll. Thus nine points between Troll and Jøkulkyrkja at 6°40' East were measured, of which four were identical to those of 1984/85, and five were new ones (Fig.3). The eastern net consists of 24 GPS-vectors, and the free network adjustment gave an average scale error of less than 3 ppm.

Reference points for satellite image rectification were determined using GPS differential code measurements (differential pseudo distances). These measurements and the baseline observations were performed simultaneously. One extra receiver were mounted in the helicopter, using a special helicopter antenna placed on the cockpit roof. The helicopter then hovered or landed on the terrain features to be measured.

The chosen reference points were terrain features such as small nunataks identifiable as one pixel (30 x 30 m), or at most as a few pixels in the images. We collected a total of twenty reference points covering the three sheets G5, G6 and G7. In the area between the mountains and the ice shelf, which were given high priority, no measurements could be made due to unfavourable weather conditions. The planned measurements along the coast were cancelled for the same reason.

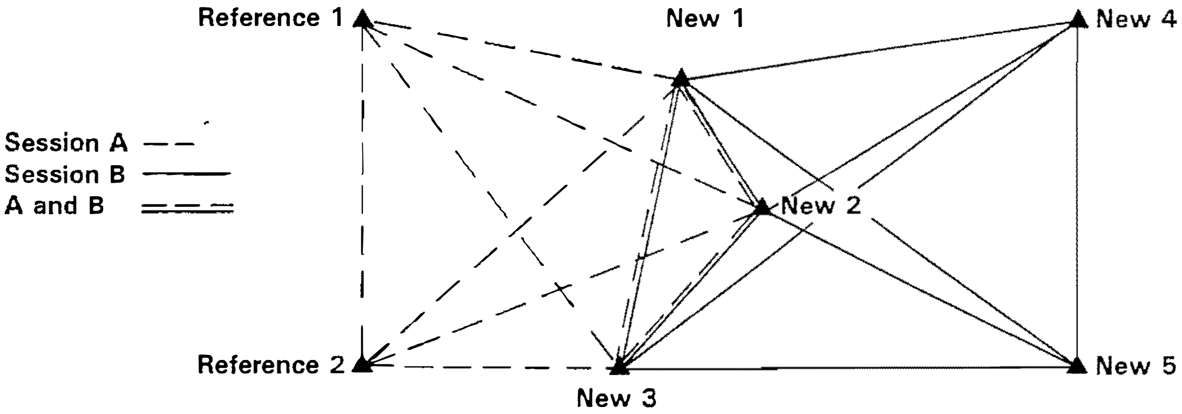

Fig. 1. Network layout using five receivers. Note that three vectors are measured in both sessions A and B.

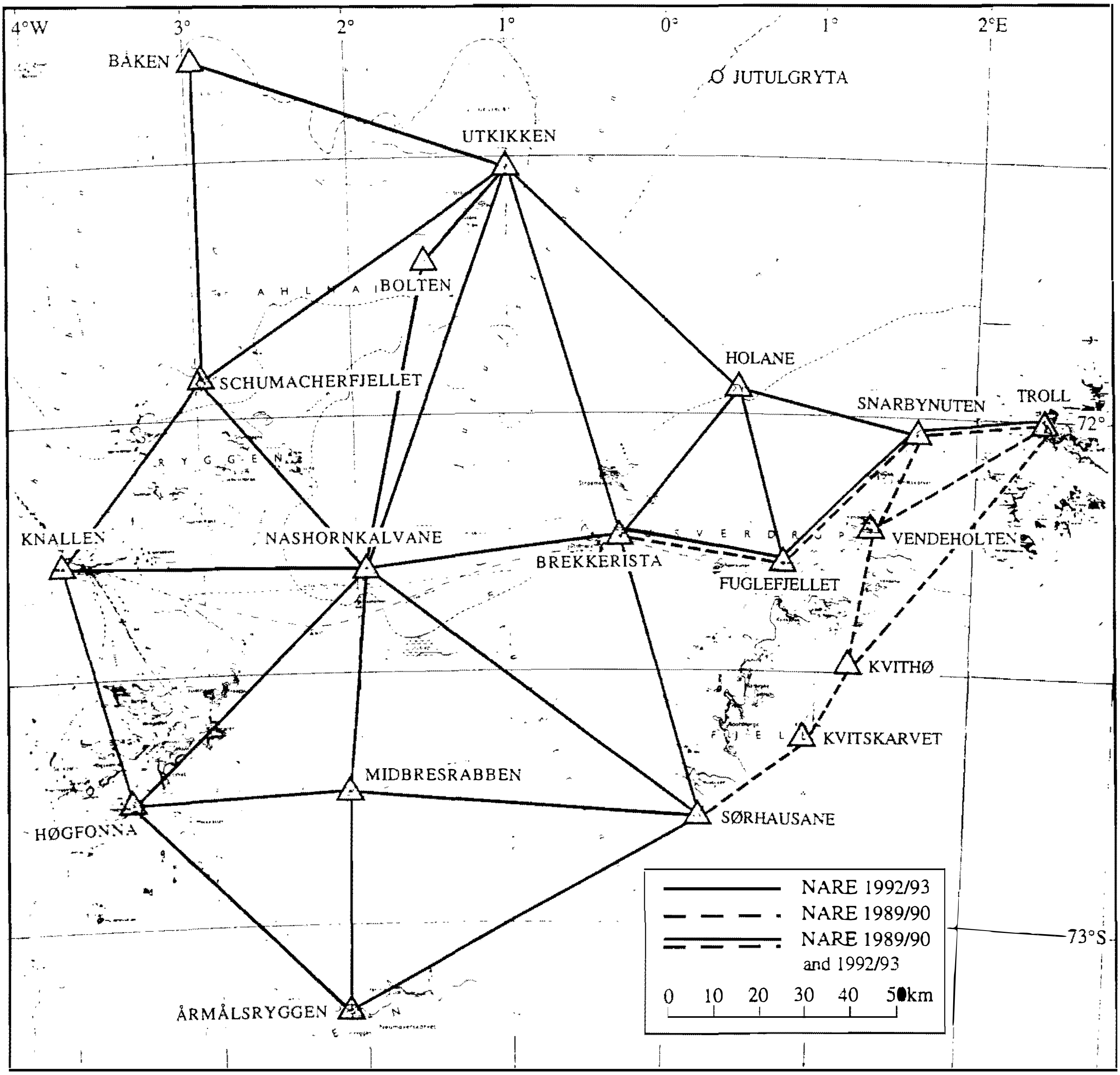

Fig. 2. GPS-network to the west of Troll. Not all vectors are shown.

Photogrammetric reference points in Jutulsessen

The photogrammetric reference points measured in 1989/90 for a new map of Jutulsessen at the scale of 1:50,000 covered mainly the area close to Troll. Some of these could no longer be identified due to changes in the snow coverage, and had to be replaced.

The detail trigonometric net was expanded with one new point by GPS measurements and one by conventional surveying. A total of fourty photogrammetric reference points including the replacement of some of those of 1989/90 were determined by conventional surveying. Most of the area of the planned new map was covered. The equipment used were Wild T2000 and T2 theodolites and Wild DI3000 and AGA Geodimeter 6000 EDMs.

Aerial photography

A Hasselblad MKWE terrestrial camera was used for aerial photography from helicopter. The helicopter had no special equipment for this purpose, so a stable tripod was mounted on the floor with rubber strings. The camera was fixed with about 30° dip from the horizontal with the lens protruding the left front window, and the optical axis perpendicular to the helicopter body.

The Hasselblad camera is a professional photographers camera converted to photogram-metric use with a reseau plate and a calibrated lens. The lens is a 38 mm, giving about 100° opening angle relative to the effective 55 by 55 mm picture on 70 mm film. The camera is equipped with film magazines of 70 or 200 frames. We brought black and white (AgfaPan 200) and colour positive film (Kodak Ektachrome 64).

The photography was carried out on the very last day of the expedition period at Troll and in rather poor weather conditions. The area was covered with eight strips of photographs at the approximate scale of 1:70,000.

Tidal measurements in Jutulgryta

We had planned to use an anchored tide gauge recording at fixed time intervals during the expedition period. At the start of the field season, however, the weather conditions did not allow a flight to Jutulgryta, preventing the placement of the tide gauge. We managed, however, to make simultaneous measurements between the floating ice and a site on what we believed was grounded ice. The height difference between this site and Troll was measured by a single GPS-vector thus enabling us to transfer the mean sea level predicted from the measurements of Østerhus 1991/92 (Østerhus & Orheim 1994).

Reference measurements between the floating and grounded ice were performed using trigonometric levelling with two Wild T2000 electronic theodolites using reciprocal sights and simultaneous recordings. At an actual distance of 1 km the accuracy of the height difference is about 20 millimetres. The single GPS-vector measured was of good quality. The sea level transfer carries some uncertainties with it. First there is the possibility of not having the site on grounded ice. Secondly the difference in geoid height between Jutulgryta and Troll is quite uncertain as it is just estimated from the Australian geoid map. Anyway, we believe that the measurements have given us a better estimate of the orthometric height at Troll than we had before.

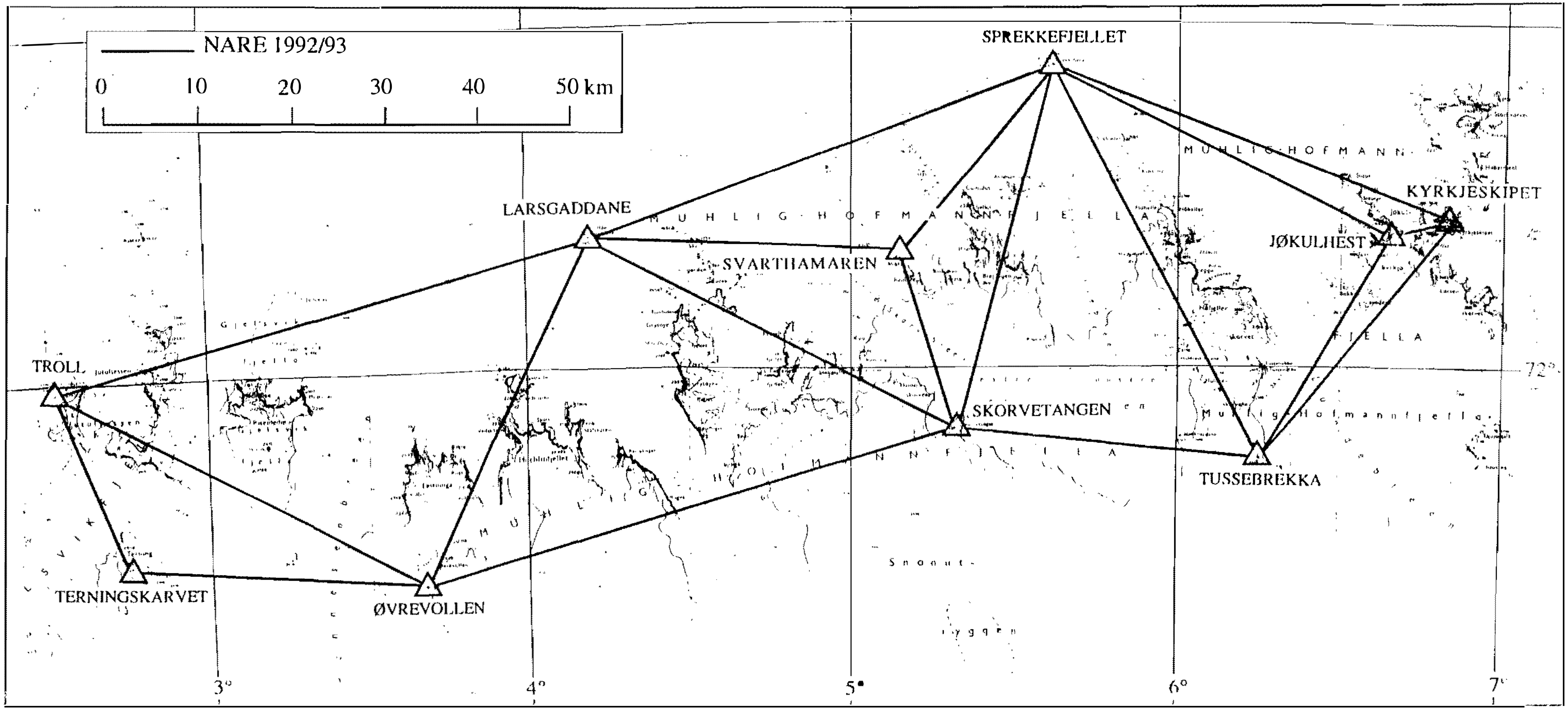

Fig. 3. GPS-network to the east of Troll. Not all vectors are shown. Reference points for satellite image rectification.

Stake network measurements in Jutulstraumen

The velocity and strain measurements in Jutulstraumen were carried out as kinematic GPS-measurements. Our previous experience with kinematic measurements in Svalbard was that the distance between the roving and reference receivers should be limited to about 15 kilometres. According to this experience, one reference receiver was placed on solid rock on each side of the ice stream and one in the middle, thus giving a maximum distance from the rover to a reference on about 12 kilometres. The stake network was made of 41 stakes divided in a western net stretching across Viddalen, a western part of Jutulstraumen, and a main net from Nashornkalvane across to Jutulrøra, a distance of 50 km.

As a total the results were acceptable, but some of the measurements could not be computed using the phase kinematic method. To establish coordinates where the phase measurements could not be used, we used a code-differential computation, giving usable results even if the accuracy was a little lower than expected.

CONCLUDING REMARKS

The geodetic programme will be continued in the 1993/94 season. Priority will be given to geodetic network measurements in Vestfjella and Heimefrontfjella as well as measuring reference points for the rectification of satellite images, as we plan to compile four new satellite image maps of these areas. Some work will also be carried out in Jutulstraumen
where the glaciologists have planned to remeasure their stake nets.

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JON OVE HAGEN[1]:

BLUE ICE FIELD STUDIES IN THE JUTULSESSEN AND TROLL AREAS

BACKGROUND AND OBJECTIVES

In NARE 1989/90 two stake nets, each of six stakes, were established on the blue ice fields west of Troll station and in Jutulsessen for mass balance and ice flow measurements. This was done in order to contribute to a better understanding of the processes that lead to the formation of large blue ice fields in the mountain areas. The blue ice fields around Troll station are at about 1200 m a.s.l. Local ablation areas exists where katabatic winds are strong, resulting in high evaporation. Few studies have been undertaken in the blue ice areas. Some reports exists where net ablation in blue ice areas of 2-7 cm/year have been observed. Detailed studies have recently been carried out in Heimefrontfjella by Swedish scientists (Jonsson 1992).

PRELIMINARY RESULTS

During this expedition (January 1993) all stakes drilled into the ice in January 1990 were found and resurveyed both for ice flow and ablation/accumulation measurements. The heights of some of the stakes were also measured during a visit in January 1992. The stake positions were all measured by traditional surveying by theodolite and EDM (Electronic Distance Meter) from fix point on bedrock close to the ice fields.

Stake positions are given on the map in Fig. 1. Measurements of stake heights showed negative net balance as a result of the ablation on all stakes in the blue ice. The results are given in Table 1. Higest ablation was measured on the ice field west of Troll with maximum 50 cm of ice during the three years period or a net ablation of nearly 17 cm of ice per year. In Jutulsessen all six stakes showed net ablation close to 30 cm of ice, i.e. 10 cm of ice per year.

The results of the ice flow measurements are given in Table 2 and in the map (Fig. 1) of Jutulsesen area showing the direction of the ice flow. It is clear that the ice flows in towards the inner part of each ice field area. This is also in agreement with the ablation values shown on the stakes and the corresponding gradient of the ice surface. The flow vectors are all parallel to the surface gradient.

These results show that the ablation caused by evaporation is important. Further detailed studies require energy balance modelling with detailed meteorological registrations including radiation, wind and albedo-measurements. The extent of the blue ice areas, and the amount of sublimation/evaporation, could be important climate indicators.

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Table 1.
STAKE HEIGHTS ABOVE ICE SURFACE IN TROLL AND JUTULSESSEN

Jutulsessen

Stake	1990	1992	1993	Total/Mean abl.	
S10	150	165	171	21	7
S11	152	189	196	44	15
S12	150	174	182	32	11
S13	149		182	33	11
S14	147		181	34	11
S15	149		178	33	11

Troll

Stake	1990	1992	1993	Total/Mean abl.	
S1	171	190	199	28	9
S2	150		196	46	15
S3	178		203	25	8
S4	128		168	40	13
S5	112		162	50	17
S6	147		188	41	14

Table 2.
VELOCITY OF STAKES IN TROLL AND JUTULSESSEN

Jutulsessen

Stake	Velocity (m/year)
S10	1.06
S11	1.15
S12	0.55
S13	0.70
S14	1.31
S15	1.01

Troll

Stake	Velocity (m/year)
S1	0.27
S2	0.31
S3	1.75
S4	4.10
S5	4.19
S6	4.10

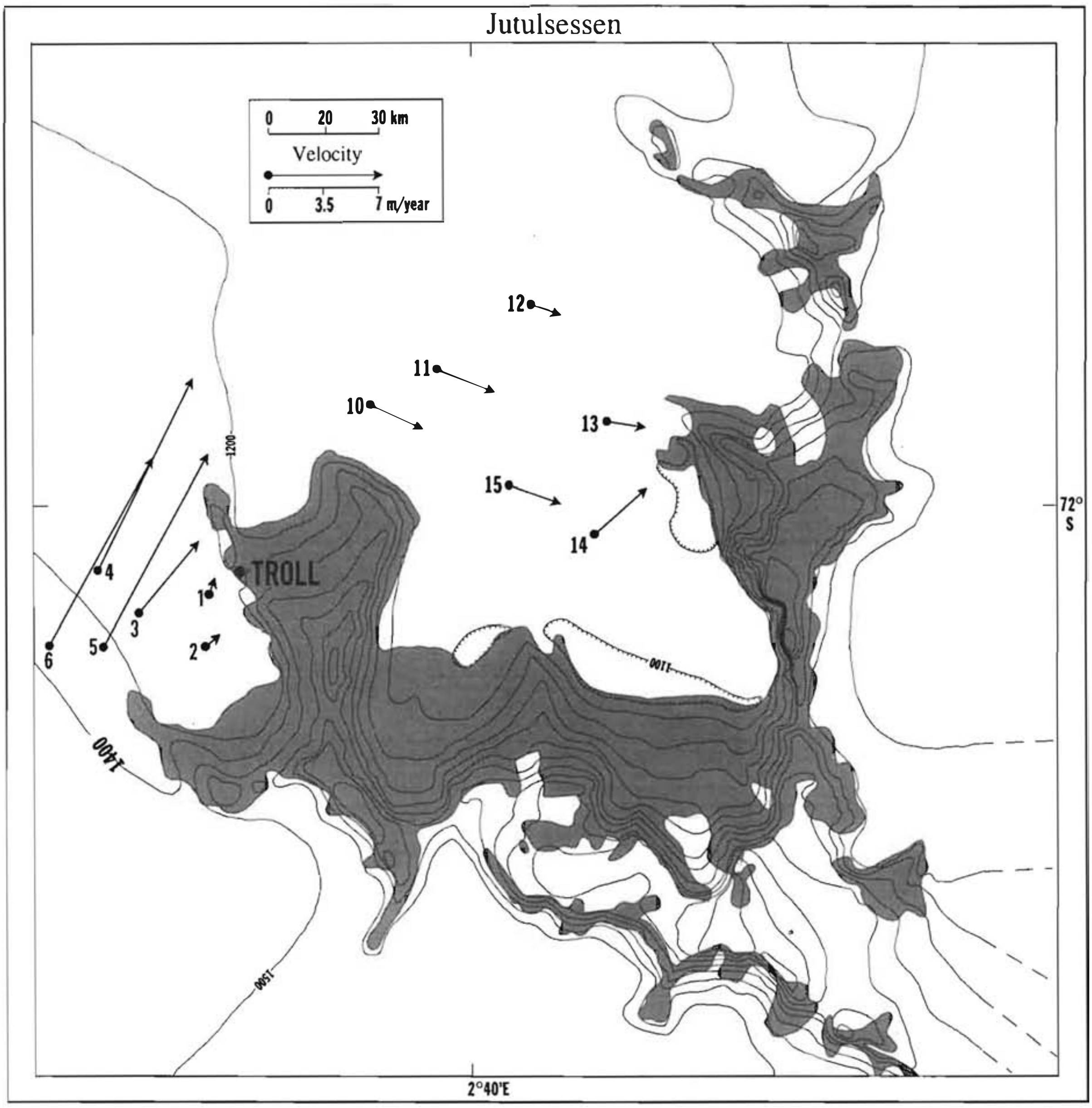

Fig. 1. Stake positions.

JON OVE HAGEN[1] & KETIL MELVOLD[1]:

MASS BALANCE AND DYNAMICS ON JUTULSTRAUMEN ICE STREAM

INTRODUCTION

The mass balance of Antarctica is still one of the most uncertain factors in discussions about the future climatic change and sea level rise (Meier 1990). Information is lacking from great areas of the Antarctic continent. The mass input is snow accumulation over the entire surface, while the output is mainly by calving but also by bottom melting at the ice/ocean interface under the ice shelves. The melting processes under the ice shelf are studied in a project started during the Norwegian Antarctic Research Expedition in 1989/90 (NARE 1989/90) (Orheim et al. 1990). This project concentrate on the furface mass balance parameters on Jutulstraumen, which with its ice shelf area Fimbulisen drains an area of 124,000 km^2. It flows at a speed of about 700 m a^{-1} close to the grounding line and has a discharge of about 12.5 km^{3}a^{-1} which makes it one of the larger ice streams in Antarctica and the largest in Western Dronning Maud Land (Van Autenboer & Decleir 1978).

OBJECTIVES

The objective of this programme is a mass balance study on Jutulstraumen ice stream and in part of its catchment area up to about 2500 m a.s.l. throughj the following investigations:

1. Accumulation rate measurements. The proposal will mainly cover the mass input by measuring a) the present, b) the last twenty-thirty years annual snow accumulation rate in different parts of the drainage basin, and c) monitoring the future accumulation rate.
2. Ice flux measurements including a) the mass output calculated from surface ice flow measurements in combination with radio-echo soundings and b) monitoring of ice flux changes.

The ice flux studies should be combined with the accumulation measurements to see if the mass outflow is balanced with the mass inflow.

FIELD WORK AND PRELIMINARY RESULTS

The field work was carried out in January 1993. A field team of five persons arrived in Jutulstraumen by snowscooters from Troll Station on 3. January.

All field work was carried out during a three-week period. The field work was concentrated on two tasks: 1. shallow core drillings, and 2. velocity and strain net measurements by GPS-positioning of stakes drilled into the ice.

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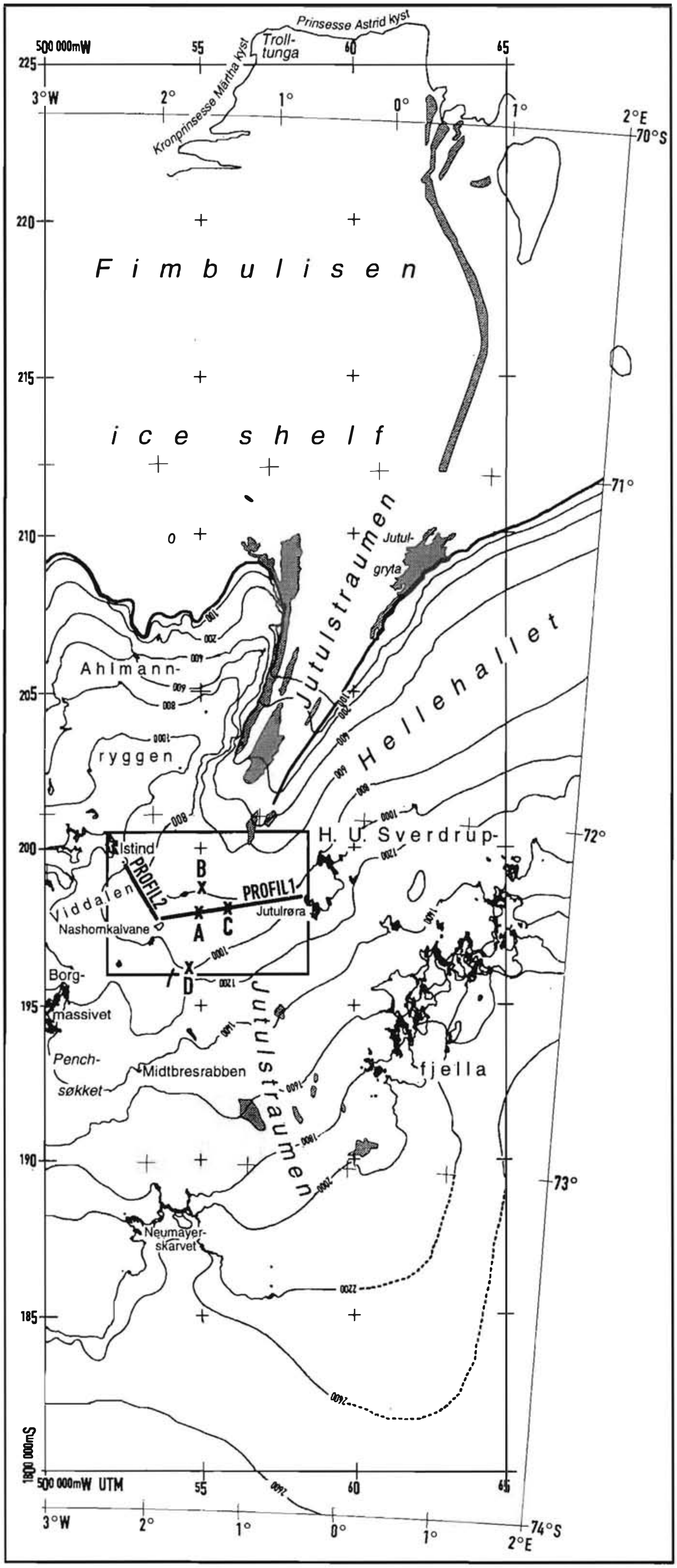

Fig. 1. Jutulstraumen and Fimbulisen with location of stake net profiles and shallow core drill sites.

Velocity measurements

The field site had to be chosen where it was possible to cross over the ice stream by scooters. The cross profile stake net was established in the same cross profile as Gjessing (1972) measured velocity by traditional survey methods. Gjessing measured the approximately 50 km long profile from Jutulrøra to Northern Nashornkalven (Profile 1), and we added the 20 km long profile Northern Nashornkalven - Istind (Profile 2) in order to cover the whole ice stram (see Fig. 1).

Altogether 36 stakes were drilled down in profile 1, but 27 of these were organized in three strain nets of 3 x 3 stakes separated by 1 km. The strain net analysis is carried out in a project described by Høydal (this volume). In this project only the surface velocity data will be discussed and used in the ice flux calculations.

The stake positions were found by GPS-measurements carried out by a geodetic/topographic team from Norsk Polarinstitutt. The positions were measured by a kinematic GPS-method. All together seven Ashtech XII dual frequency multi-channel GPS-receivers were used. Four receivers were placed stationary in each end of the profiles, while the other receivers were logging continuously as they were transported on a sledge behind a snow scooter. The portable receiver was placed on each stake for two minutes. At the end of each profile the transported receiver was swopped with the stationary one and thus linked to the stationary point. This method is very useful when many points have to be measured during a limited period when more than five satellites are visible.

The stake net was resurveyed after two weeks. The accuracy of the positions in the x and y coordinates was about 5 mm/km, and since most of the stakes moved more than 0.5 m/day, even this two-week period gave adequate precision to calculate the yearly mean velocity.

The data were processed by the same team, see Barstad et al. (this volume). The stake net map with surface velocity vectors is shown in Fig. 2. Table 1 gives the calculated annual velocity.

The results show highest velocities in the central part of Profile 1 with velocities up to 456 m/year or 1.25 m/day. Close to the edges the velocity decreased rapidly. Stake No. B1 is in a leeward position of Nordre Nashorkalven. Compared to the traditional surveying carried out in January 1971 by Gjessing (1972) we found slightly higher velocities. He found a maximum velocity of 390 m/year with a maximum velocity in the same area.

Shallow core drilling

Shallow cores were drilled at three different elevation levels. Cores A (22 m deep) and C (13.8 m) were drilled in Profile 1 at about 900 m a.s.l. Core C (20.2 m) was drilled 25 km downstream from Profile 1 at 710 m a.s.l., and core D (16.2 m) was taken 25 km upstream at about 1100 m a.s.l. (Fig. 1).

A PICO (Polar Ice Core Office, Lincoln, Nebraska) light-weight coring auger, with a diameter of 3" (7.5 cm) was used to obtain four firn cores. The uppermost meter was sampled in a snowpit due to low density.

Each core section (10-40 cm long) was packed in labelled plastic tubes and brought frozen to Norway. The first three meters of the core were cut in 3 cm lengths and packed separately in plastic bags due to low density.

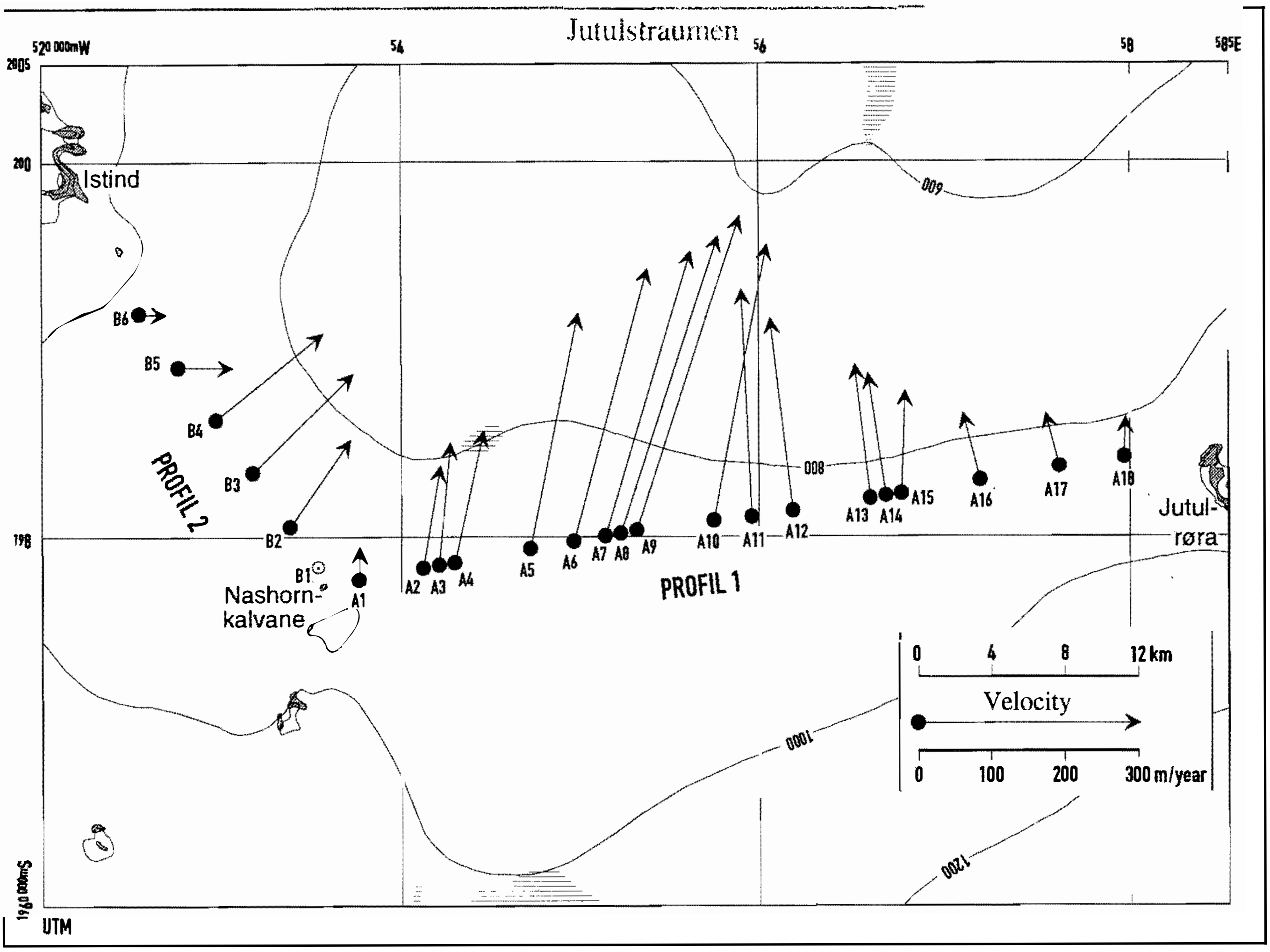

Fig. 2. Surface velocity vectors of the stakes in profiles 1 and 2.

Table 1. Velocity of stakes in the cross profile of Jutulstraumen at 900 m a.s.l.

Profil 1, Nordre Nashornkalven - Jutulrøra

Stake	Velocity (m/year)
A1 (36)	42
A2 (1)	137
A3 (2)	163
A4 (3)	179
A5 (4)	321
A6 (29)	379
A7 (5)	399
A8 (6)	421
A9 (7)	445
A10 (8)	377
A11 (22)	304
A12 (9)	258
A13 (10)	179
A14 (11)	164
A15 (12)	136
A16 (13)	91
A17 (14)	72
A18 (15)	51

Profil 2, Nordre Nashornkalven - Istind

Stake	Velocity (m/year)
B1 (37)	1
B2 (38)	141
B3 (39)	189
B4 (40)	185
B5 (41)	73
B6 (42)	35

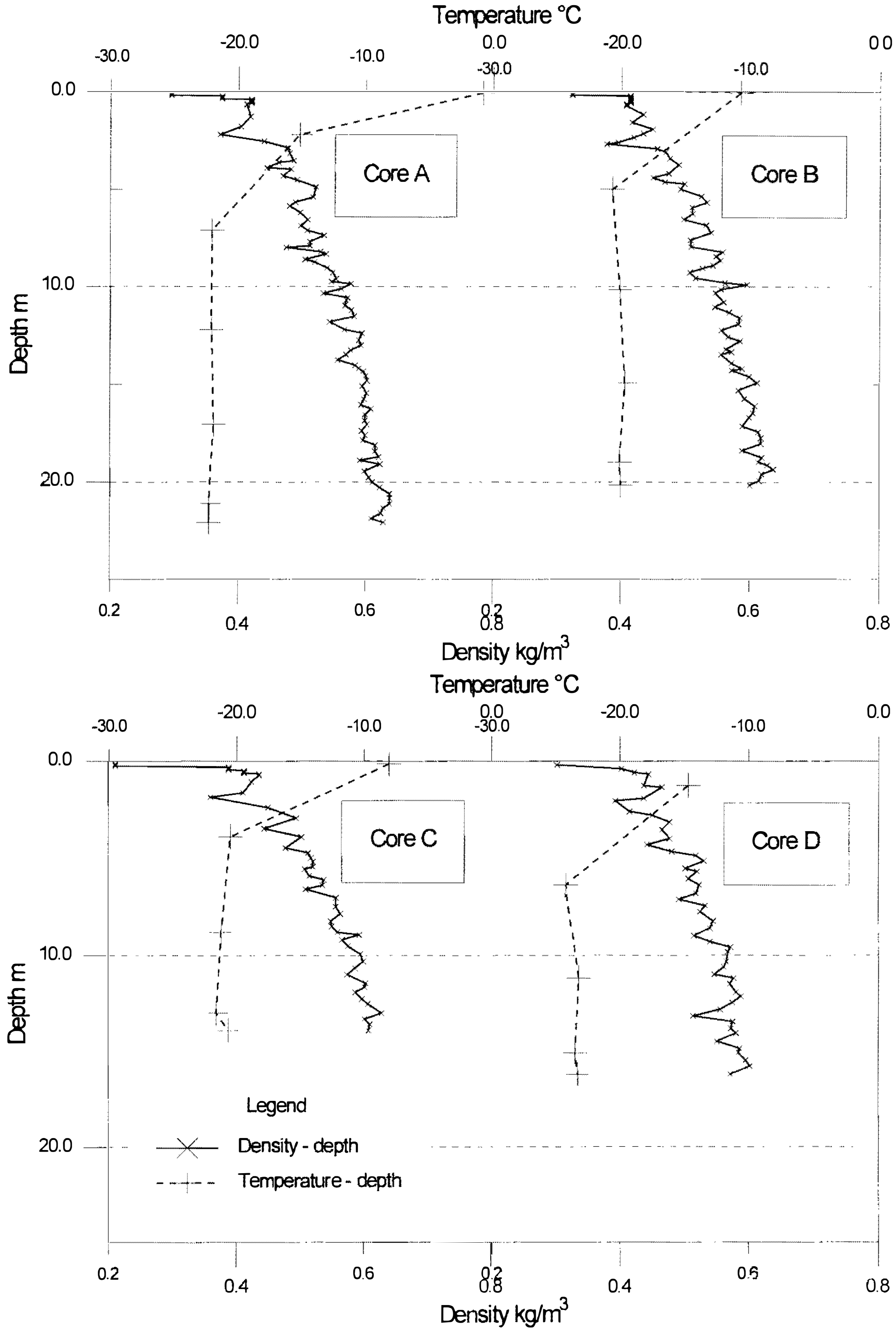

Fig. 3. Density and temperature in the core drill holes A, B, C and D.

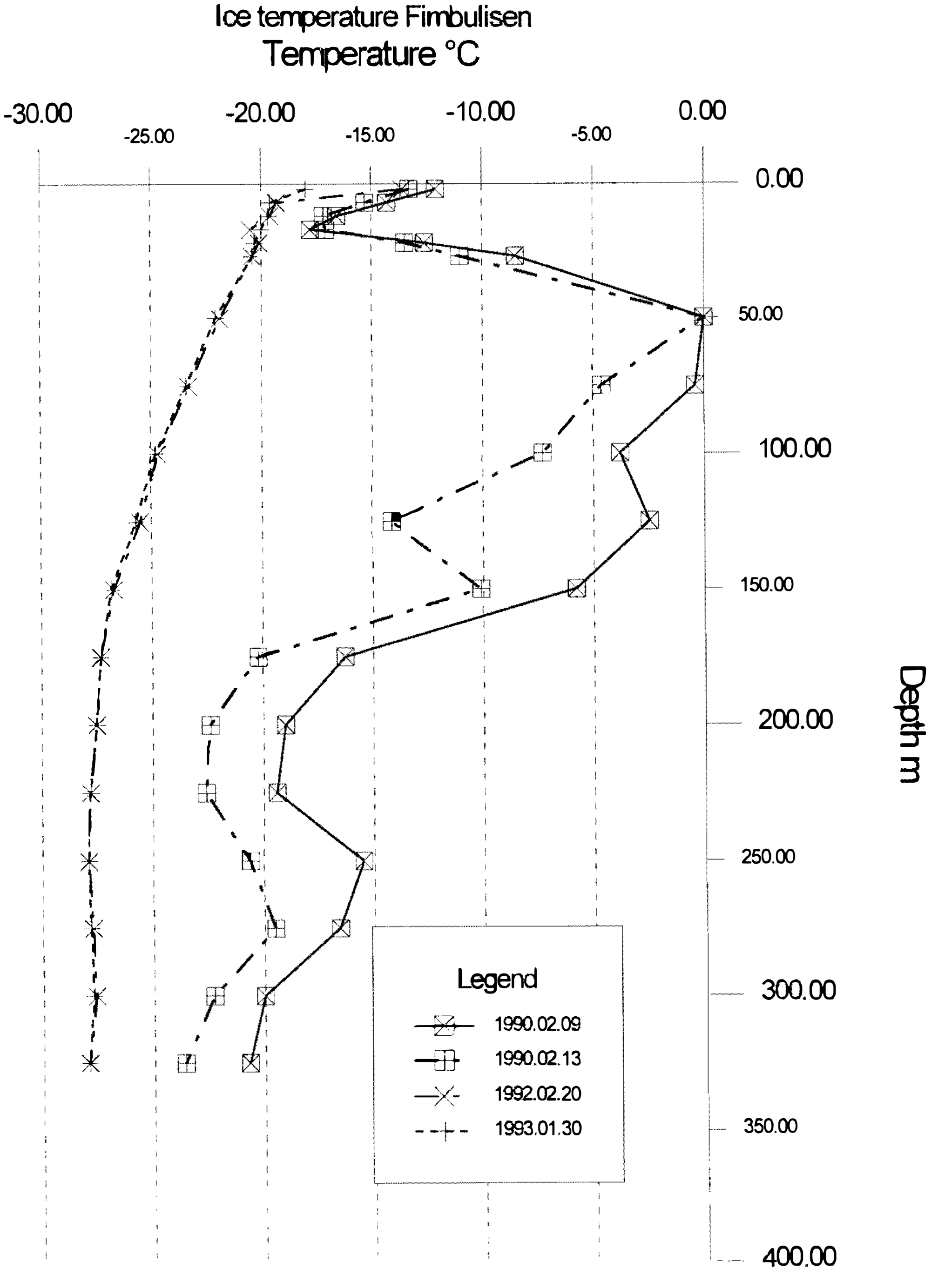

Fig. 4. Temperature in drill hole Fimbulisen in early states of refreezing and after two and three years.

The temperature was measured for every 5 m down to the bottom and one metre above the bottom. We used a thermistor string which was left in the borewhole until a stable value was obtained after about 24 hours. The thermistors were of the type Fenwall Uni-curve 192-301 CDY-A01. They were calibrated in a water tank at zero degree. The Ohm-meter that was used made it possible to read the temperature to within ±0.05°C.

The thermistor measurements showed very clear cooling at higher altitudes. At 10 to 20 metres depth drill site B at 710 m a.s.l. was close to -20°C while D at 1100 m a.s.l. was about -23°C (Fig. 3).

An electric drill was connected to the PICO-drill. No problems occurred with the drill. 10-40 cm long core sections were obtained. A 15 m deep core could be drilled in one day by three persons.

The corers will be analysed for oxygen isotopes (d^{18}O), b-activity and conductivity for identification of annual layers in similar methods as those used elsewhere in Antarctica (Clausen et al. 1979; Orheim et al. 1986; Isaksson 1992).

Ice temperature measurements on Fimbulisen

During NARE 1989/90 a thermistor string was installed in a hot water drill hole down to 327 m below the surface (Orheim et al. 1990). Thermistors were at 2, 7, 12, 17, 22 and 27 m and then for every 25 m. The theristor string was measured druing a visit in February 1992 and then again in the end of January under this expedition. The temperature had stabilized and showed almost exactly the same temperature in 1992 and in 1993. From 175 m below the surface and down to 327 m the temperature was about -27.5°C. The results are shown in Fig. 4.

Future work

The project will be continued in the coming ordic Antarctic Research Expedition 19934. A field team of three persons will continue the work and in the cming season the following work is planned.

1. Resurveying of the stake net by GPS-measurements.
2. Radio-echo soundings along Profile 1 and Profile 2.
3. Shallow core drillings upstream of drill site D.

A mass balance study of Jutulstraumen also requires data from the ice shelf area. Information from NARE 1989/90 can be used concerning velocity and radio-echo data (Kennett 1990; Orheim et al. 1990) for ice flux calculations. Additional core drillings are necessary close to the grounding line as well as on the ice shelf.

The calving rate at the front of Jutulstraumen/Fimbulisen could be estimated from velocity data ad satellite imagery data. Together with data about the melting rate under the ice shelf an estimate of the total mass balance of Jutulstraumen/Fimbulisen will be carried out.

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OLAV ORHEIM[1], SVEIN ØSTERHUS[1], KJETIL MELVOLD[1], TROND EIKEN[1], HENRIK HØJMARK THOMSEN[2], JAN-GUNNAR WINTHER[3] & HALVOR BÆVRE[4]:

HOT WATER DRILLING NEAR FILCHNER STATION, RONNE ICE SHELF

BACKGROUND AND OBJECTIVES

The water masses and currents in front of the Filchner-Ronne Ice Shelf have been studied by Norwegian oceanographers for more than 25 years. Such and other international research have made increasingly clear the need for quantitative measurements of the water column underneath the ice shelf, and of the processes at the ice/ocean interface. Instrumentation for this purpose was developed in cooperation with Chr. Michelsen Institute, Bergen, where a first version was built that was deployed on Fimbulisen in 1990 (Orheim et al. 1990). Sub-ice shelf data are especially needed in order to quantify and tune model of present-day processes in the water masses underneath the ice shelf, models that are aso needed to predict ice shelf behaviour under various climatic scenarios.

The glaciologic and oceanographic plans for NARE 1992/93 included a multidisciplinary coordinated study at the Ronne Ice Shelf, involving physical and chemical oceanographic measurements along the ice front, deployment of current meter rigs, and drilling of two acces holes arouund 20-50 km from the ice front. One hole was planned around 50°W, near the Filchner, the German summer station, the other around 58°W, near Druzhnaya II (Fig. 1). It was recognized that the sea ice conditions might not make this programme possible, especially because of the three large grounded icebergs 100 km north of the ice front. These broke off from the Filchner Ice Shelf in June 1986 and have thereafter hindered the prevailing sea ice advection, so that the southern Weddell Sea in recent years has had increased amounts of multi-year ice. However, nothing ventured, nothing gained!

The drilling programme was planned to require four weeks, with two weeks on each site. The drilling team consisted of seven persons, of which two left with *Lance* from Cape Town on 5 January. The remaining five, plus one helicopter with a two-person crew, had travelled south one month earlier by *Polarbjørn*, and were to picked up from Troll. It was hoped to be on site by 20 January. If sea ice hindered access, a secondary option was to deploy the group on Filchner Ice Shelf, and then move equipment and personnel westwards by helicopter.

Lance arrived at Prinsesse Astrid Kyst in Dronning Maud Land on 16 January to pick up the remaining drilling team and then proceed directly to Filchner-Ronne Ice Shelf. But poor flying weather, difficult sea ice conditions, and a medical problem combined

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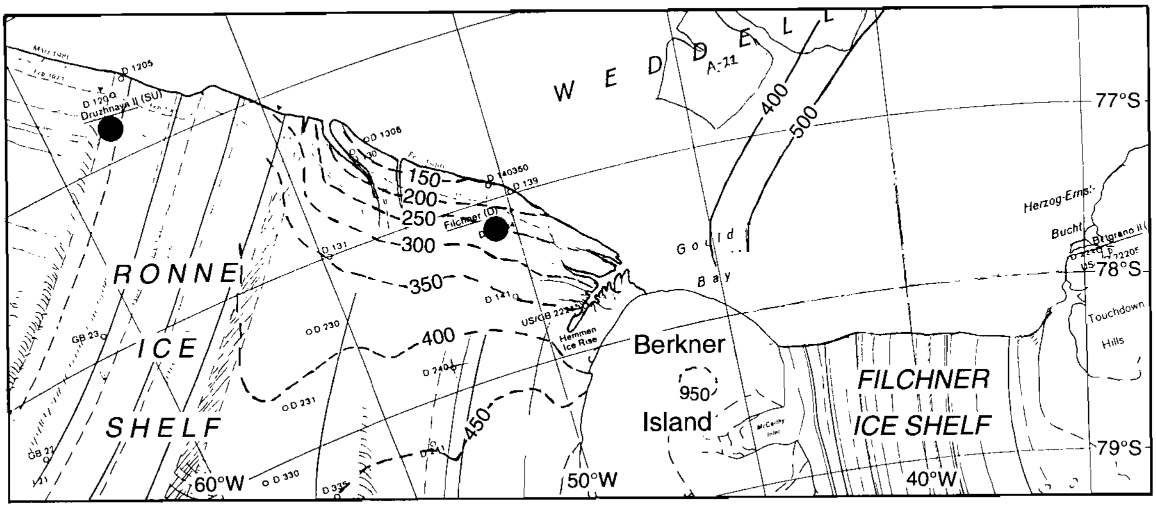

Fig. 1. Filchner and Ronne ice shelves. Circles mark the two planned sites of drilling. Note also approximate position of grounded icebergs. The map is modified from the 1.2 mill. glaciological map published by the Institut für Angewendte Geodäsi, Frankfurt.

to delay *Lance* so she coiuld not continue southwards until 29 January. The lost days meant further delays on the southwards voyage which had to include activities originally planned for a later part of the cruise. Yet further delays were caused by heavy sea ice north of Berkner Island.

Deployment of the group started on 3 February. At that time *Lance* reached only the eastern side of Berkner Island. A depot was established on the western side of the island by the helicopters, and three persons with tents and field equipment were flown to Filchner (77°05'S, 50°11'W). On 4 February Lance was able to follow narrow leads westwards to reach the ice front near Filchner Station. All personnel and equipment had been brought to the drilling site by the evening of 5 February. The next two days were spent in preparations, including building drill site, assembling all components, establishing melt water pool at 40 m depth, etc. Drilling of the main hole started in the morning of 8 February.

By this time it was clear that heavy sea ice conditions along the return route meant that *Lance* preferably should return northwards within less than a week. There would thus be only a few days available for drilling and only one hole cold be attempted. It was therefore decided to save time by drilling continuously downwards at slow speed, rather than periodically pulling up the drill to check that the hole had an adequate diameter, and that the drill went vertical. The latter procedure was used at Fimbulisen.

The estimated depth was 220-300 m. The lower estimate was taken from the ice thickness map dated 23.06.1992 produced by the Geophysics Group at the University of Münster, Germany, while the larger thickness was based on the map by Pozdeyev & Kurinen (1987). Our repeated pressure measurements to sea level by helicopter gave a mean elevation of 43 m, which suggested that the latter was most correct. However, whatever the depth might have been we had to conclude on 12 February that there was a drilling problem, as the hose length in the hole was 327 m without ice shelf penetration. We proceeded to retrieve the hose, and half of it was recovered in a stick/slip fashion while the hot water was kept running, but at 161 m it was irrevocably stuck. We believe that the fault most likely was that at this depth or deeper, the drill started deviating from the vertical. Our drilling would thereafter only partly proceed downwards, so that the lowered hose was also curling up in the hole.

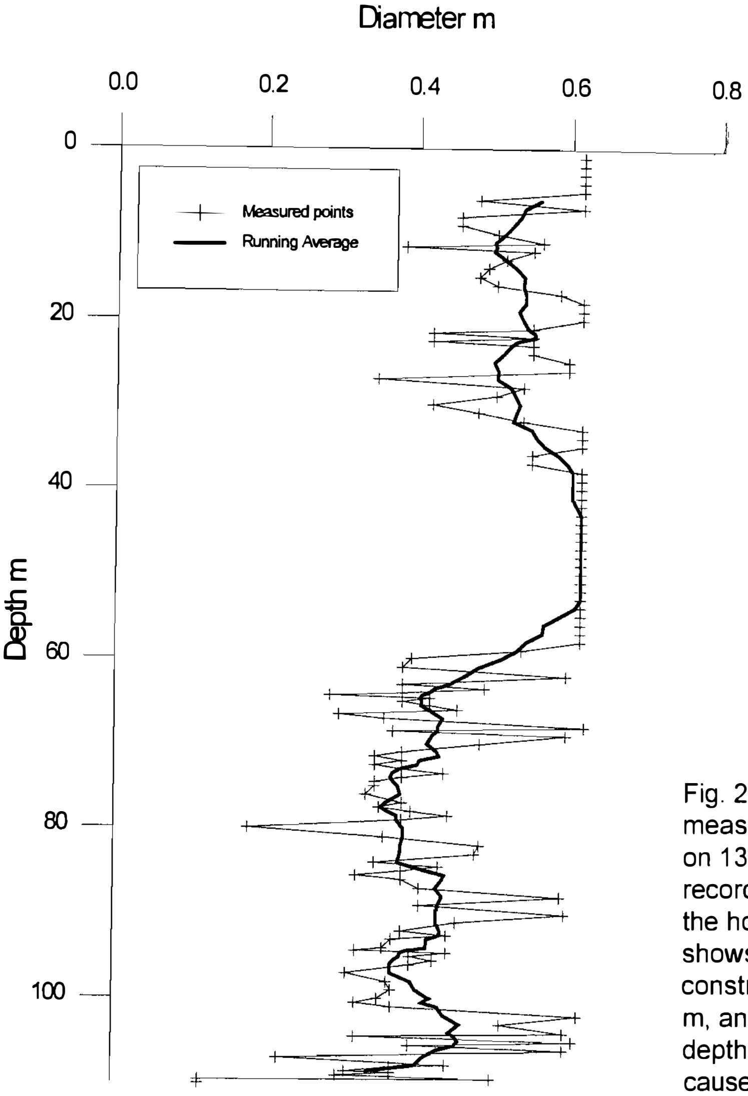

Fig. 2. Diameter of the drill hole as measured by a CH1 three-arm caliper on 13 February. The diameter was recorded approx. every ½ m along the hole to 115 m depth. Heavy line shows 11-point running mean. Note constrictions to 177 mm diameter at 80 m, and 114 mm diameter at 110 m depth. It is possible that these may be caused by the hose in the hole.

Lance arrived the ice front near Filchner in the evening of 13 February. The next day all equipment and personnel were back on the ship, and she sailed northwards.

The hole diameter was logged to 115 m depth (Fig. 2). We required a working diameter of 0.2 m at all depths and this was generally achieved. The logging was done with a three-legged caliper that had a measurement range of 35-614 mm. When the logging was done there was hose in the hole, and it is possible that some spikes in the record are caused by it.

The hot water drilling system used was essentially the same as in 1990 (Orheim et al. 1990), but boosted with more heaters, and with ¾" hose. This was much heavier than the ½" hose used three years previously, and made it more difficult to "feel" whether the drill was hanging freely. We did not use a tensiometer.

The two instrument-rigs built for sub ice shelf deployment each consisted of the following instruments: three current meters, eight salinity sensors, 19 thermistors, DSU, and two ARGOS transmitters. These were planned to record data every three hours for three years and also transmit these data via satellite over the ARGOS system.

We had also brought along the following special equipment for sampling and measurements through the access hole: one ME mini CTD with winch, one Sensordata mini CTD, and three specially constructed bottles for water sampling through drill hole.

CONCLUSIONS

The main conclusion that can be drawn from this season is that drilling under time pressure should be avoided. In retrospect it may be tht the drilling should have been done in the same mananer as the successful 400 m drilling three years previously, namely by shorter drill runs and repeated reaming. However, if the chosen method had been successful, it would have given more time for hole measurements.

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JAN-GUNNAR WINTHER[1]:

SPECTRAL REFLECTANCE OF SNOW AND GLACIER ICE AS MEASURED IN DRONNING MAUD LAND, ANTARCTICA

BACKGROUND

Snow and ice cover large areas of the Earth's surface, especially in the polar regions. Snow and ice reflect solar radiation very efficiently such that little of the incoming solar radiation is absorbed at the surface in these regions. Even so, small changes in surface reflectance can affect the Earth-atmosphere energy balance (Warren & Wiscombe 1985). Thus, it is clearly important to monitor and calculate the variability of the albedo of snow and ice. Then, accurate calculations of the energy exchange between snow and ice surfaces and the surrounding air mass can be carried out.

The reflectance of snow and glacier ice show a clear dependence of wavelength. The spectral properties of snow reflectance have been studied and reported by many investigators (Choudhury & Chang 1979; Wiscombe & Warren 1980; Warren 1982; Zeng et al. 1984). The fraction of radiation reflected from fresh snow remains high in the visible region while a distinct drop occurs in the near infra-red region of the electro-magnetic spectrum. Furthermore, the albedo of snow drops below 0.10 in the mid infra-red region. Satellites like the Landsat Thematic Mapper (TM), NOAA AVHRR, and SPOT carry sensors that record surface reflectance within the visible and infra-red wavelength regions. Consequently, satellite remote sensing enables studies to be made of surface characteristics such as topography, temperature, grain size variations, melting areas, and snow and glacier ice facies (Orheim & Lucchitta 1988; Winther 1993).

The specular reflection of snow and glacier ice introduces a problem if the true spectral response characteristics of such areas are going to be studied, for example by satellite remote sensing techniques. Freshly fallen snow can be considered a Lambertian reflector (i.e., a perfect diffuse reflector) but as snow metamorphoses the specular component characterized by forward scattering increases (Dirmhirn & Eaton 1975; Steffen 1987; Dozier et al. 1988; Hall et al. 1988, 1992). The specular properties of glacier (blue) ice are even more pronounced than for metamorphosed snow. Since many satellite sensors are nadir-viewing, the satellite will often provide different reflectances compared to the hemispheric reflectance (or albedo) on the ground. For example, an image pixel directed such that it reflects incident radiation towards the satellite sensor can give too high satellite-derived ground reflectances due to bidirectional reflectance.

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OBJECTIVES

The main objectives of this study have been to:

- measure the spectral reflectance of snow and glacier ice,
- measure surface reflectance that can be used as reference data (ground truth) forsatellite image interpretation and analyses,
- record the bidirectional reflectance characteristics of snow and glacier ice.

METHODS

Visible and near infra-red spectral albedo measurements were taken using a spectrometer that measures radiation between 370 and 1110 nm in 252 discrete steps. Each channel represents a bandwidth of approximately 3 nm. Spectral resolution of the sensor is about 10 nm. The field of view is 6° and the surface area seen by the sensor depends strongly on the observation angle, and varies between about 20 cm^2 (nadir) and 315 cm^2 (75° off-nadir) for the measurements presented here. The spectral detector head was fastened to a standard camera tripod to avoid movements during the integration time of the sensor that was less than 1 second. Immediately after each measurement sequence, a spectral measurement of a halon target at 0° nadir angle was taken as a reference for the calculations of albedo. The solar and atmospheric conditions are considered stable during one scan sequence. The limits of the sensitivity of the silicon detectors are reached in the near infra-red region, and the signal-to-noise ratio is small beyond 900 nm (Dozier et al. 1988; Hall et al. 1992). Therefore, only data between 370 and 900 nm are presented.

Scan sequences of bidirectional snow reflectance were taken by pointing the spectral detector head at nadir (0°), and then at 15°, 30°, 45°, 60° and 75° off-nadir followed by a nadir reference measurement of the halon target. Such a scan sequence typically took less than two minutes. Horizontal direction of the measurements was towards the sun.

Additionally, supporting measurements of air and snow temperature, density, liquid water content, grain size and shape, snow hardness, and stratification were recorded at each measuring site. The measuring sites were established within the area shown in Fig. 1.

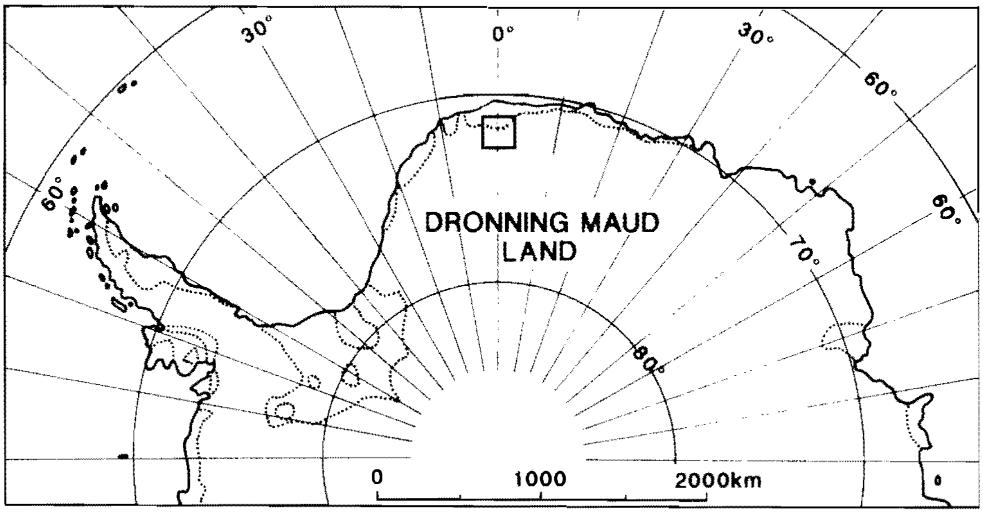

Fig. 1. Index map, showing the area where the measurements discussed in this paper were recorded. The dotted lines show the land boundary of the continent.

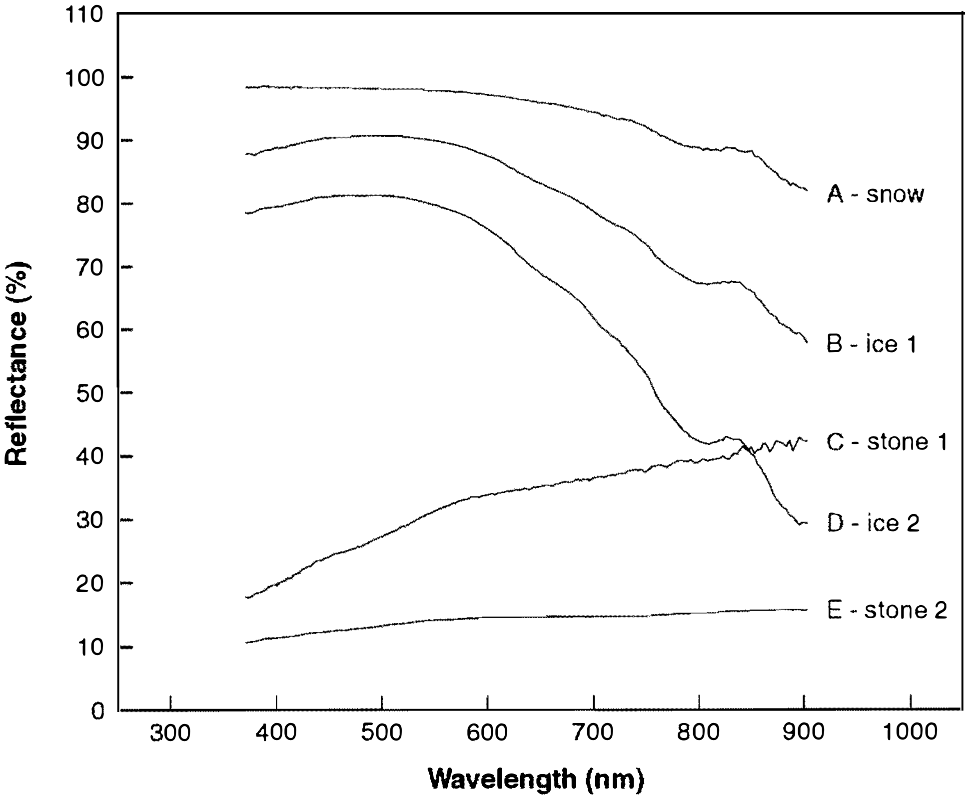

Fig. 2. Spectral reflectances of snow, superimposed ice, and stone acquired on 16 January 1993 close to the Norwegian Troll station at 72°00.7'S, 2°32.3'E. The curves show A - snow, B - superimposed ice where the upper 1 cm contained many icebound snow crystals giving a white appearance of the surface, C - bright part of a stone lying at the surface of the glacier, D - superimposed ice with many air bubbles but only a few icebound snow crystals, and E - dark part of the same stone as described above.

PRELIMINARY RESULTS

Spectral reflectances of snow, superimposed ice, and stone

Figure 2 shows spectral reflectance curves for snow, superimposed ice, and stone taken on 16 January 1993 due west of the Norwegian Troll station at 72°00.7'S, 2°32.3'E. The measuring site was located 1250 m a.s.l. at a glacier in the Gjelsvikfjella mountain range. All reflectance curves were acquired within a distance of about 50 metres. It was partly cloudy during the measurements.

The characteristic snow grain diameter for Curve A was 0.8 mm, ranging from about 0.2 to 1.2 mm. Most snow crystals were rounded. Even so, the original edged cubic form could easily be seen when looking through a magnifying lens (8x). Erosion and redistribution of snow grains took place at the surface due to the influence of wind forces. These winds produced a relatively compact snow pack with a density of 0.36 g/cm^3 at 5 cm depth. The snow temperature at 5 cm depth was -4.6°C while the air temperature was -3.8°C. Overall, the snow surface was even with a characteristic surface roughness of less than 1 cm. As seen in Fig. 2 the albedo is high and relatively stable in the visible region (98% at 370 nm) and then decreases moderately in the near infra-red. The albedo at 900 nm is 0.82. This spectral signature is typical for fresh snow that has been moderately metamorphosed (Zeng et al. 1984; Winther 1993).

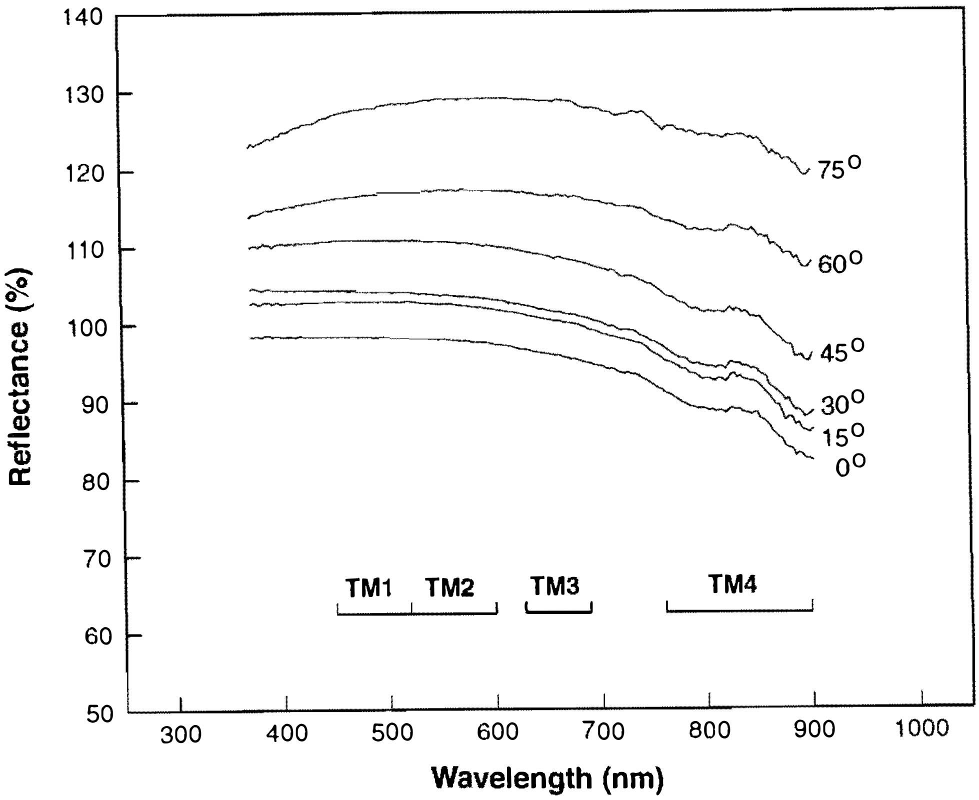

Fig. 3. Spectral reflectances of snow for viewing angles 0°, 15°, 30°, 45°, 60°, and 75° for a viewing direction facing the sun on the Jutulstraumen ice stream on 13 January 1993. The measuring site was located at 72°15.7'S, 1°15.6'E. The wavelength regions of Landsat TM Bands 1-4 are also shown. Note that the relative level of anisotropy is slightly sensitive to wavelength.

Superimposed ice forms when melt water refreezes on the glacier surface. Curve D - ice 2 represents superimposed ice with a levelled surface containing many air bubbles and a few icebound snow crystals. Curve B - ice 1 represents superimposed ice where the upper 1 cm contains many icebound snow crystals. Thus, this surface had a white appearance that increased the albedo significantly (Fig. 2). Below this thin layer, the superimposed ice was similar to the ice represented by Curve D - ice 2. Curves B and D have considerably different signatures and higher reflectances than the spectral curves of glacier ice, congelation ice, and refreezing ice reported by Zeng et al. (1984).
Finally, Fig. 2 displays two spectral reflectance curves taken at a large stone that was situated at the surface of the glacier. This stone had two distinct parts. One was very bright (Curve C - stone 1) while the other one was dark (Curve E - stone 2). Interestingly, the near infra-red reflectance (700-900 nm) of Curve C - stone 1 is not very different from that of superimposed ice, Curve D - ice 2.

Bidirectional reflectance of snow

Fig. 3 shows the spectral reflectance of snow for viewing angles 0°, 15°, 30°, 45°, 60°, and 75° for a viewing direction facing the sun on 13 January 1993. This measurement site was at the Jutulstraumen ice stream at 72°15.7'S, 1°15.6'E. The curves clearly prove the effect of anisotropic snow reflectance. Additionally, the anisotropy seems to increase slightly with increasing wavelengths. Reflectance values larger than 1.0 appear, especially for the largest viewing angles. Off-nadir reflectance values >1.0 are reported to be quite common for dry snow (Hall et al. 1992) but can also appear for wet snow (Dozier et al. 1988). This is because snow can reflect light specularly and more light may be reflected than is incident upon the snow in one particular direction.

The snow at Jutulstraumen on 13 January had a characteristic grain size diameter of 0.5 mm, ranging from about 0.2 to 0.8 mm. At a depth of 3 cm the snow density was 0.202 g/cm^3 while the corresponding snow temperature was -2.2°C. The surface was composed of freshly fallen snow that recently had been wind-blown and thus redistributed. Therefore, the snow consisted mainly of rounded snow crystals. Even so, some snow crystals appeared as needles and plates. There were no clouds in the sky during the measurements.

TM Bands 1-4 reflectances

TM-bands 1-4 reflectances are calculated by integrating in situ nadir spectral reflectance measurements. Next, deviations for 15°, 30°, 45°, 60°, and 75° off-nadir observation angles are computed. Table 1 summarises these calculations based on 22 spectral scan measurements of snow and 9 spectral scans of superimposed ise. The reflectance data may be used to study the strength of anisotropic reflectance for each TM Band. In addition, the data show how the anisotropic reflectance varies with varying observation angle. The latter can also serve as a measure of how sensitive TM-Bands 1-4 reflectances are to surface topography. Obviously, the reflectance received by a sensor for a given viewing angle and surface topography depends strongly on the solar elevation (q_S).

Table 1 displays that the anisotropic reflectance of snow and superimposed ice increases with increasing wavelengths. For example, TM Band 4 appears more sensitive to anisotropic reflectance than TM Bands 1-3. This may be the reason why higher TM Band 4 than TM Band 2 reflectances are found in the work by Hall et al. (1988, 1990) and Winther (1993).

Table 1. TM Bands 1-4 reflectances and their sensitivity to varying observation angle. Numbers are deviations (in per cent) from nadir reflectance for off-nadir observation angles (b) of 15°, 30°, 45°, 60°, and 75°. The data are computed from 22 spectral scan measurements of snow and 9 spectral scans of superimposed ice.

	β	TM1	TM2	TM3	TM4
Snow	15°	9.15	9.88	10.87	12.76
	30°	21.58	24.92	28.39	33.99
	45°	25.38	28.36	31.43	37.89
	60°	39.47	44.40	50.05	60.33
	75°	29.99	31.78	34.26	40.97
Super-imposed ice	15°	6.21	6.45	6.46	4.94
	30°	9.02	9.81	11.66	17.71
	45°	21.50	21.70	25.84	48.73
	60°	49.41	52.21	60.17	90.66
	75°	35.29	38.60	49.55	96.53

Further, each of the four wavelength regions corresponding to TM Bands 1-4 shows increasing anisotropy with increasing off-nadir observation angles up to an angle of 90°- q_S. For the measurements presented here the peak in anisotropy is at about60°. Most radiation will be reflected at this angle because of the forward scattering properties of the surface and the solar elevation of approximately 30°. Snow reflects about 10% (average of TM Bands 1-4) more radiation at the 15° off-nadir observation angle than at nadir (Table 1). Similarly, snow has 49% higher reflectance at the 60° off-nadir viewing angle than at nadir.

CONCLUSIONS

Visible and near infra-red reflectances of snow and superimposed ice show a clear dependence of wavelength. The reflectance decreases moderately with wavelength in the visible region while the reduction becomes more prominent in the near infra-red. Super-imposed ice with a 1 cm thick surface layer of icebound snow crystals has significantly higher reflectance than superimposed ice containing only a few icebound snow crystals.

Snow reflects solar radiation specularly. In addition, the anisotropic properties of snow seem to strengthen for increasing wavelengths. Reflectance values larger than 1.0 appear since more light can be reflected than is incident upon the snow in one particular direction. Consequently, satellite-derived albedo of metamorphosed snow can deviate considerably from the true spectral response of these surfaces. If satellite-derived albedos are going to be considered as *absolute* values, a topographic model may be needed to correct for the effects introduced by bidirectional reflectance.

Integrated in situ spectral ereflectances of snow and superimposed ice show that TM Bands 1-4 are affected by anisotropic surface reflectance. The anisotropy increases with increasing wavelengths, i.e. TM Band 1 is least affected while TM Band 4 I most affected. Further, the reflectance corresponding to TM Bands 1-4 show an increasing anisotropy for increasing off-nadir viewing angles up to 90°- q_S. For a sensor viewing angle 15° off-nadir the snow reflectance is about 10% higher than at nadir while it can exceed 50% for larger off-nadir viewing angles. Consequently, satellite-derived albedo of metamorphosed snow can deviate considerably from the true spectral response of these surfaces. If satellite-derived albedos are going to be considered as *absolute* values, a topographic model is needed to correct for the effects introduced by anisotropy.

ACKNOWLEDGEMENTS

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HENRIK HØJMARK THOMSEN[1] & JON OVE HAGEN[2]:

A STABLE ISOTOPE PILOT STUDY FROM BLUE ICE AREAS AT JUTULSESSEN, DRONNING MAUD LAND, ANTARCTICA

BACKGROUND AND OBJECTIVES

The large ice sheets of Antarctica and Greenland are rich sources of information about climate and environmental changes during the past c. 150,000 years, and probably much longer, as demonstrated by results of deep ice-core drilling programmes (e.g. Dansgaard et al. 1982; Lorius et al. 1985; Jouzel et al. 1987; Lorius et al. 1989). Past climate records based on oxygen-18 isotope ($\delta^{18}O$) studies are only one example of what can be retrieved from the ice cores. However, the old ice found at depth in the central regions of the ice sheets can also be retrieved at the surface of the ice sheet margins, where ice of different ages is found in a sequence with the oldest ice nearest to the ice edge (Lorius & Merlivat 1977; Reeh et al. 1987, 1991).

One example is a $\delta^{18}O$ record measured on surface ice from the ablation zone of the Greenland ice sheet near Jakobshavn, West Greenland (Reeh et al. 1987). Ice samples were collected in a profile from the ice edge and 1.2 km upstream parallel with the ice flow direction. The record was compared with the deep ice core records at Dye 3 and Camp Century in Greenland and the Vostok core in Antarctica. This reveals that palaeoclimatic data spanning back c. 150,000 years can be retrieved from surface ice at ice margin locations (Reeh et al. 1991). Similar studies made at the ice margin of the Greenland ice sheet in the Thule area, North Greenland, show that the isotopic signature of the ice, in terms of mean value as well as variability, is characteristic for the site of formation of the ice and for its thermal and phase change history since the time of formation (Reeh et al. 1990).

At many locations in Antarctica blue ice is exposed at the surface. These blue ice areas have a negative mass balance and are therefore ablation zones, which implies ice flow with a net upward emergence velocity (Orheim & Lucchitta 1990). Deeper and older ice therefore have a change to reach the surface in these locations. Model calculations of the age of the ice exposed in the Allan Hills blue ice area in Antarctica, indicates an age of the ice of up to 600,000 years (Whillans & Cassidy 1983). Furthermore, uranium series dating of dust entrained in the ice from the same location indicates an age of the ice of about 325,000 years (Fireman 1986). The blue ice areas therefore have a potential for palaeoclimatic studies, as old ice might emerge to the ice surface at these locations. $\delta^{18}O$ values of scattered ice samples from blue ice areas in the Transantarctic Mountains, indicate that data on the ice source areas and palaeoclimate can be retrieved from the surface ice (Faure 1990; Grootes 1990), like from the ablation zone of the Greenland ice sheet.

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The objectives of the present study were to investigate the stable isotope signature of the Antarctic blue ice areas, to evaluate the source area of the emerging ice, and to evaluate the potential of these areas as source areas for palaeo-environmental studies. Surface ice samples, to be analysed for $\delta^{18}O$, have been collected from two blue ice areas around Jutulsessen, Dronning Maud Land. The $\delta^{18}O$ records will be compared with deep ice core data and existing snow surface stable isotope values in Antarctica.

The Jutulsessen area

The Jutulsessen mountain complex is situated at 2°40'E and 72°S in Dronning Maud Land, Antarctica. Jutulsessen lies in Gjelsvikfjella, which is a part of the large nunatak area running approximately parallel to and about 200 km inland from the ice shelf margin at the Antarctic coast. (Fig. 1). The nunatak area forms a kind of barrier for the ice draining from the Antarctic plateau in the south at elevations over 3000 m a.s.l. The ice from the plateau, which in this area is called Wegenerisen, drains to the lower part of the ice sheet near the coast through several glacier streams separating the nunataks.

Glacier streams border Jutulsessen both to the west and to the east. The central part of Jutulsessen called Sætet is described as a glacier cirque which now is covered with ice only in the lower flat part (Dallmann et al. 1990). Minor glacier cirques are found in many places around Jutulsessen with some of them still active.

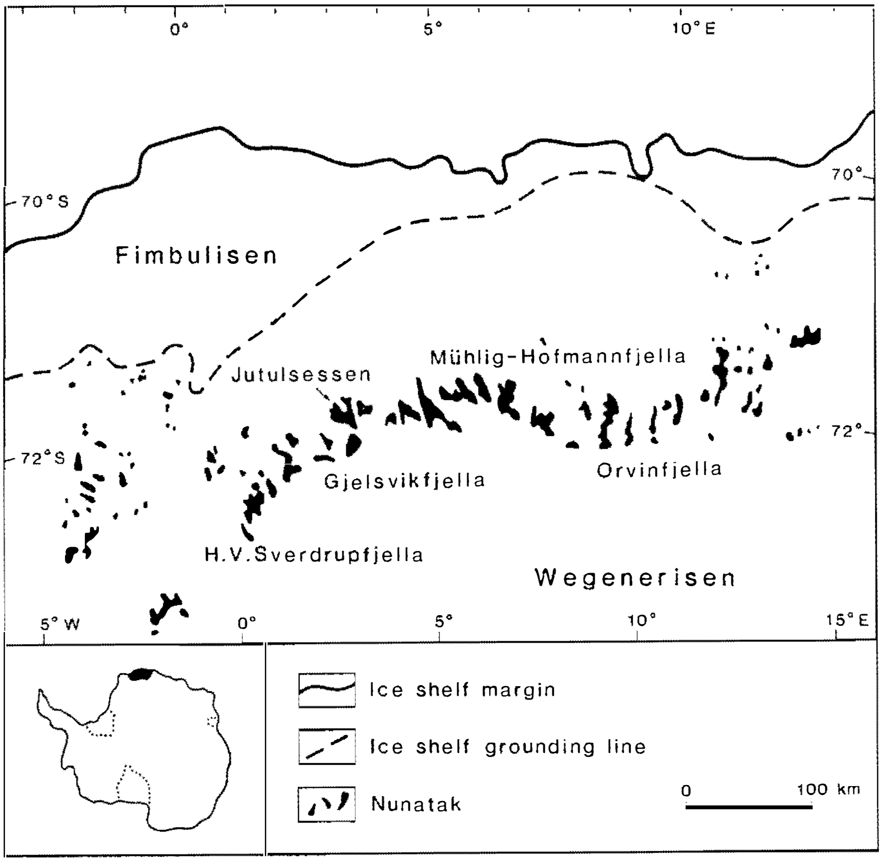

Fig. 1. General location map of NARE 92/93 expedition area in Dronning Maud Land (after Dallmann et al. 1990).

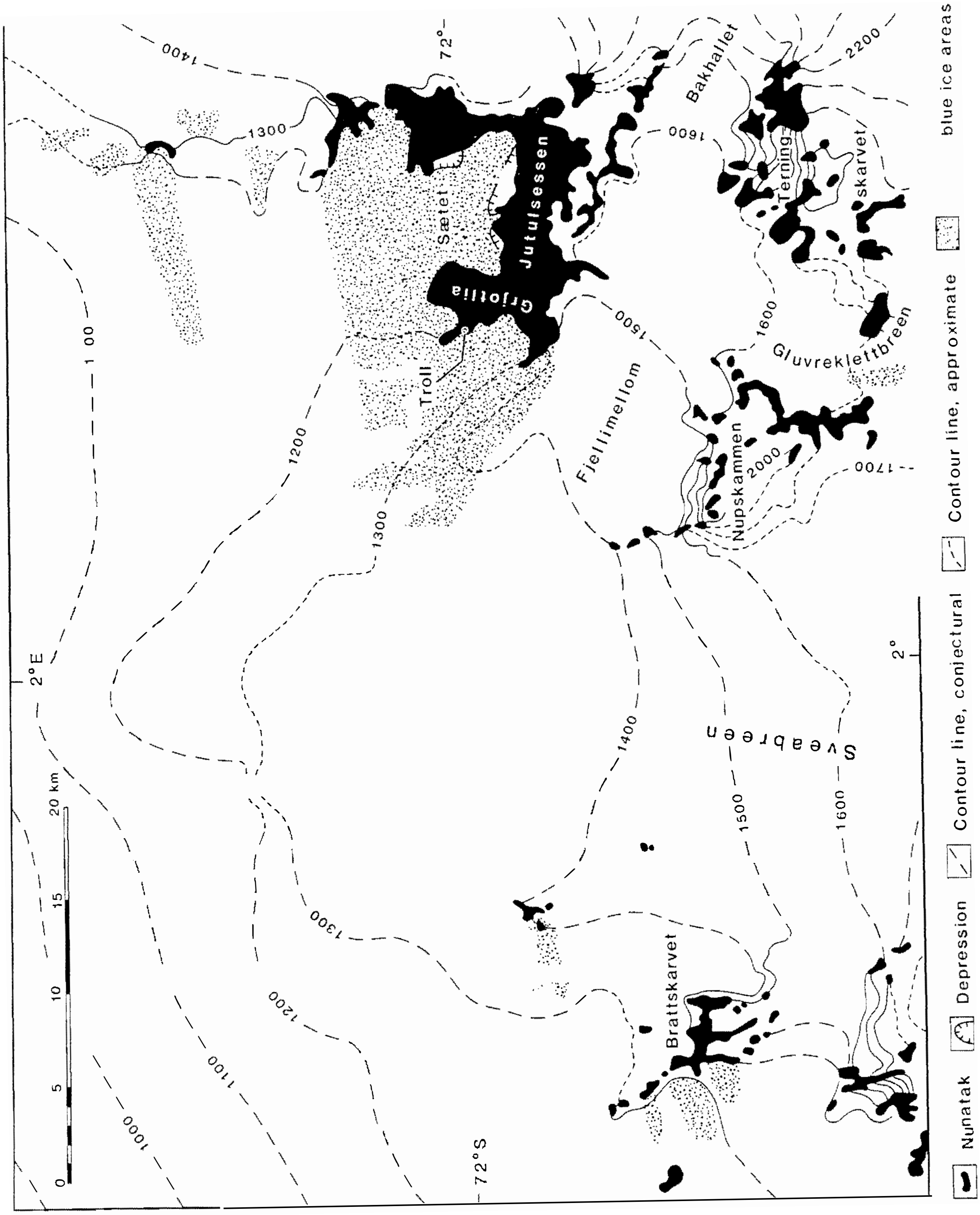

Fig. 2. Map of the Jutulsessen area. Larger blue ice areas are given. Based on Norsk Polarinstitutt (1961a, 1961b, 1991a, 1991b).

A large blue ice area is developed in Sætet and it extends to the west along the western part of Grjotlia where the Norwegian research station Troll is located (Fig. 2). The surface slope of the blue ice areas indicates that the ice flows east towards the rocks at Grjotlia around Troll and flows south towards the rocks in Sætet. The ice surface slope increases strongly towards the rock margins and is in places around 1:10 over a few tens of metres nearest to the rock attesting to very high ablation rates (Orheim & Lucchitta 1990). Frozen lakes are common at several localities along the boundary between rock and ice.

Evidence of the present ice flow to the blue ice areas are given by the general ice surface topography and ice flow structures from satellite image maps (Norsk Polarinstitutt 1991a, 1991b, 1992). This indicates that the blue ice exposed near Troll is ice draining through Fjellimellom partly from the plateau through Gluvreklettbreen and partly from the local accumulation area at Terningskarvet (Fig. 2). The same origin can be expected for the blue ice exposed at Sætet, but also with a change of finding ice here flowing from the plateau through Sveabreen or from the local accumulation area at Nupskammen (Fig. 2).

FIELD WORK

A total of about 650 ice and snow samples were collected from the blue ice area at Grjotlia around Troll and at Sætet to be analysed for $\delta^{18}O$. Two days were spend with sampling around Troll and three days at Sætet. The samples were collected from the ice surface along profiles orientated parallel to the indicated ice flow direction. Detailed $\delta^{18}O$ profiles of 1 m core sections from a blue ice area in the Transantarctic Mountains show that contamination of the surface ice due to surface effects generally becomes negligible at a depth of 5 to 10 cm below the ice surface (Grootes 1990). The upper 5 to 10 cm of the ice surface was therefore removed with an ice axe before the samples were taken. The ice was loosened from the surface with a chiseland put into plastic bottles. Where snow patches were present at the surface samples were also taken from the snow. At several places along the profiles diffuse dust bands could be observed as described from blue ice areas elsewhere in Antarctica (Koeberl 1988; Cassidy et al. 1992). The dust bands runs continuously for many hundred metres perpendicular to the indicated ice flow direction. Furthermore numerous frozen meltwater holes (cryoconite holes) each containing smaller rocks or gravel material were observed on the surface. Notes were made about the ice surface structures (e.g. dust bands and cryoconite holes) along the profile lines and photographs were taken enabling the $\delta^{18}O$ to be correlated with the surface features.

Grjotlia blue ice area

At the Grjotlia blue ice area around Troll, ice and snow samples were collected along a 1 km long profile with a sampling spacing of 4 m, Profile T, (Fig. 3). The start of the profile is located at the rock where the extension of the frozen lake along the ice margin is very limited. A cairn was built on the rock for possible future location of the start point of the profile. In addition snow samples were taken from two 0,6 m deep snow-pits. The snowpits are located in snow patches located at the ice-rock separation, one just west of Troll and one at the start of Profile T.

Sætet blue ice area

In the Sætet blue ice area samples were collected along two profiles. The first profile, Profile J starts at the shore of the fringing frozen lake, where there is a marked change in surface slope (Fig. 3). The profile runs 700 m upstream north-south parallel with the

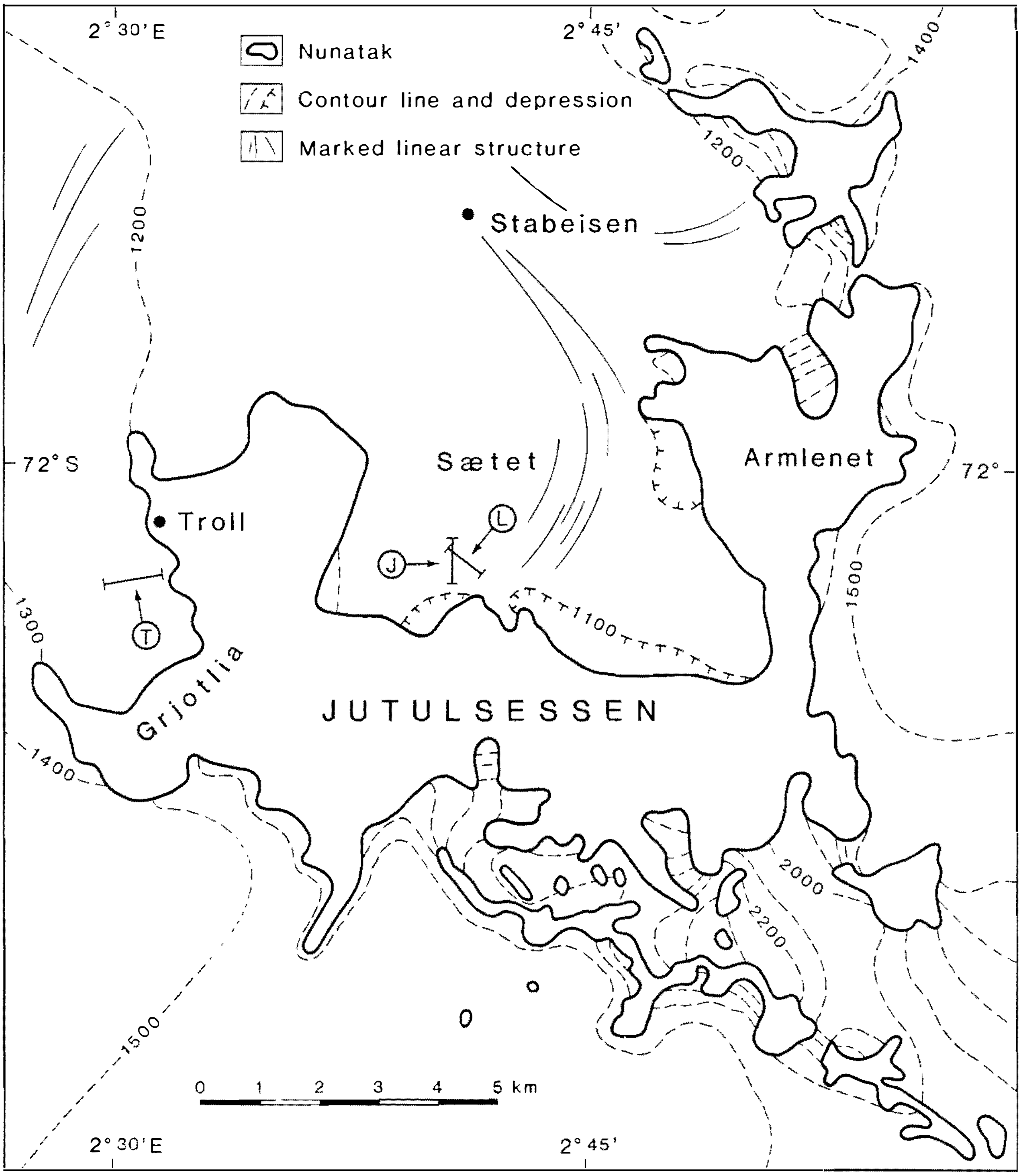

Fig. 3. Map of Jutulsessen where the Norwegian research station Troll is located. Ice and snow sampling profiles, Profile T, Profile J and Profile L are given. Based on Norsk Polarinstitutt (1992).

ice flow direction as indicated by maximum surface slope. The sampling spacing is 4 metres.

Marked linear structures were visible on the ice surface about 230 m from the profile start. Here the structures ran approximately southwest-northeast crossing Profile J in angle of 60°. Along Profile J the structures turn into a more south-southwest, north-northeasterly direction crossing Profile J in an angle of 30° at the end of the profile. The structures are made up of elongated ridges which can be followed over several metres with a spacing of 20 to 60 cm and a height of 1 to 2 cm. The structures appears as longitudinal foliation as described from glaciers elsewhere in the world (Paterson 1981), but there seems not to be any difference in dust content or ice crystal structure of the ice in the ridges and the intermediate hollows. From a satellite image map (Norsk Polarinstitutt 1992) the structures coincide with curved linear structures developed downstream of and starting from the nunatak Stabeisen (Fig. 3). The formation of these linear structures and their possible consequence for the continuity and interpretation of the sampled $\delta^{18}O$ record are not clear. The apparent connection between the structures and Stabeisen points towards an ice flow induced pattern but from the inspection in the field an interpretation of the structures as a wind-induced pattern can not be excluded.

To elucidate this point it was decided to collect samples along a profile perpendicular to the lineal structures, Profile L. The profile has an extension of 600 m and crosses Profile J so that later comparison of the two $\delta^{18}O$ records is possible. Ice samples were collected for every 10 m along Profile L. In addition the start of Profile L were continuously sampled at 20 cm interval over a 20 m distance at a location where the linear structures were particularly strongly developed. The location of ridges and hollows of this part of the profile was also described.

SAMPLE ANALYSIS

The ice and snow samples are at present being analysed for $\delta^{18}O$ at Department of Geophysics, Niels Bohr Institute for Astronomy, Physics and Geophysics at Copenhagen University in Denmark. The results are expected to be available by the end of summer 1993.

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Norsk Polarinstitutt, 1961b: H.U. Sverdrupfjella, Fimbulheimen. Dronning Maud Land 1:250,000, sheet H6.

Norsk Polarinstitutt, 1991a: Jutulgryta, Fimbulheimen. Dronning Maud Land 1:250,000, satellite image map, sheet H5S.

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Norsk Polarinstitutt, 1992: Jutulsessen, Dronning Maud Land. 1:100,000 (map with text).

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ØYVIND ARMAND HØYDAL[1]:

STUDY OF VELOCITY, MASS FLOW AND DEFORMATION IN JUTULSTRAUMEN

BACKGROUND

Jutulstraumen with its drainage area is one of the most important ice streams in Dronning Maud Land. It has a drainage area of about 124,000 square kilometres (Declair & Van Autenboer 1978) which is about one percent of Antarctica.

Based on velocity measurements from Gjessing (1970) and a constructed accumulation area Declair & Van Autenboer (1982) found that Jutulstraumen is close to balance. A calculation by Bentley & Giovinetto (1990) shows that it probably accumulates about 50 per cent more than the outflow. Today it is possible to measure a number of stake positions rationally by using GPS more accurately than a few years ago. The lower part of Jutulstraumen flows into the ice shelf Fimbulisen where it protrudes like a tongue - Trolltunga. This tongue has had a dramatic retreat during the last fifty years. Other ice streams and outlets are known to have a high velocity for one period, and a lower velocity for another, with equal mass balance and input. Based on this knowledge, Jutulstraumen would not be likely to be in balance.

OBJECTIVES

The objectives of this project are

1. to clarify and map the state of velocity and mass transport aspects of Jutulstraumen, and
2. in detail to measure the surface deformations in some areas and calculate the vertical velocity gradient.

Satellite images (Landsat) from Jutulstraumen were studied before the field research started. Flow patterns show that as much as one third of the mass in Jutulstraumen could flow west of the velocity profile investigated by Gjessing (1970). It was therefore important that also this part of the ice stream, between Northern Nashornkalven and Istind, was measured.

FIELD WORK

The field work was done in cooperation with Jon Ove Hagen's glaciological project. Members of his team were: Jon Ove Hagen, Kjetil Melvold, Jan Gunnar Winther and Henrik Højmark Thomsen. The measurements of the stake positions were organised and carried out with assistance from the topographic team: Trond Eiken, Bjørn Lytskjold and Bjørn Barstad. The work was carried out from a base camp at Northern Nashornkalven.

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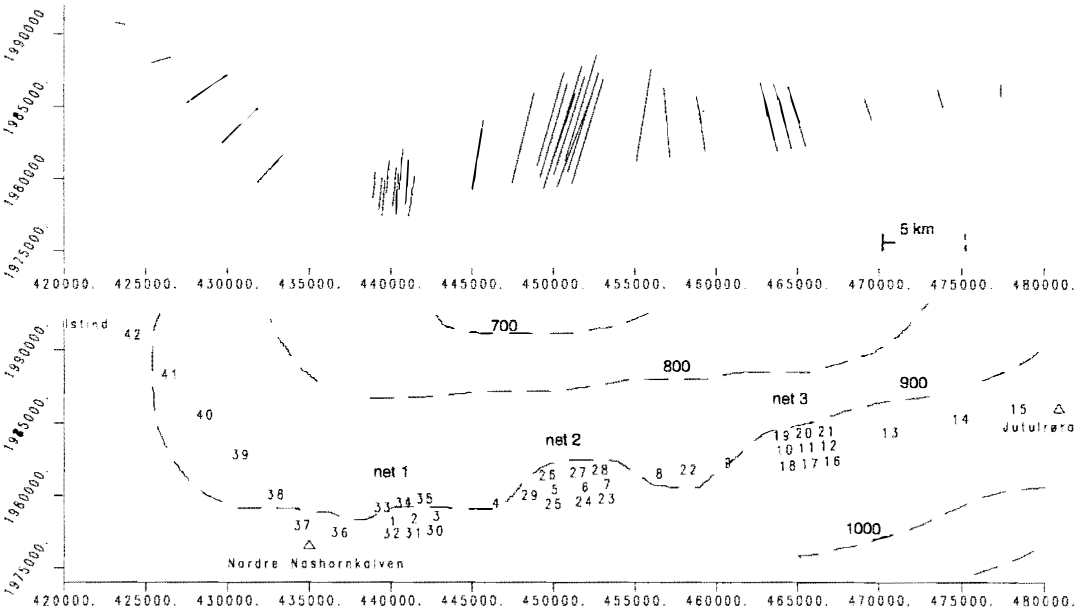

Fig. 1. Relative positions of each stake (lower part), and horizontal direction of the movements (upper part).

The profiles were set out on 5 January 1993, and consisted of :

Profile 1:	36 stakes between Northern Nashornkalven and Jutulrøra. 27 of the stakes were organised in three strain nets each consisting of 3 x 3 stakes.
Profile 2:	6 stakes between Northern Nashornkalven and nunatak 1320 south of Istind.

The profiles are at an altitude between 900 and 1150 m a.s.l. A map of the profiles is shown in Hagen & Melvold (1994).

The first survey started on 8 January. The profiles were divided into three working areas and measured by three teams with altogether seven GPS receivers, of which three measured kinematics. Stationary receivers were mounted at 1320, at Northern Nashornkalven, at stake 9, and at Jutulrøra.

Team 1 drove profile 2 and in addition the first strain net in profile 1. Team 2 started at Northern Nashornkalven and drove further on profile 1 to stake no. 9. Team 3 started at stake 9, and drove the rest of the profile.

The second survey was done on 21 January. It was divided into two sessions and carried out by two teams. In the first session every stake carried out by team 2 and 3 in the first survey, was measured. The remaining stakes were measured in the next session.

Table 1.

Stake number	Velocity [m/year]	Stake number	Velocity [m/year]
1	137	23	456
2	163	24	423
3	179	25	384
4	321	26	396
5	399	27	449
6	421	28	446
7	445	29	379
8	377	30	175
9	258	31	192
10	179	32	129
11	164	33	113
12	136	34	150
13	91	35	197
14	72	36	42
15	51		
16	155	37	1
17	169	38	141
18	176	39	189
19	180	40	185
20	166	41	73
21	152	42	35
22	304		

PRELIMINARY RESULTS

The processing has been carried out by Trond Eiken. Only preliminary results are presented here. Fig. 1 shows the relative position of the stakes (lower part) and horizontal direction of the movements (upper part). Table 1 shows the velocity of each stake. The velocities are very similar to those measured by Gjessing (1970).

Ice thickness is taken from Declair & Van Autenboer (1982). The mass transport in profile 1 is estimated at 12.3 km^3 per year, assuming no change of the horizontal velocity in depth. The ice profile described by Declair & Van Autenboer (1982) is much deeper than that of Gjessing (1970). Using the Gjessing profile, the mass transport is about 9.2 km^3 per year in profile 1. The mass transport in profile 2 is about 3.8 km^3 per year - a total of about 16 km^3 per year. Better estimates of the mass transport require radio echo measurements carried out along the profiles and calculations from the strain nets. This may change the estimates drastically.

The strain and stress calculations need a final processing of the GPS measurements before any results can be available.

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TOR GAMMELSRØD[1], STEINAR MYKING[1], ANDERS NØST[1],
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WATER MASSES IN THE SOUTHERN WEDDELL SEA

BACKGROUND AND OBJECTIVES

One of the key questions in climate research today is the mass balance of the Antarctic ice sheet. If it melts due to a global warming, the sea level will rise about 60 m. An area of the glacier comparable with France is floating on the ocean forming an ice cap which is typically 200 m thick at the outer end and 1 km at the grounding line. The oceanographic observation programme was performed along the ice barrier, in order to study the melting of the glacier which mainly takes place underneath the ice sheet. The water which is modified by the cooling and melting underneath the floating glacier forms a watermass which is crucial for the renewal of the bottom water of the world oceans (Foldvik & Gammelsrød 1988).

In general terms the water masses in the area may be described as follows:

A dense, saline water mass, called Western Shelf Water (WSW), is formed on the shallow shelves by freezing of sea ice and subsequent brine release. This process is particularly effective along the ice barrier where a polynya is kept open by the tidal currents. The temperature of this water is therefore determined by the freezing point of the sea water (-1.9°C), and due to the shape of the bottom topography it flows beneath the floating glacier. In contact with the underside of the ice, which has a bulk temperature of -27°C, the water is modified. Because the freezing point of the water is decreasing with increasing pressure, the bottom of the floating glacier will start to melt when it comes in contact with water with temperature corresponding to the surface freezing point. Generally speaking, when the water underneath the ice is moving inwards towards greater ice thickness and therefore higher pressure, the ice will melt. When moving outwards (and upwards) there is a tendency of freezing at the bottom of the floating glacier. Thus by studying the water masses along the ice shelf, models of the circulation, residence times and melting/freezing processes below the glacier may be formulated (Nøst, in preparation).

The water which has been modified by cooling/melting is easy to identify because if will have a temperature lower than -1.9°C, it will also be less saline than the 'parent' WSW, and it is called Ice Shelf Water (ISW).

The ISW flows northwards along the western flank of the Filchner Depression (see map, Fig. 1) and overflows the sill with a volume transport of about 10^6 m^3/s (Foldvik et al. 1985d), which is comparable to the total runoff from all the world rivers combined. It is accelerated down the steep continental slope where it attains speeds of up to 1 m/s

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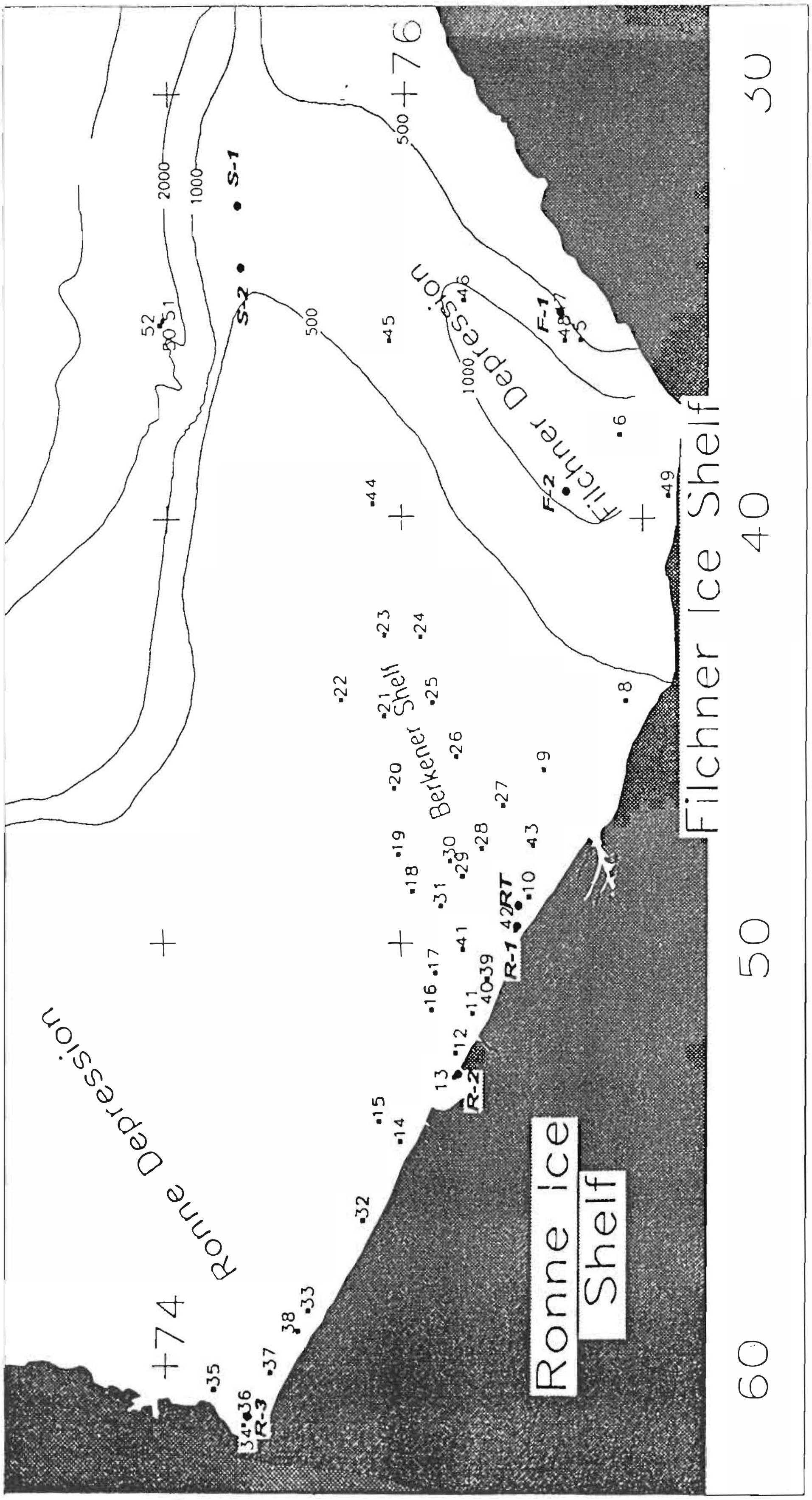

Fig. 1. Map of the study area with positions of CTD-stations and current meter moorings.

(Nordlund 1992). The dynamics of this cold bottom jet and the mixing processes with the overlying water masses are only poorly understood, but due to the ice conditions we were not able to penetrate into this area.

The experiments were set up in cooperation with a group of six chemical oceanographers who amongst other parameters studied the uptake of anthropogenic climate gases as CO_2 and Freon (Anderson et al. 1997). In addition, water samples for tracer studies using $^{18}O/^{16}O$ ratios, Tritium from the nuclear bomb tests in the atmosphere in the 1969s, and for Helium concentrations were taken. The Helium and Tritium samples will be analysed by our colleagues at the University of Heidelberg, Germany.

EQUIPMENT AND TECHNIQUES

Temperature and salinity profiles were obtained using a Neil Brown Mark IIIB CTD. For water samples a General Oceanic Rosette sampler with 24 ten-litre bottles was used. Salinity content was found using a Guildline Portasal salinometer. Usually the salinity analysis was done at most a few days after the sampling.

Aanderaa current meters and water level recorders were used for the anchored moorings. General Oceanic acoustic releases or bottom ropes were used for the recovery of the moorings. A few vertical profiles of speed were also obtained by a Simtronic UCM-40 and an Aanderaa current meter.

FIELD WORK

A total of 53 CTD casts were obtained, most of them close to the Filchner-Ronne ice shelves (see station map Fig.1). In addition a current meter mooring with two current meters and one water level recorder was deployed for ten days at the Berkner shelf (Fig.1).

Four long-time monitoring moorings were deployed along the Filchner-Ronne shelves, the three westernmost along the Ronne Shelf with two kilometers long bottom lines. The deep one in the Filchner depression is equipped with an acoustic release.

Unfortunately we were not able to deploy a mooring planned at the western flank of the Filchner Depression to monitor the out-flowing ISW, nor were we able to recover a mooring deployed earlier for the same purpose, due to the heavy ice conditions. Also the deployment of four rigs at the Filchner sill and the shelf break had to be given up, as well as the recovery of a mooring on the sill. However, a rig deployed in the sill in 1992, equipped with an acoustic release, was successfully recovered using helicopters and divers.

PRELIMINARY RESULTS

Water masses

The temperature and salinity values obtained from the rosette sampler are shown in a T-S diagram (Fig.2), together with the definitions of the typical water masses found in the Weddell Sea.

Fig. 3 shows vertical profiles of three CTD stations obtained at the Filchner ice shelf (station 6), the Ronne ice shelf at the far west end (station 34), and station 50 obtained at 2400 m depth at the shelf break; for locations, see Fig.1. The corresponding T-S diagrams are shown in Fig. 4.

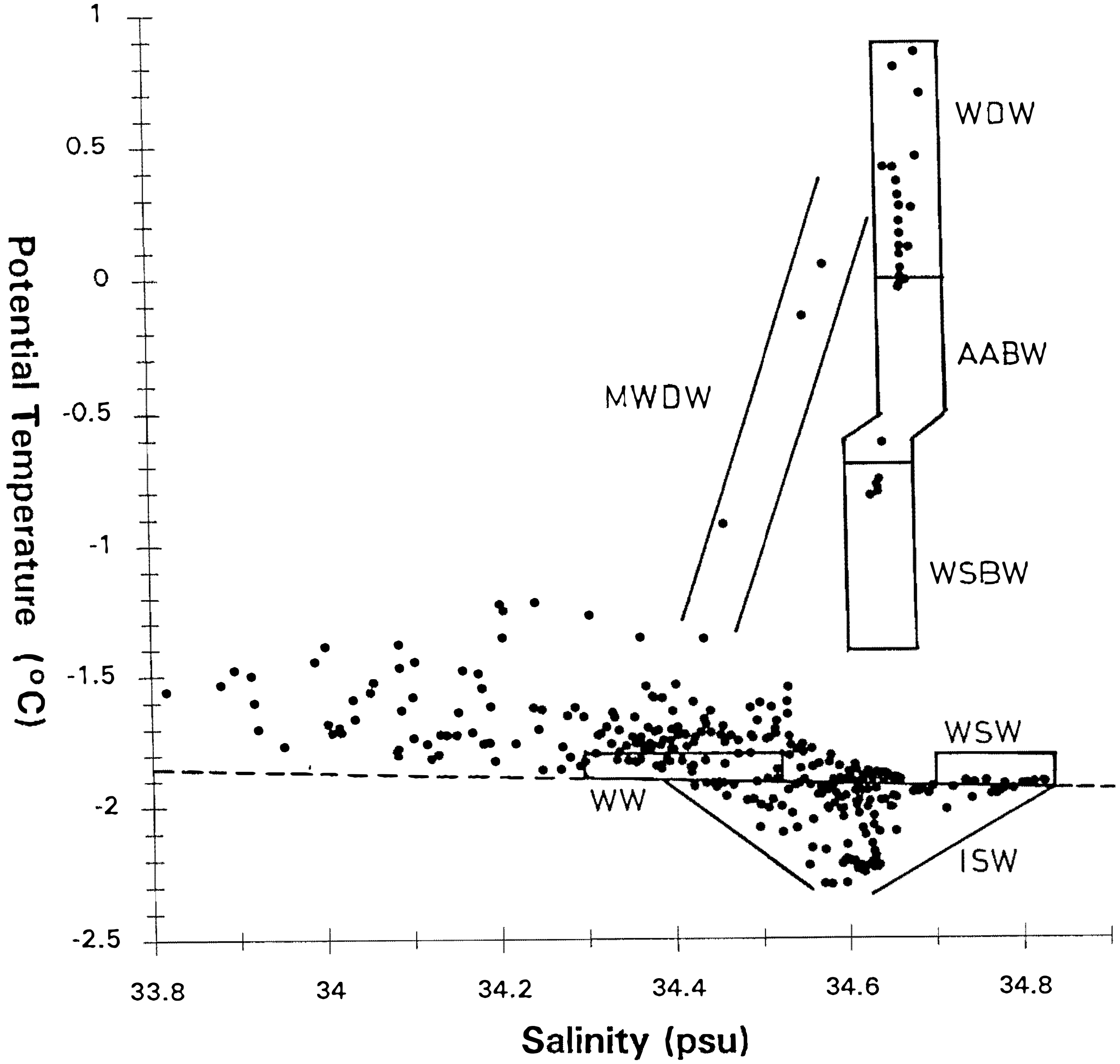

Fig. 2. Temperature versus salinity from values obtained with the rosette bottles. Freezing point temperature is indicated. Typical water masses are indicated. (WW=Winter Water, ISW=Ice Shelf Water, WSW=Western Shelf Water, WDW=Weddell Deep Water, AABW=Antarctic Bottom Water, WSBW=Weddell Sea Bottom Water, MWDW=Modified Weddell Deep Water).

Typical ISW is observed at Station 6 (Fig. 3a), where we for convenience have plotted the actual freezing temperature as a dotted line. Note that the deviation between the observed temperature and the freezing temperature is smallest at about 600 m and 300 m, indicating that the out-flowing water has most recently been in contact with the ice at these two levels. The melting/freezing processes and the initial stratification of the water masses determine the depth where the out-flowing ISW water plumes leave the underside of the ice and continue as mid-water level cold currents (Nøst 1992).

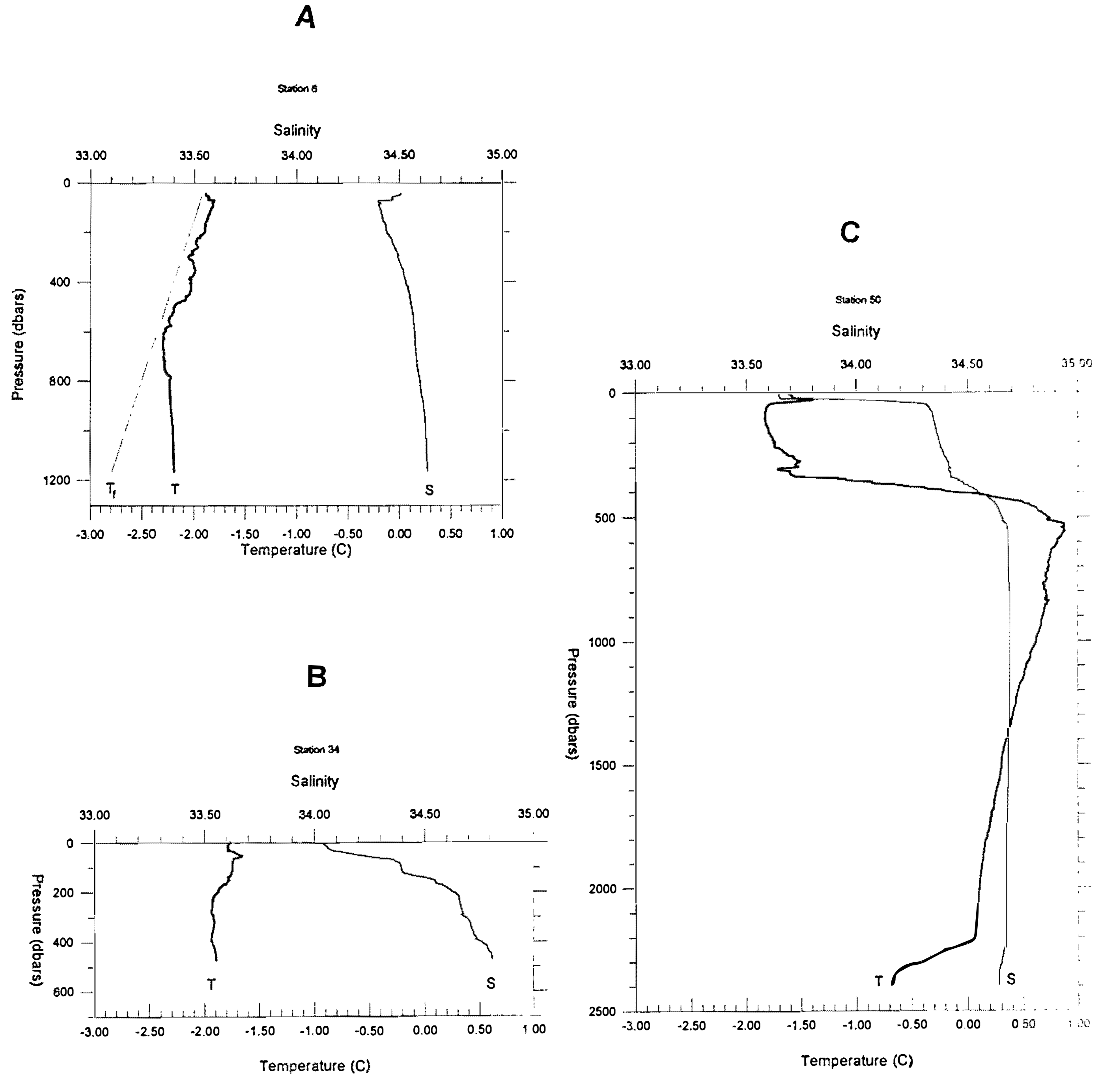

Fig. 3. Vertical profiles of temperature and salinity for three selected CTD stations: A. St. 6 in the Filchner Depression; B. St. 34 at the Western Ronne Ice Shelf; C. St. 50 at the continental slope.

At the far west of the Ronne ice shelf WSW is observed near the bottom (Fig.3b). The main production of WSW is believed to take place on the shallow Berkner shelf, but we did not observe WSW on other locations than the Ronne Depression. The reason may be that we arrived late in the summer season when the WSW production is small, and this relatively heavy water may have drained out from the Berkner shelf. It has been observed earlier that the amount of WSW water on the Berkner shelf diminishes during summer (Foldvik et al. 1985c).

At Station 50, obtained at the continental slope (Fig.3c), we recognise several typical water-masses: The upper 300 m is dominated by Winter Water (WW), produced during the winter. At 500m depth we find a temperature maximum, representing the core of the Weddell Deep Water (WDW). At the very bottom Weddell Sea Bottom Water (WSBW), defined as having temperature below -0.7°C and with salinity S~34.64, is observed.

The water types WW, ISW, WSW are formed in the area by interactions with the atmosphere and the ice shelf. Thus these represent the 'parent' water masses in the Weddell Sea, and it is of particular interest to know their characteristics in order to estimate the melting under the ice and the process of bottom water formation. Thus it may be mentioned that on this expedition we found arch-typical water masses, with ISW down to about -2.3°C and WSW with salinity above 34.82, which is the highest salinity ever observed in the Southern Weddel Sea. The WDW is usually defined having temperature between 0.4°C and 0.8°C. This definition must be changed after this expedition, because the maximum temperature at st.50, was close to 0.9°C, the highest subsurface water temperature ever observed in the area.

Fig.4 shows the T-S-diagrams for the same stations as shown in Fig.3. A tick mark is annotated for every 50m depth. The arrows indicate the processes involved in bottom water formation :

1. WSW is formed from WW by cooling and brine release.
2. Underneath the glacier WSW is transformed to ISW by cooling and melting.
3. At the continental slope mixing of ISW and WDW in about equal parts will produce WSBW.

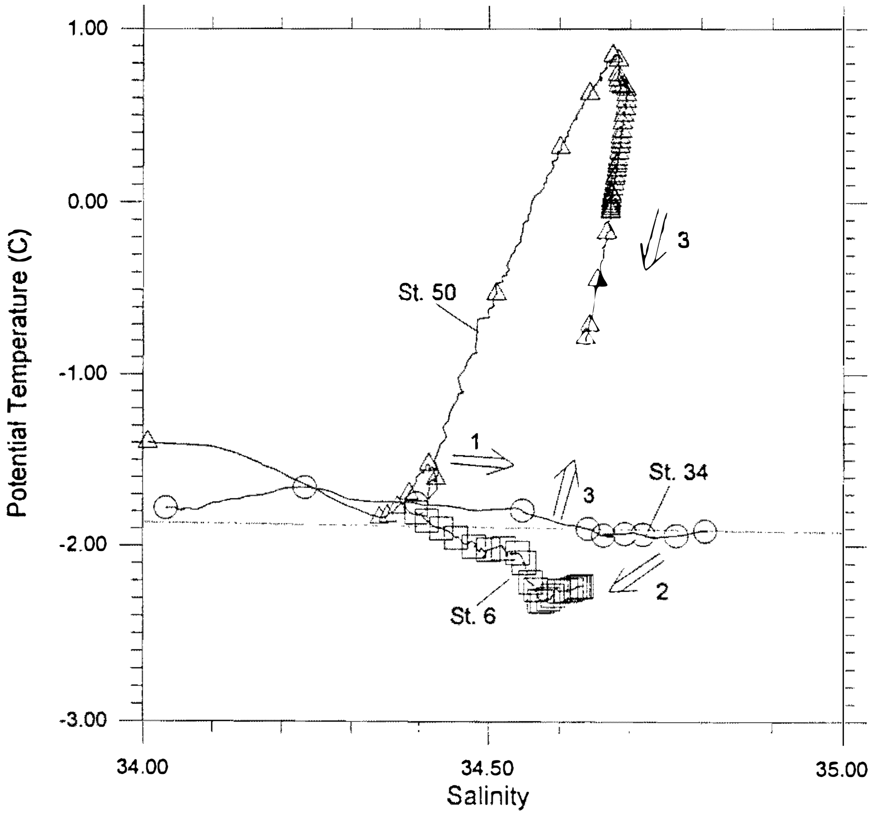

Fig. 4. T-S diagrams for the same stations as shown in Fig. 3. Arrows indicate the processes producing the bottom water (see text).

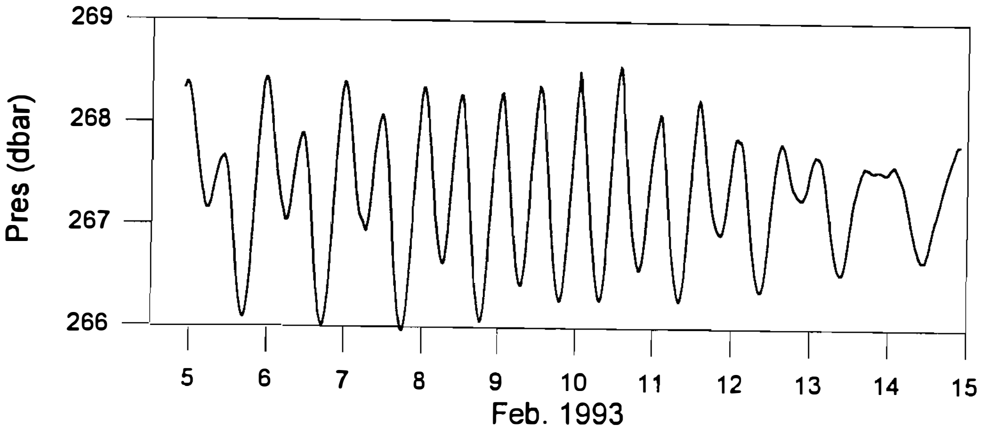

Fig. 5. Water level as recorded with the mooring RT, near the ice varrier at 50°W.

The record of ten days water level registrations obtained in position S76° 57.730', W 49° 04.507', about 10 km from the barrier is shown in Fig. 4. The mooring position is marked RT on the map (Fig. 1). Full moon occurred on February 7, and from Fig. 5 we notice that during spring tides the water level difference is about 2.5 m. Fig.5 shows that the semi-diurnal variations are dominant, but also the diurnal signal is readily seen, especially in the beginning and at the end of the ten day period.

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CHEMICAL COMPOSITION IN WATER MASSES AND INTERACTIONS WITH THE SEDIMENT IN THE SOUTHERN WEDDELL SEA

OBJECTIVES

The main objective of this investigation was, along with the physical oceanographers, to study the bottom water formation in the Weddell Sea; processes causing this formation, their time scales and how different processes, such as air/sea and sediment/water interactions affect the chemical composition of the formed bottom water. The ultimate goal of this investigation is to understand these processes well enough to be able to model the system and to study its sensitivity to climatic variations.

INTRODUCTION

The bottom water in the Weddell Sea is formed as the result of a chain of processes, described in a general way as follows: During the freezing season a high salinity water, of freezing temperature (called Western Shelf Water, [WSW]), is formed over the southwestern shelves. Because of its high density it sinks to the bottom where it follows the topography, either to the north down into the deep Weddell Sea, mixing with overlying water, or to the south under the ice shelf. The water flowing under the ice shelf will ultimately come into contact with the glacial ice, where a heat exchange will take place. In the deeper regions the ice will melt, hence producing a colder, less saline water of lower density. When this super cold water flows upwards along the bottom of the ice shelf, freezing will occur once the water temperature gets below the freezing temperature at that depth. One result of this heat exchange is that a super cold water (called Ice Shelf Water [ISW]) is formed, which flows out into the Filchner Depression. Part of this water hugs the western slope of the Filchner Depression and flows down into the deep Weddell Sea at about 36°W, mixing with overlying water, and forming Antarctic Bottom Water [AABW]. The overlying water at the break of the continental margin is the Warm Deep Water [WDW], which mostly has its source in the northern Atlantic Ocean. It is also the only water mass that enters the Weddell Sea from the outside.

Bearing this general formation scenario in mind it is obvious that the chemical composition of the water can be affected by air/sea and sediment/water interactions, biological production and organic matter oxidation, freezing of sea ice, interaction with the under side of the ice shelf, and naturally by the mixing of different water masses.

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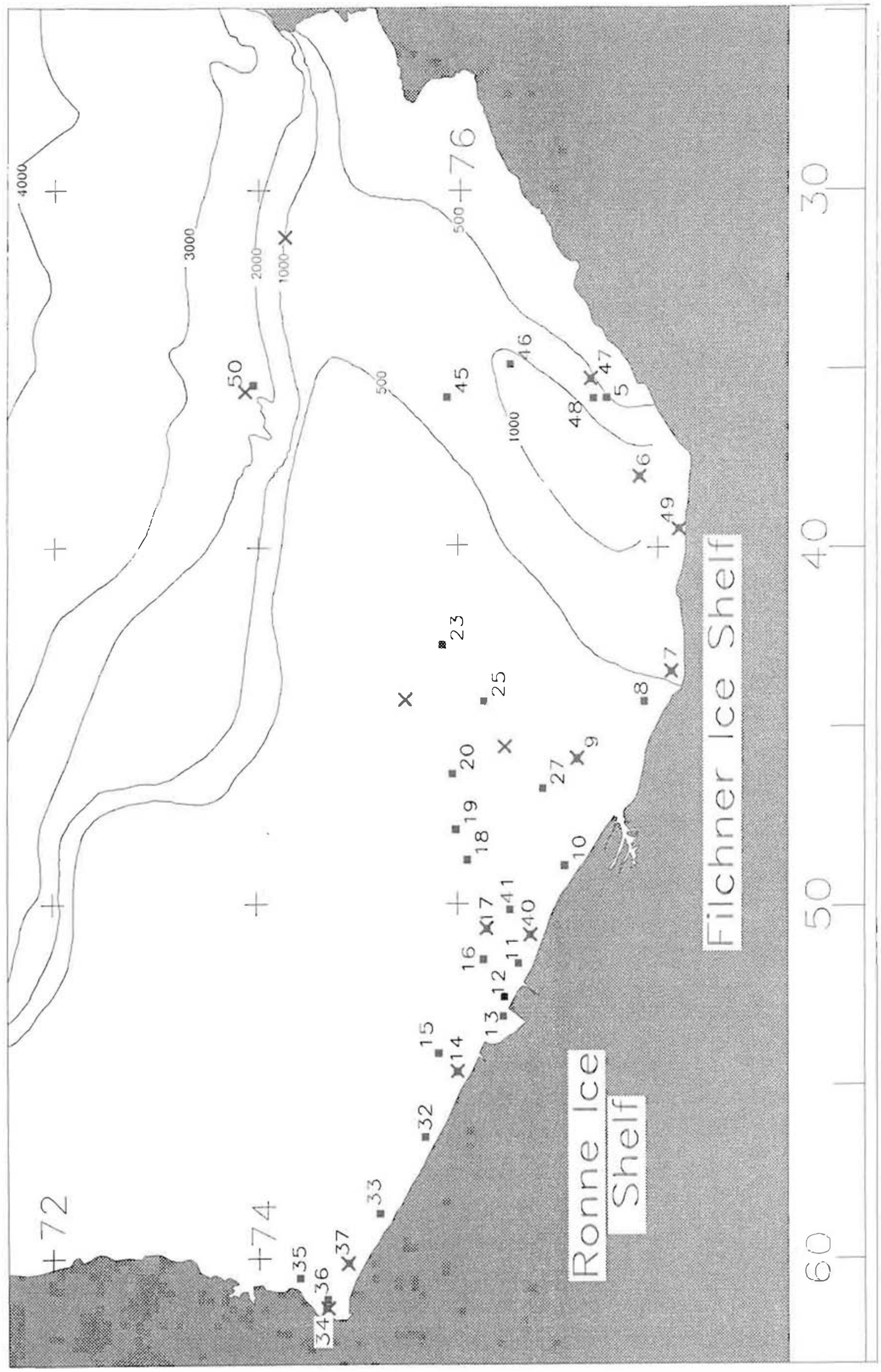


Fig. 1. Map of the southern Weddell Sea, where all stations sampled for water are marked with a square and those sampled for sediment by a cross. A few stations located north of Dronning Maud Land are outside the limits of this map.

This investigation was designed to enable us to evaluate the importance of these processes and their effect on the chemical composition of the different water masses of the region. The conducted study covered two sampling programmes, aiming at processes in the water column and at the sediment/water interface. Included in the water investigation was determination of nutrients, oxygen, the carbonate system and different transient tracers, while the sediment/water interaction study focused on solute exchange measurements, pore water analyses and closed sediment incubations.

METHODS

Seawater investigation

Sampling

Water was collected in Niskin type water bottles on a 24 bottle rosette at 35 of the 53 CTD stations occupied during the cruise (see Fig. 1). Each of the water bottles contained about 10 l and had been used on several previous cruises, thus minimizing the risk of contamination. To further minimize such risk, once the bottles were on deck, the water for the analysis of the different constituents were drawn in the following order:

- Helium-3
- Halocarbons
- Oxygen
- Total Carbonate
- Total Alkalinity
- Nutrients
- Salt
- Oxygen-18
- Tritium
- Rare earth metals

Whenever radon samples were collected, they were drawn from separate bottles.

All the samples collected, helium-3, salt, oxygen 18 and tritium, were the responsibility of the physical oceanography group. Of the others, the rare earth metals and radon samples will be analysed in Sweden by Dr. Stig Westerlund (Department of Analytical and Marine Chemistry, University of Göteborg) and Dr. Elis Holm (Department of Radiation Physics, Lund University), respectively. All other constituents were determined on board M/V Lance, shortly after sampling using the following analytical techniques.

Halocarbons

Halocarbons include the chlorofluorocarbons (CFC-11, CFC-12, CFC-113 and carbon tetrachloride) and a large set of other low molecular weight halogenated substances, anthropogenic (e.g. tri- and tetrachloroethylene) as well as biogenic (e.g. methyl iodide and bromoform). They were measured by a gas chromato-graphic method after extraction from the water matrix by purging with nitrogen and pre-concentration in a cold trap. Detection and quantification was accomplished by electron capture detection. The system has been designed for simultaneous measurements of halocarbons ranging from the chlorofluoro-carbons to the higher molecular weight biogenic halocarbons bromoform and di-iodo-methane. A total of 25 compounds were detected, 15 of which quantified in the seawater. Air samples were analysed for a total of 13 compounds.

Seawater samples were withdrawn from the bottles on the Rosette with 100 ml glass syringes avoiding contact between the water sample and ambient air. The syringes were stored in a bucket of seawater prior to the analysis, which generally took place within four hours, and never later than twelve hours after sampling. Air samples were taken in the same kind of syringes and analysed directly.

In cooperation with Dr. Erik Syvertsen, who was conducting an ice algae project on board R/V Polarbjørn, ice was collected and immediately deep-frozen for later transport to R/V Lance and analysis for halocarbons. These ice samples were collected from ice floes, where monocultural algae colonies had developed. Before analysis, the samples were slowly thawed at +2 $^{\circ}$C.

An accurately known volume of seawater, measured in a loop at the beginning of the purge and trap system, about 40 ml, was transferred to a stripping unit, in which a flow of ultra pure nitrogen gas stripped the gaseous halocarbons from the water. The analytes were passed on to an open stainless steel tube, the cold trap (0.5 m, 0.75 mm internal diameter), which was immersed in a Dewar flask with liquid nitrogen. The stripping and trapping went on for twenty minutes, controlled by a time relay. In the next step, the cold trap was heated with boiling water, the halocarbons desorbed from the trap and transferred to the gas chromatographic column. Two lines of the entire analytical procedure worked in parallel, and 4-5 samples were run per hour. The standardisation of CFCs was accomplished by comparison with a gaseous standard, introduced in the purge flow through a loop valve. This gas standard was calibrated against the SIO scale, prepared at the Scripps Institution of Oceanography, San Diego, USA, and widely used in the US, as well as another gas standard prepared in England at the Plymouth Marine Laboratory. For the other halocarbons, liquid standards were gravimetrically prepared in a methanol solution. The stripping efficiency of the CFCs under these conditions is 100%, while the yields of the other halocarbons of lower volatility have to be measured and compensated for. The efficiency of an analytical run was controlled by an internal standard, $CBrCl_3$ dissolved in methanol (as well as in the standard solutions) added to each seawater sample through a loop valve. The gas chromatographic separation was performed on a fused silica column (J&W, DB624), 75 m long and of 0.53 mm internal diameter in a Varian 3400 GC equipped with two electron capture detectors, one for each of the parallel lines. Several tests were made to confirm the linearity of the detectors by multipoint standard curves of all standard compounds, gaseous as well as liquid standards. The water sampling bottles mounted on the Rosette were tested for possible contamination and/or absorption of the analytes by filling them all at the same depth, and leaving them for several hours before sampling and analysing the contents of the water. Only a slight, and insignificant, increase in halocarbon content over time could be observed.

Oxygen

Oxygen was determined by an automated Winkler titration according to Anderson et al (1992). Duplicate samples were regularly collected from the same Niskin bottle and the variation between the determinations of these were always better than ± 0.4 μM. The accuracy was set by titration of a standard potassium iodate solution. The error in this standard solution is considerably less than the precision of the titration thus the accuracy is expected to be in the same order as the precision.

Total carbonate

Total carbonate was determined in a thermostated laboratory container by the degassing of acidified seawater samples followed by coulometric determination of the released

CO_2(g) according to the principle first described by Johnson et al. (1985). New coulometric cell solutions were used for each set of samples analyzed. For each of these solutions a reference water, supplied by Dr. A. Dickson (Scripps Institute of Oceanography, La Jolla, USA), was analyzed to set the accuracy. Each sample was automatically determined in duplicates, followed by one additional run if the first two results deviated by more than 2 μmole/kg. Hence, we believe that both the accuracy and precision are within ±1 μmole/kg.

Total alkalinity

Total alkalinity was determined, under thermostated conditions, by an automated potentiometric titration with Gran evaluation. The titration was performed in an open vessel using 39.95 ml of sample, added in two aliquots by a Metrohm burette. pH was recorded when one aliquot had been added, while the tip of the acid burette was still above the sample surface. This was followed by the addition of the second aliquot and the subsequent titration of the total alkalinity using 0.1 M hydrochloric acid. The variation between duplicate titrations was typically less than 2 μmole/kg. The same reference water used in the total carbonate determination was also titrated for its total alkalinity. The total alkalinity of the reference water in combination with its pH will give the total carbonate concentration. This in turn will be used to calibrate the hydrochloric acid used for the titrations.

Nutrients

The nutrients, phosphate, nitrate and silicate, were determined with a Technicon Auto-analyzer, using their standard methods. During each run working standards, prepared on board, were used as references. The accuracy of the working standards were compared with CSK standards. The temperature in the laboratory fluctuated quite severely both between days as well as within each separate run thus affecting both accuracy and precision. The precision was estimated to be about ±0.5 μM for both nitrate and silicate and ±0.05 μM for phosphate.

Sediment/water investigation

Sampling

Sediment for the sediment/water investigation was sampled either using a regular box corer (50*50 cm) or using a modern version of the multiple corer (MUC, core diameter 10 cm), able to sample eight separate sediment cores at the time. Several chemical constituents were determined during the study. Of these oxygen, total carbonate, nitrate, phosphate and silicate were determined on board shortly after sampling while samples for ammonium, total alkalinity, calcium, dissolved free amino acids (DFAA) and dissolved organic carbon (DOC) were taken to Göteborg for analysis. Lead-210 will be determined at the Department ofRadiation Physics, Lund University and samples for meifauna were sent to Dr. Francis de Bovée, Laboratoire Arago, France.

Sediment/water exchange

Virtually undisturbed sediment cores, toghether with ambient overlying bottom water, were collected by the MUC for sediment-water exchange measurements at three stations. At thirteen stations the box corer was used and sediment subsamples were taken by gently inserting one or two plexiglass core tubes (core diameter of 10 cm) into the sediment. A plastic sheet covered the sediment surface while bottom water, taken 10-25 m above the sediment surface, was carefully added. The sheet was then removed. One or two cores from each station, together with the overlying bottom water, were incubated at approximately *in situ* temperature for sediment water exchange measurements. Measured parameters were oxygen, total carbonate, total alkalinity, calcium, nutrients (nitrate, ammonium, phosphate and silicate), DOC and DFAA.

Sediment nitrification

Sediment nitrification rates were studied in simular cores as the sediment/water exchange investigations. Acethylene was added to the overlying water and allowed to diffuse into the sediment nitrification zone in order to inhibit nitrification. The differences in ammonium release before and after the acethylene addition, were compared and used as a measure of nitrification rates.

Sediment porewater

For sediment and interstitial water (pore water) studies, surface sediment down to approximately 30 cm was collected using both samplers and sectioned into one or two cm depth intervals. The pore water was extracted from the sediment by centrifugation and thereafter filtered through a 0.45 mm filter. Determinations were carried out for nitrate, phosphate, silicate, total carbonate, ammonium, total alkalinity, calcium, DFAA and DOC. Sediment was also extracted with 2 M KCl for exchangeable ammonium and amines/amino acids (amines/amino acids adsorbed onto sediment particles).

Uncentrifuged sediment samples from the different depth intervals were collected for determinations of water content, porosity, solid phase carbon (organic and inorganic), nitrogen, phosphorous (organic and inorganic) and silica. Information on the sediment accumulation rates will be obtained from the Pb-210 distribution.

Closed sediment incubation

Three different layers of surface sediment (0-2, 2-4 and 4-6 cm) were taken from the boxcore, carefully sieved through a 1 mm mesh, homogenized and added to gas tight centrifuge tubes. The sediment was then incubated without atmospheric contact at an approximate in situ temperature for 10-15 days for "reaction rates"; i.e determinations of the rates by which solutes are produced from the solid sediment. Pore water obtained was extracted from the sediment by centrifugation and then filtered through a 0.45 mm filter. The measured parameters from these incubations included nitrate, phosphate, silicate, total carbonate, ammonium, total alkalinity, calcium, DFAA and DOC.

Benthic fauna

To investigate meiofaunal distribution and evaluate the biomass, surface sediment (0-15 cm) from the sediment/water exchange studies was (after these had been completed) sectioned into different depth intervals and biologically quantified. The importance of bioirrigating fauna on the transport of solutes across the sediment/water interface was estimated by comparing the ratio between the measured release of nutrients from the sediment and the diffusive transport calculated from the porewater distribution.

PRELIMINARY RESULTS

Seawater investigation

This investigation has resulted in a unique data set for the waters of the southern Weddell Sea shelf area. For the first time the chemical signature of the source water, Western Shelf Water has been determined. This signature in combination with the one of the Ice Shelf Water and the profile of station 50, which includes all major water masses of the Weddell Sea, makes it possible to deduce the characteristics of the ISW that flows down the shelf break to form the Antarctic Bottom Water and the Weddell Sea Bottom Water.

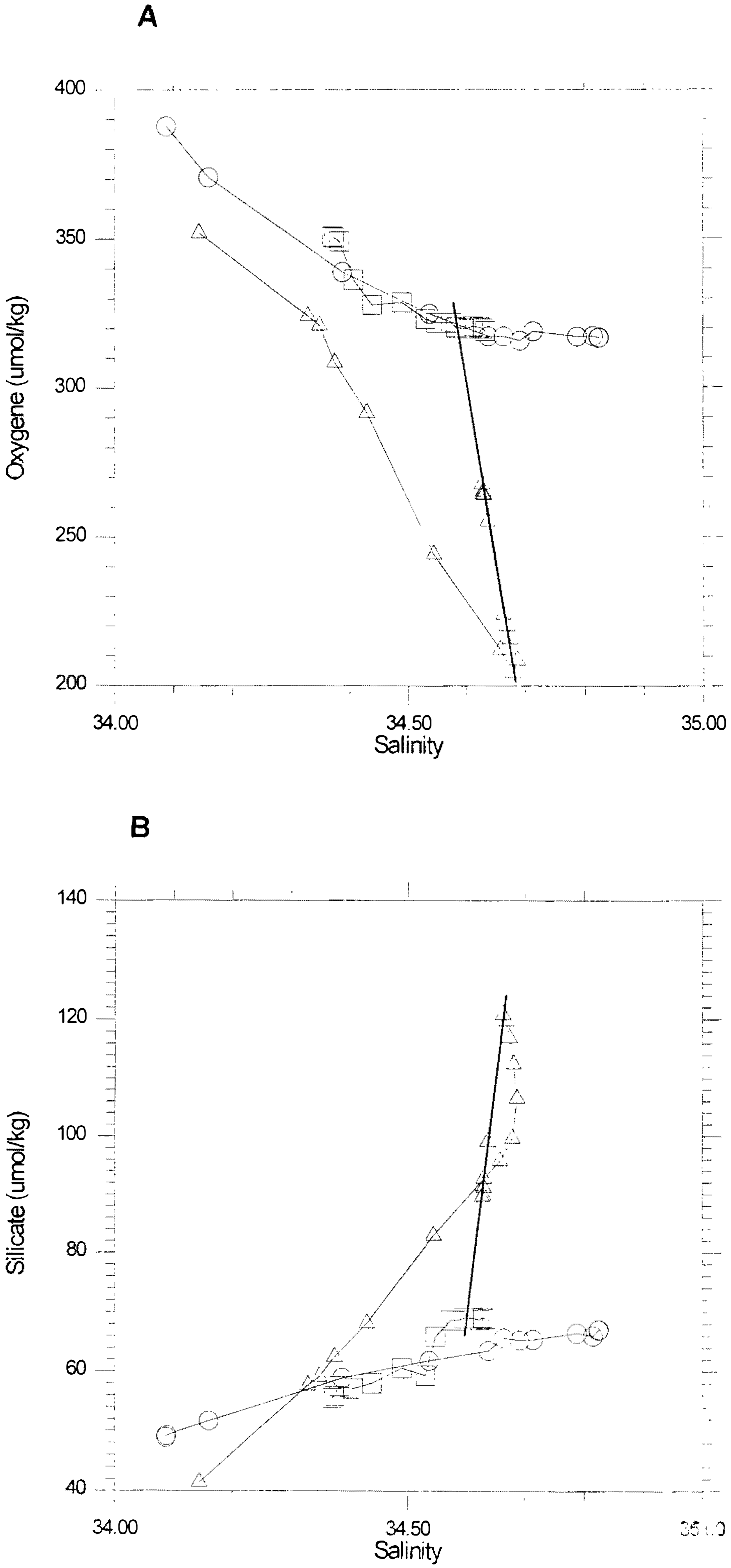


Fig. 2. Oxygen (A) and silicate (B) versus salinity for stations 6 (squares), 34 (triangles), and 50 (dots). The thick lines represent the mixing of Warm Deep Water and Ice Shelf Water during the descent of the plume down the continental slope.

The oxygen and nutrient signature

Examples of the chemical signature of the ISW that mixes in with the WDW is seen in Fig. 2, where oxygen (a) and silicate (b) are plotted versus salinity. The thick line that combines the deepest samples of station 50 is a mixing line between the Warm Deep Water and the down flowing ISW. The point where these lines converge with the data of station 6 gives the oxygen and silicate concentrations of the ISW that flows down the continental slope.

One of the problems encountered when investigating the chemical signature of waters over a shallow shelf is to what degree chemical shifts occur as a result of biological production. The stoiciometric composition of organic matter is known to be 1, 16, 106, and -138 for phosphate, nitrate, carbon and oxygen respectively. Hence, in a property - property plot of two of the above constituents, the data should fall on a line with the expected slope if biological primary production occurs. Looking at phosphate versus oxygen for two stations, no 6 in the Filchner Depression and no 34 in the western part, we see the data fitting two separate lines (Fig. 3). The line for station 6 (top line) has a slope of about -130 while the line for station 34 (bottom line) has a slope of about -90. This indicates that at station 34 the line is a result of mixing. Consequently the surface water at this station is not the source water from which the WSW was formed.

Input of anthropogenic CO_2

A topic of great interest in the global change discussion is the sequestering of anthropogenic CO_2 by the bottom water formed in the Weddell Sea. Anderson et al. (1991) estimated this input by using data from the central Weddell Sea collected during the Swedish Antarctic Expedition in 1988/89 (SWEDARP 88/89). However, that investigation did not contain any information of the WSW. It is therefore interesting to find out if the WSW changes its total carbonate content during the cooling and freshening under the ice shelf. In Fig. 4, total alkalinity and total carbonate (normalized to a salinity of 35 psu to take away dilution effects) have been plotted versus potential temperature. It is clear that both total alkalinity and total carbonate have somewhat higher concentrations in the WDW than in the shelf waters.

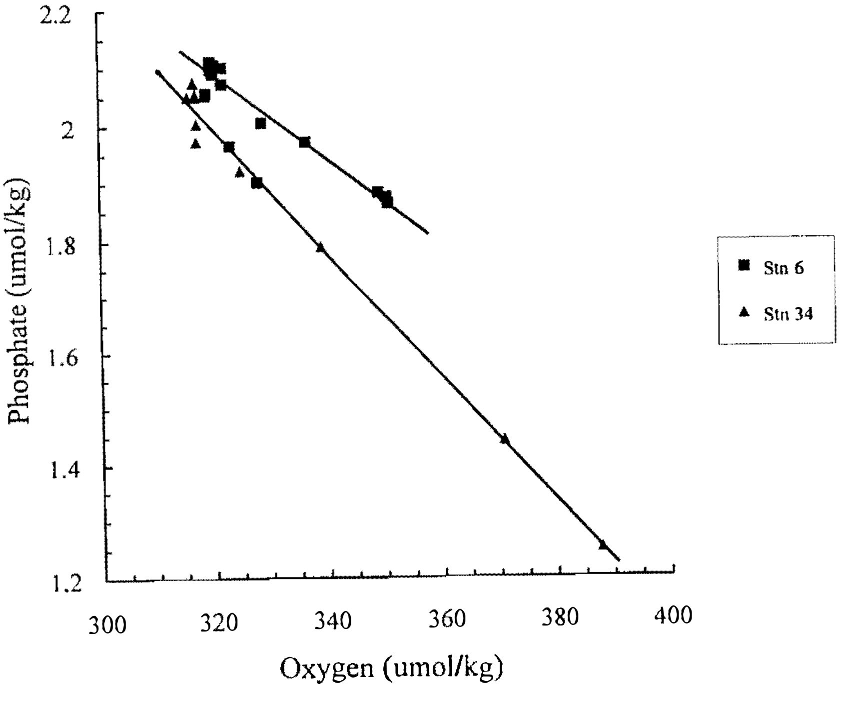
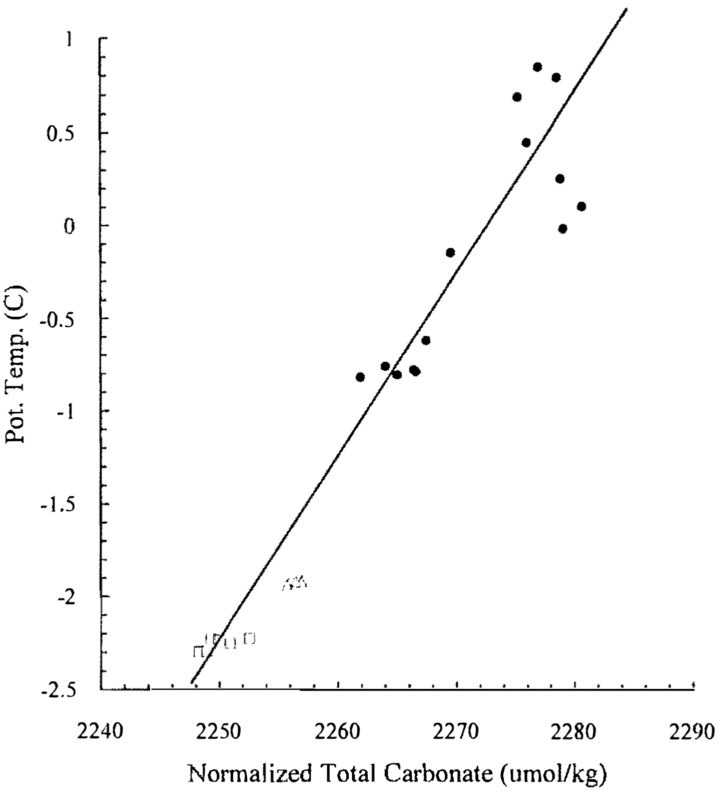


Fig. 3. Phosphate versus oxygen for stations 6 and 34. The slope of the lines are -130 for the top and -90 for the bottom one.



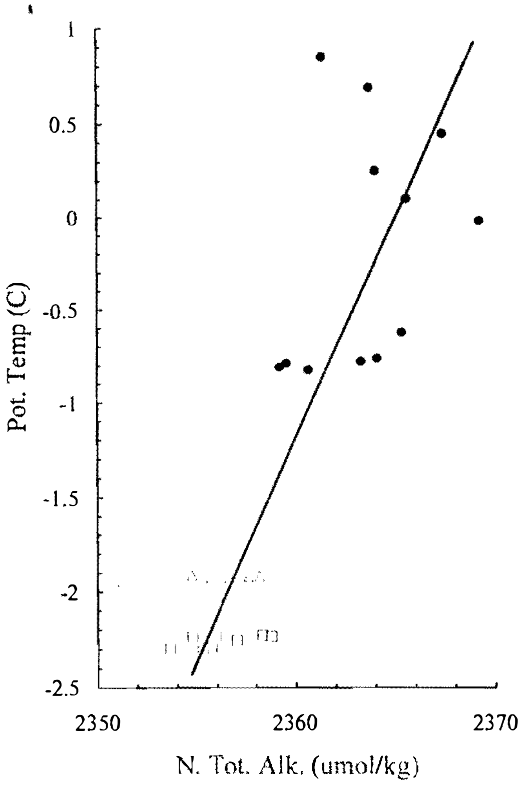


Fig. 4. Potential temperature versus normalized total alkalinity and normalized total carbonate for the ISW at station 6 (squares), the WSW at stations 34 and 35 (triangles) and the waters below 500 m of station 50 (dots). Mixing lines between the ISW and the WDW are indicated.

The total alkalinity content in the WSW (stn 34 & 35) and ISW (stn 6) has the same concentration within a few µmole/kg, eliminating any precipitation or dissolution of metal carbonates during the processes under the ice shelf. Total carbonate on the other hand shows about a 6 µmole/kg higher concentration in the WSW than in the ISW. This could come about as a result of the increasing atmospheric concentration of CO_2, considering the difference in time when the two waters where last in contact with the atmosphere. A total carbonate difference of 6 µmole/kg would be the result if the atmospheric concentration had increased by about 10 ppm, representing about a 6-year period. A comparison with the transient tracers signals (see below) indicates that the difference in time between these two waters are of the right order.

Halocarbons as transient tracers

One of the major interests concerning the chlorofluorocarbon results is the assessment of time scales for water movement under the shelf ice. The advantage using chlorofluorocarbons as transient tracers for this kind of studie is that the source function is fairly well known, i.e. the atmospheric history of the CFCs as well as the equilibration at the sea surface. Thus, the concentrations of CFCs in a water mass indicate the year when the water was last in contact with the atmosphere. A water parcel's mixing with other water masses of low CFC content on its way dilutes the CFCs, but should not change the ratios between the different CFCs. There are various models that can be used, the simplest is called the freight train model, which assumes that no mixing with surrounding water masses occurs during the transport.

This is the first time, to our knowledge, that all four of the chlorofluorocarbons CFC-11, CFC-12, CFC-113 and carbon tetrachloride (CFC-10) have been measured simultaneously in the Weddell Sea. The results presented here are preliminary and may be altered after the final calibrations in Gøteborg, but some of the observations made so far are as follows:

On three occasions we measured the equilibrium between atmosphere and surface water in order to measure the degree of saturation in the water. It has been reported earlier, in other parts of polar seas, that the surface water is undersaturated by about 15-20%, as could be expected in an area which is partly ice-covered. As mentioned above, the equilibrium concentration at the sea surface is supposed to be well known. However, this seems not to be true for carbon tetrachloride, which is, at all times, greatly oversaturated (Table 1). It is our feeling, that these results point to a need for more investigations on the solubility of carbon tetrachloride in seawater under different temperature and salinity conditions.

Table 1. Dimensionless Henry's Law constants ($H = C_{air}/C_{water}$) obtained through simultaneous determination of the halocarbons CFC-11, CFC-12, CFC-113 and CCl_4in surface water and air on three occasions in different parts of the Weddell Sea where there was no ice cover. The calculated values are based on literature data according to a) Warner and Weiss (1985), b) Watson and Fogelqvist (unpublished), c) Hunter-Smith et al. (1983)

Halocarbon	$H_{calc.}$	$H_{meas.}$ (% sat.)	$H_{meas.}$ (% sat.)	$H_{meas.}$ (% sat.)
CFC-11	1.63[a]	1.79 (90.9)	1.74 (93.7)	1.86 (87.6)
CFC-12	6.65[a]	8.59 (77.4)	9.00 (73.9)	7.23 (92.0)
CFC-113	5.23[b]	5.65 (92.6)	5.01 (104.4)	6.11 (85.6)
CCl_4	0.57[c]	0.392 (145.4)	0.372 (153.2)	0.434 (131.5)

The distribution of CFCs in the water column at Station 50 located on the slope of the continental shelf is shown in Fig. 5a. It should be compared with the profiles at Station 36 (Fig. 5b) located in the south-western corner of the Weddell Sea where the ice shelf meets the Antarctic Peninsula, and Station 49 (Fig. 5c) close to the ice edge in the Filchner Depression. First of all, the concentrations of all CFCs in the surface layer are generally lower along the ice edge in the southern part of the Weddell Sea. A possible explanation is mixing with Weddell Deep Water (WDW) from the central part of the Weddell Sea, which contains virtually no CFCs, in combination with upwelling close to the ice edge caused by wind and tidal currents. The mean concentrations of CFC-11 and CFC-12 from 200 m dow to the bottom at 600 m at Station 36 and adjacent stations with Western Shelf Water (WS resemble surface waters of 1978 to 1980. It is difficult to draw any conclusions from the CFC-113 concentration, which is very low, as it first appeared in the atmosphere in the mid seventies, but it supports the picture of an "old" water. Carbon tetrachloride is higher than expected, possibly due to the lack of good solubility data mentioned above. In the Filchner Depression, at Station 49 demonstrated in Fig. 5c, both CFC-11 and CFC-12 are at the 1974-1975 surface concentration level from 1000 m to the bottom, and CFC-113 at the detection limit. Again, the carbon tetrachloride profile does not fit into the same picture. Th age difference between the bottom waters at Stations 36 and 49, about five years, may giv an indication of the time scale of the water transport from the ice edge under the ice shelf and to the deep of the Filchner Depression, which is also the same time span as indicated the difference in total carbonate. A core of Ice Shelf Water (ISW) was observed at station at 100-300 m depth, and the CFC signature of the ISW at Station 33 is almost identical to the bottom water in the Filchner Depression. Thus, the outflowing ISW at Station 33 and th bottom water at Station 49 have about the same residence time under the ice. Coming bac to Station 50 (Fig. 5a), the bottom water shows a clear signal of the ice shelf water flowing down the continental slope. Temperature and salinity data show that this water is mixed to about 50% with Weddell Deep Water, which does not significantly contribute to the CFC content. The CFC data are somewhat scattered, mainly due to two different layers of the bottom water.

Natural production of halocarbons

Marine organisms, macroalgae in coastal areas as well as pelagic algae, produce volatile halogenated compounds. Brominated compounds such as bromoform, dibromomethane and bromochloromethanes have been observed in surface sea-water in various parts of the oceans. It has also been shown that these halocarbons contribute to the atmospheric burden of bromine, which plays a part in the decay of ozone, at least in the lower layers of the troposphere. Iodated compounds, methyliodide, cloroiodomethane and diiodomethane have also been observed in the surface layers of the oceans, as well as in the marine atmosphere. Methyliodide is supposed to be the dominating iodated species, and plays an important role in the global iodine cycle and the transport of iodine from sea to land. The other iodated halocarbons may also contribute significantly. In polar regions, algae living in the ice is an important source of halocarbons. During this cruise, both seawater and ice was investigated for brominated and iodated halocarbon content.

The following observations were made at Station 50 in the central part of the Weddell Sea: Of the iodated halocarbons, methyliodide is not, as was believed, the most abundant in the surface water. Isobutyliodide appears at about twice the concentration of methyliodide. However, both methyliodide and isobutyliodide decrease in the water column and were not detected below the depth of 50 m. Evaporation is one explanation for the very steep gradient in the water column, another possibility is that the compounds are unstable and quickly decay after their production in the surface layer. Although chloroiodomethane had a lower concentration than methyliodide by a factor of about 10, it was detected throughout the water column. The concentration was determined to be about the same in the bottom Ice Shelf Water and the surface layer. Di-iodomethane, which has been measured in the Atlantic Ocean and atmosphere, was not at all detected, neither in the seawater, the air nor in the ice samples.

The brominated halocarbons; bromoform, dibromomethane, bromodichloromethane and dibromochloromethane were all present throughout the water column at Station 50. Bromoform and dibromomethane show similar patterns, higher concentrations, by a factor of 3 to 4 in the upper 200 m than in the underlying water (WDW). The concentrations in the Ice Shelf Water, close to the bottom, are again slightly higher, possible because these compounds are quite stable in water. Bromodichloro-methane and dibromochloromethane on the other hand, show higher concentrations in the intermediate WDW than in the surface layer, about the same as in the ice shelf water. There seems to be production of those compounds at depth, possibly due to degradation products of larger molecules.

The thawed ice algae samples showed the presence of a few compounds at higher concentration levels than in the surface water. Methyliodide was slightly higher in one of the samples, n-propyliodide and n-butyliodide were considerably higher, n-butyliodide was not at all detected in the water but in the ice algae samples. It is an interesting fact that these iodated compounds were detected, for in the literature, only brominated halocarbons have been connected with ice algae. In addition, one as yet unidentified peak appeared in the chromatograms of the ice algae samples.

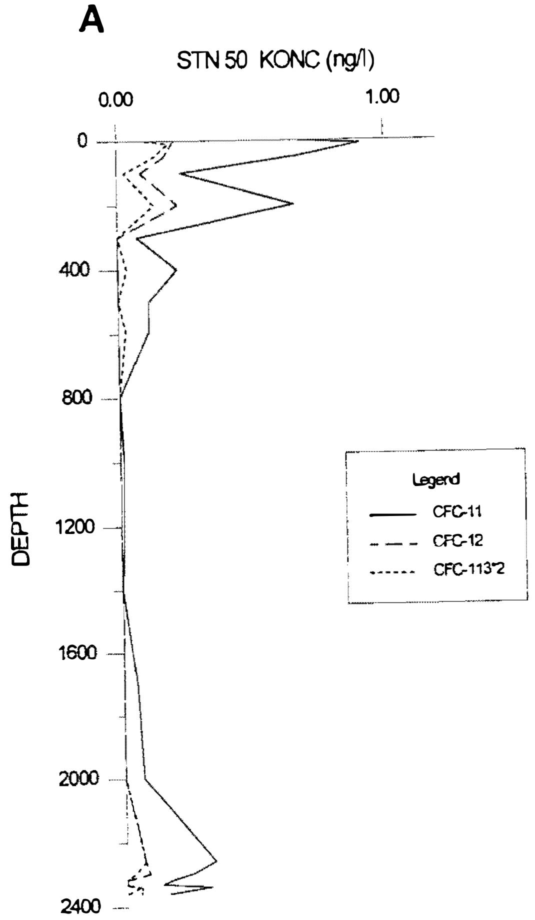


Fig. 5 a. Depth profiles of CFC-11, CFC-12 and CFC-113 at stations 50 (A), 36 (B) and 49 (C).

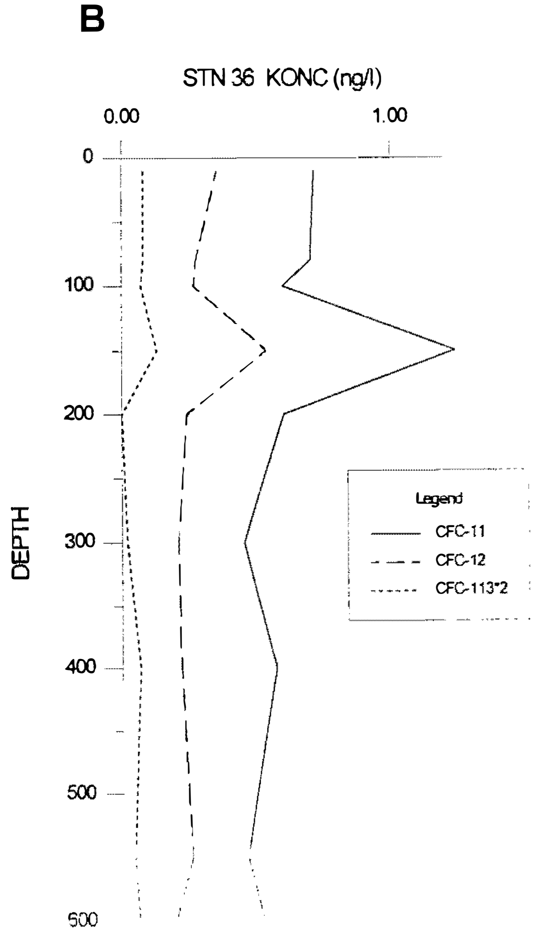


Fig. 5 b. Depth profiles of CFC-11 CFC-12 and CFC113 at stations 50 (A), 36 (B) and 49 (C).

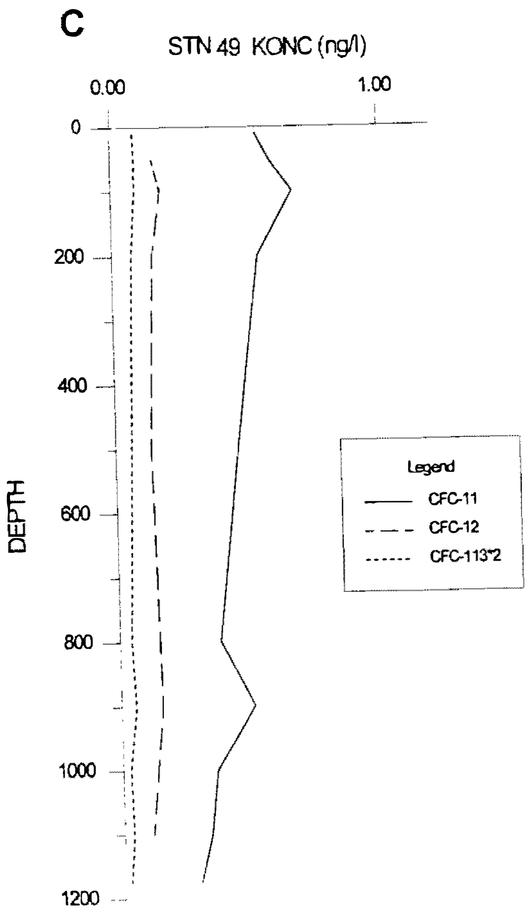


Fig. 5c. Depth profiles of CFC-11, CFC-12 and CFC-113 at stations 50 (A), 36 (B) and 49 (C).

Sediment/water investigation
We have sampled 16 stations located on the shelf and slope of the Weddell Sea. At most stations a full experimental programme was carried out. By conducting the described measurements, we have been able to determine solute sediment/water exchange, nitrification, nutrient regeneration, organic carbon oxidation, calcium carbonate dissolution/ precipitation in the shelf and slope sediments. This combination of measurements has, to our knowledge, never been conducted in this area.

The assumed low benthic activity, in conjunction with the poor availability of fresh organic matter entering the sediment surface was confirmed. This by the generally low total sediment oxygen consumption rates, minimal total carbonate and nutrient release to the overlying water. Indeed, some stations showed a nitrate and phosphate uptake. Further confirmation was provided by deep penetration of oxygen and nitrate into the sediment and almost constant pore water profiles of nutrients and total carbonate. Examples from the sediment/water investigations are illustrated in Figs.6-7.

ACKNOWLEDGEMENTS

This work was supported by a generous grant from the Knut and Alice Wallenberg Foundation. It was also supported by research grants from the Swedish Natural Research Council to Dr. L. Anderson, Dr. E. Fogelqvist and Dr. P. Hall. This work had not been possible without the logistic support of the Swedish Polar Secretariat. Finally, we are very grateful to the Norwegian organizers of this cruise, led by Dr. Olav Orheim; the cooperation with the Norwegian oceanographers, under the leadership of Dr. Tor Gammelsrød; and the never-ending cooperation of Captain Jan H. Olsen and his crew on board the M/S Lance.

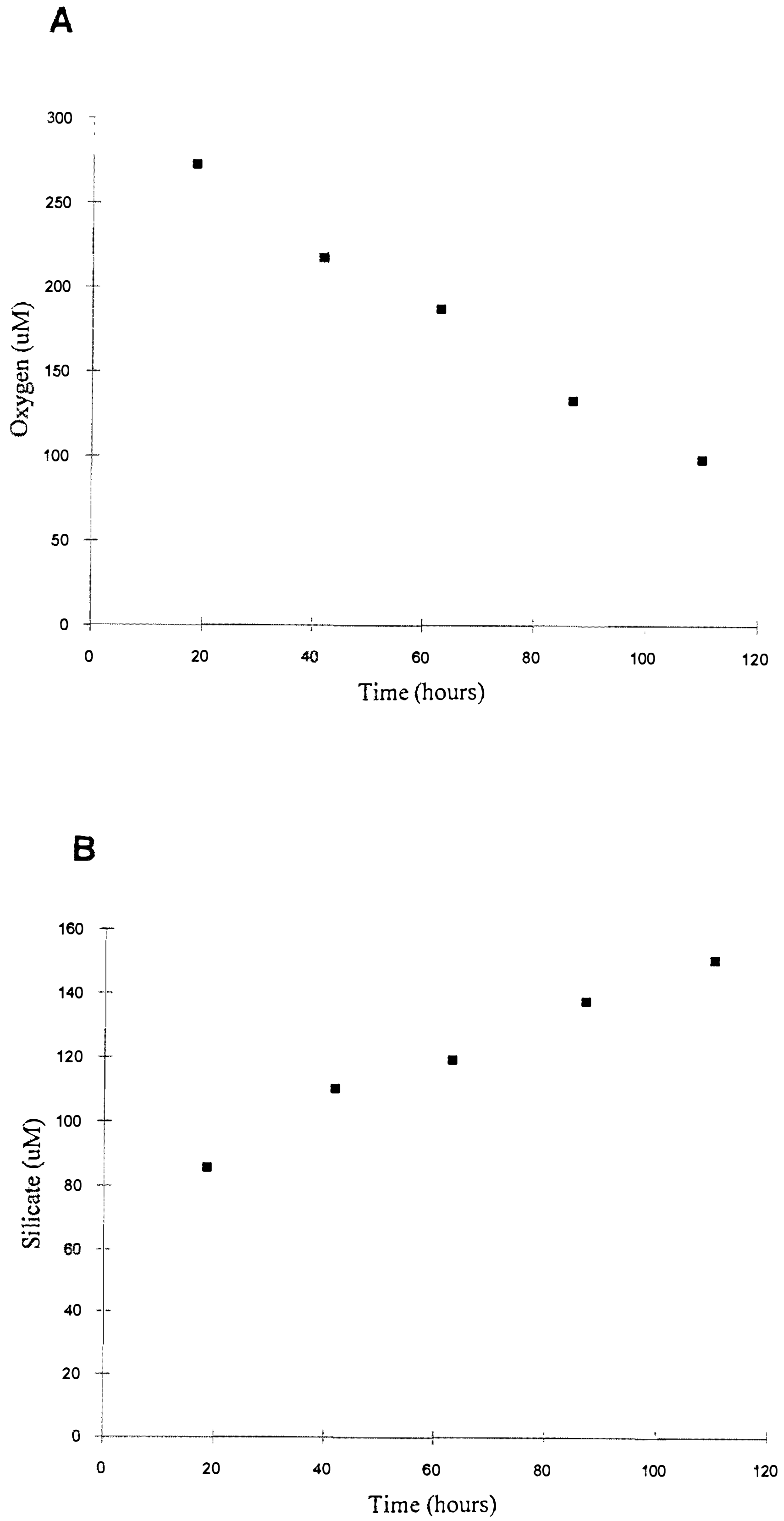


Fig. 6. Evolution of oxygen (A) and silicate (B) in the overlying water as a function of time during thesediment/water exchange incubations at station 6. Corrections have been made for dilution.

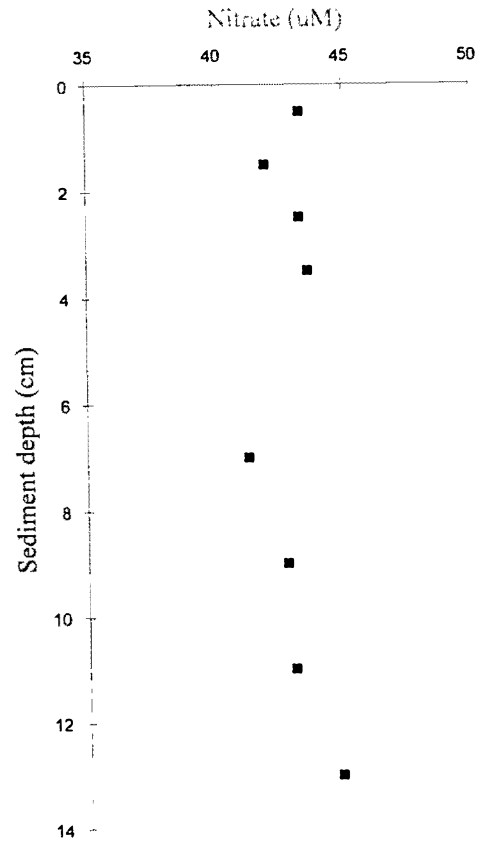


Fig. 7. Pore water distribution of nitrate at station 34

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SEA ICE PROJECTS DURING NARE 1992/93

ICE PRODUCTION AND CONVECTION - BACKGROUND

The large scale circulation in the Weddell Sea conveys about 2.5 mill square km of ice out of the area per year. This outflow is about 2.5 times the annual area ice inflow to the Greenland Sea through the Fram Strait from the Arctic Ocean. The giant Weddell Sea gyre covers an area of 5.8 mill square km. In comparison, the area of the Greenland Sea gyre is an order of magnitude less, about 0.2-0.3 mill square km. Both gyres, which perform a cyclonic circulation, cover the two main production areas of bottom water in the world. The ice circulation in the Weddell Sea is mainly determined by the wind stress field. The annual mean drift in the central area is directed northwards with an average speed of about 0.07 m/s (Vinje 1980). The current speed along the barrier, where we will measure ice production rates, assumes values around 0.02-0.04 m/s (Vinje 1979).

The brine rejection process that occurs when sea water freezes will influence the density of the water masses under the ice. An upward compensating movement of warmer water may take place when the saltier, heavier mixture sinks downward. If the newly frozen ice is carried away by wind or currents, the convective processes may support the maintenance of an open water area or a polynya. The formation of polynyas is often observed on the leeward side of islands or along the coast where the advection of older ice is hindered (e.g., Martin & Cavalieri 1989 and Vinje & Kvambekk 1992).

Typically, one may observe an ice formation of 20 cm in polynyas per day during cold spells in the Barents Sea. This would amount to an accumulation of 6 m of ice during one month in a polynya where the new frozen ice continuously is carried away. Martin & Cavalieri (1989) calculated, for example, an annual ice growth of 10-17 m in the polynyas near Franz Josef Land for the freezing seasons of 1978-1982. The far reaching effect of the formation and transport of new ice from polynyas is clearly illustrated by IR satellite images where we may see long stretches of thinner ice extending down-wind from the polynyas (Vinje & Kvambekk 1992).

The ice production rate is strongly dependent upon the temperature and the speed of the air that passes over the polynya. One of the largest temperature contrasts between water and air may be observed in the coastal polynyas along the barrier of the Filchner Ice Shelf where the cold air from the Antarctic continent is drained onto the Weddell Sea. An ice formation rate of 45 cm during one night has been observed as early as the end of February in this area (Capt. Woodfield, pers. com.). We should therefore expect some of the world largest ice production rates to be observed in the inner part of the Weddell Sea.

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The six-hourly tidal divergence and convergence will affect the whole ice filled with alternating increased ice production in unveiled water between the ice floes, and subsequent small scale ridging of the newly formed thin ice. This pulsating effect may result in a levelled rim of ice, accumulated along the perimeter of the ice floes, a feature that is frequently observed in the Barents Sea during the freezing season. The ice formation due to tides, though relatively small per unit area, will affect a far larger area than a polynya, and may thus in total represent a notable influence on the convective regime under the ice due to the pulsating intensity of the brine rejection process. In addition to the ice formation in unveiled open water areas, we also have a persistent accretion of ice at the bottom of the ice floes due to conductively transferred heat loss to the ice floe surface. This large scale freezing process will cause a more or less persistent brine rejection process in the ice fields, though at a far smaller rate per unit area than in polynyas.

Today it is possible to measure the ice formation by using upward looking sonars (ULS) attached to the top of moorings in combination with ice field dynamics determined by cross-correlation techniques applied on consecutive satellite radar images.

The first ULS for use on anchord moorings was developed at Chr. Michelsens Institute, (CMI), Bergen in 1985. However, the first year-long series was not obtained until 1987-88, and today we have recorded altogether three full series from the Greenland Sea and Fram Strait. The recordings show that the ULS is a reliable instrument that provides very detailed series on the ice thickness distribution and consequently also on ice concentration (Vinje 1989; Kvambekk and Vinje 1992).

OBJECTIVES

The objectives of this study in the southern Weddell Sea are:

1. to monitor ice production rates and calculate salt rejection rates, using upward looking sonars and remote sensing techniques, and

2. to monitor the basic surface parameters necessary for the development of an ice-production model.

METHODS

Three ULS moorings were deployed north of the Ronne Ice Shelf on 4 February 1993 in a triangle, about 9 km apart. The following table shows the positions, depths, and time of deployment.

#	Depth	Lat (S)	Lon (W)	Time (GMT)	ULS depth
1	255 m	77°02.444	48°52.78	15:37	150 m
2	255 m	77°01.993	48°54.13	16:42	150 m
3	255 m	77°00.783	48°52.07	17:12	150 m

(A map of the area is shown in O.Orheim: General report of the Expedition, this issue)

The instruments are constructed specially to avoid attachment to passing icebergs with a greater draft than the ULS operating depth of 150 m. The aperture of the sonar beam is 2 degrees and the footprint on the underside of the ice will accordingly have a diameter of about 5 m. The strength of the return signal will be monitored as well and this will give information on whether the reflected sonar signals are coming from thin ice or from open water. Otherwise the series will be calibrated with reference to passing of open water areas (Kvambekk & Vinje 1992). To secure correct sound speed estimates, the temperature is also recorded in the ULS. The effect of the salinity on the speed of sound will be calculated from the CTD-measurements in the area.

The basis parameters for the calculation of the ice production rates are the

1. ice drift pattern
2. ice concentration
3. wind speed and direction
4. air and water surface temperatures, and
5. long- and short-wave net radiation components.

The ice drift pattern and the ice concentration will be estimated using cross-correlation techniques on consecutive radar images. These data will also provide information on the divergence in the ice field.

The geostrophic wind speed, direction and temperature will be measured with the aid of three automatic stations providing the air pressure gradient. Deployment of these is described elsewhere in this report.

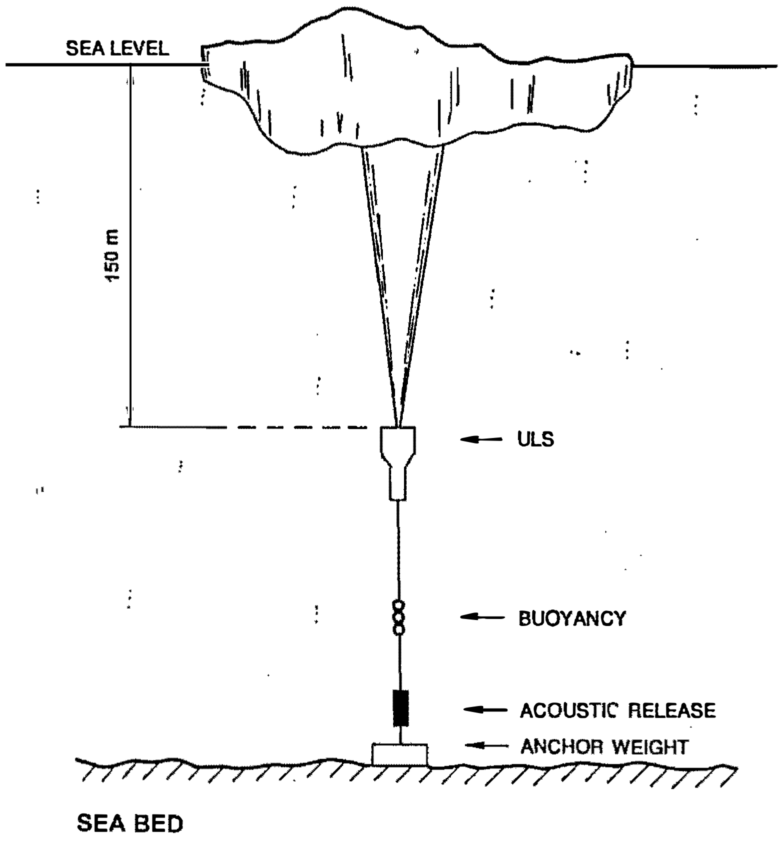

Fig. 1. Sketch of an ULS mooring.

SATELLITE PICTURES AND SEA ICE MAPS

TP Satellite pictures were received daily in the areas around Dronning Maud Land and in the Weddell Sea. The pictures were combined with ice maps from the US Navy - NOAA Joint Ice Center and the Canadian Microwave Group. This combination proved very useful. The maps from Microwave Group were both high resolution and very accurate and were particularly useful for our navigation northwards from the southern Weddell Sea through the ice and into the open sea.

VIDEO RECORDING OF SEA ICE

A video camera was mounted vertically in a metal box under the helicopter with remote controls in the cockpit. Due to low clouds and poor visibility during the cruise, this setup was only tried twice. The second try was made in clear weather at an altitude of 10,000'. The cold temperatures which decrease with increasing height, were critical for the battery capacity. A solution to the battery capacity problem would be to use a converter from the helicopter to a 9.6 V power supply for the video camera. All together we collected 30 minutes of raw film.

Position, altitude, speed and direction were noted every fifth minute.

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SHALLOW SEISMIC INVESTIGATIONS AND SEDIMENT SAMPLING IN THE WEDDDELL SEA AND DRONNING MAUD LAND

SUMMARY

Two important aspects of the Antarctic marine environment are to be studied in the marine geological program:

1. The sedimentary and seismic stratigraphy associated with ice streams, and
2. The paleocirculation of "ice shelf water".

Two main study areas were chosen for the investigations. The first, north of Trolltunga, an offshore extension of the Jutulstraumen ice stream, and secondly the northern part of the Crary Trough and the associated trough mouth fan. The latter area probably represents the seaward extension of an ice stream during periods with a more extensive glacial coverage. It is also the present location of "ice shelf water" spillover into the Weddell Sea basin.

A total of 25 hours of sleeve gun profiles and precision depth recorder (PDR) recordings were obtained outside Trolltunga. One box core, one gravity core (6.13 m) and one Selcore (12.3 m) samples were retreived from a location selected after inspection of the seismic records.

In the area of main interest, NW part of the Crary Trough mouth fan, time contstraints, caused by delays earlier in the cruise, only allowed samples to be taken at three stations and two and a half days of seismic profiling.

In addition to the target areas, 3$^1/_3$ days of seismic profiles and 30 sea floor samples were obtained to the east of Trolltunga, and in front of the Ronne Ice shelf and the adjacent continental shelf.

Cores split on board contained silty clays and silty sandy clays and sporadic ice rafted detritus (IRD). Biotstratigraphy indicates a sedimentation rate around 20 to 25 m /mill years. A more detailed stratigraphy and chronology are however needed to substantiate these estimates.

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TABLE 1.

Area	Line	start	stop	Time	Total
		date time	date time	hr:min	days hr:min
Trolltunga	AN93-01	14.01.93 14:55	14.01.93 23:43	08:48	01 08:38
	AN93-2	14.01.93 23:44	15.01.93 03:29	03:45	
	AN93-3	15.01.93 03:30	15.01.93 10:04	06:34	
	AN93-4	15.01.93 10:05	15.01.93 14:36	04:31	
	AN93-5	15.01.93 23:55	16.01.93 04:52	04:57	
	AN93-6	16.01.93 04:53	16.01.93 08:56	04:03	
Waiting	AN93-7	22.01.93 11:40	22.01.93 15:55	04:15	00 06:03
	AN93-8	22.01.93 16:00	22.01.93 16:54	00:54	
	AN93-9	22.01.93 16:57	22.01.93 17:51	00:54	
Ronne Ice Shelf	AN93-10	04.02.93 22:31	05.02.93 05:44	07:13	03 08:18
	AN93-12	06.02.93 03:12	06.02.93 14:29	11:17	
	AN93-13	06.02.93 16:01	06.02.93 18:46	02:45	
	AN93-14	07.02.93 01:40	07.02.93 03:40	02:00	
	AN93-15	07.02.93 05:10	07.02.93 09:00	03:50	
	AN93-16	07.02.93 18:33	08.02.93 00:01	05:28	
	AN93-17	08.02.93 01:27	08.02.93 03:56	02:29	
	AN93-18	08.02.93 05:13	08.02.93 08:27	03:14	
	AN93-19	08.02.93 08:27	08.02.93 11:22	02:55	
	AN93-20	08.02.93 12:40	08.02.93 12:47	00:07	
	AN93-21	08.02.93 13:14	08.02.93 18:33	05:19	
	AN93-22	08.02.93 21:38	08.02.93 23:30	01:52	
	AN93-23	09.02.93 02:44	09.02.93 07:23	04:39	
	AN93-24	10.02.93 08:56	10.02.93 15:17	06:21	
	AN93-25	10.02.93 18:37	10.02.93 21:55	03:18	
	AN93-26	11.02.93 21:15	11.02.93 23:46	02:31	
	AN93-27	12.02.93 02:12	12.02.93 06:23	04:11	
	AN93-28	12.02.93 07:57	12.02.93 12:43	04:46	
	AN93-29	12.02.93 13:44	12.02.93 19:47	06:03	
Crary Trough Mouth fan	AN93-30	18.02.93 13:44	19.02.93 00:05	10:21	01 11:22
	AN93-31	19.02.93 04:02	19.02.93 09:03	05:01	
	AN93-32	19.02.93 18:30	20.02.93 00:07	05:37	
	AN93-33	20.02.93 09:43	20.02.93 12:21	02:38	
	AN93-34	21.02.93 01:49	21.02.93 03:22	01:33	
	AN93-35	21.02.93 04:56	21.02.93 08:06	03:10	
	AN93-36	22.02.93 11:23	22.02.93 18:25	07:02	
Total					06 10:21

OBJECTIVES

Ice streams are "rivers" of ice which have a flow rate which is one or two orders of magnitude greater than the surrounding ice masses (e.g. Bentley, 1987). The high flow rate entails that ice streams are vital in controlling both the mass balance of the Antarctic ice sheets and the sediment and water transport (pore water trapped in the sediment) from the ice sheet and onto the surrounding sea floor. Overdeepened troughs with a fan like sedimetary wedge at the seaward end (trough mouth fans, Vorren et al. 1989) are characteristic of high latitude continental shelves and have been interpreted as being due to erosion/deposition by ice streams during periods with more extensive glaciations than at present.

Through seismic profiling and sea floor samples the aim is to establish the depositional history of the Crary Trough mouth fan and to relate these results to those found outside Trolltunga. Trolltunga is the seaward, floating extension of the Jutulstraumen ice stream, one of the biggest, presently active ice streams in the Antarctic. Thus, the results from the location of a previous ice stream will be compared to the results of investigations in front of a known ice stream.

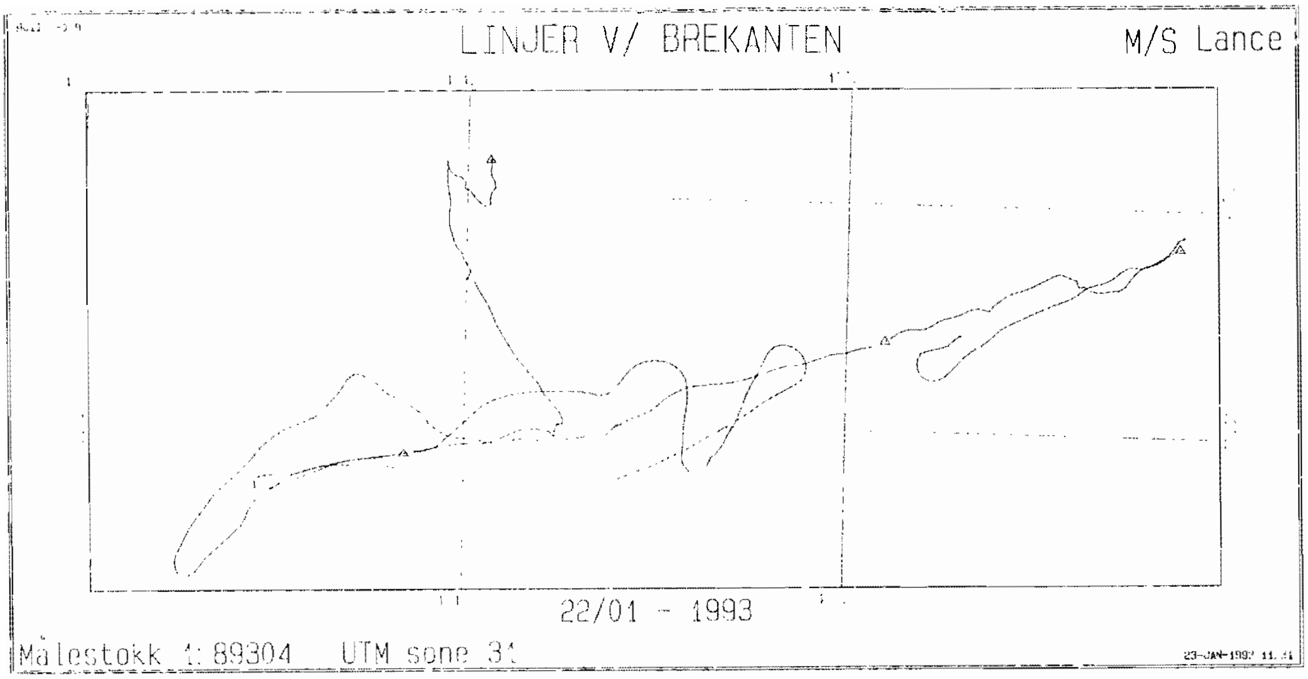
The oceanic circulation underneath the Filchner and Ronne ice shelves is at present responsible for the generation of "Ice Shelf Water" (Foldvik et al. 1985) which is an important mechanism for renewing the deep water in the southern oceans. When glaciers are grounded during more extensive glaciations, the present mechanism of "Ice Shelf Water" generation is probably significantly reduced. The $d^{18}O$ values of "Ice Shelf Water" are characteristically light due to the inclusion of melted glacier ice. Benthic organisms, such as foraminifera, living in the presence of the these water masses will inherit these low $d^{18}O$ values. The aim is therefore to compare the glacial and climatic history of the Crary trough and trough mouth fan to the history of the formation of bottom water. This will be achieved through the stratigraphic examination of seismic sections and core material.

SEISMIC PROFILES

Seismic profiles were obtained using four 40 cu. in. sleeve guns as an energy source and a streamer with an active section of 7.5 m length containing 50 hydrophones. Amplification and filtering of the signal was through an ORE Geopulse receiver (5210A). A PC running the "Dracula" programme, controlled trigger timing and performed analog to digital conversion and digital recording. Anolog data were recorded on audio tape with a Tandberg instrumentation recorder (series 115) and on paper using an EPC 4800S printer.

Figs. 1 and 2 show the track charts of the seismic profiles in the Trolltunga area and in the Weddell Sea respectively. The pre-cruise plans were for a total of about 12 days of seismic profiling in two areas, north of Trolltunga and the NW Crary Trough; this ship time included two days during logistic operations at the Troll summer station which would otherwise have been unused.

The profiles north of Trolltunga are about as planned, but do not go as far south as hoped due to unfavourable sea ice conditions during acquisition. A total of 32 hr and 38 min of seismic profiling was undertaken in this area (Table 1).



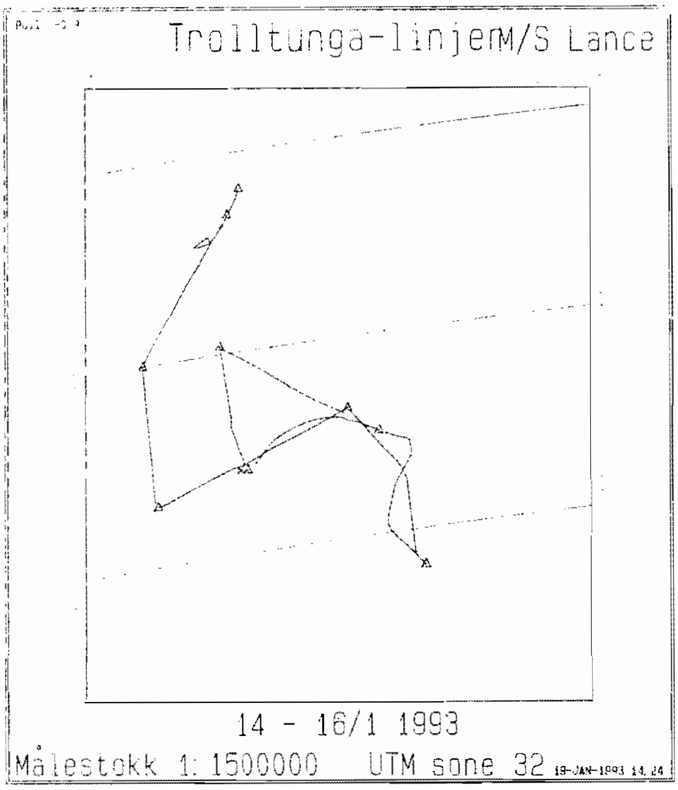


Fig. 1. Seismic profiles in the Trolltunga area:
A. North of Trolltunga (left)).
B. East of Trolltunga (above).

TABLE 2

Station	Position		Type
AN93-1	E 4° 7.600'	S 69° 50.800'	GC
AN93-2	E 4° 14.600'	S 69° 50.700'	SC
AN93-3	E 4° 12.500'	S 69° 51.800'	GC
AN93-4	E 4° 11.000'	S 69° 51.800'	GC
AN93-5	E 4° 11.100'	S 69° 51.890'	SC
AN93-6	W 1° 2.988'	S 69° 13.380'	GC,SC
AN93-7	W 38° 0.792'	S 77° 47.586'	BC,MC
AN93-8	W 43° 27.000'	S 78° 6.816'	BC,GC
AN93-9	W 44° 17.802'	S 77° 49.998'	BC
AN93-10	W 51° 34.902'	S 76° 35.502'	BC
AN93-11	W 52° 32.100'	S 76° 26.700'	BC
AN93-12	W 54° 35.580'	S 75° 58.902'	BC,GC
AN93-13	W 54° 5.598'	S 75° 47.598'	BC
AN93-14	W 50° 36.156'	S 76° 16.260'	BC
AN93-15	W 48° 42.834'	S 76° 5.088'	BC
AN93-16	W 47° 50.802'	S 75° 58.032'	BC
AN93-17	W 46° 18.258'	S 75° 55.734'	BC
AN93-18	W 44° 36.282'	S 75° 50.190'	BC
AN93-19	W 44° 14.394'	S 75° 27.912'	BC,(GC)
AN93-20	W 42° 42.774'	S 75° 49.698'	BC
AN93-21	W 44° 16.050'	S 76° 14.736'	BC
AN93-22	W 45° 33.096'	S 76° 27.228'	BC,(MC)
AN93-23	W 46° 43.116'	S 76° 50.334'	BC
AN93-24	W 47° 58.320'	S 76° 24.192'	BC
AN93-25	W 58° 41.850'	S 75° 12.276'	GC
AN93-26	W 61° 21.432'	S 74° 40.944'	BC,SC,(GC)
AN93-27	W 60° 41.328'	S 74° 24.786'	BC
AN93-28	W 60° 6.684'	S 74° 52.998'	BC
AN93-29	W 50° 47.064'	S 76° 42.618'	BC
AN93-30	W 39° 28.536'	S 78° 11.268'	BC
AN93-31	W 31° 19.998'	S 74° 16.002'	BC,MC
AN93-32	W 35° 39.930'	S 73° 53.574'	GC,SC
AN93-33	W 35° 28.530'	S 73° 56.166'	GC
AN93-34	W 35° 26.094'	S 73° 50.802'	GC, (SC)
AN93-35	W 26° 35.050'	S 74° 32.100'	BC

GC = Gravity core | MC = Multicore | Brackets indicate no recovery
SC = Selcore | BC = Box core

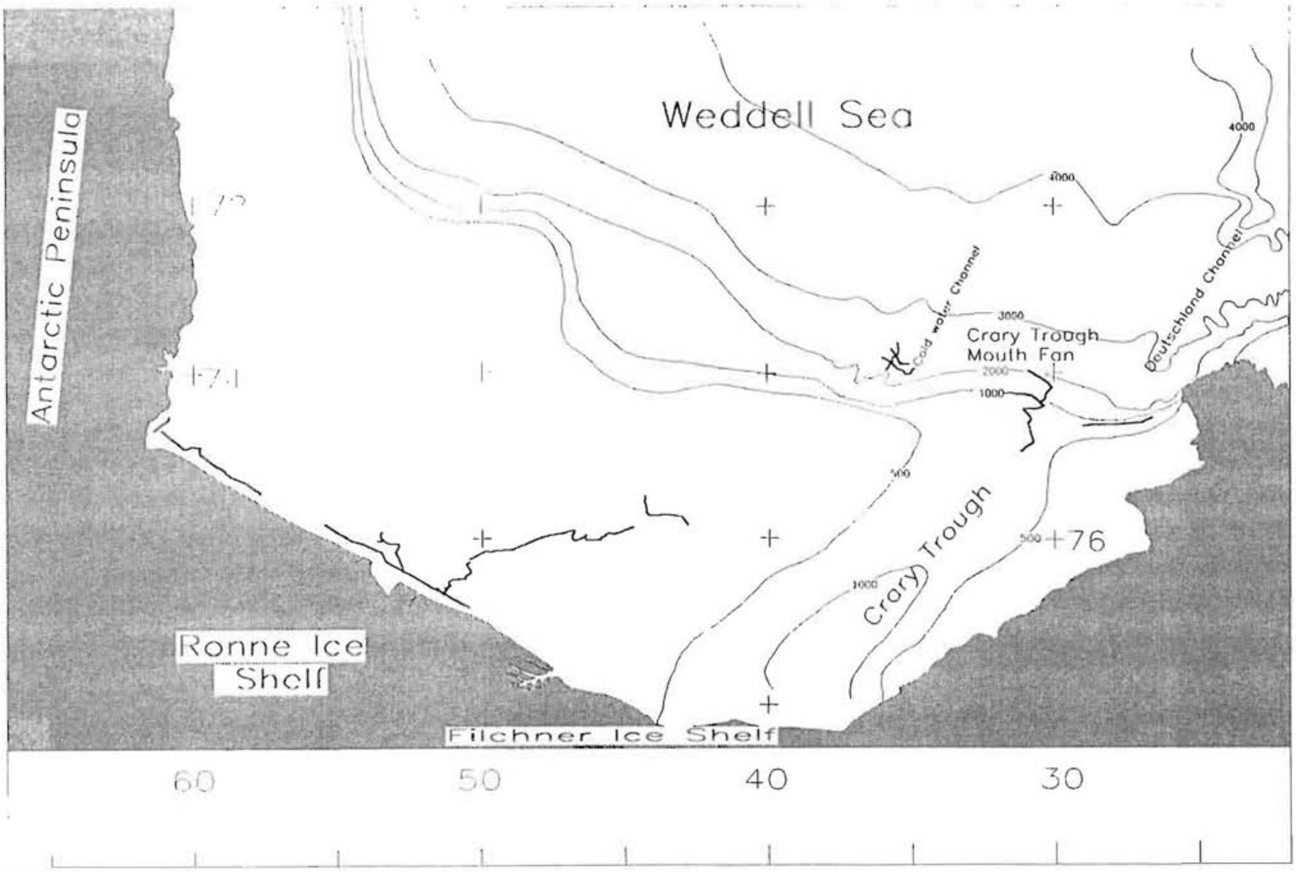


Fig. 2. Seismic profiles on the Weddell Sea continental shelf.

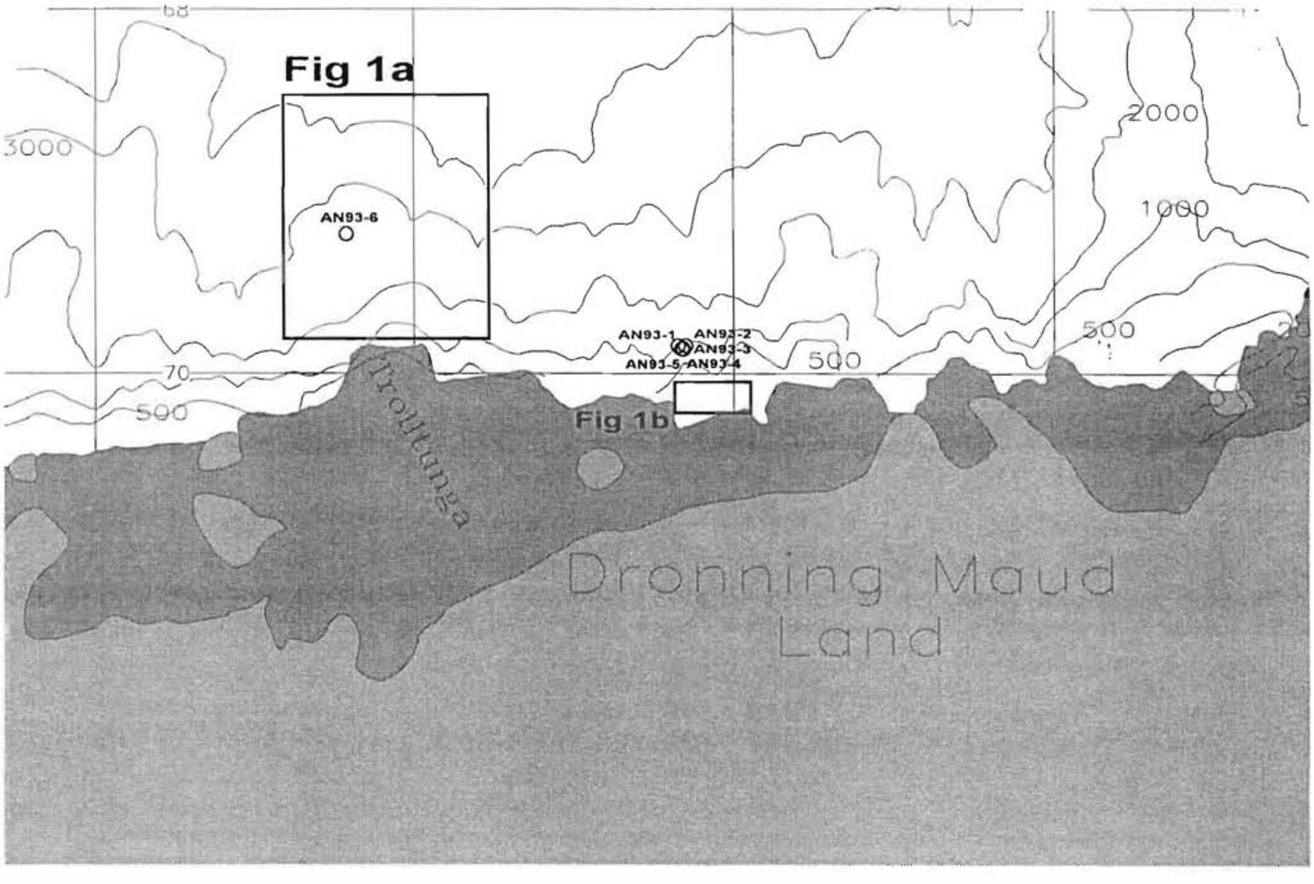


Fig. 3. Sample locations in the Trolltunga areas. The location of figures 1A and 1B are shown.

Adverse weather conditions had delayed logistical operations in connection with the land party to such an extent that when these had finished the remainder of the cruise was a race against time. This entailed that the ship was confined to the region near the Ronne Ice Shelf as long as the land party was on shore. This region was however an important area for the oceanographic investigations and an area from which shallow seismic lines are very scarce or non-existant. A total of 80 hrs and 18 min of seismics was collected from this region.

By the time the NW Crary Trough was investigated only a maximum of three or four days were available for the studies in the area, including both oceanographic and geological work. Ice conditions were partly unfavourable. 35 hrs and 22 min of seismic lines were collected. The main emphasis was placed on the ridge and trough (Figure 2, "Cold Water Channel", Kuvaas & Kristoffersen 1991) where the Ice Shelf Water flows down the continental slope.

SEA FLOOR SAMPLES

Three methods were used to obtain sea floor samples: 1. Box corer; 2. Gravity corer; 3. Selcorer.

The box core retreived sea floor samples of about 40 x 40 x 40 cm. The gravity corer was fitted with a 9 m core barrel and samples of up to 6.5 m length were retrieved. The Selcorer is a percussion coring device which uses the difference in pressure between the surface and the hydrostatic pressure at the sea floor to increase penetration by "hammering" the core barrel. The longest core retreived was 12.7m long. The device has two operating modes, one with a minimum operating depth of 700 m and the other with a minimum depth of 400 m. While the lower limit of 400 m implies that large areas of the continental shelf are too shallow for this device, it is well suited for coring in the main target areas where water depths range from about 1000m to 3000 m. The greater the water depth the greater the number of strokes taken by the corer - typically about 100 during a period of about three min. During cold spells, colder than minus 5 to minus 10°C, the mechanism in the corer was easily frozen, preventing proper functioning.

A total of 34 stations were sampled (Table 2), distributed in the same areas as discussed in the previous section (Figs 3 and 4). The box cores provide a good sample coverage in the central Weddell Sea continental shelf (Berkener shelf). The box cores were sub-sampled to obtain surface scrapes, which were preserved in alcohol, and cored using plastic liners. Gravity cores and Selcores were primarily taken in the main areas of interest.

PRELIMINARY RESULTS

Six cores were split, described and analysed on board. The following sections describe these results.

Core descriptions

Fig. 5 summarises the core descriptions. The sediments consisted mostly of silty clays and silty sandy clays with sporadic sand partings and ice rafted detritus (IRD) and is similar to the material found in cores by previous workers (e.g. Andersen et al. 1986; Elverhøi & Roaldset 1983). Of special interest are the clay platelets found in core AN93-32/GC(1), which may be pieces of clay glacially reworked from older deposits on the continental shelf. Further analyses on shore will be able to resolve this.

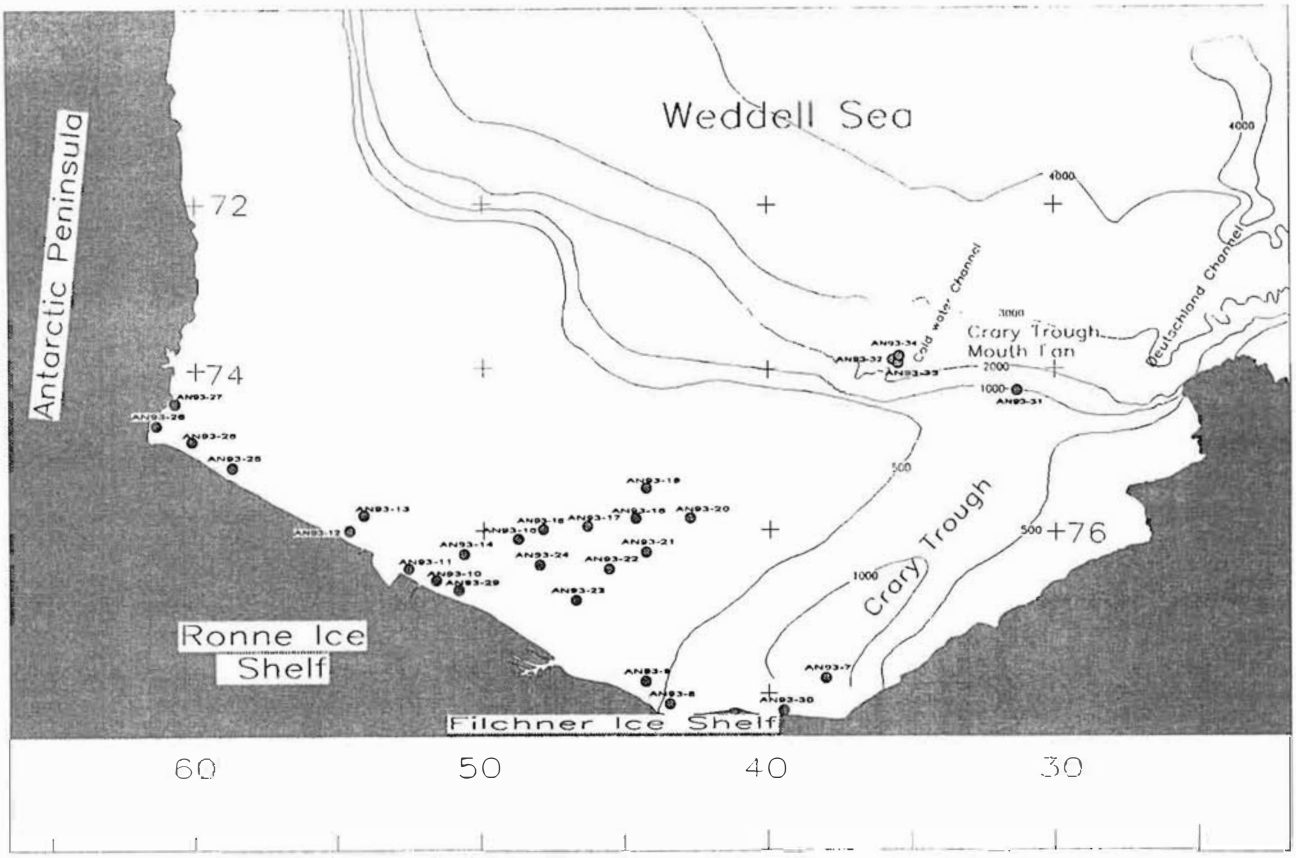


Fig. 4. Sample locations on the Weddell Sea continental shelf.

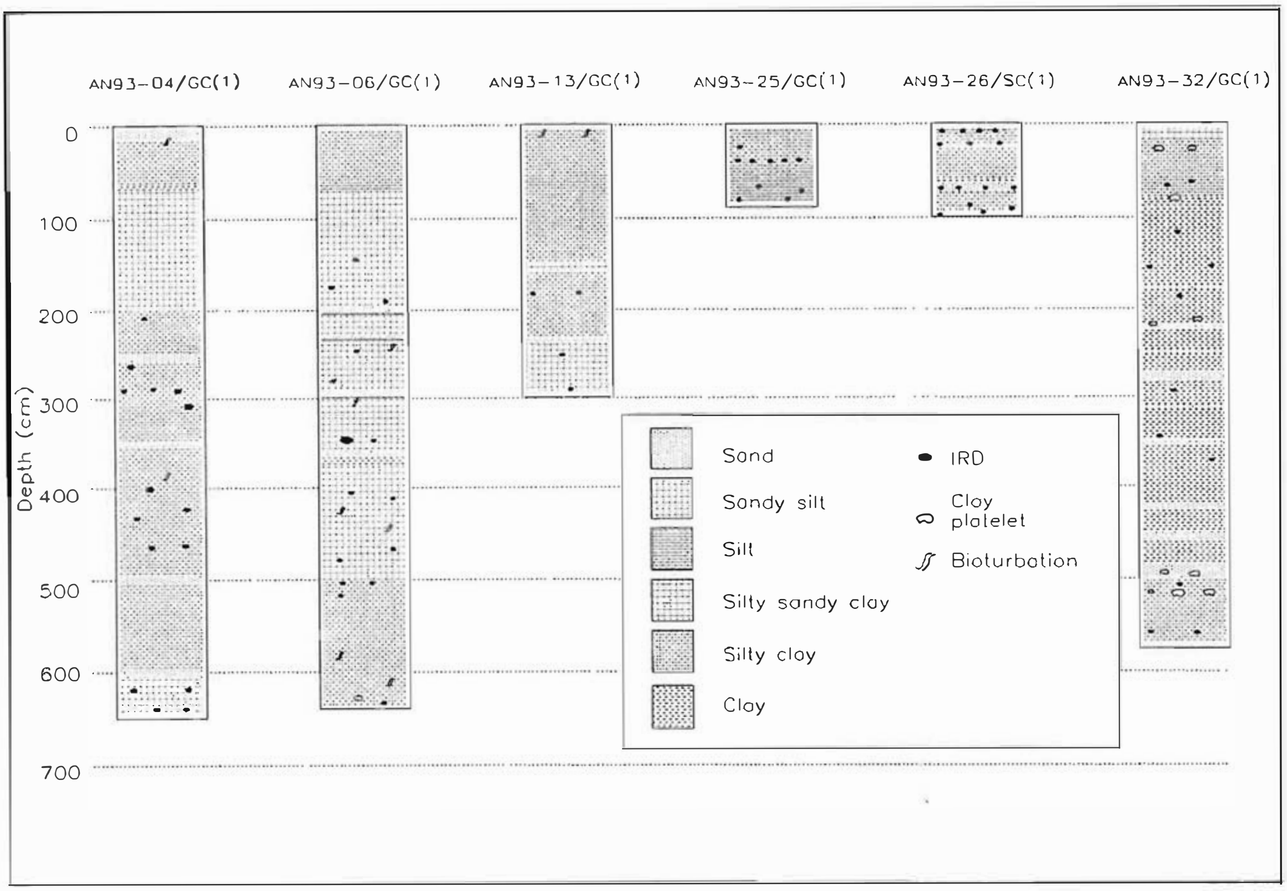


Fig. 5. Summary of core descriptions

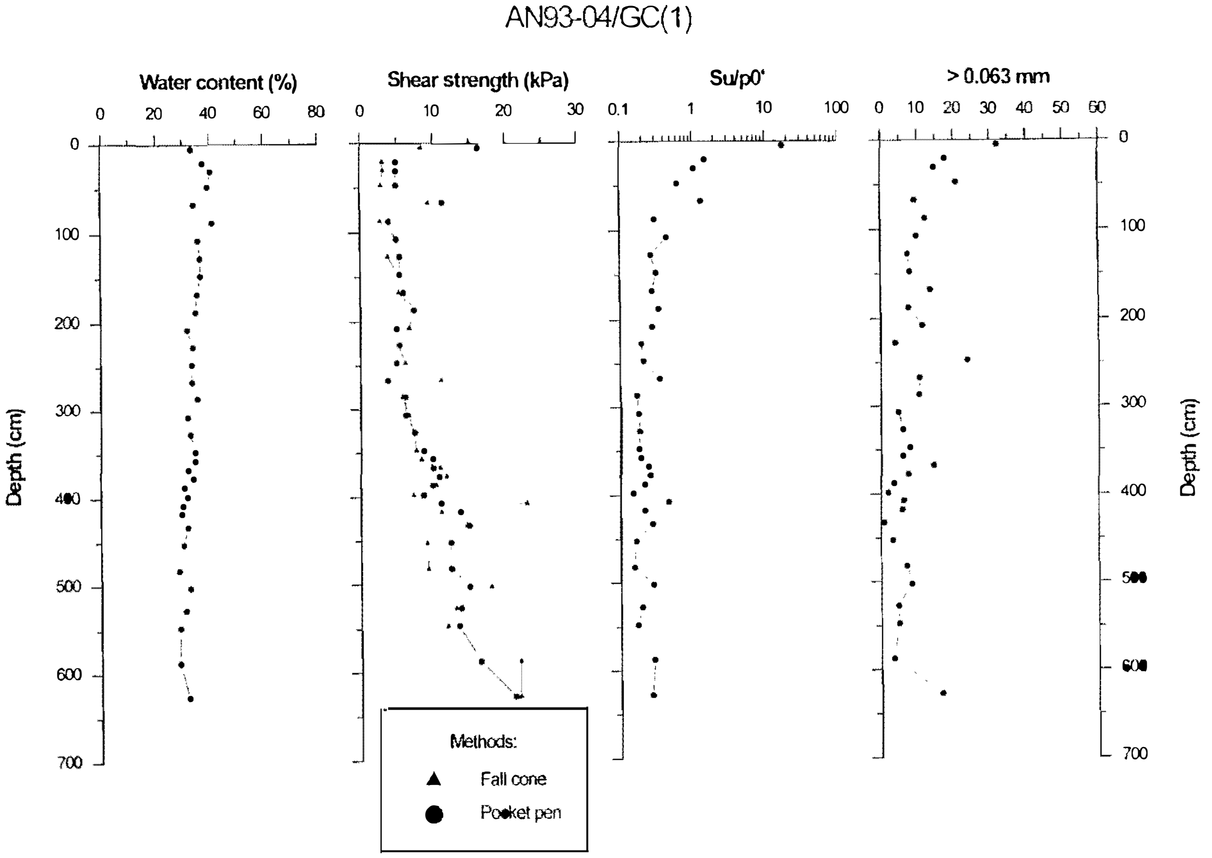


Fig. 6. Water content, shear strength su/po' and percent >63mm for core AN93-04/GC(1).

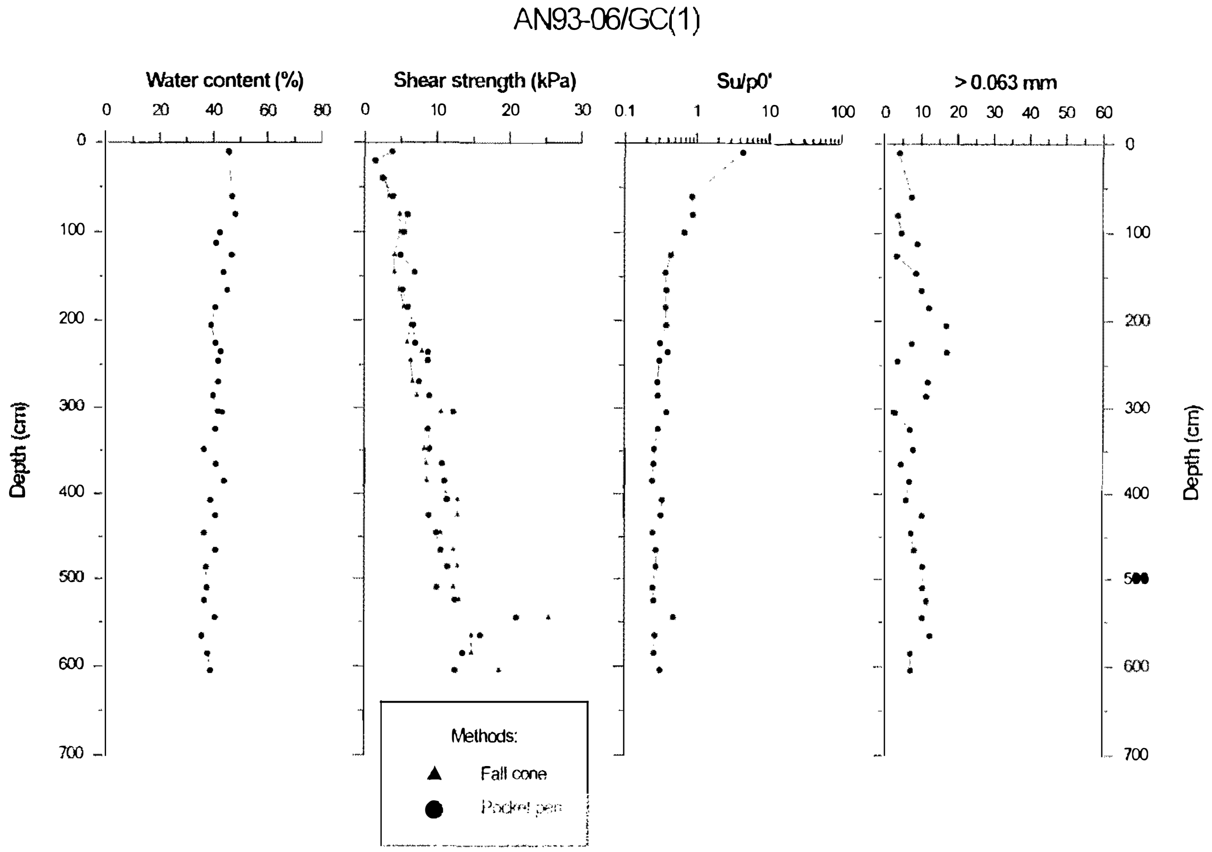


Fig 7. Water content, shear strength su/po' and percent > 63mm for core AN93-06/GC(1).

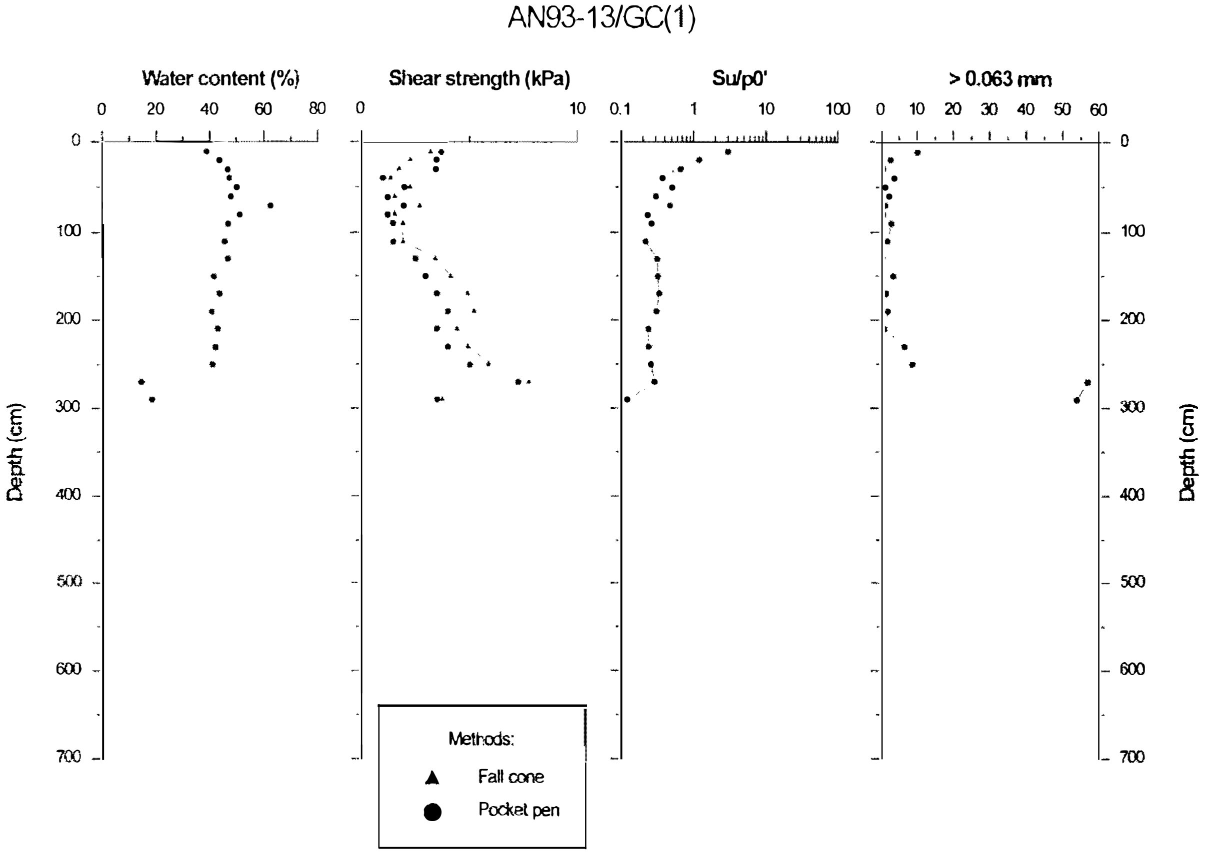


Fig. 8. Water content, shear strength su/po' and percent >63mm for core AN93-13/GC(1)

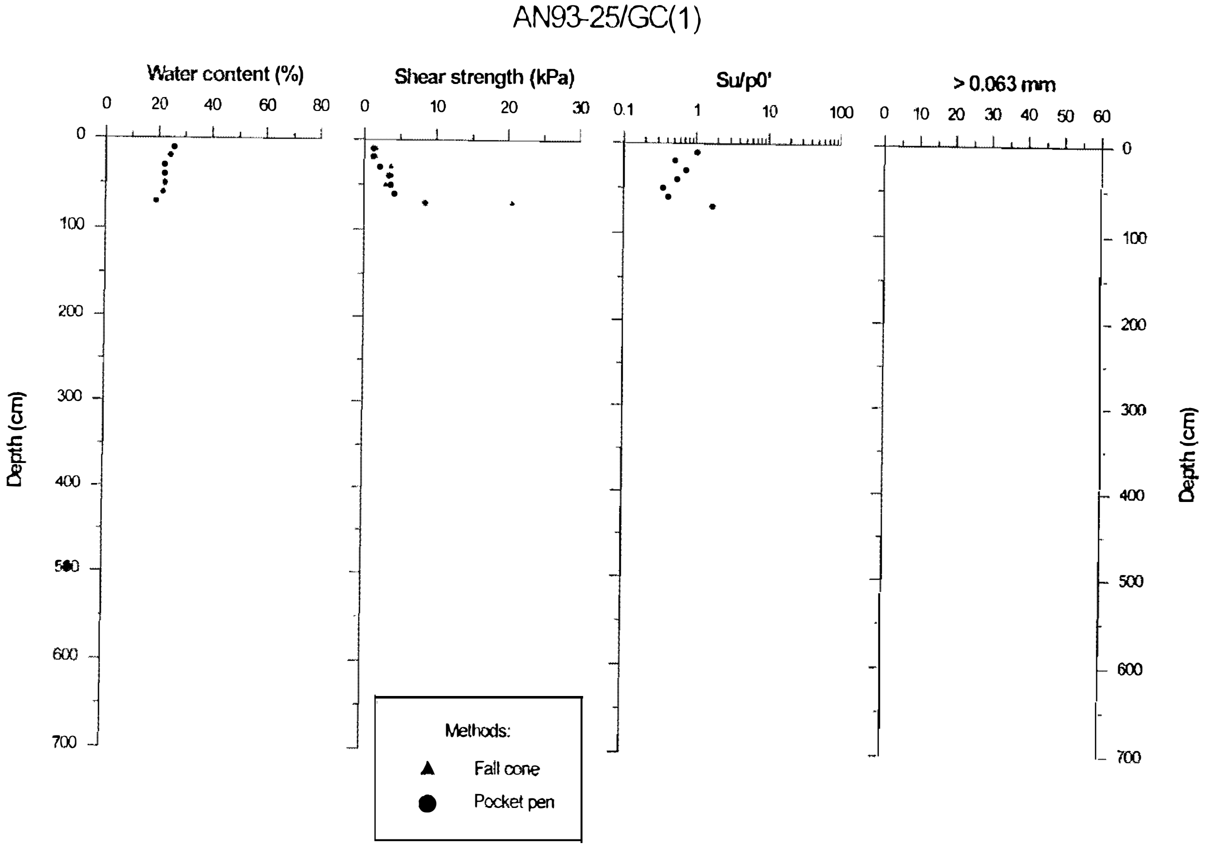


Fig. 9. Water content, shear strength su/po' and percent >63mm for core AN93-25/GC(1)

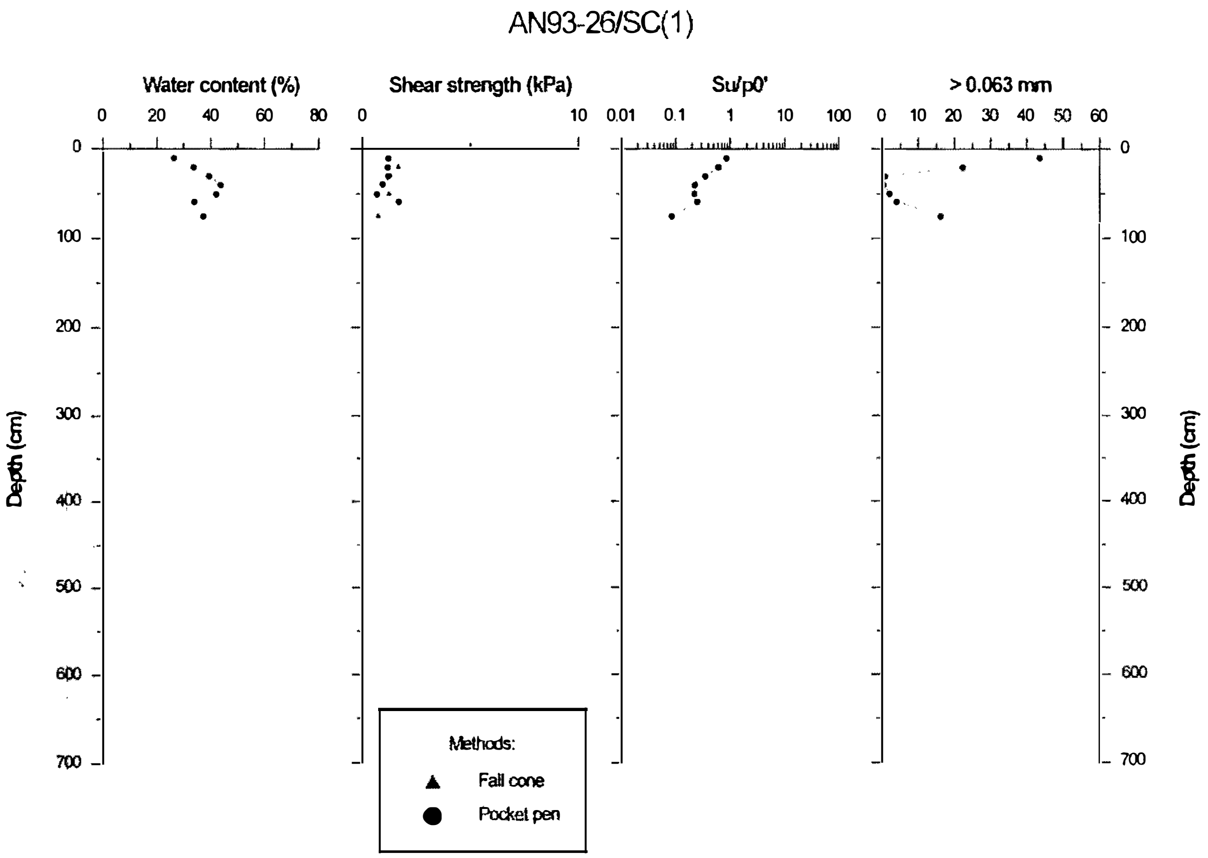


Fig. 10. Water content, shear strength su/po' and percent > 63mm for core AN93-26/SC(1).

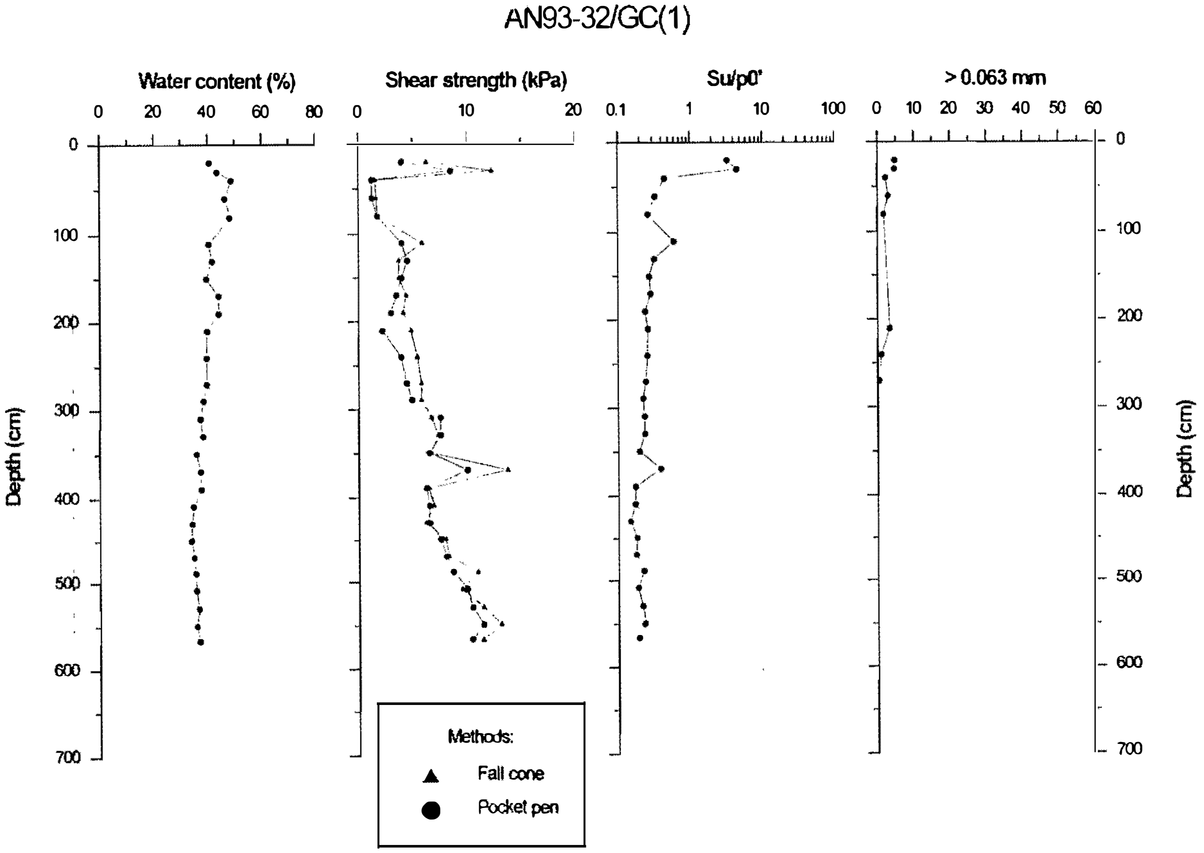


Fig. 11. Water content, shear strength su/po' and percent > 63mm for core AN93-32/GC(1).

A greenish layer, about 1/2 cm thick, was seen in many of the box cores and was also evident in core AN93-13/GC(1). This layer may be an event horizon which can be used to correlate between cores, or it may be due to diagenetic effects. Further work on shore will illucidate this.

Physical Properties

Shear strength and water content were measured on all the opened cores. The percentage of grains greater than 63 mm was found gravimetrically. Figs. 6 to 12 summarise the results.

Water contents range between about 20% and 60%. The variability is most likely due to changes in grain size of the sediment and due to dewatering during burial.

The shear strengths show a steady increase with depth. For normally consolidated sediments the shear strength divided by the effective overburden pressure (su/p_0') is about 0.25. The effective overburden pressure was estimated from the water content assuming that the solids have a density of 2.7 g/cm^3. While the samples in general seem to be normally consolidated, they are overconsolidated near the top, as is normal for marine sediments,due to the effect of interparticle attraction being greater than that due to gravitational compaction. Core AN93-25/GC(1) has stiffer sediments near the bottom, whereas cores AN93-26/SC(1) and AN93-13/GC(1) have disturbed sediments near the base. The cores show no evidence of major erosional episodes which would appear as jumps in the shear strength and su/p_0' curves.

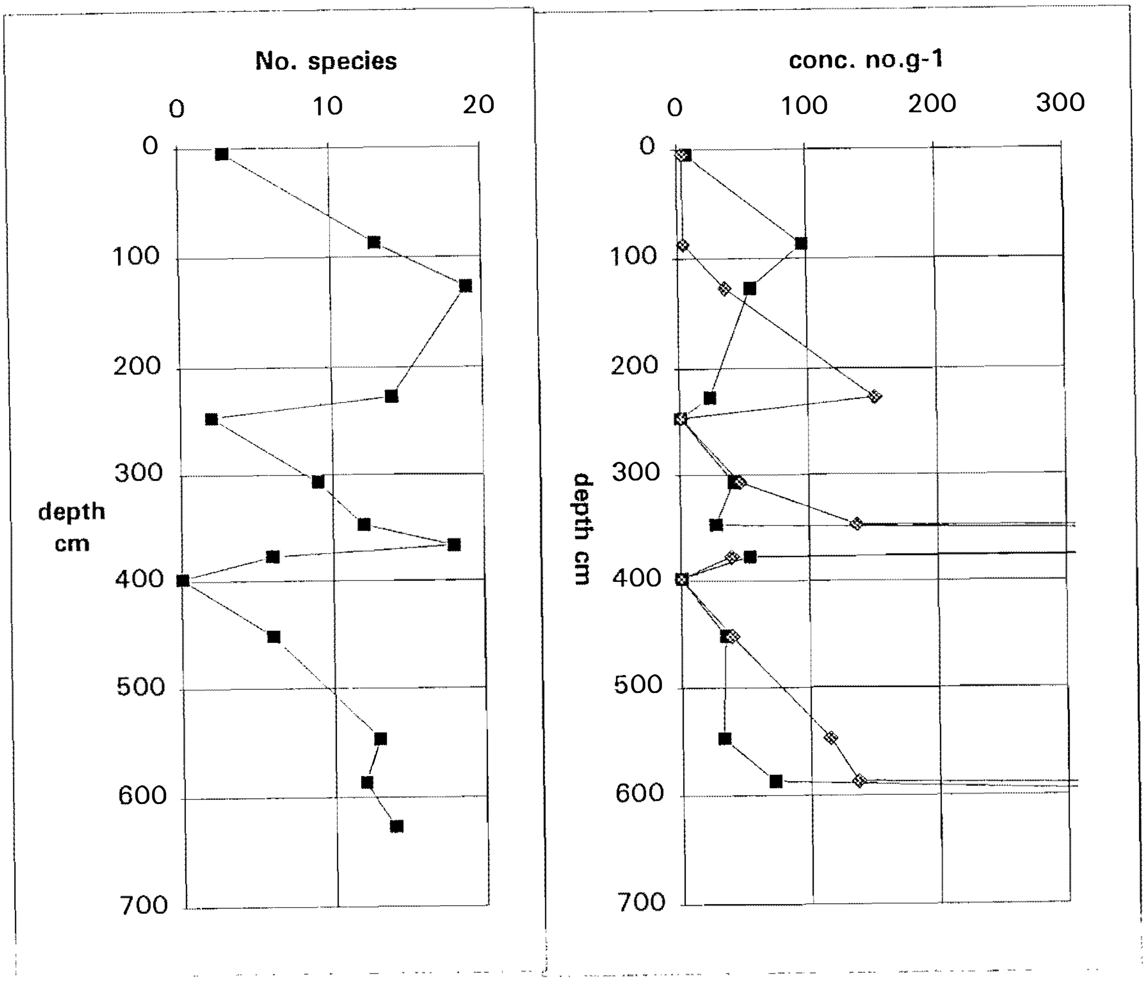


Fig 12. Summary foraminiferal diagram core AN93-04/GC(1).

Biostratigraphy

Micropalaeontological examinations of box core samples, split core sections and catcher samples were undertaken aboard ship. These can be subdivided into two groups:

1. washed residue samples of >63 μm.
2. smear slide preparations using Canada Balsam

Both types of samples were extracted, normally at 20cm intervals, from the split core sections.

Preliminary descriptions of the smear slides, including the relative proportions of diatoms, radiolaria and silicious spicules, are provided in Tables 3-8. The latter also include a subjective comment on the dominant grain form/shape. Generally, the tops of all the cores examined contain the richest faunas and floras, with core AN 93-04, GC1 exhibiting the most continuous record. However, the short cores AN 93-26 and 93-25, located near the extreme western margin of the Ronne Ice Shelf, contain very sparse faunas and floras; these are in marked contrast to the cores obtained from further north and east.

The washed residue samples have also been examined qualitatively and vary from totally barren samples to very diverse and abundant calcareous foraminiferal faunas. While over 100 different species slides have been prepared for the benthic foraminifera, the planktic component consists almost exclusively of sinistrally coiled *Neogloboqua-drina pachyderma.* Dextrally coiled specimens of the latter are far less frequent but do attain values of nearly 1% within core AN 93-04, GC1. Non-calcareous (agglutinated) foraminifera are also recognized and appear to dominate the benthic faunas at certain locations and/or core depths. Subsequent, post-cruise work will allow the distribution of calcareous and non-calcareous faunas to be mapped; in this respect, the samples adjacent to the Ronne Ice Shelf provide an important new data source.

Quantitative foraminiferal work was limited, during the time available, to core AN 93-04, GC1 and the preliminary results are illustrated in Fig.12. The concentration data, calculated as the number of specimens per gram of dry sediment, vary considerably through the core. Two levels, at 367-368cm and 627-628cm, exhibit very high (>6000 specimens.g^{-1}) specimen concentrations of both planktic and benthic foraminifera. Together with the high species diversities at these levels, they are tentatively assigned to interglacial periods; these are Stage 5 at ca.3.6m and Stage 7 at ca.6.3m. However, it should be noted, in view of this interpretation of the faunal assemblages, that the upper part of the core does not contain a diverse carbonate fauna. The latter is some-what problematic and the most likely explanation is that the surface may be disturbed; a nearby box core (AN 93-02) preserves an extremely divese calcareous fauna at 4-5 cm depth. The most common benthic species from this core are *Epistominella exigua*, *Trifarina angulosa*, *Cassidulina subglobosa*, *Fursenkoina earlandi* and *Nonionella* sp.

In conclusion, this core should provide suitable carbonate material for stable isotope and amino acid geochronology work on both planktic and benthic foraminifera. In view of the length (12.3 m) of the parallel Selcore (AN 93-04, SC1) and the presence of a very diverse calcareous fauna in its catcher, it seems probable that a further two interglacials may be present. Finally, subjective work on AN 93-06, GC1 indicates a far more continuous calcareous fauna is present and that the potential to understand the dynamics of the Trolltunga ice floe is good.

TABLE 3

AN 93-04, GC1				
core depth (cm)	Diatoms	Radiolaria	Silicious spicules	other comments
5	A	A	C	sub-rounded qtz.
10	A	A	C	sub-rounded qtz.
20	C/A	A	C	sub-rounded qtz.
30	A	C/A	C	sub-rounded qtz.
47	C/A	C	C	sub-rounded/sub-angular qtz.
66	C	R/C	C	sub-angular qtz.
87	C	R/C	C	angular/sub-angular qtz.
107	C	R	C	angular/sub-angular qtz.
127	C	R	C	angular/sub-angular qtz.
147	R/C	R	R/C	angular, fine grained
167	-	R	R	sub-rounded qtz.
187	R	R	R	angular/sub-angular qtz.
207	-	-	R	angular/sub-rounded qtz., poorly sorted
227	R*	-	R	angular/sub-rounded qtz., poorly sorted
247	-	-	R*	angular/sub-angular qtz.
267	R*	-	R*	angular/sub-angular
286	R*	-	R*	angular/sub-angular
307	-	-	-	angular/sub-angular
327	-	R*	R	angular/sub-angular
347	R	R	R/C	sub-angular
357	R*	R*	C	angular/sub-angular
367	R/C	-	C	angular/sub-angular
377	R*	R*	C	angular/sub-angular
387	-	-	R	sub-angular
397	R	-	R	sub-rounded/sub-angular
407	R*	-	R	sub-angular
417	R*	R*	R/C	angular/sub-angular
427	-	-	-	sub-angular/sub-rounded
452	R*	R*	R	sub-angular
482	R*	R*	R	sub-angular
502	-	R*	R	sub-angular/sub-rounded
527	R*	R*	R	sub-angular/sub-rounded
547	R	R*	R*	angular/sub-angular
587	R*	R*	R	sub-angular
627	R/C	R/C	C	angular

TABLE 4

AN 93-06, GC1				
core depth (cm)	**Diatoms**	**Radiolaria**	**Silicious spicules**	**other comments**
10	C/A	C	C*	sub-rounded
60	R*	-	R*	sub-angular/sub-rounded, foram. rich
100	C/A*	C	C*	angular/sub-angular
112	C/A*	C	C*	sub-angular
125	R*	R*	R/C*	angular/sub-rounded
145	R	R*	R*	angular/sub-rounded, foram. rich
165	R	R*	R*	angular/sub-rounded, foram. rich
185	-	-	R*	angular/sub-rounded, foram. rich
205	-	R*	R	angular/sub-rounded, foram. rich
225	R*	R*	R*	sub-angular
235	R*	R*	R*	sub-angular/sub-rounded, foram. rich
245	R*	R*	R*	sub-angular, foram. rich
269	R*	R*	R*	angular, foram. rich
285	R*	R*	R*	angular
306	R/C	C	R/C	sub-rounded
325	-	-	R*	sub-angular
348	-	R*	R/C*	sub-rounded/sub-angular
366	-	R*	R*	sub-angular
385	-	R*	-	sub-angular
405	-	-	R*	sub-angular/sub-rounded, foram. rich
425	-	-	R*	sub-angular/sub-rounded, foram. rich
445	-	-	R*	sub-rounded/rounded, foram. rich
465	-	R	R*	sub-angular/sub-rounded, foram. rich
485	-	-	-	rounded/sub-angular
510	-	-	-	rounded/sub-angular
525	-	-	-	rounded/sub-angular, foram. rich
545	-	-	-	sub-angular
565	-	-	R*	sub-angular, foram. rich
585	-	-	-	sub-angular/sub-rounded, foram. rich
604	-	-	-	angular, foram. rich

TABLE 5

AN 93-13, GC1				
core depth (cm)	Diatoms	Radiolaria	Silicious spicules	other comments
10	R/C	R/C	C	sub-angular/sub-rounded
20	R/C	R/C	C	sub-angular/sub-rounded
30	R	R/C*	R/C*	sub-angular/sub-rounded
40	R	R/C*	R*	sub-rounded
50	-	R*	-	sub-rounded
60	-	R*	R*	sub-rounded/sub-angular
70	-	R*	-	sub-rounded/sub-angular
80	-	R/C*	R*	angular/sub-angular
90	R*	R/C*	-	angular/sub-angular
110	R*	R/C*	R*	sub-angular/sub-rounded
130	R*	R/C*	R*	sub-angular/sub-rounded
150	-	R*	R*	sub-angular
170	R*	R/C*	-	sub-rounded/angular
190	-	R*	-	sub-rounded
205	-	-	R*	sub-rounded/angular
225	-	-	-	sub-angular
245	-	R*	-	sub-angular/sub-rounded
265	-	-	-	sub-rounded, v. poorly sorted
285	-	-	-	sub-rounded/sub-angular, v. poorly sorted

TABLE 6

AN 93-25, GC1				
core depth (cm)	Diatoms	Radiolaria	Silicious spicules	other comments
8	-	-	R	angular/rounded qtz., poorly sorted
19	-	-	-	angular/rounded qtz., poorly sorted
30	-	-	-	angular/rounded qtz., poorly sorted
40	-	-	-	angular/sub-rounded qtz.
50	-	-	-	sub-angular/sub-rounded qtz.
60	-	-	-	sub-angular/sub-rounded qtz.
70	-	-	-	sub-angular/sub-rounded qtz.

TABLE 7

AN 93-26, SC1				
core depth (cm)	Diatoms	Radiolaria	Silicious spicules	other comments
10	-	R	R/C	sub-angular qtz.
19	R	-	R	sub-rounded qtz
30	-	-	-	v. fine grained
40	-	-	-	v. fine grained
50	-	-	-	fine grained
59	-	-	-	fine grained
75	-	-	-	poorly sorted

TABLE 8

AN 93-32, GC1				
core depth (cm)	Diatoms	Radiolaria	Silicious spicules	other comments
20	A*	C/A	R/C	sub-angular qtz.
30	A	C	C	sub-angular qtz.
60	C*	C	R/C	sub-angular/sub-rounded qtz.
110	-	R*	R	sub-angular/sub-rounded qtz.
130	- R	C*	R	angular/sub-angular qtz.
150	-	R*	R	angular/sub-angular qtz.
170	-	-	R	angular/sub-rounded, poorly sorted
190	-	-	-	angular/sub-rounded, poorly sorted
210	-	-	R	angular/sub-rounded, poorly sorted
240	-	-	-	angular/sub-rounded, poorly sorted
289	-	R	-	sub-angular/sub-rounded, poorly sorted
309	-	-	-	mostly sub-rounded, poorly sorted
329	-	-	-	angular/sub-rounded, poorly sorted
349	-	-	-	angular/sub-rounded, poorly sorted
369	-	R*	-	sub-angular/sub-rounded qtz.
389	-	-	-	sub-rounded, poorly sorted
409	-	-	-	sub-angular/sub-rounded qtz., poorly sorted
429	-	-	-	sub-angular/sub-rounded qtz., poorly sorted
449	-	-	-	angular/sub-angular qtz.
469	-	-	-	angular/sub-angular qtz.
489	-	-	R*	sub-angular qtz., poorly sorted
509	-	-	-	sub-angular qtz., poorly sorted
529	-	-	-	sub-angular qtz., poorly sorted
543	-	-	-	sub-angular qtz., poorly sorted
566	-	-	R*	sub-angular qtz., poorly sorted

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INDUSTRIAL ARCHAEOLOGY AT GRYTVIKEN, SOUTH GEORGIA

BACKGROUND

The Antarctic whaling started on South Georgia in 1904, and the island was the centre of the industry before the pelagic whaling became dominant in the late 1920s. Altogether six whaling shore stations were established on the island, operating in different periods between 1904 and 1965.

After the close of whaling, the shore stations have been in a rapid decline due to rough weather, vandalism by crews of visiting ships, souvenir collecting tourists and military action. This led to the planning of a systematic survey of the stations. The two stations Husvik and Stromness were visited and surveyed by D. Nævestad and B.L. Basberg in January and February 1990 as a project within the Norwegian Antarctic Research Expedition (NARE 89/90).[1]

Fig. 1. Grytviken - overview (Photo: G. Rossnes)

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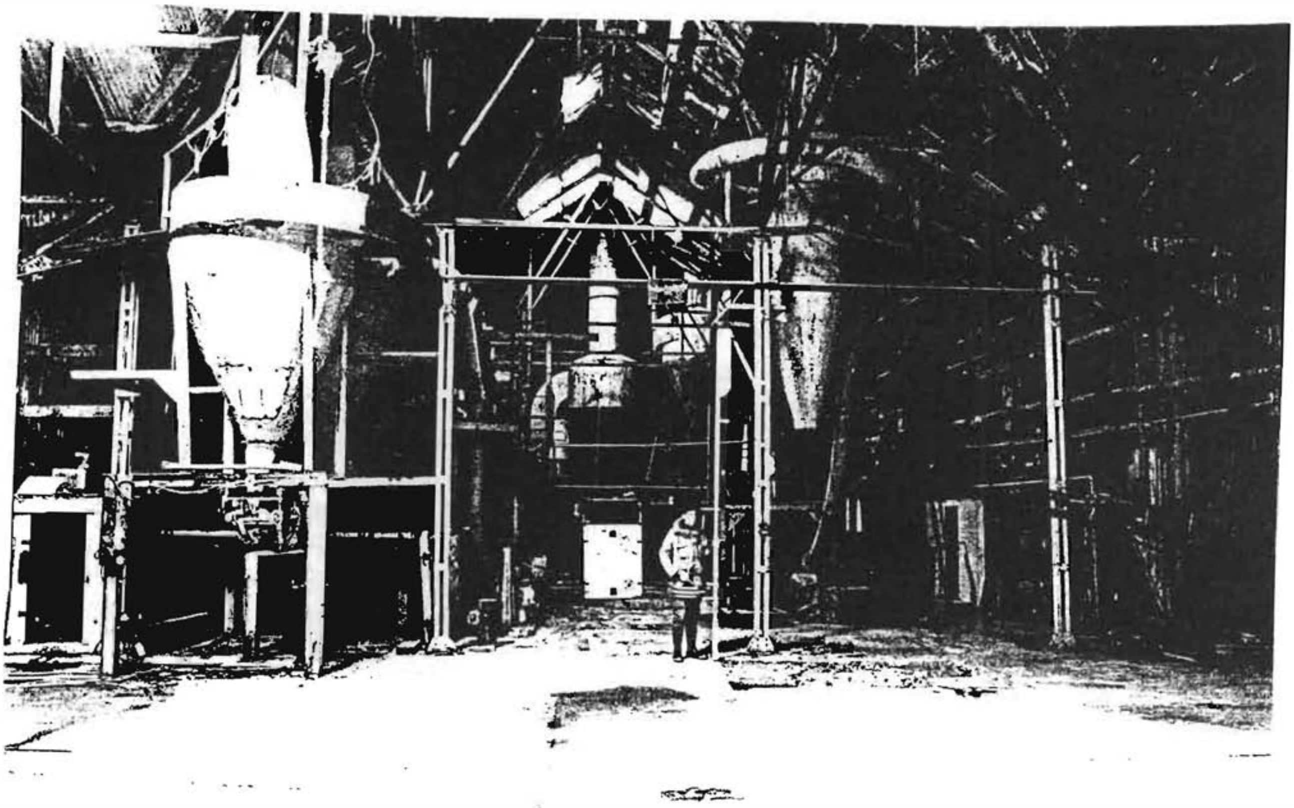

Fig. 2. Grytviken interior example - the meat meal plant (Photo: G. Rossnes)

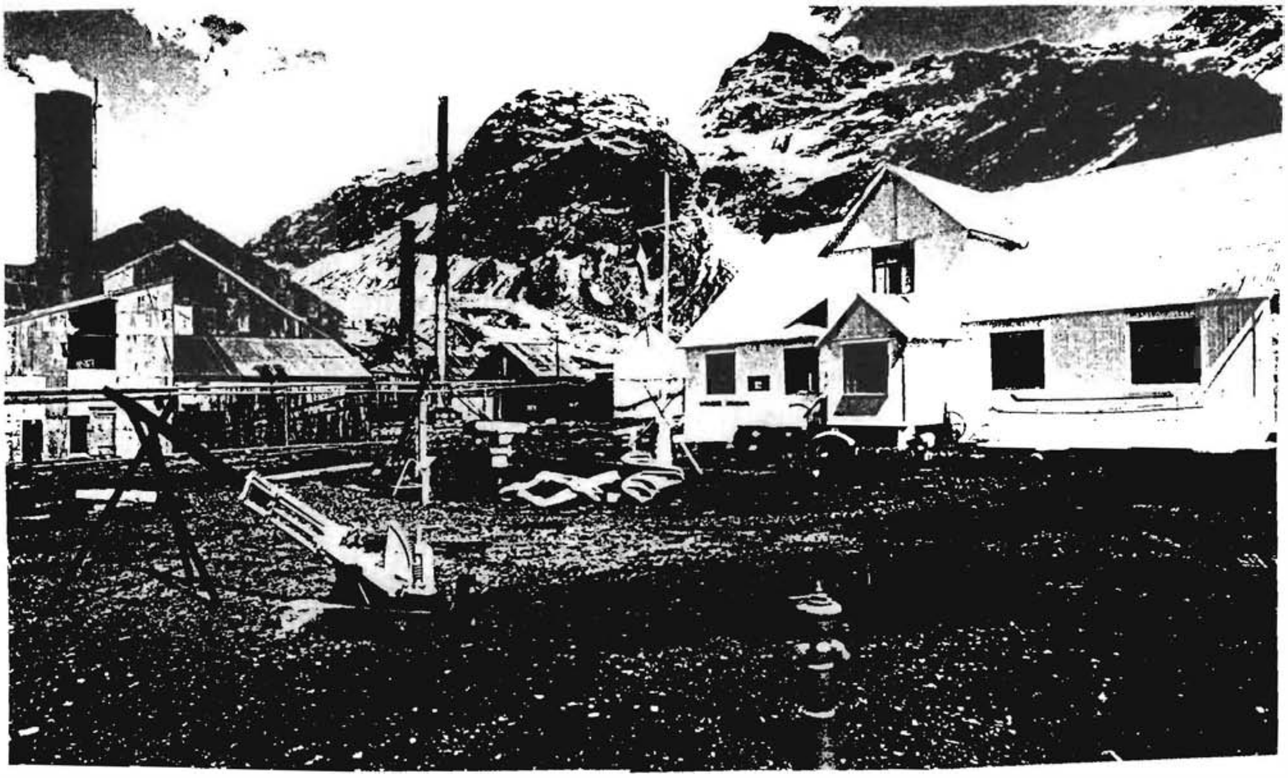

Fig. 3. South Georgia Whaling Museum in Grytviken (Photo: G. Rossnes)

As a Part II of this industrial archaeology project, the station Grytviken was surveyed in January 1993 by G. Rossnes and B.L. Basberg. The project has still been a part of the Norwegian Antarctic Research Expedition (NARE 92/93), but transportation and logistics this time was provided by the British Forces in the Falkland Islands.[2]

Grytviken was established by C.A. Larsen/Cia. Argentina de Pesca in 1904 as the first whaling station on the island. It was operated until December 1964, and a caretaker was present until early 1971. Since then the decline of the station has been severe. However, although Grytviken has the highest number of visitors of the stations, the vandalism does not seem to be greater than in any of the other stations. But some of it is of a different kind: Damage (fire) has been caused by military action during and after the 1982 campaign.[3]

Hopefully the sad development at the South Georgia whaling stations has now come to an end. In 1992 the Government of South Georgia and the South Sandwich Islands took over the ownership of the stations, and a new legislation is imposed to prevent further vandalism. In addition, the South Georgia Whaling Museum has been founded with Grytviken as a base. A first important step was reached in 1992 when the exhibitions in the restored former manager's villa was opened. The presence of the museum and staff (at least for several months every year) contributes significantly to a change in visitors' attitudes. The museum staff has also started a process of cleaning up other buildings in the station and undertaking a limited maintenance and restoration. This recent development adds importance to the survey. It can be done properly only while the plant is still fairly close to its original state.

THE SURVEY

The core of a South Georgia whaling station is the manufacturing plant (flensing plant, blubber-, meat- and bone-cookery, gluewater plant, meat extract plant, guano (whale meal) plant, and store and oil tanks). But it also contains accommodation facilities (messes, kitchen, barracks, bathhouse), recreation facilities (library, cinema, church, soccer field, ski jump), food provision houses (stores, pig house, bakery, butchers shop, cold store), workshops and repair facilities (blacksmith, engineering shop, plate shop, coppersmith, welding shop, slipway), power generation facilities (hydro electric power station, dams, diesel generator, steam boiler house). The stations are large and complex structures, modified over the years, adding more and more buildings. In Grytviken there are now 47 houses from the smallest pump sheds to the main factory building.[4] Many buildings contain several functions and more than one floor. There are 37 tanks and four boats (three catchers, one sailing ship (hull), two small tugs).

The survey has been undertaken by way of photographic documentation, measurements and mapping. All buildings and significant installations (except tanks) are photographed from all sides with a Hasselblad 500 c or a Hasselblad Super Wide C (b/w) and a Nikon FM (24x36 mm, colour diapositive).[5] The photographs also exhibit a scaling object, a horizontal 4 metre stick and a vertical 5 metre stick. Each room is also photographed from at least one position, using a Nikon FM with 24 mm lens (colour diapositive). All photographs exhibit a vertical (up to) 5 meter stick. Altogether 480 photographs have been catalogued and will be transferred to the Whaling Museum in Sandefjord, Norway.

In addition, all buildings and the interiors have been measured and mapped. The function of every single room is identified and the main machinery/manufacturing equipment, equipment stored, number of beds (if any) and several other data are plotted on the maps. The maps based on the measurements of the buildings will be completed using a CAD programme and published in the same format as similar reports for Husvik and Stromness.

Every building (defined as a separate structure) and room has received its own distinct number, and two databases (in dBASE III) are created; one for the photographs giving the number of the structure/room, the direction in which the photograph was taken and additional data; and one for the rooms giving the function, number of square meters and inventory (machinery, equipment, beds etc.). The number of records (rooms) with a distinct number is 377, totalling approximately 24,000 m^2 (this includes the flensing plan, but excludes the tanks). The databases will provide quick access to the data and facilitate statistical analyses and comparisons with the databases already compiled for Husvik and Stromness.

The time constraints involved obviously have put some limitations to the survey. The degree of detail especially in the survey and mapping of machinery, artefacts and inventory had to be limited. The measurements were made by an electronic distant meter (SONIN) which saved time and in most cases was very accurate (guaranteed at 99.5% accuracy), but which had limitations especially due to wind. However, the method which is used (a combination of photographs, measurements and mapping) is believed to be a useful compromise. It may serve as a model for similar surveys of complex and large historical remains, when labour and time is scarce and a "traditional" very detailed survey is beyond reach.

CONCLUSIONS

The survey of Grytviken - and the other whaling stations on South Georgia - may be considered a part of the conservation of this historical heritage. It is also hoped that the data which is now collected for three of the stations may be used in further historical and ethnological research on this part of the whaling industry. The surveys will be a specially valuable source in studying both the manufacturing processes (a history of technology approach) and the living conditions (a social history approach) at the stations.

The material may also be used in education. One project is already in progress, where the aim is to design and produce a multimedia presentation containing the documentation data from the surveys. The project develops an archive and exhibition system based on a 400MB CD-ROM disk. The system will also contain archive documentation, photographs, video[6] and film footage, text and other graphic material in an interactive multimedia interface.

We hope that it will be possible in the future also to make surveys of the two remaining stations (Prince Olav and Leith), which will make the South Georgia industrial archaeology project complete, and consequently give a better background for future research of this very unique aspect of our industrial history.

NOTES

1. For reports on the 1990-project, see:

- Basberg, B. & Nævestad, D. 1990: Industrial Archaeology at South Georgia. In O. Orheim (ed.): Report of the Norwegian Antarctic Research Expedition, *Norsk Polarinstitutt Meddelelser No. 113.*
- Basberg, B. & Nævestad, D. 1990: Hvalfangstminneregistrering på Syd Georgia. Vurdering av tilstand og verneverdi, *Norsk Polrinstitutt Meddelelser No. 110.*

- Basberg B. 1992: Dokumentasjon og bevaring av norsk hvalfangststasjoner på Syd Georgia. In *Årbok for Norske Kunst- og Kulturhistoriske Museer.*

2. The party arrived at South Georgia from the Falkland Islands on December 23. 1992 with RFA Gold Rover, stayed with the British Garrison at King Edward Point, and left the island on HMS Dumbarton Castle on January 16, 1993.

3. In addition to the cooperation with the British Forces in the Falkland Islands, the party received valuable help in the planning and the undertaking of the project from the Falkland Islands Government (London Office) and the South Georgia Whaling Museum.

4. The large foremen's house, the wireless house and the hull of the sailing ship Louise (b. 1869). The number does not include buildings dismantled or completely burnt down.

5. Due to a technical failure, the b/w photographs were not successful.

6. Refsvik, K. A. et al. 1993: Konstruksjon og produksjon av en CD-ROM inneholdende forskningsinformasjon fra hvalfangststasjonen Husvik på Syd-Georgia (prosjektbeskrivelse, systemdokumentasjon og brukerveiledning). Dept. of Computer Sciences, Østfold Regional College,