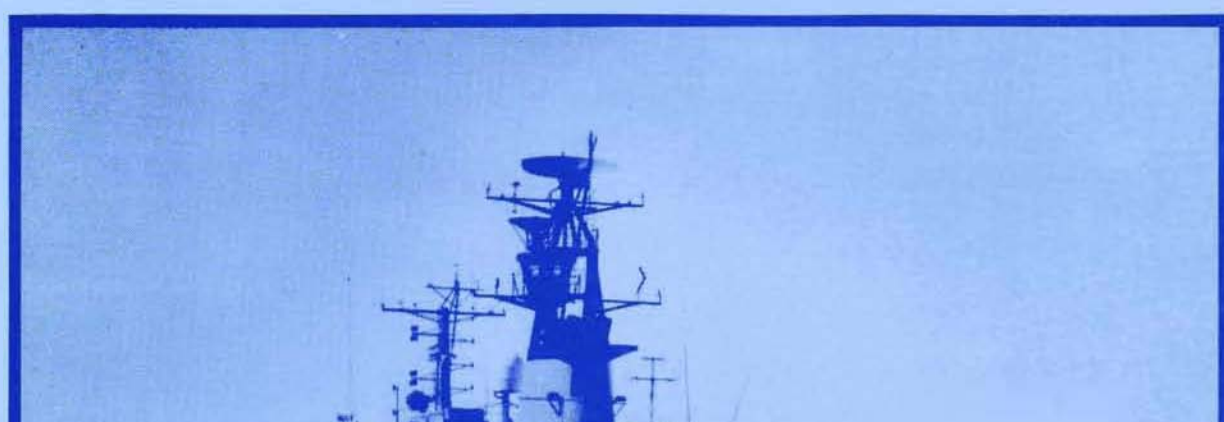
NORSK POLARINSTITUTT

RAPPORTSERIE

REPORT OF THE NORWEGIAN ANTARCTIC RESEARCH EXPEDITON (NARE) 1984/85



Nr. 22 - Oslo 1985

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Edited by OLAV ORHEIM

K/V 'Andenes' alongside fast ice by Fimbulisen, at 70°33'S, 4°33'E, 12 January 1985. Photo: Egil Eriksson.

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CONTENTS

PREFACE

This report describes the research conducted on the Norwegian Antarctic Research Expedition (NARE) 1984/85. The expedition involved 28 scientists working in Antarctica during January and February 1985, and the report contains 15 contributions from altogether 22 authors. Responsibility for contents rests with the individual authors, but the reports have been edited for uniformity of style. They generally contain sections on 1) background, 2) objectives, 3) field work, and 4) preliminary results. This report first includes a broad account of the expedition, followed by an account of the topographic-geodetic, ornithological, geological, botanical, glaciological, and invertebrate work done by a ten-person group at Camp Norway 5 and in the region of Gjelsvikfjella and Mühlig-Hofmannfjella. The next section covers geological and geophysical work done from Camp Norway 6 in Vestfjella. The last part of the report describes the marine geophysical and geological, oceanographic, and glaciological research done from the expedition vessel, K/V "Andenes", in the central and southern parts of the Weddell Sea. Some of the individual reports also contain descriptions of work done at Bouvetøya.

Olav Orheim
Editor

GENERAL REPORT OF THE EXPEDITION

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INTRODUCTION

The Norwegian Antarctic Research Expedition (NARE) 1984/85 was the largest and most ambitious Antarctic expedition mounted by Norway in recent years. Altogether 77 persons participated, including 28 scientists, mainly at professorial and senior scientist level. The expedition lasted four months, of which two and a half months were spent in the Southern Ocean. The expedition vessel, K/V "Andenes", sailed 26 000 nautical miles until return to Norway, with the main research conducted in the Weddell Sea area. Two hired Bell 206B (Jet Ranger) helicopters were stationed on "Andenes" and used for 165 hours within Antarctica, including transport of personnel and equipment up to 200 km from the ship.

Detailed planning of the expedition started in February 1983, when a 7-person scientific committee was jointly established by NAVF (The Norwegian Reseach Council for Science and the Humanities) and by Norsk Polarinstitutt (NP) (Norwegian Polar Research Institute). This committee was charged with selection of the scientific programme for the expedition, drawn from submitted proposals, while Norsk Polar-institutt had the responsibility for the general organization and leadership of the expedition. Altogether more than 40 proposals were submitted, of which 17 were accepted for participation, and some others were included in sampling programmes.

The requirement for personnel space necessitated a larger ship than that used on recent Norwegian expeditions to Antarctica. After a number of joint consultations and evaluations the Norwegian Coast

Guard and Norsk Polarinstitutt agreed to use K/V (Coast Guard Vessel) "Andenes" (Fig. 1). "Andenes" was commissioned in 1982 and is one of three sister-ships, the Nordkapp class, built for operations in ice-covered waters. They are all 106 m long, 14.8 m extreme width, 7.4 m moulded depth, 3 200 displacement tons, and with 14 400 HP on 4 engines and twin screws. In addition they have bow thruster, a helicopter hangar, and accommodation for more than 120 persons.

For this cruise the ship complement consisted of 16 officers and 26 ratings, a smaller number than usual because the part of the complement related to military operations was deleted. 28 scientists, 4 helicopter crew, 2 journalists, and 1 ice pilot made up the remaining 35 participants.

Considerable modifications were made to "Andenes" before departure from Norway. Ballast tanks were converted to fuel tanks to increase the operating range, and eight winches for various marine programmes were welded on the aft-deck, with attendant electricity and hydraulic supplies. A container with four compressors for the air guns was welded onto the upper deck, and an O.R.E. 3.5 kHz penetration echo sounder installed. Six smaller rooms were put in use as laboratories and offices. These arrangments were made possible by a cooperative agreement between the Norwegian Coast Guard and Norsk Polarinstitutt, which essentially involved that Norsk Polarinstitutt and the expedition leader laid down the plans and sailing instructions for the ship during the expedition. The expedition budget covered all costs of operating "Andenes" beyond the personnel costs of the complement and the "normal" wear and tear that would have been incurred under regular coast guard operations. It also included bringing "Andenes" back to her pre-expedition state, except for those modifications that were considered advantageous to keep.

Fig. 1. K/V "Andenes". Note also the small boat conducting studies close to the iceberg, which has 25 m freeboard. Photo: Egil Eriksson.

PROGRAMME AND PARTICIPANTS

"Andenes" sailed from Oslo on 30 November 1985 and arrived in Ushuaia, Argentina, as the first port of call on 26 December. The 35 civilians joined the ship here, with nearly all leaving Oslo on 26 December. "Andenes" departed Ushuaia at 0900 on 29 December.

The overall programme included establishment of two summer stations in Dronning (Queen) Maud Land, Camp Norway 5 and 6, with respectively 10 and 5 scientists. The remainder worked from the ship executing various science programmes during the one-and-a-half months between deployment and retrieval of the land parties.

The expedition included the following scientists and programmes:

Name	Institution	Location	Function
Knut Svendsen	NP	Camp Norway 5	Base leader, topography
Trond Eiken	"	"	Geodesy
Claus Bech	UTrh	"	Ornithology
Svein Haftorn	"	"	"
Fridtjov Mehlum	NP	"	"
Yoshihide Ohta	"	"	Geology
Bjørn Tørudbakken	UO	"	"
Torstein Engelskjøn	"	"	Botany
Lauritz Sømme	"	"	Invertebrates
Yngvar Gjessing	UB	"	Meteorology & glaciology
Kåre Bratlien	NP	Camp Norway 6	Base leader
Harald Furnes	UB	"	Geology
Reidar Løvlie	"	"	Paleomagnetism
Snorre Olaussen	Stat	"	Geology
Stig Jonsson	USth	"	Geology and glaciology
Olav Orheim	NP	Andenes	Expedition leader, glaciology
Kristen Haugland	UB	"	Marine Geophysics
Eirik Sundvor	"	"	"
Fridtjof Veim	"	"	"
Eldar Lien		"	"

Yngve Kristoffersen	UB	"	Marine Geophysics and Geology
Anders Solheim	NP	"	Marine Geology
Eystein Hansen	IKU	"	"
Øistein How	"	"	"
Arne Foldvik	UB	"	Oceanography
Tor Gammelsrød	"	"	"
Clark Darnall	UW	"	Oceanography and Glaciology
Monica Kristensen	NP	"	Glaciology

Institutions: NP = Norwegian Polar Research Institute, Oslo
UTrh = University of Trondheim
UO = University of Oslo
UB = University of Bergen
Stat = Statoil, Stavanger
USth = University of Stockholm, Sweden
IKU = Continental Shelf Institute, Trondheim
UW = University of Washington, Seattle, WA, USA

More than half of the scientists had worked before in Antarctica, and practically all had been on previous polar expeditions.

The other civilian personnel included:

Gabriel Gaard	Helicopter Service A/S	Helicopter pilot
Paul Ellingsen	"	"
Arne Søreide	"	Helicopter mechanic
Per Tednes	"	"
Guttorm Jacobsen		Ice pilot
Torill Nordeng	Aftenposten	Journalist
Egil Eriksson	Stavanger Aftenblad	Photographer

Captain on board was commander Torstein Myhre, Norwegian Coast Guard.

The first station to be established, Camp Norway 5, was to be located by Svarthamaren in Mühlig-Hofmannfjella at $71^0 53'S$, $5^0 10'E$, at an elevation of about 1600 m. "Andenes" therefore first sailed to the nearest point by the ice shelf barrier, at $70^0 10'S$, $4^0 42'E$. This was reached on 9 January, and was about 200 km from Svarthamaren. Establishment of the 10-person field party commenced in earnest the previous day, when "Andenes" was still in heavy pack ice about 10 nautical miles from the barrier. Nine skidoos together with about 5 tons of cargo, including one small hut, were flown to the ice shelf edge and were driven towards an intermediate depot 120 km from the barrier. Altogether 70 helicopter flights were carried out to deploy the field party, including 16 flights to the 120 km depot at 1 000 m elevation and two to Svarthamaren. In total about 11 tons of cargo was transported to Camp Norway 5, with the skidoos transporting most of the cargo from 120 km to Svarthamaren.

Deployment of Camp Norway 5 was completed by 12 January, when three skidoos - that were to be used at Camp Norway 6 - and drivers returned to "Andenes". The ship then proceeded to Riiser-Larsenisen, where the five-man group at Camp Norway 6 was deployed from 17 to 20 January in Vestfjella in position 73°18'S, 13°55'W. Camp Norway 6 was located about 120 km from the barrier at 820 m elevation. Most of their cargo was flown in place, although over 1 ton was carried by three snowscooters that were driven from the ice edge of Riiser-Larsenisen. Deployment of this group involved about 20 flights, including 10 to the camp. Various sea bed and ice shelf studies were carried out from the ship in parallel with the deployment of the field party.

Various marine programmes were thereafter carried out from "Andenes" during the period 20 January to 23 February, with main emphasis on marine geophysics and geology, and smaller programmes within oceanography and glaciology. The locations of the marine research programmes were determined by the results from the two previous Norwegian research expeditions to the Weddell Sea. The expedition mostly worked between 74° and 78°S, and 25° and 40°W. Favourable ice conditions made it possible to cover new parts of the central area of the Weddell Sea with seismic studies, and we had compensation for some of the time that was lost due to heavy ice during the first two weeks of the expedition. We could also deploy 9 oceanographic rigs with little ice hindrance; these instruments are planned to be recovered on a subsequent expedition. The sailing route is presented in Fig. 2.

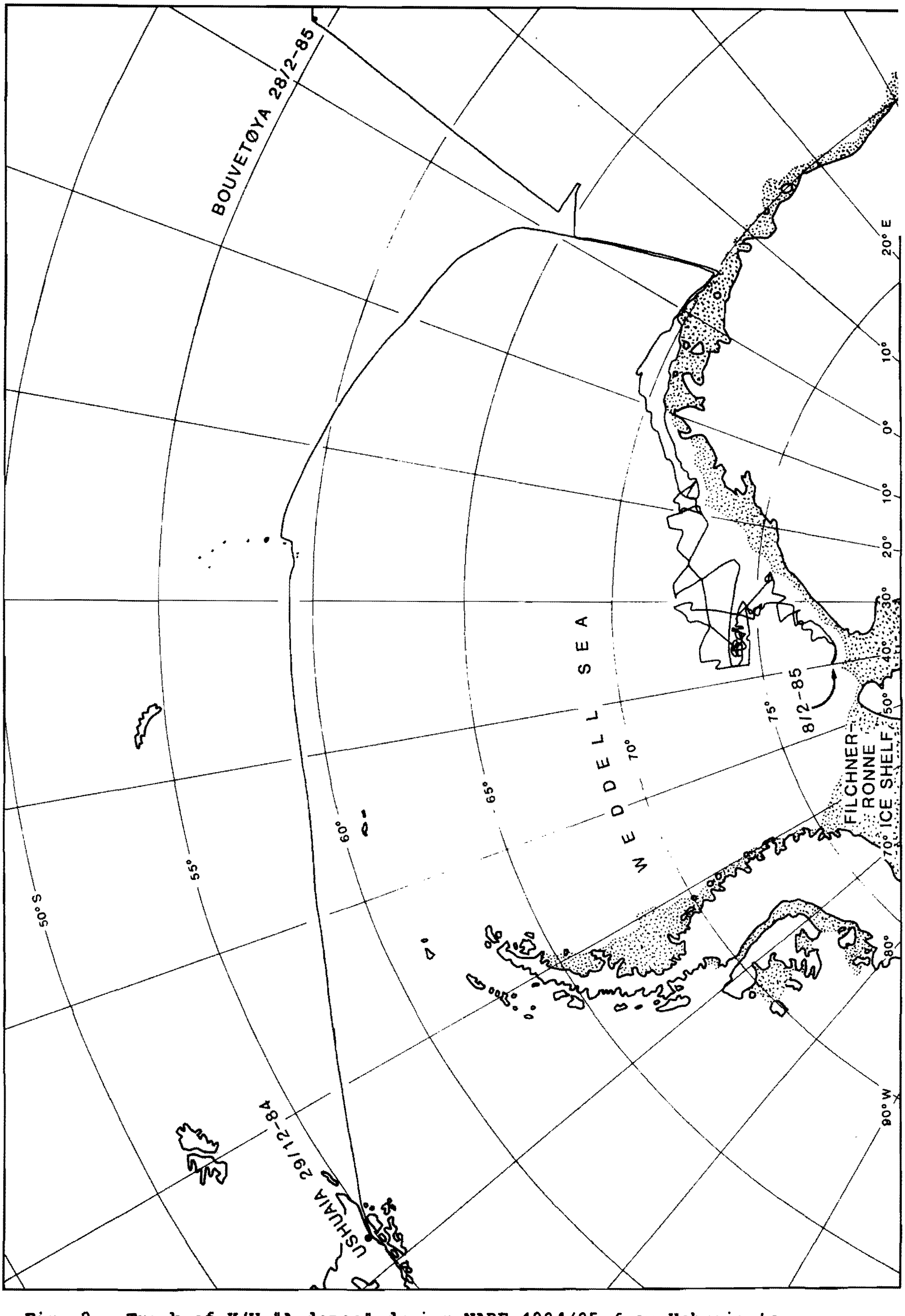

Fig. 2. Track of K/V "Andenes" during NARE 1984/85 from Ushuaia to Bouvetøya.

Weather conditions were generally good, and we received twice-weekly sea ice maps from US Fleet Weather Facility/NOAA which were very useful for making decisions on the order of visit to high-priority regions.

The field party from Camp Norway 6 was picked up on the morning of 20 February, and Camp Norway 5 on the morning of 23 February. Each operation took only a few hours, as the field parties had driven to the pre-arranged pick-up point near the ice shelf barrier. No stores were left behind at Camp Norway 6, while at Camp Norway 5 a well-secured hut measuring 2 m by 3 m was left behind on solid rock at Svarthamaren, in position 71°53'25"S, 5°09'35"E, at an elevation of 1625 m (Fig. 3). This hut contains 300 l petrol, 200 l kerosene, 300 man-days of varied food rations, and various tools and other equipment.

The group also left behind a meteorological station on the moraine ridge in northeastern part of Jutulsessen, in position 71°56'06"S, 2°46'19"E, and at an elevation of 1 315 m (Fig. 4). This Aanderaa automatic weather station will store three hourly observations of the following parameters: 1) average and maximum wind speed, 2) wind direction, 3) air temperature, 4) global radiation, 5) air pressure, and 6) ground temperature at three depths. The station has a battery capacity to last for 1.6 years. The observations will be used to obtain long term statistics on the local weather conditions as a basis both for climatic studies and for the planning of future expeditions.

The expedition left the Antarctic Continent on 23 February, and after a 40-hour seismic survey of Maud Rise we arrived Bouvetøya (Bouvet Island) on the morning of 28 February. The weather was unusually good, and allowed completion of, and addition to, various surveys carried out in the 1978/79 field season. We re-established the automatic weather station on Nyrøysa, and established a back-up station. Both transmit over the ARGOS system and into the GTS, with the main station having ARGOS ID No. 01591, WMO No. 17001, and the second station ID No. 01594, WMO No. 17002. Both stations transmit air pressure and temperature, and the first station also transmits 3-hourly air pressure change. The vast desolate areas of the Southern

Fig. 3. The hut of Camp Norway 5 established by Svarthamaren.
Photo: T. Eiken, 15 Feb. 1985.

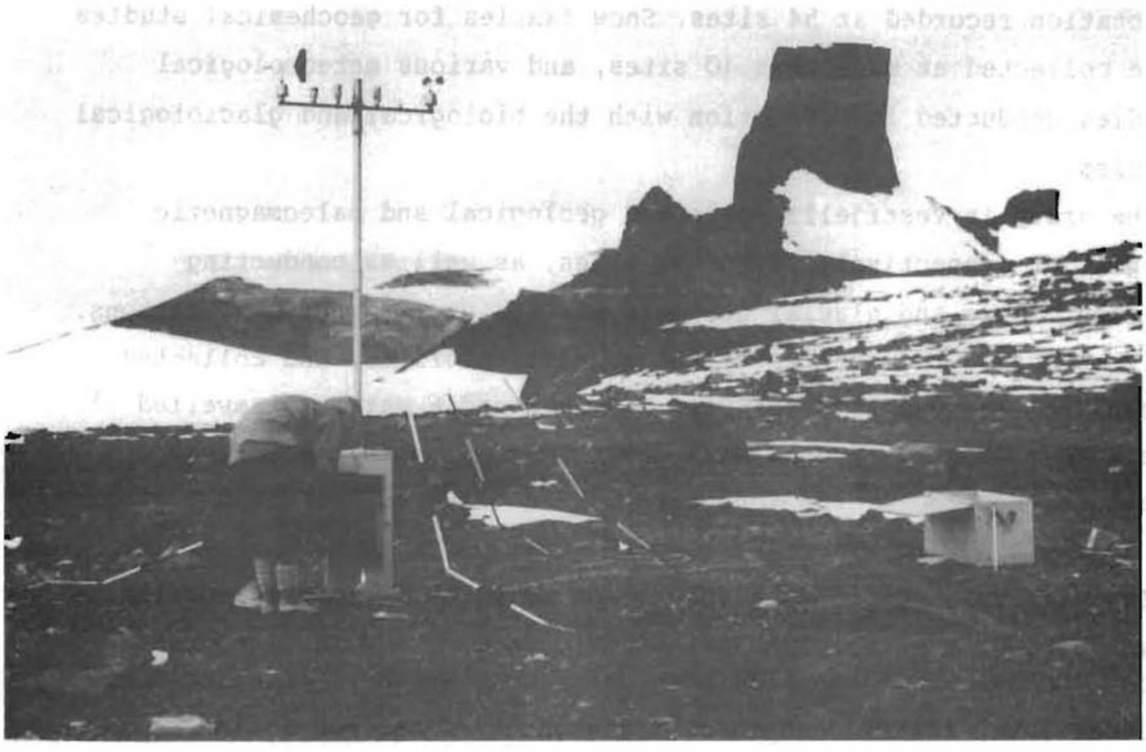

Fig. 4. The automatic weather station by Jutulsessen, with Stabben in the background. Photo: K. Svendsen, 20 Jan. 1985.

Ocean make it especially important to maintain automatic stations on the few islands around the Antarctic continent, and both stations have been installed with battery capacity to last for three years.

"Andenes" arrived Abidjan, Ivory Coast, on 12 March, and from here 38 persons flew back to Norway. The ship arrived in Bergen on 25 March.

RESULTS

The work of the Camp Norway 5 group covered ornithological studies of the Antarctic Petrel colony at Svarthamaren of nearly 1 million individuals, including energetics, thermoregulation, behaviour, census and ringing. The topographers positioned six points by satellite, and another eight by triangulation, and surveyed a net-work along 150 km of the mountain chain. Regional geologic mapping was done in Gjelsvik-fjella and around Svarthamaren, including visits to 203 sites, and sampling at five localities for age determinations. Collembola and mites, mainly from the Svarthamaren area, were investigated, and vegetation recorded at 54 sites. Snow samples for geochemical studies were collected at more than 10 sites, and various meteorological studies conducted in connection with the biological and glaciological studies.

The group in Vestfjella collected geological and paleomagnetic samples at respectively 24 and 82 sites, as well as conducting sedimentologic and glacial geologic studies at a number of locations. They also measured over 200 km of magnetic profiles, and collected vegetation at 10 sites. The Camp Norway 5 and 6 parties travelled altogether about 12 000 km with their skidoos, with the longest distances covered by the topography and geology parties amounting each to nearly 2 000 km.

The main results from the ship-borne research include collection of nearly 3 000 km of multichannel seismic data, 1 500 km of sparker data, 100 km of sea bed side scan data, continuous penetrating echo sounder data, nearly continuous magnetometry data, and marine gravimetry for the first half of the cruise. Sea bed samples were collected at 18 sites, and bottom photography done at 14 sites. Hydrographic (CTD) observations were done at 87 sites, and 9 current meter rigs were deployed with altogether 19 current meters, one water level recorder, and a thermistor chain. Two sophisticated ice berg experiments were conducted, and over 100 km of side-scan sonograms collected showing under-water shapes of ice fronts and ice bergs. Sea ice samples were collected at 10 localities.

Work at Bouvetøya included obtainment of the first cloud-free mapping photography of the upper part of the island, and completion of a survey network initiated in 1978, re-census of the penguin and seal colonies, and collection of vegetation and geologic samples from locations not previously visited.

The helicopters were used for airborne magnetometry studies over Riiser-Larsenisen, and radio echo soundings of ice thickness here and over Trolltunga, in addition to the logistic support of the land parties and ice berg studies, and for sea ice reconnaissance. Altogether about 300 flights were done during the expedition.

More detailed reports of these investigations and the preliminary results are presented in the following articles.

CONCLUSIONS

The results from NARE 1984/85 show that K/V "Andenes" was a very suitable ship for this kind of operations. No serious mishaps occurred during the expedition, the nearest being when the ship for a short period was without use of one propeller. Sea ice conditions were good, with the exception of the first part of the field season. The weather was generally favourable, although the group in Vestfjella experienced lower temperatures and generally poorer conditions than those at Camp Norway 5. The combination of light helicopters and skidoo transport proved adequate for this type of limited field operations, but more extensive operations will need different logistics, and in places crevasses reduced the safety of the surface travel. With the exception of parts of the marine geological programme and a planned visit to Heimefrontfjella it can be stated that all main objectives were met, and the data collected exceeded expectations for some programmes.

ACKNOWLEDGEMENTS

The execution of this expedition has involved assistance from a number of institutions. Those institutions, mentioned above, that sent participating scientists have given the largest contributions, generally in the form of lending equipment free of charge, and giving the scientists leave of absence with full pay. But also other institutions have made important contributions, and we would like to thank especially: Statoil and Norsk Hydro for financial contributions; University of Tromsø, Forsvarets Forskningsinstitutt at Kjeller and at Horten, Norges Geografiske Oppmåling, Hønefoss, Scott Polar Research Institute, Cambridge, UK, and School of Oceanography, University of Washington, Seattle, USA, for loan of equipment; and Alfred Wegener Institut für Polarforschung, Bremerhaven, FRG, for very helpful cooperation in the field.

GEODETIC-TOPOGRAPHIC MEASUREMENTS IN DRONNING MAUD LAND AND ON BOUVETØYA

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GEODETIC MEASUREMENTS IN DRONNING MAUD LAND

BACKGROUND

The trigonometric network in the area of intended work was measured in the 1950s to serve as a basis for topographic maps at the scale of 1:250 000. Datum was fixed through astronomic observations. Only tape measured distances were acquired for scale information except one line further east measured with tellurometer during the 1958/59 field season of The Norwegian Antarctic Expedition, 1956-60. It was therefore planned to use satellite positioning methods (Transit - doppler) and electro-optical distance measurements to improve the existing trigonometric network.

Control points for ordinary small scale map construction are not always suitable for rectification of satellite imageries. The work with the satellite-imagery-based map, Filchnerfjella Nord, a joint project between Norsk Polarinstitutt (NP) and IBM, showed that the ideal control points for rectification were small exposed nunataks of about one pixel size.

It was intended to produce more maps based on satellite imageries, and specially selected control points for their purpose were to be surveyed. NASA accepted to activate the Landsat-5 satellite to obtain as far as possible cloud free imageries from the relevant part of Dronning Maud Land during the 1984/85 Antarctic summer season.

OBJECTIVES

The objectives of the geodetic - topographic measurements were:

a) To establish a satellite based geodetic datum in an area from Svarthamaren (lat. $71^{0}53'$S, long. $5^{0}10'$E) and westwards as far as possible depending on weather and driving conditions.

b) To determine the exact positions of small nunataks suitable as control points in satellite imagery rectification. The nunataks should be spread evenly in the covered area, and especially with the largest possible north-south spreading.

c) To support the existing trigonometric network with new trigonometric points, with supplementary angle measurements in old points, and with azimuths and precisely measured distances between trigonometric points.

d) To measure magnetic bearings to find the magnetic deviation in the area.

EQUIPMENT AND TECHNIQUES

Satellite positioning

A Transit satellite positioning system (doppler) was found to be the easiest method to establish a new geodetic datum in the area, and our Magnavox MX 1502 Satellite surveyor was used. As a backup we brought a Canadian Marconi receiver, borrowed from the Geographical Survey of Norway (NGO), but it was not in operation.

Mean observation time in each point was about three days, with about 100 satellite passes recorded. Data were recorded on tape for later processing and possible precise ephemeris computation.

The Magnavox was powered with two battery packs, each containing two

12V 40Ah Power-Sonic batteries. Charging was done with two 12V 20W solar panels. Power consumption of the Magnavox can be as high as 3A. With the intense light charging was no problem even in temperatures down to -20^{0}C.

Triangulation and distance measurements

All angle measurements were made with a Wild T2 one second theodolite. Directions were usually observed three full rounds horizontally, and one to two vertically. During azimuth observations to the sun a Roelofs sun-prism was used additionally. For timing of the azimuth observations a quartz stopwatch was used in combination with the very precise time of the Magnavox. Magnetic bearings were measured with a tripod mounted Wild prismcompass.

Distances were measured with a Wild Distomat DI20 (electro-optical (infrared) distancer) mounted on the theodolite, and in combination with an eleven prism reflector. The instrument has a range under ordinary air conditions of about 15 km, and a little longer under favourable conditions. Our longest measured distance was nearly 17 km. The DI20 is powered by a 12V 6Ah Power-Sonic battery, with sufficient power for several measurements even in very low temperatures. Earlier experience with the DI20 has shown operational temperatures down to about -30^{0}C.

WORK DONE

We had 46 days in field, and about 15 of them were used for transport to/from the edge of the ice shelf, and establishing the base, "Camp Norway 5", in Svarthamaren. Six of the remaining 30 days were used mainly for transport between camps. Two days had unfavourable weather. That left us with 22 days for measurements.

A total of five points were positioned using the doppler satellite method, with a mean distance of approximately 70 km between points. One additional point was measured on the edge of the ice shelf while waiting to be picked up by the expedition vessel. This point was measured for geoidal height estimation in the area. In addition to the five satellite positioned points, another eight were visited and angular measurements conducted. A total of 300 directions to trigonometric points and control points were measured. Azimuth control measurements were performed in the five doppler stations, and in one additional trigonometric point. The azimuths included magnetic bearing for deviation control. Distances were measured between eight of the trigonometric stations with a mean length of 11 km.

The newly measured network stretches from Snarbynuten $1^0 37'$E to Plogskaftet $5^0 20'$E. Directions have been measured to about 20 points included in the old triangulation. Six of our trigonometric stations have formerly been measured. The area of work is shown in Fig. 1.

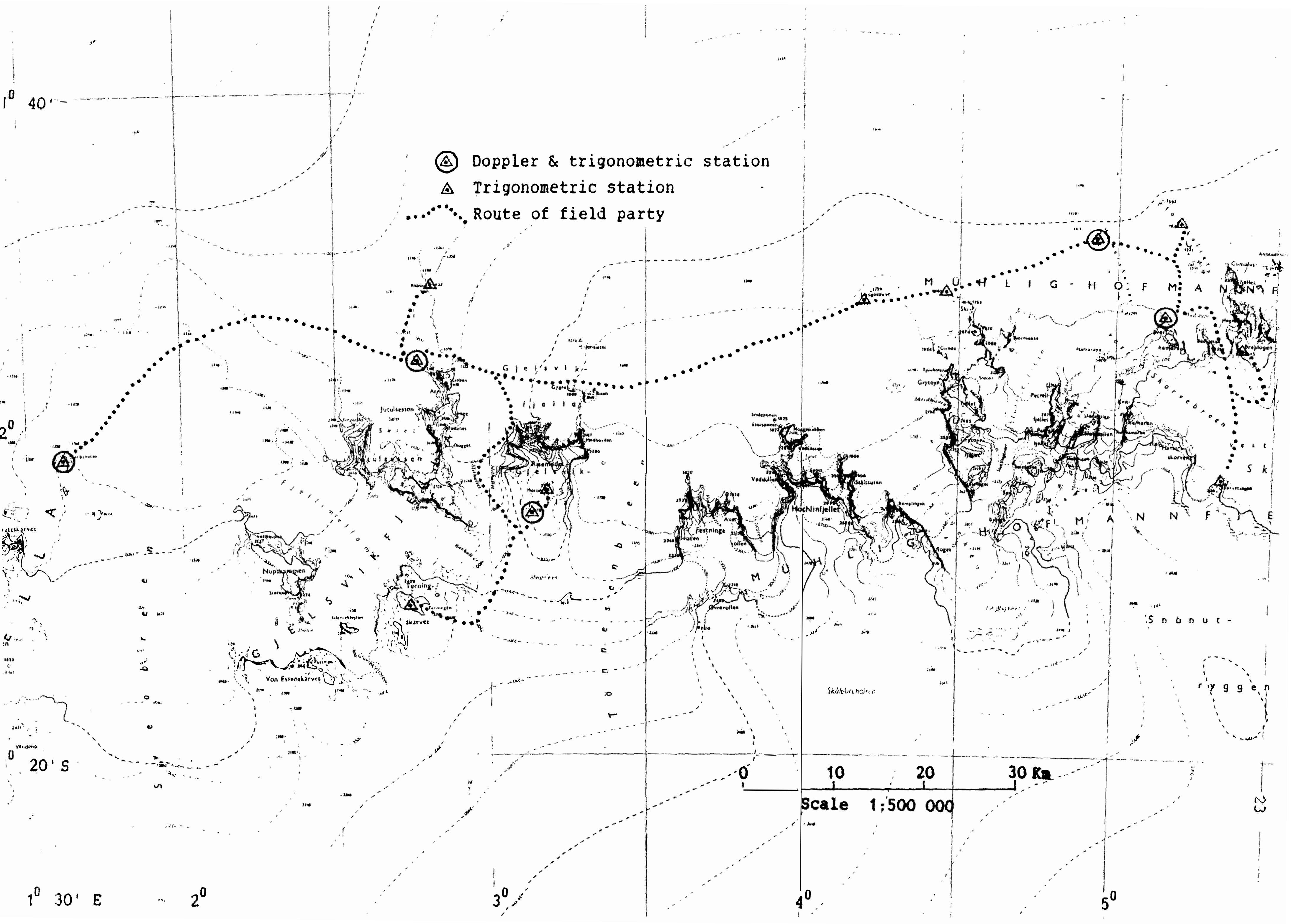
We had two small mapping projects in the main camp at Svarthamaren in addition to the triangulation and satellite positionings:

- The large bird colony should be roughly mapped to attempt estimating the number of birds. Six control points on the mountain slope, and six terrestrial photo-stations were measured. Pictures were taken with a Pentax 6 x 7 cm camera.

- A small area used for studies of algae and collembola (L. Sømme) was mapped tachymetrically.

PRELIMINARY RESULTS

The Magnavox MX1502 doppler receiver has a built-in equipment for on-site computation of position. Computation is not performed with a multi-pass, least squares solution, but with simple updating of position during each pass. The on-site computed positions have quite large standard deviations, usually 10-20 m in each coordinate.


Doppler & trigonometric station
Trigonometric station
Route of field party
M U H L I G - H O F M A N N F
M U H L I G - H O F M A N N F J E
G J E L S V I K F J E L L A
Gjelsvikfjella
Skorvebreen
Snonut-ryggen
Tonnesenbreen
Jutulsessen
Nupskammen
Von Essenskarvet
Hochlinfjellet
Festninga
Grytoya
Skålebreholten
0 10 20 30 Km
Scale 1:500 000
1⁰ 40'
2⁰
0 20' S
1⁰ 30' E
2⁰
3⁰
4⁰
5⁰

Usually post-processing with more sophisticated programmes does not change the position more than tenths of seconds in longitude and latitude, and a few metres in H. The on site calculated positions are listed in Table 1.

Angular measurements and distance and azimuth measurements have so far not been computed. They will be used together with positions computed from precise ephemeris in a common calculation using the method of least squares.

Table 1

Site No. - Name	Latitude S	Longitude E	Height m a.s.l.	No. Pass.
1 Svarthamaren	71°53'18".779	5°09'37".520	1606.555	78
2 Jutulsessen	71°56 26 .591	2°46 48 .763	1378.154	115
3 Snarbynuten	72°02 25 .789	1°37 15 .239	1582.476	70
4 SV Risemedet	72°05 31 .622	3°08 29 .664	2207.147	113
5 Hamarskaftet	71°48 35 .552	4°56 15 .072	1661.063	87
6 Shelf-edge	70°15 23 .676	4°39 14 .539	56.563	85

Measurements from the bird colony have been computed and the nesting colony mapped in the scale of 1:1000.

A small map (scale 1:1000) covering the study area of L. Sømme has been drawn from tachymetric datas.

CONCLUDING REMARKS

Calculation of the positions from the recorded satellite data will take place at NGO, using their GEODOP programmes and, if available, precise ephemeris in single point positioning.

We hope to finish the computation of the triangulation quite fast after the computation of the satellite positioned points. These computations will be performed at NP using the MAPDAT programme.

Our agreement with NASA turned out to be very successful thanks to the good weather in the area this season. A total of nine satellite imageries with a cloud cover less than 10% were recorded.

Our present aim is to be able to publish the first map based on satellite imagery and the new measurements in 1986 or 1987.

AERIAL PHOTOGRAPHY AND CONTROL POINT MEASUREMENTS AT BOUVETØYA

The existing map of Bouvetøya is made from aerial photos and measurements conducted during the Norwegian Antarctic Research Expedition (NARE) 1978/79. Clouds covered the highest part of the island when these air photos were collected, and new photographs were needed to complete the existing map. Furthermore, control points were only measured on the west and south side of the island. Control points on the north side were also needed, as a quite large area had been mapped without control.

In spite of the very brief visit planned for the expedition, our objectives were:

- To photograph the island from a helicopter, even if the chance to get a clear sky was very small.

- To measure a blind polygon from one of the old geodetic points in Nyrøysa on the western side and to the north side.

A Zeiss Jena UMK 10/1318 terrestrial camera was used mounted on a special bracket in one of the Bell 206B helicopters. The camera had a 100 mm wide angle lens and was equipped to take glass-plates of the size 13 x 18 cm. Because no glass-plates were available in Norway, a sheet of ordinary film was laid on an old glass-plate and secured in the frame used when loading the casette. The camera could be used either with the axis in horizontal position or dipped in steps of 15^{o}.

One of the main problems in a helicopter is vibrations. We tried to reduce them by using a rubber mount between camera and bracket, but because of the high center of gravity of the camera a good rubber mount is difficult to establish.

In a small helicopter with very few navigation instruments the navigation can be a problem. We had estimated the ideal height for photographing to 1500 m with a camera dip of 15^0, and a 3000 m flying distance from the coast. Our only help to navigate was compass, speed and time. Because of wind and other problems, some extra pictures would be necessary in case of navigational errors.

The photography was planned to give 80% overlap at the coast, but because of the rather slow rate of photographing with manual loading and the necessary speed of about 55 knots (to stay on course), the actual overlap had to be a little smaller than ideal.

The weather was better than we could have expected, and we got about 40 minutes with clear sky, and nearly no fog or clouds on the highest tops. The time enabled us to fly once around the island and to get the necessary pictures. On the last leg some clouds disturbed the coastline. However, the mountain tops were still cloudfree.

The aerial photos have been developed with very good results. 30 photos have no cloud cover, and the five remaining from the west coast have small dots of clouds covering parts of the mountain side. The contrast in the snow is very good due to blue ice and crevasses.

A blind polygon was measured from the triangulation point at Nyrøysa via Kapp Circoncision to Kapp Valdivia. Orientation had to be done with azimuth measurements to the sun, as one of the trigonometric points at Nyrøysa had disappeared into the sea. Unfortunately Olavs-toppen was covered with clouds during the time of the measurements.

Probably the new photos and measurements from Bouvetøya will enable us to complete the existing preliminary map or if necessary compile a new one.

ORNITHOLOGICAL INVESTIGATIONS IN MUHLIG-HOFMANNFJELLA, DRONNING MAUD LAND

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BACKGROUND AND OBJECTIVES

The Antarctic Petrel *Thalassoica antarctica* is the only petrel breeding exclusively on the Antarctic continent. Only nine breeding colonies are known (Watson 1975). The largest of these colonies is situated in Dronning Maud Land, and should comprise about one million birds according to Konovalov (1964). The breeding biology of the Antarctic Petrel is largely unknown. Only Orton (1968) and Pryor (1968) give fragmentary data on behaviour and ecology. Breeding at sites up to 200-250 km from the sea and in areas where the ambient temperature can fall below -25^{0}C, the Antarctic Petrel probably inhabits one of the most extreme breeding habitats for seabirds in the world.

The objectives of the present study were to elucidate factors involved in adaptations to nesting under such conditions. Although we mainly studied the Antarctic Petrel, additional data on ecology and behaviour were obtained on the Snow Petrel *Pagodroma nivea* and South Polar Skua *Catharacta maccormicki*, which also breed in the area but in smaller numbers.

FIELD WORK AND PRELIMINARY RESULTS

The main study site was the mountain Svarthamaren (71°53'S, 5°10'E), where the large colony of Antarctic Petrel is situated. (Figs. 1, 2). The study was carried out during the period 11 Jan. to 15 Febr. 1985. The colony counted more than 200 000 breeding pairs of adult Antarctic Petrels, while Konovalov (1964) reported the total number of birds present in the colony at 19 Jan. 1961 to be about 1 million. It is not clear if his information of colony size represents only breeding birds or the total number of adults in the colony.

No census of Snow Petrel was conducted, but the number of breeding pairs was probably 500-1000.

Additionally, about 50 pairs of South Polar Skua claimed territories at the base of the Antarctic Petrel colony.

About half of the eggs of the Antarctic Petrel were already hatched when we arrived. Thus we could follow the last part of the incubation period only in a limited number of nests. The study of chicks was confined to the first month of the nestling period.

The topics studied were the following:

Antarctic Petrel

1. <u>Census of colony size</u>

The number of nests containing eggs or young was registered, as well as the number of empty nests occupied by failed breeders or non-breeders. The census comprised 96 plots each covering 9 m^2 that were evenly distributed in the colony.

Colour photographs of all subcolonies were taken by a Pentax 6x7 camera. Fixed points and terrestrial photogrammetric stations were measured by topographers for later mapping of the colony and estimation of total colony size.

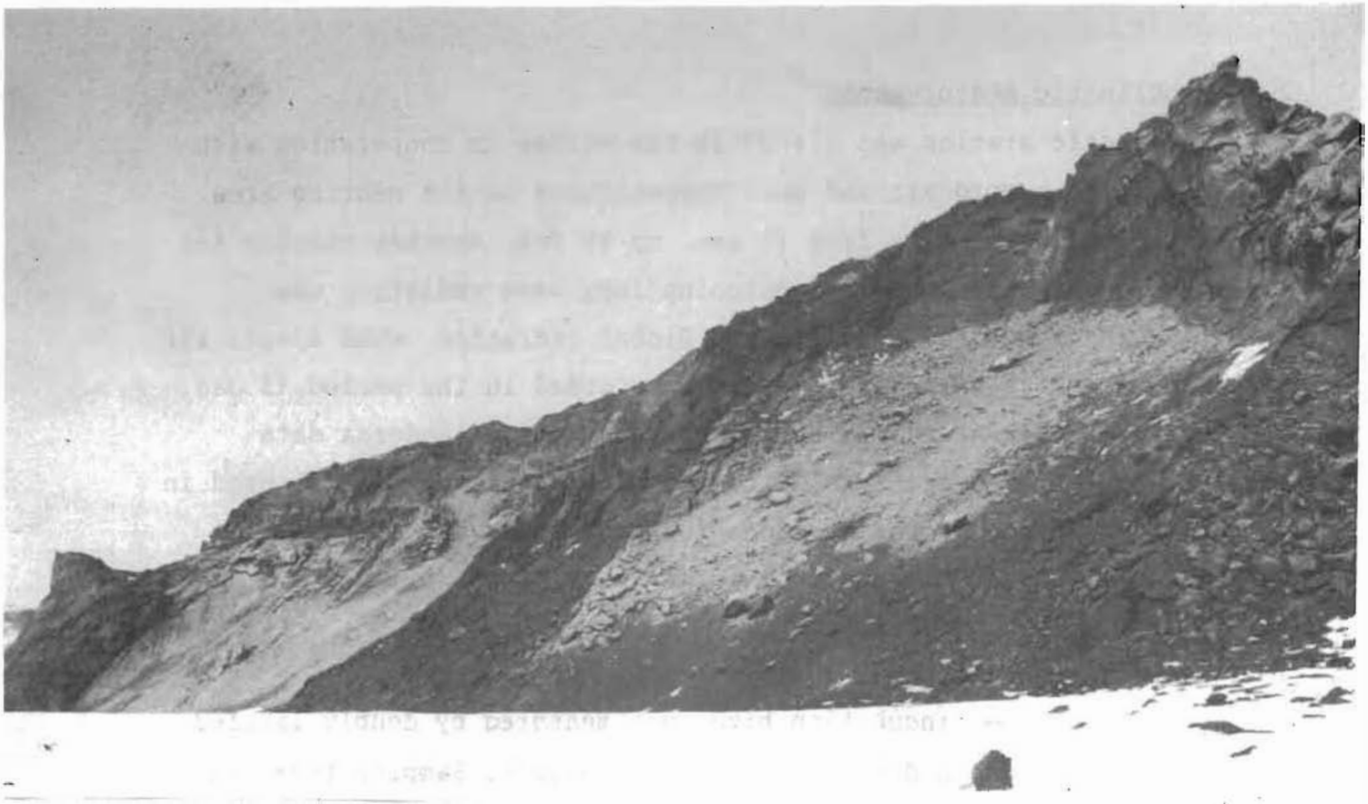

Fig. 1. Svarthamaren seen from Camp Norway 5. The lightcoloured areas show the location of the Antarctic Petrel colony.

Fig. 2. Antarctic Petrel with chick at Svarthamaren.

2. Microclimatic measurements

A microclimatic station was placed in the colony in cooperation with Y. Gjessing to record air and soil temperatures in the nesting area. The station was operative from 15 Jan. to 15 Feb. Another station for registration of wind speed and outgoing long wave radiation was operative in the period 8 to 15 Feb. Global radiation, wind speed, air temperature and relative humidity were recorded in the period 13 Jan. to 15 Feb. at the base camp. Data were recorded on Aanderaa data loggers at all three stations. Data from the base camp will be used in comparison with the colony stations for describing the effects of colony topography on the nesting microclimate of the petrels.

3. Incubation energetics

Energy metabolism of incubation birds was measured by doubly labeled water technique, using deuterium and O^{18} isotopes. Samples from six birds were obtained for measurements of 1-day-energy use during incubation. Egg temperatures were recorded by thermocouples, and heat flow between brood patch and egg, and footweb and egg were registered by heat flow disks on a Cristie data logger.

4. Egg shell analysis

Eggs were collected for analysis of total shell weight, pore area and pore structures.

5. Nesting behaviour

The general behaviour of the adults at the nests were registered by means of movie films and sound recorders.

6. Thermoregulation in newly hatched young

A laboratory study on the thermoregulation in one-day old chicks was conducted. The data obtained included measurements of body temperature, oxygen consumption and respiratory frequency during exposure to ambient temperatures ranging from +12 ^{0}C to +35 ^{0}C, allowing determination of thermal conductance, insulation and thermogenic rate.

7. Growth and energetics of chicks

The growth of the chicks was registered by daily weighings of a number of chicks in which the hatching date was known. In addition 27 chicks (1-33 days old) were collected for further analyses. These analyses will include organ growth, lipid, non-lipid, and water content. In some chicks weight changes during the fasting period between two parental feedings were recorded by weighing the chicks at shorter intervals (3-6 hours). We will be able to estimate the metabolic rate of the chicks during natural conditions from the weight change.

8. Energetics of free flying adults

The energy metabolism of adults during feeding bouts between the nest and the sea was measured by doubly labeled water technique. A total of 13 birds were injected with isotopes, but only 3 were recaptured for blood sampling during a period 3-5 days later while feeding chicks.

9. Division of labour between mates

The feeding frequency and division of labour between mates concerning nest attendance (incubation, brooding) and feeding visits were studied by means of time-lapse photography and direct observations of colour marked birds.

10. Food

The quantity of food brought to the young was studied by weighing nestlings immediately before and after feeding. Ten adults were collected for detailed stomach analysis.

11. Mortality of nestlings

Two survey plots, one at the periphery of the colony and one in the centre, each containing 100 nests, were visited every 10th day and the nest contents noted.

12. Thermoregulation of adults and chicks

The metabolic rate of adults and chicks (age 10-15 days) was measured at ambient temperatures between -5 ^{0}C and +15 ^{0}C. These measurements were conducted in the laboratory. In addition several parameters associated with general thermoregulation in the chicks were measured when they were alone in the nests (10-30 days old). These measurements included circadian changes in body temperature, heart rate by telemetry, heat flow over the skin using heat flow disks, web skin temperature by thermocouples, and back surface radiation temperature using PRT 10 radiation thermometer.

13. Blood sampling for Thyroxine measurements

Blood samples were collected from 45 chicks (age 1-32 days) and from 13 adults for analyses of both T_3 and T_4 to clarify to what extent thyroxine are involved in the achievement of thermoregulatory ability. The samples were centrifuged and the plasma fractions frozen for later analyses. The same procedure was used for blood samples collected in the doubly labeled water studies.

14. Diurnal rhythm of birds leaving the colony

A time-lapse camera was directed to the part of the mountain from which most birds left for the sea, in order to study the diurnal rhythm of petrels leaving the colony.

15. Ringing

A total of 17 adults and 1483 pulli were ringed by steel rings from Stavanger Museum, Norway.

Snow Petrel

1. Nest microclimate

Air temperatures and temperatures of the ground in the opening of, and just outside, the cave of an occupied nest were recorded continuously for 10 days by thermistors connected to a Grant recorder.

2. Olfactory orientation

12 incubating birds were captured to test whether the adults are dependent of olfactory abilities for orientation to their nests. After their nares had been blocked, they were released about one km away

from their nests, together with 12 control birds. An equal number of birds from both groups returned to their respective nests, indicating that Snow Petrels under the prevailing conditions do not depend on the olfactory sense for nest orientation.

3. Ringing
A total of 25 adults caught on the nest was ringed with steel rings from Stavanger Museum, Norway.

South Polar Skua

1. Predation on Antarctic Petrel chicks
About 50 pairs of South Polar Skua nested close to the Antarctic Petrel colony. They were completely dependent on the petrels with regard to food requirements. Information about the rate of predation was collected from special survey plots (see paragraph 11 above) by countings of fresh prey remains in the skua territories, and by direct observations.

2. Ringing
A total of 50 chicks were ringed with steel rings from Stavanger Museum, Norway.

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GEOLOGY OF GJELSVIKFJELLA AND WESTERN MÜHLIG-HOFMANNFJELLA

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BACKGROUND

Reconnaissance geological mapping in the western Dronning Maud Land began from the 1950's (Roots 1953, 1969) and the results had been synthesized in the "Atlas Antarctiki" (Akademii Nauk 1966). Petrological studies have been done by Russian and South African geologists (Ravich & Soloviev 1966; Gavshon & Erasmus 1975). Some radiometric ages by the K-Ar method gave a concentration of data around 450 Ma for the last orogenic event in western Dronning Maud Land (Ravich et al. 1962).

Norsk Polarinstitutt's expedition 1970/71 mapped H.U. Sverdrupfjella (Hjelle 1974) and three main lithostratigraphic units and structural outline were described.

Japanese expeditions in the last 15 years have recovered more than 6000 meteorites from blue-ice areas behind the coastal mountain ranges in eastern Dronning Maud Land.

OBJECTIVES

a) Regional geological mapping of Gjelsvikfjella and western Mühlig-Hofmannfjella. Since H.U. Sverdrupfjella is totally composed of metamorphic rocks of amphibolite facies, the rocks of Gjelsvikfjella were expected to have a similar grade of metamorphism. However, large charnockite masses have been mapped in western Mühlig-Hofmannfjella to the east. The boundary relation between the rocks of the amphibolite facies and granulite facies was expected to be observed in western Mühlig-Hofmannfjella.

b) Sampling of the rocks for Rb/Sr dating. Most radiometric ages previously obtained are K-Ar ages and reflect the last geological events in the area. It is believed that the rocks experienced a complexed history including events of folding and regional metamorphism older than these ages. Careful sampling of older rocks for the Rb/Sr isochron method may put age constraints on these expected older events.

c) Preliminary search for meteorites. Accumulation of meteorites by ice movement could be expected in the areas behind the mountains of western Dronning Maud Land, similar to those observed in eastern Dronning Maud Land. The group should therefore search for blue ice fields inland of the mountains.

The planned laboratory work include the following:

1. Metamorphic mineral assemblages and digestion process of the amphibolite facies rocks in the charnockites in the Svarthamaren zone will be the main subjects of microscopic studies. Some minerals will be analysed by EMPA for the calculation of metamorphic temperature and pressure.

2. The dating samples will be processed for the mass-spectrographic measurement of isotopes and the Rb/Sr isochron method will be applied to calculate the age of the rocks.

EQUIPMENT

Usual field equipment for geological survey, including explosives to get fresh rocks for the dating.

FIELD WORK

a) The primary aim was to cover the area from Gjelsvikfjella to Svarthamaren in central Mühlig-Hofmannfjella. The crevasse conditions and our skidoo transport prevented us from covering such a large area, but we chose two zones: 1) Gjelsvikfjella zone: Jutulsessen-Terningskarvet (amphibolite facies area), and 2) Svarthamaren zone: Plogskaftet-Skorvebradden (granulite facies area) (Fig. 1). Both zones cut the general trend of the mountain ridges.

Some scattered observations and distant reconnaissance have also been made in western Gjelsvikfjella and Mühlig-Hofmannfjella.

b) After regional mapping of the two zones, the rocks suitable for age determinations were carefully considered and sampled in both zones, each sample 15-100 kg in weight.

c) Blue ice fields were searched for by binoculars from the tops of high peaks visited, but no such fields were observed. A surface search for meteorites was made on hard crusted snow fields, without success.

PRELIMINARY RESULTS

a-1) The Gjelsvikfjella zone:
Detailed lithological and structural studies were achieved in the Jutulsessen area, while the rest of the Gjelsvikfjella was covered by reconnaissance observation. The whole area consists mainly of granitic gneisses and migmatites of amphibolite facies, with small amounts of micaceous and hornblende-bearing gneisses. These rocks were intruded by a biotite-rich, massive melanocratic diorite, and all were again cut by numerous dykes of granitic pegmatite and aplite. Several thin dykes and sheets of the Mesozoic dolorite have been seen in Jutulsessen. Tight and isoclinal folds simultaneous with metamorphism, in a N-S trend, and open large scale folds of km wave length, in a E-W trend, were recognized throughout Gjelsvikfjella.

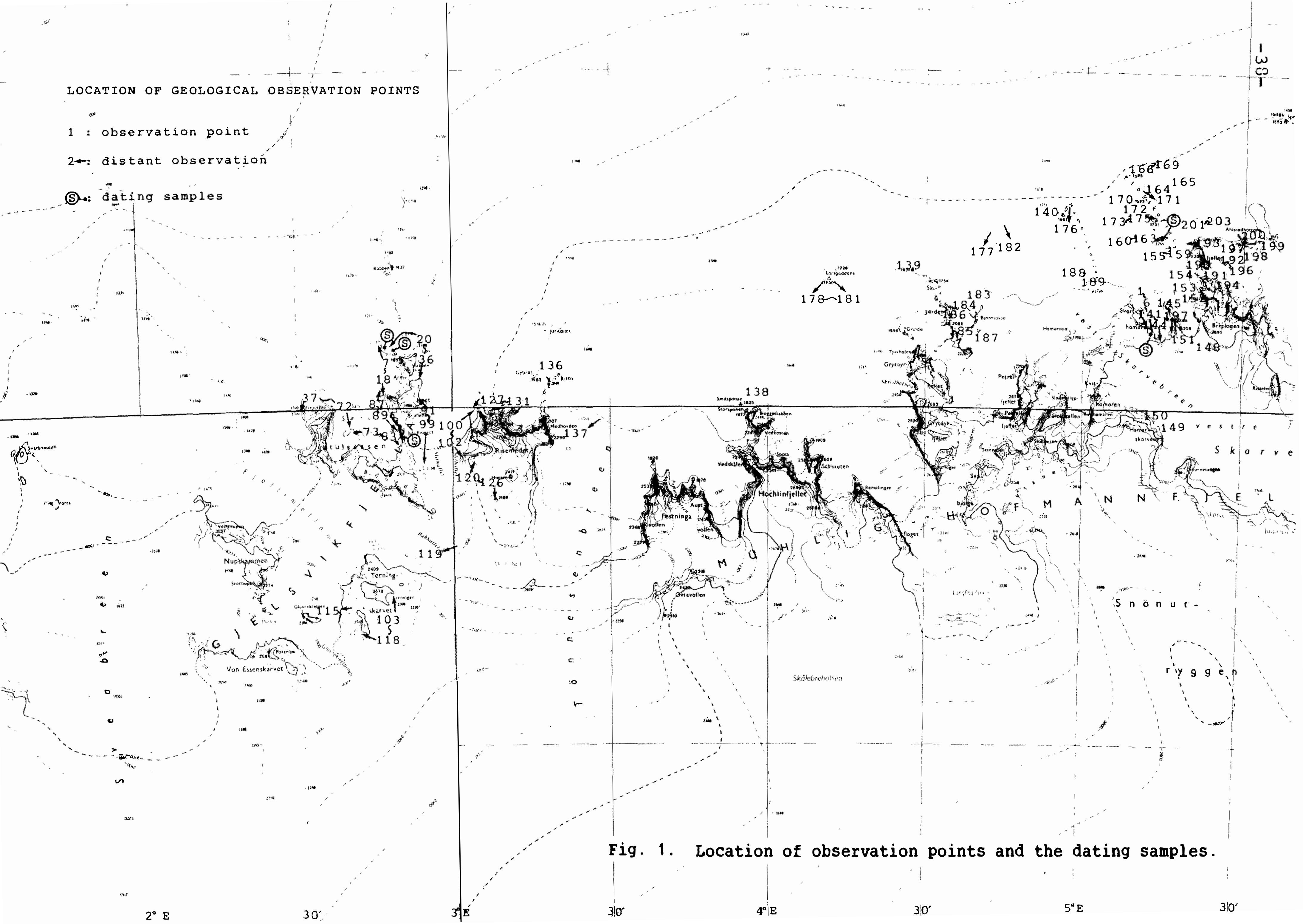

Fig. 1. Location of observation points and the dating samples.

a-2) Svarthamaren zone:
Main rock types are coarse- and medium-grained charnockites (charnockitoids of the Russian definition) and various sizes of xenoliths; banded gneisses, biotite amphibolites and granites of the amphibolite facies mineralogy are included in the charnockites. The amphibolite facies rocks form large masses in the southern part of Mühlig-Hofmannfjella. The contact between the charnockites and the amphibolite facies rocks, so far as observed, is intrusive, the former intruded into the latter, and a zone of transition, as much as 500 m wide, developed locally. It is not clear whether the amphibolite facies rocks of this zone are continuous to those of the Gjelsvik-fjella zone. It is evident in this zone that there is an older amphibolite facies metamorphism before the emplacement of the charnockites.

b) Three dating sample-series were collected in Jutulsessen: pink granitic gneiss, biotite diorite, and cross-cutting granitic peg-matite. Three sample series have been obtained from the Svarthamaren zone: coarse- and medium-grained charnockites and xenolithic granite of the amphibolite facies. The samples are all together about 500 kg.

c) No meteorites were recovered. Snow sampling behind the mountain ridges shows that soft snow is more than 5-6 m in the region and ex-posures of meteorites on the ice surface could not be expected. Possible blue-ice fields are far away from the mountain ridges and a helicopter operation is necessary for the search of meteorites.

Bouvetøya was in addition studied during a day on the return voyage, and four points were visited: 1) Rustadkollen (340 m ridge), 2) 410 m ridge N of Ny Sandefjord, 3) Kapp Valdivia, and 4) E-cliff of destroyed crater SE of Smalstranda. Block lavas at 1), layered thin lavas and tuffs at 2), columner-jointed trachyte at 3), and amygdaloidal lavas altered by secondary fumalor activities at 4) were observed and many samples and a series of dating sample have been collected.

CONCLUDING REMARKS

Because of extremely good weather and snow surface conditions, the field work was satisfactory. We could use more than half the field days for our specific works of geology, and in this respect we thank very much for the help of our field-mates: topographers, glaciologist and botanist.

The first objectve was not completed, but the two geological traverses of the mountain range gave us ideas on the main problems in the area. The second objective is a matter of laboratory work and we are looking forward to the results. The third objective was beyond our transport facilities. A helicopter operation will be needed to establish whether the area has good conditions for the accumulation of meteorites.

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BOTANY OF GJELSVIKFJELLA AND MÜHLIG-HOFMANNFJELLA, DRONNING MAUD LAND

- with some contributions from H. U. Sverdrupfjella and Vestfjella

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BACKGROUND AND OBJECTIVES

There were virtually no documented records of plant life in Gjelsvikfjella and Mühlig-Hofmannfjella prior to the Norwegian Antarctic Research Expedition 1984/85.

The terrestrial flora had previously been treated in other parts of Dronning Maud Land: Heimefrontfjella and Tottanfjella (Ardus 1964, Bowra & al. 1966, Lindsay 1971); Vestfjella (Lindsay 1972, Øvstedal 1983 b), H. U. Sverdrupfjella (Øvstedal 1983 a), the Novolazarev- skaja station area (Sopolev 1969), the Syowa station area (Matsuda 1968, Kashiwadani 1970) and the Sør-Rondane mountains (Dodge 1962).

The work in progress aims at a combined floristic and field description of a continental Antarctic mountain environment. Co-workers at the Universities of Bergen and Trondheim, and at the Norwegian Institute for Water Research, as well as abroad, will deal with the lichen, bryophyte, and algal material from a taxonomical point of view. The total number of collections amount to about 350 lichen specimens, 50 bryophyte and 35 algal samples.

FIELD WORK

I joined a field party of Camp Norway 5 working in the mountains from the eastern outlier of the H. U. Sverdrupfjella at $1^0 35'$E, throughout Gjelsvikfjella, to the middle part of Mühlig-Hofmannfjella eastwards to $5^0 33'$E. Latitudinally, the part of the study area containing rock exposures and plant life extends from $71^0 45'$ to $72^0 20'$S.

The survey maps (Fig. 1a, b) show the location of the 68 stations visited. Most of the stations were seen by the present author, but other members of the expedition, including those of Camp Norway 6, kindly contributed plant collections as seen from Tables 1 and 2. Two reference localities at Jutulsessen (JU) and Svarthamaren (SH) were visited several times, mainly for investigations of the thermal regime, partly in cooperation with Y. Gjessing.

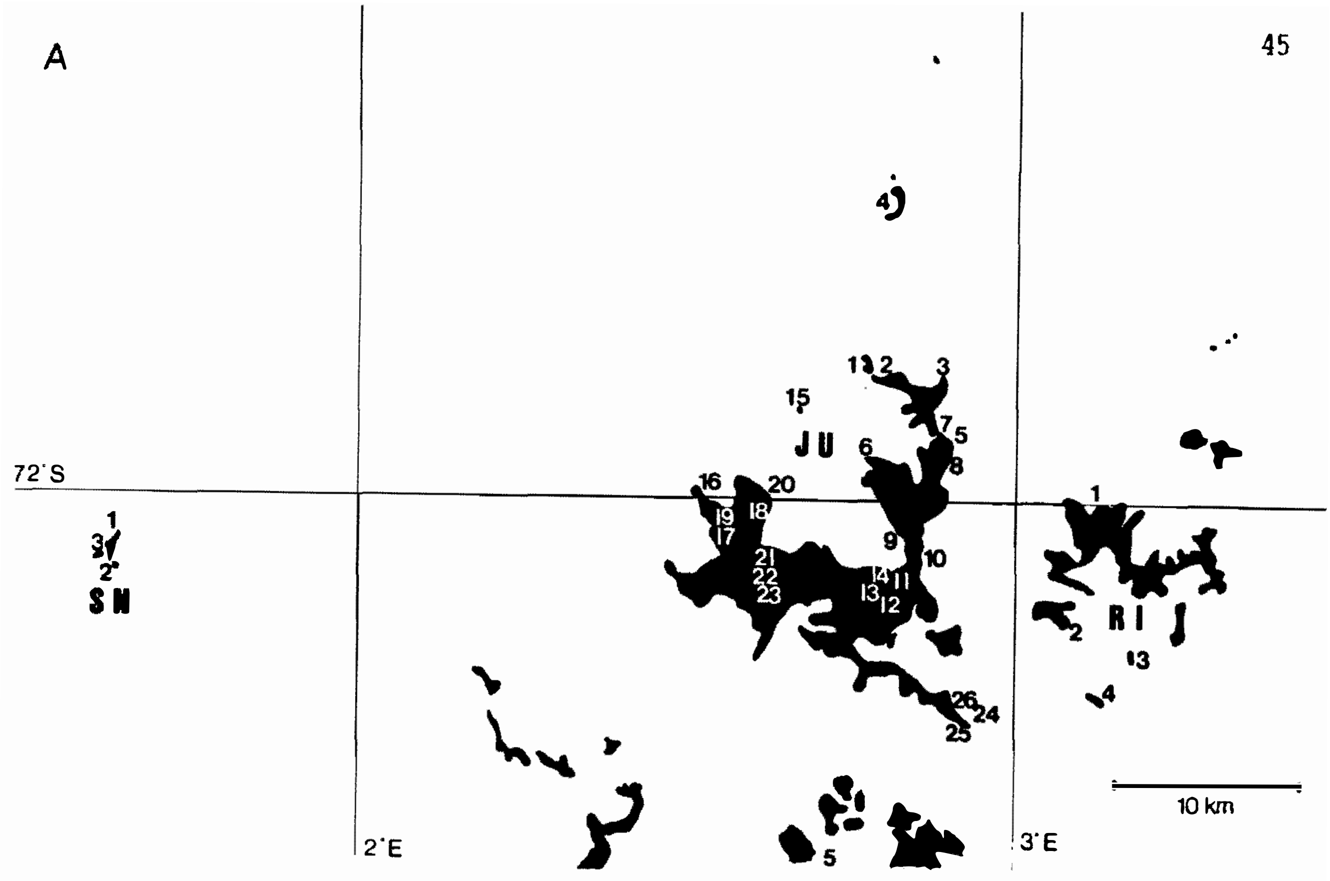
Gjelsvikfjella are situated 220 km inside the ice shelf margin. The lowest exposed ground is the base of the Jutulsessen amphitheater, 1080 m a.s.l. (Fig. 2). This is the largest ice-free area encountered in the region, comprising about 100 km^2 of rocky slopes, talus, and moraine deposits.

Mühlig-Hofmannfjella are generally higher and experience lower temperatures than Jutulsessen.

RESULTS

The following survey of plant communities within the study area is provisional, but indicate the main vegetation units encountered. All may be subsumed under the Antarctic cold desert cryptogame formation (cf. Aleksandrova 1970).

The classification goes from the most species-poor and exposed communities (subformations 0 and 1), through an intermediate one (subformation 2), to the ecologically most demanding fruticose lichen and moss subformations (3 and 4).



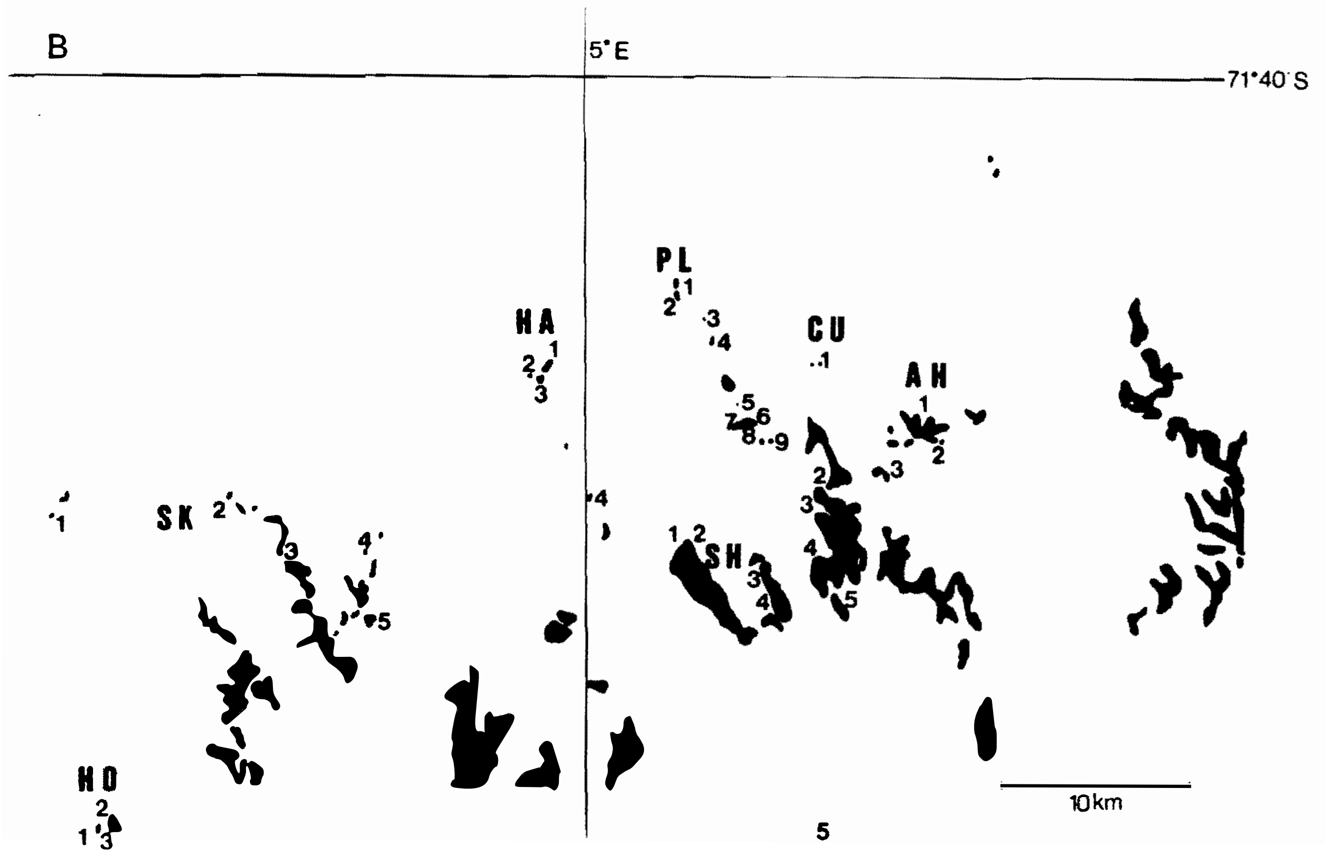


Fig. 1a. Sketch map of part of Gjelsvikfjella, with locality numbers for botanical investigations (cf. Table 1).

Fig. 1b. Sketch map of part of Mühlig-Hofmannfjella with locality numbers for botanical investigations (cf. Table 1).

Fig. 2. The interior of the Jutulsessen amphitheater seen from the N, with extensive areas of bare rock and weathered material. In the background, the mountain Brugda, 2 370 m above sea level.
Photo: T. Engelskjøn, 18 Jan. 1985.

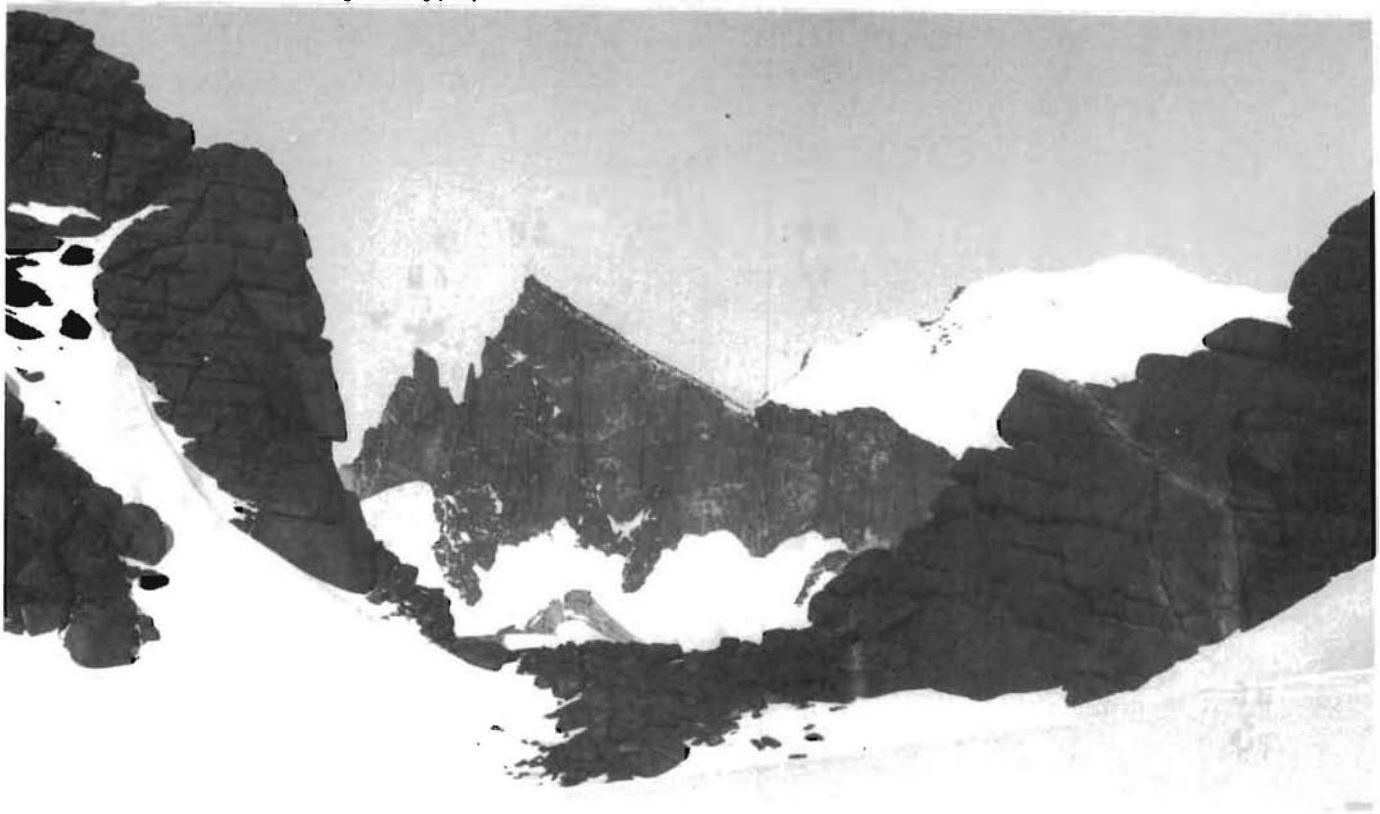


Fig. 3. Cumulusfjellet seen from Plogskaftet. The summit is at 2 333 m elevation, and is extensively ice-covered. In front, charnockite rocks with Xanthoria elegans crusts.
Photo: T. Engelskjøn, 6 Feb. 1985.

Antarctic cold desert cryptogame formation

0. Unicellular algae Subformation
    1. *Chlamydomonas* Association (of open water ponds)
    2. Endolithic algae Association
1. Thallose algae Subformation
    1. Encrusted Cyanophycean - Chlorophycean Association
        1. *Pleurococcus* Sociation
        2. Cyanophycean - *Lepraria* Sociation
        3. *Nostoc* Sociation
        4. *Nostoc* - *Oscillatoria* - *Phormidium* Sociation
    2. *Prasiola* - *Ulothrix* Association
        1. *Prasiola* Sociation
        2. *Ulothrix* Sociation
        3. Various mixed Cyanophycean - Chlorophycean Sociations

2. Epilithic lichen Subformation
    1. *Lecania* sp. - *Lecidea* spp. - *Umbilicaria decussata* Association
        1. *Lecania* sp. - *Lecidea* spp. Sociation
        2. *Buellia frigida* Sociation
        3. *Umbilicaria decussata* - *Acarospora chlorophana* Sociation
        4. *Candelariella hallettensis* - *Rhizoplaca melanophtalma* Sociation
        5. *Acarospora* spp.* Sociation. *) Sect Phaeothallia
    2. *Xanthoria elegans* Association
        1. *Xanthoria elegans* - *Candelariella hallettensis* - *Nostoc* Sociation
        2. *Xanthoria elegans* - *Physcia caesia* - *Umbilicaria aprina* Sociation
        3. *Xanthoria elegans* - *Buellia frigida* - *Acarospora gwynnii* Sociation
        4. *Xanthoria candelaria* Sociation
    3. *Rhizocarpon geographicum* Association
        1. *Rhizocarpon geographicum* Sociation

2. *Lecanora sverdrupiana* Sociation
3. Fruticose lichen Subformation
    1. *Neuropogon* - *Pseudephebe minuscula* Association
    2. *Neuropogon* - *Grimmia* sp. Association
4. Moss cushion Subformation
    1. *Grimmia* sp. Association
        1. *Grimmia* sp. Sociation
        2. *Grimmia* sp. - *Lepraria angardiana* Sociation
    2. *Sarconeurum glaciale* Association
        1. *Sarconeurum glaciale* Sociation

Of special interest were the fairly well vegetated sites on Jutulsessen, and - at the other extreme - the occurrence of sparse vegetation on the cold- and wind-exposed summits of Horten (locality RI 3, 2471 m a.s.l.) and Terningskarvet (locality RI 5, ca. 2500 m a.s.l.). The latter may be the highest sites with macrovegetation from this part of the Antarctic. We could not find comparably elevated records of lichen vegetation from Marie Byrd Land (Siple 1938), although the finds at $86^{0}03'$ in Queen Maud Range (Siple 1938, p. 496) may be at a considerable altitude.

Specific content

Some specific and generic determinations were quoted in the preceding section, to provide a general picture of the composition of vegetation. Considerable more work is needed to determine various critical groups. The algae presently cultivated at the Norwegian Institute for Water Research belong i.a. to the Cyanophycean genera *Chroococcus*, *Lyngbya*, *Nostoc*, *Oscillatoria*, *Phormidium*, *Scytonema*, *Stigonema*, and *Synechococcus*, and the Chlorophycean genera *Chlamydomonas*, *Pleurococcus*, *Prasiola*, and *Ulothrix*.

A preliminary survey of the lichen species comprises i.a.: *Acarospora chlorophana*, *A. gwynnii*, *Bacidia* sp., *Lecanora expectans*, *L. sverdrupiana*, *Lecidea* spp., *Lepraria angardiana*, *Neuropogon antarcticus*, *N. sulphureus*, *Physcia caesia*, *Pseudephebe minuscula*, *Rhizocarpon* aff. *geographicum*, *Rhizoplaca melanophtalma*, *Umbilicaria aprina*, *U.*

decussata, *Xanthoria candelaria*, and *X. elegans*. There are also other species of the genera mentioned.

Among mosses, *Sarconeurum glaciale* and *Grimmia* sp. seem to be the only representatives.

CONCLUSIONS

The material now available comprises about 35 species of lichens, 2 bryophyte species, several cyanophyceans belonging to at least 8 genera, a similar number of chlorophyceans, and some diatoms. The future working up of the material aims at a taxonomic clarification of the groups mentioned; a phytogeographical comparison with floras to the W and E of the study area, and an ecological assessment of the particular Antarctic-alpine environment visited, which supports plant growth up to an elevation of about 2500 m above sea level.

Table 1. Visited localities in Gjelsvikfjella, Mühlig-Hofmannfjella and H. U. Sverdrupfjella

Locality index	Place designation	Elevation (m)	Investi-gator	Date 1985
JU - Jutulsessen area				
1	Stabben WNW	1200-1380	TE	18-31.1
2	Stabben NW	1300-1400	"	20.1
3	Stabben NE	1400-1600	"	19.1
4	Rabben	1300-1432	"	19.1
5	Armlenet NNE	1400-1450	BT	31.1
6	Armlenet NW	1150-1250	TE	18.1
7	Armlenet, pass to N	1450	BT	31.1
8	Armlenet NE	1550	"	20.1
9	Jutulhogget NNW	1100	TE	23.1
10	Jutulhogget SSW	1500-1600	YG, YO	27.1
11	Jutulhogget SW, SE valley	1080-1300	TE	23.1
12	Brugda N	1350-1500	"	23.1
13	Brugda NW, plateau	1500-1600	"	23.1
14	S cirque, lower slopes	1080-1200	"	23.1
15	Nunatak 1170	1160-1170	"	18.1,21.1
16	Grjotlia NW	1150-1390	"	21.1
17	Grjotlia SW 1620	1400-1500	"	21.1
18	Grjotlia S 1620	1600-1700	"	21.1
19	Grjotlia, brook to NW	1450	"	21.1
20	Grjotlia, N base	1100	"	22.1
21	SW cirque, outlet	1120	"	22.1
22	SW cirque, middle part	1200-1300	"	22.1

23	SW cirque, interior	1300-1500	"	22.1
24	Brugda, SE outlier	1990-2020	"	27.1
25	Brugda, SE slope	2000-2150	"	27.1
26	Brugda, SE summit	2150	"	27.1
RT - Risemedet - Terningen area				
1	Medmulen N	1500	BT	31.1
2	Nunatak NNW 2188	2050	"	29.1
3	Horten, N side and summit	2450-2471	TE	28.1
4	Summit 2188	2160-2188	"	29.1
5	Terningskarvet SW 2678	2550-2678	KS	28.1
HO - Hoggestabben area				
1	Småsponen E	1700	TE	1.2
2	Hoggestabben NW	1650	"	1.2
3	Hoggestabben W	1650	"	1.2
SK - Skigarden area				
1	Larsgaddane SW	1630-1650	TE	16.1
2	Skigarden 1651	1600-1640	"	1.2
3	Skigarden S 1754	1650	"	10.2
4	Bjørnsaksa N, outlier	1620-1650	"	10.2
5	Nunatak S Bjørnsaksa	1759-1850	"	10.2
HA - Hamarskaftet nunatak group				
1	Nunatak NE 1661	1600-1620	TE	1.2,3.2
2	Nunatak SW 1661	1600-1620	"	3.2
3	Summit 1661	1600-1661	TE,BT,KS	16.1,1.2,3.2
4	Nunatak NNW 1745	1580-1600	TE,LS	10.2,13.2
PL - Plogskaftet nunatak group				
1	Nunatak N 1595	1550	TE,CB	8.2
2	Summit 1595	1540-1560	TE,CB	8.2
3	Small nunatak NW 1623	1530	TE	8.2
4	Summit 1623	1550-1623	"	8.2
5	Small nunatak NE 1755	1610	"	7.2
6	Summit 1755, NE base	1580-1590	"	7.2
7	Summit 1744, N base	1600-1620	TE,SH	7.2
8	Summit 1755, E crest	1670-1680	TE	7.2
9	Nunatak ESE 1755	1600	"	6.2,7.2
SH - Svarthamaren area				
1	Svarthamaren, NW base	1600	TE	11.1,14.1
2	Svarthamaren, NE base	1590-1600	"	11.1,15.1, 12-14.2
3	Båsbolken, NW base	1620-1630	TE,LS	15.1
4	Båsbolken W 2385	1650	BT	
5	Skorvetangen	2600-2680	TEi,KS	12.2

CU - Cumulusfjellet - Breplogen area

1	Cumulusfjellet N, E nunatak	1550-1570	TE	11.2
2	Cumulusfjelleet SW	1800-1820	TE, YO	11.2
3	Høgsenga, NW cirque	1700	TE	16.2
4	Høgsenga, W cirque	1650-1660	"	6.2
5	Breplogen, summit 2695	2600-2695	BT	9.2

AH - Ahlstadhottane area

1	Crest E summit 2065	1920	TE,BT	11.2
2	Nunatak SE 2065	1790-1820	TE,YO	11.2
3	Nunatak N Sengekoven	1700	" "	11.2

SN - H. U. Sverdrupfjella NE: Snarbynuten

1	Summit 1615 N	1600/10	KS	23.1
2	Summit 1615 S	1600/10	"	23.1
3	SW outlier of Snarbynuten	1570/80	"	23.1

Table 2. Additional localities in Vestfjella

Locality index	Place designation	Elevation (m)	Investigator	Date 1985
VN - Vestfjella, northern summits				
1	Basen, SE side	400-580	SJ,SO	28.1-1.2
2	Plogen, N side	200-250	SJ,SO	24.1
3	Plogen, W side, outlier	250	SJ,SO	24.1
VM - Vestfjella, middle summits				
1	Dagvola, upper part	1132	RL, HF	24.1
2	Dagvola, nunatak NE summit	1000	SJ,SO	23.1
3	Fossilryggen	709	KMB	8.2
4	Pukkelryggen NW and S	769-810	SJ,SO	25.1
VS - Vestfjella, southern summits				
1	Skansen S	280-300	RL,SJ,SO	6-9.2
2	Muren E/ Nimbusryggen NE	490	RL,SJ,SO	7.2
3	Steinkjeften W and E	400-550	SJ,SO	11-12.2

Name of collectors - abbreviations:

CB: Claus Bech
KMB: Kaare M. Bratlien
TE: Torstein Engelskjøn
YG: Yngvar Gjessing
SH: Svein Haftorn
SJ: Stig Jonsson
SO: Snorre Olaussen
KS: Knut Svendsen
LS: Lauritz Sømme

TEi: Trond Eiken RL: Reidar Løvlie BT: Bjørn Tørudbakken
HF: Harald Furnes YO: Yoshihide Ohta

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TERRESTRIAL INVERTEBRATES OF MÜHLIG-HOFMANNFJELLA

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BACKGROUND AND OBJECTIVES

Relatively little is known about the invertebrate fauna of the remote areas of the Antarctic continent due to their inaccessibility. Reviews on the invertebrates of the Antarctic in general have recently been published by Block (1984) and Sømme (1985). In Dronning Maud Land studies on the fauna of terrestrial invertebrates have so far been concentrated on mites and insects. The oribated mite Maudheimia wilsoni was the first known representative of these groups from this part of the continent (Dalenius & Wilson 1958). Later collections have been made in Heimefrontfjella (Bowra et al. 1966), H.U. Sverdrupfjella (Strandtmann & Sømme 1977; Lawrence 1978) and Vestfjella (Sømme 1980), as well as from Lützow-Holm Bay, East Antarctica (Ohyama & Matsuda 1977). Some information on other groups of invertebrates - protozoans, nematodes, rotifers and tardigrades - is available from East Antarctica (e.g., Sudzuki 1979), but not from the main mountain ranges of Dronning Maud Land.

One of the purposes of the present study was to collect samples of all groups of invertebrates from the mountain range of Mühlig-Hofmann-fjella. Information on the occurrence and distribution of the invertebrates is of great interest for zoogeographical studies. Data from this range may contribute to the discussion on the origin of the fauna, which may comprise both relic and an immigrant element.

Another purpose was to make ecological investigations on insects and mites from the mountain ranges of Dronning Maud Land. At present very little is known about the cold hardiness of invertebrates from the Antarctic continent, while more information is available from the maritime and Sub-Antarctic zones (for reviews, see Block (1984) and Sømme(1981)). It is remarkable that all springtails and mites studied so far are killed by freezing, and depend on supercooling for their survival. It has become increasingly clear that the adaptation of invertebrates to polar climates involve several factors. The present project is an attempt to understand the occurrence and survival of arthropods in one of the earth's most hostile environments.

EQUIPMENT AND METHODS

A single species of springtails (Collembola) was found to occur in large numbers at the base of the *Prasiola* vegetation. Due to its availability the ecological studies were concentrated on this species.

Laboratory work was carried out in a small field hut. The space of 2 x 3 m was shared with two of the ornithologists. Collembola and mites were extracted from samples of vegetation in small Tullgren funnels. Sources of heat during daytime were 15 W bulbs, which were supplied by electricity from a portable petrol generator, and 15 W bulbs during the night based on electricity from a lead battery re-loaded by a solar panel. In addition to extraction, Collembola were collected directly with an aspirator in the field.

For studies on the cold-hardiness of the Collembola, supercooling points were measured by a copper-constantant thermocouple connected to a one-point Grant battery-operated recorder. Measurements were made on field-collected specimens at the beginning and end of the period. To study the effect of starvation on cold tolerance, some specimens were kept without food for several days. The tolerance to desiccation was studied at 0-5% and 40-50% RH. The temperature of the laboratory hut could not be controlled during the experiments, and varied between -10 ^{0}C at night and up to +10 ^{0}C on sunny days.

The temperatures of the microhabitats of the Collembola were monitored at hourly intervals by a Grant Squirrel Logger. Three series of four days duration were conducted.

PRELIMINARY RESULTS

Habitat description

The ecological part of the project was carried out at the main camp at Svarthamaren in the Mühlig-Hofmannfjella (see map, p. 23). The camp was situated at 1600 m a.s.l. During our stay from 13 Jan. to 15 Feb. the air temperatures never rose above 0^{0}C, and ranged mostly from $-5\ ^{0}$C to $-15\ ^{0}$C. The weather was mainly sunny, with a few overcast days. Light precipitation of snow occurred only once or twice.

North of the giant Antarctic petrel colony (Mehlum et al., this volume), at the NW side of Svarthamaren, a small field of ice-free ground was covered by relatively dense vegetation of green Prasiola algae. The abundant growth of this plant in the gravel of the field was based on fertilizers from the petrel colony, and on the seepage of melt water from the edges of surrounding glaciers on sunny days. Due to its lower position (Fig. 1) in relation to the glaciers, the "Prasiola-field" received ample supplies of water during the summer months. Close by the plants also grew in crevasses of large boulder, were they received moisture by the melting of drifting snow.

Ecological studies

After the author's return to Oslo the species of Collembola from Svarthamaren has been identified as Cryptopygus sverdrupi Lawrence, 1978 (Fig. 2). This species is previously only reported from the H.U. Sverdrupfjella about 100 km west of the present location (Lawrence 1978).

Counts of Collembola from samples of vegetation indicate that numbers per area may equal those of temperate and Arctic habitats. The occurrence of Collembola at Svarthamaren, however, was spotwise and sporadic. Thus, specimens of C. sverdrupi were only present in a small fraction of vegetation samples from the Prasiola-field.

The relatively dense clusters of Collembola in some places suggest that favourable ecological conditions exist. These are based on the

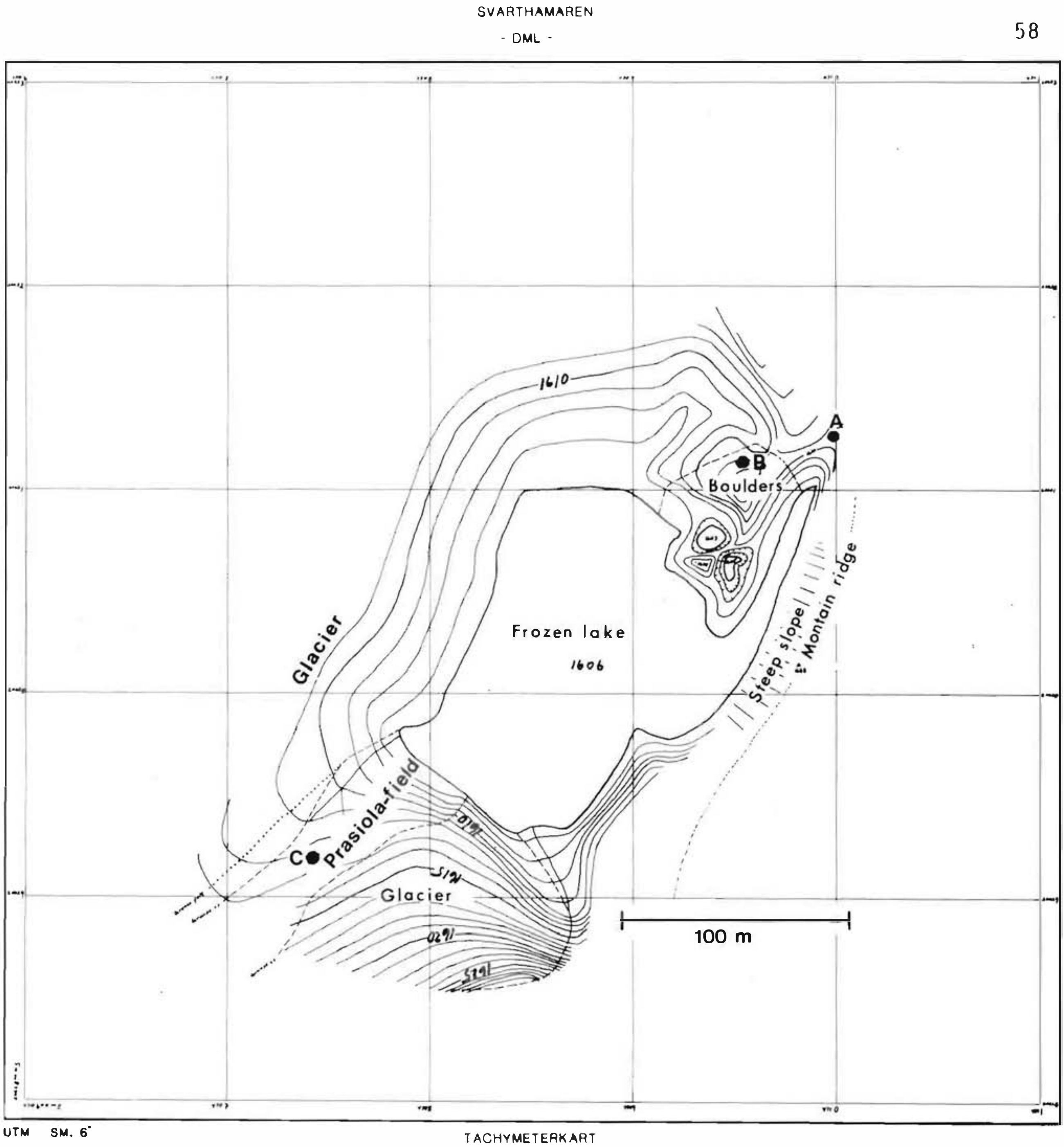

Fig. 1. Map of the "Prasiola-field" at the NW side of Svarthamaren. A, B, and C are sites of temperature recordings as presented in Fig. 3. Measurements and drawing by Trond Eiken and Knut Svendsen, Norsk Polarinstitutt.

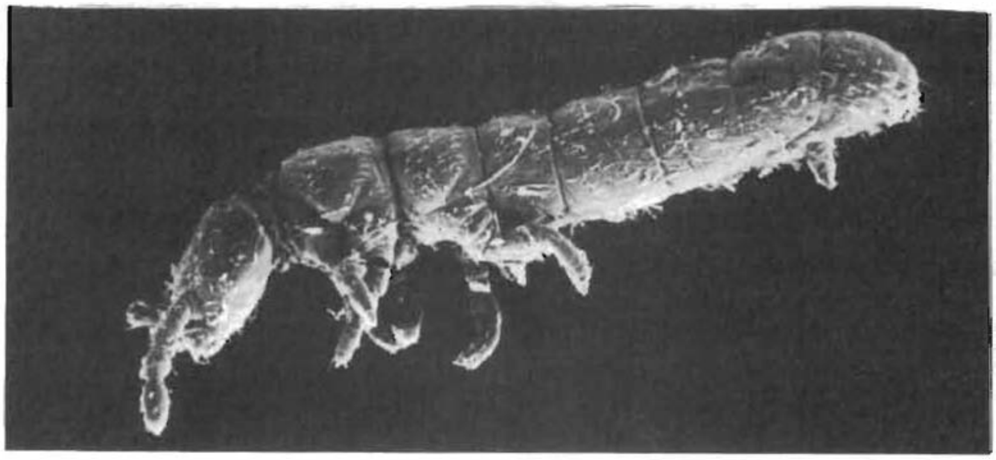

Fig. 2. Collembola from the _Prasiola_ field at Svarthamaren, identified as _Cryptopygus sverdrupi_ Lawrence 1978. SEN photo: Laboratory for Electron Microscopy, Dept. of Biology, University of Oslo.

moisture and fertilizers that give growth to Prasiola and associated micro-algae. The Collembola presumbly feed on unicellular and filamentous green algae at the base of the Prasiola vegetation.

In January the temperature at the base of the vegetation rose above 0^0C for some hours each day (Fig. 3A,B). On some sunny days +8^0C to +9^0C were recorded. Lower temperatures were recorded on cloudy days, or when the vegetation was covered by drifting snow. At night the temperatures sank several degrees below freezing. From early February a marked change in the temperature regime took place, and it remained below 0^0C during daytime at the base of the vegetation (Fig. 3C). At this time the Collembola had a tendency to gather underneath rocks that were slightly heated by the sun. Gradually they disappeared, probably seeking deeper into the gravel. These observations suggest that for the Collembola the summer comes to an end in the early part of February. It is not known when their summer activities start, but probably not until the month of December. This gives an overwintering period of ten months. Furthermore, during the summer the animals are only active part of the day, when their microhabitats are heated by the sun (Fig. 3).

Preliminary studies on cold hardiness suggest that C. sverdrupi has greater capacity of supercooling than other Antarctic species. Further investigation on this question is in progress with long-period cold acclimation of specimens brought to Oslo.

The resistance of C. sverdrupi to desiccation above silica gel or at 40-50% RH is high compared to most other Collembola. The present Cryptopygus-sp. may be exposed to desiccation in their microhabitats when melting of ice and snow ceases during unfavourable weather conditions, or during the winter.

Faunistical studies

Several samples of prostigmate mites and of Collembola were collected by the author on nunataks within 10-15 km of the camp. Other samples were collected by Torstein Engelskjøn (this volume).

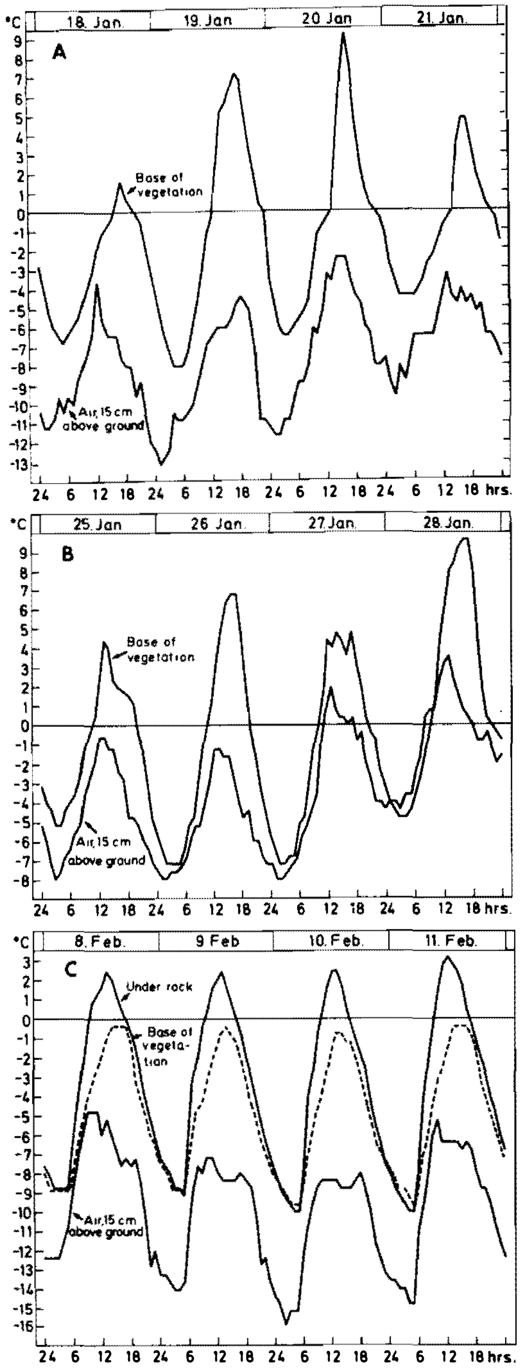

Fig. 3. Temperature recordings from micro-habitats of Collembola at the base of Prasiola vegetation. Corresponding air temperatures about 15 cm above the ground were recorded by a thermistor surrounding and shaded by rocks. A: in crevasses on boulder; B, C: in gravel.

at Jutulsessen about 80 km west of Svarthamaren. An oribated mite was present in material from this location.

Vegetation samples for the studies of other invertebrates were also collected from the surrounding nunataks by the author, and by Torstein Engelskjøn and Bjørn Tørudbakken from more distant habitats further west. A total number of twenty samples were collected for this purpose. Preliminary examination for the Prasiola vegetation at Svarthamaren revealed a rich fauna of protozoans, nematodes and rotifers.

Furthermore, ten samples of vegetation for faunistical studies were collected from Vestfjella in the western part of Dronning Maud Land by Dr. Stig Jonsson, who was a member of the Camp Norway 6 group.

The vegetation samples were stored at outdoor conditions in the camps, and shipped to Oslo in the cold room (+3^{0}C) of the expedition ship. They were subsequently divided in sub-samples for the examination of protozoans, nematodes and tardigrades by the following specialists on these groups:

Dr. H.G. Smith, Coventry Polytecnic, Coventry (Protozoans)
Dr. N.R. Maslen, Tropical Development and Research Institute, London (Nematodes)
Dr. W. Block, British Antarctic Survey, Cambridge (Cold hardiness of nematodes)
Cand. real. Terje Meier, Dept. of Biology, University of Oslo (Tardigrades)

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METEOROLOGICAL AND GLACIOLOGIAL STUDIES IN DRONNING MAUD LAND

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BACKGROUND AND OBJECTIVES

I conducted three studies during NARE 84/85:

a) Studies of the microclimate in the vegetation on nunataks.

b) A survey of the SO_4/Na ratio and of the content of heavy metals in snow.

c) Studies of the energy and mass balance of the blue-ice area near Jutulsessen.

a) The conditions at the nunataks in Mühlig-Hofmannfjella in Antarctica, situated 1500- 3000 m above sea level, represent one of the limits for plant life on earth.

The mean temperature for the warmest month is below 0^0C and winter temperatures may drop below -50^0C. Due to high intensity of solar radiation in summer and low albedo the surface temperature of the nunataks may be considerably higher than the air temperature, especially in small niches protected from the wind. The vegetation in these niches is very susceptible to desiccation.

b) It has recently been shown that in the central areas of the Greenland and Antarctic ice sheets the chemical composition of surface snow and of the low altitude atmosphere are closely related (Boutron & Lorius 1979). Dronning Maud Land is 3-4000 km from the nearest anthropogenic source of atmospheric contaminant, making this region quite suitable for an areal study of the relative contribution of marine and non-marine sources to the snow chemistry.

Studies at the ice shelf Riiser-Larsenisen (Gjessing 1984) showed a close co-variation between ions of presumably marine origin, and non-correlation between these ions and ions of presumably nonmarine origin. Evidence also indicate that a loss of SO_4^{2-} from the snow to the atmosphere by volatilization was occurring near the coast.

The concentration of NO_3^- and NH_4^+ in snow on Riiser-Larsenisen was constant from the coast towards the interior as was the annual snow accumulation. These ions are supposedly transported to Antarctica through the stratosphere from remote sources. It is therefore reasonable to assume that the background concentrations of these ions are constant over larger areas. The constant content of nitrogenic ions in snow at Riiser-Larsenisen indicates that the contribution from dry and wet deposition of these ions is constant in this area. By studing the concentration of nitrogenic ions in areas with snow accumulation gradient, it should be possible to study the relative contributions from dry deposition and wet deposition.

c) There are areas in Dronning Maud Land with blue ice where snow drifts away and the mass balance is negative. These areas are often depressions where the saddle point is 100-200 m higher than the lowest point of the depression. The albedo for these areas (about 50%) is much lower than for snow and ablation from melting and evaporation may take place. On the other hand, the negative mass balance must be compensated for by an ice flow into the depression. This project was proposed by Olav Liestøl.

EQUIPMENT AND FIELD WORK

a) Some 30 thermometers were placed in the vegetation or just under the sandy surface at locations with different slope and slope directions, different vegetation and different wind exposure. In addition, solar radiation, albedo, wind velocity, and air temperature were recorded every 15 min. on Aanderaa data loggers during a 2-5 week period. The surface temperatures were also measured by infrared thermometers (PRT-5). The evaporation from different species of moss and lichen was also calculated by a weighing method.

b) Snow samples were collected from the wall of 5 snow pits on the shelf at different distances from the shelf edge, and from 3 pits inland at different elevations. Also, a number of ice cores from the blue ice areas were taken. Samples were collected at intervals of 7-10 cm, transferred to double polyethylene bags and kept frozen during the transport to the laboratory.

Concentrations of the following elements will be determined: Ca^{2+}, Na^{+}, Mg^{2+}, SO_4^{2-}, Cl^{-}, NH_4^{+}, NO_3^{-}, and Cd^{2+}.

c) Profiles of temperature and air humidity, wind velocity and fluxes of short wave and long wave radiation over the blue ice area were recorded every 15 min. on Aanderaa data loggers during a 15 day period. The ice flow was determined by measuring the position of stakes on ice relative to stations on rock before and after the 15 day period. Differences in concentration of sea salt in ice samples taken from these blue ice areas and in snow outside this area will be used as a measure of evaporation from blue ice.

PRELIMINARY RESULTS AND CONCLUDING REMARKS

The meteorological data were recorded on magnetic tape and the processing of these data are in progress.

The chemical analyses of the about 150 snow and ice samples that were collected are now carried out at Bergen Technical Engineering College. The glaciological studies near Jutulsessen also included measurements of the ice flow into the depression. The velocity of this flow was determined to 2-3 m $year^{-1}$.

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GEOLOGICAL AND PALAEOMAGNETIC RESEARCH IN VESTFJELLA DRONNING MAUD LAND

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BACKGROUND

The nunataks of the Vestfjella region consist of subaerial basalt flows dipping slightly to the west/northwest and cut by numerous dykes (locally as dense swarms). Radiometric (K-Ar) ages of the continental, predominantly tholeiitic lava flows increase progressively from 170 Ma in the east (Kjakebeinet) to 330 Ma to the west (Muren) (Furnes & Mitchell 1978). Taking into account that all lava piles have a westerly dip, the observed age relationship suggests the presence of a fault system downthrowing the sequence to the east and separating at least some of the nunataks.

If the observed ages of the lava piles are seen in conjunction with the proposed fault system, some problems may arise if Vestfjella are regarded as the counterpart to the coastal Mesozoic lavas in S.E. Africa.

Palaeomagnetic pole positions from both dykes (155-170 Ma, Furnes & Mitchell 1978) and lava flows are in general accordance with proposed reconstruction models for Gondwanaland (Løvlie 1979), in which the Mesozoic lavas in S.E. Africa appear to be the continuation of the Vestfjella basalts.

OBJECTIVES

a) Extended geological and palaeomagnetic sampling programme of basalts in Dronning Maud Land (DNM) in order to elucidate the hypothses that the latter represents repeated (?) failed rift magmatism.

b) Determine the regional extent of different geochemical provinces (incompatible trace elements) in DML to compare with those of S.E. Africa, enabling a more precise reconstruction of the relative position of the two continents prior to the onset of the Mesozoic continental drift episode.

c) Establish magnetostratigraphic sections for a more precise local/ regional correlation between different nunataks.

EQUIPMENT AND TECHNIQUES

1. Water-cooled, motorized (two-stroke) diamond drill corer (diameter: 19 mm) for collecting oriented core-samples (Fig. 1). Azimuthal orientation performed by employing both magnetic and sun compass.

2. Spinner-magnetometer (MINISPIN) for the determination of directions and intensities of the natural remanent magnetization (NRM) in short (15-25 mm) cores.

3. Proton-precession magnetometer (Geometrics G 826) mounted on a sledge, with data acquisition at 200-500 metres intervals (Fig. 2).

Fig.1. Field operation of motorized, water-cooled diamond corer.

Fig. 2. Tape recording of magnetometer measurement. Note position of magnetometer sensor above the head of the operator.

FIELD WORK

Samples for geochemical and palaeomagnetic analysis were collected from lava flows at 13 different nunataks, extending the sampling coverage of representative dykes obtained during NARE 1976/77. Sampling localities are shown on the sketch map, Fig. 3. Table 1 summarizes the number of samples collected at each site.

TABLE 1

Summary of sampling program

NUNATAK	Number of sites/samples	
	Geological	Palaeomagnetic
Fossilryggen	3 / 7	5 / 38
Grushallet	1 / 3	2 / 11
Dagvolinga	1 / 3	3 / 15
Dagvola	1 / 5	3 / 17
Pukkelryggen	3 / 16	7 / 33
Salryggen	2 / 11	9 / 43
Basen	2 / 23	6 / 29
Plogen	2 / 12	6 / 31
Pagodromen	1 / 15	15 / 54
Nimbusryggen	1 / 7	4 / 14
Skansen	2 / 21	4 / 16
Muren	3 / 15	9 / 29
Steinkjeften	1 / 6	3 / 13
Kjakebeinet	1 / 8	6 / 22
Total	24 /152	82 /365

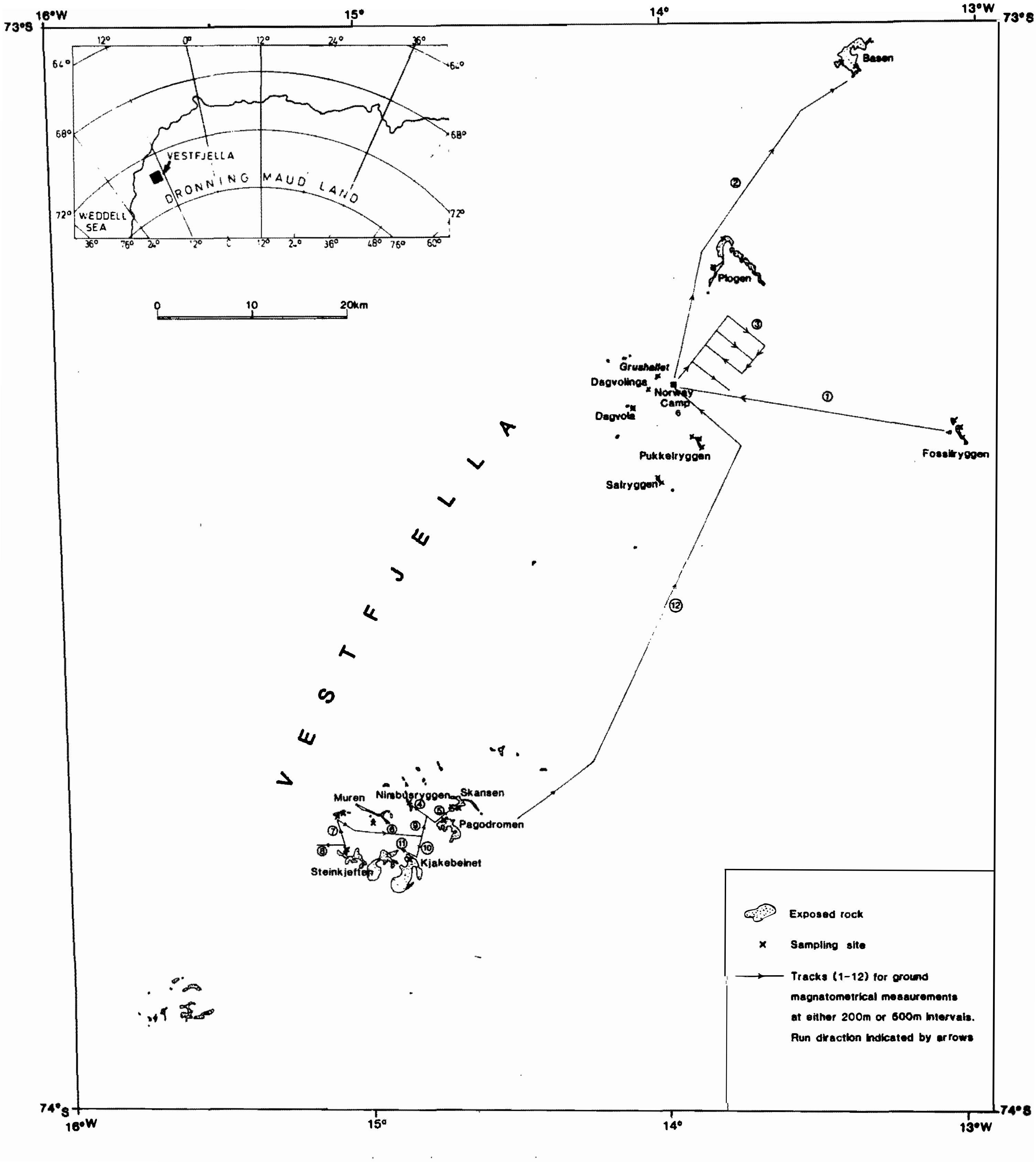

Fig. 3. Sketch map of the Vestfjella region. Sampling localities are marked by X. Numbered straight lines = magnetometer tracks.

PRELIMINARY RESULTS

Field observations confirmed the presence of slicken side structure always associated with dyke contacts. The sense of relative movement is in accordance with the proposed working hypothesis; a fault system downthrowing the sequence to the east.

Palaeomagnetic measurements (NRM) indicated the presence of both normal and reversed polarity lava flows, the latter modified by magnetic overprints of predominantly normal polarity. NRM intensities from 16 lava flows covering a vertical section (400 m) of the exposed part of Pagodromen showed significantly higher values at the top 1/3 of the section, reflecting significant differences in either geochemical composition (bulk magnetomineralogy), or degree of hydrothermal alteration. Unambiguous reversed polarity magnetizations were encountered only in lava flows from Grushallet. The degree of magnetic overprint appears to depend on the distance to neighbouring dyke intrusions.

Combined magnetic/sun compass readings (N = 120) define a magnetic deviation in the area of -9.4 ± 1.8 (9.4^0W).

Total magnetic field strength was obtained along 13 profiles covering some 218 km. The results (direct readings) indicate significant contrasts in magnetic source body properties occurring at short distances from the exposed parts of nunataks. The NNE strike of a magnetic "lineament", running east of Dagvola, are in general agreement with the strike of one set of dykes found at all nunataks.

CONCLUDING REMARKS

Geological structures within the Vestfjella region appear to confirm the proposal that at least this part of the Transantarctic Mountains was exposed to tectonic activity succeeding or coinciding with the presumably last intrusive event in this area occurring in late middle Jurassic times.

The collected samples are likely to yield additional geochemical, radiometric and palaeomagnetic information necessary for a better understanding of the evolution of this magmatic province situated close to the continental margin of East Antarctica.

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SEDIMENTOLOGICAL RESEARCH IN NORTHWESTERN PART OF DRONNING MAUD LAND

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BACKGROUND

Sedimentological investigations of Jurassic and Permian rock sequences were carried out on the nunataks of the northern part of Vestfjella, Dronning Maud Land (Fig. 1A). The nunataks in this area are predominantly Jurassic subaerial basalt flows with rare intercalations of sedimentary rocks which are cut by dykes. The Permian sequence in Fossilryggen (Fig. 1), has been previously interpreted as continental deposits. The flora within the sequence suggests an early Permian age and is slightly younger than the flora from Heimefrontfjella, approximately 100 km southeast of Fossilryggen (Hjelle & Winsnes 1972). Radiometric dating (Furnes & Mitchell 1978) combined with geological mapping (Hjelle & Winsnes 1972) suggests the presence of a fault system downthrowing to the east (Furnes & Løvlie this volume). Minor normal faults, downthrown to the northwest and often associated with Jurassic dykes, are seen at the Fossilryggen locality. Vestfjella, together with Heimefrontfjella 100 km to the southeast, is probably part of a Jurassic rift system (Furnes et al. unpubl.) and Fossilryggen could then be interpreted as situated on a horst block within the rift (Fig. 1).

OBJECTIVES

This project, being undertaken is in close cooperation with the current volcanic and palaeomagnetic study (Furnes & Løvlie this volume), places emphasis on the description and interpretation of Permian sedimentary rock sequences at Fossilryggen. The facies patterns and petrography of the sedimentary rock sequences will be related to basinal tectonism, volcanicity and regional development. Sedimentary rocks associated with the Jurassic lava flows in the area are also included in the project.

TECHNIQUES

The following methods are used in the project:

1. Field work, including sample collecting, logging and description of each different lithology and outcrop.

2. Laboratory analysis including petrographic studies (thin section analyses - polarized/luminescent light, x-ray diffraction and scanning electron microscopy of whole rock and clay minerals) and biostratigraphic studies if sufficient material is available.

FIELD WORK AND PRELIMINARY RESULTS

Sedimentology of the Permian beds at the Fossilryggen and adjacent nunataks

The sedimentary sequence at Fossilryggen was examined in three different sections. The most complete section (section 1, Fig. 1B) was logged in the southern part. Here a 55 m thick sandstone and shale sequence with minor limestone (marble) beds are exposed. An approximately 30 m thick sequence (section 2, Fig. 1B) of shale with Permian plant fossils and minor sandstones outcrops in the northern part. The third sequence (section 3, Fig. 1B) occurs in two nunataks close to Fossilryggen. Section 3 comprises a 30 m thick sequence of burrowed sandy shale, and shale intercalated with thin sandstone and minor limestone (marble) beds. In addition, an approximately 5 m thick cross-stratified sequence of sandstone and black shale similar to the lower part of section 1 at Fossilryggen, outcrops 5 km towards the northeast (Fig. 1A). The suggested continental nature of the outcropping sedimentary rocks at Fossilryggen (Hjelle & Winsnes 1972) is probably mainly based on the occurrence of dark coaly shale with Permian plant fossils in the northern part (section 2). Plant macrofossils in the southern part (section 1) are too badly preserved for specific determination.

It was concluded by Hjelle & Winsnes (1972) that section 1 and 2 are correlatives. However, this conclusion is questioned because of the following:

1. The shale is sandy and in part thoroughly burrowed in section 1, and not in section 2.
2. Limestone (marble) beds are interbedded in section 1 whereas only individual carbonate cemented beds and concretions are seen in section 2.
3. Coal fragments and coaly shale occur in section 2, but are not observed in section 1.
4. The sandstone in section 2 differs from that of section 1 in the lack of burrows, colour and facies patterns (see Fig. 2).

Normal faults, often associated with Jurassic dykes, are common. The faults are seen as faultplanes dipping toward the northwest in the southern part of the nunatak. Due to the lack of exposure the stratigraphic relationship between the sections cannot be determined. Downfaulting towards the northwest, separating the southern and northern parts of Fossilryggen, suggests that section 2 is stratigraphically younger than section 1. The topographically much lower section 3 is probably also separated by faults and is downfaulted towards the west in comparison with section 1 and 2. Similarities in lithology and bioturbation in the upper part of section 2 and lower part of section

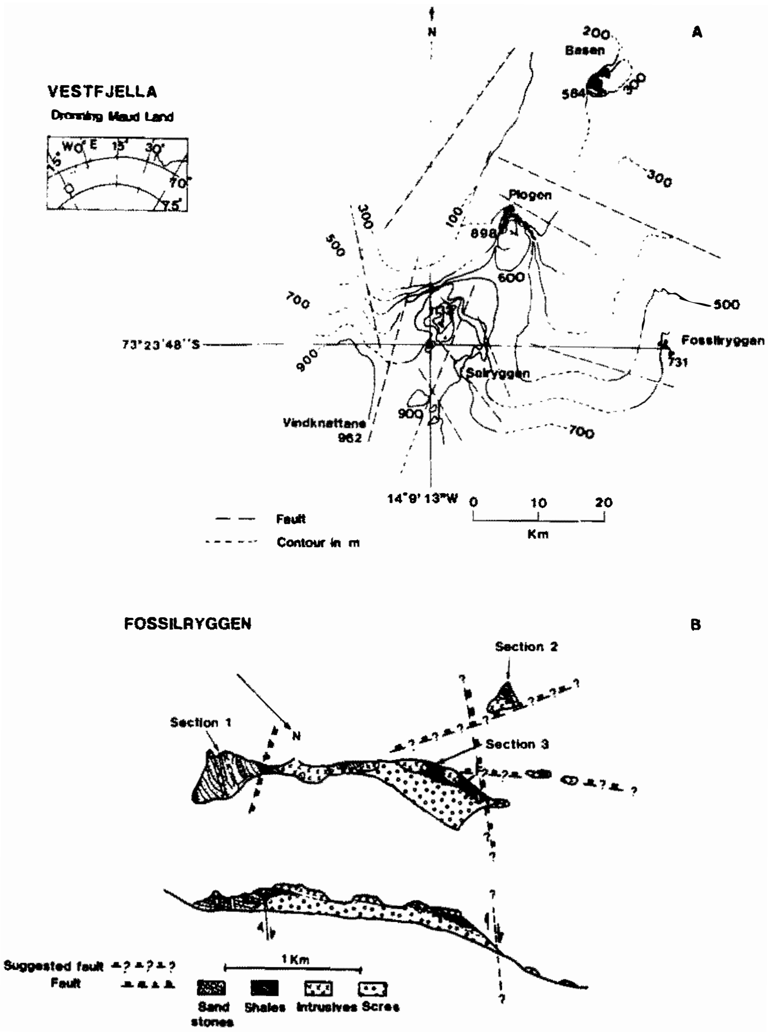

Fig. 1. Location map of the northern part of Vestfjella (A) and simplified geological map of Fossilryggen (B). Modified after Hjelle & Winsnes (1972).

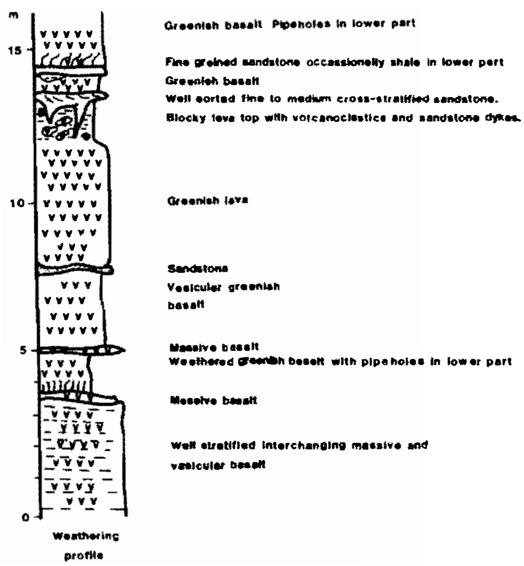

Fig. 3. Profile through lava and intercalated sedimentary rocks at Plogen. See text for discussion.

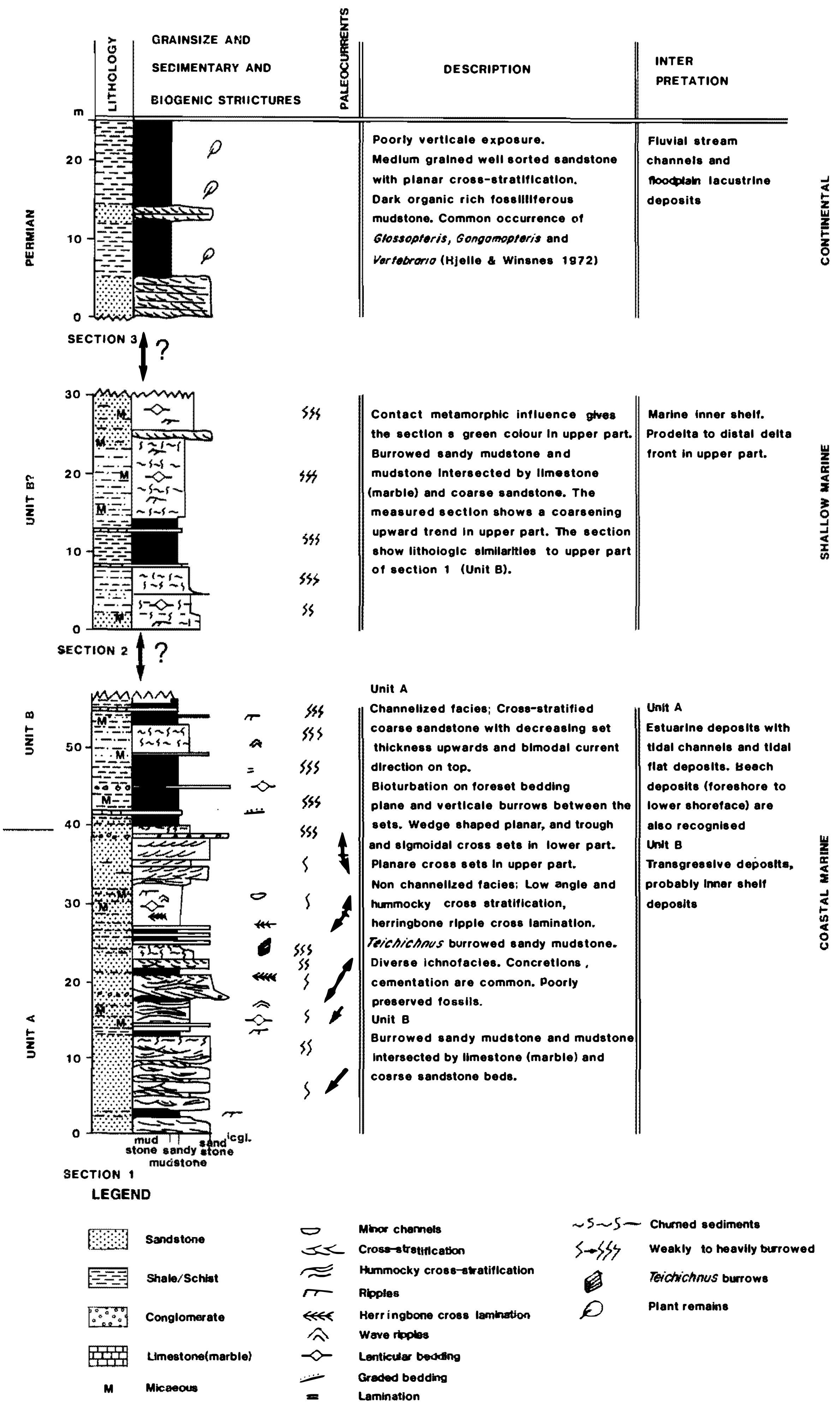

Fig. 2. Description and preliminary interpretation of the three sections at Fossilryggen in suggested stratigraphical order.

3 suggest a stratigraphic relationship between the two sections. Until better biostratigraphic control is obtained, the following stratigraphic order is assumed, based on lithology and a hypothetic tectonic setting (Fig. 1): section 1 is overlain by section 3, and section 3 is followed by section 2. A description and a preliminary interpretation of these sections are given in Fig. 2.

Sedimentary rocks associated with Jurassic subarial lava flows

The occasional occurrence of thin layers of siliciclastic sedimentary rocks interbedded in the Jurassic subaerial lava flows at Plogen and Basen (Fig. 1A) was also investigated.

Occasionally thicknesses of a few metres are seen and can be followed for a few hundred metres. The sedimentary sequences occur on the top of lava flows or as sandstone wedges and dykes (up to 2 m thick) between lava blocks or along the blocky tops of flows (Fig. 3). The sandstones are fine to medium grained, green coloured, usually well sorted and well stratified, and have an erosional contact with the underlying or laterally associated types of volcanic rocks. Trough cross stratification and channel trough fill are common. Conglomerate, with clasts of up to cobble size from the underlying flows, occurs in the northwestern part of Plogen. Greenish shale sometimes fills local depressions on the weathered surface of the lava flows.

CONCLUDING REMARKS

The sedimentary sequences outcropping at Fossilryggen have been logged and interpreted. A preliminary stratigraphic tectonic and depositional hypothesis is:

- Fossilryggen is situated on a horst block within a Mesozoic rift system
- The three sections seen at Fossilryggen can be summarized in the following way (Fig. 3)
    - Section 2; Continental (alluvial and lacustrine), cf. Hjelle & Winsnes (1972)

  - Section 3; Offshore marine (inner shelf-prodelta-distal part of a delta front)
  - Section 1; Coastal marine (fluviomarine channels, tidal flats and estuarine)
- Palaeocurrent measurements and facies patterns indicate a marine Permian basin west of Fossilryggen which might have been linked with the epicontinental basin known from the area to the south and west (e.g. Theron Mts and Ellsworth Mts, Elliot 1975, Grikurov 1982).

The sedimentary rocks assosiated with the Jurassic lava flows are interpreted as fluvial stream and pond deposits. This is consistent with the interpreted subaerial origin of the flows themselves, which also show evidence of deep weathering of their upper surfaces. Occurrence of non-volcanic quartz grains and the good sorting may also indicate stream reworked aeolian deposits.

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GEOMORPHOLOGICAL AND GLACIOLOGICAL OBSERVATIONS IN VESTFJELLA, DRONNING MAUD LAND

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BACKGROUND

Midyear 1984 the Swedish Government formed a special organisation called Polarforskningssekretariatet (The Polar Research Secretariat) to handle polar questions and to coordinate Swedish research in polar areas. They asked for the possibility of Swedish participation in the Norwegian Antarctic Research Expedition 1984/85 and as a result I was chosen to take part as an observer, and to study the glacial geology.

Little was known of the glacial geology in Vestfjella. Hjelle & Winsnes (1972) mentioned 23 scattered observations of glacial striae in Vestfjella, some of which were found at least 200 m above the present ice surface, but they gave no directions, nor did they specify where the different sites were.

OBJECTIVES.

The main research task at Camp Norway 6 was a continuation of earlier research on Vestfjella lava flows (Hjelle & Winsnes 1972; Furnes & Mitchell 1978) by sampling a number of outcrops.

My research was to include geomorphological observations on the nunataks (erosion surfaces, glacial drift, patterned ground, weathering ande slope processes, aeolian erosion, glacial erosion including possible ice striae). If possible an attempt should be made to decipher parts of the glacial history of the nunatak areas. Ground and air temperature measurements on slopes of different aspects should be compared.

Locations of local ablation areas should be registered and their morphology described. Ice structure as well as ice texture should be analysed. The morphology of the moraines in the ablation areas should be studied not only in their own rignt, but also to interpret the ice movement. Climatological change, if any, during the last decades ought to be found by comparing the present size of the snow- and ice-free areas of the nunataks with older air photos. During poor weather glaciological pit studies of accumulation, density and temperature should be made at the camp.

Sampling of vegetation on the nunataks was later also included as an objective. These samples were to be studied by Drs. Torstein Engelskjøn and Lauritz Sømme. On arrival in Vestfjella the unexpected existence of ice-dammed lakes around many of the nunataks made registration of these one of the objectives.

EQUIPMENT AND TECHNIQUES

The field work was based on standard geologic field equipment.

FIELDWORK

We stayed at our base Camp 5 km ENE of Dagvola in northern Vestfjella between January 19 and February 4. Although temperatures during daytime varied only between -5^{0} and -10^{0}C, the weather was unreliable with frequent mist and snow-fall, wherefore we had to cancel our trip to Heimefrontfjella. Instead more time could be devoted to the surrounding nunataks, namely Basen (28/1, 29/1, 1/2), northern end of Plogen (24/1, 2/2), Fossilryggen (21/1), Pukkelryggen (25/1), Dagvolinga and Grushallet (23/1). The latter nunataks are two small outcrops 2.5 and 4.5 km, respectively, NE of Dagvola. In 1951 Grushallet was a crevassed ice area, as seen on the the topographical map, while now 150 m of bare rock is exposed. This was the most evident change in ice area in Vestfjella since 1951. Smaller changes were also noticed, especially on Basen.

We stayed at a camp west of Pagodromen in southern Vestfjella between 4 and 13 February. Here my fieldwork was concentrated on the following sites: the moraine area between Pagodromen and Skansen (5/2, 6/2, 8/2), western end of Skansen (9/2), Nimbusryggen (7/2), Muren (10/2, 11/2), Steinkjeften (11/2, 12/2) and central part of Kjakebeinet (12/2).

PRELIMINARY RESULTS

Most of the Vestfjella nunataks have a morphology typical of interaction between glacial and periglacial activity. Arêtes with rectilinear slopes are dominant, but many horns were also seen. The best example of the latter landform was the westernmost nunatak of Fossilryggen.

Basen, the northernmost nunatak, has a shape different from the others although its structure is the same. It has a substantial (3 km^2) and rather flat summit area around 550 m elevation, which to the west abruptly ends with a vertical cliff (Fig. 1). Its Mesozoic bedrock is exposed in places and this rather flat area must be a remnant of a larger planation surface.

The regolith of Basen consists partly of frost-weathered local rocks centred around bedrock knobs and partly of a till cover mainly in depressions and on the eastern slopes (Fig. 2). The till includes clasts of granite, gneiss, sandstone and shale. The shape and glacial striae of a partly buried roche moutonnèe on the summit plateau showed that ice had flowed across the relatively flat summit area in a direction perpendicular to the vertical cliff.

The lower northern end of Plogen is a local ablation zone. Ice is actively flowing toward the nunatak from the southwest for a distance of at least 3 km. In other directions this depression in the ice sheet is more limited. Micropenitentes as well as meltwater channels on the ice surface at the end of January, 1985, showed that evaporation and melting at least had been active processes earlier during the summer. The meltwater channels lead down to a frozen lake at the bottom of the depression.

Fresh water channels were present at Basen and northern Plogen and in southern Vestfjella, but flowing water on a glacier surface was only seen on January 24 at Plogen and on January 28 at Basen. No ice-dammed lakes were seen with open water or watercovered ice.

This suggests that the summer season 1984/85 must have been short, as confirmed by observations near Plogen and Skansen - Pagodromen. At both places 0.5 m of clean superimposed ice covered the glacier surface, which was identified by a thin cover of melt-out till. Samples of the underlying glacier ice at the northern end of Plogen had all a nicely developed foliation in contrast to the superimposed ice. Some of these ice samples have been brought to Sweden for cold-room analysis.

Frost-weathering is very active in forming the present landscape. Severely shattered rocks dominate most areas that are not too steep. But other forms of weathering could also be seen, e.g. cavernous weathering at Fossilryggen in rocks of dolerite reddened by desert varnish and facing the dominant wind. Core stones of dolerite were also seen there and on the basalts of easternmost Steinkjeften. Old lava flow structures have been exhumed by weathering on many nunataks.

A series of temperature measurements were performed on February 7 on a small nunatak to investigate the expansion and contraction process. The weather was calm and sunny with an air temperature of about -7^0C in the afternoon. A sensor pushed 2-3 cm into cracks in the rock showed temperatures of $+20^0$C to $+30^0$C between 1500 & 1700 hours. Temperature fell to below 0^0C less than 2 hours after the rock was shadowed. At night the rock temperature must have been around -20^0C, that is at least as low as the air temperature. Thus the daily temperature range in the superficial rock layer can be as high as 50^0C in February and more than half of this variation probably takes place during a couple of hours.

Much weathered debris has been deflected from talus cones into lateral or median moraines, and all but the smallest nunataks had accompanying moraines. Small local glaciers in southern Vestfjella

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Fig. 3. Terminal moraine of a local glacier on the southern side of Skansen. Ice-dammed lakes were seen on both sides of the ridge. →

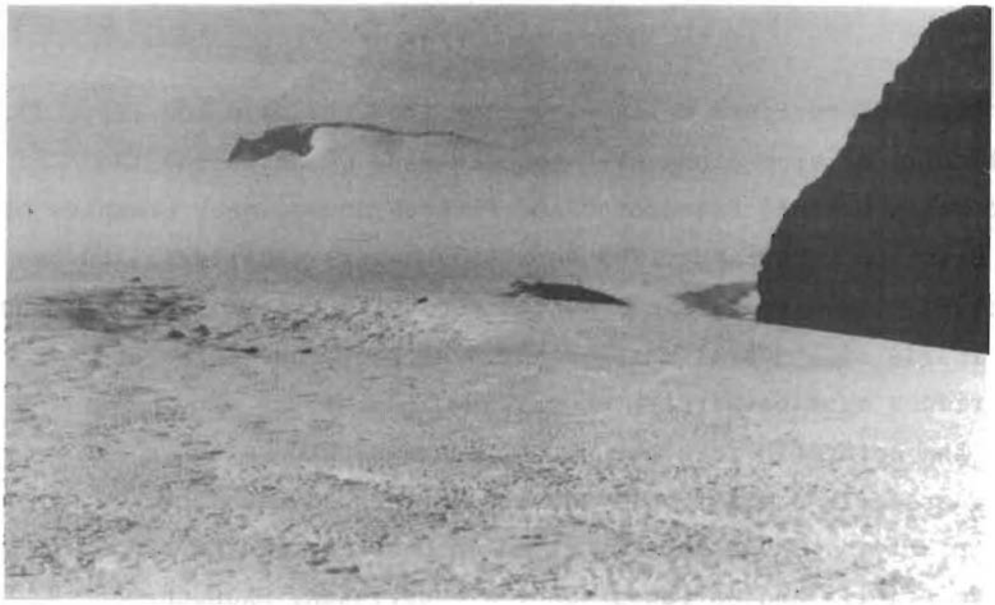

Fig. 1. Local ablation area at the northern end of Plogen. Next to the nunatak (right) are parts of an ice-dammed lake and a lateral moraine. To the left are meltwater channels as well as a depression formed by ablation. Melt-out till is seen at the bottom of the latter. Basen is seen in the shape of a giant roche moutonnèe in the background, 22 km away.

Fig. 2. Summit area of Basen. Notice the difference between frost-weathered material in the foreground and the lighter till in the middle. The edge of the vertical cliff is in the back-ground.

even had terminal moraines delimiting them from the main ice (Fig. 3). A large lateral moraine along the southern side of Muren and the moraine complex between Pagodromen and Skansen showed many examples of hummocky dead-ice topography. The depressions were usually filled or almost filled with circular ice-covered ponds. Water was seen draining from the inside of a medial moraine north of Pagodromen. Therefore ice in these ridges must be partly temperate.

Even if the Antarctic ice sheet at present is cold-based in the Vestfjella area, it probably has not always been so, as shown by many glacial striations. These were observed on Basen and Pukkelryggen in northern Vestfjella and on Pagodromen, Nimbusryggen, Skansen, Steinkjeften and Kjakebeinet in southern Vestfjella. Glaciofluvially rounded stones were furthermore seen on Basen and on the summit of central Kjakebeinet.

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GEOPHYSICAL STUDIES IN THE SOUTHERN WEDDELL SEA

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BACKGROUND

Current state of knowledge points to the Weddell Sea Embayment as a key area to address the most significant geological problems on Gondwanaland fragmentation. The present effort towards an improved Gondwanaland reconstruction compatible with geological and geophysical information from the surrounding oceans and continents has pointed out the necessity to consider a number of independent micro-plates for explaining the early Mesozoic geological relation between West and East Antarctica (Dalziel & Elliott 1982). In this context the southern Weddell Sea margin represents the most critical area because:

1. One or more ancient plate boundaries should be present in the area.

2. A thick (>4km) sedimentary succession which carries the sedimentological response to the tectonic history of the area, is present on the margin.

3. The area is partly accessible by ships under favourable ice conditions.

The seismic multichannel survey of Hinz & Krause (1982) has shown that the Dronning Maud Land (DML) margin (25^0W-20^0E) is a sediment starved continental margin which consists of rifted and shear segments. In general a 1-2 km thick undisturbed sedimentary section is unconformably overlying a seaward dipping wedge ("Explora wedge") of seismic velocity >4 km/s. These findings are supported by the NARE 1978/79 data from the same area. The Explora wedge abuts the prominent Explora Escarpment along the Riiser-Larsen segment of the margin and is considered to be syn-rift sediments (volcanics?) deposited in a marginal basin during the break-up of Gondwanaland and initiation of seafloor spreading (Hinz & Krause 1982).

A distinctly different depositional environment is evident in the southernmost Weddell Sea where extensive margin progradation at least throughout the late Cenozoic is manifested by submarine fan developement in the Crary Trough area. Basement exposures are present out to 50-100 km from the barrier between Halley Station and the Filchner Ice Shelf and form the eastern boundary of a large sedimentary basin (thickness >5km) in the Weddell Sea Embayment (Haugland 1982; Haugland et al. 1982; Grikurov et al. 1980). The sedimentary section shows little evidence of fault tectonics, but several major unconformities are present. Correlation between the seismic data from the inner shelf is not possible because of lack of data and stratigraphic complexities in the submarine fan environment. The Crary submarine fan is a sensitive although complex indicator of changes in the geological paleoenvironment. In view of the points mentioned above and recommendations SEG-1982-6 and -9 of the SCAR Working Group On Solid Earth Geophysics addressing the need for high quality seismic multi-channel reflection data, the marine geophysical programme for NARE 1985 focusing on the southern Weddell Sea margin was proposed.

OBJECTIVES

The objectives of the integrated marine geophysical programme were a reconnaisance survey of the Southern Weddell Sea in order to map the seismic stratigraphy and deep structure of the Crary submarine fan and the Eastern Weddell Embayment Basin in sufficient detail to provide a meaningful database for focus on the following key geological questions:

a) to define the major geological structures in the underlying basement and evaluate their significance in a plate tectonic framework and subsequent control on sediment deposition and basin evolution.

b) to outline the depositional history of the basin and the submarine fan evolution.

c) to define the subsidence history of the southern Weddell Sea margin and the depositional paleoenvironment through geologic time.

d) to identify in the sedimentary record the appearance of an ice sheet between West and East Antarctica and define its influence on sedimentation.

The Ocean Drilling Programme (ODP) has planned a leg in the Weddell Sea area in 1987. First priority on this programme is given to two drill sites on the Maud Rise to establish an Early Ceneozoic - Late Mesozoic paleoenvironmental record and age of Maud Rise. The NARE 84/85 was asked by the Southern Ocean Panel of the ODP to perform a survey of these proposed drill sites.

EQUIPMENT AND TECHNIQUES

The following equipment was used for the marine geophysical programme at NARE 84/85.

Seismic equipment:

Recorder:	DFS V, 48 channels SEG C format. Filters: Lo cut: out; Hi cut: 90 Hz Sampling interval: 4ms
Camera:	SIE electrostatic; 60 channels
Near trace recorder:	EPC model 4100, filter Krohn Hite
Streamer:	48 channel, 1200 m active length HSS, transformercoupled, delivered from Fjord Instruments.
Depth controllers:	Syntron, individually adjustable.
Source:	Normally 2 x 1500 C PAR air guns, total volume approx 1000 cu.inch, operated at 2000 psi (137 bars) and fired every 50 m.
Compressors:	4 x Junker compressors, capacity 4 x 2.05 m^3 free air per minute.
Refraction system:	Reftek Lo band sonobuoys and Reftek sonobuoy receiver.
Gravity meter:	La Coste & Romberg, analog and digital recording.
Magnetometer:	Geometrics proton magnetometer model 801/03, analog recording.
Heat flow:	Lamont Doherty Geological Observatory digital heat flow instrument.
Echosounder:	O.R.E. 3,5 KHz penetrating echosounder.
Navigation:	Magnavox 1107 dual channel Satelite Receiver integrated with log and gyro.

The seismic reflection data were acquired with these typical parameters:

shot interval: 50 m
source depth: 7.5 m
streamer depth: 11 m
No of channels: 48, for profiles 1-15
24 x 50 m for profiles 16-24.

Maud Rise: Source depth: 3 m.
Streamer depth: 8 m.
Source: Single air gun 600 cuinc w/wave shaper.

Sonobuoy stations were recorded parallel to the reflection lines and recorded on seismic channel no 1 on the DFS V.

FIELD WORK

The marine geophysical programme on NARE 84/85 started when K/V "Andenes" sailed from Ushuaia on 29 Dec. 1984. Gravity, magnetic and bathymetric data were collected all the way until we reached heavy pack pack ice on 7 Jan. 1985 at approximately 2^0E and 68^0S, when the magnetometer had to be taken in. The period 8 - 21 Jan. was used to launch the two land parties and other marine scientific programmes. The seismic programme started on 21 Jan. and continued until the 26th, and lines 1-9 were recorded (Fig. 1). Three heat flow stations were acquired on the continental margin at 38^0 W at water depths of 800 m, 1000 m, and 1200 m on 1 Feb, and thereafter lines 10-18 were shot until 6 Feb. Lines 19, 6, 4b, 21-24, and 2b were recorded between 15 and 20 Feb. This concluded the seismic programme in the Weddell Sea, and approximately 15 days net ship time was used. The survey on Maud Rise took place on 24-26 Feb., and used 40 h shiptime (Fig. 2).

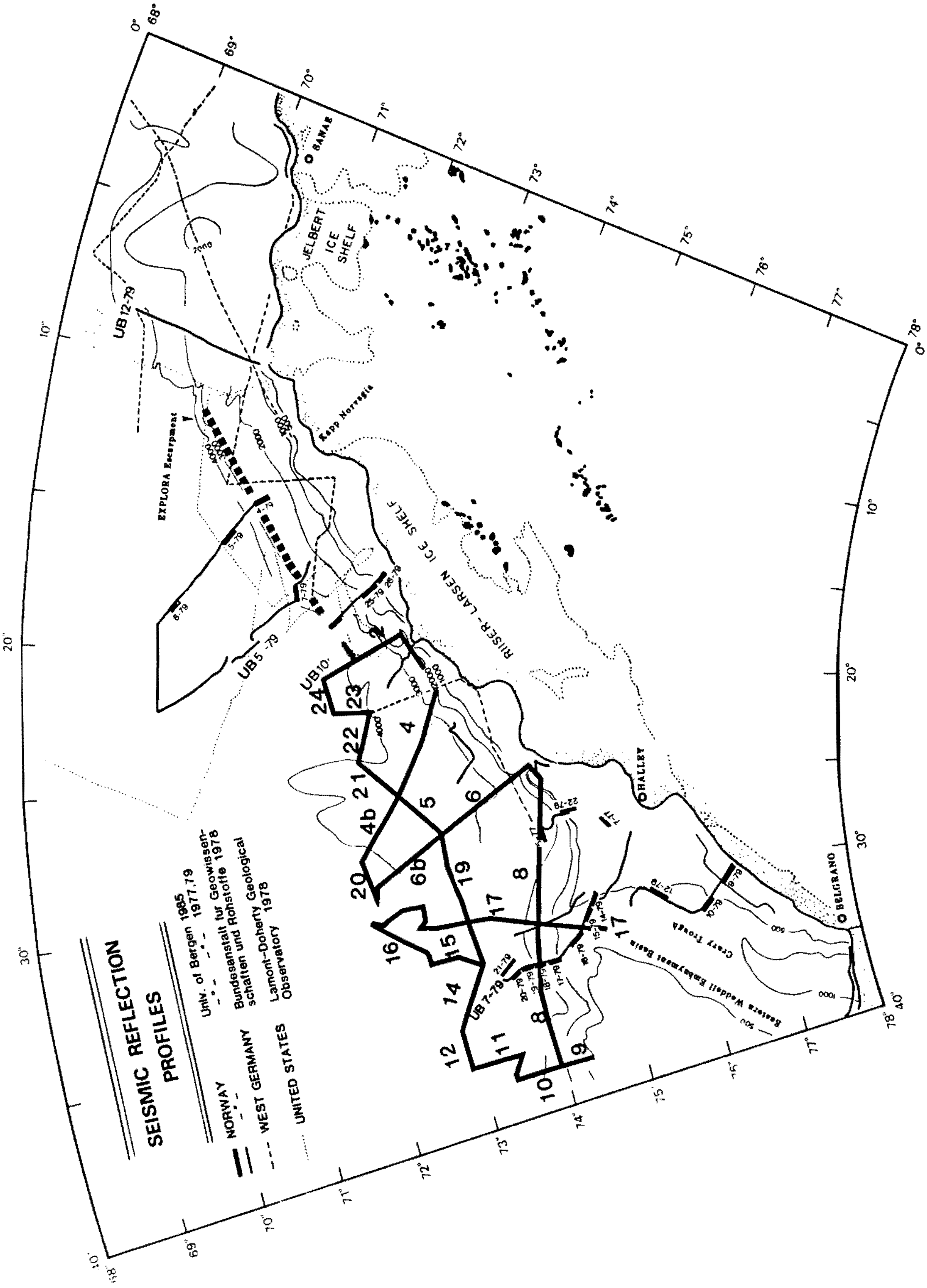

Fig. 1. Track lines of the seismic programme in the Weddell Sea during NARE 1984/85.

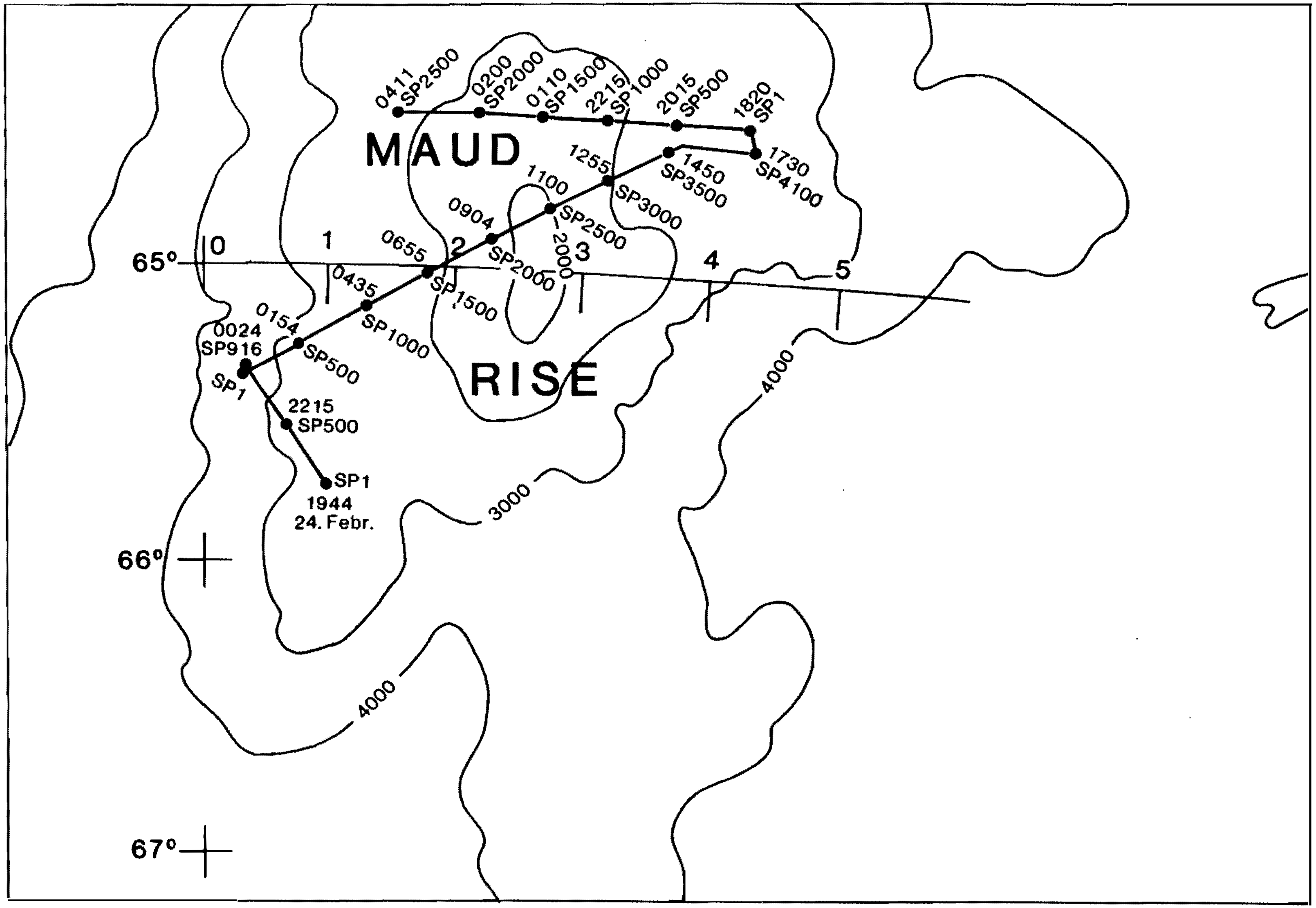

Fig. 2. Track lines of the seismic programme on Maud Rise, NARE 1984/85.

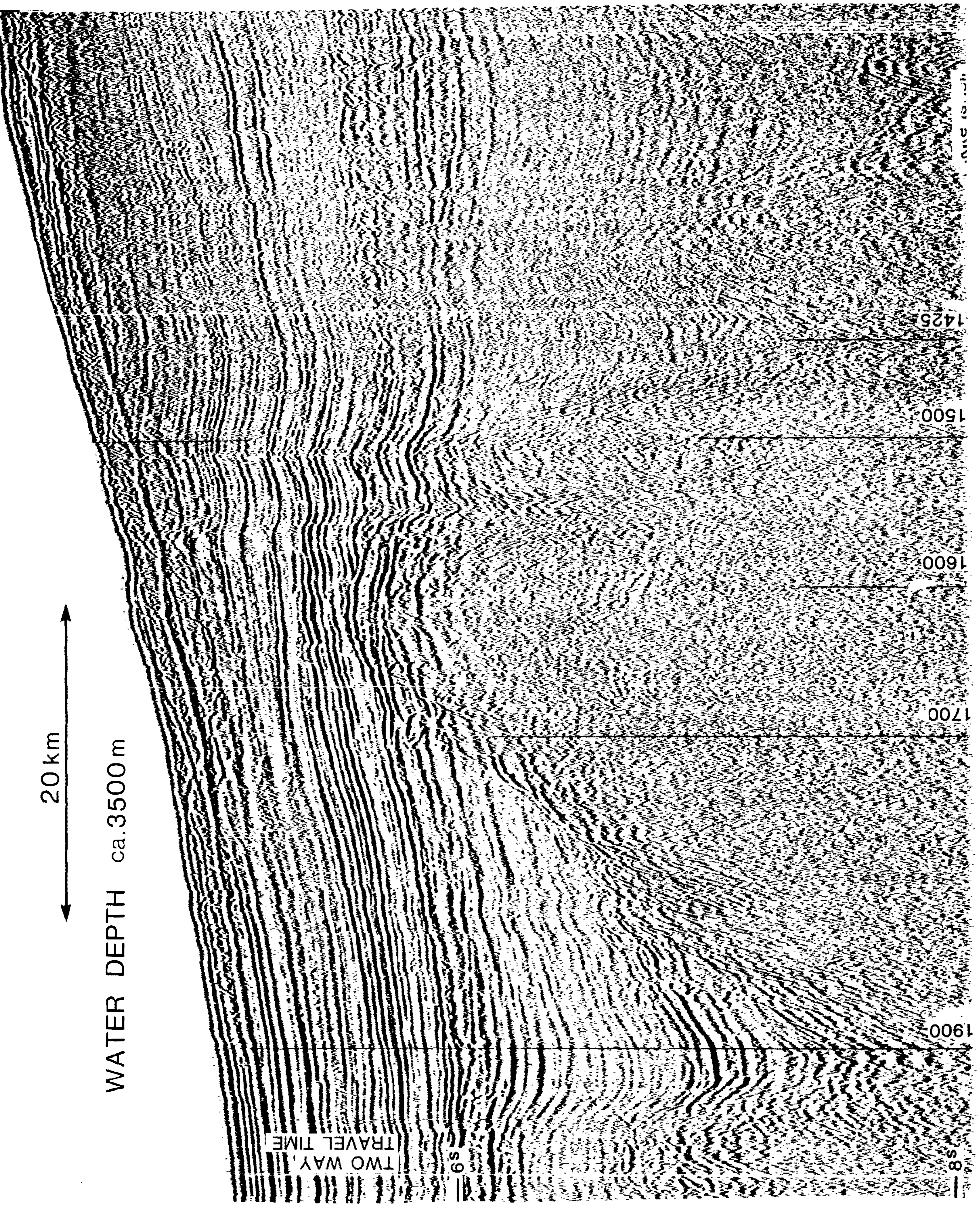

Fig. 3. Near trace seismic record of line 15, NARE 1984/85. For location, see Fig. 1.

Gravity was recorded from Ushuaia and until break down of one of the gyros on 29 Jan. Total magnetic field intensity was recorded from Ushuaia until approximately 30^{0}N on the way to Abidjan, except for areas with heavy pack ice. Bathymetric data were recorded continuously underway to Abidjan.

The sonobuoy stations were recorded along the seismic lines when weather conditions were favourable and in areas with poor coverage on NARE 76/77 and 78/79. Totally 15 stations were recorded with fair to good data quality.

The tracks of the seismic programme are shown on Figs. 1 and 2. Approximately 2 250 line km multichannel seismic data were collected in the Weddell Sea, and 150 km with single channel analog recording. The Maud Rise program included 350 km of multichannel seismic data along with magnetic and good quality 3.5 KHz echosounder data.

Although we are quite pleased with the amount, and the geographical distribution of the data, we would like to acquire more data on the shelf to the south. In particular an East-West profile along the Filchner and Ronne ice shelfs would be interesting. Unfortunately the ice situation did not allow this in the period we had at our disposal.

PRELIMINARY RESULTS

The results reported here are mainly based on the seismic near trace records and the raw magnetic data.

Lines 11, 14, 15 (Fig. 3), 17, 6b, 4b, 21, 22, 23 and 2 outline a linear basement ridge buried below the continental slope over a distance of 700 km. This structure is 40-60 km wide, 1-2.5 km high and trends WSW-ENE oblique to the present continental margin north of the Filchner-Ronne Ice Shelves. The basement ridge is associated with a positive magnetic anomaly and mark the transition between acoustic basement on the seaward side characterized by multiple reflection hyperbolae typically seen over oceanic crust, and a thick sedimentary section on the landward side. This structural high appears to be continuous with the basement ridge mapped by Hinz & Krause (1982). To the northeast and to the southwest it truncates the trend of the large sedimentary basins below the Filchner-Ronne Ice Shelves. We propose to name this structure the Andenes-Explora Escarpment. Its dimensions and parallelism to magnetic lineations in the eastern Weddell Sea indicate that it relates to the ancient Gondwana plate margin.

The Filchner depression may have extended to the upper continental slope as suggested by a major unconformity at 1 sec. TWT below sea floor on line 8.

Furthermore, a drastic change in depositional environment is manifested by an acoustically laminated upper 0.5 sec. thick sedimentary section deposited by two migrating lobes of the Crary submarine fan on the lower continental slope.

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MARINE GEOLOGICAL STUDIES ON THE WEDDELL SEA SHELF

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BACKGROUND

The southern Weddell Sea has been identified as a key area in unravelling early Gondwanaland fragmentation and evolution of the Weddell Sea (Dalziel & Elliott 1982). Presently, the seismic stratigraphy of this area is only tied to paleoenvironmental changes in the southern areas (Hinz & Krause 1982) rather than geologic samples. A significant finding of the two earlier Norwegian expeditions (NARE 1976/77 and NARE 1978/79) was an apparent absence of overburden in certain areas in the Crary Trough, where westward dipping sedimentary rocks seem to outcrop on the sea floor (Elverhøi & Maisey 1983). This type of situation gives favourable conditions for bedrock sampling, either by shallow drilling or by conventional rock dredging.

Glacial conditions have probably prevailed in Antarctica since Oligocene (Denton et al. 1971; Hayes & Frakes 1975; Drewry 1975; Barrett 1981). While the ice cover in the first period probably was limited, the period Pliocene to recent is characterized by an extensive ice cover, including ice shelves (Drewry 1976; Barrett 1981). Results from the two earlier Norwegian expeditions indicate that grounded ice probably covered the entire Weddell Sea shelf, including the Crary Trough, during Late Weichselian time (Elverhøi 1981). Unconformities further down in a sediment accumulation in the mouth of the Crary Trough indicate former advances and retreats.

Icebergs are a major environmental factor on the Antarctic continental shelf. Our earlier investigations have shown in certain areas that a large part of the sea floor is affected by iceberg gouging, down to 700 m water depth. From investigations on the Norwegian continental shelf, where an average of 55% of the sea floor shows gouging (Lien 1983), we know that this process affects not only the local topography, but also the sediment properties, stability, etc. The ice shelf environment of the Antarctic continental shelf is a setting that also may have existed on parts of the Norwegian continental shelf during Pleistocene glaciations.

Glacial sediments have been identified in all geological eras since the Proterozoic, apart from the Mesozoic. Traditionally, glacigenic sediments are regarded as pure clastics, and carbonate deposits interbedded with or capping the glacigenic sediments have caused interpretational problems. The Antarctic shelf areas support a prolific bioclastic fauna of high diversity (Knox 1970), and reconnaissance surveys outside Riiser-Larsenisen indicate that biogenic calcareous sediments form as an integrated part of the glaciomarine sediments (Elverhøi & Roaldset 1983). Thus there appears to be no environmental conflict between glacigenic and calcareous sedimentation.

OBJECTIVES

The major objectives of the marine geology programme on NARE 1984/85 were:

a) Mapping of suitable areas for future bedrock sampling by means of shallow rock core drill or related equipment, and sampling of bedrock by conventional coring and dredging for dating of the seismic stratigraphy.

b) Establishing maximum extent and timing for withdrawal of the last ice sheet that covered the Weddell Sea shelf.

c) Mapping and characterization of bedforms formed by iceberg scouring, with emphasize on the origin of "washboard patterns" (Lien 1982), and the effect of gouging on sea floor properties.

d) Investigating sediment facies distribution, lithology and rate of deposition outside an ice shelf.

EQUIPMENT

Acoustic:

- HUNTEC Deep Tow System (DTS), with boomer and side scan sonar.
- EG & G sparker systems, with 3-electrode arrays, operated with 1, 3 and 5 kJ energy. Signals were received on a single channel BENTHOS 50-element streamer, filtered in the pass band 80-500Hz and recorded on analogue tape and an EPC 3200 graphic recorder.
- O.R.E. Model 140 3.5 kHz penetration echo sounder.
- KLEIN side-scan sonar system with 100 kHz transducers.

Sampling:

- Vibrocorer, barrel length: 3.5 m, diameter: 90 mm.
- Gravity corer, barrel length: 3 m, diameter: 110 mm.
- Rock dredge.

- Pipe dredges.

Photography:
- BENTHOS deep sea utility camera and flash units, models 371 and 381.

Local navigation:
- Motorola Miniranger System.

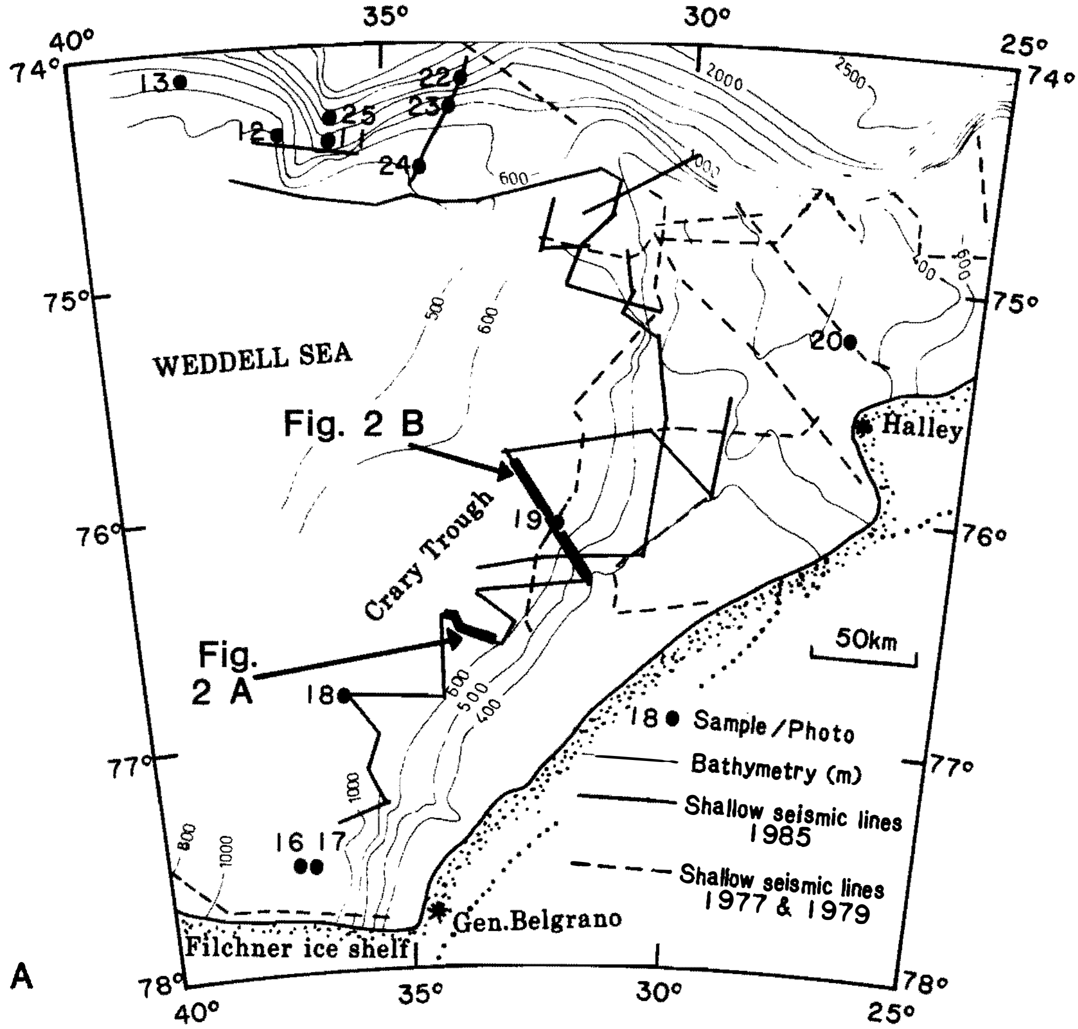
FIELD OPERATIONS

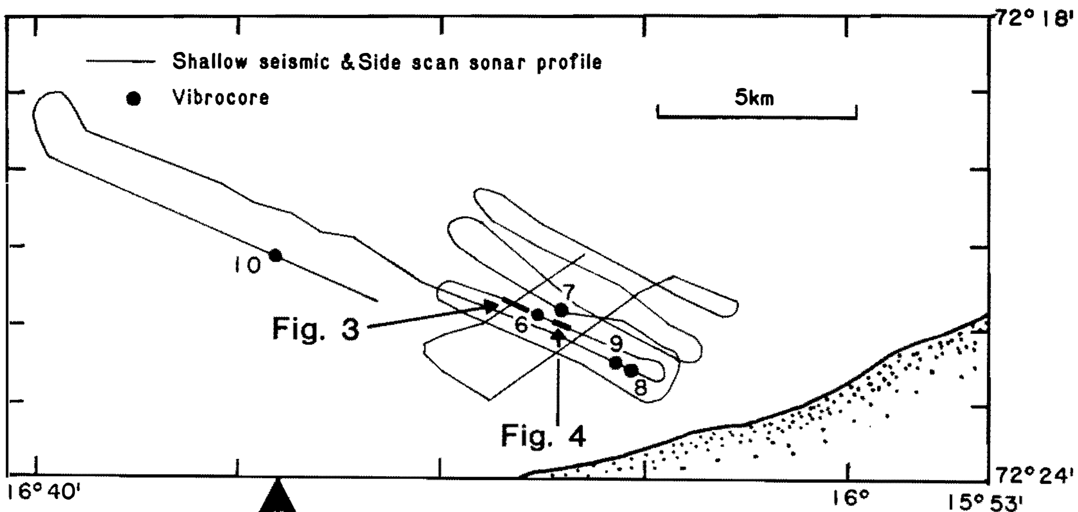
A total of 1450 line km of shallow seismic (sparker) data and 110 km of side-scan sonar data were acquired (Fig. 1), within 9 days of ship time allocated for the marine geology programme. The 3.5 kHz echo sounder was operated continuously during the entire cruise. Geological sampling was carried out at 20 localities to yield 7 gravity cores, 6 vibrocores and 5 dredge hauls (2 gravity cores were empty). The bottom camera was used at 14 stations (Tables 1 and 2).

In general ice conditions limited operations to the eastern part of the Crary Trough, except near the shelf edge (Fig. 1 A).

Dredging for bedrock sampling was attempted outside the Filchner Ice Shelf and in a canyon on the upper continental slope to the north, but with fair success only. This operation was severely hampered by breakdown of the HUNTEC deep towed boomer, which was intended to provide resolution for outcrop identification superior to the available sparker data.

The sparker profiling focussed on defining the boundaries of the two main units of a major accumulation of glacially derived sediments in the mouth of the Crary Trough, and also the boundary between consolidated sedimentary rocks and acoustic basement of the East-Antarctic craton. (Figs. 2 A & B). Lines were extended into areas covered by 2-5/10 ice to meet objectives wherever deemed necessary. The speed of "Andenes" was 5-7 knots and sea states generally less than 2. When operated at 3 kJ, a maximum penetration of 1 sec. was achieved.





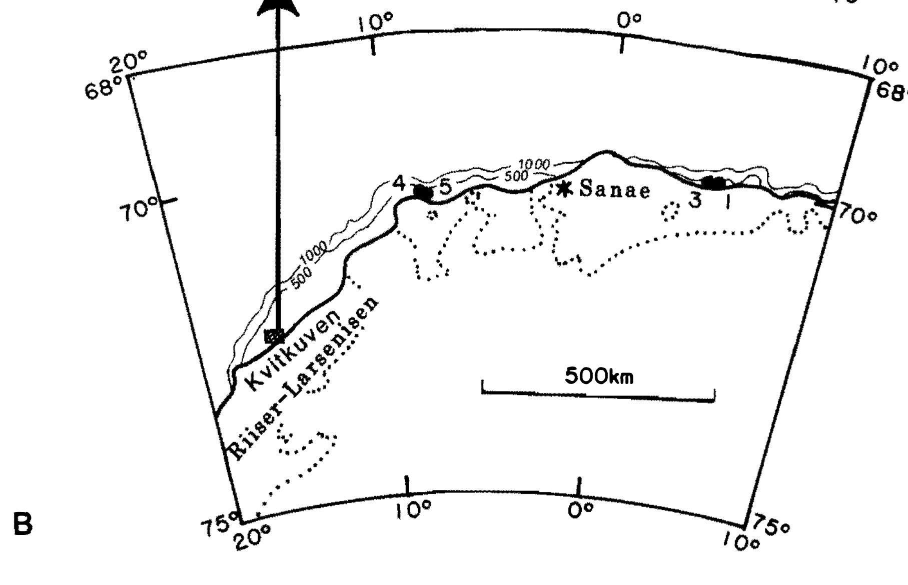


Fig. 1. Shallow seismic profiles and marine geological stations in A: the Crary Trough area, and B: the eastern part of the NARE 1984/85 cruise area, including the Kvitkuven area.

Table 1. Dredge and -core samples.

Station	Lat	Lon	Water depth (m)	Equipment	Core length (cm)	Description	Depth in core	Shear strength (kPa)	Colour
A85-1/1	S 70°08.9'	E 04°37.9'	730	GC	10	Sandy, gravelly mud		5.0	5Y 2.5/2
A85-1/2	S 70°08.9'	E 04°37.9'	730	PD		Varied lithology, dominated by gneissic rocks. Some basalt and meta-sandstone.			
A85-3	S 70°12.1'	E 04°29.1'	180	GC		Corer empty. A few quartz sand grains on core cutter.			
A85-4	S 70°29.6'	W 08°21.2'	244	GC		Corer empty and clean			
A85-5	s 70°25.4'	W 08°20.0'	468	GC	10	Firm, gravelly mud, overconsolidated.			5Y 3/2
A86-6	S 72°21.7'	W 16°15.9'	315	VC	50	Pebble-rich mud			
A85-7	S 72°21.7'	W 16°14.7'	317	VC	260	Soft, gravelly mud.	90cm: 180cm:	2.0 8.0	5Y 2.5/1 5Y 2.5/2
A85-8	S 72°22.4'	W 16° 2.5'	314	VC	346	Pebbly, gravelly mud.	90cm: 180cm: 270cm:	 5.7 8.7	5Y 2.5/2 5Y 2.5/2 5Y 2.5/2
A85-9	S 72°22.4'	W 16°11.8'	315	VC	350	Firm, fine grained mud. Overconsolidated in lower part of core.	90cm: 180cm: 260ca: 350cm:	10.6 40.0 40.0 70.0	5Y 2.5/1 5Y 2.5/1 5Y 2.5/1 5Y 2.5/1
A85-10	S 72°20.9'	W 16°29.7'	319	VC	345	Soft, sandy mud.	90cm: 180cm: 270cm:	4.6 7.8 4.6	5Y 3/2 5Y 3/2 5Y 3/2
A85-12	S 74°21.9'	W 36°43.7'	130	RD		Dominance of quartzitic meta-sandstone, reddish, grayish, greenish in colour. Minor amounts of gneissic rocks and biogenic limestone.			
A85-13	S 74°07.5'	W 38°15.0'	850	GC	280	Soft mud			
A85-16	S 77°32.2'	W 37°14.8'	114	RD		Mixed lithology; Biogenic limestone, dense, quartzitic sandstone, dark shale/ mudstone and a few igneous fragments.			
A85-17	S 77°33.4'	W 37°11.1'	113	RD		Mixed lithology, dominated dominated by dense, quartzitic sandstone. Minor amounts of biogenic limestone w/corals, sandy shale, phylitic rocks and igneous rocks.			
A85-18	S 76°49.4'	W 36°12.9	980	GC	35	Soft, sandy mud.			5Y 2.5/2
A85-19	S 76°05.2'	W 32°13.6'	773	RD		Dominance of dense, quartzitic sandstone, minor amounts of igneous fragments,			
A85-20	S 75°15.26	W 27°12.23	301	VC	182	Top: sand, 80cm: muddy sand, 182cm: Firm, sandy mud w/some gravel	180cm:	>200	
A85-22	S 74°09.9'	W 33°42.1'	140	GC	295	Soft, sandy mud.	98cm: 196cm:	 4.0	5Y 4/1 5Y 3/1
A85-23	S 74°17.7'	W 33°55.8'	820	GC	248	Soft, sandy mud w/ some gravel.	90cm: 170cm:	 3.7	5Y 4/1 5Y 4/1
A85-24	S 74°32.4'	W 34°19.1'	540	GC	80	Sandy, gravelly mud.			

GC : gravity corer, VC : vibrocorer, PD : pipe dredge, RD : rock dredge
Shear strength was measured on board with a pocket penetrometer.
Colour refers to Munaell Soil Colour Charts.

Table 2. Bottom photography

Station	Lat.	Lon.	Depth
A85-1/1	S 70° 08.9'	E 04° 37.9'	730
A85-1/2	S 70° 08.9'	E 04° 37.9'	730
A85-3	S 70° 12.1'	E 04° 29.1'	180
A85-4	S 70° 29.6'	W 08° 21.2'	244
A85-5	S 70° 25.4'	W 08° 20.0'	468
A85-6	S 72° 21.7'	W 16° 15.9'	315
A85-7	S 72° 21.7'	W 16° 14.7'	317
A85-11	S 74° 25.8'	W 35° 46.6'	1100
A85-18	S 76° 49.4'	W 36° 12.9'	980
A85-19	S 76° 05.2'	W 32° 13.6'	773
A85-20	S 75° 15.3'	W 27° 12.2'	301
A85-22	S 74° 09.9'	W 33° 42.1'	1401
A85-23	S 74° 17.7'	W 33° 55.8'	820
A85-25	S 74° 21.2'	W 35° 49.8'	1500

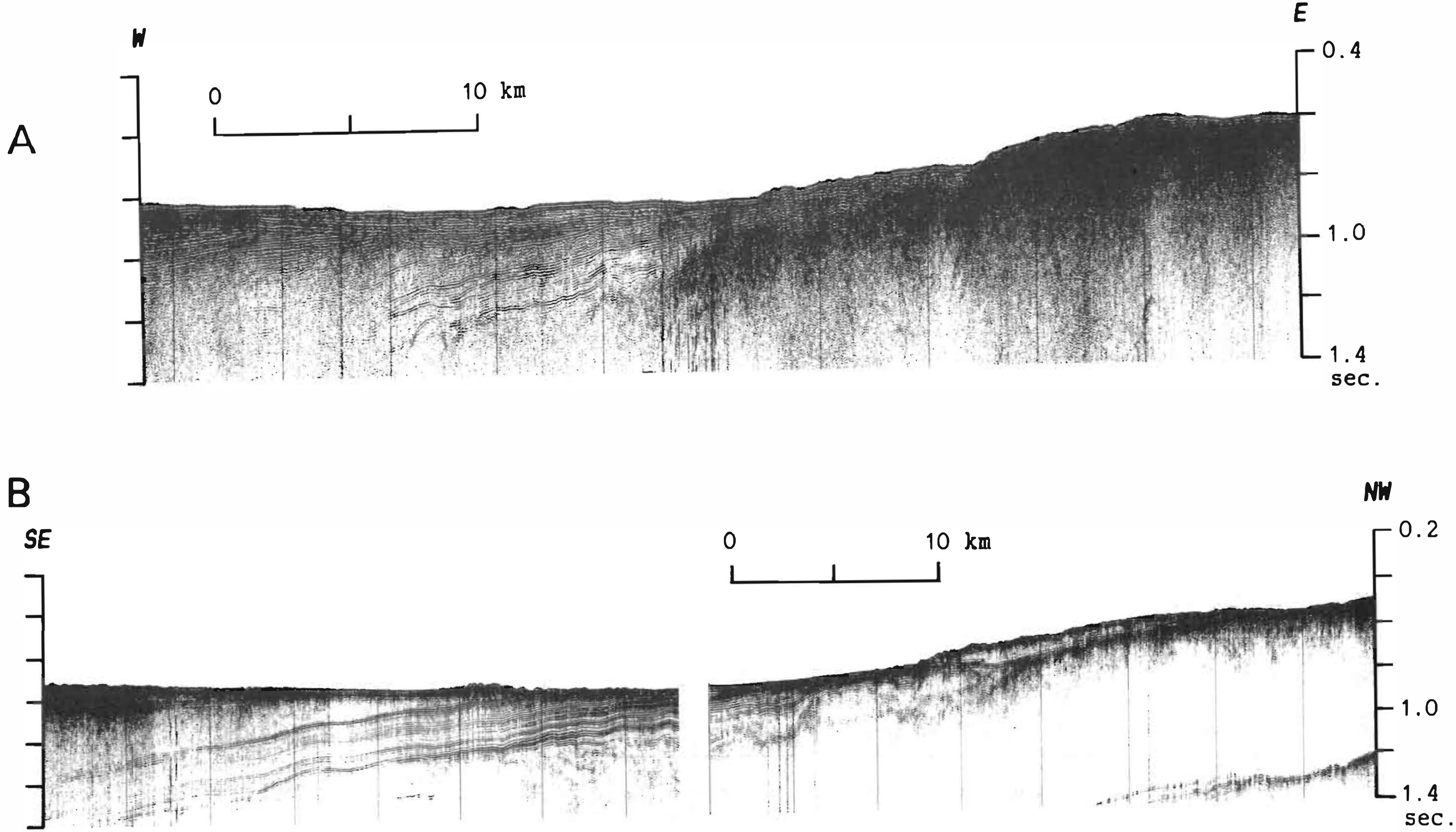


Fig. 2 A & B. Sparker profiles crossing the boundary zone between crystalline rocks of the East Antarctic craton and layered sedimentary rocks. For location, see Fig. 1 A.

Vibrocoring to obtain samples of the overconsolidated till was considered an essential element of the glacial geology programme. The vessel was able to maintain station very nicely by alert maneuvering in response to wire angle deviations during the vibrating operations on the sea floor. A Motorola Miniranger System with two transponders on the barrier provided an excellent station reference outside Kvitkuven. Sediment cores of 0.1 m to 3.5 m were obtained that also penetrated the overconsolidated glacial till. Unfortunately, at station 21, north of Halley, the required pull-out force exceeded the wire breaking strength, and the vibrocoring rig was lost.

Gravity coring and bottom photography were carried out routinely with no complications.

The proposed survey area for the iceberg scouring programme outside Kvitkuven (formerly termed "Blåenga") at Riiser-Larsenisen was moved 10 nautical miles southeast because of fast ice and grounded icebergs. Two Motorola Miniranger transponders were placed on the barrier, 13 km apart, to provide precise navigation for covering the sea floor by side scan mosaic. Due to instrumental problems with the DTS, a 100 kHz side-scan tow fish was used for a detailed survey of the different types of sea floor microtopography, some of which identified as a "washboard pattern" (Lien 1982) (Fig. 3).

PRELIMINARY RESULTS

The central and inner parts of the Crary Trough have an asymmetrical cross section. Crystalline basement, characterized by an irregular surface with frequent diffraction hyperbolas, is exposed in much of the steeper eastern slope. At the bottom of the slope, basement continues downwards beneath a sequence of layered sedimentary rocks (Fig. 2 B). The sedimentary rocks alternate between units of finely layered rocks and more homogeneous units, each 2-300 msec. thick. The same type of succession was observed on a seismic line during NARE 1976/77, running along the Filchner Ice Shelf. Lithology of the dredge samples (Table 1), is dominated by dense, quartzitic sandstones, with smaller amounts of shale and a biogenic limestone. Comparison with samples from previous cruises, and more detailed petrographic analyses have to be done to state the likeliness of the clasts being autochthonous or allochthonous, brought in by drifting icebergs.

The cover of glacigenic sediments is more sparse in the central and inner parts of the Crary Trough, but it does exist over most of the area. Sedimentary bedrock may be exposed in a small area of the deepest part, between 76^0S and 77^0S. The sediment cover increases to more than 50 msec. to the west. Along the eastern slope of the trough, crystalline basement is probably exposed in the southern part, while there are sediment accumulations, probably till, further northeast, north of $76^0$30'S.

Gravity core A85-18 contain 0.35 m of sandy mud. This is comparable to previous cores from the central Crary Trough. Also the 3.5 kHz echo sounder shows no penetration over most of the area, indicating that the cover of soft sediments is less than the system resolution. Elverhøi & Roaldset (1983) calculated a Holocene sedimentation rate for the Weddell Sea shelf of 2-5 cm/kA. Thus, the existing data suggest that the Crary Trough was covered by grounded ice during Late Weichselian time, and that normal glaciomarine sedimentation has only prevailed through the Holocene.

A major sedimentary accumulation forms the Crary Trough sill, as described by Elverhøi & Maisey (1983). The upper, homogeneous unit of this accumulation has a somewhat wider extension than previously mapped. The lower, layered unit continues to the west and southwest. Layers are dipping towards northwest, and several of the internal reflectors are erosional truncations, forming rather smooth surfaces. A quite similar sequence of probably glacigenic sediments is described from the Bjørnøyrenna trough in the Barents Sea (Solheim & Kristoffersen 1984), where the erosional surfaces are interpreted in terms of glacier advances and retreats. This is an interpretation we find highly likely also for the Weddell Sea.

The vibrocore (A85-20) from the top unit of the sediment complex shows highly overconsolidated material. The most likely cause is compaction by grounded ice, during the last expansion of the East Antarctic ice sheet. The timing of this event is, however, still a matter of debate, and the obtained cores will be thoroughly examined for datable material.

Two lines pass the shelf edge and run some distance down the upper slope (Fig. 1 A). Both these lines clearly show the layered, prograding shelf structure. The easternmost line passes over the homogeneous top unit of the main sediment complex. There is no distinct boundary of the unit. It gradually gets more layered near the edge. A possible explanation for this may be small scale oscillations of the glacier front when it was in a maximum position.

The slope surface is very smooth, apart from some slump structures. However, at a depth of 20-40 msec. there are numerous smaller depressions and disturbances, indicating less sediment stability, probably due to higher sediment input from an expanded ice sheet, at a previous stage.

The depression (canyon) on the slope at about 36^{0}W was extensively mapped with 3.5 kHz records. The one sparker line, running across the upper part of it (Fig. 1 A), clearly shows a complicated geological build-up of the area, with a distinct difference between the western and eastern parts. Of particular importance, however, is a finely layered sequence of sediments, approximately 60 msec. thick, confined to the western part of the depression. This sequence could well be the result of periodic deposition through pulsating currents (see physical oceanography cruise report in this volume). However, more data are needed on sediment structure and type, current velocities, etc.

The side-scan sonographs show a number of different ice plough features. A similar "washboard pattern" as described by Lien (1982) was found also here (Fig. 3), mainly in one part of the survey area, but also in several single, large plough marks. This could indicate that the wobbling movement of the icebergs, thought to cause this pattern, is a common mode of movement for grounded, tabular icebergs. The relief of the transverse pattern is small, around 1 m or less, with individual ridges approximately 10 m apart. The longitudinal ridges may have a relief of 2-3 m and a spacing of 30-50 m.

There are surprisingly many narrow plough marks, 20-50 m wide, which are in general deeper (up to 10 m) than the wider ones. One explana-

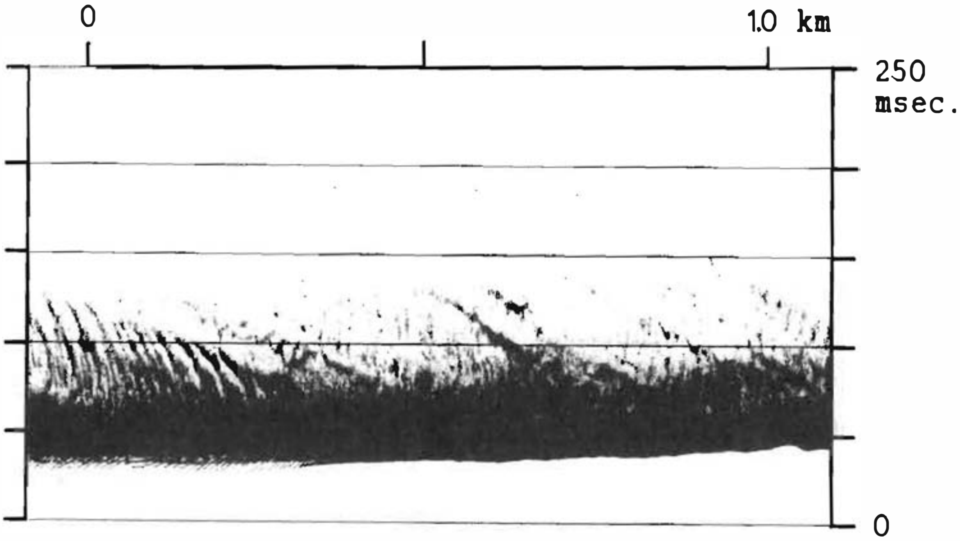


Fig. 3. Side scan sonograph from the Kvitkuven area, showing "washboard pattern". For location, see Fig. 1 B.

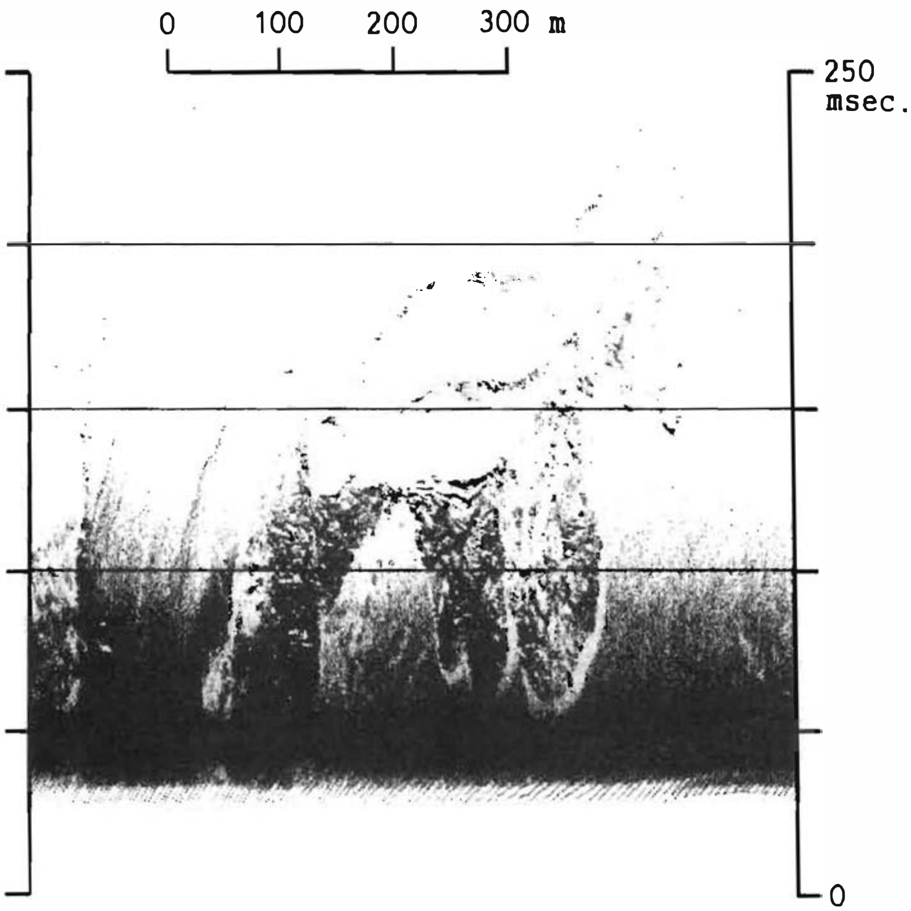


Fig. 4. Side scan sonograph showing slump lobes from the edges of an iceberg plough mark. For location, see Fig. 1 B.

tion may be that the icebergs have narrow keels, or that they may be in a tilted position during gouging. Some of the wider marks also show evidence of a multi-keel structure.

The ploughing process causes sediment disturbance also outside the actual plough mark. Formation of the rims causes unstable sediment configurations, and slumps are observed (Fig. 4). Blocky structures around the plough marks can also be seen, probably caused by over-consolidated material being ploughed up.

The cores from the Kvitkuven area all showed a relatively poorly sorted mud, with varying clast content. Only one core (A85-9) recovered in the trough of the largest plough mark recorded (250m wide, 10 m deep), show a different character, as at least the lower 1 m of the core is a more fine grained, overconsolidated mud. Shear strengths measured by pocket penetrometer are in the range of 40-70 kPa. This overconsolidation may be due to effect of the iceberg, as one should expect a higher degree of compaction from expansion and grounding of the East Antarctic ice sheet.

CONCLUDING REMARKS

The generally favourable ice conditions permitted acquisition of new good quality seismic and geologic information in spite of instrument problems with the deep tow system.

Sufficient resolution for identification of bedrock outcrops on the sea floor and detailed seismic stratigraphy of the glacial sediments were considered imperative to meet the objectives of the marine geology programme. We were, however, only able to augment our data set from previous expeditions without the additional insight provided by higher resolution.

Our experience of sediment sampling in this type of glacial shelf environment clearly shows that a heavy duty vibrocorer is the best tool, apart from drill equipment, for obtaining cores which also sample overconsolidated till.

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RADIOLARIA IN THE SURFACE PLANKTON COLLECTED ON THE TRANS-ATLANTIC CROSSING OF THE NORWEGIAN ANTARCTIC RESEARCH EXPEDITION 1984-85

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During the trans-Atlantic crossing of the Coast Guard Vessel "Andenes" it was arranged by the expedition leader, Dr. Olav Orheim, that radiolaria should be collected from the surface water masses. Dr. Jan Helge Halleraker kindly assisted in the sampling programme, and without his cooperation this programme could not have been carried out.

The ship's sea-water pump was used. 6 m^3 of sea-water was taken from 3.5 m depth and filtered through a 63 µm plankton net on deck. This quantitative collection will make the backbone for the investigation of the density and species distribution of Radiolaria in the profile defined by the track of "Andenes", starting at 45^0N, 8^0W and ending at 79^0S, 29^0W. A total of 91 samples were collected. Between 20^0N and 20^0S the samples were taken for each degree of latitudes, while outside this zone the samples were collected for every second degree of latitude.

This collection is unique as the profile covers a large area and crosses several important oceanic convergence and divergence zones, and therefore great ecological barriers. This closely sampled profile should make it possible to map in detail how the major oceanographic fronts are reflected in the Radiolaria fauna.

The Radiolaria studies will be done by Kjell R. Bjørklund. In addition Dr. Bjørg Stabell, Univ. of Oslo, will receive a split of the samples to make a comparative study of the big centric diatoms, and map their distribution patterns, even though the material may not be completely suited for diatom studies. It will be of particular interest to see how the concentrations of Radiolaria and diatoms in the water masses match the provinces of siliceous ooze in the South Atlantic.

HYDROGRAPHIC OBSERVATIONS ON THE SOUTHERN WEDDELL SEA SHELF BREAK

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BACKGROUND AND OBJECTIVES

Ever since the pioneering work of Brennecke (1921), Mosby (1934) and Deacon (1937) it has been known that the Weddell Sea is the main source for the Antarctic Bottom Water. However, the processes involved in forming bottom water, and the exact location where these processes are active, are not well known.

The most accepted theory so far is that very saline water, which forms due to brine release on the Weddell Sea Shelf during ice freezing, mixes with the surrounding water masses at the shelf break in a rather complicated scheme and sinks down the continental slope towards the deep ocean (Foster & Carmack 1976). Obsevations from the two previous Norwegian Expeditions indicate, however, that large volumes of very cold water which form below the floating Filchner Ice Shelf at several hundred metres depth, overflow at the sill of the Filchner Depression and descend towards large depths as an organized and well defined bottom current (Foldvik et al. 1985a, b).

Current meter observations recovered during NARE 1978/79 indicated that the resultant production of Weddell Sea Bottom Water was of the same order of magnitude as earlier estimates for the entire production of Weddell Sea Bottom Waters. Thus it seemed that this flow of Ice Shelf Water ultimately was of considerable importance for the general circulation of the world ocean.

On this background it was decided to focus the physical oceanography programme of NARE 84/85 on a study of the outflowing Ice Shelf Water. The general aim was

a) to quantify the amount of supercooled water which flowed over the sill of the Filchner Depression, and
b) to study the dynamics of the dense, cold flow at the continental slope and its subsequent transformation towards bottom water.

EQUIPMENT AND TECHNIQUES

Vertical profiles of temperature and salinity were obtained using a Neil Brown CTD sonde and on-line computing facilities. The wire capacity was 3000 m. The CTD was combined with a 12 bottle remotely controlled General Oceanics Rosette for water sampling. Water samples were collected for on-shore laboratory analysis of salinity, tritium, helium and oxygen isotopes.

Nine deployed current meter rigs were all equipped with an acoustic release manufactured by Christian Michelsen's Institute, Bergen, and Geophysical Institute, University of Bergen. In addition the three shallow rigs at the sill of the Filchner Depression (Fig. 1) were equipped with 1000 m, 12 mm diameter polypropylene ground line for bottom dredging. The current meters were manufactured by Aanderaa Instruments, Bergen, type RCM-4 and RCM-5. Measurement depths were 25 m above bottom and 10 m above bottom. The instruments record current speed and -direction, temperature, and conductivity every hour and store the data internally on tape. The battery capacity is sufficient for one year of recordings. One of the shallow rigs (S2) is also equipped with a third current meter at 190 m above bottom, a 50 m thermistor chain, and an Aanderaa WLR-5 water level recorder.

Attempts to measure the currents at CTD stations were also made. For

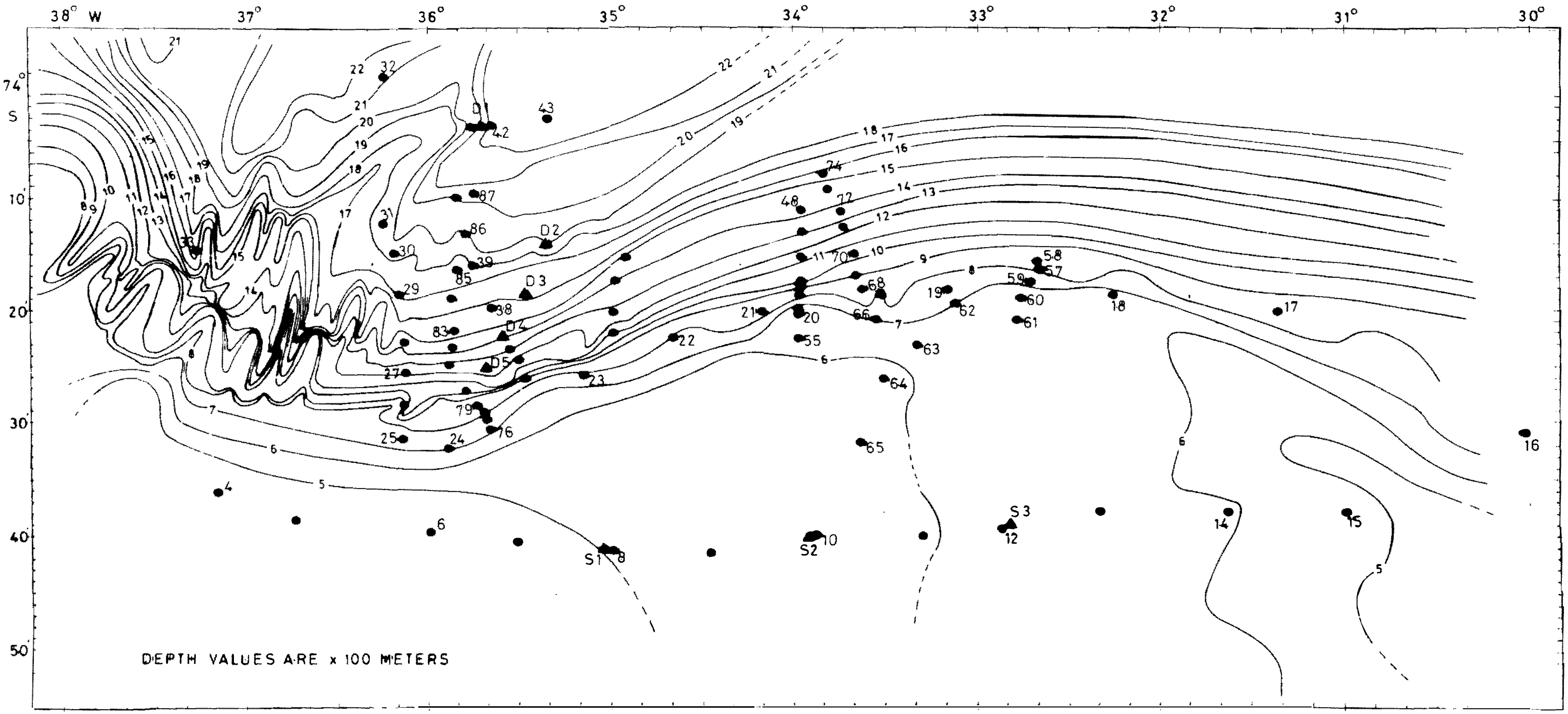

Fig. 1. Map of the local topography near the sill of the Filchner Depression. The CTD stations are numbered and marked with a black dot. The currentmeter rigs are marked with triangles, and symbols S1-S3 and D1-D5.

this purpose a specially designed RCM-4 current meter was hung under the CTD. Measurements were made every minute and recorded both internally and on board the ship using a hydrophone.

FIELD WORK

Ice conditions were rather favourable and we were able to obtain nine closely spaced CTD sections in the area at altogether 87 sites (Fig. 1). The CTD stations represent three major investigations: one survey on the shelf and two surveys taken on the slope at two weeks interval.

The investigations on the shelf consist of two east-west sections (st. 4-25, see Fig. 1). The section at $74^0 40'S$ crosses the sill of the Filchner Depression and the other section further north roughly follows the 800 m isobath.

The first survey on the slope consists of four north-south sections (sts. 25-55) and the second survey (sts. 57-87) defines three north-south sections.

In connection with the CTD stations water samples were obtained with a rosette sampler for salinity calibration and oxygen isotope analysis. We also collected samples for tritium and helium analysis at a few stations.

The positions for the current meter arrays were chosen on the basis of a CTD survey and 9 current meter rigs were deployed with altogether 19 current meters, a water level recorder and a thermistor chain. Eight of the current meter mooring positions are marked on the map, the last one was put out near the Filchner Ice Shelf where extremely cold water flows out from the ice shelf, defining the source of the cold bottom current in the study area.

PRELIMINARY RESULTS

The extremely cold Ice Shelf Water (ISW) which is formed below the floating Filchner Ice Shelf follows the western slope of the Filchner Depression towards the north (Foldvik et al. 1985a). At about $74^0 25'S$

this water spills over the shelf break and down the slope where we located at least three separate cores of cold bottom currents.

The major branch seems to cross the sill at about $33^0 30'W$ and can be traced as it penetrates down to 1800 m at about $35^0 50'W$. Here the core temperature was -1.9^0C, which is still below the surface freezing point.

Fig. 2 shows an example of the extreme gradients separating the cold plume from its surroundings. The homogeneous bottom layer shows that the plume is thoroughly mixed. An attempt to measure the relative velocity of the plume indicated velocities of about 1 m s^{-1} which would imply that the interface is dynamically unstable. This question might be resolved when the moored current meters are retrieved.

The position of the cold plume was found to vary with time. During the first survey the plume was relatively warm and did not penetrate as deep as observed during the previous years (Foldvik et al. 1985a, b). Towards the end of the first survey a major outbreak of ISW was observed at 34^0W, which probably is seen as a plume of ISW on st. 85 at 1800 m depth two weeks later.

A major reason for the observed variability of the cold bottom current on the slope is that the flow of Ice Shelf Water on the sill is modulated with a twelve day period (Foldvik et al. 1985b).

Both the main plume and the two minor branches observed at each side mix with the warm and more saline water above to form a 100 m thick bottom layer which covers the whole slope with temperatures below 0^0C. This layer is dense and may also contribute to the Weddell Sea bottom water.

Our observations have proved that water which is cooled below the floating Filchner Ice Shelf spills over the shelf break in large quantities. On its way towards the deep ocean it mixes with the overlying warmer, but more saline water. The mixing product has the same characteristics as Weddell Sea Bottom Water. The current meter rigs which are designed to monitor the current for one year will hopefully help us to better understand the dynamics of the cold plumes and also determine the rate of production of Weddell Sea Bottom Water.

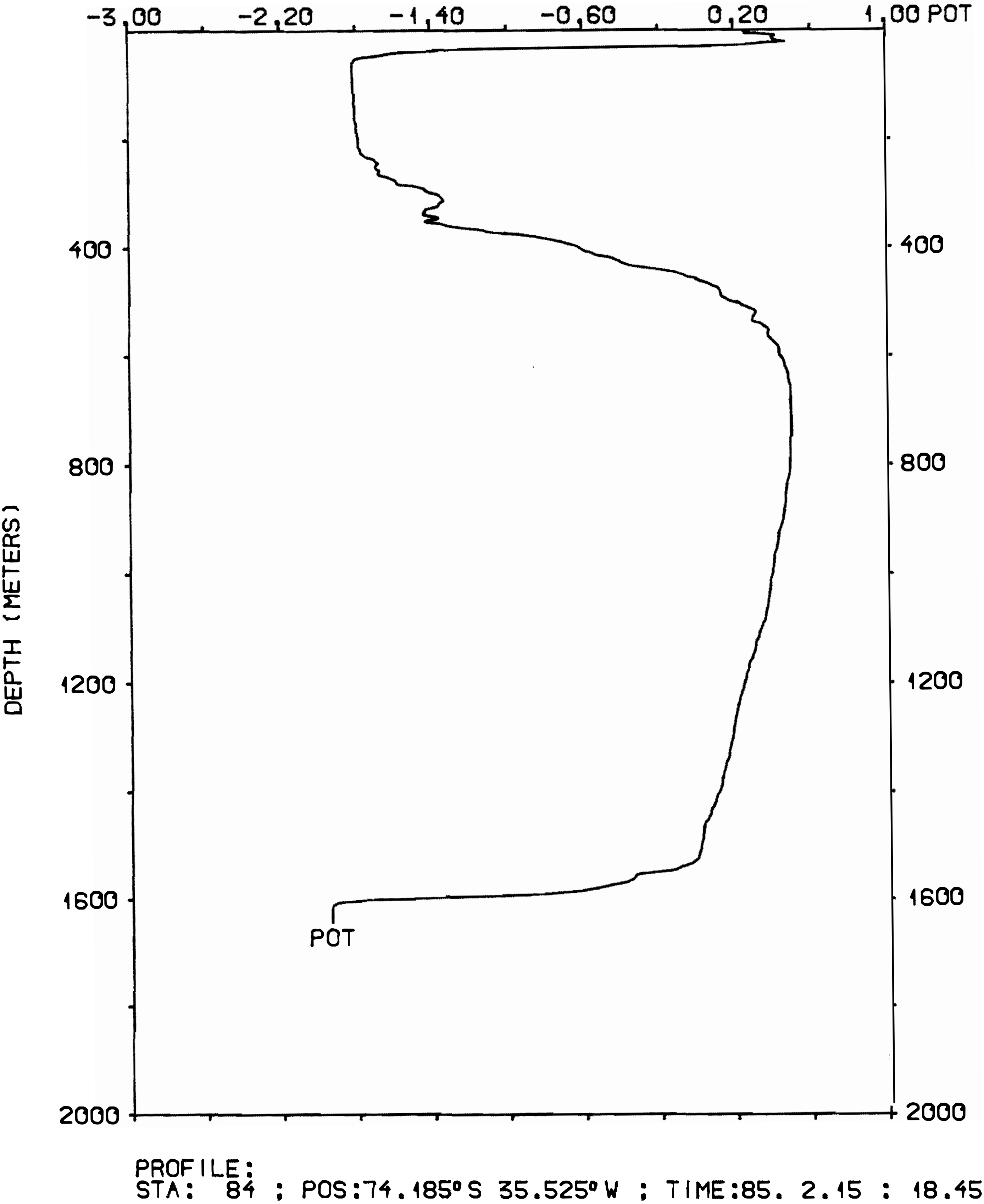

Fig. 2. Vertical profile of temperature at CTD station No. 84.

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ICEBERG RESEARCH AND OTHER GLACIOLOGICAL STUDIES FROM K/V "ANDENES"

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BACKGROUND AND OBJECTIVES

The glaciological research from K/V "Andenes" had four aspects: a) to investigate the shape and deformation of icebergs, b) mapping the underwater shape of both icebergs and ice shelves, c) sea ice investigations, and d) ice thickness measurements on Trolltunga and Riiser-Larsenisen. These are described below, with main emphasis on the iceberg programme.

a) Extensive studies of Antarctic tabular icebergs have led to good understanding of iceberg properties and have shown that resonant rigid body motion and bending occurs as a response to long period swells, dependent both on iceberg geometry and swell amplitude and period (Orheim 1980; Foldvik et al. 1980; Kristensen et al. 1981; Kristensen et al. 1982). Measured strain rates at the surface of the bergs may vary with a factor of several orders of magnitude. Cyclic surface strain due to ocean waves is particularly sensitive to variations in iceberg thickness.

Two-dimensional, linear models have been developed to calculate rigid body motions, cyclic water pressures at the iceberg bottom and resonant bending (Kristensen & Squire 1983). Good agreement has been found between the models and field observations for medium-sized icebergs. However, field data have been lacking on underwater shapes of icebergs and on the behaviour of very long icebergs as well as small, thin ones.

The objective of the iceberg programme was to investigate the rigid body motions and flexural bending of icebergs with geometries different to those previously visited, including collection of data on iceberg underwater shapes, both to better understand melting and calving processes and investigate viscous eddying around the icebergs, as a preparation for development of models to include non-linear effects.

b) Very little field evidence is available on the underwater shapes of large ice bodies, and on the combination of oceanographic melting processes and glaciological calving processes that determine the shapes of icebergs, of ice fronts, and of ice walls. A successful pilot project of side-scan sonar of ice fronts and icebergs was carried out on NARE 1978/79 (Klepsvik & Fossum 1980), and this showed that there was a need for a collection of systematic data on ice underwater shapes to test various ideas proposed in the literature (e.g. Robin 1979). On this cruise it was planned to collect side-scan sonar records from a variety of features, including locations studied in 1978/79, and from other locations where the calving history was known, to investigate how the underwater shapes change with time, and to develop a model for these changes. An important new modification to the instrument was that it was fitted with depth control so that repeated sections at various depths could be pieced together to give the three-dimensional shape.

c) Sea ice cores collected in the Weddell Sea by Clarke & Ackley (1983), revealed large variations in the contents of nutrients in sea ice, both within the core itself and between cores at different geographical locations. However, the data collected were concentrated in a small region of the Weddell Sea. The cruise made by K/V "Andenes" during NARE 1984/85 thus offered a unique opportunity to further study the salinity and nutrient profiles of one-year and multi-year sea ice along the coast of Dronning Maud Land and in the Weddell Sea.

d) Measurement of ice thickness and structures of Riiser-Larsenisen was carried out by radio echo sounding during NARE 1978/79 (Orheim in press). There was incomplete geographic coverage west of Kvitkuven, (formally termed "Blåenga") and further measurements of some special phenomena were also desired if the opportunity would arise. Also planned was a pilot study of the Jutulstraumen/Trolltunga glacier system in preparation for a larger glaciological programme in a subsequent field season. Jutulstraumen is the largest outflow glacier in Dronning Maud Land and no studies have been done in the area where it enters into the ice shelf Fimbulisen and changes name to Trolltunga.

FIELD WORK

a) Two complete iceberg experiments were carried out. The first on an iceberg approximately 540 m by 270 m and 110 m thick, in position $70^0 11'S$, $10^0 37'W$ (Fig. 1), and the second on an iceberg about 1150 m by 850 m, and 160 m thick, in position $70^0 14'S$, $4^0 27'E$.

During the iceberg experiments a large number of operations were conducted simultaneously on the iceberg, from the ship, and from survey boat and helicopter (Fig. 1). Investigations could be divided into three categories:

i) measurements concerning iceberg shape,
ii) Waverider measurements of sea state
iii) 'in situ' measurements mainly concerning rigid body motions and flexural bending of icebergs.

i) Iceberg shape: Iceberg thickness was measured by radio-echo sounding from helicopter flying along transects in a grid pattern. We

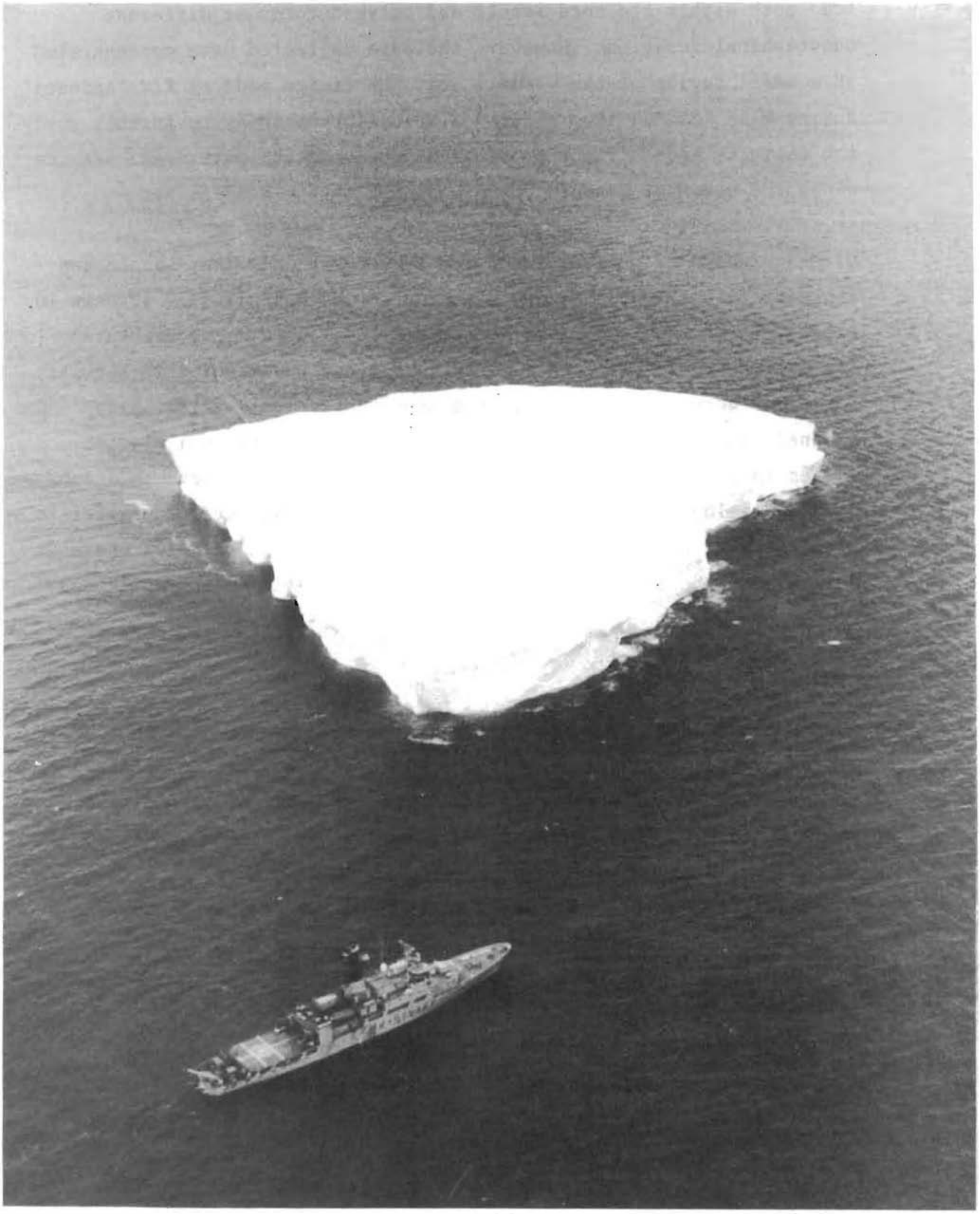

Fig. 1. "Andenes" by the iceberg where the first experiment was conducted. Note the camp in the middle of the iceberg.
Photo: Egil Eriksson, 21 Feb. 1985.

used the SPRI Mk IV System operating at a center frequency of 60 MHz (Evans & Smith 1969) together with a Honeywell oscillograph visicorder with a heat processing unit for high quality, permanent records. A simple 3.8 m dipole antenna, constructed at the Technical University of Denmark, was mounted parallel to the helicopter body at a distance of 2 m using fibreglass supports. About 10 transects were flown over each berg. We had difficulty getting good echoes over the first, thin iceberg.

The underwater shapes of the sides of the icebergs were investigated mainly by side-scan sonar. We used a Klein Model 400, with an output frequency of 100 kHz, a 0.1 ms pulse length, and a horizontal beam width of 1^0. The "fish" was modified to tilt 90^0 compared to a standard sea-bed sonar and the vertical beam width was 40^0 tilted up and down from the horizontal. In addition the "fish" was fitted with a depth sensor that was read from the ship. About 3 hours of underwater profiling was done at each iceberg, towing the sonar at different depths round the bergs. In addition some sounding was done at selected points by lowering and raising the sonar vertically. The underwater shapes, in particular protruding ledges, were also sounded from a small vessel.

The surface shape was recorded by photography from the air, and spot measurements of surface elevation was made at numerous localities by Paulin altimeter. Radar mapping of the horizontal shape of the berg as well as freeboard measurements were also made from the ship.

ii) Sea state: A Waverider buoy manufactured by Datawell Ltd. was deployed from the ship. The buoy is spherical with a diameter of 0.7m and it measures its own motion with an internal, stabilized accelerometer. The output is integrated twice, and thus the buoy transmitted data on wave periods and amplitudes to a receiver on board the ship throughout the duration of the experiments. The buoy was not anchored to the ocean floor, but was free floating with a heavy chain to secure that the buoy followed the wave motion.

iii) 'In situ' measurements: Heave (vertical acceleration), sway and surge (horizontal acceleration along the principal axes) were measured using Schaevitz accelerometers mounted on a levelling platform attached to a heavy brass pendulum. Thus cyclic motions were recorded only in the vertical and the horizontal plane. The resolution of the accelerometers was 10^{-5}g. For periods above 20 seconds, heave energy is probably not accurately resolved. Pitch and roll (angular tilting) were measured by electrolytic, bubble-type tiltmeters (TILT Instruments Ltd.). The resolution of the tiltmeters was 0.5 microradians. Initial levelling of the tiltmeters was done manually using a bubble display. Both accelerometers and tiltmeters were housed in a waterproof aluminium box which was placed on an insulating surface to prevent drift in the data through melting under the box. These instruments were borrowed from Scott Polar Research Institute, Cambridge, UK.

Surface bending was measured using strainmeters developed from an earlier design at Scott Polar Research Institute (Moore & Wadhams 1980). A trench about 2 m by 2 m and 0.5 m deep was excevated using a chain-saw. The surface of both the visited icebergs had very little surface snow cover, and the trench was mainly dug through blue ice. Holes were drilled down to a depth of 1.5 m and aluminium poles, which served as strainmeter anchors, were secured in the ice. Water was poured into the holes to make the anchoring of the strainmeters to the ice even better. The three strainmeters were placed in a triangle, and make it possible to calculate the components of a strain rosette.

All the cyclic data were recorded through amplifiers on a 14 channel Racal magnetic tape recorder. The power sources were 12V Duracell compact batteries for the instruments and amplifiers and a Honda aggregate delivering 240V for the Racal. The total duration of each experiment was approximately 8 hours.

b) About 130 km of side scan sonar data of ice fronts and ice walls was collected using the Klein instrument described above. Twelve profiles were collected at various depths along a selected section of Riiser-Larsenisen, which in part overlapped with the section investigated by Klepsvik & Fossum (1980). High-precision navigation was achieved by use of two Motorola Miniranger transponders placed on the ice shelf. Part of the sounded section also included the grounded portion in front of Kvitkuven, and the main section was repeated after one month. Three profiles were collected by the Brunt Ice Shelf, including grounded areas and sections where the ice shelf had recently broken off. The iceberg studies described above also included both freshly-calved and more mature sections. The side-scan data were in most places supplemented by direct soundings of the underwater ledges.

c) The sea ice investigations were conducted on an opportunity basis on ice floes located in the vicinity of the ship, by flying out with helicopter. Ice cores were collected on 10 locations using a SIPRE corer with an internal diameter of 8 cm. Samples of surface water and plankton hauls were collected at some localities. Salinity and temperature profiles of the upper 12 m of the water column were measured through the core hole when time permitted. The cores were divided into segments of 10 cm, and were melted down on board the ship. All handling of the cores was done using rubber gloves to eliminate contamination. Salinity was measured in the melt water of each segment using a Watnable salinometer. Samples were taken to measure the nutrient content of nitrate, nitrite, sulphate and silicate. These samples were fixed with chloroform and kept cool (around $+3^0$C). Samples to study the presence of ice algae in the sea ice were taken from each segment and fixed with formalin. Analysis of nutrient and algae contents will be made in Norway.

d) The radio echo sounding equipment described above, was primarily brought for the iceberg studies. Time constrains meant that only limited radio echo soundings were flown over Riiser-Larsenisen and Trolltunga. About 30 km of ice thickness measurements were done in a profile running west from Kvitkuven and parallel with, and a few km from, the ice front. The outer part of Trolltunga was measured across its whole width of about 40 km, mostly along one track about 10 km from the ice front.

PRELIMINARY RESULTS

a) The cyclic data recorded during the two iceberg experiments are being processed and compared with theoretical models to provide improved understanding of iceberg behaviour. Some of the recorded data are shown in Fig. 2 in the form of continuous recording (time series). It is clear that, as noted during previous experiments, the icebergs act as filters to the broad spectrum ocean swell. Thus response periods of 20 seconds dominate in the pitch and roll data, while heave and strain have typically shorter response periods of 12 and 16 seconds.

b) The studies of the underwater shape of the icebergs, together with similar data from the ice fronts, show that the shape undergoes considerable modification with time. A side where major fracture has taken place will initially be plane and essentially vertical. With time this becomes modified both on a small scale, and on a major scale of severals tens of meters (Fig. 3). Then the ice fronts develop underwater ledges, and the icebergs demonstrate rounded under-water shapes, including types of keels.

c) Some mean parameters characterizing the collected ice cores are shown in Table I. It is evident that salinities are similar to those found by Clarke & Ackley (1984) and that most of the cores are from one-year ice. There was some evidence of algae at the bottom of the ice cores, but also within the ice. Whether these algae were alive at the time of sampling cannot yet be established.

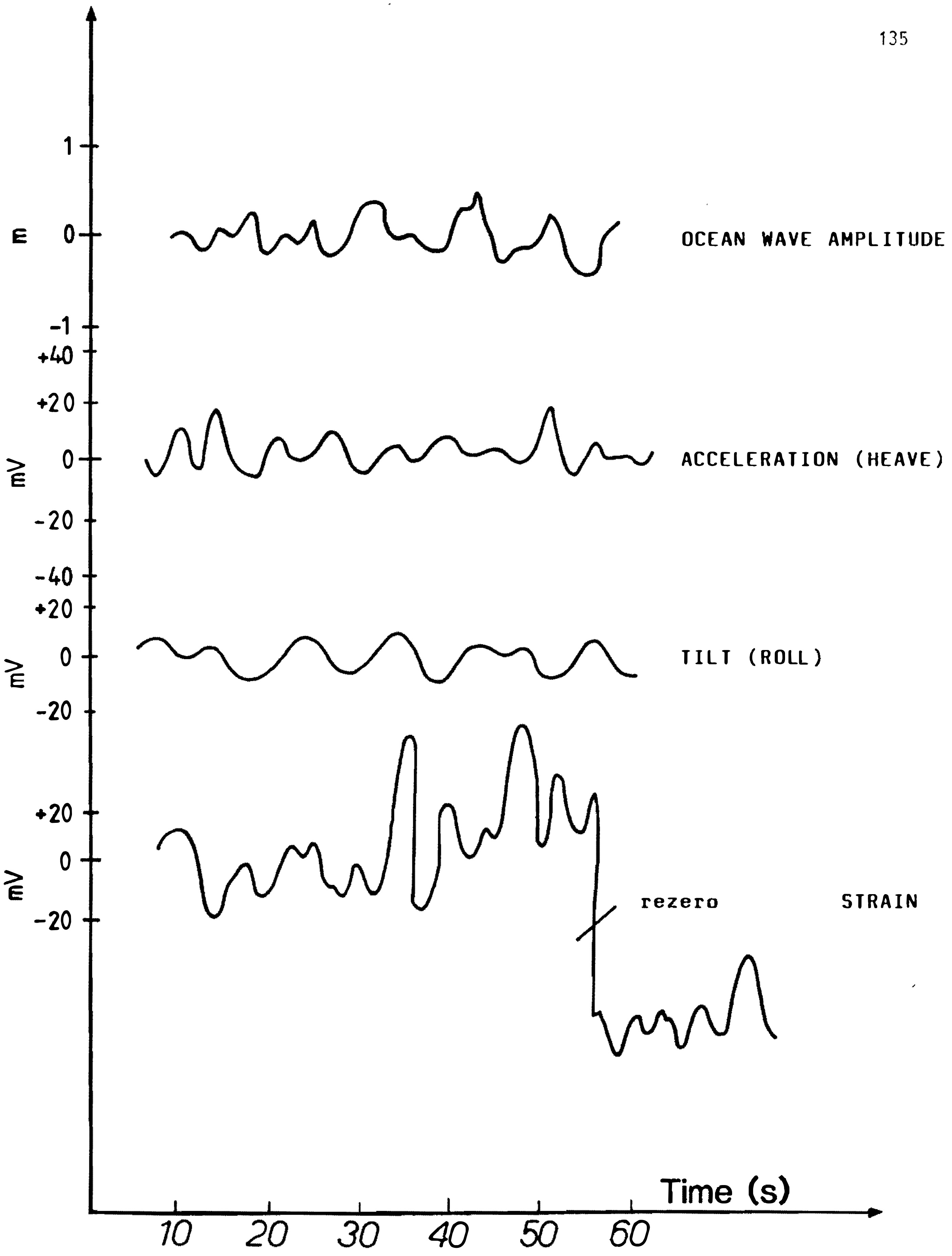

Fig. 2. Ocean wave amplitudes, rigid body motions (heave and roll), and flexural response of the iceberg during experiment no. 2. The heave, roll, and strain responses are given in uncoverted units (mV).

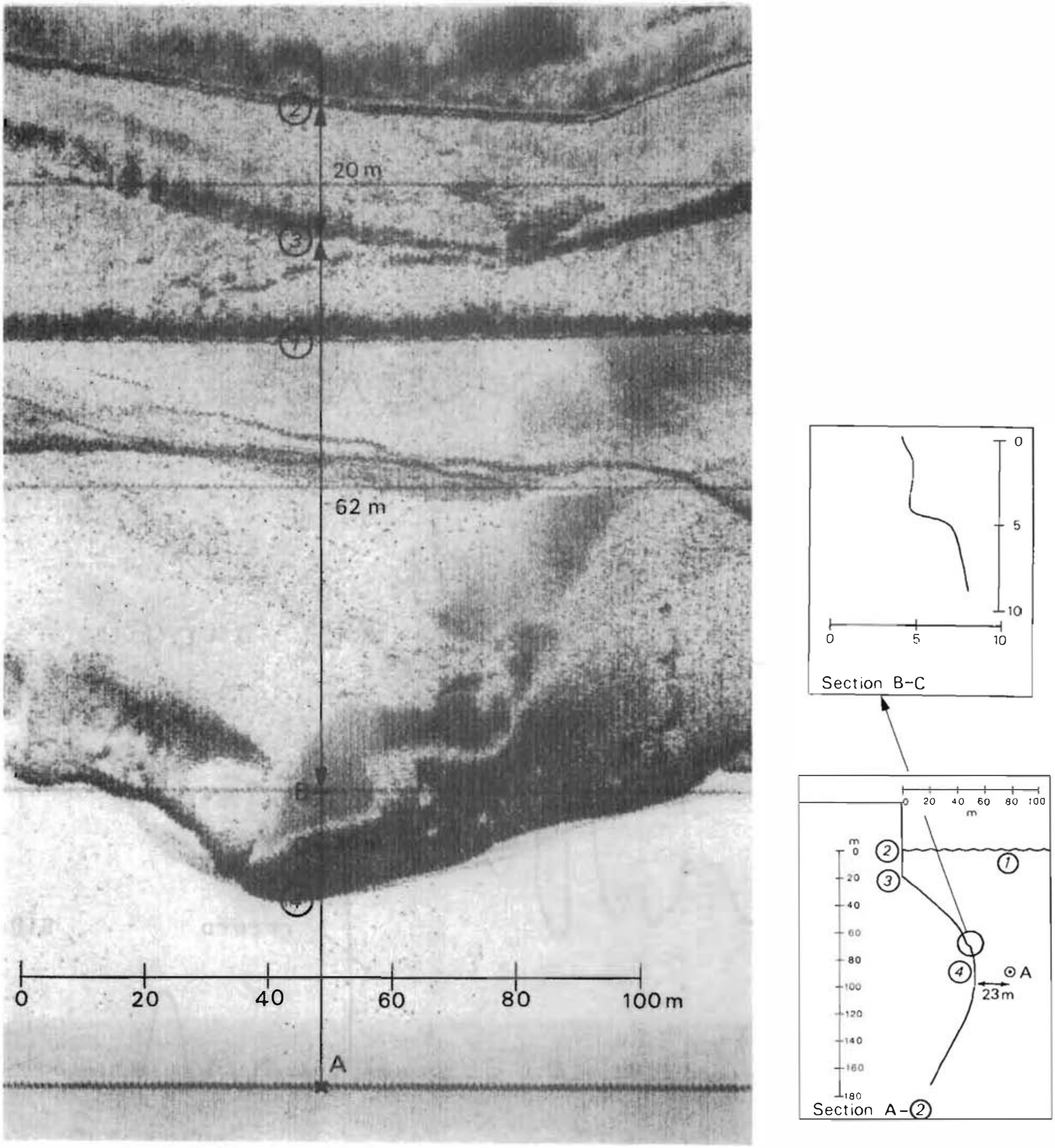

Fig. 3. A section of Brunt Ice Shelf registered by side-scan sonar, (left) with indicated distances from the sonar. A simplified interpretation along the section from A - 2 is given on the right. The sonogram shows the ice wall from a depth of 90 m to the surface. The sonar (O in lower righthand diagram) is located at A.

TABLE I: Sea ice cores collected during NARE 1984/85.

Ice core no.	Date Day/Mo.	Position Lat.	Long.	Sea ice type	Length (m)	Mean salinity (‰)
1	8/1	70 04 S	04 19 E	One-year	1.63	2.8
2	9/1	70 03 S	04 08 E	"	1.31	5.2
3	14/1	69 59 S	02 09 E	Fast ice	2.44	3.0
4	17/1	72 23 S	16 07 W	"	1.34	4.9
5	27/1	74 51 S	31 31 W	Multi year	2.28	3.5
6	8/2	77 22 S	39 50 W	One-year	1.68	5.2
7	9/2	76 48 S	36 03 W	"	1.09	6.1
8	13/2	74 17 S	32 43 W	Multi year	1.76	4.5
9	14/2	74 10 S	33 49 W	"	2.12	3.9
10	15/2	74 23 S	35 51 W	"	2.39	3.7

d) The radio echo soundings of the outer part of Riiser-Larsenisen showed thicknesses around 200 m. The section across Trolltunga showed much larger thickness variations with a mean of about 300 m.

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