RAPPORTSERIE

Nr. 11 - Oslo 1982

YNGVE KRISTOFFERSEN:

US ice drift station FRAM-IV:
Report on the Norwegian field program

NORSK
POLARINSTITUTT

Nr. 11 - Oslo 1982

YNGVE KRISTOFFERSEN:

US ice drift station FRAM-IV:
Report on the Norwegian field program

Contents

ABSTRACT

The US ice drift station FRAM-IV was deployed in the Arctic Ocean at 83°57'N, 21°E on 15 March 1982 about 200 n.m. north of Svalbard and manned by twenty US and three Norwegian scientists. During 57 days of operation, the camp drifted about 165 n.m. southwestwards from the Eurasian Basin onto the northern flank of the Yermak Plateau. The US scientific program focused on ocean acoustics, oceanography, and meteorology while the main objective of the Norwegian program was to obtain a geophysical traverse from the deep ocean to the continental margin north of Svalbard. Generally good weather and ice conditions permitted all major scientific objectives to be completed successfully. The main achievements of the Norwegian program were acquisition of 200 km of seismic multi-channel (20) reflection data and joint with US institutions seven refraction profiles of 20-80 km length. A total of 87 regional depth and gravity measurements was made to map the northeastern extension of the Yermak Plateau.

1. BACKGROUND

The long term effort by the United States to acquire basic scientific information in a broad range of disciplines in the Eurasian Basin of the Arctic Ocean has during 1979-82 been carried out by a series of temporary manned stations deployed on and drifting with the polar ice pack. Typical duration is 50-60 days with a crew of 20-25 scientists (Fig. 1). The usable time window for these exclusively aircraft-supported operations is set by the return of daylight during the first week of March and terminated by predominant overcast and foggy conditions as warmer air masses penetrate into the Arctic Ocean; generally during the first week of May.

The research has focused on physical oceanography, ocean acoustics, and marine geophysics/geology with different priorities in alternate years. International cooperation has been encouraged by the participation of Canadian, Norwegian, and Danish scientists in joint as well as separate scientific programs. An outline of the research carried out during the FRAM-I expedition has been given by Hunkins et al. (1979), of FRAM-II by Baggeroer and Dyer (1982), and of FRAM-III by Manley et al. (1982).

Ice stations FRAM I-IV were funded by the Arctic Programs Office of Naval Research (ONR). The logistic support has been provided under contract with Polar Science Center (PSC), University of Washington (UW), Seattle. Norwegian participation was kindly invited by ONR with the commitment that no classified research would be carried out from these platforms.

2. PLANNING

General FRAM-IV scientific objectives were presented by a number of US research groups as well as Canadian and Norwegian participants at the first planning meeting on November 18, 1980, at Lamont-Doherty Geological Observatory, New York, with ocean acoustics and marine geophysics designated priority disciplines. A second meeting was held at Woods Hole Oceanographic Institution 17-18 July, 1981, for presentation of final programs (Table 1) and detail implied logistics requirements.

The Norwegian input was coordinated through Norsk Polarinstitutt (NP) by Dr. Yngve Kristoffersen, research geophysicist. Based on our FRAM-I experience, the Norwegian effort was concentrated on marine geophysics. The general scope of the Norwegian scientific program was to obtain a geophysical traverse from the deep ocean basin onto the continental margin north of Svalbard.

In the FRAM-IV science program, ocean acoustics were given priority during the first half of the drift period and marine geophysics during the last half. Dr. A. Baggeroer, MIT, was designated FRAM-IV chief scientist from deployment to 15 April, Dr. I. Dyer, MIT, 15-25 April, and Dr. Y. Kristoffersen, NP, from 25 April until termination of the science program around 10 May.

Table 1

FRAM-IV science program

Discipline	*Institution*	*Personnel total*
Ocean acoustics		
Ambient noise	MIT/WHOI	2
	LDGO	1
	NRL	
LF transmission	MIT/WHOI	6
	LDGO	
	NRL	3
	NUSC	3
Reverberation, backscattering	MIT/WHOI	
Bottom interaction	NUSC	
Oceanography		
Physical ocanography	LDGO	1
Testing of data buoy	UW	
Current measurements	LDGO	
Solid earth geophysics		
Seismic reflection	NORSAR/NP	3
Seismic refraction	MIT/WHOI	
	NORSAR/NP	
Bathymetry, camp	LDGO/WHOI	
Bathymetry, regional	NP	
Gravity	UiO	
Heat flow	LDGO/UiO	
Geology		
Gravity coring	LDGO	
	UiO	
Meteorology		
Winds, temperature, pressure	UW	1
ARGOS data buoy	NP	
Navigation	LDGO/NP	
Support		
Helicopter		2
Cook		1
Camp services		2-3

LDGO : Lamont-Doherty Geological Observatory, USA
MIT : Massachusetts Institute of Technology, USA
NORSAR : Norwegian Seismic Array, Norway
NP : Norwegian Polar Research Institute, Norway
NRL : Naval Research Laboratory, USA
NUSC : Naval Underwater Systems Center, USA
UiO : University of Oslo, Norway
UW : University of Washington, USA
WHOI : Woods Hole Oceanographic Institution, USA

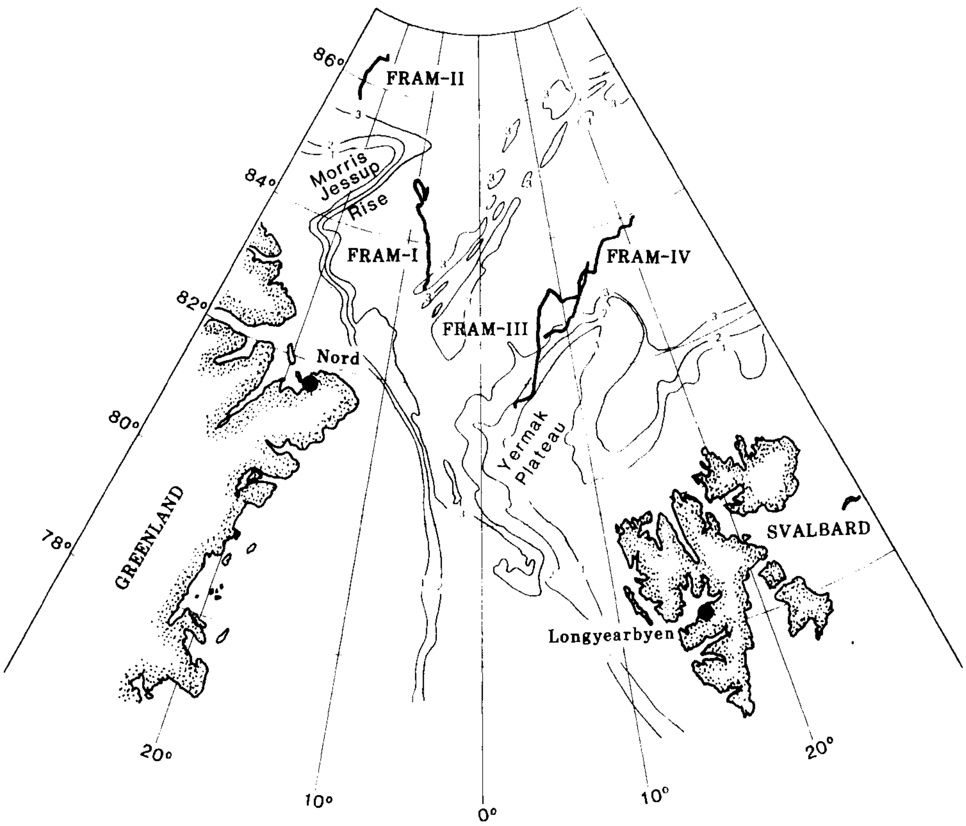


Fig. 1. Drift tracks of U.S. ice drift stations FRAM I-IV, 1979-82. Depth in kilometers.

The planning effort at the national level was mainly concerned with our proposed seismic multichannel program. Altogether five meetings were held at NORSAR during the period to discuss program requirements, technical solutions and to check on progress. In particular, modification of the sonobuoys (40) required a considerable effort. A detailed list of all required camp equipment, tools and clothing was given the logistics support group at NP for processing by mid-December 1981.

3. LOGISTICS

3.1. Field support

FRAM-IV logistic support was provided by the Polar Science Center, UW, under the leadership of Andreas Heiberg. The PSC services range from management of aircraft operations to on-the-ice provisions of housing materials, food services, electricity, heating, vehicles, and the odd piece of tool somebody inadvertently left at home. This arrangement allowed the participating scientists to devote full attention to their experiments.

Fig. 2. The Twin-Otter and Bell 204 helicopter in camp.

Alan Hielscher was station leader on FRAM-IV with Allan Gill as assistant and Miss Eileen Murray as cook. This PSC crew, together with Jay Ardai, LDGO, provided the daily camp services for about twenty scientists.

At Nord, Andreas Heiberg supervised field operations and directed the supporting aircraft. Matt Valley, cook, provided food for transit personnel. Project liaison at Thule Airbase was Imants Virsnieks.

Two aircraft were contracted from Bradley Air Services, Canada, for FRAM-IV: A Twin-Otter and a C-47, the latter only during the deployment phase. A Tri-Motor turbo DC-3 from Specialized Aircraft Services, California, also assisted. All aircraft were operated out of Nord, Greenland. A Bell 204 helicopter from Greenland Air Charter was stationed on FRAM-IV during the whole period for support of the scientific programs (Fig. 2).

3.2. Activities in 1981

In the spring of 1981, about 50,000 gallons of fuel was air lifted from Thule Airbase, northwestern Greenland, to Nord, northeastern Greenland,the FRAM-IV staging point.

From the Norwegian side, arrangements were made with Longyearbyen Airport authorities for provision of fuel for the aircraft support necessary for Norwegian participation.

3.3. Staging of FRAM-IV

With the arrival of two Hercules C-130 aircraft at Thule Airbase on 9 March with equipment and US personnel, FRAM-IV was underway. They proceeded to Nord on 12 March. On Sunday, 14 March, the Twin-Otter made the first search flight from Nord for a suitable ice floe in the target area defined by the box 83°30'N, 85°N, 25°E, and 30°E, to establish the FRAM-IV camp. No satisfactory floes were spotted and the plane returned with the three-man advance party. Later in the day the C-47 made a second search flight with the same result. However, on the next day, Monday 15 March, FRAM-IV was established at 83°57'N, 21°E on a floe 2 x 1 km (Fig. 3). A Twin-Otter runway was laid out on the floe, but a refrozen lead about four kilometers to the northwest had to be used as landing area for the C-47. The helicopter arrived FRAM-IV on 17 March from Nord and was used to sling the C-47 cargo to camp. By 23 March almost all US scientific equipment and personnel had been moved from Nord to FRAM-IV by twelve Twin-Otter flights and nine C-47 runs. At that time the planes were routed to Longyearbyen to pick up the Norwegian group.

A satellite ice station named White Dwarf was deployed on 26 March at 86°12'N, 04°25'W and manned by 3-5 persons to operate a low frequency sound source through mid-April. To complete the Fram deployment required a total of fifteen Twin-Otter and thirteen C-47 flights to deliver about 80,000 lbs. or 40 tons of equipment.

Drummed fuel was air dropped at FRAM-IV on ten Hercules missions out of Thule during the period 19 March - 1 April and explosives for the seismic refraction experiments required three missions on 26-27 March by the USAF 317th Tactical Air Wing.

Backhaul of equipment started shortly after mid-April. The FRAM-IV science program was terminated on 9 May and the final party left the dismantled ice station on 11 May.

4. THE NORWEGIAN FIELD OPERATIONS

4.1. Personnel

The estimated personnel requirement for Norwegian programs on the ice was five persons to maintain an around-the-clock operation and carry out the anticipated daily work load. Due to competing requirements from other US groups this was cut to three persons to keep the number of scientists on the ice station at a level that could be adequately supported with the available logistic resources.

Yngve Kristoffersen, geophysicist, was heading the Norwegian group which consisted of: Paul Larsen, engineer, NORSAR, Anders Solheim, geologist, Norsk Polarinstitutt, Alf K. Nilsen, engineer, NORSAR, and Oddmund Liabø, engineer, University of Oslo. Nilsen and Liabø were rotated with Larsen and Solheim on 16 April, i.e. midway through the drift period.

The NP Svalbard office in Longyearbyen was manned during the field operation by logistics manager Kåre Bratlien and later by assistant Jan Mikalsen to handle radio-communications and support aircraft operations.

4.2. Main field events

The Norwegian scientific equipment, about 1900 kg, was air freighted to Longyearbyen during mid-February to mid-March. In addition 500 kg of gel batteries for the sonobuoys had been shipped by boat in the summer of 1981.

A summary of the main field events is given in Table 2.

Kristoffersen, Larsen, and Solheim arrived in Longyearbyen (LYR) on 19 March and were moved to FRAM-IV with all equipment by project Twin-Otter and C-47 aircraft on 24 March. The flight time LYR – FRAM-IV was 2 hrs. 30 mins.

As the planned air gun operation caused some concern over potential induced break-up of the ice, the Norwegian operation was sited away from camp towards a relatively young refrozen lead (Fig. 3).

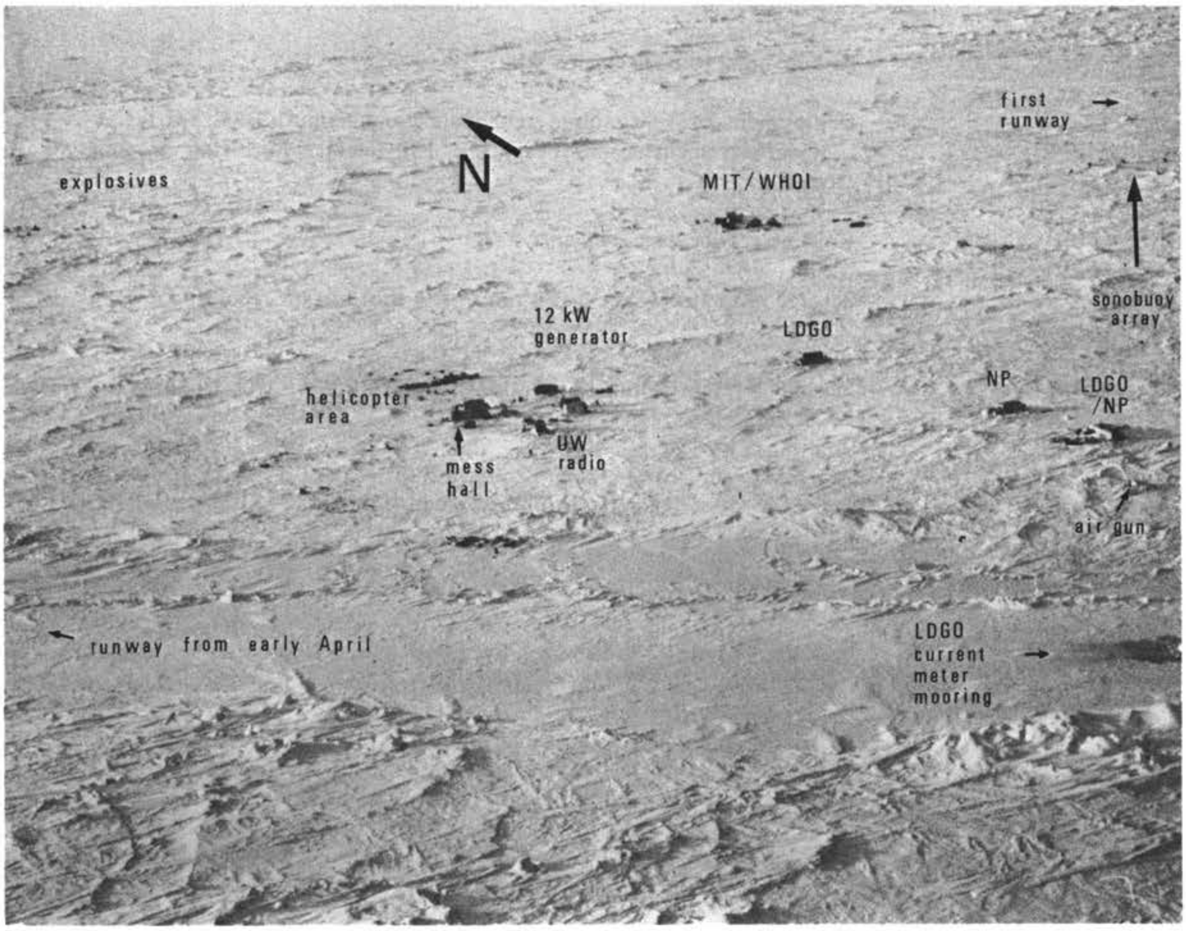


Fig. 3. FRAM-IV camp overview.

Table 2

Norwegian field program - Summary of events

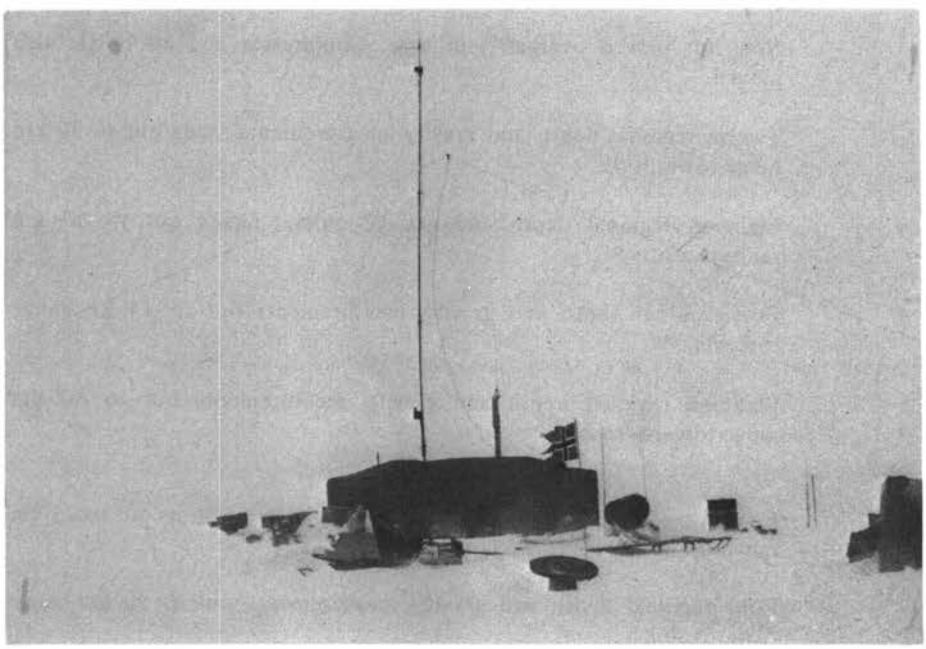
Date	*Event*
March 15	FRAM-IV deployed at 83°57'N, 21°26'E by three-man advance party.
23	Bulk of US scientific equipment and personnel at the ice.
24	Norwegian group arrives FRAM-IV, manigan for accomodation erected. LDGO navigation starts.
26	Work on hydrohole and LDGO/NP manigan - approximately two days. First part of MIT science program (ambient noise) operational.
27	NP recording of navigation starts.
28	Deployment of 13 sonobuoy channels along azimuth 055° for refraction measurements, sensor spacing 150 meter. Receiving antenna erected.
29	Routine gravity measurements start.
31	Seismic refraction shake down run to test shot instant recording.
April 1	Seismic refraction line No. 1 along azimuth 055° - MIT 14 shots out to 70 km range.
2	Refraction line No. 2 along azimuth 220° - MIT 17 shots to 80 km range. Air gun readied. Compressor will not start because of voltage drop in cable.
3	Air gun firing problems.
6	Seismic reflection profiling for five hours with WHOI 80 cuinch air gun operated at 40 kg pressure in LDGO/NP manigan.
7	Work begun on new hydrohole 60 meter towards lead. Blasting was required to complete hole as a separate 1.2 m thick layer of underthrusted ice was encountered below 2.2 m.
8	Start of first extensive period of reflection profiling 8-10 April, with 120 cuinch air gun. Work on new array begun.
9	Switched recording to new array along azimuth 025° with 100 meter sensor spacing - 16 channels operational out of 20.
13	Recording of NRL refraction line - 34 shots set at 1500 meter depth out to 45 km range.
14	Tests of 3.7kHz echosounder suspended below helicopter unsuccessful due to low S/N ratio.

15	First regional depth and gravity measurements with helicopter on NE part of Yermak Plateau - 18 spot measurements with 5 km spacing.
16	Visit by Governor of Svalbard and Gjelsvik, Director of Norsk Polarinstitutt. Crew rotation: Nilsen and Liabø arrive, Larsen and Solheim leave.
17	Regional depth and gravity measurements towards NW to 80 km range. Later five measurements out to 25 km range towards south.
18	Refraction line No. 3 along azimuth 225° - MIT 7 shots to 25 km range.
19	Refraction line continued - MIT 6 shots 29-74 km range. Refraction line No. 4 along azimuth 050° - MIT 9 shots 10-40 km range.
20	Refraction line No. 4 continued - MIT 4 shots 40-60 km range. First sediment sample recovered by gravity coring - 10 cm core. Water depth 3880 m.
23	MIT/WHOI, NRL, and NUSC programs completed.
24	Four gravity cores less than 50 cm long recovered up to now - several failed attempts with various core catcher configurations.
25	New hut moved over air gun hole. Compressor and air bottle also moved.
26	Twelve regional depth and gravity measurements made out to 30 km range towards SE.
27	Eighteen regional depth and gravity measurements out to 50 km range towards SE.
29	Five regional depth and gravity measurements out to 15 km range towards NW.
30	Eighteen regional depth and gravity measurements out to 80 km range towards south.
May	
1	Refraction line No. 6 along azimuth 225° - NP 5 shots out to 23 km range. Line aborted due to bad weather.
2	Four regional depth and gravity measurements out to 90 km range towards south.
3.	Refraction line No. 7 along azimuth 225° - NP ten shots in 7-31 km range.
4-8	Regional science program curtailed by persistent white out conditions unfavourable for helicopter operations. All in-camp geophysical data acquisition at full capacity.
7	ARGOS environmental data buoy arrives FRAM-IV and thermistor string deployed.
9	FRAM-IV science program closed down and Norwegian group departed to Longyearbyen.
11	FRAM-IV abandoned.

Upon arrival the immediate task of erecting the 8' x 16' 'manigan' which served as combined accommodation and electronics laboratory, was completed after three hours (Fig. 4). The 'manigan' had a floor of 1/2" plywood resting on pieces of lumber, 2" x 4". A frame of aluminum pipes braced diagonally, was covered with an insulated nylon blanket. Shirts around the perimeter was covered with snow to secure the building. Two 4" x 4" lumber across under the manigan served as hook-up points in case the building needed to be moved by helicopter. A 50,000 Btu. stove provided more than adequate heating. Sturdy instrument racks and work bench were made of lumber and plywood and gave excellent working conditions (Fig. 4).

A double manigan 8' x 30' was subsequently built jointly with the Lamont group (Fig. 3) to house the deep sea winch, compressor and air gun. The building was positioned over a 1 x 1 m hole made through the 2.5 m thick ice.

Work was then started to install the sonobuoy array in time for the first seismic refraction experiment. On 1 April, a 13-channel array, 1800 m long, successfully received the signals from fourteen shots set off by MIT out to a range of 70 km from the camp. Line 2 was shot the following day in the opposite direction.



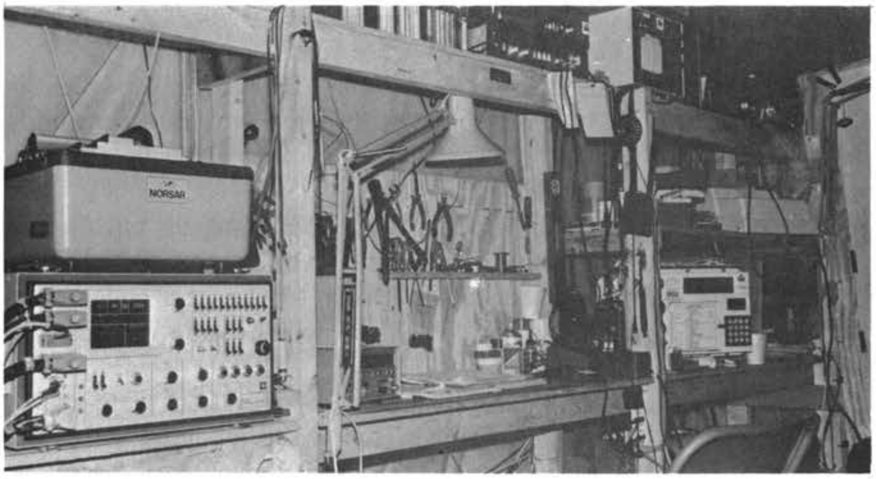
A

Fig.4. A.: NP hut with sonobuoy receiver antenna.

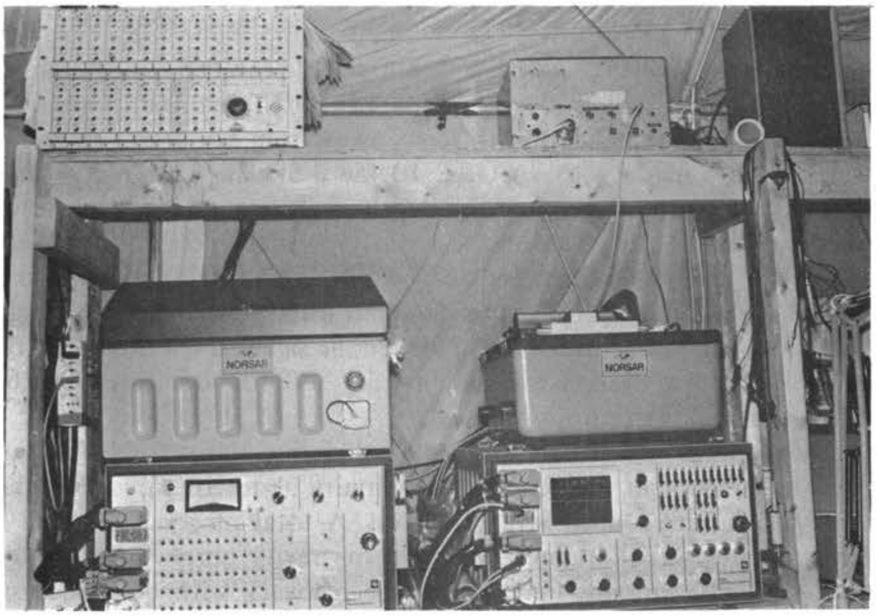
B. (opposite): Work bench and positioning instruments (far right) consisting of dual channel Magnavox satellite receiver and Magnavox integrated Omega/satellite receiver.

C. (opposite): Sonobuoy receiver (top left) and DFS-V seismic digital recording system. The airgun firing circuit (top right) was kindly provided by the Seismological Observatory, University of Bergen.

D. (opposite): Sleeping quarters and electronics rack (right). →



B



C

D

A sonobuoy array for the seismic reflection experiment was then installed along an azimuth of 025° based on the observed drift direction under favourable weather conditions. On 9 April, sixteen channels were operated and later extended to twenty channels.

Air gun operation was initiated in the LDGO/NP manigan, but discouraged for safety reasons and interference with other work through the hydrohole. A new hydrohole was then made 60 m closer to the lead and covered with a single canvas. No heating was available here which made working conditions extremely akward.

Initial problems in obtaining a stable air gun operation were mainly overcome by 8 April. After part of the MIT/WHOI group left around 25 April a building was moved over the air gun hole. The priority given to the acoustics program did not permit contineous airgun operation as well as work with the deep sea winch until after 23 April.

Gravity readings were taken with a 2 km sample interval, using a gravimeter resting on the ice through a hole in the LDGO/NP manigan floor. The same instrument was used on helicopter traverses away from camp.

Three trials were made with an ORE 10 kw 3.5 kHz echosounder suspended 25 meter below the helicopter for depth measurements in open leads away from camp. However, excessive noise levels prevented recognition of any clear bottom echos in the 4000 meter deep water. Regional depth measurements were then carried out by helicopter landings using polar bear fire crackers as sound source and by recording the hydrophone signal and a time code on casette tape. The recording system was designed by MIT for monitoring of the shot instant for seismic refraction shooting.

The Lamont deep sea winch was installed during the second week of April, but due to concern in the acoustic community about the noise, general operation was not allowed until after 23 April. A total of seven short (10-50 cm) sediment cores were obtained with a 3 m gravity corer. Considerable joint LDGO/NP effort went into improving the recovery with little success.

A new digital heatflow probe, owned jointly by Lamont and Norwegian institutions, arrived in pieces, but was assembled and successfully operated on four runs by J. Arday, LDGO.

4.3. Camp life

Camp support enabled each group to devote full attention to their respective programs. All meals were served at regular hours in the 16' x 24' 'parcoll' structure which served as mess hall (Fig. 3). Breakfast 0730-0830, lunch 1200-1300, coffee 1600, and dinner 1800-1900.

The seismic reflection program required around-the-clock attention of the navigation and manual firing of the airgun. The NORSAR engineer responsible for maintenance of the electronics had a +12 hour shift during daytime. Kristoffersen and Solheim (later rotated with Liabø) shared the night watch and were responsible for airgun and array maintenance as well as work on the other Norwegian experiments during daytime.

5. THE ENVIRONMENT

The ice pack in the FRAM-IV area moves steadily in a south-westerly direction under the influence of the Transpolar Current (Fig. 5). This motion is modulated by the local weather with prevailing south to easterly winds. In general during late March to mid-April when FRAM-IV was far into the polar pack, major changes in drift velocity were relatively smooth and delayed by a day or so relative to major changes in the wind speed (Fig. 6). However, in late April - early May, drift rates became more oscillatory and the response to the wind stress much faster, probably related to the ice station being closer to open water (81°N). Prior to mid-April air temperatures were in the range

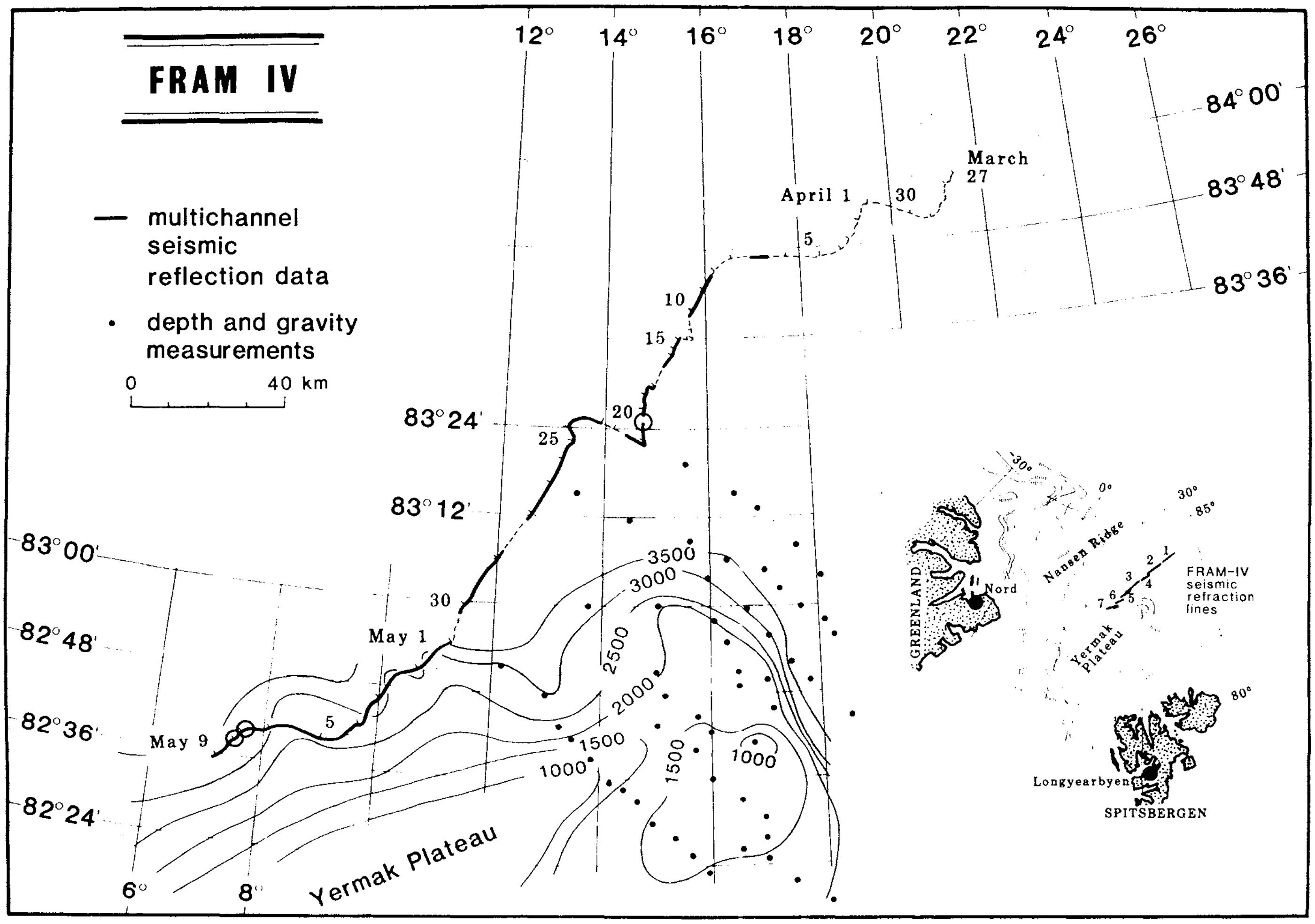


Fig. 5. The drift track of the ice station and summary of Norwegian geophysical measurements. The seismic refraction measurements were carried out jointly with MIT/WHOI and sediment sampling jointly with LDGO. Sediment core locations shown by circles. Bathymetric contours from GEBCO chart 5-17 modified by the new data.

-28°C to -36°C with several intrusions of warmer air in late March (Fig. 6). After mid-April, temperatures increased steadily towards zero degrees centigrade. The warmer air in May generated frequent fog banks and overcast conditions with low cloud base. The resulting poor ground contrast represented serious problems for aircraft operations and kept the helicopter grounded during the last week on the ice.

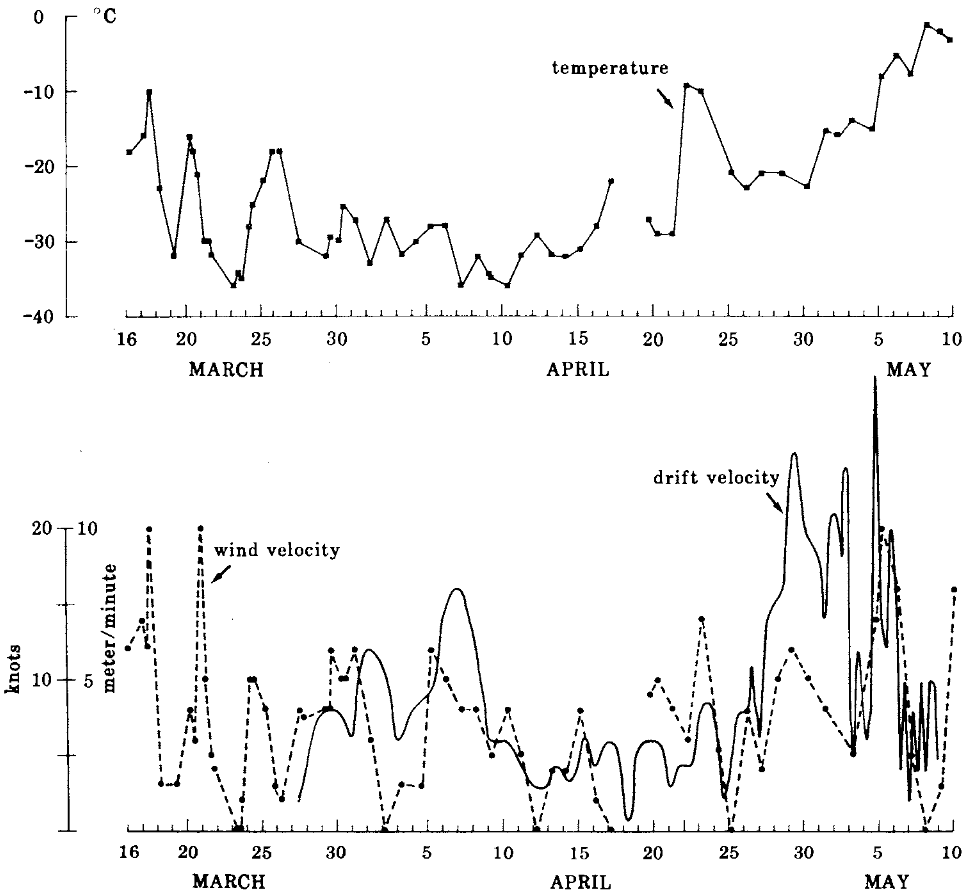


Fig.6. A: Daily air temperatures 0700 GMT at FRAM-IV from aviation weather reports. B. Correlation between wind velocities in knots (observed at 0700 GMT) and FRAM-IV drift speed in meters/minute. Wind data and temperatures kindly provided by Allan Hielscher, Polar Science Center, University of Washington.

6. FRAM-IV SCIENCE PROGRAM

6.1. Participating institutions and programs

USA: MASSACHUSETTS INSTITUTE OF TECHNOLOGY/WOODS HOLE OCEANOGRAPHIC INSTITUTION

a) Acoustic transmission experiments between FRAM-IV and ice station White Dwarf.
b) Reverberation experiments for measurements of back-scattering from the ice and the perimeter of the Polar Basin.
c) Ambient noise measurements.
d) Seismic refraction measurements jointly with the Norwegian group.

USA: LAMONT-DOHERTY GEOLOGICAL OBSERVATORY

a) Navigation.
b) Acoustic transmission experiments between FRAM-IV and White Dwarf.
c) Ambient noise and microearthquake monitoring.
d) Deployment of two current meter strings down to 300 m depth for continuous recording during the FRAM-IV drift.
e) Sediment coring jointly with the Norwegian group.
f) Bathymetric measurement with 3.5 kHz echosounder jointly with WHOI.
g) Water sampling.
h) Heat flow measurements jointly with the Norwegian group.

USA: UNIVERSITY OF WASHINGTON

a) Meteorology. Continuous logging of winds at two levels, air pressure and temperature.
b) Testing of oceanographic data buoy.

USA: NAVAL UNDERWATER SYSTEMS CENTER

a) Acoustic transmission experiments between FRAM-IV and White Dwarf.
b) Bottom interaction measurements.
c) Ambient noise measurements.

USA: NAVAL RESEARCH LABORATORY

a) Sound field measurements of coherent signals and ambient noise using a vertical array.

NORWAY: NORSK POLARINSTITUTT

a) Navigation.
b) Seismic multichannel reflection measurements jointly with NTNF/NORSAR.
c) Seismic refraction measurements jointly with NTNF/NORSAR and MIT/WHOI.
d) Regional depth measurements.
e) Deployment of ARGOS meteorological data buoy with a 75 meter thermistor chain in the water.

NORWAY: NTNF/NORSAR

a) Seismic multichannel reflection measurements jointly with Norsk Polarinstitutt.
b) Seismic refraction measurements jointly with Norsk Polarinstitutt and MIT/WHOI.

NORWAY: UNIVERSITY OF OSLO

a) Gravity measurements on FRAM-IV.
b) Regional gravity measurements.
c) Jointly with LDGO sediment sampling by gravity coring.
d) Jointly with LDGO, heat flow measurements.

The progress of the FRAM-IV field experiments for the participating institutions is summarized in the weekly science reports given in Appendix A.

7. NORWEGIAN SCIENTIFIC PROGRAMS AND RESULTS

An overview of the Norwegian scientific results are given in Fig. 5.

PROJECT: NAVIGATION

Principal investigator:
Dr. Yngve Kristoffersen, Norsk Polarinstitutt

Objective:
- Provide position information for calculation of drift velocity.
- Monitor Omega offset in camp for navigation of helicopter in differential Omega mode.

Instrumentation:
a) Dual channel Magnavox MX-1502 satellite receiver recording on tape.
b) Magnavox MX-1105 integrated Omega/satellite receiver with printer.
c) Motorola Mini-Ranger navigation system with printer.

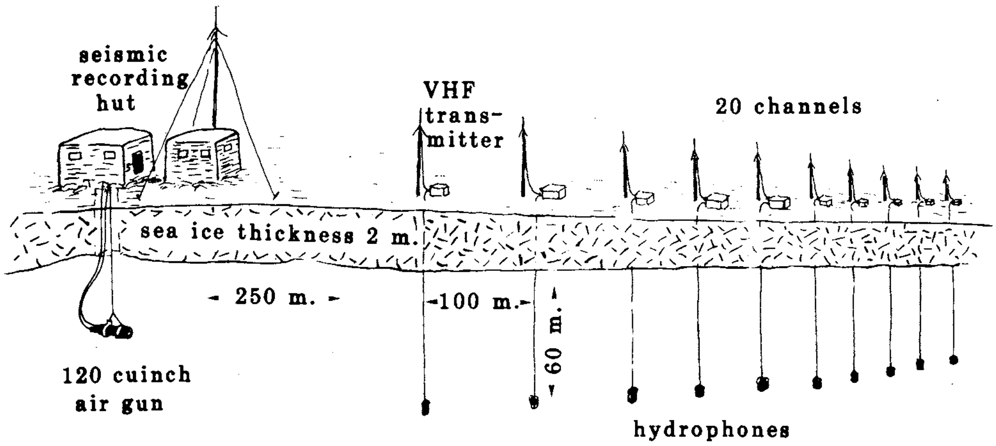


Fig. 7. Cartoon showing the concept of the seismic multichannel reflection experiment.

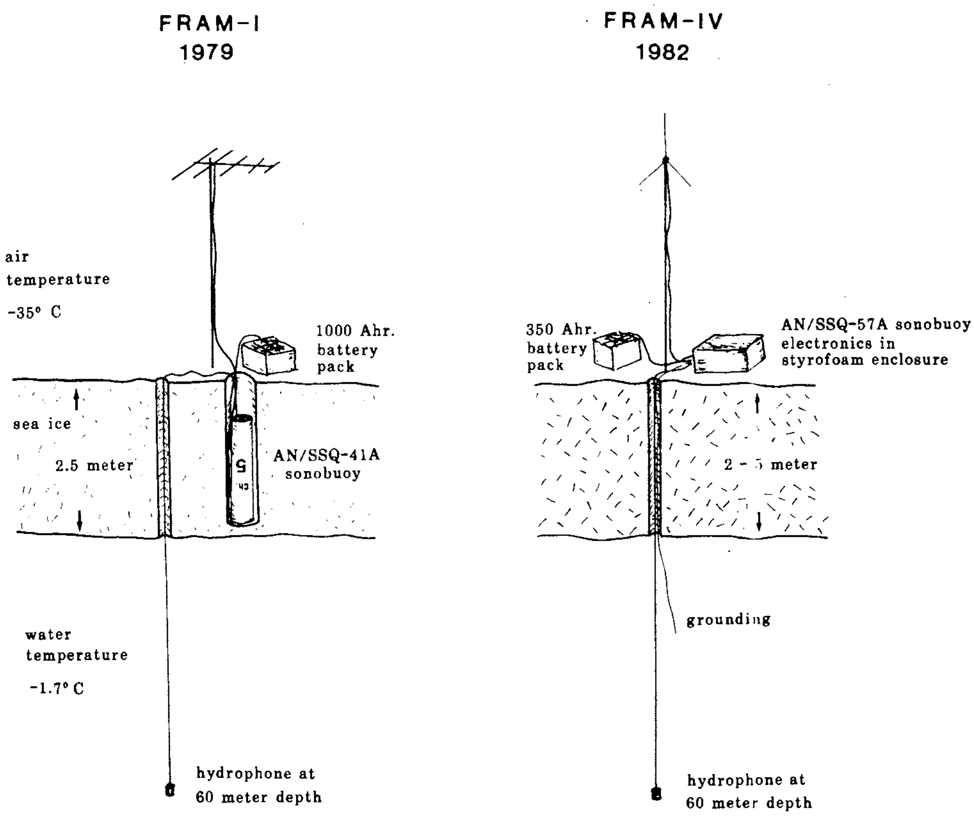


Fig. 8. Concept for sensor arrangement used in 1979 and on FRAM-IV (right).

Field work and results:

An average of 1.3 satellite fixes per hour was acquired between 1522 GMT 27 March and 0630 GMT 9 May. These fixes have been evaluated with respect to elevation of satellite (20°-65°), number of Doppler counts (>30), number of iterations in the calculations (⩽2) and a standard deviation in the final solution of less than 50 meter. The edited navigation log (Appendix B) yields 0.5 fix per hour or about one fix every 500 meter. Drift speeds varied from 1 to 15 meters/ minute and correlates with the observed surface wind speed (Fig. 6).

The number of fixes acquired by the single channel satellite receiver was substantially lower.

Start-up problems were encountered with the Omega/sat.nav. system as a stiff cable inadvertently caused switching of polarity when the antenna cable was connected to the antenna preamplifier. Spares requested from California via Oslo arrived on the ice in less than a week.

Omega offset distances range from 1 to 3 kilometers and show systematic variation with time of the day.

PROJECT: SEISMIC REFLECTION MEASUREMENTS

Principal investigators:

Dr. Eystein S. Husebye, NTNF/NORSAR
Dr. Yngve Kristoffersen, Norsk Polarinstitutt

Objective:

- To investigate the potential of a telemetered array of expendable elements for acquisition of high-quality multichannel seismic reflection data from oceanic areas with permanent ice cover.
- To deploy a long array (aperture ~ 2-3 km) for mapping of deeper horizons in the crust.
- To undertake some passive seismic data collection for mapping of the ambient noise field.

Instrumentation:

a) 48 ea. modified AN/SSQ-57A sonobuoys - 24 channels.
b) 24 channel sonobuoy receiver custom made by Teletron Industri A/S, Tromsø.
c) Texas Instrument DFS-V 24 channel digital seismic recording system.
d) 120 cuinch air gun kindly provided by University of Bergen.
e) 80 cuinch back-up air gun kindly provided by WHOI.
f) Diver compressor and air bottle.

Field work and results:

The field strategy was planned jointly with Bård Johansen, Superior. A seismic reflection array was laid out along azimuth 025° determined as an average steady drift direction from observations 27-29 March and 1-3 April (Figs. 5 and 7). Sensor spacing was 100 meters and offset to first channel 250 meters.

A 10 cm diameter hole was drilled at each sensor location and the hydrophole suspended at 60 meter depth (Figs. 8 and 9). Ice thicknesses in the range 2-5 meter were encountered as a major part of the array had to be laid out in an area with abundant pressure ridges. Installation time ranged from 30 minutes to 2 hours or more. The signal was telemetered to the recording hut by the sonobuoy electronics housed in a 10 cm thick styroform enclosure placed on the ice together with the 350 Ahr. battery pack. The heat from the output power transistor kept the electronics above 0^{o}C. A quarter wave ground-plane antenna was mounted on a 3 meter bamboo pole (Fig. 9).

The array performed reasonably well with more than 75% of the channels operational at any one time. Downtime during the first 1-2 weeks was mostly due to transmitter or hydrophone malfunction. After mid-April the array stabilized, but marginal battery capacity in cold weather appeared to be a problem at 4-6 sites and necessitated replacement by rechargeable batteries twice a day.

There was no significant ice activity within the area of the array or the camp and consequently no relative motion between individual sensor sites during the drift. The orientation of base line monitored daily by the Lamont group taking sun shots with a theodolite stayed within ±3^{o} of its initial orientation.

The air gun was first (6 April) operated through the hydrohole in the LDGO/NP manigan but subsequently moved to a separate hydrohole made behind a pressure ridge about 60 meters towards a refrozen lead. Lack of heat at this site caused the hole to gradually refreeze and the air gun to freeze into a lump of ice when recovered for maintenance.

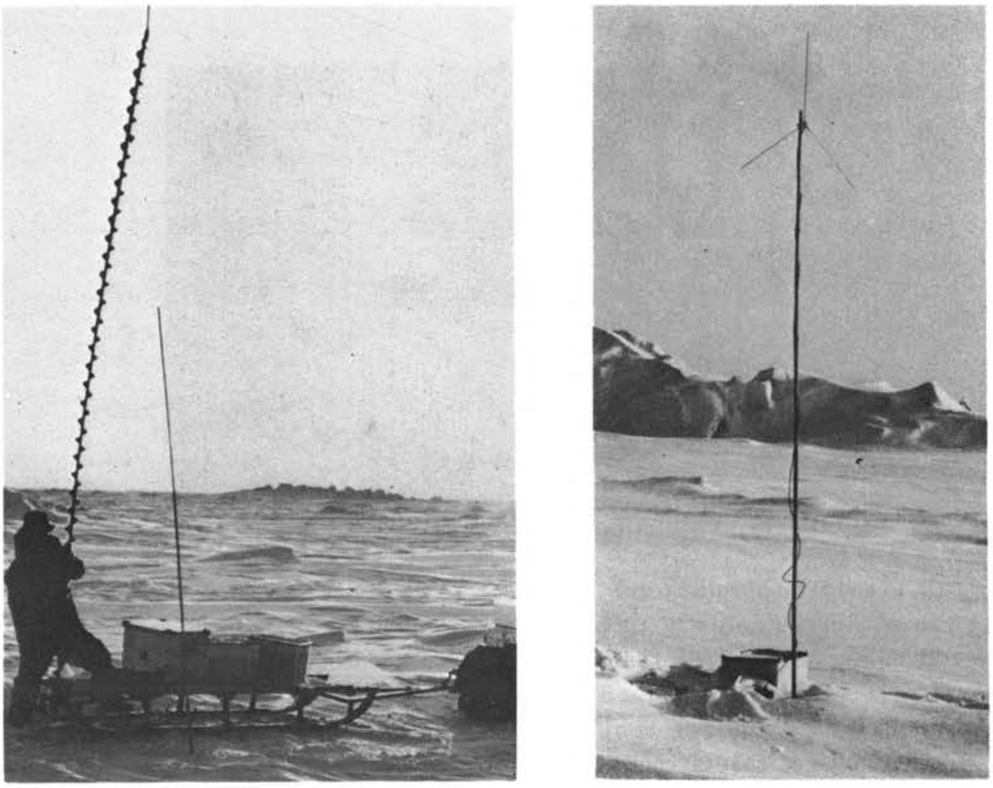


Fig. 9. Drilling hole for the hydrophone (left) and the completed sensor site (right).

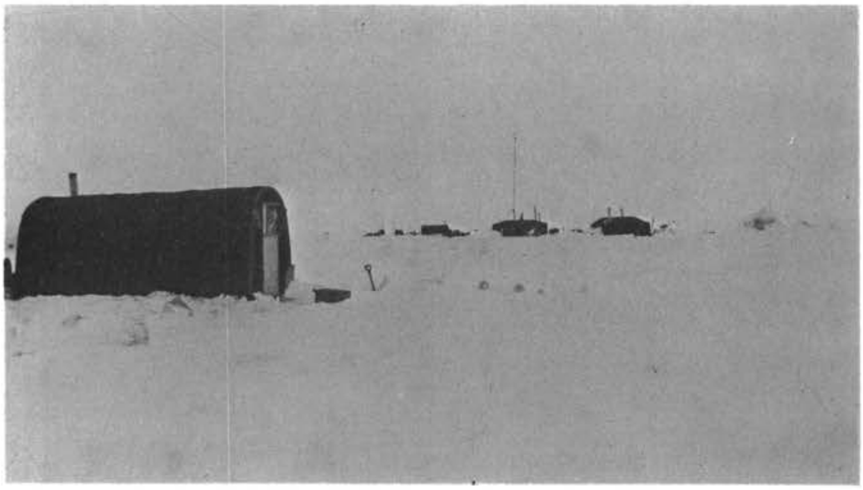
The low water temperature of -1.7°C and infrequent firing (4-60 mins) caused considerable initial problems in obtaining a stable air gun operation. The air gun firing circuit was modified to give a stronger trigger pulse to the solenoid valve and misfires were eliminated. Also in the cold water, the air gun would not seal properly and often leaked for extended periods. This was partly remedied by lowering the operating pressure from 2000 to 1500 psi. Over the last 2-3 weeks maintenance was only required every 3-4 days with air gun down-time reflected by the data gaps in Fig. 5.

After 25 April an available heated building was moved over the air gun hole with the compressor and air bottle (Fig. 10). Working conditions were excellent from this date.

The air gun signal was monitored by a hydrophone suspended at 50 meter depth (Fig. 10b). Test shots were fired with gun depths of 9-13 meters below the surface (5-9 meters below the bottom of the ice) and 13 meters were maintained throughout the experiment.

Estimated shot intervals were continuously updated from 1 to 3 satellite fixes per hour. To maintain a 50 meter shot interval, the fastest firing rate encountered was one pop every 3.5 minutes and the slowest one pop per hour, the general range being 7-15 minutes (Fig. 11).

At the recording site the signal was received with a 5/8 wavelength ground plane antenna with amplifier. The 24 channel sonobuoy receiver and the DFS-V digital recording system performed extremely well throughout the experiment. The custom built receiver had a sensitivity of 1-2 uV/m and was equipped with a ±75 kHz ceramic filter to allow for the wide frequency deviation of military type sonobuoys.



A

Fig. 10 (B. C, and D on opposite page).

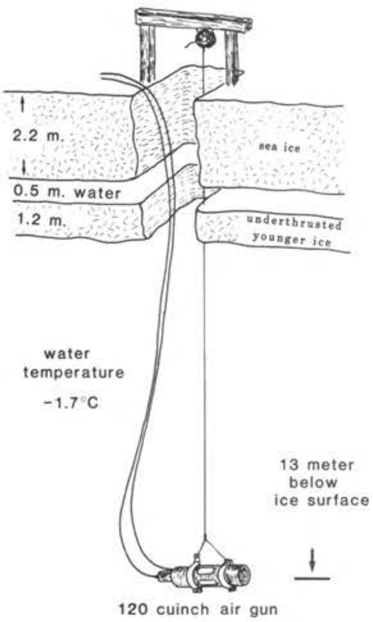
A. Air gun hut in use after 26 April with recording hut in the background.

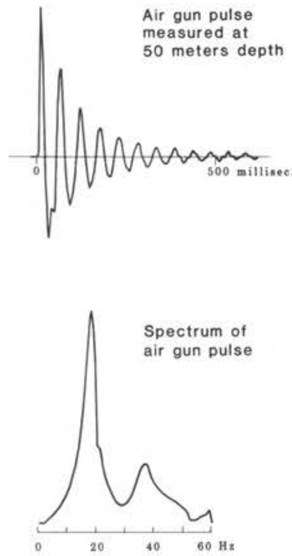
B. Sound source operating conditions and signal characteristics.

C. Air gun being lowered into the hydrohole.

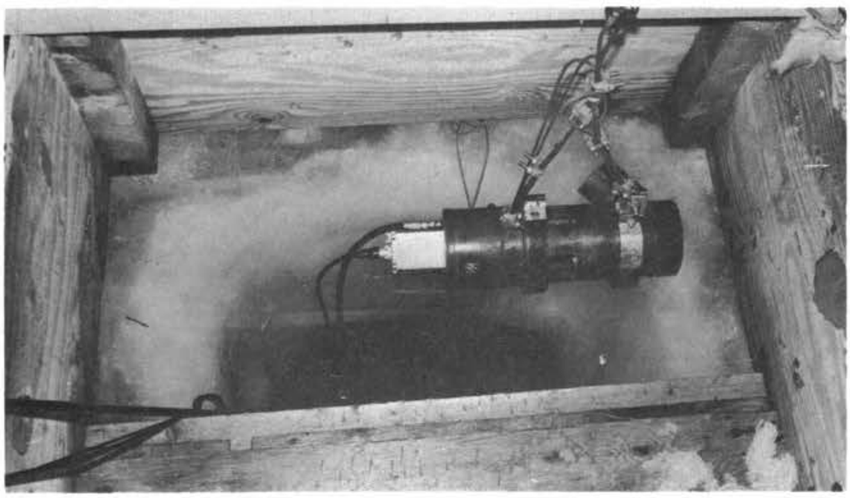
D. Diver compressor and air bottle. Maximum air capacity sufficient for one pop every four minutes of the 120 cuinch gun.

→


2.2 m.
sea ice
0.5 m. water
1.2 m.
underthrusted younger ice
water temperature
-1.7°C
13 meter below ice surface
120 cuinch air gun


Air gun pulse measured at 50 meters depth
0
500 millisec.
Spectrum of air gun pulse
0
20
40
60 Hz

B



C

D

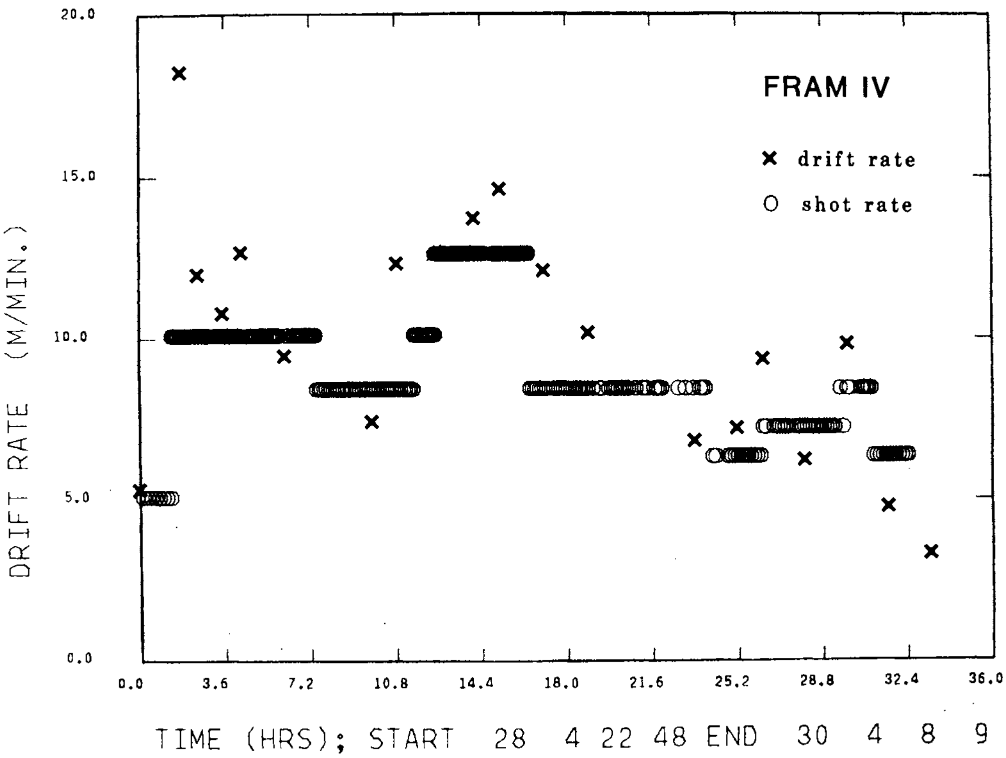


Fig. 11 Ice station drift rates 28-30 April and corresponding 'shot rate' (50 meter shot distance divided by shot interval in minutes).

Data quality on all channels was checked on an oscillograph camera and a near trace monitored continuously on a drum recorder. Record lengths were 12-15 seconds, water depth 3.5-5 seconds, and no delays were used. For extremely slow drift rates (1 meter/minute) signal to noise ratios were around 50 in water depths near 4000 meter and 6 dB down for a ten-fold increase in drift rate (Fig. 12). A seismic section displaying the thickest sediment (max. 1.5 sec.) accumulation encountered along the drift track is shown in Fig. 13. The deconvolution operator was designed from the recorded air gun signal. The sediments, mainly turbidites derived from the Yermak Plateau, overlie faulted volcanic basement inferred to be of mid-Oligocene age from identification of magnetic lineations (Vogt et al. 1979). An unconformity is seen at 5.65 sec. most clearly to the left of the basement high and differential thickening of the deeper strata towards the right (Yermak Plateau) is evident.

Fig. 14 shows a seismic section along the slope of the Yermak Plateau collected on the 1st and 2nd of May. This section is interpreted as evidence for extensive mass waste along the margin, the depressions being slide scars possibly partly infilled later.

The sediment distribution along the FRAM-IV track is shown in Fig. 15. Several basement highs are present with little or no cover and maximum sediment thickness is about 1.5 sec.

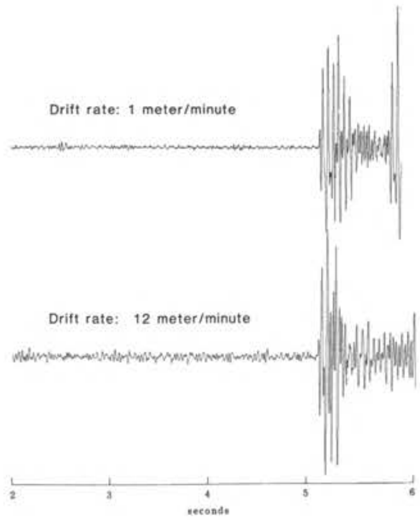


Fig. 12. Samples of near trace showing signal/noise ratios for extreme drift speeds.

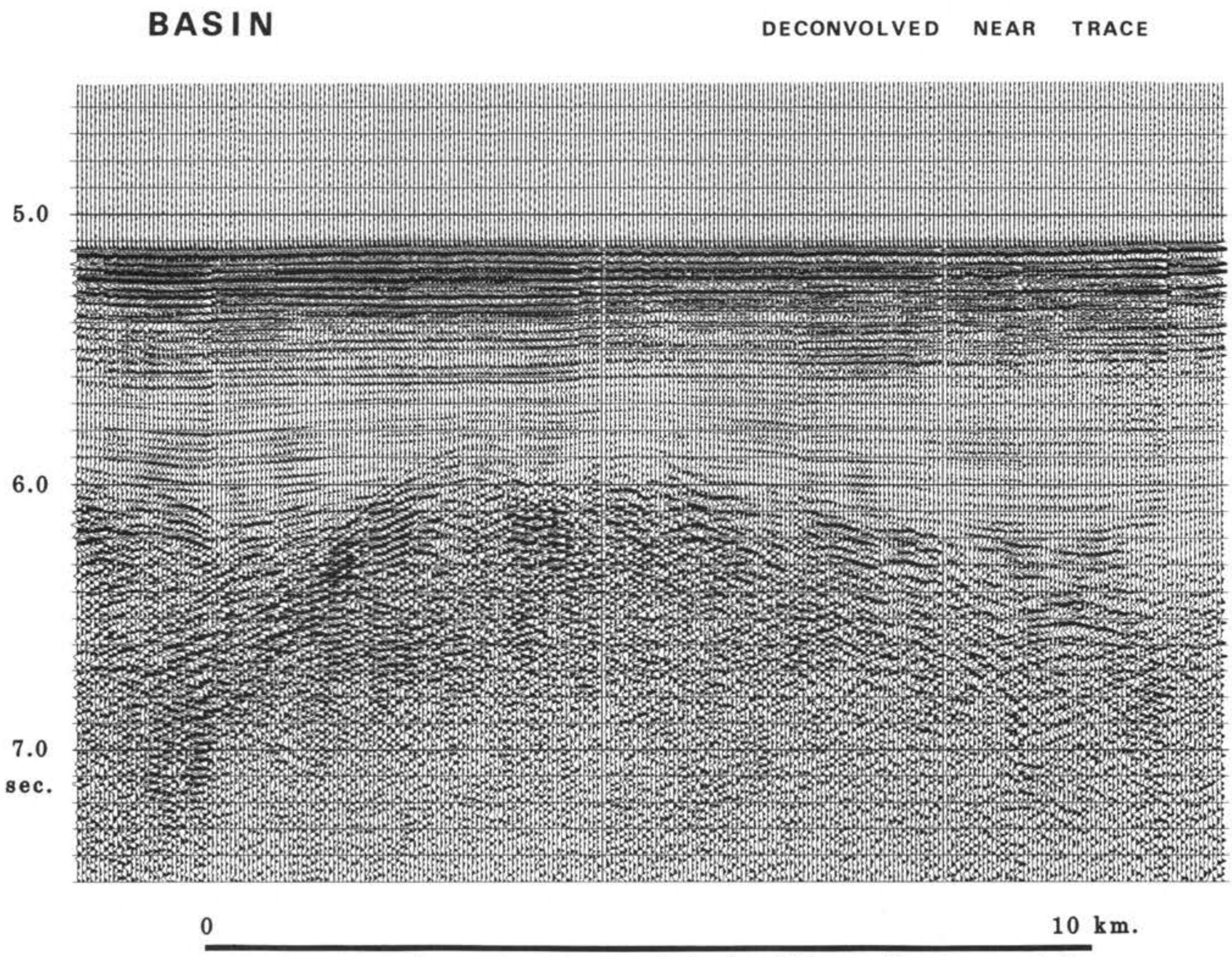


Fig. 13. Seismic section (deconvolved near trace) showing thickest sediment accumulation encountered along the FRAM-IV drift track. Data collected on 29 April. See Fig. 15 for location.

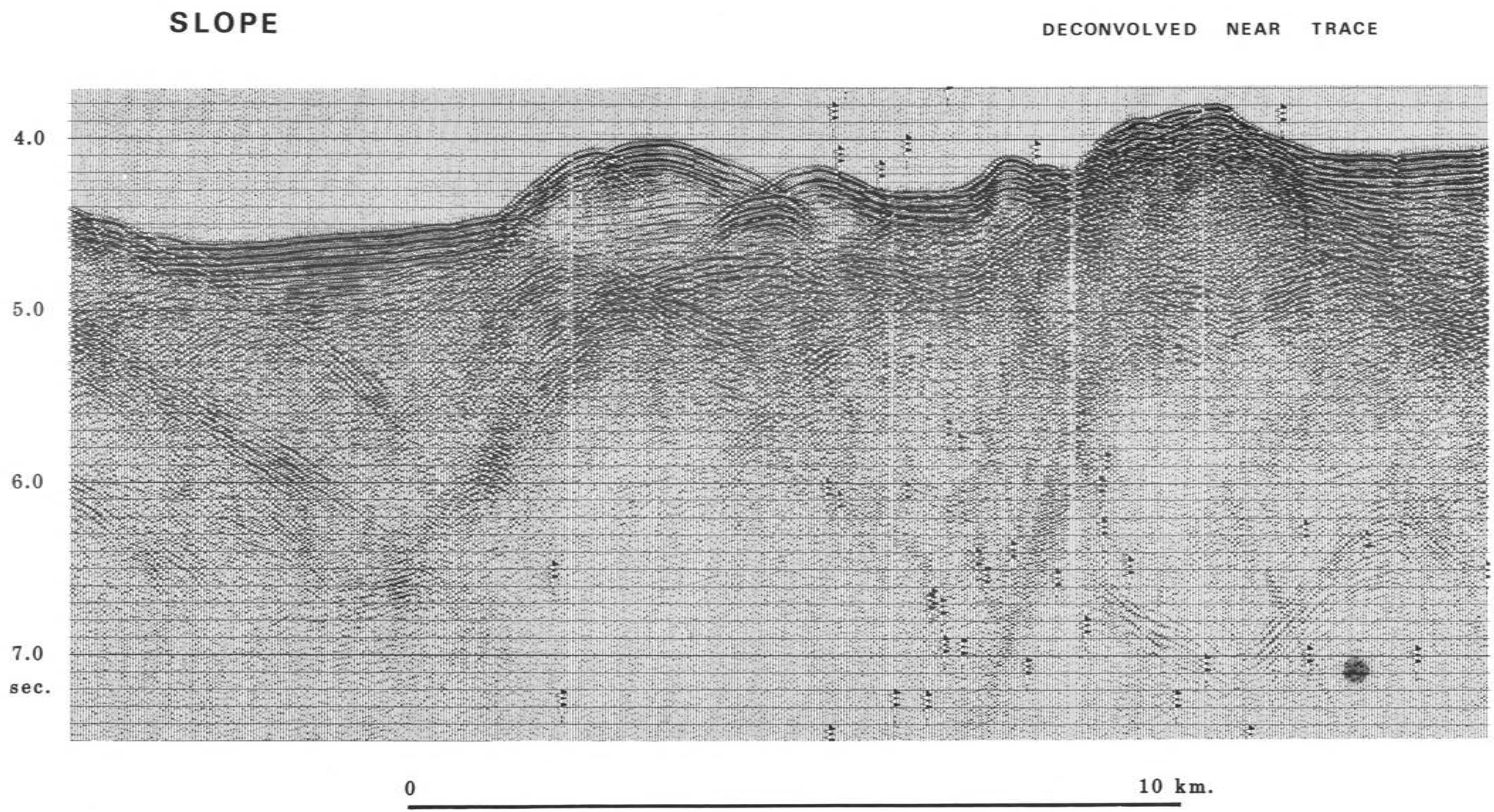


Fig. 14. Seismic section (deconvolved near trace) along the slope of Yermak Plateau. Low frequency erratic signals (right central part of section) are due to interference from 3.7 kHz echosounder. Data collected on 1-2 May. See Fig. 5 for location.

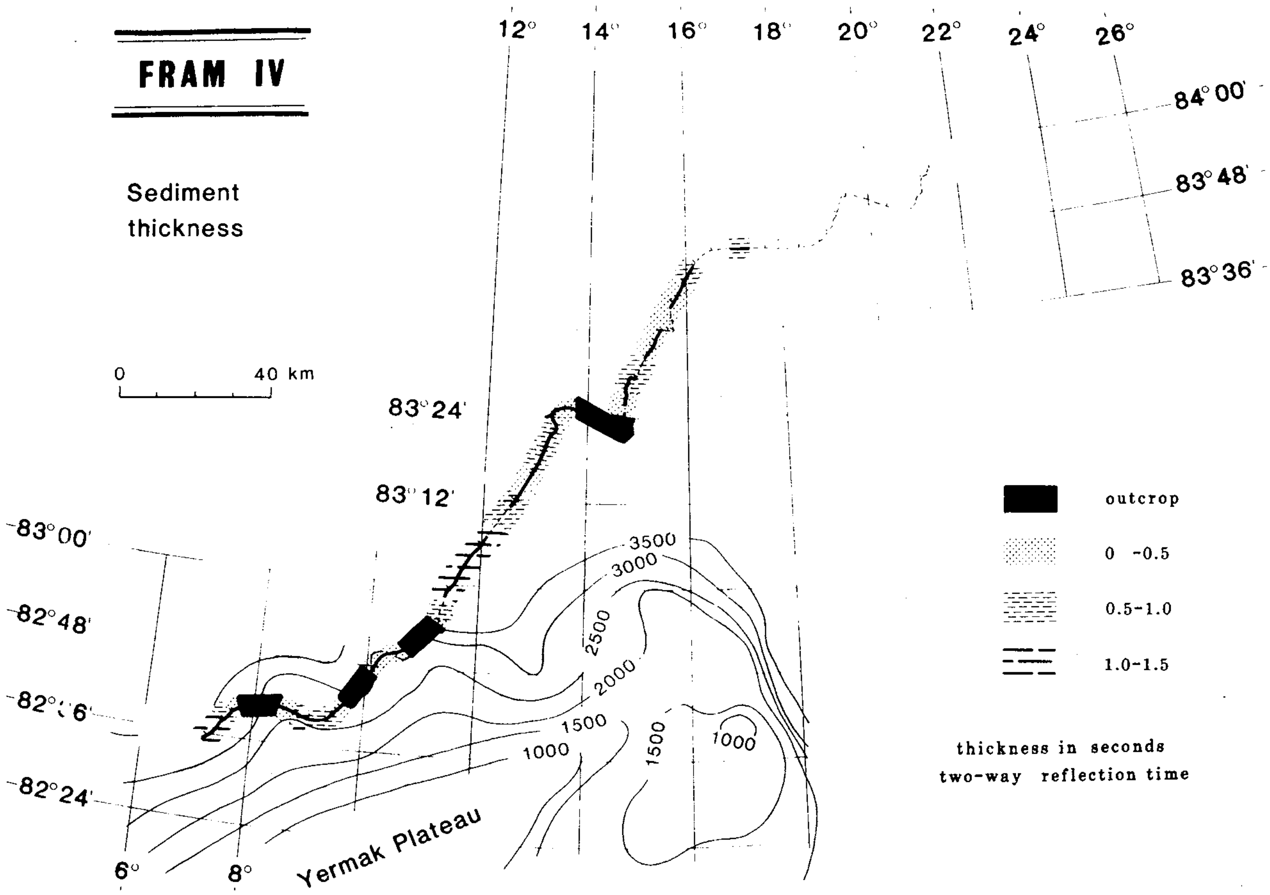


Fig. 15. Total sediment thickness along the FRAM-IV drift track.

PROJECT: SEISMIC REFRACTION MEASUREMENTS

Principal investigators:

Dr. Eystein Husebye, NTNF/NORSAR
Dr. Yngve Kristoffersen, Norsk Polarinstitutt
Dr. Brian Kennett, Cambridge University, UK
Mr. Bård Johansen, Superior Norge Exploration Company

Objective:

- Investigate the velocity structure of oceanic crust along the drift track.
- Investigate the wavelength of lateral heterogeneities in the oceanic crust.
- Investigate the tectonic relation between the volcanic construction of the Yermak Plateau and the adjacent oceanic crust.

Instrumentation:

a) Explosives provided by ONR.
b) Shot instant recording via VHF telemetry.
c) MIT/WHOI shot instant recorder.
d) 20 channel sonobuoy array.
e) DFS-V digital seismic recording system.
f) Motorola Mini-Ranger navigation system.

Field work and results:

The FRAM-IV seismic refraction program was a joint MIT/WHOI and Norwegian undertaking. The first four seismic refraction lines (Table 2) were shot by the MIT/WHOI group and the last three by the Norwegian group (Fig. 16). Jay Ardai, Lamont, responsible for all handling of explosives on FRAM-IV, supervised and carried out the actual shooting with MIT or NP assistance. The 20-80 km long lines had variable shot spacing due to ice conditions. The shots were dropped in open or newly refrozen leads less than 0.5 m thick, and detonated by depth sensitive primers set at 256 m depth. 55 lbs. cans of TNT were used out to 40 km range and 110 lbs. farther out. On the last three lines the ice was particularly tight and charges made of C4 sticks stuffed in surplus stovepipe tubes were dropped through holes in the ice drilled by a 10" auger. A 20 shot refraction line could be carried out in a day under favourable conditions.

Initial tests were made to relay the shot instant by VHF telemetry via a repeater in the airborne helicopter, but the approach proved unreliable in the cold. The shot instant hydrophone signal was recorded on cassette tape together with a coded time signal synchronized with the clocks in camp. At the near ranges (<40 km) shot distances were measured with the Mini-Ranger to ±10 m for most of the lines. At longer ranges the water wave arrival together with the position from the helicopter Omega system will be used for ranging.

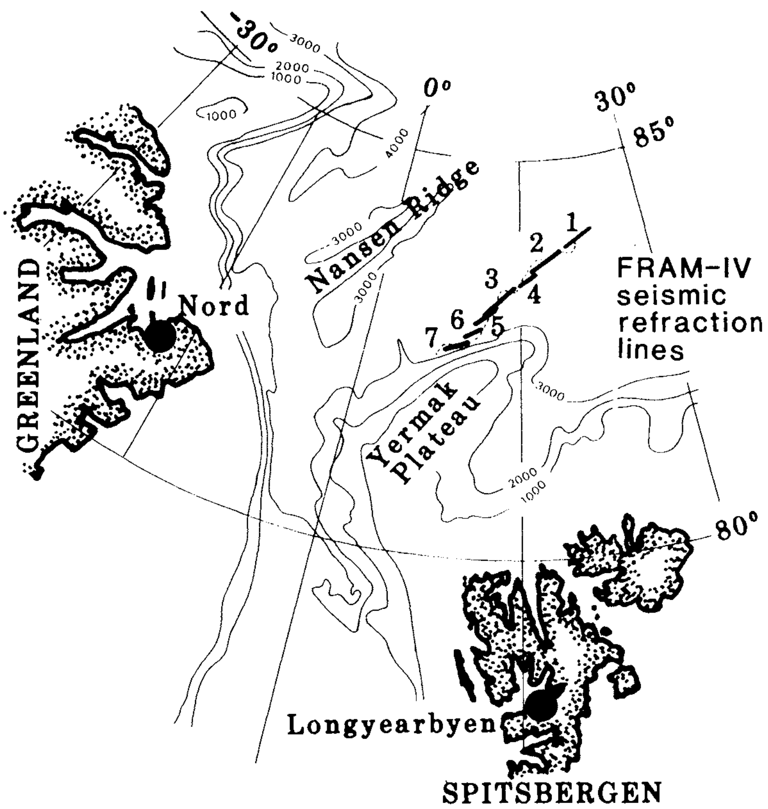


Fig. 16. Location of seismic refraction lines.

The data was recorded by the MIT (first four lines only) and the Norwegian array.

The DFS-V was started to record the second minute mark after the reported drop time (average sinking time 2 mins. 40 sec.) and run for 100 seconds. A drum recorder was used as single channel monitor. The relatively long recording window proved necessary for safe recording of all shots due to deviations in estimated arrival time incurred for various reasons. However, the long records which require near 3 Mega-byte of memory for the demultiplexing operation necessitate special software action and a large computer for initial processing.

PROJECT: REGIONAL DEPTH MEASUREMENTS

Principal investigator:
Dr. Yngve Kristoffersen, Norsk Polarinstitutt

Objective:
- Investigate the possibility of using an echosounder suspended below a helicopter for spot soundings in open leads.
- Carry out depth soundings away from camp within the 200 mile zone north of Svalbard.

Instrumentation:
a) 3.5 kHz ORE echosounder, 10 kW output with transducers mounted in tow fish vehicle.
b) Fire crackers as alternate sound source and recording on the MIT shot instant recorder with Sprengnether digital seismic event recorder as back-up.

Field work and results:

Leads with open water can at times be relatively abundant in the Arctic Ocean. Therefore to simplify acquisition of bathymetric data, trials were made with an echosounder suspended below a helicopter to obtain spot soundings in open leads (Fig. 17). The tow fish was 25 m below the helicopter and was lowered to depths of 5-15 m, but no bottom echos could be discerned above the noise level in the actual water depth of 3800 m. Beam width was 55° and output power 10 kW. Two trials were made with a sonobuoy hydrophone attached to the tow fish with the same result as above. Main sources of noise were the helicopter electric system, air coupled waves from the rotor wind and the mechanical coupling between helicopter and tow fish. Unfortunately no attempt was made to decouple the fish by suspending it from a float.

The standard method of obtaining a spot sounding requires landing by helicopter. At the site two holes were drilled. A fire cracker normally intended for polar bear prevention was tied to a pole and positioned below the ice. The shot was recorded via a hydrophone on a stereo cassette tape along with

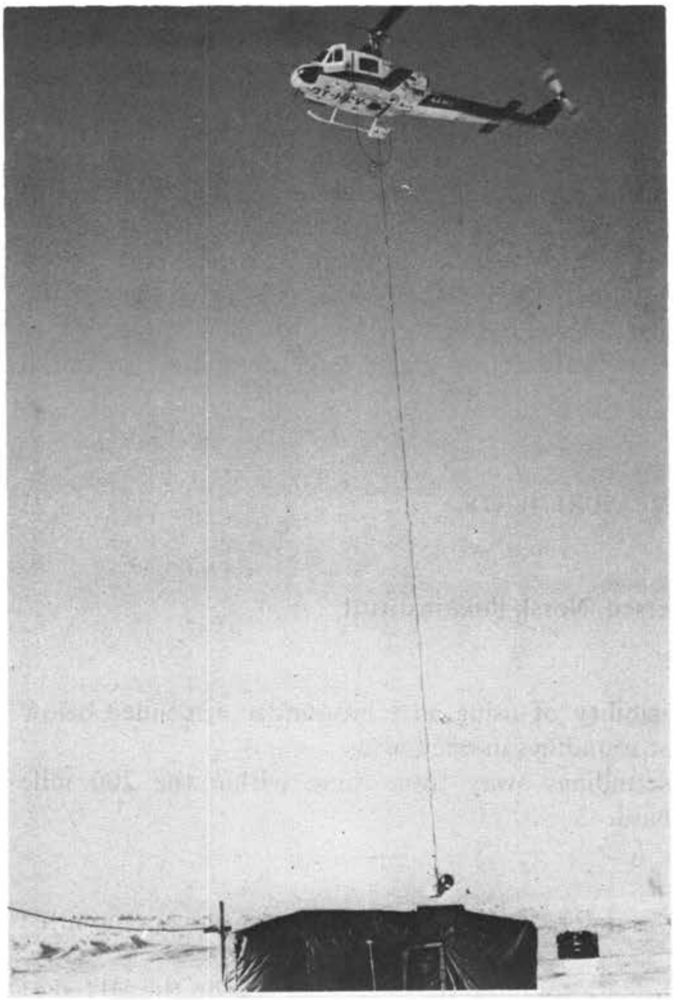


Fig. 17. The ORE 3.5 kHz tow fish suspended below the helicopter.

a time code. A total of 87 spot measurements was made in this way (Fig. 5). The new data show that the northeastern part of the Yermak Plateau is terminated towards east by a steep scarp which could possibly be related to a fracture zone when seen in conjunction with the aeromagnetic data of Vogt et al. (1980).

PROJECT: GRAVITY MEASUREMENTS

Principal investigator:

Professor Olav Eldholm, University of Oslo

Objective:

- Define sub-bottom density contrasts along the drift track by gravity measurements.
- Use regional gravity measurements to investigate the deep structure of the northeastern end of the Yermak Plateau.

Instrumentation:

LaCoste Romberg gravimeter with damping.

Field work and results:

The gravimeter was placed on a stand resting on the ice through a hole in the LDGO/NP manigan floor and was free of any contact with the hut itself (Fig. 18). On the average a reading was taken every eight hours, but more frequent during periods of rapid drift to give a spatial sampling of about 2 km.

The instrument was also used on helicopter surveys in conjunction with depth soundings in order to obtain information on the structure of the northeastern end of the Yermak Plateau (Fig. 5).

The gravity measurements were tied in to the reference value at Longyearbyen Airport of 982 962.995 mgal.

Date	*Time*	*Reading*	*MGALS*
22 March	1500	6376.120	6688.609
11 May	1100	6377.705	6690.275
		Drift:	1.666 mgal

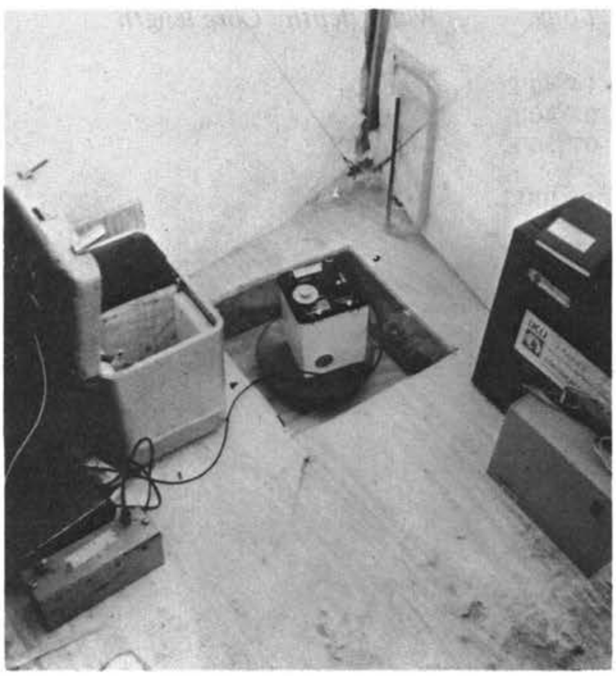


Fig. 18. The LaCoste Romberg gravimeter on its stand in the LDGO/NP manigan.

PROJECT: GEOLOGICAL SAMPLING

Principal investigators:

Dr. Kenneth Hunkins, Lamon-Doherty Geological Observatory
Professor Jørn Thiede, University of Oslo

Objective:

- Improve the data base for studies of Pleistocene Eurasian Basin paleoenvironment.

Instrumentation:

Lamont-Doherty Geological Observatory deep sea winch with 5000 m Kevlar nylon wire and gravity corer with 3 m long pipe.

Field work and results:

Routine winch operation was not possible until after 20 April due to the acoustics program requirement for a quiet camp. A coring attempt in 3800 meter water depth took 2-3 hours. The gravity corer having a 50 kg pear-shaped lead weight at the top of a 3 m long $1^1/_2''$ diameter pipe was free falling the last 3-5 m above the bottom. The recovery was a discouraging 0-50 cm and a number of trials were made with different tension excerted by the core catching mechanism with little success. The accessories for piston coring were available, but were not utilized due to lack of time. A total of seven short cores was successfully recovered and divided between LDGO (4) and the University of Oslo (3).

Core	*Date*	*Lat.*	*Long.*	*Water depth*	*Core length*
1	20 April	83°25'N	14°40'E	3880	
7	6 May	82°41'N	07°40'E	3475	
9	7 May	82°39'N	07°30'E	3436	

The sediments were all dark green fine mud.

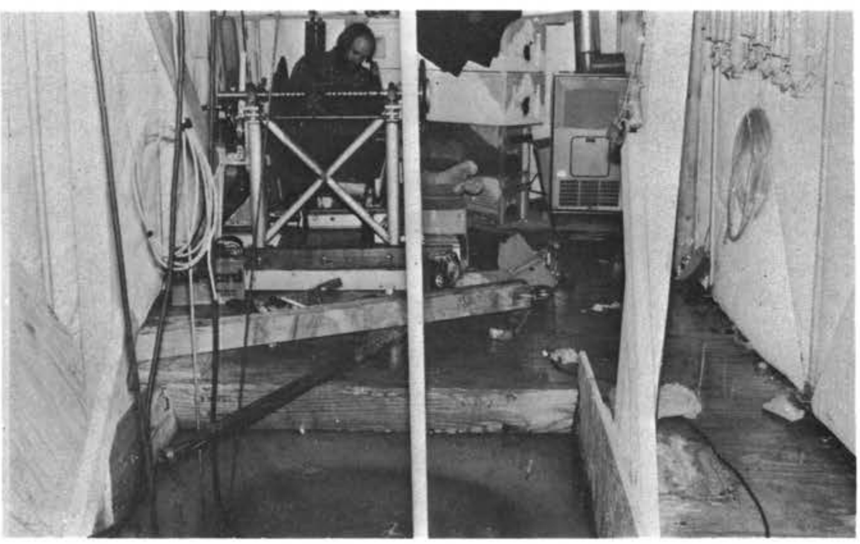


Fig. 19. Hydrohole with deep-sea winch in the background. The gasoline engine and hydraulic power pack for the winch were located outside.

PROJECT: ICE DRIFT IN THE FRAM STRAIT

Principal investigator:
Dr. Torgny Vinje, Norsk Polarinstitutt

Objective:
- Study the relation between ice dynamics and oceanographic and meteorological parameters in the marginal ice zone.

Instrumentation:
An automatic ARGOS data buoy with sensors for air pressure, ambient temperature and a 75 meter string with ten thermistors suspended in the water.

Field work and results:

The buoy arrived FRAM-IV on 7 May after being activated and checked at Longyearbyen Airport. It was installed on 8 May in a flat area free of any other objects between the NP hut and the mess hall. Environmental data were transmitted via the ARGOS system until 17 July when the buoy became silent (Fig. 20). Daily noon positions are given in Appendix C. The results of the temperature measurements demonstrate the gradual influx of warmer sub-ice water masses as the FRAM-IV site drifted south (Fig. 21).

PROJECT: HEAT FLOW ON THE CONTINENTAL MARGIN NORTH OF SVALBARD

Principal investigators:
Professor Olav Eldholm, University of Oslo
Dr. Kathleen Crane, Lamont-Doherty Geological Observatory

Objective:
- Obtain heat flow measurements along a traverse across the continental margin north of Svalbard.

Instrumentation:
Digital heat flow probe with four thermistors spaced on four meter long pipe.

Field work and results:

The components for the heat flow instrument arrived FRAM-IV mid-April and were assembled and tested by J. Ardai, LDGO. It was lowered on four locations to obtain a suite of measurements and performed well.

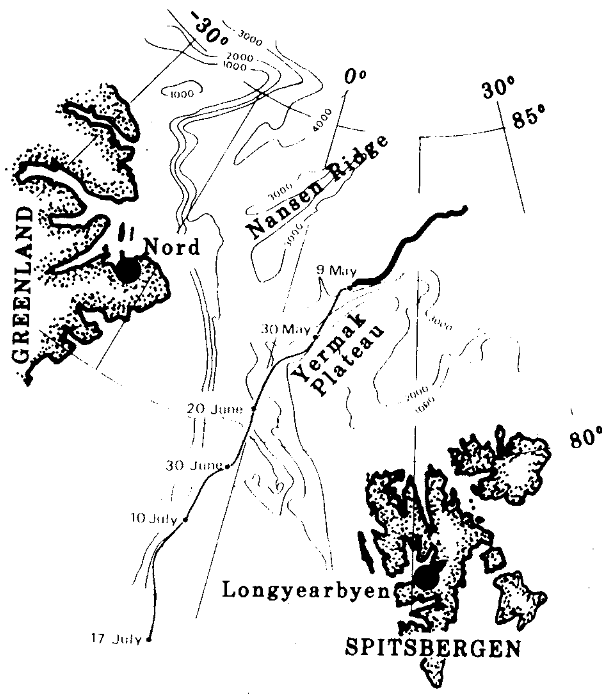


Fig. 20. Drift track of the abandoned FRAM-IV camp site as monitored by ARGOS environmental data buoy.

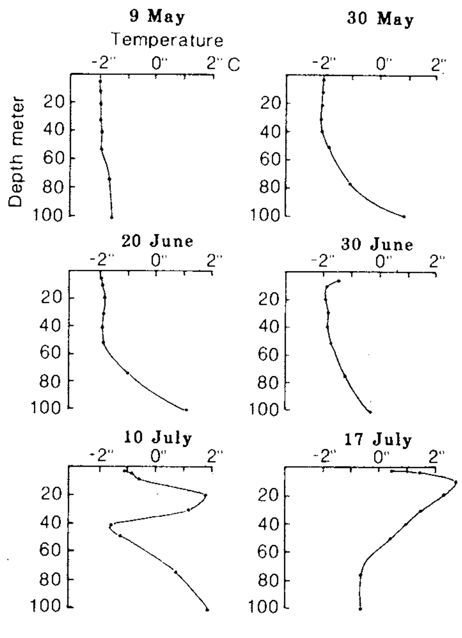


Fig. 21. Temperature - depth profiles recorded by the thermistor string of the ARGOS data buoy.

8. OBSERVATIONS OF ANIMAL LIFE

Polar bears were only sighted on flights away from camp. On 15 April a female bear with a cub was observed at 82°49.7'N, 15°48.5'E.

On 17 April about 20-30 narwhales were observed in a large lead at 82°41.3'N, 16°14.4'E.

The arrival of the small snow bunting in camp in late April has been observed on all FRAM stations (Fig. 1) (H. Siljuberg, pers.comm.).

Seals were observed in a lead which opened during the last few days of FRAM-IV, 100 meters west of the air gun site.

9. VISITORS

On 16 April the Governor of Svalbard, Jan Grøndahl, accompanied by Tore Gjelsvik, Director of Norsk Polarinstitutt, visited the ice station at 83°34'N, 15°10'E with the Governor's Bell 212 helicopter. At this time FRAM-IV was within the 200 mile limit north of Svalbard. The Governor being responsible for search and rescue in the Svalbard region, utilized this opportunity as a training mission into the remote areas of the Arctic Ocean proper. Rotation of Alf Nilsen and Oddmund Liabø with Paul Larsen and Anders Solheim was also carried out on this trip. The party returned to Longyearbyen after refueling and a four-hour stay.

Professor R. Goody of Harvard University, a member of the US Academy of Sciences, spent several days on FRAM-IV to get an impression of the effort required for scientific data acquisition in the Arctic.

Argentine personnel (a logistics manager and a geophysicist) engaged in Antarctic research, visited FRAM-IV for a few days to get a first hand idea of the usefulness of drifting ice stations as scientific platforms.

The Russian ice station NP-22 was visited on 1 April at 86° 0'N, 2°E by a party from Nord. The ice-island was being abandoned as the sixteen persons on the ice were busily packing.

10. OTHER EVENTS

During packing, Robert Lee, a NRL scientist, accidentally received a blow below the chest from a cross bar as he tripped and fell towards the hydrohole. The injury was diagnosed as a ruptured spleen. The patient was transferred to Longyearbyen Hospital by Twin-Otter and operated ten hours after the accident.

11. ECONOMY

In January 1981 Norsk Polarinstitutt decided to commit Nok. 700,000.- out of its 1981 and 1982 budgets to secure Norwegian participation in FRAM-IV, the initial cost estimate being Nok. 1.5 mill. For FRAM-IV participation we are expected to contribute to Polar Science Center for flight hours and use of camp facilities. The committed funds were clearly insufficient for any seismic experiments and a proposal to obtain industry support for this part was considered favourably by Arco, Elf, Norsk Hydro, Norske Shell, Superior, and Texaco Norway providing Nok. 600,000.-.

Expences covered by Norsk Polarinstitutt

Clothing and camp gear	Nok. 60,000.-
Equipment and spares	125,000.-
Field pay	130,000.-
Travel	65,000.-
Freight	55,000.-
Services Longyearbyen Airport	35,000.-
Polar Science for flight support	230,000.-
	Nok. 700,000.-

Expences for seismic experiment covered by sponsors

Spare parts DFSV	Nok. 260,000.-
Sonobuoy receiver	80,000.-
Travel and field pay	70,000.-
Insurance	50,000.-
Tape and photo paper	25,000.-
Freight	25,000.-
Salaries	40,000.-
Miscellaneous	50,000.-
	Nok. 600,000.-

On FRAM-IV the Norwegian group received 141 man-days of camp services and food, and the following aircraft support (fuel included):

Helicopter:	24 hours a $1500.-	=	$ 36,000.-
Twin Otter:	15 hours a $1100.-	=	$ 16,500.-
C-47:	5 hours a $1500.-	=	$ 7,500.-
	Total:		$ 60,000.-

Toward these services our budgetary constraints only permitted a reimbursement of $ 40,000.- to Polar Science Center. In addition ONR provided sonobuoys (48) and explosives (1.5 ton) for the seismic experiment to an estimated value of $ 50,000.-.

The total FRAM-IV science program amounted to 650 man-days plus logistics and observers 298 man-days, which gave a 'science to support ratio' of 2.2 (source: A. Heiberg).

We gratefully acknowledge the opportunity to participate in FRAM-IV and the excellent services provided for implementation of the Norwegian programs. We also acknowledge the aircraft support provided by the Governor of Svalbard with the opportunity to rotate crews in connection with his visit to FRAM-IV.

12. ACKNOWLEDGEMENTS

The versatility, working spirit, and companionship of Jay Ardai, LDGO, the PSC group: Allan Hielscher, Allan Gill, Eileen Murray, and Roger Anderson, together with the helicopter crew: Helge Siljuberg and Göran Lindmark, make Arctic field work a memorable experience. Furthermore, it is a pleasure to acknowledge the excellent support of Kåre Bratlien and his group: Jan Mikalsen, Oddvar Andersen, and Jørn Fortun, during all stages of this field experiment. We thank Oddvar Andersen for his conscientious effort with modification of the sonobuoys. The Seismological Observatory, University of Bergen, generously provided the air gun and accessories and Woods Hole Oceanographic Institution a back-up unit. Kristen Haugland and Fridtjof Veim contributed with advice to make it pop under adverse conditions.

Implementation of the Norwegian seismic field program was made possible by the following companies with an interest in future Arctic exploration: Arco, Elf Aquitaine, Norsk Hydro, Norske Shell, Superior Exploration Norway, and Texaco Norway.

13. REFERENCES

Baggeroer, A. and I. Dyer, 1982: Fram-I in the Eastern Arctic. *EOS Trans. AGU* 63(14).

Hunkins, K.L., Y. Kristoffersen, G.L. Johnson, and A. Heiberg, 1979: The FRAM-I Expedition. *EOS Trans. AGU* 60(52).

Manley, T.O., L.A. Codispoti, K.L. Hunkins, H.R. Jackson, E.P. Jones, V. Lee, S. Moore, J. Morison, T.T. Packard, and P. Wadhams, 1982: The FRAM-III Expedition. *EOS Trans. AGU* 63(35).

Vogt, P.R., L.C. Kovacs, G.L. Johnson, and R.H. Feden, 1979: The Eurasian Basin. *Norwegian Sea Symposium, Norwegian Petroleum Society* NSS/3:1-29.

APPENDIX A

FRAM-IV weekly science reports

FRAM-IV science report - 26 March 1982

MIT/WHOI - Sixteen hydrophones and two geophones have been installed and are in operating condition. All appear to have greatly reduced strum with the Sparton suspension system and far less hum with the shielding on the WHOI hydrophones. The data acquisition system has been configured and operated successfully. Data acquisition will begin this evening for ambient noise measurements. The spectrum analyzer does not work and arrangements for a replacement unit from CONUS have been initiated. The ambient noise monitor has been calibrated and is operational. The radio antenna for the remote sensing system has been erected.

LDGO - One hydrophone and one geophone have been installed and are now being recorded continuously on two drum recorders and magnetic tape. Continuous navigation has been done since 3/24/82. The joint NP/Lamont hydrohole has been started.

NRL - The hydrohole has been constructed and the floor and gantry installed.

NP - The hydrohole has been started for the coring and heat flow programs.

NUSC - White Dwarf was established today.

U of W - The meteorological tower has been erected and the logging equipment will be installed tomorrow.

ARTHUR B. BAGGEROER
Chief Scientist

FRAM-IV science report - 2 April 1982

LDGO - Continuous monitoring of hydrophones, horizontal and vertical geophones, and long period geophone has been done with twelve channels of tape recording. Numerous seismic events have been recorded at a rate of two or more per day. Continuous 3.5 kHz echosounding with approximately .1 sec. of penetration has been done since 31 March. Once daily azimuth fixes with magnetic declination began on 31 March and tied with the met data. Hydrohole through two meters of ice completed. Shooting program from White Dwarf to FRAM shot for two days.

U of W - All equipment set up and is operating correctly. Camp baseline established with azimuth determined by celestial observation. Rotation to apex of MIT/WHOI array surveyed.

NP - Eleven channels on a 2 km sonobuoy array operational. Data from the refraction line recorded on these hydrophones. Air gun system to be deployed in a separate hydrohole near adjacent lead. Winch in NP/LDGO hydrohole now being installed for geologic sampling.

NUSC - White Dwarf source to be tested tomorrow (4/3/82).

NRL - Vertical array deployed on 4/1/82. Fairing on only 250 feet of array due to incorrect zipper tubing and failure of zippers. Installation of the 250 feet required over ten hours. Four phones inoperable, two are marginal. Amplifiers completed 4/1/82. Some problems on the preamps for the low-gain setting and shot data clipped on the high gain.

MIT/WHOI - 25 hydrophones and four geophones installed and operational. Data acquisition system operating successfully. Two reverberation and two 80 km refraction lines shot successfully. Remote sensing system deployed and four phones operating. Ambient noise recording done since 3/31/82.

ARTHUR B. BAGGEROER
Chief Scientist

FRAM-IV science report - 9 April 1982

NP - The initial problems with the air gun and compressor operation have now been overcome. Continuous common depth point seismic reflection profiling with recording on 16 channel sonobuoy array. The array is aligned along an assumed good weather drift direction of 205 degrees. Routine gravity readings being taken in camp.

NRL - The NRL vertical array has 28 hydrophones operational. All except two have little 60 Hz pickup. Signals from White Dwarf have been well received on the array. Initial testing for light bulb ice reflectivity initiated today.

U of W - All sensors and data recording equipment are performing properly. The camp rotated two degrees clock-wise this week. The SALARGOS buoy arrived at FRAM today (4/9/82).

LDGO - Continuous recording of hydrophones, 1Hz geophone and long period geophones are underway. Continuous drum paper recording of hydrophone and long period geophone also being done. A second hydrophone has been installed and one tape recorder repaired. Continuous recording on 3.5 kHz echosounder indicates slightly shoaling bottom as mid oceanic ridge axis approached. Continuous satellite navigation being recorded and daily azimuth and magnetic declination taken. One ODEC survey line started to White Dwarf. Four stations taken before instrument problems. ODEC now being overhauled.

MIT/WHOI - Twenty-six hydrophones and four geophones operational with data acquisition system operating very successfully. LOFAR system now operational with spectrum analyzer. All signals from White Dwarf recorded, although some during very noisy environments. Four long range reverberation shots from FRAM and one from White Dwarf now completed. Initial testing of acoustic self positioning array begun.

NUSC - All facets of NUSC program have been recorded successfully. Analog recording of ten horizontal and two vertical array hydrophones being done.

ARTHUR B. BAGGEROER
Chief Scientist

FRAM-IV science report - 16 April 1982

U of W - All sensors and data recording equipment performed normally. SALARGOS buoy arrived at FRAM on 11 April. Test set - Computer interface failed. Repaired by van der Heydt of WHOI. Buoy checkout proceeding as time permits.

NRL - Twenty-seven phones now operating. CW recording and ice reflectivity experiments are now 80% complete. Initial indications of the data looks good. Concentration for the next week will be on shot data.

LDGO - Additional hydrophone added to the system 4000 ft from camp. Six channels of hydrophones, six channels of horizontal, vertical, and long period geophones are now being recorded. Several very large T phases recorded. Continuous tape and drum recording done for geophone and hydrophone events. Winch work begun with completion of Sr 90 profile. Echosounder operational with some interruption to avoid conflict with acoustical experiments. Satellite and azimuthal fixes taken.

MIT/WHOI - Extensive recording of all events in the White Dwarf program using both the horizontal and vertical arrays has been made. Data quality is excellent with high signal to noise. Paths are stable, and science content valuable. Bottom interaction shooting completed. Systematic ambient noise and comparisons with physical models promising. Seismic reflection data now being recording in background mode. Program ahead of schedule.

NUSC - White Dwarf and bottom interaction programs on schedule and completed.

NP - Ten kilometers seismic reflection CDP profiling and bottom interaction refraction profile recorded on 17 channel sonobuoy array. Spot gravity and depth measurements along two 40 kilometers profile across northeastern part of the Yermak Plateau. Continuous gravity measurements made in camp. Preliminary tests of helicopter borne echosoundings unsuccessful due to low signal to noise ratio.

ARTHUR B. BAGGEROER
Chief Scientist

FRAM-IV science report - 23 April 1982

Adverse flying weather caused some changes in science schedule, but overall, programs are on target.

U of W - All systems OK. SALARGOS buoy transmitting well and acquiring instantaneous data.

LDGO - Acoustics program at full capacity. ODEC casts successfully completed. Gravity cores recovered. One complete vertical tritium profile made.

NP - Continuous seismic reflection profiling with two kilometer array closely aligned with the drift direction. Sixteen channels operational. Also five line kilometers recorded along portions of the drift track oblique to the direction of the array. Air gun system works satisfactorily in hydrohole. Two seismic refraction lines recorded. Continuous gravity measurements made. One sediment core 20 cm long recovered.

NRL - Ice reflectivity and scattering experiments completed. Long distance SUS signals successfully recorded. Vertical array program completed on 23 April.

MIT/WHOI - Transmission, reverberation, ambient noise and MIT portion of refraction programs now completed. Preparations underway for return of MIT/WHOI team. Work continues with reduced party on remote sensor testing.

IRA DYER
Chief Scientist

FRAM-IV science report - 30 April 1982

LDGO - Two hydrophone, three geophone channels monitored continuously. Analog and tape recording continues. One cast completed for tritium samples. Heat flow gear set up. All other work continued.

U of W - SALARGOS buoy 1946 operated all week with down periods for battery charging and sensor depth adjustment. Meteorology equipment performed normally.

MIT/WHOI - Last WHOI/MIT science completed. Had some success with ASLS system. All packed and ready to leave.

NP - 38 km seismic reflection CDP profiling recorded on sonobuoy array with seventeen operative channels. Also one 35 km seismic refraction line run, however this type of experiment hampered by tight ice conds. Regional spot gravity and depth measurements made at 45 locations with 100 km range of the camp. Continuous gravity measurements in camp.

YNGVE KRISTOFFERSEN
Chief Scientist

FRAM-IV science report - 8 May 1982

Last week of FRAM-IV drift covered 33 n.m. in a southwest direction with 10 n.m. mid week on a westerly course. FRAM-IV position 82°36'N, 07°14'E 1800 GMT 8 May. Water depth 3450 meter.

NP - Continuous recording of seismic reflection data on 18 channels with 120 cuinch air gun as sound source. One 30 km refraction line run. Science program curtailed by persistent white out conditions unfavourable for helicopter operations. Science programs shut down 9 May and personnel departed.

YNGVE KRISTOFFERSEN
Chief Scientist

APPENDIX B

FRAM-IV navigation

Time in GMT and positions in degrees, minutes, and fraction of minute

27 03	1982	01
2100	8354.92	2215.60
28 03	1982	22
0032	8354.36	2110.97
0156	8354.03	2109.45
0238	8353.87	2109.46
0342	8353.66	2108.23
0426	8353.47	2108.26
0528	8353.33	2107.33
0614	8353.15	2107.29
0802	8352.79	2105.93
0951	8352.50	2104.39
1115	8352.26	2102.29
1321	8351.86	2101.51
1414	8351.67	2059.43
1430	8351.64	2059.53
1518	8351.58	2059.26
1559	8351.46	2058.07
1616	8351.44	2058.04
1708	8351.35	2057.71
1802	8351.23	2056.16
1858	8351.13	2055.80
2048	8350.96	2053.21
2115	8350.96	2054.89
2300	8350.85	2051.81
29 03	1982	19
0047	8350.77	2049.57
0215	8350.71	2048.87
0234	8350.79	2046.84
0403	8350.67	2045.89
0552	8350.73	2043.00
0650	8350.81	2042.55
0740	8350.64	2039.39
1152	8351.10	2034.21
1212	8351.19	2033.42
1306	8351.21	2034.55
1400	8351.31	2029.83
1524	8351.28	2027.92
1636	8351.47	2026.28
1710	8351.55	2026.08
1835	8351.74	2025.41
1921	8351.76	2026.41
2152	8351.95	2023.19
2214	8352.01	2014.69
2338	8352.03	2019.77
30 03	1982	17
0004	8352.03	2029.41
0124	8352.12	2017.55
0152	8352.08	2017.41
0226	8352.06	2014.28
0310	8352.04	2014.50
0340	8352.15	2015.11
0457	8352.28	2013.73
0529	8352.15	2013.80
0717	8352.18	2011.66
0905	8352.19	2008.96
1310	8352.49	2004.94
1432	8352.50	2004.42
1622	8352.54	2002.67
1812	8352.56	2001.63
2002	8352.55	1959.87
2020	8352.40	1959.91
2151	8352.56	1957.96
31 03	1982	11
0129	8352.45	1958.40
0318	8352.51	1954.97
0348	8352.57	1953.18
0506	8352.51	1953.21
0654	8352.48	1952.01
1050	8352.51	1950.38
1409	8352.80	1945.37
1526	8352.77	1942.64
1712	8352.78	1940.40
1848	8352.67	1937.31
2128	8352.60	1934.29
01 04	1982	17
0106	8352.48	1934.61
0254	8352.38	1930.58
0443	8352.38	1947.93
0632	8352.24	1925.81
0820	8351.99	1923.39
1008	8351.06	1921.81
1102	8351.04	1923.68
1346	8351.87	1922.37
1457	8351.73	1920.85
1536	8351.67	1920.94
1642	8351.57	1918.73
1726	8351.55	1919.49
1806	8351.52	1918.32
1916	8351.35	1918.21
2105	8351.26	1917.47
2158	8351.22	1918.42
2344	8351.09	1917.25
02 04	1982	15
0130	8350.96	1918.90
0232	8350.78	1916.68
0420	8350.73	1915.07
0609	8350.52	1913.75
0757	8350.45	1912.87
0945	8350.35	1911.38
1019	8350.27	1914.13
1204	8350.14	1912.51
1323	8350.12	1912.65
1349	8350.00	1911.39

1513	8350.00	1910.84
1534	8349.90	1909.86
1852	8349.63	1908.77
1936	8349.52	1910.47
2122	8349.37	1908.98
03 04	1982	16
0054	8349.14	1907.14
0354	8348.99	1905.32
0540	8348.79	1904.10
0614	8348.79	1902.21
1056	8348.27	1901.57
1137	8348.27	1900.47
1300	8348.09	1858.85
1426	8347.92	1858.47
1450	8347.93	1857.34
1610	8347.73	1855.93
1640	8347.78	1855.70
1755	8347.62	1855.15
1830	8347.55	1854.07
2019	8347.35	1852.45
2209	8347.19	1851.47
2312	8347.12	1849.62
04 04	1982	19
0058	8347.01	1848.56
0115	8347.01	1848.41
0146	8346.84	1848.49
0245	8346.90	1847.26
0303	8346.90	1846.99
0334	8346.76	1846.34
0431	8346.76	1845.31
0450	8346.82	1845.49
0523	8346.63	1844.80
0711	8346.61	1842.63
1010	8346.50	1839.99
1133	8346.41	1838.85
1157	8346.41	1838.37
1343	8346.33	1837.11
1502	8346.27	1835.94
1529	8346.26	1835.31
1647	8346.22	1833.96
1715	8346.23	1833.82
2246	8346.11	1829.94
05 04	1982	11
0022	8345.96	1827.59
0124	8345.84	1828.77
0210	8345.95	1825.62
0837	8346.26	1813.19
1025	8346.55	1806.55
1539	8347.11	1801.41
1623	8347.22	1800.06
1743	8347.46	1757.92
2123	8347.63	1747.52

2241	8347.68	1745.65
2330	8347.71	1743.82
06 04	1982	10
0012	8347.56	1742.01
0117	8347.68	1740.16
0304	8347.69	1736.33
0438	8347.47	1733.02
0719	8347.69	1725.19
0814	8347.54	1720.11
1055	8347.86	1712.60
1341	8347.93	1705.76
2100	8348.11	1639.12
2318	8348.04	1634.49
07 04	1982	17
0104	8347.91	1631.18
0227	8347.64	1630.85
0251	8347.72	1627.93
0415	8347.53	1626.43
0603	8347.39	1622.54
0751	8347.27	1618.62
0940	8347.08	1615.15
1106	8346.86	1616.58
1152	8346.80	1614.58
1252	8346.59	1614.29
1438	8346.33	1612.29
1507	8346.28	1612.46
1624	8346.02	1610.28
1810	8345.79	1607.71
2037	8345.43	1604.32
2209	8345.22	1604.54
2331	8345.01	1603.55
08 04	1982	11
0118	8344.69	1602.35
0141	8344.62	1602.19
0306	8344.39	1601.47
0352	8344.24	1602.04
0454	8344.17	1600.12
1030	8344.46	1559.58
1400	8343.06	1557.97
1544	8342.90	1557.77
1730	8342.77	1558.12
2014	8342.50	1555.93
2246	8342.22	1554.57
09 04	1982	16
0032	8342.11	1554.13
0116	8342.04	1554.85
0219	8341.92	1554.33
0330	8341.81	1554.09
0518	8341.69	1553.58
0706	8341.56	1552.43
0854	8341.41	1551.54
1012	8341.29	1549.83

1200	8341.02	1548.76
1252	8340.83	1548.48
1421	8340.71	1547.50
1611	8340.51	1547.35
1801	8340.34	1546.83
1951	8340.17	1545.86
2055	8340.05	1545.17
2241	8339.86	1543.70
10 04	1982	15
0027	8339.69	1542.91
0110	8339.60	1542.28
0256	8339.37	1541.65
0442	8339.17	1541.16
0734	8338.88	1539.42
0922	8338.60	1539.09
1110	8338.27	1538.92
1144	8338.15	1538.87
1258	8337.93	1539.01
1328	8337.85	1539.15
1513	8337.58	1539.71
1658	8337.29	1540.32
1928	8336.97	1539.41
2215	8336.69	1538.79
2337	8336.63	1539.87
11 04	1982	24
0001	8336.52	1539.23
0027	8336.51	1539.54
0147	8336.39	1539.85
0215	8336.36	1540.41
0244	8336.33	1540.62
0334	8336.24	1540.97
0402	8336.20	1541.18
0432	8336.19	1541.43
0520	8336.15	1541.63
0620	8336.07	1541.81
0832	8336.01	1541.50
0924	8335.99	1540.72
1020	8335.94	1541.59
1110	8335.87	1543.52
1207	8335.84	1542.27
1256	8335.85	1542.31
1335	8335.79	1542.21
1442	8335.71	1542.82
1525	8335.70	1542.58
1628	8335.64	1543.13
1714	8335.61	1542.98
1905	8335.32	1541.98
2054	8335.57	1543.14
2334	8335.54	1542.29
12 04	1982	13
0221	8335.44	1542.60
0310	8335.45	1542.81
0457	8335.43	1543.51
1113	8335.47	1541.42
1204	8335.48	1541.31
1257	8335.48	1541.03
1442	8335.51	1540.29
1535	8335.52	1540.26
1627	8335.49	1540.46
1828	8335.52	1539.73
1842	8335.56	1540.07
2143	8335.61	1538.62
2329	8335.64	1537.72
13 04	1982	14
0116	8335.65	1537.19
0158	8335.62	1536.57
0302	8335.68	1536.47
0346	8335.66	1535.95
0448	8335.70	1536.29
0723	8335.74	1534.53
0911	8335.84	1533.74
1027	8335.94	1532.87
1215	8335.90	1531.91
1334	8335.81	1531.12
1439	8335.86	1530.27
1628	8335.80	1529.99
2034	8335.69	1528.22
2220	8335.62	1528.14
14 04	1982	12
0136	8335.43	1527.47
0512	8335.28	1526.39
0700	8335.23	1526.25
0848	8335.16	1526.79
1125	8335.04	1523.98
1205	8334.95	1523.69
1226	8334.94	1522.63
1556	8334.70	1522.32
1756	8334.59	1521.87
1945	8334.49	1521.46
2135	8334.35	1520.89
2258	8334.32	1519.99
15 04	1982	13
0044	8334.21	1519.20
0230	8334.08	1519.10
0301	8334.01	1519.13
0449	8333.93	1518.39
0637	8333.86	1518.24
0826	8333.78	1517.67
0933	8333.70	1517.06
1222	8333.53	1515.18
1353	8333.48	1513.57
1542	8333.36	1512.72
1732	8333.23	1511.68
1922	8333.11	1510.80

2149	8333.08	1509.54
16 04	1982	10
0121	8332.92	1508.55
0308	8332.82	1508.47
0454	8332.68	1507.87
0756	8332.41	1506.50
1010	8332.36	1505.49
1340	8331.96	1503.76
1538	8331.72	1502.28
1724	8331.56	1501.79
2027	8331.30	1500.46
2213	8331.19	1500.23
17 04	1982	13
0027	8330.95	1459.06
0146	8330.87	1458.85
0216	8330.76	1458.37
0404	8330.65	1457.38
0552	8330.56	1456.90
0740	8330.38	1455.90
1042	8330.24	1454.47
1230	8330.10	1453.56
1456	8329.94	1452.46
1646	8329.81	1451.96
1836	8329.67	1451.89
2026	8329.57	1451.81
2339	8329.52	1451.63
18 04	1982	14
0050	8329.49	1451.69
0341	8329.40	1451.58
0529	8329.41	1451.61
0717	8329.39	1451.75
0906	8329.40	1451.93
1308	8329.39	1450.29
1354	8329.38	1449.75
1433	8329.42	1449.41
1540	8329.33	1448.59
1623	8329.33	1448.31
1813	8329.24	1447.10
2003	8329.11	1446.34
2035	8329.10	1446.51
2246	8328.96	1445.98
19 04	1982	17
0034	8328.81	1446.15
0222	8328.62	1446.14
0500	8328.18	1445.83
0714	8327.76	1444.74
0902	8327.25	1444.93
1016	8326.90	1445.07
1050	8326.81	1445.10
1116	8326.66	1445.01
1302	8326.31	1444.27
1344	8326.22	1444.45
1410	8326.18	1443.60
1448	8326.00	1443.76
1633	8325.62	1442.46
1750	8325.45	1442.67
2130	8324.84	1442.79
2232	8324.69	1442.26
2341	8324.58	1441.99
20 04	1982	18
0018	8324.50	1442.16
0129	8324.41	1442.09
0204	8324.35	1442.11
0316	8324.26	1442.29
0350	8324.19	1442.15
0536	8323.97	1442.11
0812	8323.64	1441.82
0907	8323.47	1442.18
1024	8323.26	1442.46
1052	8323.22	1442.60
1147	8323.08	1442.98
1237	8322.98	1443.13
1422	8322.79	1443.60
1537	8322.69	1443.67
1606	8322.61	1444.02
1728	8322.43	1444.38
2042	8321.96	1443.78
2123	8321.88	1443.05
21 04	1982	11
0044	8321.51	1443.84
0233	8321.37	1443.99
0421	8321.34	1443.95
0609	8321.27	1443.30
0757	8321.22	1442.62
0909	8321.28	1441.59
1244	8321.70	1437.71
1458	8321.93	1432.15
1704	8322.48	1427.09
1854	8322.82	1422.43
2346	8323.26	1409.98
22 04	1982	11
0210	8323.42	1407.41
0358	8323.46	1406.23
0546	8323.61	1404.49
0734	8323.68	1403.05
1007	8323.91	1401.76
1155	8323.97	1401.78
1301	8323.98	1401.00
1451	8324.07	1400.13
1641	8324.11	1358.83
1831	8324.17	1356.80
2359	8324.46	1348.43
23 04	1982	10
0038	8324.52	1348.13

0147	8324.52	1347.14
0336	8324.57	1345.01
0524	8324.61	1341.85
0712	8324.72	1337.91
0917	8324.99	1334.61
1238	8325.13	1329.40
1958	8324.73	1320.87
2128	8324.57	1317.54
2314	8324.33	1316.14
24 04	1982	12
0101	8324.13	1315.51
0247	8324.01	1315.46
0320	8323.98	1315.35
0433	8323.90	1315.27
0826	8323.57	1314.34
1014	8323.42	1315.03
1202	8323.28	1316.18
1319	8323.26	1317.51
1405	8323.16	1318.11
1555	8322.92	1320.14
1744	8322.65	1321.29
2352	8322.02	1319.49
25 04	1982	16
0102	8321.91	1319.49
0138	8321.97	1319.42
0250	8321.86	1319.38
0324	8321.87	1319.06
0438	8321.82	1318.62
0626	8321.73	1318.02
0736	8321.65	1316.34
0814	8321.58	1316.75
0924	8321.47	1315.61
1026	8321.32	1314.79
1112	8321.23	1314.40
1211	8321.06	1313.84
1342	8320.93	1312.86
1532	8320.65	1312.76
1722	8320.39	1311.92
2243	8319.69	1308.06
26 04	1982	16
0029	8319.33	1307.78
0216	8319.05	1307.49
0402	8318.82	1307.17
0603	8318.60	1306.38
0752	8318.37	1305.91
0834	8318.26	1303.97
1022	8317.89	1303.03
1103	8317.62	1302.27
1248	8317.26	1300.51
1319	8317.27	1259.63
1508	8316.93	1259.57
1658	8316.74	1258.73

1848	8316.50	1257.81
2038	8316.33	1256.46
2103	8316.32	1256.35
2320	8316.14	1255.57
27 04	1982	15
0106	8315.96	1254.79
0204	8315.89	1254.30
0253	8315.85	1254.17
0352	8315.77	1253.79
0540	8315.60	1253.21
0729	8315.49	1252.09
0954	8315.11	1250.01
1140	8314.82	1248.04
1256	8314.57	1246.22
1324	8314.45	1246.46
1446	8314.19	1244.89
1635	8313.81	1243.65
1825	8313.67	1242.55
2015	8313.15	1240.40
2346	8312.42	1236.65
28 04	1982	05
0654	8311.33	1230.64
1029	8310.56	1226.46
1546	8308.89	1217.05
1952	8307.73	1209.56
2248	8307.01	1209.08
29 04	1982	14
0035	8306.46	1201.54
0119	8306.10	1200.93
0221	8305.94	1158.18
0307	8305.64	1156.86
0455	8305.33	1153.12
0832	8304.56	1149.16
0939	8304.22	1146.73
1108	8303.56	1144.83
1253	8302.82	1141.65
1359	8302.47	1138.52
1549	8301.69	1136.28
1739	8301.05	1134.28
2208	8300.04	1130.82
2354	8259.76	1128.38
30 04	1982	09
0056	8259.46	1127.15
0244	8259.08	1125.96
0432	8258.84	1121.51
0620	8258.56	1120.54
0809	8258.22	1120.93
1037	8257.48	1119.57
1225	8256.74	1118.53
1514	8255.71	1117.40
1716	8255.08	1115.54

01 05	1982	12
0033	8254.28	1114.26
0222	8254.09	1111.48
0410	8253.81	1108.10
0558	8253.64	1105.38
0852	8253.42	1101.61
1037	8253.11	1059.68
1222	8252.67	1057.31
1406	8252.20	1054.50
1503	8252.00	1054.34
1653	8251.44	1048.91
1843	8250.93	1045.64
2108	8250.45	1040.28
02 05	1982	13
0001	8250.01	1033.05
0227	8250.02	1026.99
0413	8249.87	1023.30
0535	8249.65	1020.24
0856	8249.27	1015.38
0929	8249.09	1015.20
1044	8248.83	1013.84
1250	8248.24	1011.60
1440	8247.58	1010.43
1630	8246.83	1008.42
1959	8245.76	1002.46
2145	8245.47	0959.79
2331	8245.36	0956.31
03 05	1982	10
0118	8245.38	0953.68
0136	8245.32	0953.17
0245	8245.35	0951.67
0324	8245.28	0951.51
0512	8245.21	0950.79
0700	8245.07	0950.34
0849	8244.89	0950.56
1607	8243.31	0946.78
1757	8242.77	0945.24
1947	8242.30	0943.15
04 05	1982	11
0114	8242.05	0936.65
0302	8242.11	0935.53
0638	8242.01	0934.37
0858	8241.83	0933.32
1042	8241.68	0932.69
1227	8241.49	0931.98
1354	8241.37	0930.05
1412	8241.25	0929.99
1544	8241.04	0927.27
1734	8240.56	0923.58
2318	8239.27	0904.18
05 05	1982	11
0252	8239.91	0849.88
0418	8240.21	0846.39
0934	8240.74	0832.27
1119	8240.85	0829.22
1304	8240.92	0826.03
1330	8241.06	0825.17
1448	8241.04	0822.48
1710	8241.09	0817.64
2004	8240.74	0810.05
2150	8240.48	0806.25
2337	8240.28	0802.95
06 05	1982	16
0142	8240.08	0800.37
0310	8240.04	0758.05
0404	8239.92	0755.88
0552	8239.88	0751.98
0740	8239.90	0747.51
0911	8240.05	0744.60
1011	8239.98	0743.25
1059	8240.05	0742.79
1222	8240.03	0742.11
1308	8240.04	0742.11
1458	8240.04	0741.85
1554	8240.01	0741.52
1648	8239.97	0740.53
1838	8239.79	0738.86
2027	8239.59	0736.81
2301	8239.46	0734.52
07 05	1982	12
0049	8239.42	0734.69
0153	8239.41	0734.59
0342	8239.38	0734.53
0530	8239.28	0733.88
0758	8239.04	0732.16
0944	8238.89	0731.37
1316	8238.63	0730.94
1434	8238.57	0730.78
1624	8238.47	0730.41
1903	8238.15	0728.46
2118	8237.95	0725.72
2305	8237.82	0724.45
08 05	1982	11
0131	8237.75	0723.39
0238	8237.73	0723.48
0318	8237.73	0723.24
0507	8237.66	0722.65
0655	8237.50	0722.11
0919	8237.15	0720.04
1124	8236.77	0718.65
1309	8236.57	0718.00
1751	8236.19	0715.02
1941	8235.99	0713.20
2320	8235.67	0709.19
09 05	1982	04
0108	8235.58	0708.50
0256	8235.55	0708.23
0444	8235.50	0707.85
0632	8235.37	0707.04

APPENDIX C

Daily ARGOS data buoy positions at 1200 GMT

DATE	LATITUDE	LONGITUDE
May		
8.	82.612	7.316
9	82.581	7.063
10	82.610	6.919
11	82.629	6.951
12	82.638	6.784
13	82.660	6.302
14	82.671	6.086
15	82.659	5.970
16	82.640	5.838
17	82.627	5.704
18	82.569	5.527
19	82.475	5.356
20	82.383	5.427
21	82.280	5.467
22	82.167	5.361
23	82.074	5.109
24	82.025	4.910
25	81.962	4.778
26	81.922	4.744
27	81.905	4.695
28	81.871	4.480
29	81.856	4.317
30	81.859	4.198
June		
1	81.836	3.499
2	81.791	3.213
3	81.716	2.991
4	81.677	2.972
5	81.635	2.823
6	81.573	2.635
7	81.497	2.222
8	81.453	2.047
9	81.418	1.895
10	81.328	1.607
11	-	-
12	81.233	1.126
20	80.429	359.731
21	80.328	359.557
22	80.221	359.620
23	80.125	359.700
24	-	-
25	79.949	359.739
26	79.846	359.922
27	79.733	359.774
28	79.631	359.346
29	79.593	359.113
31	79.469	358.858

DATE	LATITUDE	LONGITUDE
July		
1	79.452	358.596
2	79.443	358.298
3	79.388	358.068
4	79.304	357.953
5	79.231	357.825
6	79.141	357.893
7	79.037	357.872
8	78.826	357.488
9	78.565	357.872
10	78.446	357.396
11	78.285	356.018
12	77.890	355.829
13	77.521	356.048
14	77.215	356.859
15	76.990	357.334
16	76.781	357.686
17	76.664	357.605