Well summary Marraat-1, Nuussuaq - West Greenland

Gregers Dam and
Flemming G. Christiansen

Open File Series 94/11

April 1994

GRØNLANDS GEOLOGISKE UNDERSØGELSE
Ujarassiortut Kalaallit Nunaanni Misissuisoqarfiat
GEOLOGICAL SURVEY OF GREENLAND

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FIGURES

1.0 PERTINENT WELL DATA, INTRODUCTION AND SUMMARY

1.1 Pertinent well data

Well:	Marraat-1 (GGU 408001)
Well profile:	Vertical, deviation 1–2° in approximately NW direction
Location:	Between Marraat Kangilliit and Marraat Killiit, 800 m NE of Geologhuset, Nuussuaq, Greenland (Fig. 1)
Coordinates:	70°31′08″N, 054•12′03″N
Elevation:	Ground level: approximately 12 m above mean sea level
Depths:	All depths concerning the core refer to those measured by the drillers; 90 cm above ground level (floor of drill rig). All other depths are measured from ground level, unless otherwise specified
Total depth, driller:	447.75 m
Total depth, logger:	345 m
Hole diameter:	60 mm (2 23/64 inches) (BQ rod)
Core diameter:	36.5 mm (1 7/16 inches)
Casing:	5.18 m (17 feet) BW casing
Outer dimensions:	73 mm (2 7/8 inches)
Inner dimensions:	60.3 mm (2 3/8 inches)
Drill mud, fuel and other fluids:	EZ drill mud, Matex (GGU 408026) Diesel (GGU 408027) Lubricating grease (GGU 408029) Gear oil (GGU 408030) JET-Al for heater (GGU 408031) ESSO XD3, extra engine oil (GGU 408032) Hydraulic oil (GGU 408033) Sea water from Vaigat (GGU 408036)
Objective:	Paleocene Vaigat Formation. The aim of the well was to evaluate number and thickness of oil-impregnated zones, reservoir and petrophysical properties, and reach the underlying sedimentary succession

DRILLING PROGRAMME	See time distribution chart (Appendix 1)
Date arriving Marraat:	13 August, 1993
Date spudded, drilling:	15 August, 1993
Date rig released:	21 August, 1993
Date drilling programme completed:	23 August, 1993
Days on drill site location:	11

LOGGING PROGRAMME	See time distribution chart (Appendix 2)
Date arriving Marraat:	22 October, 1993
Date spudded, logging:	24 October, 1993
Date logging programme completed:	1 November, 1993
Days on drill site location:	11

Well status:	Suspended, with a valve mounted on the top of the casing and an electric heat cable lowered down into the uppermost 20 m of the hole
Conventional cores:	The hole was cored throughout recovery close to 100%
Drilling problems:	Several levels with bad rocks (fractured volcanics) in the lower part of the hole Lack of necessary spare parts for the oil cooler and cylinders. The diesel seemed not to be the same as in Canada resulting in reduced efficiency of the engine The bit and reamer broke off in 447.75 m and drilling was terminated before the planned 600 m
Logging problems:	Since completion of the drilling programme, an ice-plug had developed in the uppermost 17 m of the water filled hole. The ice was removed using the GGU hot water jet drill (Olesen, 1988; Olesen & Clausen, 1988). During the following geophysical logging

	programme the hole was kept ice-free by adding salt and inserting an electric heat cable in the uppermost 20 m of the hole
Operator:	The Geological Survey of Greenland
Drilling contractor:	Petro Drilling Limited
Drilling rig:	Diamond drill Longyear fly-in 38 (Appendix 3)
Personnel on drill site during drilling:	Gregers Dam, Well-Site Geologist, GGU Mogens Lind, Geologist, GGU Jeff Goodyear, Pilot, Universal Helicopters David Brooking, Helic. Engineer, Universal Helicopters Mel Upwards, Driller, Petro Drilling Geoff Upwards, Driller, Petro Drilling Dave Matthews, Driller, Petro Drilling Barry Tizzard, Driller, Petro Drilling Paul Philpott, Cook, Falconbridge 6 employees from Falconbridge with whom the base camp was shared Greenland Air, Helicopter Contract Sortsiden, Ship Contract, KNI
Logging contractor:	Rambøll, Hannemann & Højlund A/S
Personnel on drill site during logging:	Gregers Dam, Well-Site Geologist, GGU Morten Dam, Contract Assistant, GGU Carsten Ploug, Geophysicist, RH&H 'Maja S', Ship Contract, Finn Steffens Puttut, Ship Contract, Jacky Simoud
Company names/addresses listed above:	The Geological Survey of Greenland, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark

	Petro Drilling Company Ltd., P.O. Box 1021, Armdale, Halifax, Nova Scotia B3L 4K9, Canada
	Universal Helicopters Newfoundland Ltd., P.O. Box 9025, Str. "B", St. Johns, Newfoundland A1A 2X3, Canada
	Falconbridge Ltd., P.O. Box 398, 124 Water Street, Windsor, Nova Scotia, Canada
	Kalaallit Niuerfiat (KNI), P.O. Box 211, 3950 Asiaat, Greenland
	Rambøll, Hannemann & Højlund A/S, Bredevej 2, 2830 Virum, Denmark
	Finn Steffens, P.O. Box 100, 3953 Qeqertarsuaq, Greenland
	Jacky Simoud, P.O. Box 55, 3953 Qeqertarsuaq, Greenland
	Greenland Air, 3900 Nuuk, Greenland
External Communication:	Furono FS-1550 HF
(During the drilling programme)	Furono FM-2520 HF
Positioning system:	Magellan 5000 PRO (GPS)
Budget, Drilling:	742.660 D.Kr.
Budget, Logging:	632.600 D.Kr.

1.2 Introduction

1.2.1 Location

The surface location of the Marraat-1 well is situated between Marraat Kangilliit and Marraat Killiit on the south-west coast of Nuussuaq, approximately 800 m NE of Geologhuset and 200 inland from the coast (Fig. 1). The elevation is approximately 12 m above mean sea level and the coordinates are 70°31′08″N, 054°12′03″N.

1.2.2 Objective

The objective of the Marraat-1 well was:

1) To evaluate the number and thickness of the oil-impregnated zones, their geological control, as well as 'reservoir' and petrophysical properties.
2) To penetrate the lowermost part of the volcanic succession in order to reach into the underlying sedimentary succession that is assumed to contain an oil-prone source rock, probably within the Itilli succession described by Dam & Sønderholm (in press) and possibly also intercalated oil-impregnated sandstones.
3) To penetrate the volcanic and sedimentary successions in an area with relatively low thermal maturity and limited hydrothermal alteration, so that it would be possible to carry out detailed geochemical analysis (see Christiansen *et al.*, 1994a).
4) To obtain as much information as possible on the stratigraphy and lithology of the volcanics and sediments in order to integrate data in future seismic or other geophysical surveys. It was also considered important to measure the down-hole temperature distribution, especially for evaluating the possibility of permafrost as a secondary seal for oil and gas, for technical purposes and to measure the geothermal gradient and heat flow for basin modelling studies.
5) To obtain information of the porosity of the oil-impregnated zones, petrophysical characteristics of the volcanics, and a detailed down-hole temperature distribution by geophysical logging.
6) To perform a Vertical Seismic Profile (VSP) in order to integrate data in future seismic or other geophysical surveys, and if possible to record deeper reflectors that could give information of the depth to the sediments and basement. As a supplement to the VSP a Walk-away Noise Test (WNT) was performed close by the well (Fig. 1).
7) To sample formation fluids in the uppermost 90 m of the hole.

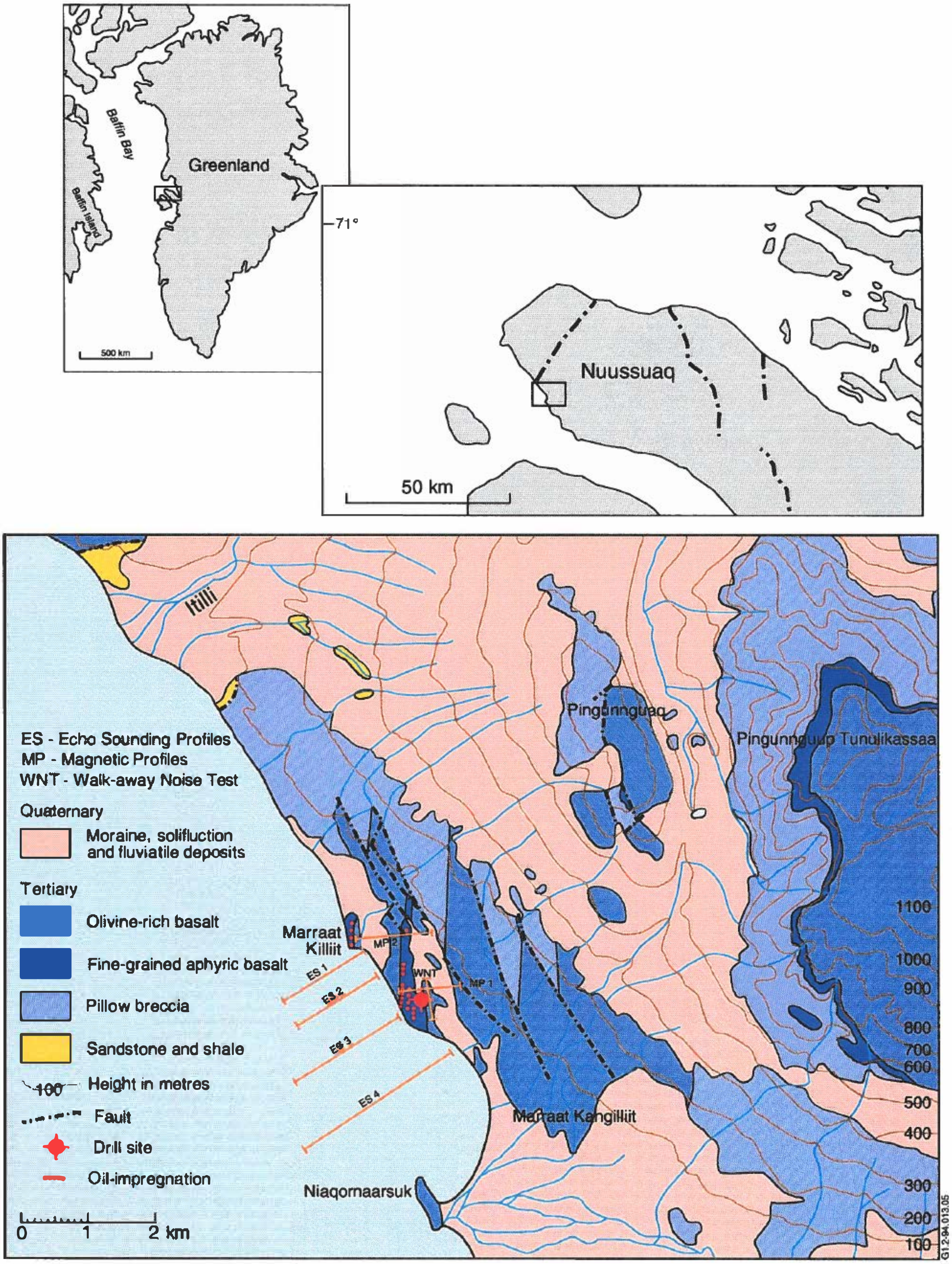

Fig. 1.
Geological map of the Marraat area showing locations of drill site, magnetic profiles, walk-away noise test, and echo-sounding profiles. Map based on Henderson (1975) and Christiansen (1994).

8) To perform a reconnaissance of magnetic measurements in the nearby area in order to obtain information on geomagnetic analomies (Fig. 1).
9) Four echo-sounding lines perpendicular to the coast in the Marraat area (Fig. 1). The objective of these lines were to see if the fault bounded ridges of volcanic rocks present onshore could be traced into offshore areas and to support future offshore seismic or other geophysical surveys.

1.3 Results

1.3.1 Drilling

A total of 447.75 m of core with a recovery close to 100% was sampled, described and subsequently shipped back to Copenhagen. The core piece at termination depth represents the oldest known Tertiary volcanic rock onshore West Greenland. The core confirmed the very important results from the previous fieldwork, namely that a series of porous zones in the aphyric, feldsparphyric, and olivine-feldsparphyric basalt lavas down to a depth of 86 m contain liquid oil (Fig. 2). These lavas overlie a succession of mainly olivine-phyric basalt and picrite lavas and picrite hyaloclastites with poor porosity and permeability and with only traces of oil. Eighty-three flow units have been recognized (L. M. Larsen and A. K. Pedersen, unpubl. data). A thin limestone horizon was penetrated at a depth of 208 m. This limestone probably correlates with a thin shell conglomerate, just NE of the drill site, that was discovered during the fieldwork that preceded the drilling programme. As the bit and reamer broke off in 447.75 m, after having penetrated a number of horizons with bad rocks, drilling had to be terminated and the well did not penetrate through the volcanic succession.

1.3.2 Logging and other tests

A geophysical programme was carried out in the upper 345 m of the borehole. Borehole logging, vertical seismic profiling, and formation fluid sampling were performed in the borehole and, additionally, a seismic walk-away noise test and reconnaissance magnetic measurements were made at the surface. Four echo-sounding lines were sailed perpendicular to the coast in the Marraat area (Fig. 1).

Marraat -1 core (GGU 408001)

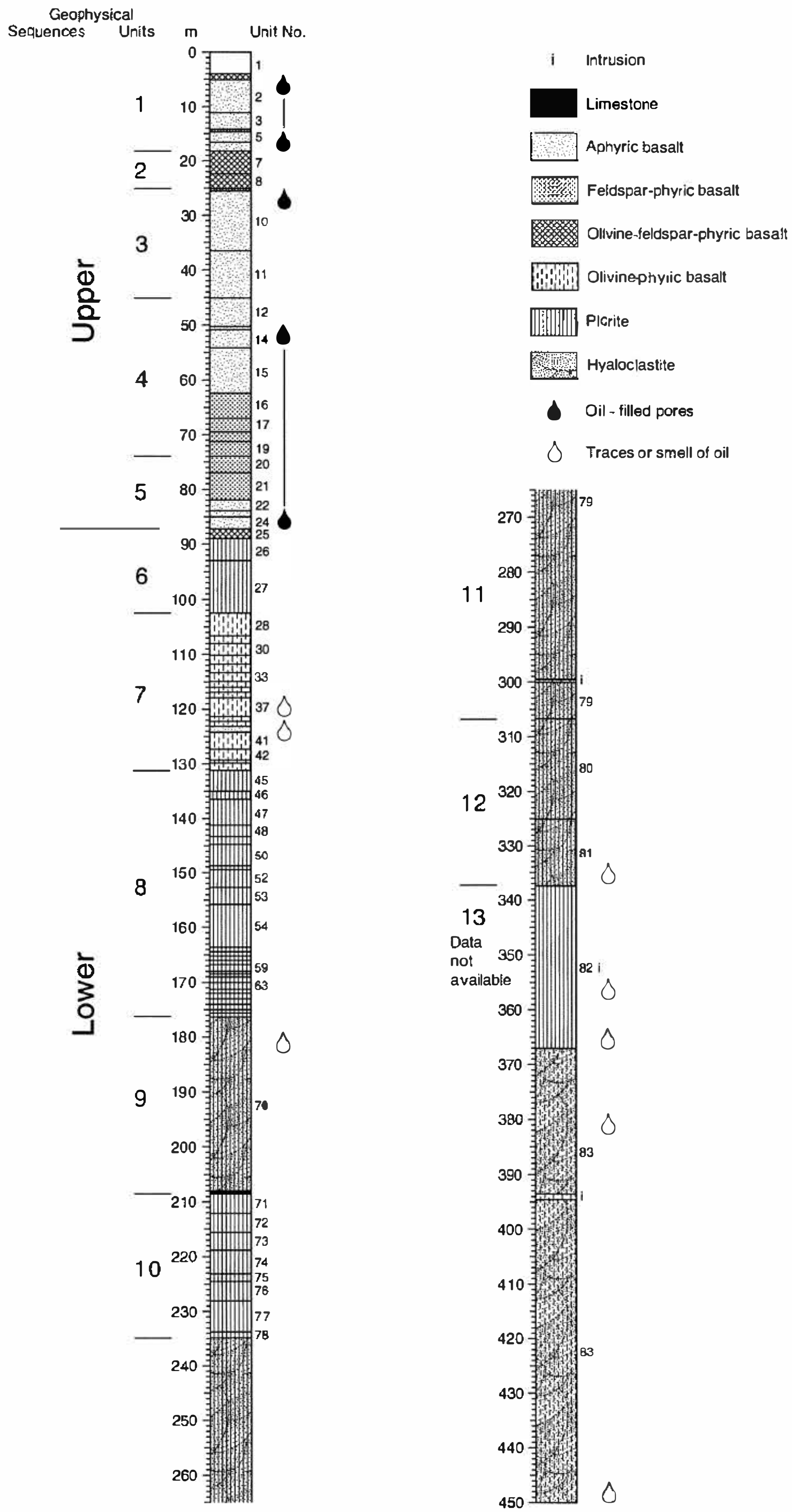

Fig. 2.
Simplified stratigraphic and geophysical log of the Marraat- 1 core, based on Larsen & Pedersen (unpubl. data), and a geophysical formation evaluation of the borehole by Carsten Ploug, Rambøll, Hannemann & Højlund A/S (Appendix IV).

The geophysical borehole logging resulted in a subdivision of the succession in two major sequences, each subdivided into 5 and 8 units, respectively (Fig. 1; Appendix 4). The upper sequence, c. 88 m thick, is defined by lower neutron-neutron porosities than those determined from gamma-gamma readings. It is also characterised by low M-factor values and fluctuating natural gamma values. The latter forms the main basis of a subdivision of the sequence into 5 units.

The lower sequence exhibits either no curve separation of the porosity logs or, alternatively, higher neutron-neutron porosities than gamma-gamma porosities. The natural gamma-gamma level is constant throughout the sequence. Individual units are mainly defined by the resistivity log. The lowermost unit, with top in c. 337.5 m depth, is distinctly different from the units above. It differs in the levels of resistivity, gamma-gamma, porosity, and M-factor.

The geophysical logging results may form the basis of a conventional formation evaluation. A petrophysical core analysis is, however, needed to perform such an evaluation.

Based on the vertical seismic profile and seismic walk-away noise test the P- and S-wave velocities have been interpreted to c. 4700 m/s and c. 2700 m/s, respectively. No pronounced change in the velocities in the upper 345 m can be observed.

The temperature log indicates an increase of 20°C from –4°C at the top to 16°C at the bottom resulting in a temperature gradient of 55-60°C/km.

Formation fluid (salty water) sampling was successfully applied at 6 levels in the upper 90 m of the borehole of the bore hole.

Both the appearance of the magnetic profiles and the amplitude of individual anomalies clearly show the presence of highly magnetic basalts. Local gradients are high and can in one case almost certainly be related to the presence of a fault (Appendix 5).

The echo-sounding profiles show that water depth within 1.5 km from the coast increases to about 200 m, indicating that the seabed has the same general topographic inclination as the land surface. Moreover, it seems possible to follow some of the topographic ridges from onshore areas into offshore areas.

2.0 OPERATIONS

2.1 Drilling history

The expeditions to the onshore part of the Cretaceous-Tertiary sedimentary basin in the Disko-Nuussuaq-Svartenhuk area of West Greenland were focused on stratigraphic, sedimentological and organic geochemical studies of the sediments in order to assess the hydrocarbon potential of the area (Christiansen, 1993). In addition one team studied the development of the Tertiary volcanics and their interaction with the sediments. Both for the teams working on the sediments and the volcanics some time was devoted to the search for seeps or impregnations of bitumen. One significant oil-impregnation was found in the lowermost part of the Tertiary volcanics on the south-west coast of Nuussuaq near Marraat at the end of the 1992 field season (Christiansen, 1993). This discovery was not a surprise, since it was located only a few kilometres from the previously described locality with highly coalified bitumen.

However, it was very encouraging that analysis by extraction, gas chromatography and mass spectrometry showed that the oil had only suffered minor biodegradation and no thermal alteration. Furthermore the presence of the biomarker compound oleanane suggests that the source rock is Tertiary (or latest Cretaceous) in age and was deposited in a marine environment dominated by terrestrially derived organic matter, e.g. a deltaic succession or prodeltaic muds (Christiansen *et al.*, 1994a).

The implications of these organic geochemical data are very important: for the first time the existence of an oil-prone source rock is demonstrated in West Greenland which exploration-wise has suffered from the 'gas-prone' reputation based on experience from the activities in the 1970s offshore Labrador and West Greenland. Based on the preliminary encouraging results it was decided to carry out additional field work in 1993 in order to study the extent of the oil-impregnation and to aim at drilling close to the discovery locality if appropriate equipment could be made available (Christiansen *et al.*, 1994b).

2.2 Position of drill site

The positioning was technically constrained by logistical (max. drilling depth, availability of rods, timing, price, transport, availability of water etc.) and geological factors. It was generally assumed that a position farther north would give a higher risk for stronger hydrothermal and thermal degradation of the underlying succession; a position further west would only penetrate a minor part of the oil-impregnated series although it probably would give a higher chance of reaching into the underlying sediments. A position farther east would increase the risk of drilling in a different fault block, or even worse to drill directly in a fault zone. Finally a position much farther south is not possible due to the nearby coast (Fig. 1).

2.3 Drilling programme

The drilling of the Marraat-1 well took place in the period August 15-21 and was performed by Petro Drilling Company Limited, Canada. A wire-line diamond drilling outfit (Fly-In model 38 Longyear with a Deutz engine) was used (Fig. 3) (Appendix 3). This equipment had been used earlier in the summer of 1993 by Falconbridge Limited on the island of Disko during their nickel exploration programme. The drill, as the name implies, is a specially modified model 38, for use on helicopter supported jobs, with each major component weighing no more than 545 kg. The drill has a theoretical capacity of 725 m using BQ rods (59 millimetres in diameter), but only 550 m of rods were available. The drill was operated by four drillers, working continuously in twelve hour shifts (two man in each shift). The drill and camp gear were transported from the Kuganguaq valley on Disko to Marraat by helicopter, boat and barge immediately before the drilling operation started. A base camp, shared with Falconbridge, was established close to the Geologhuset 800 m south of the drill site (Fig. 1). Helicopter charter services were provided by Universal Helicopters using a Bell Long Ranger 206 that was under contract to Falconbridge Limited.

During the first two days (Aug. 15-16) drilling went very quick and smooth and 234 m of volcanics were cored (Appendix 1). In the morning of the third day the oil-cooler refused to function and drilling had to be temporarily stopped. It quickly became apparent that the drillers did not have the necessary spare parts in the camp and that it would take several days to fly them from Canada. However, the mechanic remembered having seen some old Deutz engines at the abandoned coal mine at Qullissat. Within a few hours the drillers had constructed the necessary spare parts and during the afternoon on the same day drilling was reassumed. The following days (August 18-19) the speed of drilling was reduced considerably, mainly due to the increased time of bringing the core to the surface, but also due to technical problems with the engine. On August 20 'bad rocks' (fractured

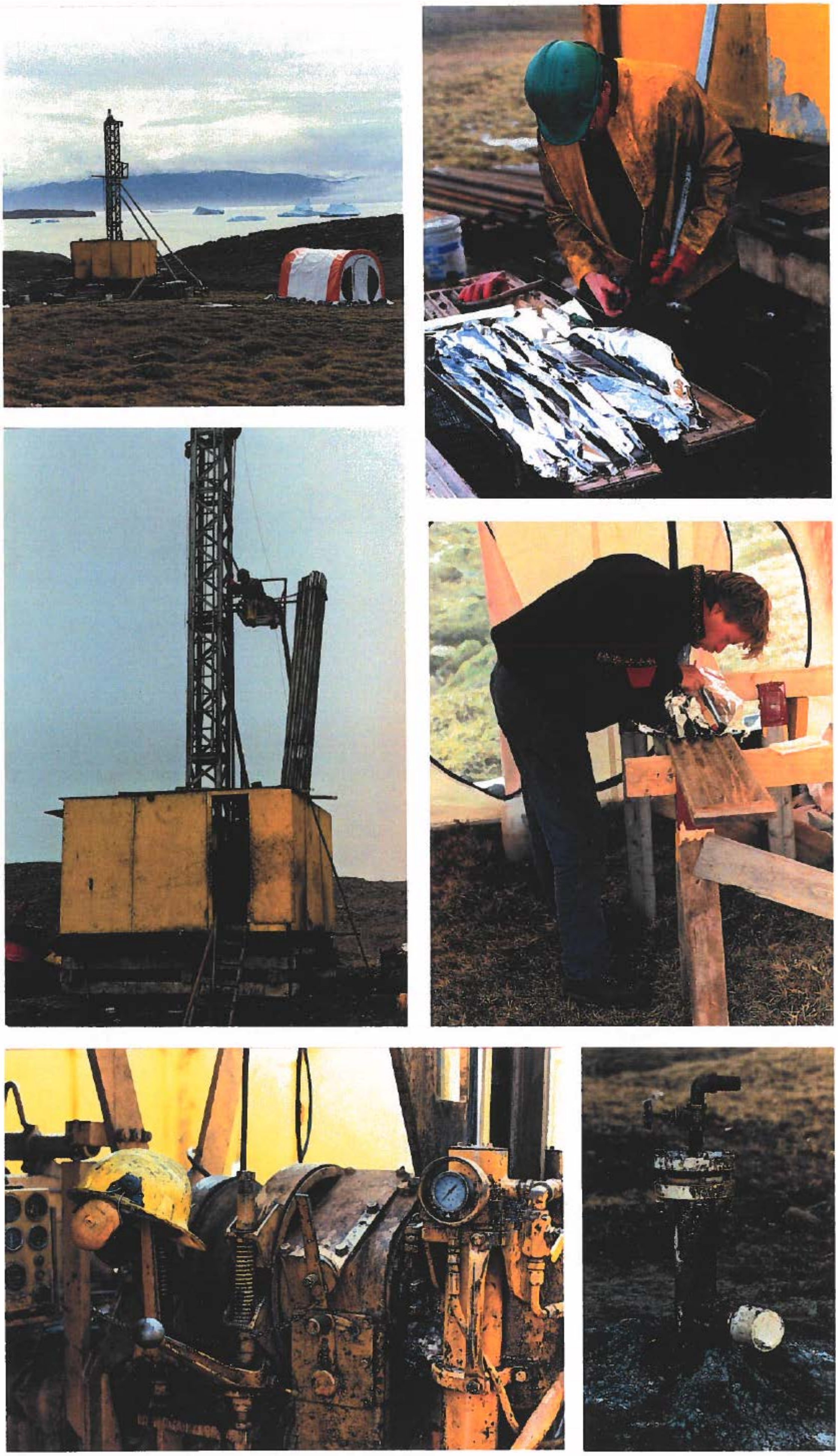

Fig. 3. The drilling programme.

volcanics) appeared at several levels. This became an increasingly harder problem and the drillers had to pull up the rods several times in order to change damaged bits and replace broken cables. Finally, at a depth of 447.75 m the bit and reamer broke off, and when pulling the drill string up, these parts were left at the bottom of the hole.

The necessary gear for catching the damaged parts in the hole or for deviating the hole at a higher position was not available. It would take several days to fly in a wedge from Canada in order to decline the hole. Such an operation would increase the costs of the drilling considerably without any guarantee that drilling could be resumed. Consequently it was decided to terminate the drilling programme on August 21. In the following two days the drill rig was taken apart and placed on a 'safe spot' just north of the drill site, and the camp was taken down and shipped back with Sortsiden to Ilulissat.

After completion of drilling and moving of equipment it became evident that formation water and flammable gas were liberated from the hole and a valve was therefore mounted on the top of the casing (Fig. 3). A thermistor string was lowered into the water-filled hole in order to measure the temperature variation and the thickness of the permafrost in the area.

2.4 Logging programme

After the drilling of the Marraat-1 well was successfully completed and the first promising geochemical results from samples brought back as land luggage, it was decided to perform a series of geophysical programmes in the well, including a geophysical logging programme, sampling of formation fluids, a Vertical Seismic Profile (VSP), a Walk-away Noise Test (WNT), reconnaissance magnetic measurements, and a reconnaissance echo-sounding survey in the nearby sea. The programme was designed and performed by Rambøll, Hannemann & Højlund A/S, Denmark, assisted by personnel from GGU.

The programme was carried out in late October to early November 1993 under very harsh weather conditions. Mobilisation took place out of Ilulissat using the two ships 'Puttut' and 'Maja S' from Qeqertarssuaq. Arriving at Marraat, all equipment was landed with rubber boat, and brought up to the drill site by hand (Fig. 4).

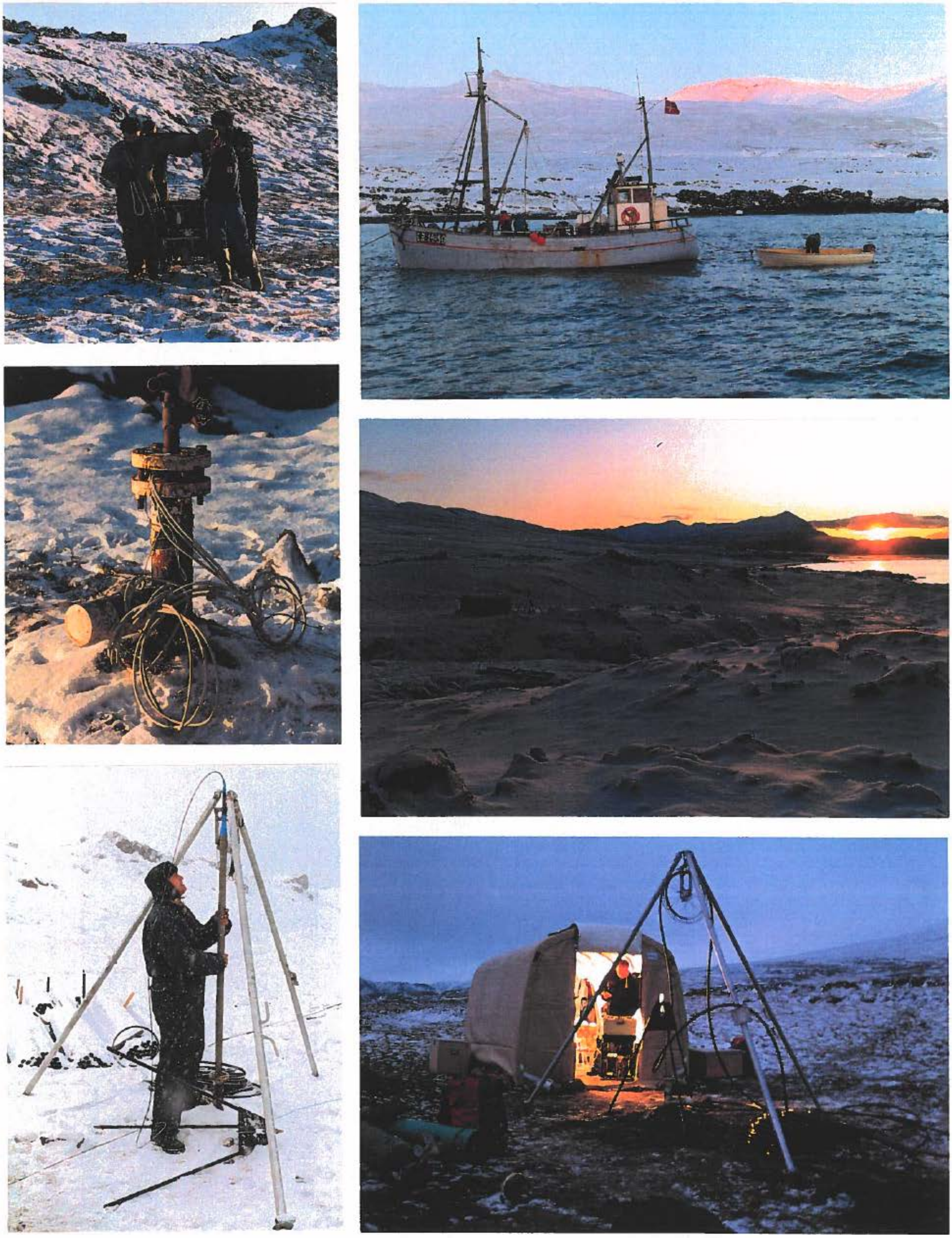

Fig. 4. The logging programme.

2.4.1 Logging

After completion of the drilling programme, an ice-plug had developed in the uppermost 17 m of the water-filled hole. The ice was removed using the GGU hot water jet drill, originally constructed for drilling through glacial ice (Olesen, 1988; Olesen & Clausen, 1988). During the following geophysical logging programme the hole was kept ice-free by adding salt and by inserting an electric heat cable into the hole. In spite of the technical challenges all planned logs were run. The calliper log demonstrates a nice constant-sized hole with only few caves or 'breakouts'. However, there is a major obstruction at a depth of ~350 m which the logging tools were not able to pass.

The suite of geophysical logs included: natural gamma (CPS = Counts Per Second); gamma-gamma (CPS); neutron-neutron porosity (percent); resistivity, 139.7 cm guard (ohm-m); spontaneous potential, SP (mV); single point resistance (ohm); temperature (degrees C); calliper (cm); deviation (degrees); and total magnetic field (CPS). Specifications of the logging equipment used and a geophysical formation evaluation has been presented by Carsten Ploug, Rambøll, Hannemann & Højlund A/S (Appendix 4).

2.4.2 Sampling of formation fluids

Following the geophysical logging programme, 24 formation fluid samples (saline water) were taken at 6 levels in the upper 90 m of the well. The pump was constructed according to the principle of Montejus (Appendix 4, Enclosure EO3) and nitrogen was used as propellant. The tool was lowered to the desired depth and was fixed by two packers. Each, 40 cm long, were inflated by nitrogen to an excess of 10 bar. The nitrogen was supplied through a tube from a bottle at the surface. The packers were situated in such a way that pumping took place over a vertical distance of 1 m. Afterwards the Montejus pump was emptied three times to ensure that the fluid came from the formation. The fluid was raised in a tube to the surface by nitrogen.

2.4.3 Vertical Seismic Profile (VSP)

The vertical seismic profile (VSP) was carried out with a borehole hydrophone streamer with 12 hydrophones, spaced 2 m, resulting in a coverage of 22 m per shot. The VSP was produced by lowering the borehole streamer 20 m after each shot, resulting in an overlap of two hydrophones to control the zero time of the shots. In order to carry out the VSP profile to a depth of 330 m, 16 shots were produced at distances between 5 and 20 m from the drill site. The energy source was 200 g of explosives placed c. 0.8 -1.6 m below the surface. To get a optimum contact for the explosives to the ground, all the shot holes were drilled at locations where the surface was basalt. The shot holes were drilled with an Atlas Copco petrol-driven drill/breaker named Cobra. It had been planned to drill the shot holes to a depth of 2.4 m, but because the drill steels easily got stick in the shot holes during drilling, this was abandoned. A full description of the VSP is presented in Appendix 4.

2.4.4 Walk-away Noise Test (WNT)

In order to obtain key data for planning future geophysical and drilling campaigns, and to supplement the present logging programme, a number of tests were carried out in addition to the borehole measurements. A seismic Walk-away Noise Test (WNT) and a few geomagnetic lines were acquired in the drill site area, and 4 echo-sounding lines were recorded in the near-shore areas. The location of these lines are shown in Figure 1.

The WNT was carried out at the surface c. 200 m NE of the drill site, between 70°31′15″N, 054°12′10″W, and 70°31′07″N, 054°12′01″W, for evaluating the seismic response at the locality (Fig. 1). Twenty-four single 10 Hz geophones, spaced 3 m, were placed on a straight line at the surface, while energy was generated with varying offsets to the geophone layout. The geophones and shot holes were placed on basalt outcrops for optimum contact with the ground. The energy source was 200 - 300 gram of explosives placed c. 0.8 – 1.6 m below the surface. These were shot at five locations beyond each end of the geophone layout. It was planned that the offsets to the nearest geophone should be 1.5, 70.5, 139.5, 208.5 and 277.5 m, but due to the presence of peat this was not possible. The shot points were placed 1.5, 70.5, 133.5, 202.5, and 271.5 m from the closest geophone at one end, and 1.5, 70.5, 136.5, 205.5, and 274.5 m from the other end of the geophone line. By using a distance of 69 m between successive shot points, an overlap between geophones was established and the time for firing and the distance to shot point could be controlled. Ten explosions were produced and the seismic instrumentation and procedure were the same as for the VSP. The applied equipment and data are listed in Appendix 4.

2.4.5 Reconnaissance magnetic measurements

The objective of the reconnaissance magnetic work was to acquire a few magnetic profiles near the Marraat-1 well to examine the magnetic response of rocks and structures in the area in preparation for possible further geophysical fieldwork in 1994. Two short magnetic profiles were measured using a Geometric 856 proton magnetometer with a single sensor, and the diurnal variation in the Earth's magnetic field was recorded by a similar instrument c. 30 m SW of the drill site. During sampling of the field data the base magnetometer made measurements automatically every 10 or 30 s. The time setting of the two instruments was synchronised to approximately one second. The sampling distance along the lines was 10 m. The first were made in the drill site area, perpendicular to the coast and the fault bounded ridges (Fig. 1). The second line went across the lower regions of the Tufdal valley, across a supposed major fault that may have acted as a migration conduit for the oil present in the basalts (Fig. 1). Data were dumped to a PC and compiled and prepared in Copenhagen by Leif Thorning, GGU (Appendix 5).

2.4.6 Reconnaissance echo-sounding survey

In order to obtain key data for planning of future shallow water geophysical field work in the Marraat area, and to see if the oil-impregnated ridges continued into offshore areas, four echo-sounding lines were recorded with 'Maja S'. The lines are 1.2-2.0 km long and oriented 57°-237°, perpendicular to the coastline (Fig. 1). The lines are shown in Appendix 6.

2.4.7 Well temperature measurements

After drilling was terminated, three thermistor strings with each six thermistors, were lowered down into the hole in order to record a vertical temperature profile. The first string was 20 m long, and thermistors were placed in 2.53 m, 5.86 m, 9.20 m, 12.53 m, 15.86 m, and 19.20 m. The second string was 200 m long, and thermistors were placed in 49.2 m, 79.2 m, 109.2 m, 139.2 m, 169.2 m, and 199.2 m. The third string was 351.9 m long, and thermistors were placed in 18.6 m, 85.2 m, 151.9 m, 218.6 m, 285.2 m, and 351.9 m. Results were read as resistance on an ohm meter and later converted into absolute temperatures. Temperature measurements are shown in Appendix 7. The results indicate that the third thermistor string was short circuited, and the strings were pulled and brought back to Copenhagen for replacement. A continuous temperature profile was measured in the upper 345 m of the bore hole in addition to the thermistor string measurements (Appendix 4, Enclosure BO1).

3.0 GEOLOGY

3.1 Setting and stratigraphy

In West Greenland previously described evidence of hydrocarbon generation has been restricted to two examples of highly coalified solid bitumens, one on the island of Qeqertarsuaq to the north of Uummannaq (Henderson, 1969) and one at Marraat Killiit on Nuussuaq (Pedersen, 1986). Additional evidence of hydrocarbon generation (but gas), observed as bubbles in fountains or lakes in pingos in the Aaffarsuaq valley on Nuussuaq was mentioned by Henderson (1969) and Henderson *et al.* (1976), who also quoted old local rumours of seepage.

The volcanics (and the minor sediment exposures) in the Marraat area were mapped and studied in detail in 1971 and 1972 by Gilroy Henderson (GGU unpublished map 1:10 000); results that were published by Henderson (1975) and compiled onto the GGU 1:100 000 map 70 V1 N. Furthermore, a preliminary exposure map on the scale 1:2000 covering the oil-seep and the drill-site was prepared by A. K. Pedersen with the aid of Multi-Model photogrammetry (cf. Dueholm & Pedersen, 1992) using oblique small frame colour diapositives taken from a helicopter (Fig. 1). These data and maps serve as an excellent background for the present study.

The oil-impregnated lavas belong to the oldest part of the Vaigat Formation and to a level deeper than found on Disko and described lithostratigraphically by Pedersen (1985). They have probably once been covered by several kilometres of younger volcanic rocks. The main oil-impregnation is found in vesicular flow tops within a series of subaerial basaltic lava flows mapped by Henderson (1975) as "fine-grained aphyric basalts". These flows both include feldsparphyric and aphyric basalts affected by high-level magma chamber processes, and some of the lavas are contaminated basalts silica-enriched through the reaction with upper crustal rocks (L. M. Larsen and A. K. Pedersen, unpubl. data).

The lavas can be mapped out as a light brownish-weathering marker horizon and help to define the structures of the area. The marker horizon is underlain by subaerial picrite lavas and more olivine-poor basalts and by two units of hyaloclastite formed by the filling of marine basins by the inflow of picrite lavas and by eruptions on the sea-floor. Inferred from the outcrop pattern along the coast north of the first oil-discovery locality, the hyaloclastites have a thickness exceeding 300 m. Minor oil-impregnation has affected the uppermost hyaloclastite.

The extent of the oil-impregnation as presently known in surface exposures is indicated on Figure 1, many individual thin zones have been traced along distances from 20 to more than 100 m. The two main areas of oil-impregnation, in both cases hosted by the same marker flows but in two different fault blocks, are spaced apart by about 1.5 km. At the oil-discovery locality, the breccias are inferred to have a thickness of at least 300 m. The boundary to the underlying sediments is only observed as a fault exposed along the coast but the general pattern in the terrain may be deduced from minor outcrops in the poorly exposed terrain east of the Itilli valley.

Structurally the Marraat area is rather complex being situated in the eastern margin of a major fracture zone system - the Itilli Fault zone, which is centred in the Itilli valley about 5 km to the north. The margin of the fault zone displays compressional features and a large number of dykes (up to 5-10% of the total rock volume is reached very locally) which represent several phases of dyke emplacement. Due to the heating effects of local dykes and sills and specially due to a number of hydrothermal fields marked by an abundance of mineralised veins (Binzer & Karup-Møller, 1974; Karup-Møller, 1969) and possibly also deeper subsidence and higher uplift than other areas on Nuussuaq, the thermal maturity of the sediments in the Itilli valley is high with vitrinite reflectance values between 2% and 3.5%.

However, a few kilometres east of the Itilli valley, the uppermost part of the exposed sediments found immediately beneath Tertiary hyaloclastites, has a much lower thermal maturity (TAI: 2^{+}-3) and palynomorphs may be recognised and identified (Nøhr-Hansen, 1993).

In the Marraat area the volcanics dip 15°-25° towards east (exactly 18.0° at the drill site) and the succession is cut by a number of N-S and NNW-SSE steeply dipping faults with a westerly downthrow (Henderson, 1975, Fig. 3) (Fig. 1). Several kilometres farther to the north, north-east and east, the dips of the flows are lower (~5° to the E and SE), and in central Nuussuaq they are close to a horizontal position and the number of faults is much smaller.

3.2 Lithology

The volcanic succession in the core consists of an upper sequence of aphyric, feldspar-phyric, and olivine-feldsparphyric basalts, and a lower sequence of picrites, olivine-phyric basalts and hyaloclastites. Eighty-three flow units are recognised in the succession (Fig. 2). A detailed description of the lithology of the cores will be presented later by L. M. Larsen and A. K. Pedersen.

3.3 Cores

447.75 m of conventionally core was cut, with a recovery of close to 100% (Fig. 2). A detailed description of the cores will be presented by L. M. Larsen and A. K. Pedersen.

3.4 Geophysical formation evaluation

Logging was provided by Rambøll, Hannemann & Højlund A/S (Appendix 4). The geophysical borehole logging resulted in a division of the succession into two major sequences, each subdivided into 5 and 8 units, respectively. The upper sequence, c. 88 m thick, corresponds to the sequence composed of aphyric, feldsparphyric, and olivine-feldsparphyric basalts of L. M. Larsen and A. K. Pedersen (unpublished data), and the lower sequence corresponds to the picrite and olivine-phyric basalts and hyaloclastites. Most of the geophysical units corresponds to major lithological units (Fig. 2).

The upper sequence is defined by lower neutron-neutron porosities than those determined from gamma-gamma readings. It is also characterised by low M-factor values and fluctuating natural gamma values. The latter forms the main basis of a subdivision of the sequence into 5 units.

The lower sequence exhibits either no curve separation of the porosity logs or, alternatively, higher neutron-neutron porosities than gamma-gamma porosities. The natural gamma-gamma level is constant throughout the sequence. Individual units are mainly defined by the resistivity log. The lowermost unit, with top at c. 337.5 m depth, corresponding to the intrusive body (Fig. 2), is distinctly different from the units above. It differs in the levels of resistivity, gamma-gamma, porosity, and M-factor.

The temperature in the borehole increases from –4°C in the top to 16°C in 345 m, giving a temperature gradient of 55 - 60°C/km.

Based on the vertical seismic profile and seismic walk-away noise test, the P- and S-wave velocities have been interpreted to c. 4700 m/s and c. 2700 m/s, respectively. No pronounced change in the velocities in the upper 345 m can be observed.

Formation fluid sampling has been applied at 6 levels in the upper 90 m. The samples are presently being analysed.

Both the appearance of the magnetic profiles of the reconnaissance measurements and the amplitude of individual anomalies clearly show the presence of highly magnetic rocks, almost certainly the basalt common to the area. Local gradients are high; a type of variation in the magnetic field that may be caused by near surface variation in magnetic susceptibility and/or remanences, blocky moraine, varying thickness of overburden, change of normally to reversely magnetised basalts, or visa versa, and/or the presence of cracks and faults.

Based on the results of the reconnaissance work it is clear that further magnetic work in similar detail and with more parallel lines at closer spacing would accurately map the occurrence of near surface basalts, point out faults, and give thickness of the superficial moraine beds etc.

The field measurements, the results of the reconnaissance magnetic measurements, and a discussion of implications for further ground geophysical field work in the Marraat area is compiled in an internal GGU report by Leif Thorning (Appendix 5).

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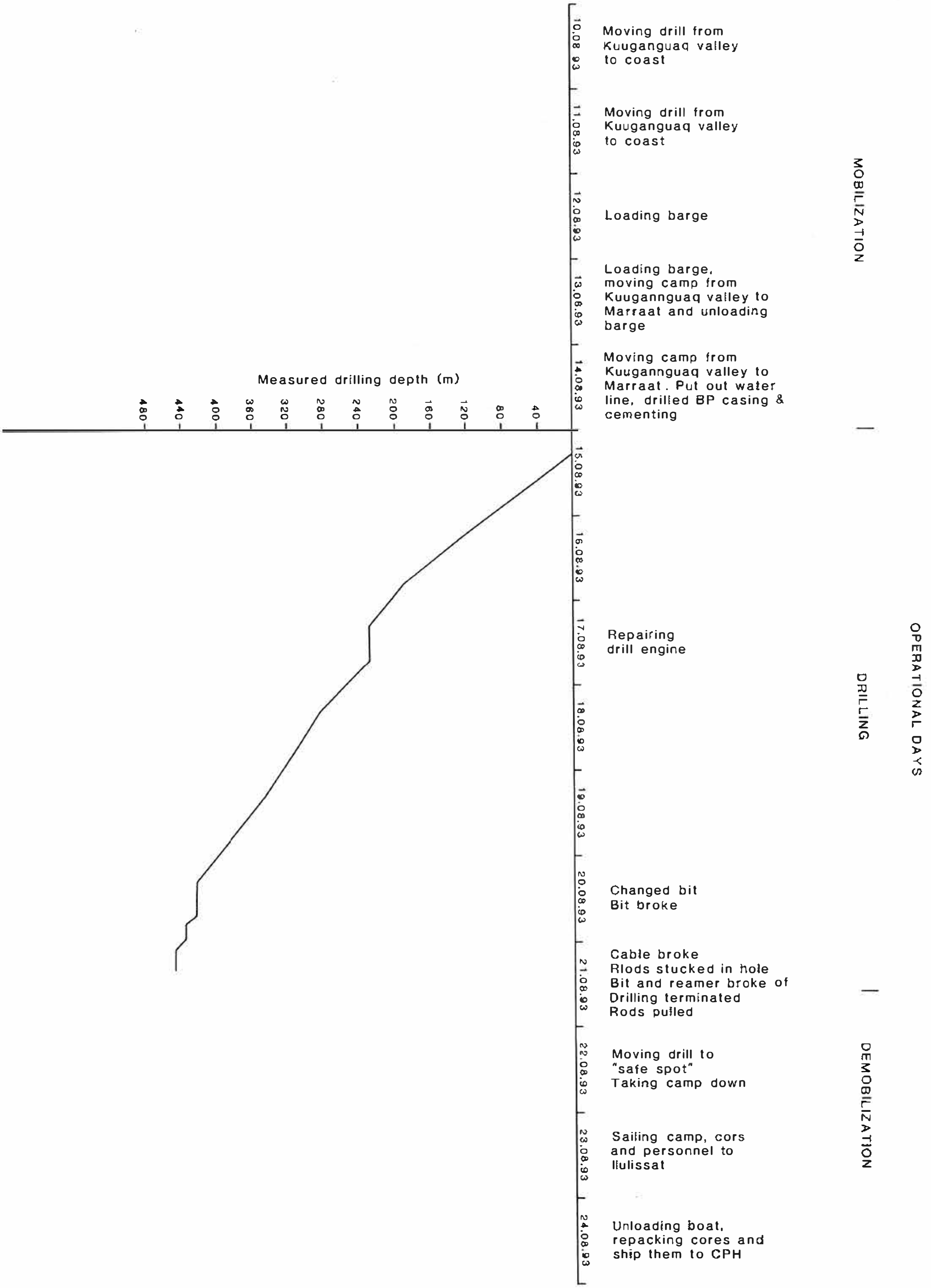
Appendix 1 Time distribution chart for the drilling programme



Appendix 2 Time distribution chart for the logging programme

20.10.93	Arriving Ilulissat
21.10.93	Delivery of equipment Sailing for Marraat
22.10.93	Arriving Marraat Pilotage of equipment from ship to drill site
23.10.93	Pilotage of equipment from ship to drill site Temperature measurements
24.10.93	Melting ice core in bore hole Ecco-sounding survey
25.10.93	Logging Sailing for Saqqaq with injured sailor
26.10.93	Sailing for Marraat with 2 new saylors
27.10.93	Magnetic measurements Logging
28.10.93	Formation fluid sampling Magnetic measurements
29.10.93	Vertical Seismic Profile
30.10.93	Formation fluid sampling
31.10.93	Walk-away Noise Test Loading ship
1.11.93	Sailing for Ilulissat Arriving Ilulissat

MOBILIZATION

LOGGING

DEMOBILIZATION

OPERATIONAL DAYS

FLY-IN 38 DIAMOND CORE DRILL

Longyear

SECTION A
CATALOG 200
Effective March 1, 1982
First Edition

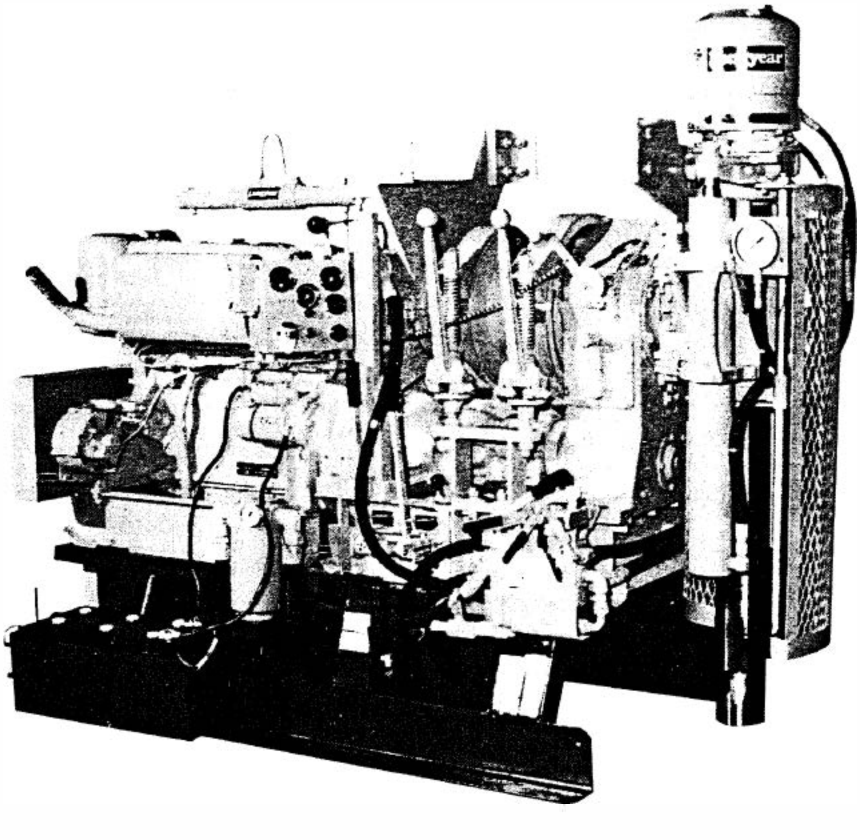
Fly-in 38

The Longyear Fly-in 38 Diamond Core Drill is an excellent drill for remote drilling situations that require a drill with enough power to handle larger size down-hole tools and has a low range for efficient penetration of overburden.

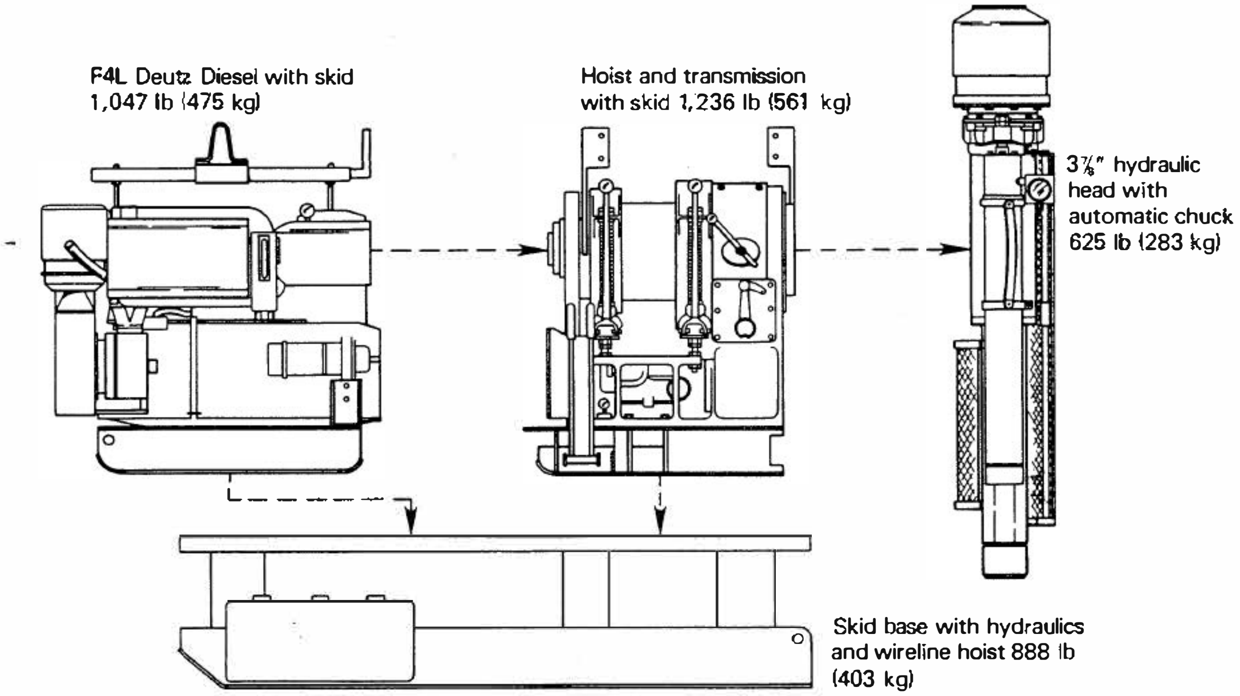
Important modifications which have been made to the Fly-in 38 are:

- The length of the drill has been reduced by utilizing a close-coupled design and a disc type clutch.
- All hydraulics are mounted on the lower portion of the surface frame. This eliminates the need to disconnect hoses, valves and the hydraulic pump. The wireline hoist is operated hydraulically and is located on the lower frame.
- The engine, main hoist and the hydraulic head can be disassembled quickly for transportation.

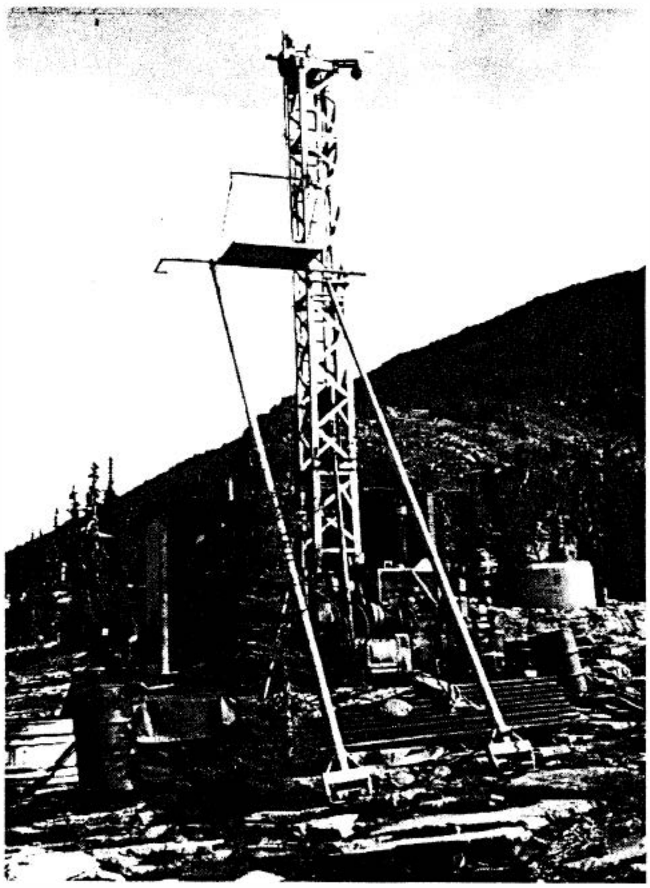
The modifications made on the Fly-in 38 result in a small weight reduction. There is a choice of Deutz or John Deere power units. The mast recommended for the Fly-in 38 is aluminum for maximum strength with minimum weight.



Description	lb	kg	ft³	m³
Fly-in 38 with 3" head, less chuck. Unit includes safety headguards, and an air-cooled Deutz diesel F4L-912 power unit.	3799	1727	230	6.5
Fly-in 38 with 3-7/8" head, less chuck. Unit includes safety headguards, and an air-cooled Deutz diesel F4L-912 power unit.	3829	1740	260	7.2
Fly-in 38 with 3" head, less chuck. Unit includes safety headguards, and a water-cooled John Deere diesel 4239 power unit.	4499	2045	230	6.5
Fly-in 38 with 3-7/8" head, less chuck. Unit includessafety headguards, and a water-cooled John Deere diesel 4239 power unit.	4529	2059	260	7.2
NA 3" Automatic Chuck	–	–		
HA 3-7/8" Automatic Chuck	–	–		
Wireline Hoist, oil powered	–	–		
20' Aluminum mast	1565	711		



The Fly-in 38 drill can be disassembled for transportation to remote drilling locations.



For maximum strength with minimum weight, Longyear recommends the use of an aluminum mast for the Fly-in 38.

Examine the features of the Longyear 38 drill

Hoist clutch — extra-wide, uniformly-concentric clutch and brake bands apply more holding power for a given amount of effort on the part of the operator. They also have the additional surface needed to prevent overheating under heavy load.

Power — modular design provides a choice of dependable diesel or gasoline engines. Air or electric power are available on special order. Stub-shaft units are also available for customer installation of power unit. (Illustrated: Deutz diesel)

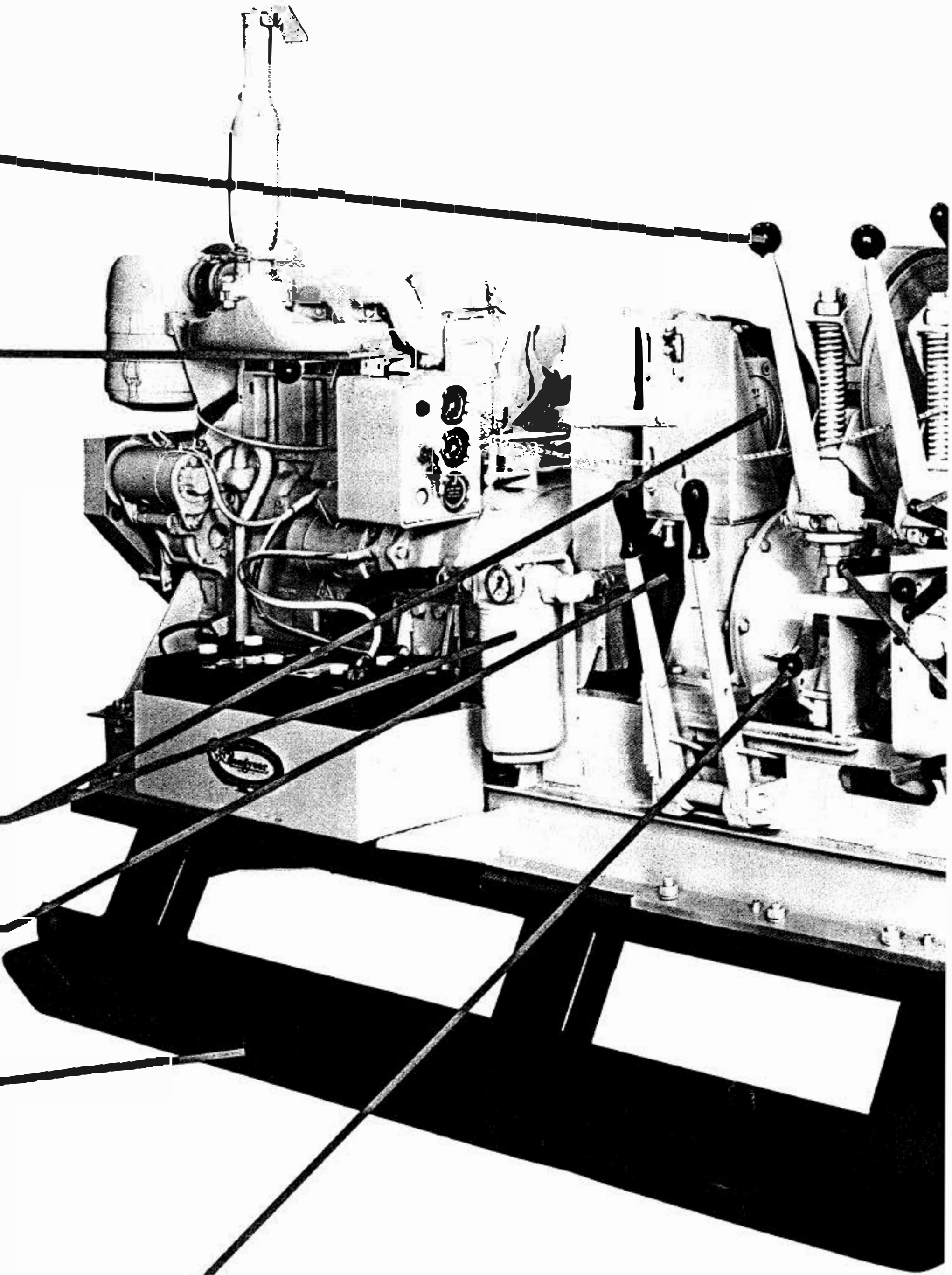
Self-propelling attachment — this option provides the necessary fairleads, sheaves and rollers to allow the drill to be moved under its own power by using the hoisting cable.

High-capacity hydraulic system — live hydraulic system provides for operation of hydraulic components when drill clutch is disengaged. Variable volume, vane-type pump delivers exactly the amount of oil required, thus overheating, foaming of oil and horsepower requirements are minimized. An efficient oil filter is provided to protect the hydraulic system.

Flexible coupling — compensates for minor misalignment and cushions shocks imposed by drilling.

Skid — welded structural steel construction provides long life under severe operating conditions. Modular design permits easy transfer of drill from skid to truck-mount and vice versa.

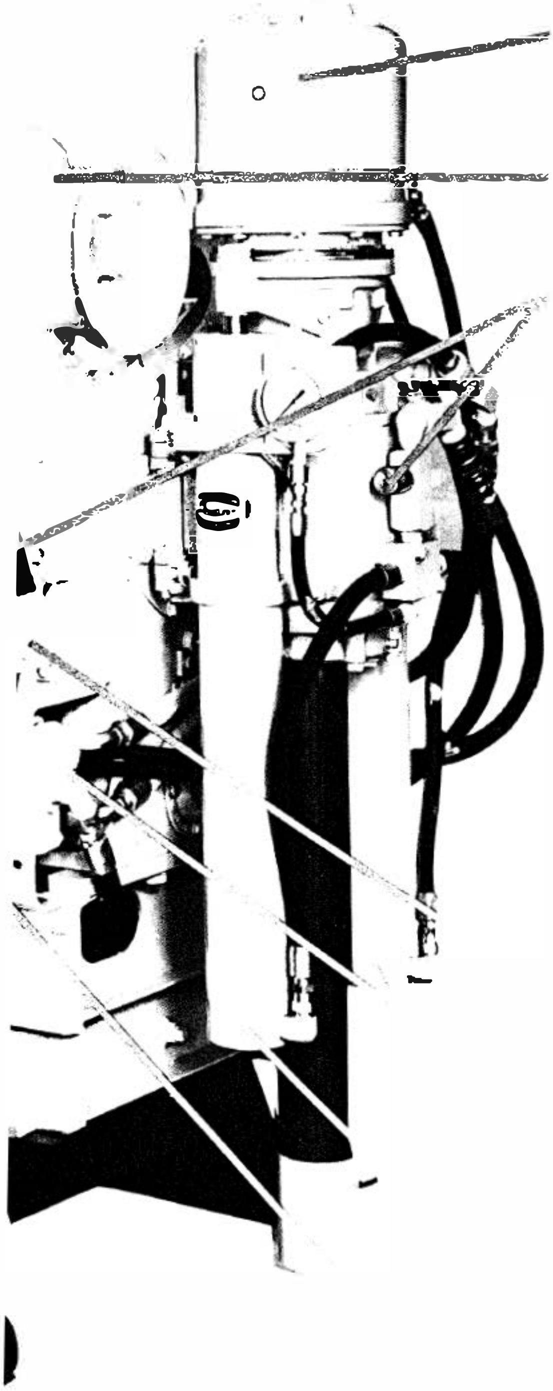
Transmission — synchro-mesh. Four forward speeds. Combination of Speed Range Selector and 4-speed transmission provides the correct bit speed for any drilling situation without the need for changing bevel gears. There are 8 usable bit speeds for each throttle setting. By simply shifting a selector lever, the operator can select higher drilling speeds when using diamond bits and lower speeds for roller or drag bits . . . assuring the most efficient engine and drilling performance on any job.



Drill capacities

Drill rod size	Feet	Meters	Drill rod size	Feet	Meters
AQ Wireline	3100	950	AW*	2800	850
BQ Wireline	2400	725	BW*	2300	700
NQ Wireline	1900	575	NW*	1800	550
HQ Wireline	1200	375	HW*	1100	325

*DCDMA upset wall tubing.



Automatic chuck — An optional feature which eliminates the manual chucking operation to increase drilling efficiency and operator safety.

Cathead — an optional feature for drive hammer operation, general handling and lifting tasks.

Feed control — positive control of weight on the bit and rate of advance is accomplished by bleeding oil from the lower end of the feed cylinders through a needle type control valve. A quick-return circuit is provided for raising the drive rod to re-chuck. The directional control valve used to control the hydraulic head incorporates four independent valve positions: up, down, neutral and float. At shallow depths, the directional control valve should be set in a down position, where full hydraulic pump pressure can be applied above the pistons to provide bit weight. At greater depths, set the directional control valve in float position, and the weight of the drill string can be employed to provide bit weight, without the necessity of applying hydraulic pressure above the pistons. Advantages: less horsepower required . . . cooler oil . . . less wear.

Speed range selector — for selecting high or low range swivelhead rotating speeds.

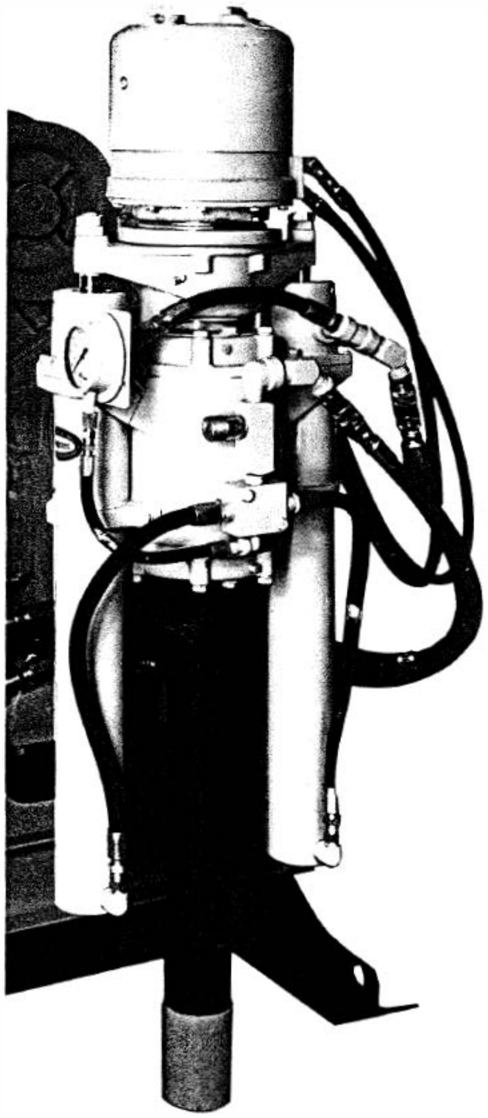
3-spool, 4-way hydraulic valve — simplifies installation and minimizes the cost of adding extra hydraulic accessories. When needed, accessories are simply connected to receive full hydraulic power.

Hydraulic swivelhead — available in 3" size for rods through NQ size or casing through BW size, or 3-7/8" for rods through HQ size or casing through NW size. Incorporates twin (3-1/2") hydraulic cylinders with a full 24" stroke.

Hydraulic retraction — This option features a full 13" travel giving 10" minimum hole clearance.

Overcenter clutch — featured on all "38" Drills is a heavy-duty twin-disc industrial clutch of overcenter design for positive disengagement.

This smooth-acting clutch has 55 square inches of friction area for efficient operation and longer life.



Swivelhead

Longyear hydraulic swivelheads have accurate control of bit pressure and rate of advance. Variable-volume pump delivers correct volume of oil to the head for efficient advance of bit in constantly changing rock formations.

Large cylinders provide powerful bit pressure and rod pull plus fast chuck return. Wide spacing of cylinders and guide rods give excellent rigidity and smooth operation.

"38" drills can be supplied with either the NQ (3-inch) or HQ (3-7/8-inch) hydraulic swivelheads. The NQ will pass NQ wireline, NW rods or BW casing. The HQ will pass HQ wireline, HW rods or NW casing.

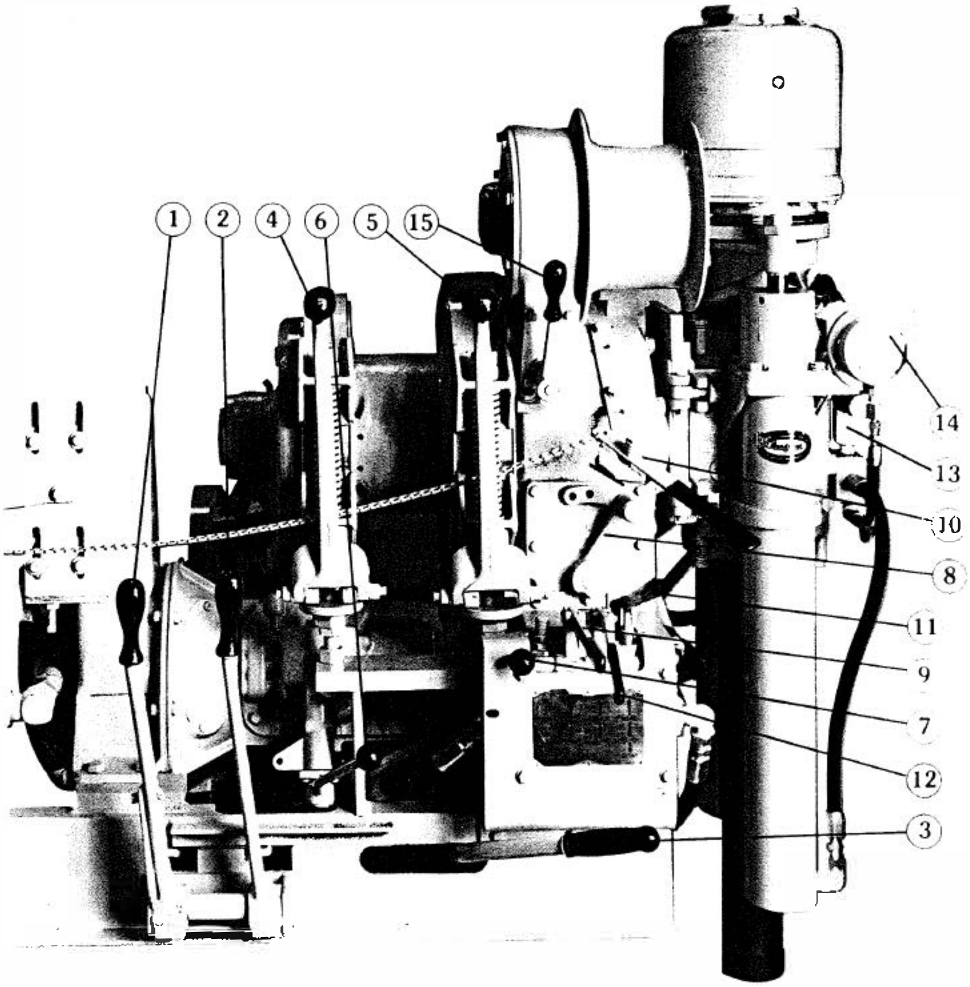
The HQ head (shown above) features a brass measuring rod scaled in inches.

Special features, optional equipment

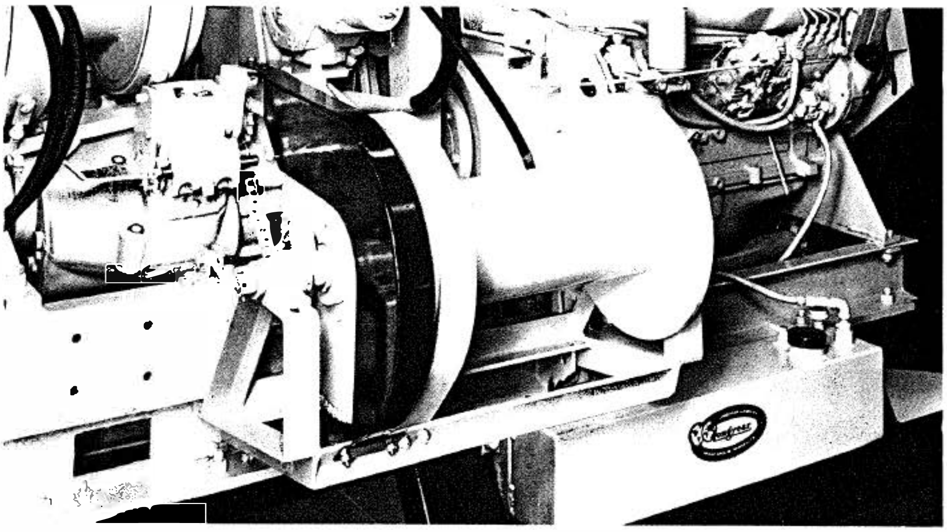
38 drill controls

1 Wireline hoist brake lever
2 Wireline hoist clutch lever
3 Main clutch lever
4 Hoist clutch lever
5 Hoist brake lever
6 Transmission shift lever
7 Wireline hoist engaging lever
8 Speed range selector lever
9 Retraction lever
10 Engine throttle control
11 Swivelhead control lever
12 Control lever for optional. automatic chuck
13 Hydraulic swivelhead feed control valve
14 Hydraulic feed pressure gauge
15 Cathead engaging lever

Central grouping of all controls saves waste motion and allows the operator more hours of profitable drilling.

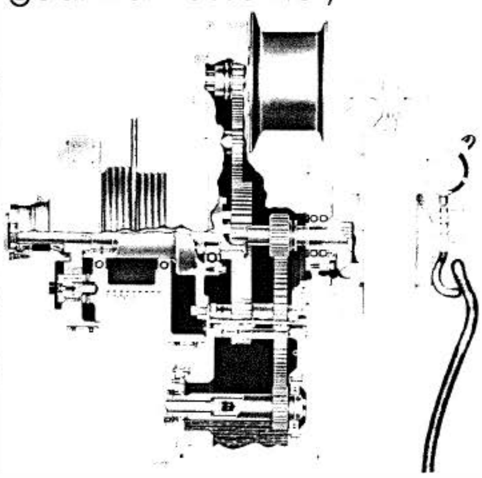


Wireline hoist



A build-in wireline hoist can be supplied as accessory equipment. The drum assembly mounts securely on the skid frame and features maintenance free sealed ball bearings. It is driven from the transmission power take-off by roller chain. The power take-off can be disengaged when drilling. The "built-in" feature eliminates the nuisance of a separate hoist unit while giving the operator "finger-tip" control from the central control station.

Transmission and hoist gear train assembly



Smooth-running planetary gear hoist with ball bearings facilitates the hoisting and lowering of drill rods as hoist brake and clutch can be used independently.

BV-3820 mast

For drilling vertical or angle-holes
Combination vertical-and-angle-hole mast features advanced design for efficient drilling operations. Adequate capacity to handle rods in either vertical or angle-hole position at the rated capacity of the drill.

Designed so that forces developed when hoisting drill string are confined within the drill mast assembly. There is no tendency for the drill to lift off the ground.

ROLLER BEARING SHEAVES in heavy-duty crown block.

ACCOMMODATES PULL OF 20-FOOT ROD LENGTHS.

2-PART MAIN POLE is flanged and bolted together. Easily dismantled for transporting.

ROD RACK. Adequate capacity to store rods to the rated capacity of the drill.

WORKING PLATFORM. Swivels to remain horizontal as mast is angled. Platform has access from built-in ladder provided with the mast.

QUICK-DETACH PINS are used throughout at adjustment points.

MAST — Raised and Lowered by hoist cable or by optional hydraulic cylinder. For optimum safety and ease of operation, the hydraulic cylinder is recommended.

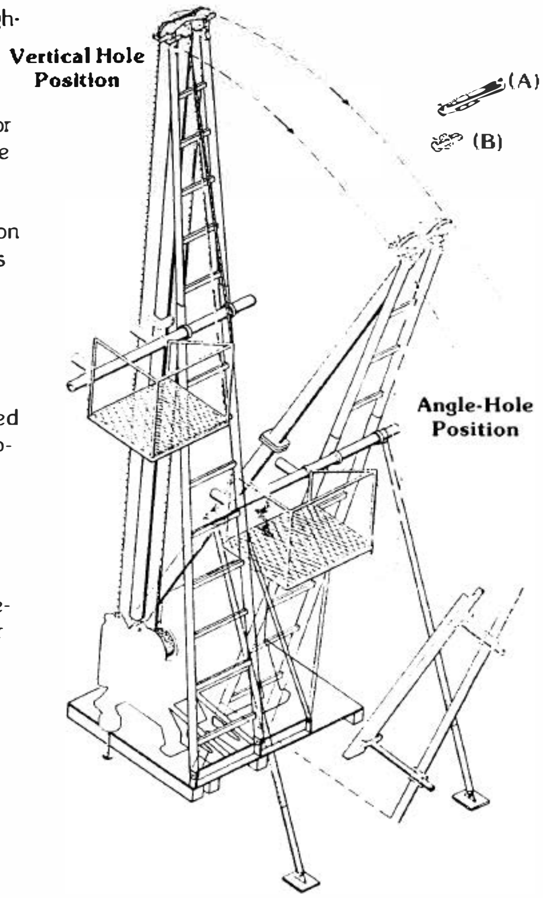
RETRACTION. Mast allows drill retraction of up to 13 inches. Crown sheave remains in perfect alignment with hole even when drill is retracted and when mast is in any operating position.

BACKSTAY LEGS telescope and adjust with quick-detach pins when mast is angled or lowered. Purchased as accessory equipment with rod slide.

ROD SLIDE for ease in feeding rods through the swivelhead when angle-hole drilling. Rod slide and backstay legs are accessory items and are specified as angle-hole attachments. Neither is necessary for vertical hole drilling.

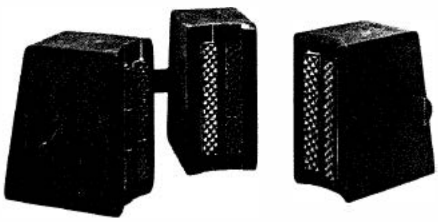
ACCESSORY WIRELINE SHEAVE ATTACHMENT is purchased separately for use with the wireline hoist. (A)

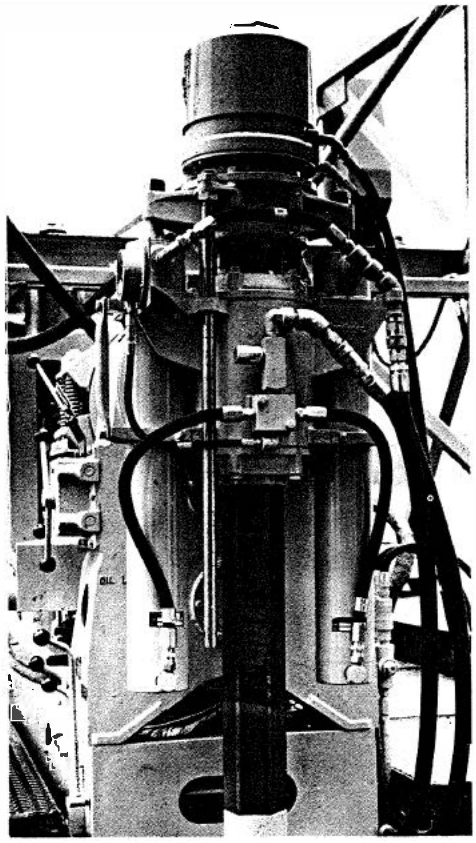
ACCESSORY CATHEAD SHEAVE ATTACHMENT is purchased separately for use with cathead. (B)



Automatic chuck

Optional, automatic chuck is spring loaded and hydraulically released. Advantages are increased footage, smoother rotation, safer operation and operator ease. Chuck has three hardened steel chuck jaws with Longyear designed, tungsten carbide inserts to grip rods firmly.





Instrumentation kit

The instrumentation kit gives a visual reading of the drill string RPM and bit weight. The kit contains a 12V DC electric tachometer and a hydraulic pressure gauge.

A dial ring on the pressure gauge is "zeroed" with the bit just off bottom. When drilling commences, the load transferred to the bit can be read directly in pounds or kilograms on the dial.

The hydraulic gauge is equipped with an oscillation damper for easier, more accurate reading.

The accurate readings obtained with the kit enable the driller to maximize penetration rates and extend bit life.

Adaptability is standard equipment on every Longyear 38 drilling rig

The modular selection process

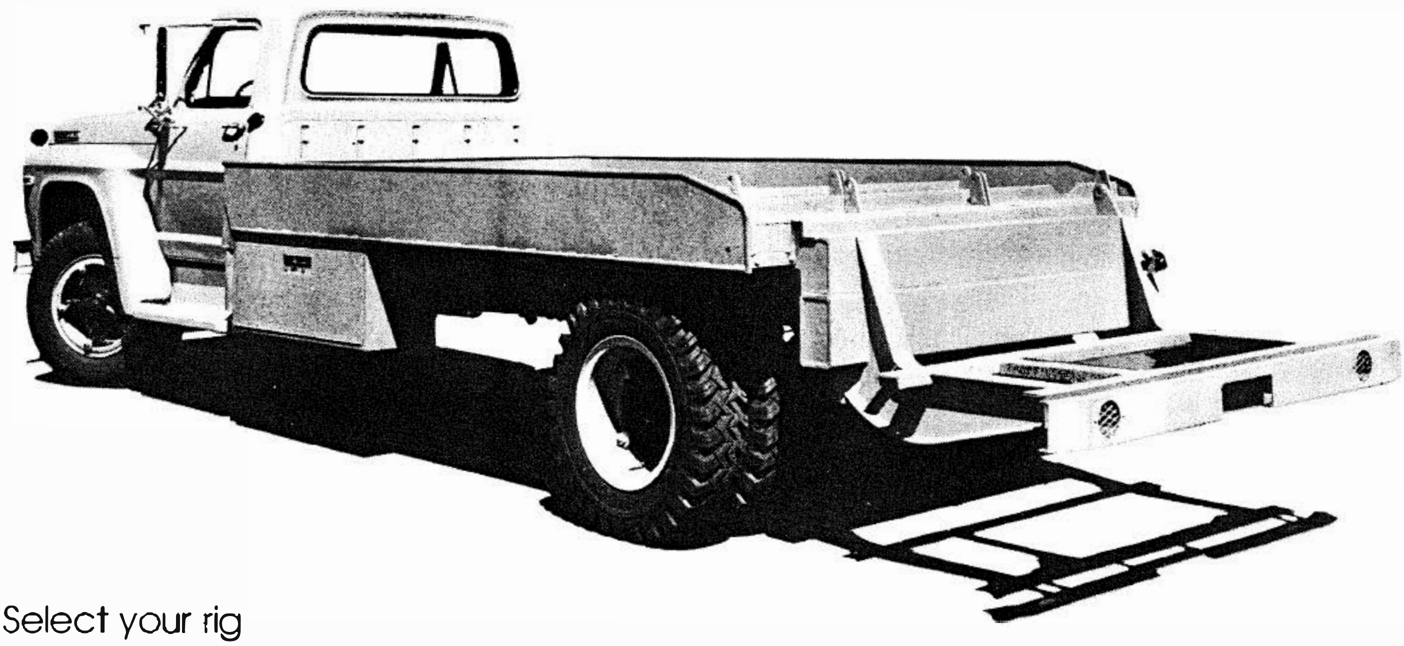
Standardization of basic drilling rig components allows flexibility in selecting the components to meet your drilling requirements, together with the economy and careful engineering of a factory-built system.

Modular Design gives you unmatched *adaptability* . . . an important benefit for as long as you own your Longyear drill.

Module and mounting interfaces are standardized, so it is a simple matter to alter the configuration of your drill rig as your drilling requirements change.

Many modular features can even be added or substituted in the field. Frames and mounting surfaces are pre-drilled to eliminate the fuss of complicated custom fitting.

The result is fast flexibility to meet changing needs, decreased drill downtime, and lower operating costs.



Select your rig

1 / Construct a model number by selecting one of the basic drill assemblies. All subsequent selections must be made from the same vertical column.
Example: A 38 Skid-mounted drill with 3-7/8" head. **38SH**

2 / Select the power option from Table II.
Example: A Ford Diesel **DF19**

3 / Select the desired Chuck from Table III.
Example: 3-7/8" Mechanical Chuck **HM**

4 / Select the Drive Rod Bushing and Chuck Jaw size by placing that size in the model number from the table.
Example: Drive Rod Bushing and Chuck Jaw size desired is HQ **HQ**

For information to order additional or different size sets, see table.

5 / You may select one of the five Truck Options offered by Longyear under Table IV, or you may furnish your own truck. Customer-furnished trucks must meet the following minimum specifications: single rear axle with 187" wheelbase and 120" cab to rear axle length OR tandem rear axle with 169" wheelbase and 102" cab to centerline of tandem axle length; 17,000# minimum rear axle capacity; 8:00 x 20 minimum tires; reinforced frame; 108" maximum height to top of cab; 60" maximum height from frame to top of cab. For skid and trailer mounted units no selection should be made.
Example: No Selection **0**

6 / Select Accessory Equipment as desired from Table V for best operation. (Longyear recommends the 535 RQ Pumping Unit available with either gas or diesel power, see Price Book for complete specifications). All trucks and trailers are furnished pre-drilled for mounting the pump and are equipped with a standpipe and discharge hose. Other ancillary equipment such as the suction hose and water swivel hose should be selected from the Longyear Catalog.
Example: Cathead, Hydraulic Retraction, Wireline Hoist (Drill Mount) and Self-Propelling. **C,R,W,SP**

For example the Unit Model Number is:
38SH-DF19-HM-HQ-O-C, R, W, SP
which describes the entire drill.

	Skid mounted		Vehicle mounted **Angle Mast, 20 foot**		Vehicle mounted **Vertical Mast, 20 foot or 30 foot**	
I	Model	Description	Model	Description	Model	Description
	38SN	Drill Unit with 3" Hydraulic Head	38TA2N	Truck Mtd. Drill. 3" Head. 20' Mast	38TV2N	Truck Mtd. Drill. 3" Head. 20' Mast
	38SH	Drill Unit with 3-7/8" Hydraulic Head	38TA2H	Truck Mtd. Drill. 3-7/8" Head. 20' Mast	38TV2H	Truck Mtd. Drill. 3-7/8" Head. 20' Mast
		Units include	38UA2N	Trailer Mtd. Drill. 3" Head. 20' Mast	38TV3N	Truck Mtd. Drill. 3" Head. 30' Mast
		Transmission. Drum Hoist.	38UA2H	Trailer Mtd. Drill. 3-7/8" Head. 20'	38TV3H	Truck Mtd. Drill. 3-7/8" Head. 30' Mast
		Speed Range Selector. 90' Single Part		Mast	38UV2N	Trailer Mtd. Drill. 3" Head. 20' Mast
		Hoisting Cable.		Units include:	38UV2H	Trailer Mtd. Drill. 3-7/8" Head. 20' Mast
				Mast Raising Cylinder. Truck or Trailer Bed.		Units include
				Transmission. Drum Hoist. 90' Single Part		Mast Raising Cylinder. Truck or Trailer Bed.
				Hoisting Cable. Retraction. Price does not		Transmission. Drum Hoist. 90' Single Part
				include truck or trailer.		Hoisting Cable. Retraction
						Price does not include truck or trailer.
II	0	No Power Unit (Stub-shaft)	0	No Power Unit (Stub-shaft)	0	No Power Unit (Stub-shaft)
	DD4	Air-cooled Deutz Diesel Engine	DD4T	Air-cooled Deutz Diesel Engine	DD4T	Air-cooled Deutz Diesel Engine
III	NM	3" Mechanical Chuck	NM	3" Mechanical Chuck	NM	3" Mechanical Chuck
	HM	3-7/8" Mechanical Chuck	HM	3-7/8" Mechanical Chuck	HM	3-7/8" Mechanical Chuck
	NA	3" Automatic Chuck	NA	3" Automatic Chuck	NA	3" Automatic Chuck
	HA	3-7/8" Automatic Chuck	HA	3-7/8" Automatic Chuck	HA	3-7/8" Automatic Chuck
IV•		No Vehicle Selection	0	No Vehicle Selection	0	No Vehicle Selection
			FS700	Ford - F700 Single Axle	FS700	Ford - F700 Single Axle
			FS750	Ford - F750 Single Axle	FS750	Ford - F750 Single Axle
			IS1800	International 1800 Single Axle	IS1800	International 1800 Single Axle
			IS1890	International 1890 Single Axle	IS1890	International 1890 Single Axle
			IT1800	International 1800 Tandem Axle	IT1800	International 1800 Tandem Axle
			UA	Trailer	UV	Trailer
V	C	Cathead	C	Cathead	C	Cathead
	R	Hydraulic Retraction **3	WT	Wireline Hoist	WL•	Wireline Hoist (oil powered)
	W	Wireline Hoist Built-in	A	Angle-Hole Attachment. BV-3820 Mast **2	3S	Triple Line Sheave Assembly
	SP	Self-Propelling Unit	24	Cathead Attachment. BV-3820 Mast (Sheave)	12	Traveling Block w/ shackle **1
	M	BV-3820 Mast	22	Wireline Attachment. BV-3820 Mast (Sheave)	HJ	Hydraulic Leveling Jacks **1
	A	Angle-Hole Attachment BV-3820 **2	26	Mast Lighting Harness	11	Drilling Fluid Pump Remote Control
	22	Wireline Attachment. BV-3820 Mast (Sheave)	HJ	Hydraulic Leveling Jacks **1	26	Mast Lighting Harness
	24	Cathead Attachment. BV-3820 Mast (Sheave)	11	Drilling Fluid Pump Remote Control		Hoisting Cable other than standard
	26	Mast Lighting Harness	F	Blank Bore Flex Coupling	105	105' 2 Part for 20' Mast
	F	Blank Bore Flex Coupling	K	Instrument Kit 3"	130	130' 2 Part for 30' Mast
	K	Instrument Kit 3"	KH	Instrument Kit 3-7/8"		or 3 Part for 20' Mast
	KH	Instrument Kit 3-7/8"			170	170' 3 Part for 30' Mast
					F	Blank Bore Flex Coupling
					K	Instrument Kit 3"
					KH	Instrument Kit 3-7/8"

FOOTNOTES: **1 Price on request **2 Must be added for angle-hole operation with BV-3820 mast. **3 Must be added if option M is selected.

Chuck jaw sets & bushing for mechanical chuck

DRILL ROD SIZE		E	EW	A	AW.AQ	B	BW.BQ	N	NW	NQ	HQ
Mechanical Chuck 3"	Drive Rod Bushing	18980	18976	18979	18975	18978	18974	18977	18973	18972	N/A
	Chuck Jaw Set	15862		15863		15864		15865		15870	N/A
Mechanical Chuck 3-7/8"	Drive Rod Bushing	25181	25182	25183	25184	25185	25186	25187	25188	25189	25147
	Chuck Jaw Set	25820		25823		25826		25829		25832	25169

Chuck jaw sets & bushings for automatic chuck

Size		EW	AW	AQ	BW	BQ	NW	NQ	HW, HQ, HWY
Chuck Jaw Set (3 Jaws)	Rod	38456	38458	38458	38460	38462	38463	38465	38464
	Casing	38457	38459	—	38461	—	38464	—	—
Hood Bushing	Rod		29012		29013		29014		29015
	Casing	29012	29013	—	29014	—	29015	—	29015
3" Drive Rod Bushing	Rod	29173	28364		28362		28359	28358	—
	Casing	29171	29170	—	28357	—	—	—	—
3-7/8" Drive Rod Bushing	Rod	29179	28341		28338		28336	28335	28333
	Casing	29177	29178	—	28334	—	28333	—	—

Specifications

POWER	
Deutz Deisel	4-cylinder **54 HP @ 2200 RPM

**Rated 15% below engine manufacturers maximum hp rating

TRANSMISSION, type	Heavy-duty synchromesh
Speeds	4 forward
HOIST, type	Planetary
Drum Dimensions	9½" (241 mm) diameter, 5½" (140 mm) long
Drum Capacity (9/16" cable)	130' (40 m) 90' (27.4 m) cable furnished with drill
Bare Drum Line Speeds**	72, 150, 278, 468' (22, 46, 85, 143 m) per minute
RANGE SELECTOR, type	Sliding gear
Ranges	Low, high, neutral
Number of Bit Speeds	8 forward
HYDRAULIC PUMP, type	Variable volume
Volume	0-12 gallons (0-45 liters) per minute
Maximum Pressure	1000 psi (70 Kg per square cm)
HQ 3-7/8" HYD. HEAD	Twin-cylinder type
Spindle I.D.	3-7/8" (98.4 mm)
Hydraulic Cylinder I.D.	3½" (88.9 mm)
Feed Length	24" (610 mm)
Angle Range	360°
NQ 3" HYD. HEAD	Twin-cylinder type
Spindle I.D.	3" (76 mm)
Hydraulic Cylinder I.D.	3½" (88.9 mm)
Feed Length	24" (610 mm)
Angle Range	360°

	Stub-shaft Power Take-Off	Water-cooled Gasoline Engine	Water-cooled Diesel Engine	Air-cooled Diesel (Duetz)
OVERALL DIMENSIONS				
Width	42" (107 cm)	42" (107 cm)	42" (107 cm)	42" (107 cm)
Length	96½" (244 cm)	103" (261 cm)	103" (261 cm)	96½" (244 cm)
Height	57" (145 cm)	57" (145 cm)	57" (145 cm)	57" (145 cm)
APPROX. WEIGHT Net				
HQ 3-7/8" Hyd. Head	2510 lbs (1140 Kg)	3165 lbs (1440 Kg)	3305 lbs (1500 Kg)	3230 lbs (1460 Kg)
NQ 3" Hyd. Head	2390 lbs (1086 Kg)	3045 lbs (1380 Kg)	3185 lbs (1450 Kg)	3110 lbs (1410 Kg)
For Domestic Shipment				
HQ 3-7/8" Hyd. Head	2920 pounds	3575 pounds	3715 pounds	3640 pounds
NQ 3" Hyd. Head	2500 pounds	3460 pounds	3600 pounds	3525 pounds
For Export				
HQ 3-7/8" Hyd. Head	3210 lbs (1459 Kg)	3865 lbs (1755 Kg)	4005 lbs (1820 Kg)	3930 lbs (1783 Kg)
NQ 3" Hyd. Head	3100 lbs (1409 Kg)	3750 lbs (1700 Kg)	3890 lbs (1765 Kg)	3815 lbs (1730 Kg)
CUBIC DISPLACEMENT				
Crated for Export	160 cu.ft (4.5 cu.m)	175 cu.ft (5 cu.m)	175 cu.ft (5 cu.m)	170 cu.ft (4.8 cu.m)

Accessory equipment

CATHEAD, type	Topside
Spool Diameter, length	8" (203 mm) diameter, 6½" (165 mm) long
Bare Spool Speeds**	176, 357, 660, 1108' (54, 109, 201, 338 m) per minute
Approximate Weight	115 lbs (52 Kg)
WIRELINE HOIST, type	Built-in
Drum Diameter, length	7" (178 mm) diameter, 17" (432 mm) long
Drum Capacity	4200' (1280 m) of 3/16" (4.76 mm) wire rope
Bare Drum Speed**	416' (127 m) per minute
Approximate Weight	250 lbs (113 Kg)
RETRACTION KIT	Hydraulic
Travel Length	13' (330 mm)
Approximate Weight	60 lbs (27 Kg)
BV-3820 MAST, type	Vertical or angle
Rod Length Capacity	20' (6.1 m)
Approximate Weight	1900 lbs (862 Kg)
AUTOMATIC CHUCK, type	Spring-loaded, hydraulically released
Capacity	EW rods through HQ rods/NW Casing
Jaws	Tungsten Carbide insert type

**Based at engine speeds of 2200 rpm. For stub shaft model, speeds will vary according to power unit used

Forward Bit speeds

	Engine RPM	Low Range RPM	High Range RPM
HQ 3-7/8" HYD. HEAD	2200	51, 105, 192, 323	211, 438, 803, 1350
	1800	41, 85, 156, 265	172, 357, 653, 1105
	1100	25, 52, 96, 161	105, 219, 401, 675
NQ 3" HYD. HEAD	2200	70, 144, 264, 444	290, 600, 1100, 1850
	1800	56, 118, 217, 364	236, 490, 900, 1510
	1100	35, 72, 132, 222	145, 300, 550, 925

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REPORT

THE GEOLOGICAL SURVEY OF GREENLAND

Marraat Killiit, Nuussuaq

Geophysical Formation Evaluation

18 March 1994

RH&H CONSULT
RAMBØLL HANNEMANN & HØJLUND A/S

Prepared: CAP/HNO | Checked: JKH | Approved: JKH

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Appendix A	Geophysical Borehole Logging, Methods and Procedures

1. SUMMARY

A geophysical programme has been carried out in the upper 345 m of a 448 m deep borehole in basalts at Marraat Killiit, Nuussuaq in West Greenland. Borehole logging, vertical seismic profiling, and formation fluid sampling were performed in the borehole and, additionally, a seismic walkaway noise test was made at the surface.

The geophysical borehole logging resulted in a subdivision of the succession in two major sequences, each subdivided in 5 and 8 units, respectively.

The upper sequence, c. 88 m thick, is defined by lower neutron-neutron porosities than those determined from gamma-gamma readings.
It is also characterized by low M-factor values and fluctuating natural gamma values. The latter forms the main basis of a subdivision of the sequence into 5 units.

The lower sequence exhibits either no curve separation of the porosity logs or, alternatively, higher neutron-neutron porosities than gamma-gamma porosities. The natural gamma-gamma level is constant throughout the sequence. Individual units are mainly defined by the resistivity log. The lowermost unit, with top in c. 337.5 m depth, is distinctly different from the units above. It differs in the levels of resistivity, gamma-gamma, porosity, and M-factor.

The geophysical logging results may form the basis of a conventional formation evaluation. A petrophysical core analysis is, however, needed to perform such an evaluation.

Based on the vertical seismic profile and seismic walkaway noise test the P- and S-wave velocity have been interpreted to c. 4700 m/s and c. 2700 m/s, respectively. No pronounced change in the velocities in the upper 345 m can be observed.

Formation fluid sampling has been applied at 6 levels in the upper 90 m. The samples have been sent to The Geological Survey of Greenland for further analysis.

2. INTRODUCTION

During the period 24 to 30 October 1993 RH&H Consult has carried out a geophysical programme in a 448 m deep borehole in basalts and at the surface nearby. The borehole is located at Marraat Killiit on the western part of Nuussuaq (Enclosure A01).

The borehole could only be logged to 345 m depth below surface due to collapse of the borehole below this depth.

The geophysical programme in the borehole included:

- Geophysical borehole logging
- Vertical Seismic Profile (VSP)
- Formation fluid sampling

The geophysical programme at the surface included:

- Seismic Walkaway Noise Test (WNT)

All depths in this report are depths below surface.

3. GEOPHYSICAL BOREHOLE LOGGING

3.1 Logging Programme and Equipment

The geophysical borehole logging programme included recording of the following logs (CPS = Counts Per Second):

- Natural gamma (CPS)
- Gamma-gamma (CPS)
- Neutron-neutron porosity (percent)
- Resistivity, 139.7 cm guard (ohm-m)
- Spontaneous potential, SP (mV)
- Single point resistance (ohm)
- Temperature (degrees C)
- Caliper (cm)
- Deviation (degrees)
- Total magnetic field (CPS)

The recorded logs are shown in Enclosure B01 and the applied equipment is listed in Enclosure E01.

The applied logs, not recorded in CPS, have been calibrated against known standards before logging.

The other logs (natural gamma, gamma-gamma and total magnetic field), recorded in CPS, show only the relative variation.

It should be remarked that the CALIPER shows that the diameter of the borehole is approx. 6.5 cm but the borehole is drilled with an approx. 6.0 cm bit. This difference can be due to the accuracy of the mechanical caliper probe.

It should also be remarked that the flux log records a low flux in CPS when the total magnetic field is relatively large and records a high flux in CPS when the total magnetic field is relatively small.

In Appendix A a short description of each of the logs included in the logging programme and of their procedures is given.

Some of the recorded logs are used more intensively in the interpretation. These logs plus four calculated logs are shown in Enclosure B02.

All the log curves in B01 and B02 are filtered with a 20 cm moving average filter.

The calculated logs are

DEN(GAM) = Gamma-Gamma Density

The gamma-gamma log was not calibrated during recording. But the very small caliper variation makes it relevant to establish an emperical relation between CPS and gram/cm³ in a 60 mm borehole. The gamma-gamma probe has recorded the CPS values in five 200 litres drums with 60 mm Al pipes and material of known densities.

The results and the emperical relation is shown in Enclosure No. E02.
The DEN(GAM) has then been calculated from the empirical relation.

POR(GAM) = Gamma-Gamma Porosity

The porosity based on the gamma-gamma density has been calculated:

$$\mathrm{POR(GAM)} = \frac{\mathrm{DEN(MATRIX)} - \mathrm{DEN(GAM)}}{\mathrm{DEN(MATRIX)} - \mathrm{DEN(FLUID)}}$$

where

DEN(MATRIX) = 3.2 g/cc (matrix density)
DEN(FLUID) = 1.1 g/cc (fluid density)

POR(DIF) = POR(NEU) - POR(GAM)

(POR(NEU) = neutron-neutron porosity)

POR(DIF) will change if the matrix density changes due to for instance change in lithology or if the density of the fluid (water, hydrocarbons or gas) changes due to change in the composition of the fluid.

MFAC = - LOG10(RES(MG)) / LOG10(POR(NEU))

(RES(MG) = resistivity, 139.7 cm guard)

Archie [1] found that for a sandstone it was reasonable to use the following expression:

$R_F/R_W = a \cdot \Phi^{-m}$

where

R_F = resistivity of the formation
R_W = resistivity of the fluid
Φ = porosity
a = factor
m = factor

In a sandstone m is termed the cementation factor.

Taking LOG10 on both sides of the equal sign

$$\mathrm{LOG10}(R_F) - \mathrm{LOG10}(R_W) = \mathrm{LOG10}(a) - m \cdot \mathrm{LOG10}(\Phi)$$

$$\Downarrow$$

$$m = -\frac{\mathrm{LOG10}(R_F) - \mathrm{LOG10}(a \cdot R_W)}{\mathrm{LOG10}(\Phi)}$$

Assuming that $a \cdot R_W$ does not vary much in the formation and assuming for simplicity that $a \cdot R_W = 1$, the equation is

$$m = -\frac{\mathrm{LOG10}(R_F)}{\mathrm{LOG10}(\Phi)}$$

3.2 Presentation of Logs

The field recorded logs are shown in Enclosure No. B01.

The temperature log indicates an increase of 20°C from -4°C at the top to 16°C at the bottom resulting in a temperature gradient of 55-60°C/km.

The deviation (SANG and SANGB) shows that the borehole deviates 1-2 degrees in approximately NW direction.

Based on 9 different log curves a provisional subdivision of the drilled succession has been made. A total of 13 units has been established (Enclosure B02).

The logs included in this interpretation are:

- Caliper
- Flux (total magnetic field)
- Resistivity, 139.7 cm guard
- Natural gamma
- Density, gamma-gamma
- Porosity, neutron-neutron
- Porosity, derived from gamma-gamma
- M-factor
- Porosity difference (neutron-neutron porosity minus gamma-gamma porosity)

For all logs except the CALIPER the average and standard deviation (STDEV) is calculated for each of the 13 units. No calculation for the CALIPER has been performed due to the small variation for this log. The results are shown as plots and in table in Enclosures Nos. D03 and D04.

Two major sequences may be distinguished on the basis of log responses of the porosity difference and the natural gamma logs.

The upper sequence includes units 1-5 ranging from the top of the measured section (c. 15 m) to c. 88 m depth. The porosity difference log level is below 0%, mainly between -15% and -5%, and exhibiting marked local changes.

The natural gamma log subdivides the sequence in 5 distinct units, bounded by rapid shifts in the level of natural gamma counts. Individual units exhibit relatively constant levels between c. 5 CPS and 130 CPS, though units 1 and 3 record some local variations.

The density and porosity logs show relatively nervous patterns. Compared to the lower sequence, the density log level (and corresponding gamma-gamma porosity) does not differ significantly, but the neutron-neutron porosity percent is relatively lower than the level recorded in the lower sequence, differing c. 15%.

The M-factor, computed for the upper sequence, also indicates a distinction between the two sequences, with values 1-2 lower in the upper sequence.

The caliper is constant (c. 6.5 cm) throughout the sequence except for unit 1, which is c. 0.2 cm larger.

The magnetic flux is relatively constant, though weakly increasing from c. 3850 to 4000 CPS downwards through the sequence.

The resistivity log response is rather nervous, ranging between c. 100 ohm-m and 1000 ohm-m, exhibiting no systematic trends.

The lower sequence is characterized by relatively constant porosity difference and natural gamma log levels of c. 0-6% and c. 5-10 CPS, respectively. Units 6 and 7 are picked out very well by the porosity difference log and less distinctly by the natural gamma log.

The density and porosity logs exhibit nervous patterns but define rather unambiguously units 10 and 13 by their higher densities/lower porosities compared to adjacent units. Especially unit 13 exhibits extreme values, i.e. density c. 0.3 g/cc higher and porosity c. 15-18% lower than unit 12.

The M-factor exhibits wide variations in the sequence and forms a good basis for subdivision of the main succession into units 9-13. The mean value varies between c. 2.2 and 4.5.

The CALIPER is very constant throughout the sequence (c. 6.5 cm) with a few extreme values, up to c. 8 cm in unit 12.

The total magnetic field log indicates two downward increasing flux intervals, i.e. unit 10 to 13 (c. 3700 CPS to c. 4000 CPS) and units 6 to 9 (c. 3500 CPS to c. 4000 CPS).

The resistivity log varies between c. 70 ohm-m and c. 1500 ohm-m. Marked changes in resistivity levels form the basis of subdivision of the main part of the sequence, though units 7 and 8 are not clearly distinguished.

3.3 Discussion of Results

The separation of the two porosity log curves, giving rise to negative porosity difference values in the upper sequence (units 1-5), may be explained by either rock matrix or fluid characteristics. No marked change in the gamma-gamma density is observed going from the upper sequence to the lower, whereas a distinctly lower neutron-neutron porosity is observed in the upper sequence.

This may indicate the presence of gas in the upper sequence. A more complicated explanation is a combination of a lower rock matrix density and a lower porosity in the upper sequence, resulting in similar bulk densities in the two sequences and a lower neutron-neutron porosity level in the upper sequence.

A conclusive interpretation of the separation of the porosity log curves should, however, await a petrophysical core analysis, allowing a reliable calibration of the geophysical logs. In general, core analysis of the entire succession should be carried out if a traditional formation evaluation, including interpretation of the hydrocarbon saturation, is to be performed.

The natural gamma log indicates rapid internal changes in the upper sequence in contrast to the relativelty constant low gamma level in the lower sequence. This is indicative of very varying composition of the volcanic rocks in the upper sequence with respect to radioactive elements.

The difference in M-factor reflects a difference in the interconnectedness of pores in the two sequences. The low value in the upper sequence may indicate low tortuosity of interconnected pores and/or a high ratio of effective porosity to total porosity. The latter could be caused by fractures in the lower sequence, the high values of the M-factor in units 9 and 11, in contrast, may indicate the presence of numerous closed pores or high tortuosity. The poor development of pore interconnectedness is also reflected in the high resistivities for the two units, whereas the total porosities are high, as indicated by the porosity logs.

The magnetic flux subdivides the succession into three downward decreasing parts. The upper part corresponds to the upper sequence, whereas the lower sequence is divided into two downward decreasing parts. At this moment these systematic trends are not interpreted in terms of rock characterististics.

The resistivity variations seem to reflect an interplay of porosity variations and variations in the M-factor. The M-factor, however, seems to be the most important controlling factor, i.e. in general high resistivities correspond to high values of the M-factor.

Unit 13 differs significantly from other units in the succession, with respect to resistivity, gamma-gamma density, porosity and M-factor. The first two are much higher than normally seen in the succession, whereas the latter two exhibit very low values. This is indicative of a very massive rock unit with low total as well as effective porosity. The unit may be distinguished as a separate sequence, differing from both the upper sequence and the remaining part of the lower sequence.

The lack of logging data below 345 m depth prohibits, however, such an interpretation, as it can not be ruled and that unit 13 may be only a thin bed with differing characteristics.

4. VERTICAL SEICMIC PROFILE (VSP)

A vertical seismic profile (VSP) has been carried out in the upper 8-330 m of the borehole. The purpose was to determine the P-wave velocity in the formation.

4.1 VSP Programme and Equipment

The VSP programme was carried out with a borehole hydrophone streamer with 12 hydrophones spaced 2 m resulting in a coverage of 22 m per shot.

The VSP was produced by lowering the borehole streamer 20 m after each shot resulting in an overlap of two hydrophones to check the zero time of the shots.

The complete vertical profile with 2 m spacing between the traces was constructed during the data processing (Drawing No. C01).

The seismic instrument recorded 4096 samples with 0.5 ms intervals resulting in 2048 ms totally recorded time.
During recording a 1000 Hz analogue high cut filter was applied. No analogue low cut filter was applied.

The applied equipment is listed in Enclosure E01.

The energy source was 200 gram of explosives placed c. 0.8 - 1.6 m below the surface. The horizontal distances from the borehole to the shotpoints were 5 - 20 m.

Aiming at an optimum contact for the explosives to the ground, all the shotholes were drilled at locations were the surface was basalt. The shotholes were drilled with an Atlas Copco petrol-driven drill/breaker named Cobra to a depth of 0.8 - 1.6 m. It had been planned to drill the shotholes to a depth of 2.4 m, but because the drill steels easily stuck in the shotholes during drilling, this was abandoned.

4.2 Presentation and Discussion of VSP

The composite VSP of the fleld recorded data from 0 to 2000 ms is shown in Enclosure No. C01. A scaling of 200 ms AGC has been applied but no digital filtering.

In Enclosure No. C02 the first 400 ms is shown, with 200 ms AGC scaling. The prominent event is at c. 190 ms at 330 m depth and can be traced upward to c. 0 ms at the surface. Less dominating events are seen before this prominent event. For better recognition of the early events a 10 ms AGC scaling has been applied (Enclosure No. C03). The following events can be observed and are marked in Enclosure No. C04:

- P-wave, first arrival (4700 m/s)
- S-wave, first arrival (2700 m/s)
- Tube wave mode 1 (1800 m/s)
- Tube wave mode 2 (1100 m/s)
- Tube wave mode 3 (1400 m/s)

No pronounced change in the velocities in the profile can be observed.

Tube waves are a common name for surface waves travelling along the cylindrical fluid-rock boundary between the borehole fluid and the surrounding formation. The velocity of the tube waves depends on the type/mode of the tube waves.

Tube wave mode 1 is the dominating tube wave. It is the strongest tube wave and creates mode 2. Tracing the event upward to determine its point of origin shows that this mode is generated at the earth's surface by the direct surface waves from the explosions.
The jagged appearance is due to the varying distance between the borehole and the shotpoints.

Tube wave mode 2 is a reflection of mode 1 from pronounced formation boundaries and the bottom of the borehole.

Tube wave mode 3 can be identified by tracing the events to find the point of origins. Both P- and S-waves generate tube waves at c. 175 m depth corresponding to the top of unit 9 interpreted from the geophysical borehole logs (Enclosure No. B02).

Very low frequency noise is observed on the recorded data (Enclosure No. C01). A 100 Hz. digital low cut filter has been applied (Enclosure No. C05). The low frequency noise has been removed and it is seen that tube wave mode 2 is dominating the first 1000 ms.

Three of the dominant tube waves mode 2 are marked in Enclosure No. C06. The origin of the waves are at c. 175, 265 and 335 m depth. 175 and 335 m depth correspond to the tops of the units 9 and 13 interpreted from the geophysical borehole logs (Enclosure No. B02). A boundary at 265 m depth has not been interpreted.

Likewise a lot of tube waves mode 2 with origins at greater depths than 335 m appear. The sources are probably a combination of reflection from boundaries or objects in the collapsed part of the borehole and reverberation.

The tube waves are so dominating that it has not been possible to damp them sufficiently with ordinary processing (frequency and f-k filtering). For that reason it is not possible to observe reflected P-waves.

5. SEISMIC WALKAWAY NOISE TEST (WNT)

C. 200 m NE of the drill site a seismic walkaway noise test has been carried out at the surface for evaluating the seismic response at the locality.

5.1 WNT Programme and Equipment

The WNT was carried out by placing 24 single 10 Hz. geophones spaced 3 m at the surface and generating energy with varying offsets to the geophone layout.

The geophones and shotholes were placed on outcropped basalt for optimum contact with the ground.

The energy source was 200 - 300 gram of explosives placed c. 0.8 - 1.6 m below the surface at five locations outside each end of the geophone layout.
It was planned that the offsets to nearest geophone should be 1.5, 70.5, 139.5, 208.5 and 277.5 m but due to the existence of peat this was not possible. The shotpoints were placed 1.5, 70.5, 133.5, 202.5 and 271.5 m plus 1.5, 70.5, 136.5, 205.5 and 274.5 m from nearest geophone.

The seismic instrumentation and the procedures were identical to the recording of VSP.

The applied equipment is listed in Enclosure E01.

5.2 Presentation and Discussion of WNT

The composite WNT of the field recorded data from 0 to 2000 ms is shown in Enclosure No. D01. There has been applied 200 ms AGC scaling but no digital filtering.

The first 200 ms with 200 ms AGC scaling is shown in Enclosure No. D02.

For better identification of the early events a 25 ms AGC scaling has been applied (Enclosure No. D03). The following events can be observed and are marked in Enclosure No. D04:

- P-wave 1, first arrival (5400 m/s)
- P-wave 2, first arrival (4800 m/s)
- S-wave, first arrival (2800 m/s)
- Ground Roll (2400 m/s)

Two P-waves with different velocities can be observed. The P-wave velocity observed in the VSP is nearly the same as the velocity for P-wave 2. The considerable higher velocity for P-wave 1 is therefore probably due to permafrost in the upper part of the ground.

The shotpoint resulting in coverage from c. 210 to 280 m was placed off the line due to existence of peat at the surface. Consequently the first arrivals in this interval do not line up with the first arrival generated from the surrounding shotpoints.

The consequence of shooting in peat has been tested. The shotpoint for coverage from c. 210 to 280 m has also been placed where the basalt was covered by c. 2 m peat. The composite WNT is shown in Enclosure No. D05. When compared with Enclosure No. D01 it can be seen that shooting in peat results in lower frequency energy.

High frequency noise can be observed on Enclosure No. D01. A digital 200 Hz. high cut filter has been applied (Enclosure No. D06) resulting in reduction of the high frequency noise. At c. 1500 - 1600 ms a dominant event with the same apparent velocity as the first arrived S-waves and/or ground roll can be observed. It can therefore not be reflections from deep reflectors. A likely explanation has, so far, not been established.

The first 1000 ms filtered with the digital 200 Hz. high cut filter is shown in Enclosure No. D07. There are no very prominent events that with certainty can be interpreted as reflections from deep reflectors. The results from the borehole logging and VSP indicate that at least the upper c. 345 m of the formation is relatively heterogeneous. That will result in reverberation of the seismic waves and masking of reflections.

An event that is flat and can be followed over a large part of the seismogram can be observed at c. 380 ms. The event is marked in Enclosure No. D08. It can be a reflection from a deep reflector. If it is a reflection, it is most likely a reflected P-wave. Using an average P-wave velocity of 4800 m/s results in a depth of c. 900 m.

6. FORMATION FLUID SAMPLING

Formation fluid has been sampled from the upper c. 90 m of the formation.

The fluid samples have been sent to The Geological Survey of Greenland for further analysis, but RH&H Consult has measured the fluid conductivity of some of the samples.

6.1 Sampling Programme and Equipment

Formation fluid sampling has been applied by a tool with two packers and a montejus fluid pump.

The tool was lowered to the desired depth and the two packers were inflated by Nitrogen to an excess pressure of 10 bar. The Nitrogen was supplied through a tube from a bottle at the surface. The two packers are 40 cm long and spaced 1 m.

Afterwards the montejus pump was emptied three times to ensure that the fluid came from the formation. The fluid was raised in a tube to the surface by Nitrogen. The principle for a montejus pump is shown in Enclosure No. E03.

Two attempts to sample the fluid were made. The first attempt was made on a day with air temperatures of c. -10 degrees C. Due to the low temperature the fluid froze in the tubes at the surface.

The second attempt was made on a day with air temperatures of c. -4 degrees C. There were no problems and the sampling was successful.

6.2 Presentation and Discussion of Fluid Sampling

Formation fluid was sampled from 6 levels. The results are presented in Table No. 1.

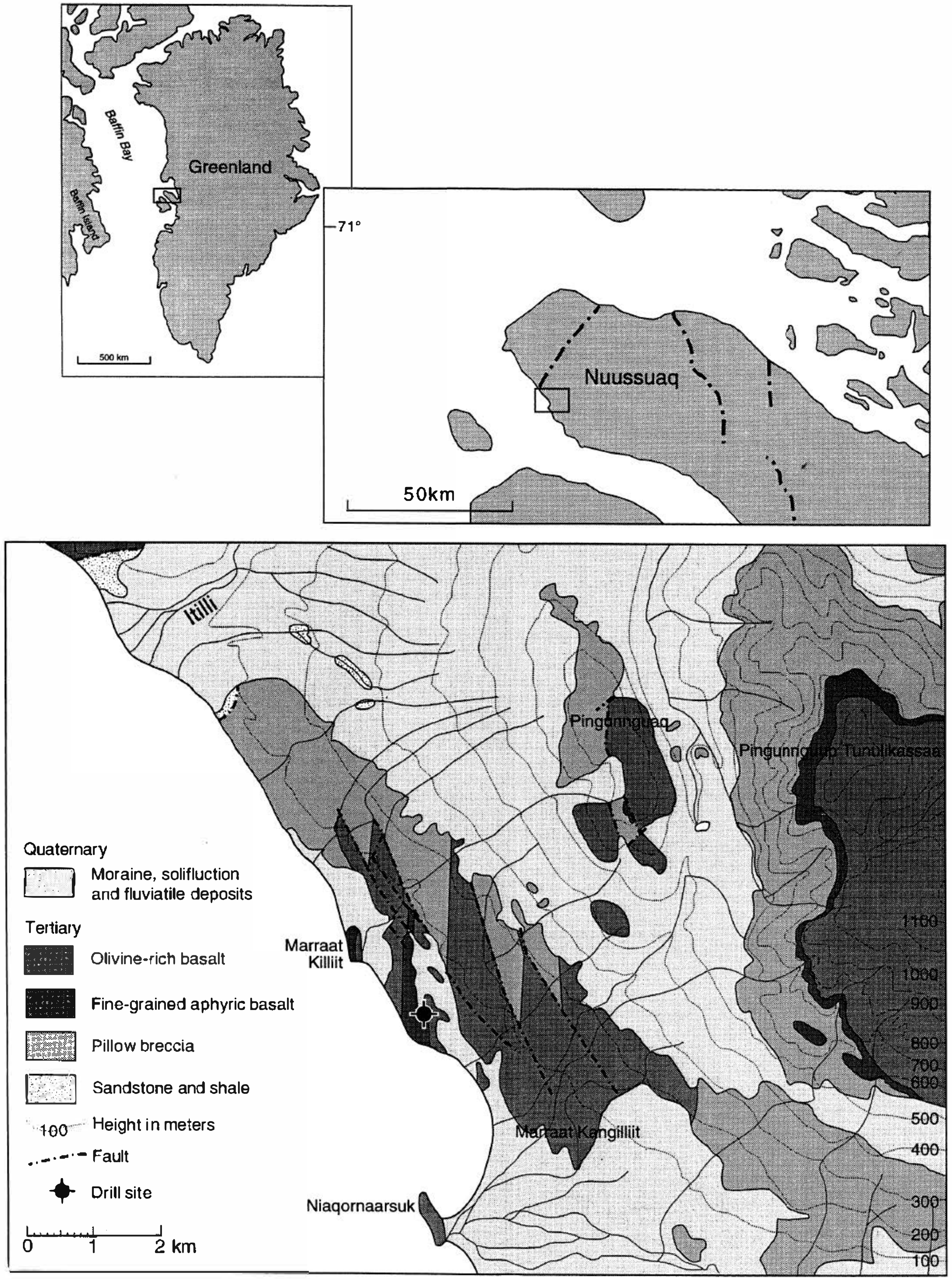
Depth m	Collection no.	Duration minutes	Volume dl	Conductivity at 25° C
89 - 90	1	10	5	83.8 mS/cm
	2	10	3	83.4 mS/cm
	3	10	1	82.6 mS/cm
81½ - 82½	1	10	5	76.4 mS/cm
	2	15	2	73.2 mS/cm
	3	10	1	73.8 mS/cm
50 - 51	1	10	5	51.6 mS/cm
	2	10	2	51.3 mS/cm
	3	10	6	51.8 mS/cm
40½ - 41½	1	10	3	-
	2	10	2	-
	3	10	7	-
26½ - 27½	1	10	3	71.1 mS/m
	2	10	2	57.3 mS/cm
	3	10	2	58.3 mS/cm
11½ - 12½	1	8	2	78.6 mS/cm
	2	8	2	72.7 mS/cm
	3	8	1	78.1 mS/cm

Table No. 1: Formation Fluid Sampling and Conductivity of Samples.

It is remarkable that the volumes of the samples are so relatively small compared to the relatively long duration of the sampling/pumping. It should also be observed, that except from the collection No. 1 at the interval 26½-27½ the conductivities of the samples from the same levels are relatively uniform.

7. REFERENCES

[1] Archie, G. E., 1942: The Electrical Resistivity Log as an Aid in Determining Some Reservoir Characteristics. Trans. AIME, v. 146, 1941, p. 54.



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THE GEOLOGICAL SURVEY OF GREENLAND
Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale:
Date: 1994-03-18

Geophysical Formation Evalvation
Location of Drillsite

Dwg. No.: **A01**

Drawn by: CAP | Controlled: UTN | Approved: CAP | File:

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Borehole Logging Programme

CALIPER	=	Caliper
FLUX	=	Total Magnetic Field
RES	=	Single Point Resistance
RES(MG)	=	Resistivity, 139.7 cm Guard
GAM(NAT)	=	Natural Gamma
POR(NEU)	=	Neutron-Neutron Porosity
GAM-GAM	=	Gamma-Gamma
TEMP	=	Fluid Temperature
SP	=	Spontaneous Potential
SANGB	=	Slant Angle Bearing
SANG	=	Slant Angle

NOTE:

Low FLUX in CPS ~ large total magnetic field
High FLUX in CPS ~ small total magnetic field

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THE GEOLOGICAL SURVEY OF GREENLAND
Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale: 1:500
Date: 1994-03-18

Geophysical Borehole Logging
Recorded Logs

Dwg. No.: **B01**

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Borehole Logging Programme

CALIPER	=	Caliper
FLUX	=	Total Magnetic Field
RES(MG)	=	Resistivity, 139.7 cm Guard
GAM(NAT)	=	Natural Gamma
DEN(GAM)	=	Gamma-Gamma Density
POR(NEU)	=	Neutron-Neutron Porosity
POR(GAM)	=	Gamma-Gamma Porosity
MFAC	=	- LOG10(RES(MG)) / LOG10(POR(NEU))
POR(DIF)	=	POR(NEU) - POR(GAM)

NOTE:

Low FLUX in CPS ~ large total magnetic field
High FLUX in CPS ~ small total magnetic field

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THE GEOLOGICAL SURVEY OF GREENLAND
Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale: 1:500
Date: 1994-03-18

Geophysical Borehole Logging
Interpretated, Recorded and Calculated Logs

Dwg. No.: **B02**

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Borehole Logging Programme

FLUX	=	Total Magnetic Field
RES(MG)	=	Resistivity, 139.7 cm Guard
GAM(NAT)	=	Natural Gamma
DEN(GAM)	=	Gamma-Gamma Density
POR(NEU)	=	Neutron-Neutron Porosity
POR(GAM)	=	Gamma-Gamma Porosity
MFAC	=	- LOG10(RES(MG)) / LOG10(POR(NEU))
POR(DIF)	=	POR(NEU) - POR(GAM)

NOTE:

Low FLUX in CPS ~ large total magnetic field
High FLUX in CPS ~ small total magnetic field

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THE GEOLOGICAL SURVEY OF GREENLAND
Marraat Killilt, Nuussuaq

Job No.: 93.1222
Scale: 1:500
Date: 1994-03-18

Geophysical Borehole Logging
Calculated Average and Standard Deviation

Dwg. No.: **B03**

Drawn by: CAP Controlled: HVD Approved: CAP File:

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DEPTH	GEOPHYSICAL	FLUX [CPS]		RES(MG) [OHM-M]		GAM(NAT) [CPS]		DEN(GAM) [G/CC]		POR(NEU) [PERCENT]		POR(GAM) [PERCENT]		POR(DIF) [PERCENT]		MFAC [NONE]	
M	UNIT	AVERAGE	STDEV	AVERAGE	STDEV	AVERAGE	STDEV	AVERAGE	STDEV	AVERAGE	STDEV	AVERAGE	STDEV	AVERAGE	STDEV	AVERAGE	STDEV
5 - 17	1	3847	148	665	390	131,62	46,61	2,79	0,18	8,90	9,21	19,48	8,68	-10,59	11,43	2,55	0,72
17 - 25	2	3896	128	281	193	7,92	9,20	2,89	0,12	11,29	6,13	14,66	5,79	-3,43	2,79	2,41	0,42
25 - 44½	3	3945	107	219	131	28,79	6,79	2,75	0,17	15,95	9,47	21,62	8,19	-5,61	5,15	2,74	0,68
44½ - 76½	4	3882	144	246	129	5,17	1,60	2,92	0,11	6,43	4,44	13,16	5,06	-6,71	3,04	1,90	0,37
76½ - 88	5	4009	82	319	241	21,94	3,41	2,74	0,10	8,92	3,98	22,08	4,90	-13,15	2,80	2,23	0,29
88 - 102	6	3464	691	651	628	10,76	3,41	2,90	0,16	20,24	6,00	14,49	7,56	5,79	3,01	3,53	0,37
102 - 129½	7	3734	199	176	113	8,31	3,06	2,84	0,12	17,37	7,52	17,12	5,66	0,26	2,49	2,80	0,52
129½ - 175½	8	3732	216	192	167	3,87	2,13	2,86	0,14	22,25	6,59	16,30	6,65	5,94	2,37	3,28	0,43
175½ - 208½	9	3993	115	422	205	4,54	1,91	2,70	0,09	26,94	4,88	23,68	4,49	3,27	4,23	4,54	0,60
208½ - 233	10	3695	262	194	179	7,13	2,46	2,86	0,10	19,06	4,94	16,24	4,67	2,82	2,11	3,01	0,33
233 - 306	11	3974	117	592	273	7,33	2,06	2,71	0,14	24,55	5,39	23,54	6,51	0,98	2,35	4,43	0,67
306 - 337½	12	4035	52	296	255	6,35	1,78	2,73	0,12	24,60	3,54	22,67	5,69	1,94	4,02	3,79	0,39
337½ - 345	13	3990	6	1044	517	5,30	1,16	3,04	0,13	6,79	6,07	7,44	6,18	-0,66	1,53	2,35	0,49

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Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale:
Date: 1994-03-18

Geophysical Borehole Logging
Calculation of Average and Standard Deviation

Dwg. No.: **B04**

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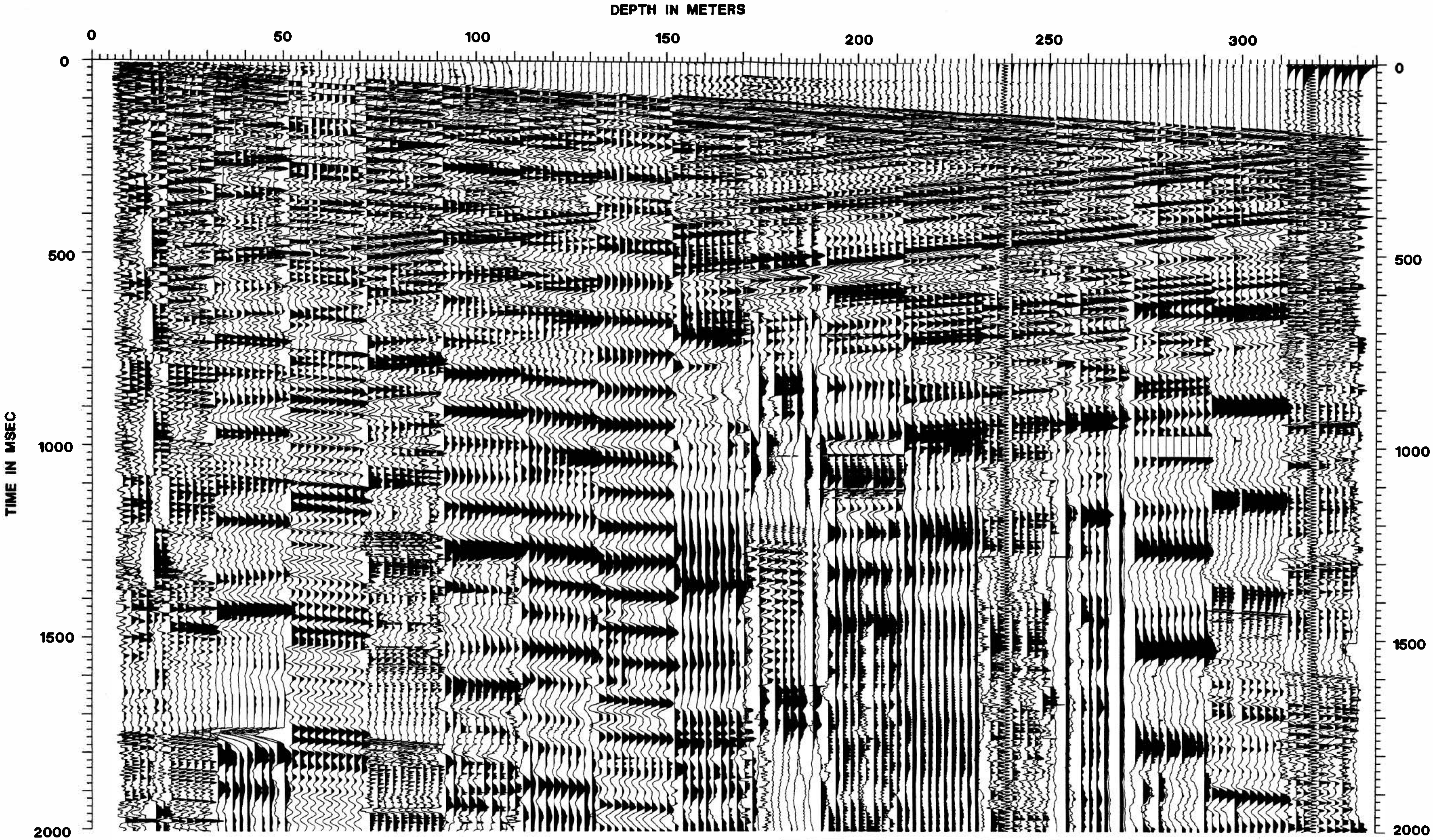

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Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale: 1:1000
Date: 1994-03-18

Vertical Seismic Profile
0–2000 ms, 200 ms AGC

Dwg. No.: **C01**

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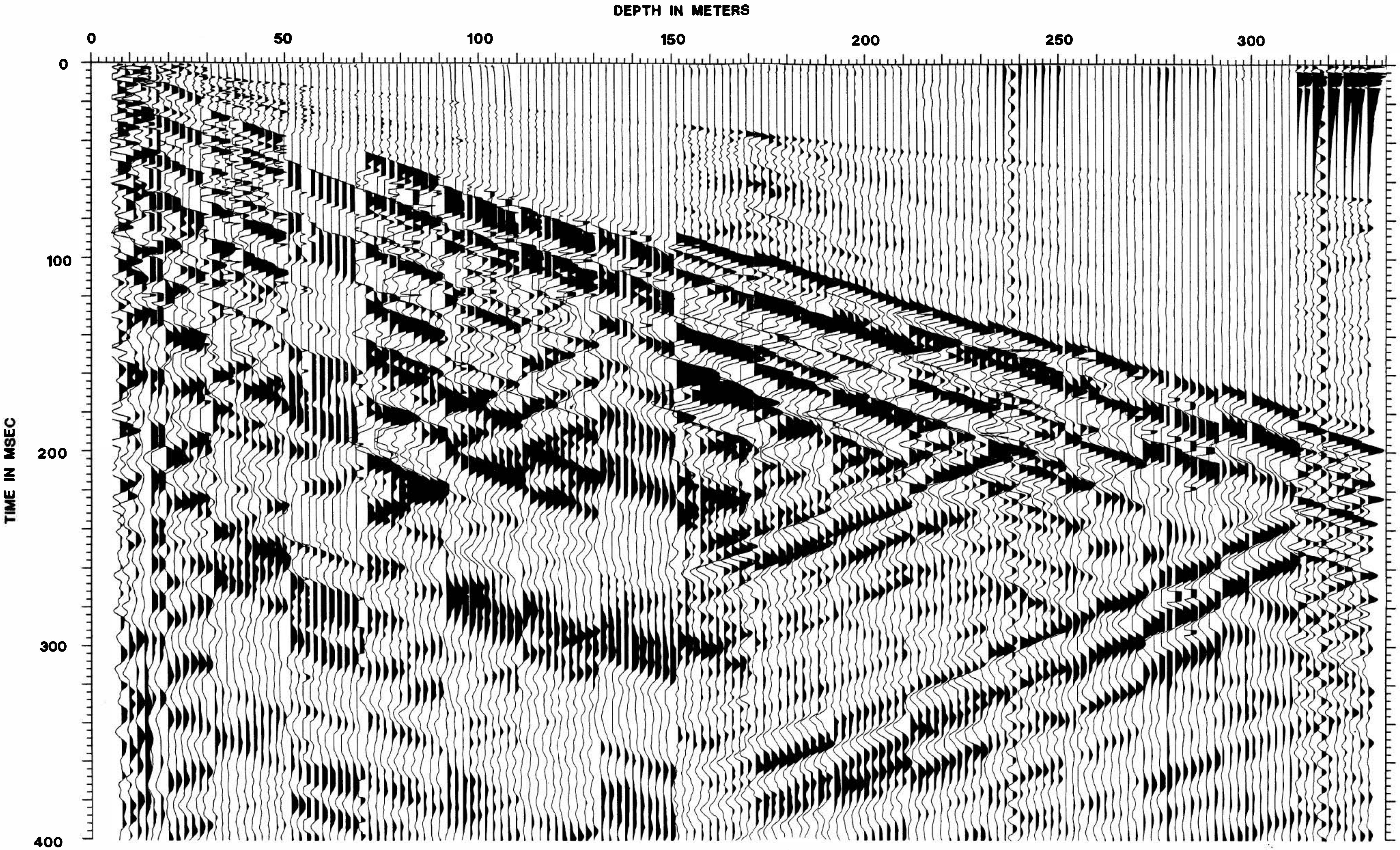

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THE GEOLOGICAL SURVEY OF GREENLAND
Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale: 1:1000
Date: 1994-03-18

Vertical Seismic Profile
0-400 ms, 200 ms AGC

Dwg. No.: **C02**

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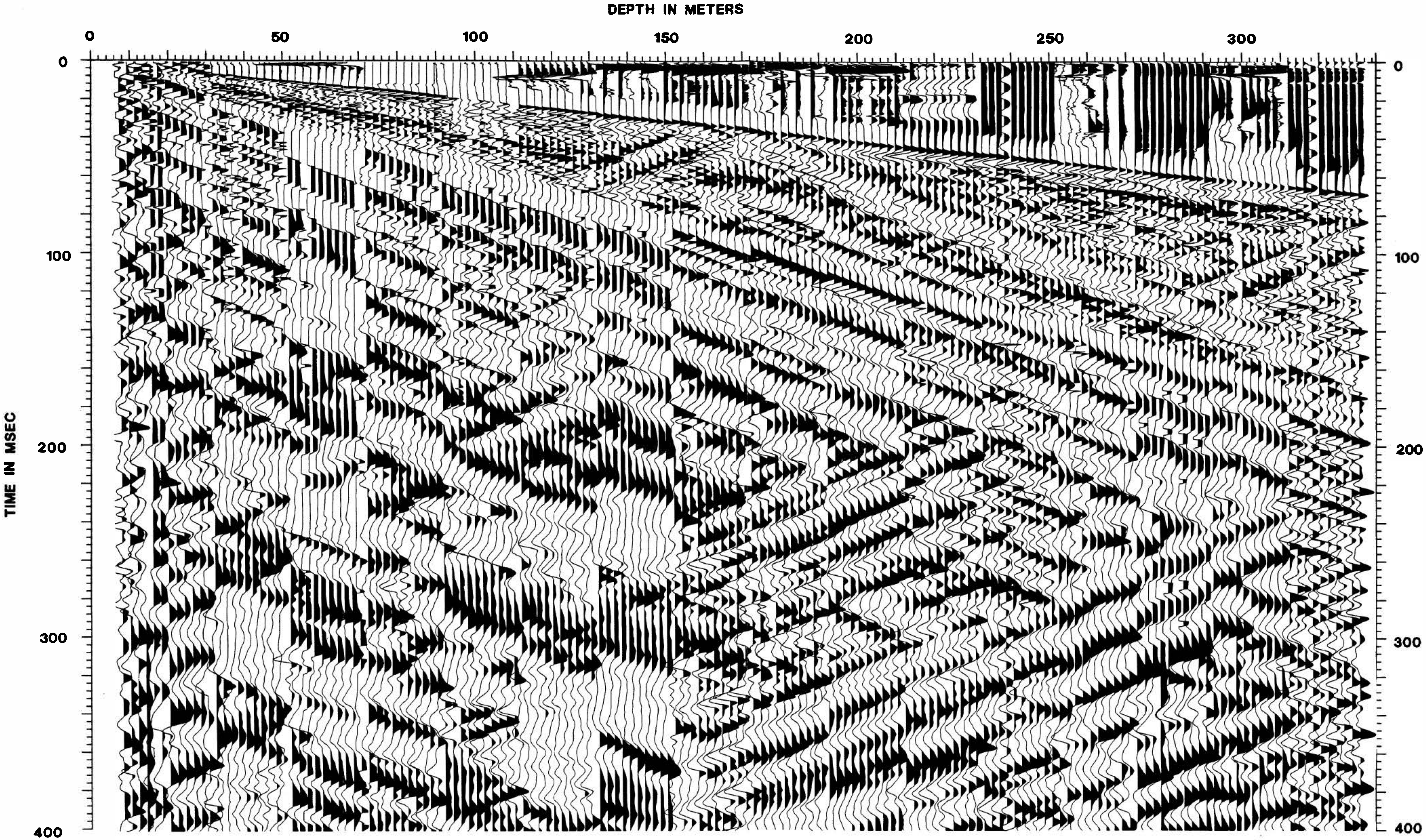

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THE GEOLOGICAL SURVEY OF GREENLAND	Job No.: 93.1222
Marraat Kllllt, Nuussuaq	Scale: 1: 1000
	Date: 1994-03-18
Vertical Seismic Profile	
0–400 ms, 10 ms AGC	Dwg. No.: **C03**
Drawn by: CAP Controlled: UTN Approved: CAP	File:

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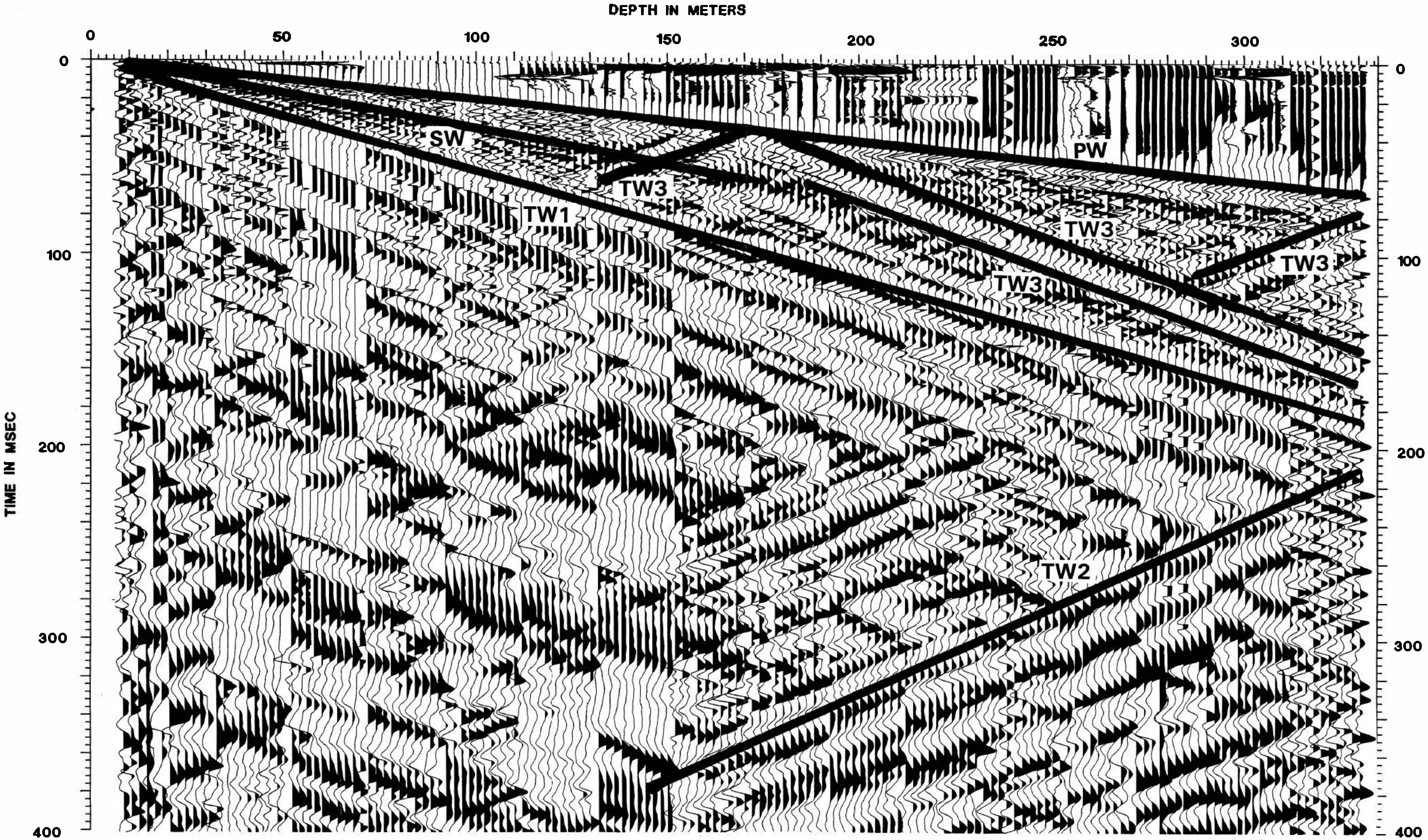

PW	=	P-Wave
SW	=	S-Wave
TW1	=	Tube Wave Mode 1
TW2	=	Tube Wave Mode 2
TW3	=	Tube Wave Mode 3

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THE GEOLOGICAL SURVEY OF GREENLAND
Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale: 1:1000
Date: 1994-03-18

Interpretated Vertical Seismic Profile
0–400 ms, 10 ms AGC

Dwg. No.: **C04**

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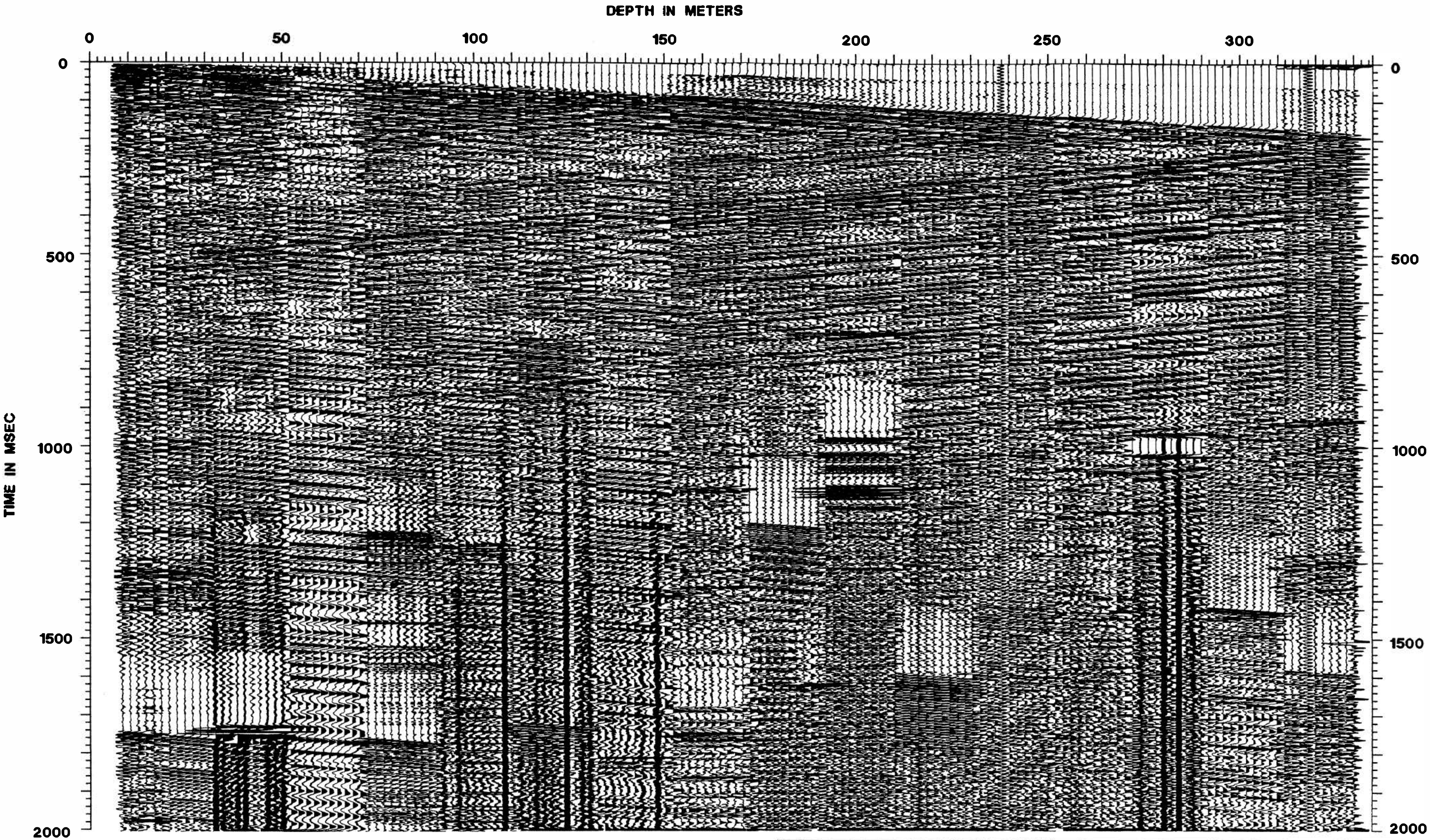

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THE GEOLOGICAL SURVEY OF GREENLAND

Marraat Killiit, Nuussuaq

Job No.: 93.1222

Scale: 1:1000

Date: 1994-03-18

Vertical Seismic Profile

0-2000 ms, 200 ms AGC, 100 Hz Low Cut

Dwg. No.: **C05**

Drawn by: CAP   Controlled: UTN   Approved: CAP

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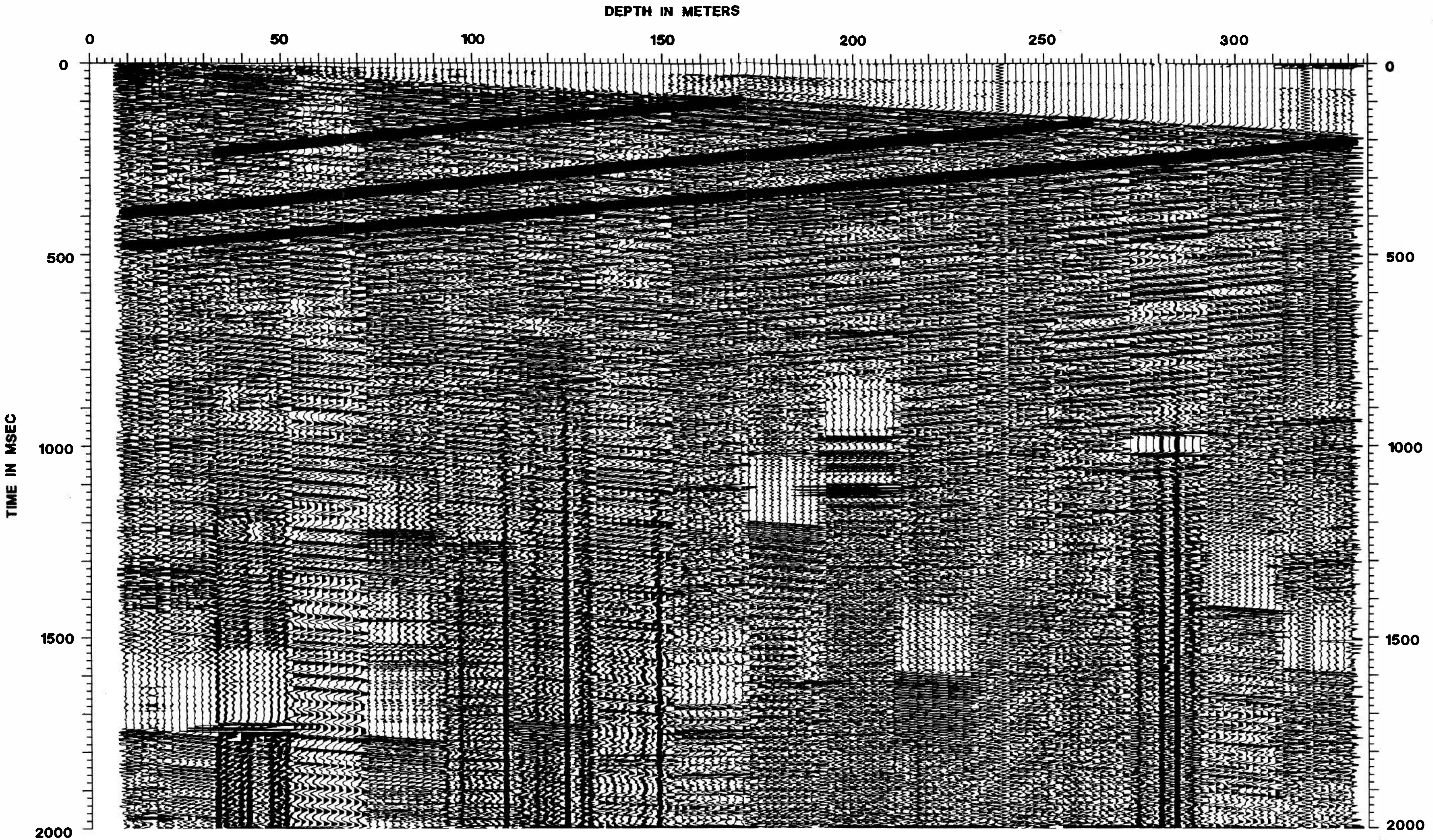

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THE GEOLOGICAL SURVEY OF GREENLAND

Marraat Killiit, Nuussuaq

Job No.:	93.1222
Scale:	1: 1000
Date:	1994-03-18

Interpretated Vertical Seismic Profile

0-2000 ms, 200 ms AGC, 100 Hz Low Cut

Dwg. No.: **C06**

Drawn by: CAP Controlled: UTN Approved: CAP

File:

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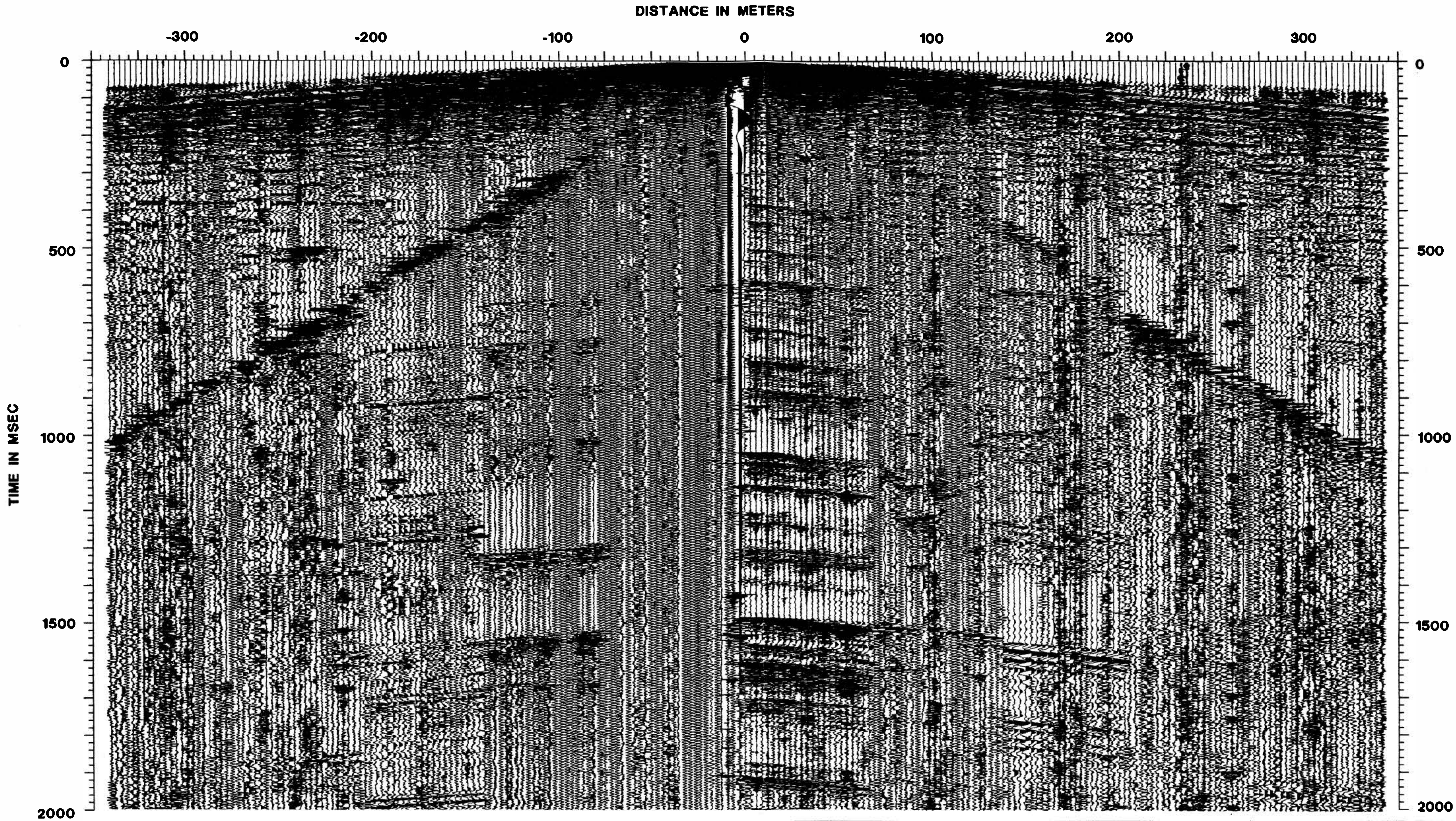

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THE GEOLOGICAL SURVEY OF GREENLAND
Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale: 1:2000
Date: 1994-03-18

Walkaway Noise Test
0–2000 ms, 200 ms AGC

Dwg. No.: **D01**

Drawn by: CAP Controlled: UTN Approved: CAP File:

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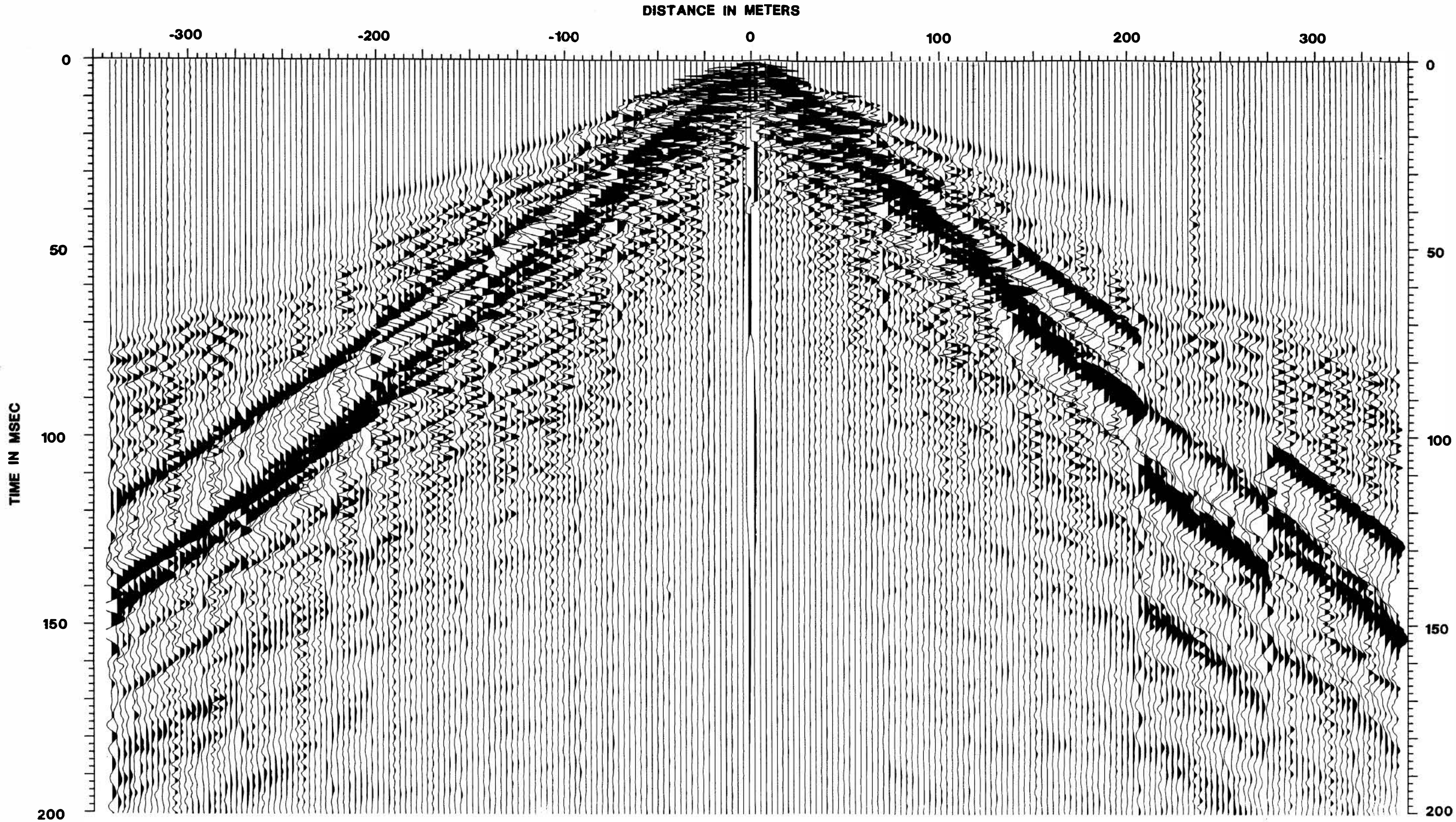

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THE GEOLOGICAL SURVEY OF GREENLAND		Job No.:	93.1222
Marraat Killiit, Nuussuaq		Scale:	1:2000
		Date:	1994-03-18
Walkaway Noise Test			
0-200 ms, 200 ms AGC		Dwg. No.:	**D02**
Drawn by: CAP	Controlled: UTN	Approved: CAP	File:

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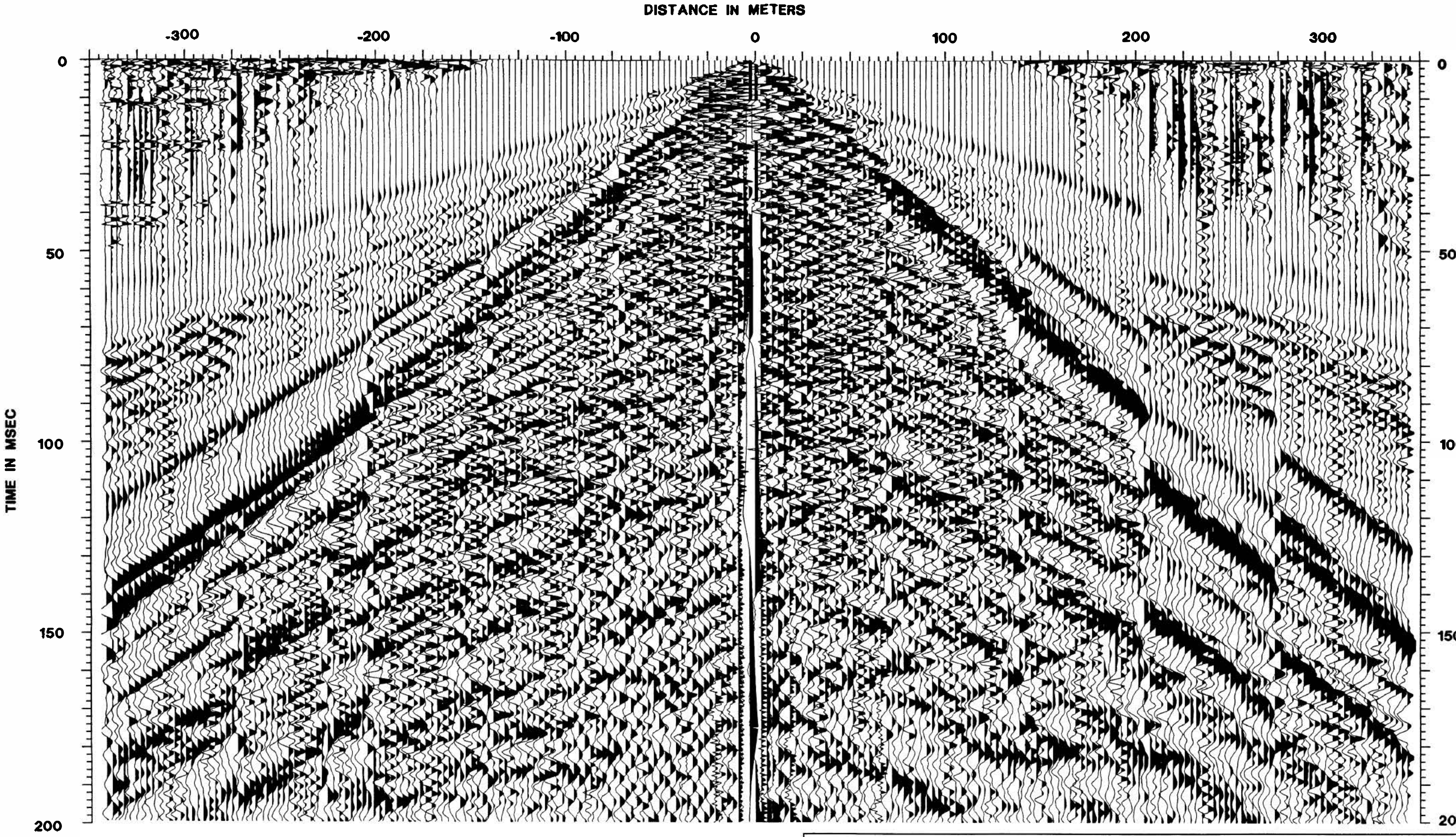

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THE GEOLOGICAL SURVEY OF GREENLAND

Marraat Killiit, Nuussuaq

Job No.: 93.1222

Scale: 1:2000

Date: 1994-03-18

Walkaway Noise Test

0-200 ms, 25 ms AGC

Dwg. No.: **D03**

Drawn by: CAP Controlled: UTN Approved: CAP File:

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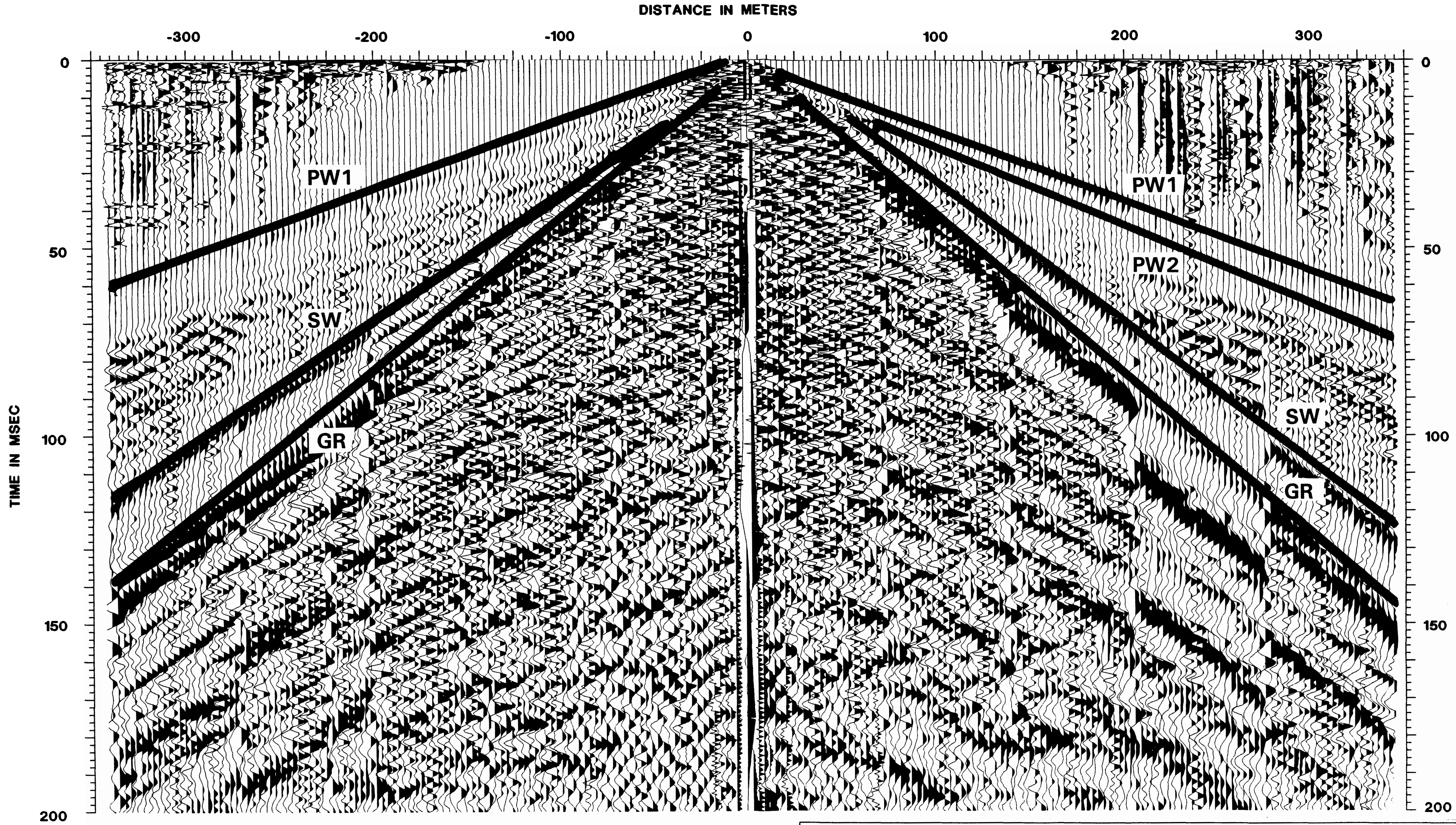

PW1 = P-Wave No. 1
PW2 = P-Wave No. 2
SW = S-Wave
GR = Ground Roll

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THE GEOLOGICAL SURVEY OF GREENLAND	Job No.:	93.1222
Marraat Killiit, Nuussuaq	Scale:	1: 2000
	Date:	1994-03-18
Interpretated Walkaway Noise Test 0–200 ms, 25 ms AGC	Dwg. No.:	**D04**
Drawn by: CAP Controlled: UTN Approved: CAP	File:	

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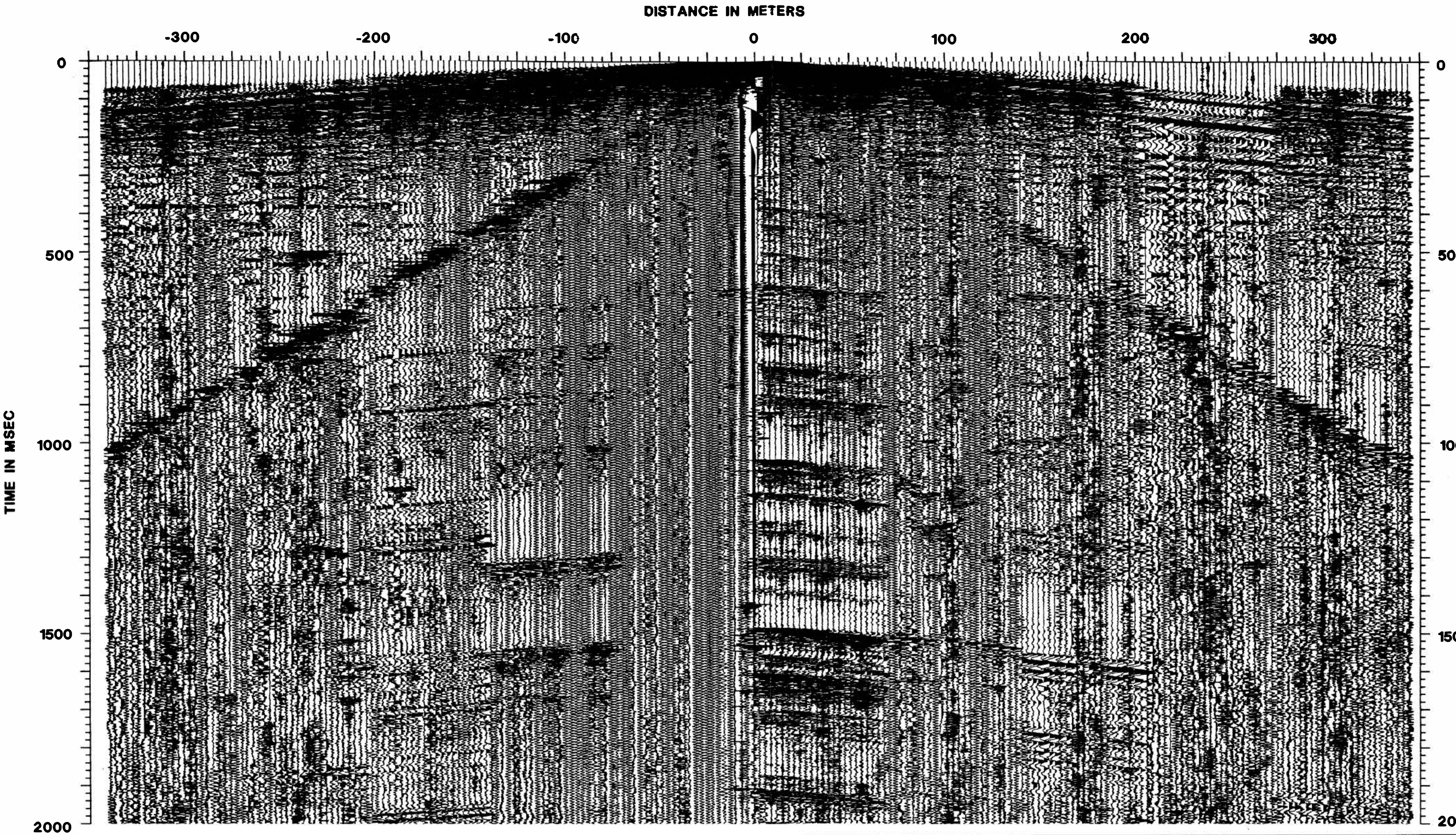

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THE GEOLOGICAL SURVEY OF GREENLAND

Marraat Killiit, Nuussuaq

Job No.:	93.1222
Scale:	1:2000
Date:	1994-03-18

Walkaway Noise Test with Test Shot in Peat

0–2000 ms, 200 ms AGC

Dwg. No.: **D05**

Drawn by: CAP Controlled: UTN Approved: CAP File:

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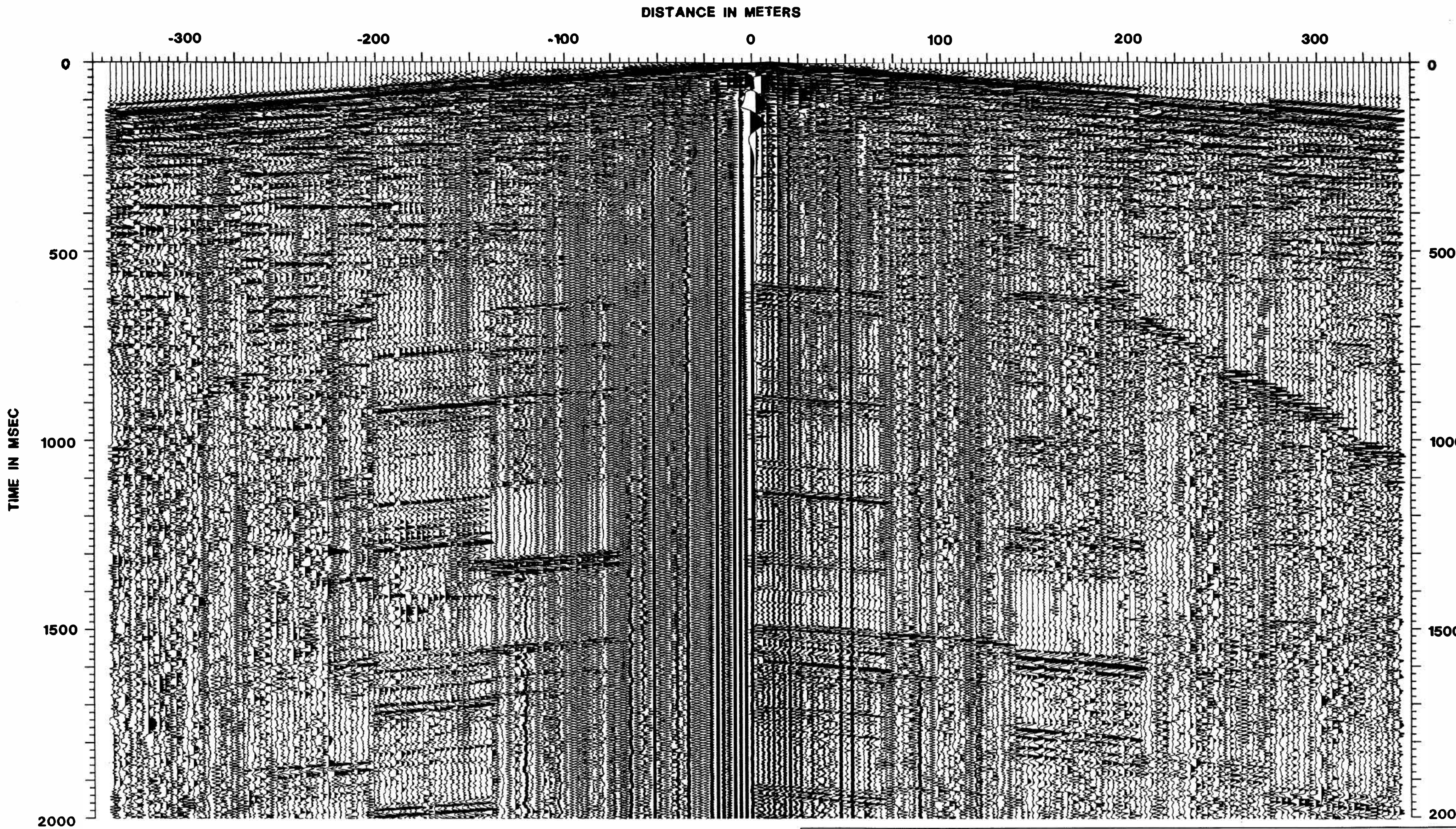

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THE GEOLOGICAL SURVEY OF GREENLAND	Job No.: 93.1222
Marraat Killiit, Nuussuaq	Scale: 1: 2000
	Date: 1994-03-18
Walkaway Noise Test	
0–2000 ms, 200 ms AGC, 200 Hz High Cut	Dwg. No.: **D06**

Drawn by: CAP Controlled: UTN Approved: CAP File:

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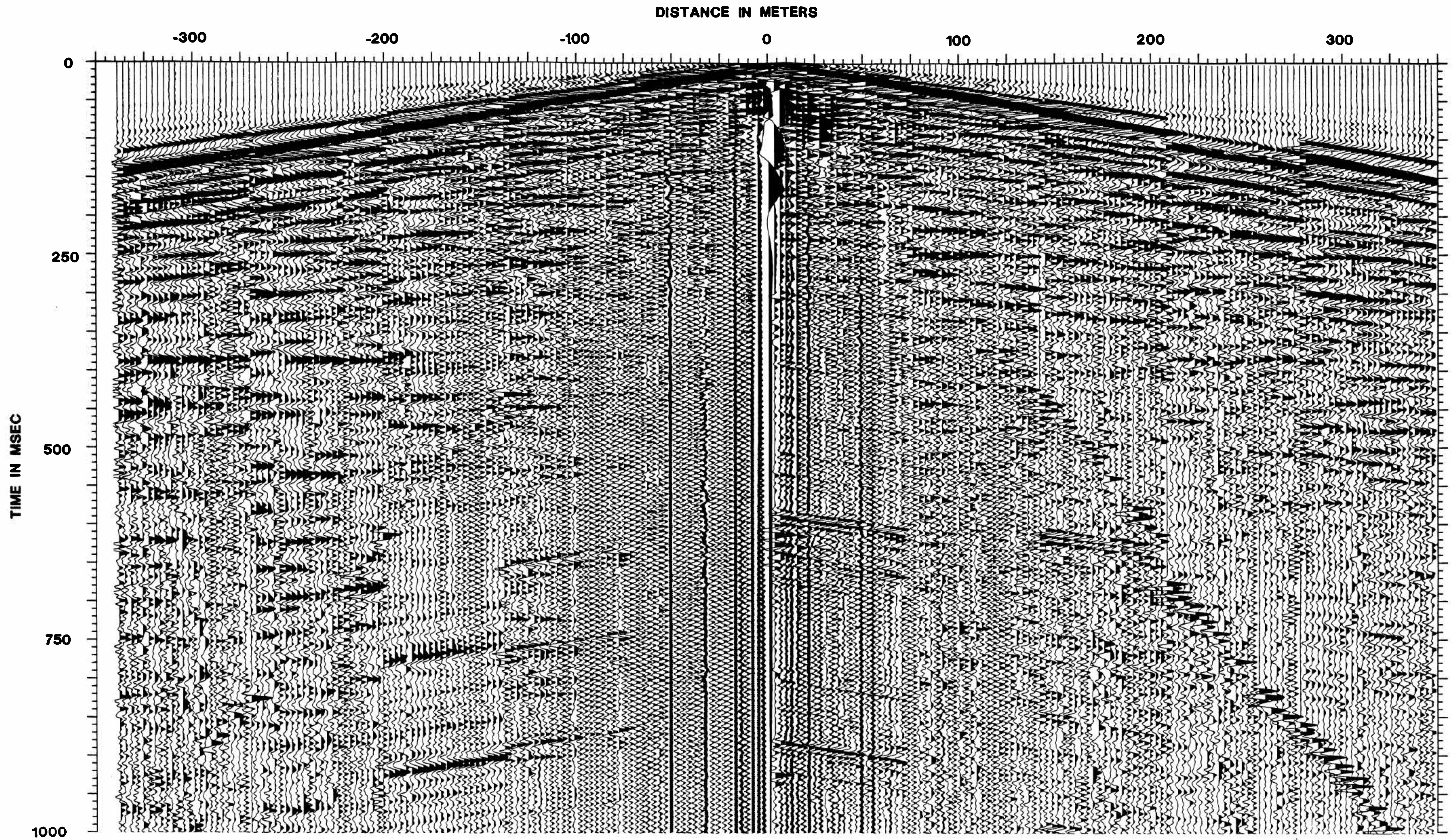

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THE GEOLOGICAL SURVEY OF GREENLAND
Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale: 1:2000
Date: 1994-03-18

Walkaway Noise Test
0-1000 ms, 200 ms AGC, 200 Hz High Cut

Dwg. No.: **D07**

Drawn by: CAP Controlled: UTN Approved: CAP File:

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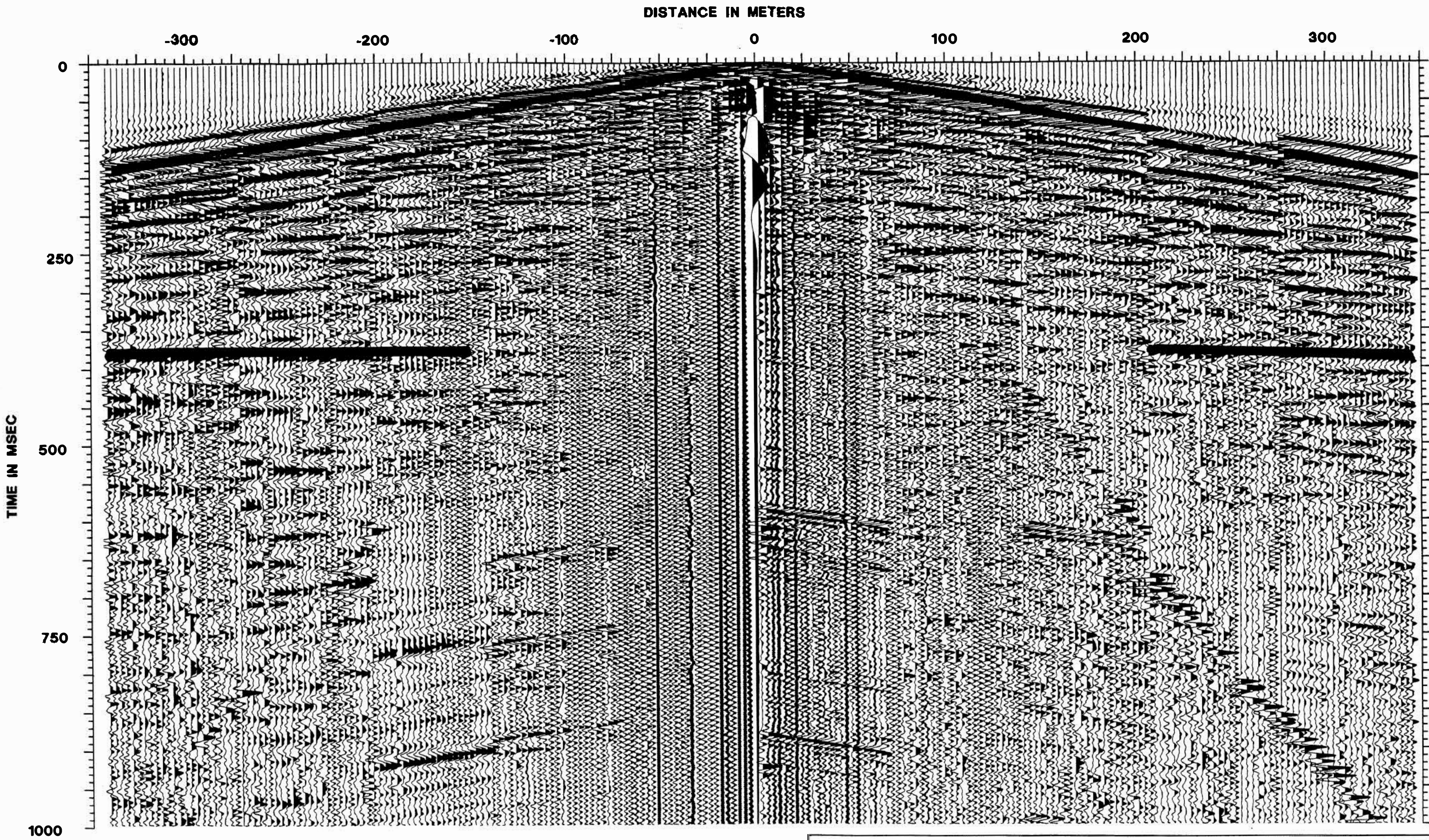

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THE GEOLOGICAL SURVEY OF GREENLAND
Marraat Killiit, Nuussuaq

Job No.: 93.1222
Scale: 1:2000
Date: 1994-03-18

Interpretated Walkaway Noise Test
0-1000 ms, 200 ms AGC, 200 Hz High Cut

Dwg. No.: **D08**

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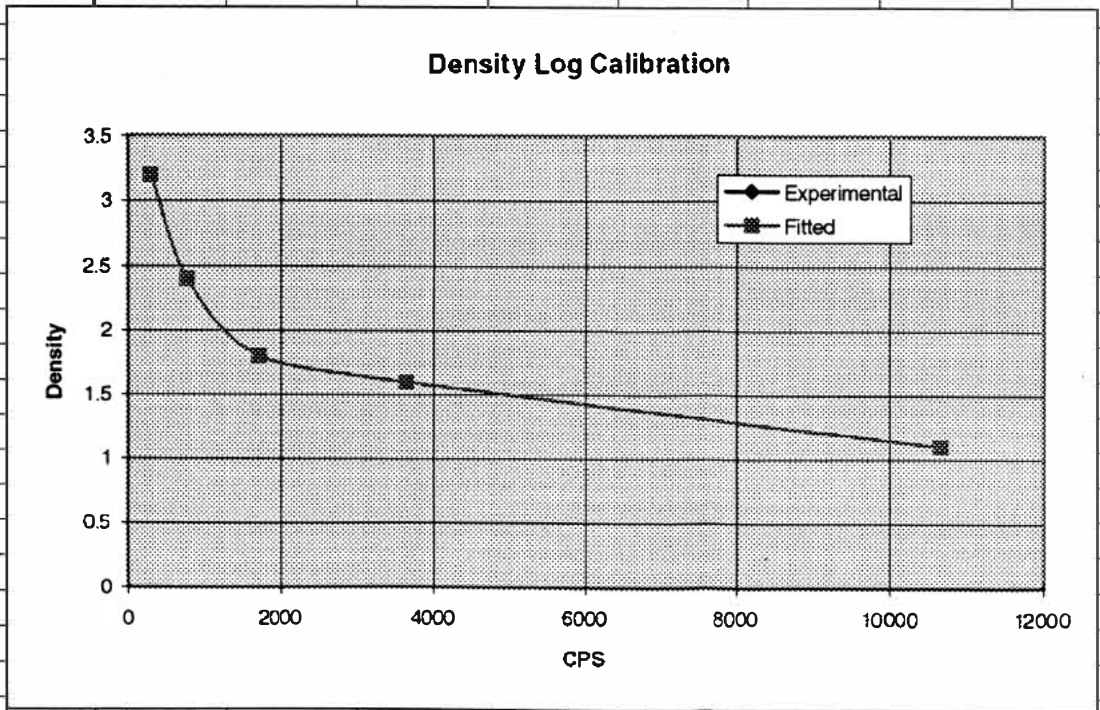
Manufac-turer	Product	Description	Serial No.
Century Gephysical Corp.	Logging Computer	Compu-Log Portable Logging System with built-in thermal primer	103
	Drawwork	Portable Drawwork with 1000 m 4 conductor steel armed cable	117
	Probe 9030	Natural Gamma, 55" Guard Resistivity Dimensions: 152 cm x 5.0 cm	412
	Probe 9055	Natural Gamma, Neutron Porosity, Spontaneous Potential. Single Point Resistance, Temperature, Vertical Deviation. Total Magnetic Field Dimensions: 290 cm x 4.6 cm Source Detector Spacing: 35.6 cm Source: 1 Ci AmBe	059
	Probe 9060	4 Pi Gamma-Gamma Density Dimensions: 224 cm x 3.5 cm Source Detector Spacing: 38.1 cm Source: 125 m Ci Cs_{137}	173
	Probe 9065	3-arm Caliper, 20" Dimensions: 203 cm x 4.3 cm	790
Geometrics	Seismograph	ES-2401 with 24 channels and 4096 samples per channel	44050
Innovative Transducers	Hydrophones	DH-5 Down-Hole Array with 12 channels Dimensions: 470 m x 3.2 cm	-
Geospace	Geophones	30 10 Hz PC-7	-

Job no. 93.1222	Job: Marraat Killiit, Nuussuaq		
Subject: Applied Equipment for Geophysical Borehole Logging and Seismic			Version: 1
Prepared: CAP	Checked: HTN	Approved: CAP	Date: 1994-03-18	Encl. No. E01
RH&H CONSULT			

Ref.no. BG402994, 1994-03-15
RH&H 93.1222, cap/hno/rh

		x	x^2	x^3	x^4		DENSITY
		CPS	2	3	4		DENSITY
X	1	10660	1.14E+08	1.47E+24	4.64E+96		1.1
	1	3640	13249600	2.33E+21	2.93E+85		1.6
	1	1716	2944656	2.55E+19	4.25E+77		1.8
	1	770	592900	2.08E+17	1.89E+69		2.4
	1	295	87025	6.59E+14	1.89E+59		3.2
			0	0	0		
			0	0	0		
			0	0	0		
			0	0	0		
			0	0	0		
XX	5	17081	1.31E+08	1.27E+12	1.31E+16		
	17081	1.31E+08	1.27E+12	1.31E+16	1.38E+20		
	1.31E+08	1.27E+12	1.31E+16	1.38E+20	1.47E+24		
	1.27E+12	1.31E+16	1.38E+20	1.47E+24	1.57E+28		
	1.31E+16	1.38E+20	1.47E+24	1.57E+28	1.67E+32		
Xy	10.1						
	23430.8						
	1.53E+08						
	1.42E+12						
	1.45E+16						
RESULT:	**$Y=b0+b1*x+b2*x^2+b3*x^3+b4*x^4$**						
b0	**3.94942**						
b1	**-0.00292**						
b2	**1.4E-06**						
b3	**-2.6E-10**						
b4	**1.4E-14**						



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RAMBØLL HANNEMANN & HØJLUNDA/S

THE GEOLOGICAL SURVEY OF GREENLAND

Marraat Killiit, Nuussuaq

Job No.: 93.1222

Scale:

Date: 1994-03-18

Geophysical Borehole Logging
Calibration of Gamma-Gamma Density

Dwg. No.: **E02**

Drawn by: CAP | Controlled: UTN | Approved: CAP | File:

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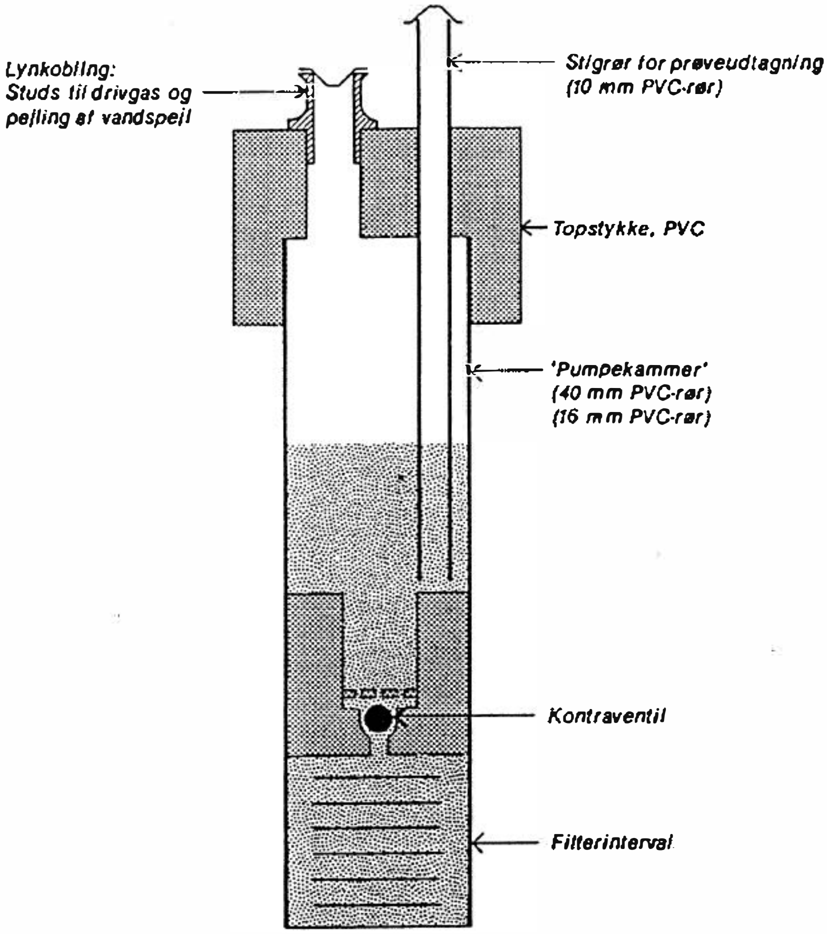

Princip for prøveudtagning:

1) Drivgas tilføres via studs.
2) Kontraventilen lukker på grund af overtryk.
3) Vandet i 'pumpekammeret' drives op gennem stigrøret.
4) Efter udtømning af 'pumpekammer', udlignes trykket, hvorved kontraventilen igen åbner, og pumpekammeret' fyldes med vand.
5) Processen gentages nogle gange, før en vandprøve udtages.
6) For at nedsætte afgasningen skal udligning af overtrykket, sidste gang før prøvetagning, ske trinvis.

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RAMBØLL HANNEMANN & HØJLUND A/S

THE GEOLOGICAL SURVEY OF GREENLAND	Job No.: 93.1222
Marraat Killiit, Nuussuaq	Scale:
	Date: 1994-03-18
Formation Fluid Sampler Principle for a Montejuspump	Dwg. No.: **E03**
Drawn by: CAP Controlled: UTN Approved: CAP	File:

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APPENDIX A

GEOPHYSICAL BOREHOLE LOGGING

Methods and Procedures

Prepared: CAP | Checked: HNO | Approved: CAP

Ref.no. BG402995, 1994-03-16
RH&H 93.1222, cap/rh

Table of Contents **Page**

1. INTRODUCTION

The measurement of features in a borehole, or in the geological formation adjacent to the borehole, can be carried out by geophysical borehole logging. A logging unit comprises a monitoring console, a set of tools and a winch with the necessary conductor cable. Each tool is designed to measure one or more variables as it is lowered down the borehole on the end of the cable. Measurements are sent as electronic signals from the tool, up the cable, to the console as a continuous record of the parameter being studied.

The recorded parameters can be interpreted to characterize the different formations and their typical properties.

2. METHODS

Below a short description of each of the logs included in the logging programme and of their procedures is given.

2.1 Natural Gamma

This log measures the natural gamma ray emission from the formation surrounding the probe. The emission is a result of disintegration of the radioactive elements Uran (U), Thorium (Th), and Potassium (K) bound in the minerals. These show statistical fluctuations due to the random nature of the nuclei decay. However, by reducing the speed of logging and by applying an averaging filter the statistical fluctuations can be reduced enabling identifications of changes in gamma ray emission due to changes in lithological formation characteristics.

The unit of gamma ray emission is Counts Per Second (CPS).

The diameter of investigation by the gamma probe depends upon the bulk density of the material surrounding the detector. In a basaltic environment (mass density about 2.6 - 3.2 g/cm^3) the penetration is about 3 dm.

2.2 Fluid Temperature

The fluid temperature logs are made with a resistance thermometer, which is an element whose electrical resistance changes with changes in temperature.

2.3 Spontaneous Potential (SP)

The spontaneous potential or self potential log is a measurement of the potentials (voltages) resulting from the flow of electrical currents in the rocks. There are many possible sources of these currents. In open boreholes their major source is the different salinity and clay content between the borehole fluid and the formation.

The SP-probe measures the natural direct current potential differences between an electrode in the borehole and a fixed reference electrode on the surface.

The SP-log is mainly a good indicator of clay in the formation.

2.4 Single Point Resistance

The single point resistance log is very simple in function. It measures the resistance between an electrode in the borehole and a fixed reference electrode on the surface.

The major use of the log is for stratigraphic correlation.

2.5 Guard Resistivity

The guard resistivity logs have excellent thin bed resolution, deep formation penetration and work very well in salt water filled boreholes.

The applied guard resistivity logs have a small measure electrode, with large guarding electrodes above and below, and focus the current into a thin horizontal disc, which penetrates the formation laterally instead of flowing up the walls.

The penetration of the guard log is one to two times the length of the guard log, and the bed resolution is approximately 1 dm. The applied guard log has a length of 139.7 cm resulting in a penetration of approximately 1.5-3 metres.

2.6 Neutron-Neutron

The neutron-neutron probe consists of a neutron emitting source (1 Curie Americium Beryllium) that directs neutrons into the formation. A counting device (Helium 3 detector) above the source, counts the returning neutrons at the tool. In relative terms, more porous materials with pore water or liquid hydrocaobon capture more neutrons, so the counting rate is low. Conversely, more dense (less porous) materials allow more counts to be returned to the tool.

The neutron porosity method uses a source of high energy (2 to 12 MeV) neutrons. These are emitted into the borehole and formation material, where they collide with the formation atoms and loose their energy. They loose most of their energy when they collide with a particle with an identical mass. Collisions with heavier particles (atoms) result in progressively less energy transfer, as the atoms are more massive. A hydrogen atom and a neutron have nearly the same mass. Therefore, collisions with hydrogen result in the greatest energy loss. Most of the hydrogen, by far, in the formation, is in the water or hydrocarbons.

When the neutrons have lost most of their energy, they can be detected. The more efficient energy loss will result in a lower population of neutrons at the detector. Thus, the presence of hydrogen will lower the neutron count.

The applied neutron-neutron porosity probe has a single detector spaced 35.6 cm from the source. The counts of the detector is calibrated quantitatively and its units are %.

The probe is also calibrated to compensate for the water in the borehole. The diameter of the borehole must therefore be entered into the logging computer.
If the diameter of the borehole changes down through the boring, the calculated porosity will be effected.

The neutron log is effected by clay minerals and chloride. Since the neutron log is sensitive to all hydrogen nuclei, it is sensitive to both free and bound water. The former is formation water or hydrocarbons, the latter occurs in clays either within the molecule or absorbed between clay mineral layers. The neutron log will therefore give a too high porosity when the formation contains clay.

The neutron log is also effected by the content of chloride in the borehole water and formation water. Chloride absorbs neutrons, resulting in too high measured porosity in saline water, but the compensated neutron probe reduces the effect.

The penetration depends upon the amount of hydrogen in the neighbourhood. A high porosity environment may have a penetration of 2 dm for 50% of its signal. A massive basalt may have a penetration of 5 dm.

2.7 Gamma-Gamma

The gamma-gamma logging probe consists of 125 mCurie $Cesium_{137}$ gamma source and one scintillation counter. The applied probe directs the gamma radiation in all directions (4 Pi.).

The gamma rays leaving the source are scattered by the orbital electrons of the atoms in the materials being measured. This compton scattering results in the loss of energy of the gamma rays. If the material is very dense (contains many electrons) the gamma rays are scattered more, and more are absorbed by the material due to the low energy. This absorption near to the source results in fewer gamma rays reaching the detector. In formations with fewer electrons (lower density) the gamma rays are not slowed down as much and more rays reach the detector.

The probe is very slim. The gamma radiation is directed in all directions. The source-detector spacing is 38.1 cm. The probe is not calibrated to record the bulk density of the formation but to measure the gamma radiation in Counts Per Second (CPS).
The penetration is dependent on the source-detector spacing and is 1-3 dm for 50% of the signal.

2.8 Caliper

The caliper log measures the diameter of the borehole in cm. The applied caliper log is mechanical and consists of three arms.

2.9 Borehole Deviation

The borehole deviation log measures the slant angle and the slant angle bearing of the tool. The applied probe uses two inclinometers to measure the slant angle and three magnetometers to measure the slant angle bearing. The probe can not be used in steel cased boreholes, and the slant angle bearing will not be correct in open boreholes where magnetic rocks occur.

2.10 Total Magnetic Field

The relative total magnetic field has been calculated from the three magnetometers used for the calculation of the borehole deviation. The total magnetic field is not calibrated. A large CPS value equals a relatively small magnetic field and a small CPS value equals a relatively large magnetic field.

3. APPLIED PROCEDURES

As part of the quality control all logs were recorded both downward and upward. The caliper could only be recorded in upward direction. The natural gamma log was recorded with approx. 3 metres/minute while the other logs were recorded with a speed of approx. 5 metres/minute. The measured values were digitized for each 2 cm and stored on the harddisk of the logging computer for later processing. Simultaneous to the recording, the data was also plotted as a quality control.

Reconnaissance magnetic measurements at Maraat.

Internal GGU report

Leif Thorning

February 1994

Objective

The objective of this reconnaissance work was to acquire a few magnetic profiles near the Maraat drill hole to examine the magnetic response of rocks and structures in the area in preparation for possible further geophysical field work in 1994. The lines were measured by Gregers Dam, and this note presents the compiled data.

Field work

During the logging work carried out in the drill hole in October 1993 two short magnetic profiles were measured near the drill site, see enclosed map. A Geometrics 856 proton magnetometer with a single sensor was used, and the diurnal variation in the Earth's magnetic field was recorded by a similar instrument at the camp site. The time setting of the two instruments was synchronized to approximately one second. The sampling distance along the lines was 10 m. Data were later dumped to a PC and compiled in Copenhagen.

Corrected field measurements and notes to the two profiles are included in the appendix.

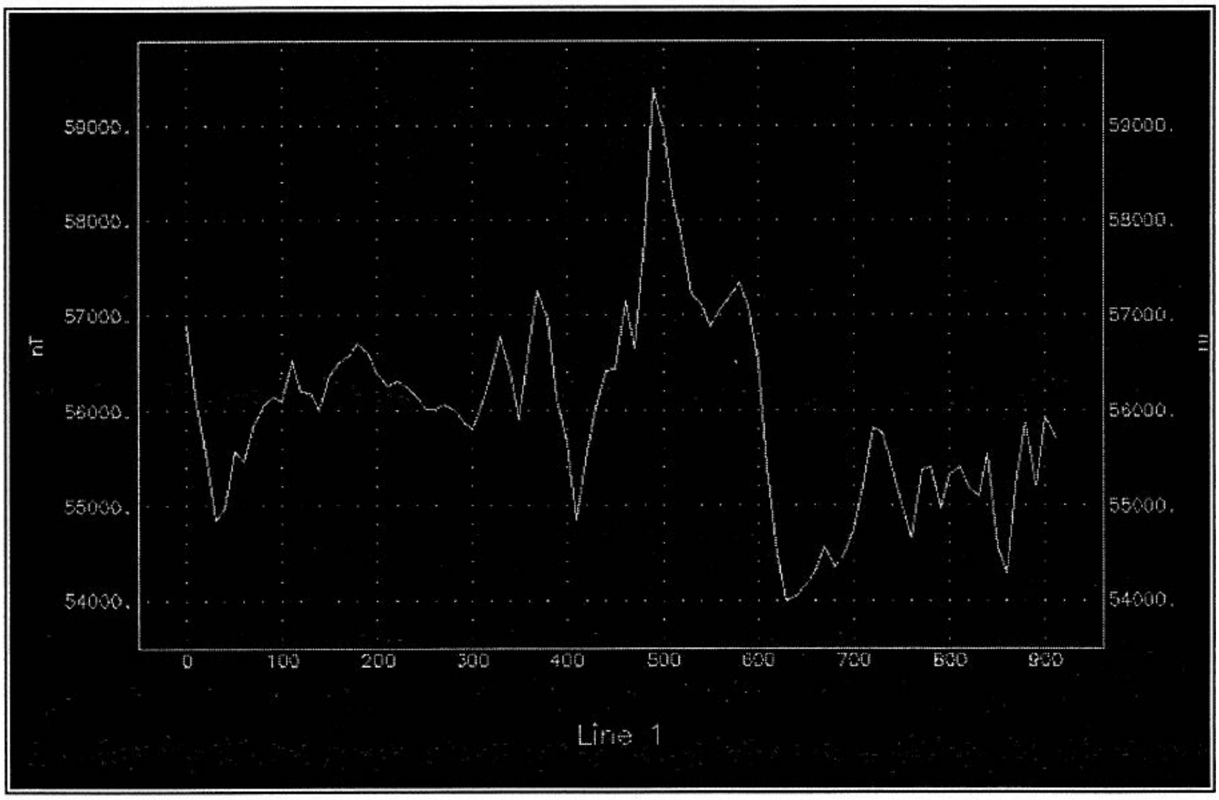
Compilation

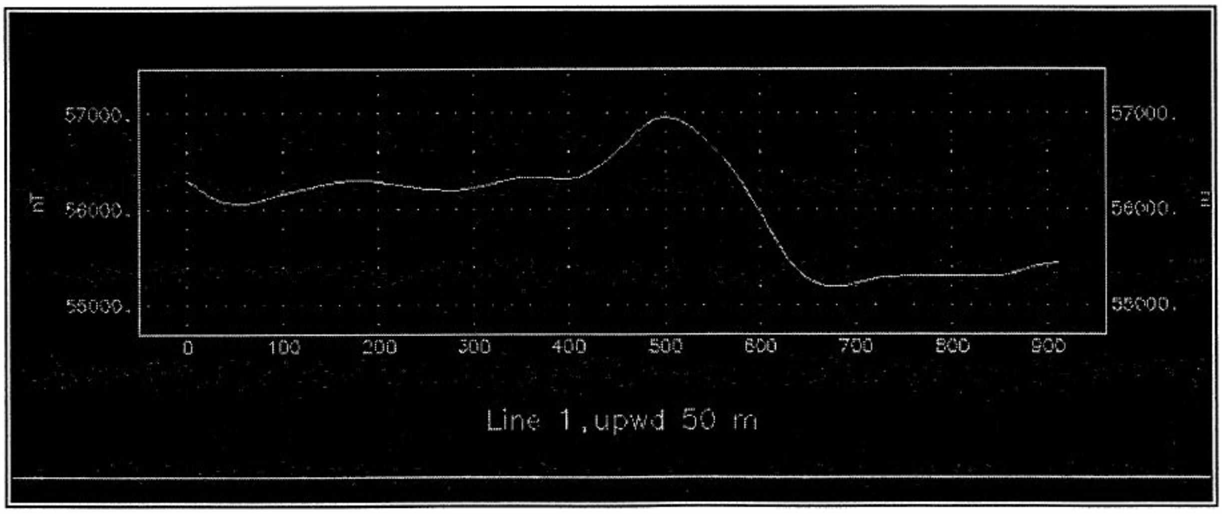
The magnetic profiles were standard corrected for diurnal variation at the site by using the base magnetometer data to calculate a correction then applied to the profile data. Because location of the profiles and the base magnetometer are close together, the magnetic profile data presented here can be assumed to be free of diurnal error. Thus, the magnetic anomalies only exhibits effects from the underlying rocks. The data were transferred to the Geosoft suite of programs, which were used for further processing, including the production of the plots.

Discussion and conclusions

Each of the two magnetic profiles is displayed in two versions: the magnetic profile after diurnal correction and the same profile upward continued 50 metres to enhance the regional trend and filter away the details of the profile, most probably originating very near the surface.

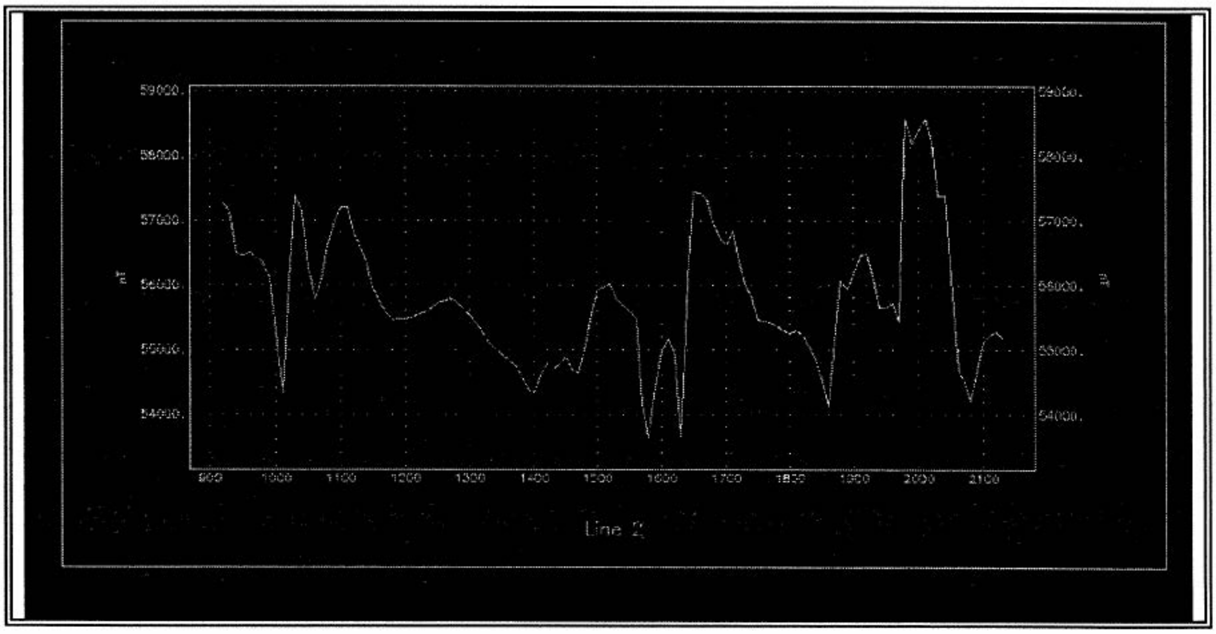
Both the appearance of the magnetic profiles and the amplitude of individual anomalies clearly show the presence of highly magnetic rocks, almost certainly the basalt common to the area. Local gradients are large, see e.g. Line 1 at L=4-500 metres, where the field

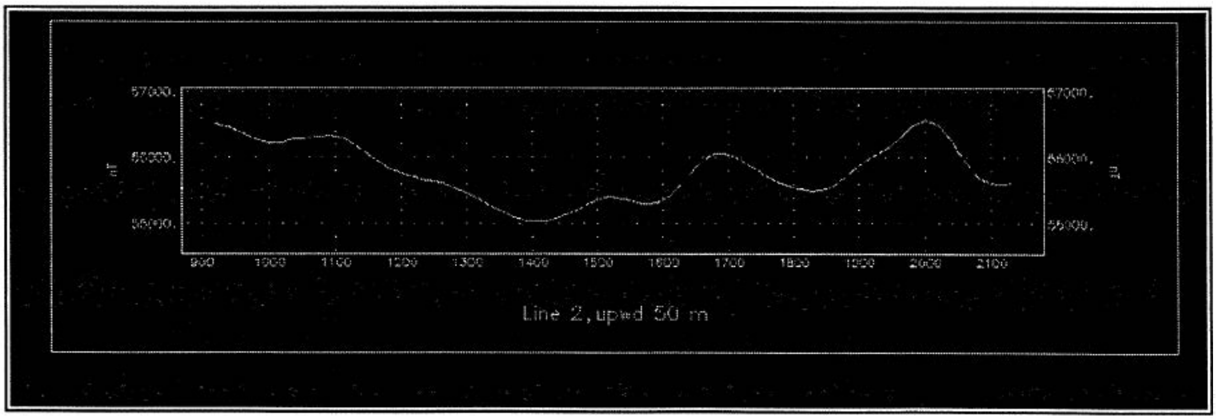




goes from less than 55.000 nT at L = 400 to more than 59.000 nT at L = 490. This was already realised in the field: at places the magnetometer had difficulty registering the field at maximum accuracy because of local strong gradients. This type of variation in the magnetic field may be caused by near surface variation in magnetic susceptibility and/ore remanens, blocky moraine, varying thickness of overburden, and/or the presence of cracks and faults where magnetite has been weathered and changed into haematite. It is known that there are both normally and reversely magnetized basalts in the area, and this could be a significant factor for the anomaly pattern.

Line 1 gives indications of a fault or contact structure, near L = 600 m, either downfaulted to the right, or with less magnetic rock to the right. This is seen more clearly on the upward continued version of the profile, where the superimposed shorter wavelength anomalies are absent. Line 2 exhibits the same high frequency content in the anomalies, but gives less clear indications as to the underlying structures. The two lines are parallel with about 1 km between them, so based on the magnetic data alone nothing can be said about the strike length of the structures involved. Based on the geological structures





shown on the enclosed map it can be argued that the anomalies around L = 100 of Line 1 may correspond to the anomalies around L = 2000 of line 2. The major structure, probably a fault, mentioned above would maybe have been intersected by Line 2, if it had been extended a few hundreds metres to the East.

A comparison of the higher frequency anomalies of both lines with the geology indicated on the map show several good visual correlations. However, the circumstances of this work do no warrant exact modelling, but at this stage the qualitative discussion above is sufficient to support further magnetic work in the area.

Implications for further ground geophysical field work

Based on the results of these two magnetic profiles it is clear that further magnetic work in similar detail and with more parallel lines at closer spacing would accurately map the occurrence of near surface basalt, point out faults, and give the thickness of the superficial moraine, river beds etc. The lines would, however, have to be significantly longer if response from the underlying precambrian (?) basement is looked for. These anomalies would be very subtle compared with the sharp, high frequency anomalies displayed on these two reconnaissance lines. Based on magnetic data there are two ways to get indications of the depth to the basement:

(1) Power spectrum analyses, basically a statistical method, which under certain assumptions will give an average depth to the basalt (near 0) and a probable depths to the underlying basement provided this has a magnetic contrast to the sediments. Here it is important to remember that the magnetic susceptibility of the exposed basement further East on Arveprinsens Ejland etc, varies considerably, and in many case is effectively zero, in which case there will be no contrast to the sediments. The thickness of the sediments between the basalt and the basement would be difficult to determine exactly by magnetics alone, because lower boundaries of magnetic bodies are difficult to determine in any case.

(2) Modelling of the geology as 2.5 dimensional bodies could be more accurate. Usually results obtained by (1) could be used as constraints for the modelling together with information from the drill hole. However, the success of this would very much depend on how well the magnetic properties of the basalt and the basement are known, and it would be advisable to support the magnetics by another method like gravity.

The following can be recommended as a contribution to additional geophysical field work in 1994:

a) Carry out a magnetic survey over an area something like 3 by 1 km in size, maybe with one line extended (perpendicular to strike). Surface height should be known to within a few metres.

b) Carry out a gravity survey over (approximately) the same area. Here the altitudes needs to be known to within less than .5 metres Alternatively, if the position of the looked-for basement structures, highs or the like, is known approximately, then well place gravity profiles along the coast may provide some answers. This would take away the need for accurate determinations of height. If this method is used, then probably also coincident magnetic profiles should be acquired, although there may be difficulties with diurnal corrections, if distance to base gets to be too great.

c) It is not recommended to use VLF although this could be used in an attempt to map the major faults. Results would probably be uncertain, and the topography will give problems.

d) As much information of the petrophysical properties of the rocks of the area (included likely exposed candidates for the basement) should be gathered preferably before, but if this is not possible, then during the coming fieldwork: Density, susceptibility, Q-factor or magnetic remanence is of special interest.

e) In-field processing of geophysical data. Magpack- and Geosoft programs available for compilation and plotting. Further, purchase of Geosoft programs for gravity compilation should be considered. This will make it possible to compile data in the field, and given the time, also carry out the first attemps of modelling there.

f) Re-activate and bring into the field the aeromagnetic regional reconnaissance profiles (survey NU) flown by GGU in the seventies.

Appendix: Data and notes

Line 1

Measured: 27 Oct 1993

Start of line:	70° 31.0193′ N	054° 12.3375′ W	corresponding to 60n i FGC grid, c. 25 m from coast line.
End of line:	70° 31.3687′ N	054° 11.0720′ W	

Notes to line 1:

Pnt	L	note
0	0	start of line
19	190	start of river bed
23	230	end river bed, start moor
35	350	end moor
36	360	ridge
39	390	start moor
55,56	555	brook between the two points
77	770	end moor
91	910	end of line

Line 2

Measured 28 Oct 1993

Start of line:	70° 31.3687′ N	054° 13.5349′ W	start on ridge, 30-40 metres from coast, altitude 10-15 metres.
End of line:			No GPS measurement, but exact position on map.

Notes to line 2:

Pnt	L	note
92	920	start of line
97	970	end ridge, gradual transition to river bed
142	1420	gradual transition from river bed to plain
158	1580	slumped ridge
163	1630	start ridge
170	1700	top of ridge
175	1750	plain
197	1970	start ridge, up 7 metres
198	1980	top ridge
206	2060	river plain
213	2130	river, end of line

Measurements after correction for diurnal variations are shown on following page 7.

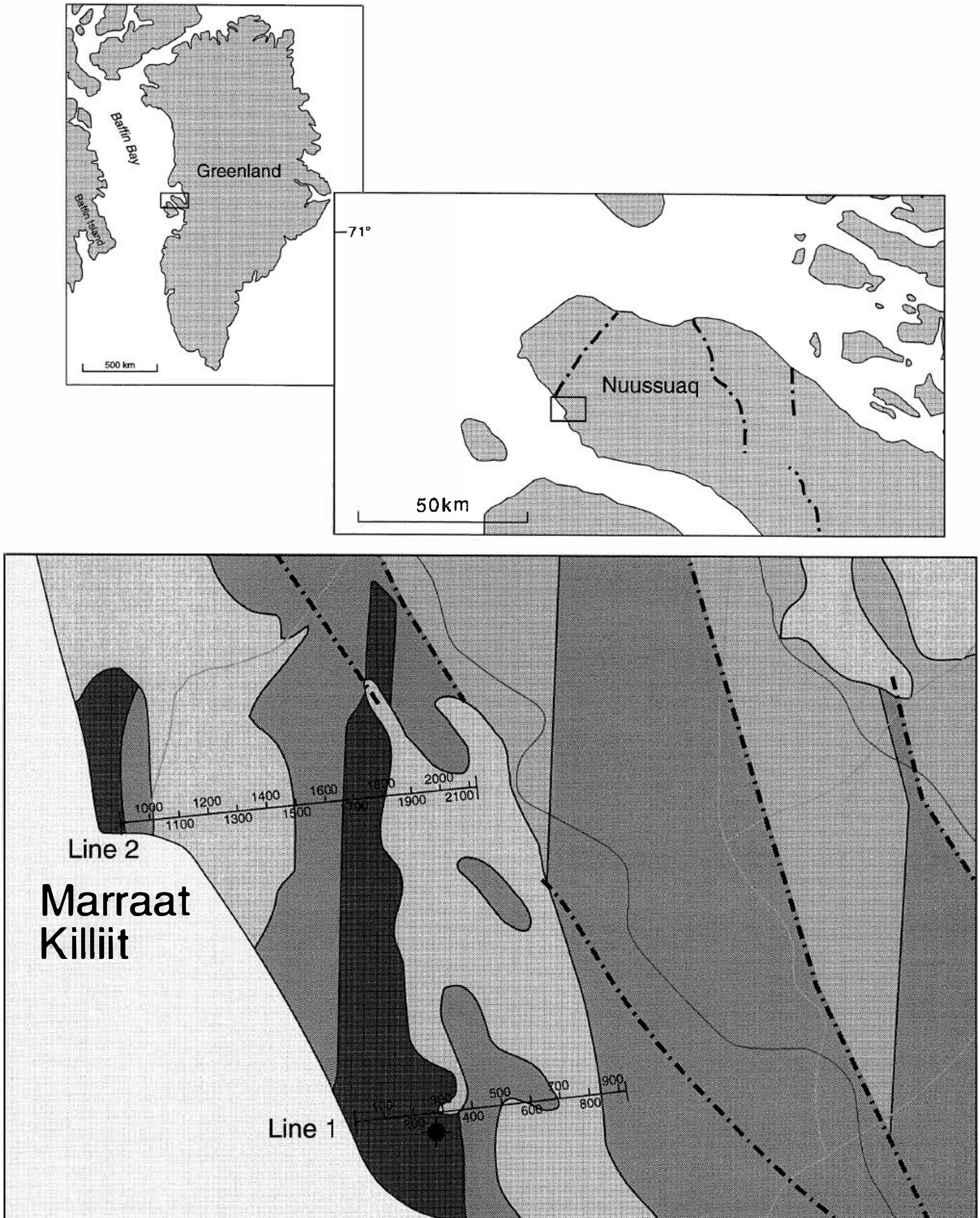
Position of lines are shown on map page 8, which is a copy of Hendersen original map from the area. See original map for details of legend. Lines are provided with indications of L along the lines corresponding to the L- values listed in the table on page 7.

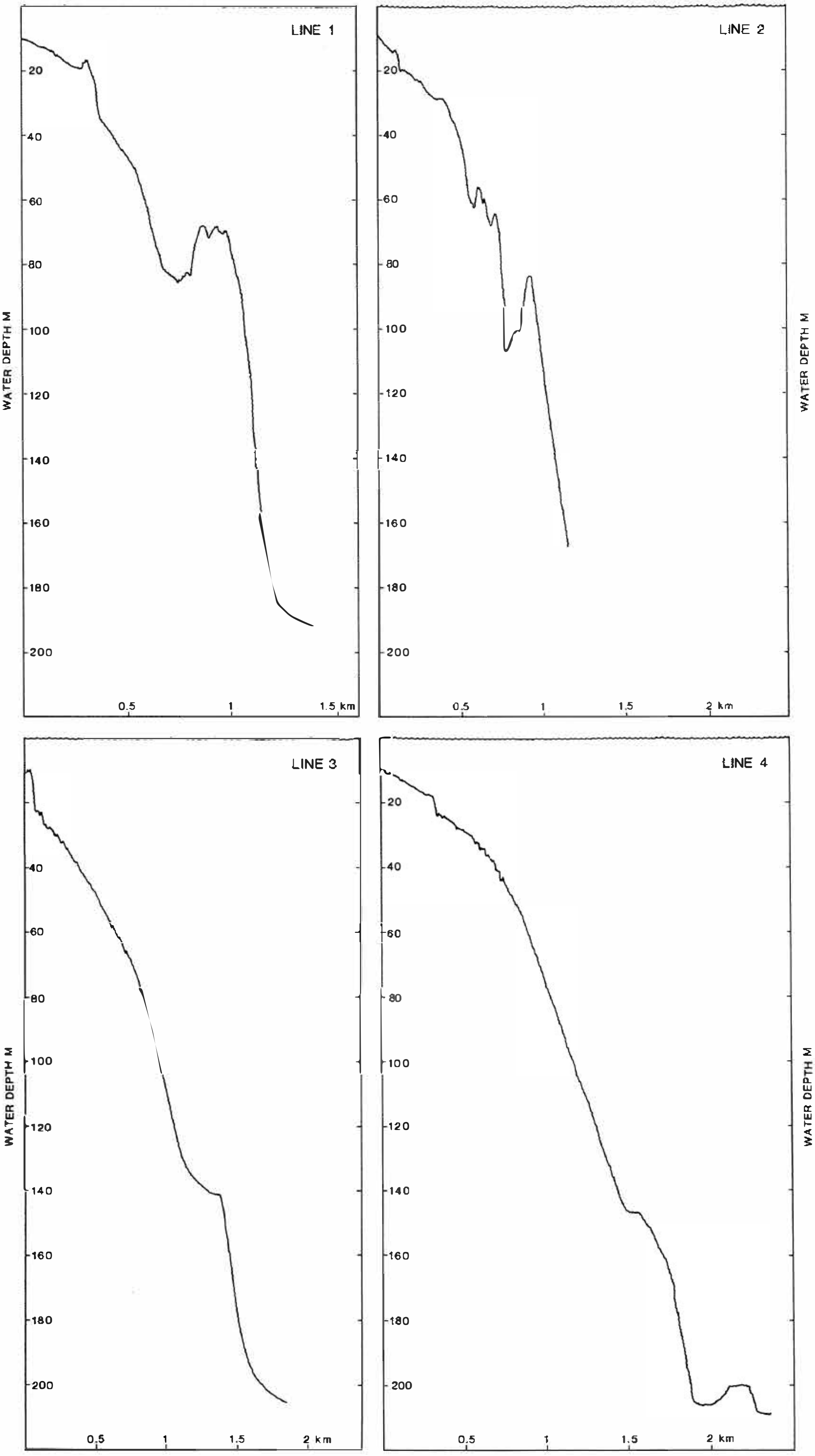
LINE 1

0.	100.	56899.3
10.	100.	56071.5
20.	100.	55570.1
30.	100.	54852.3
40.	100.	54982.9
50.	100.	55576.8
60.	100.	55473.4
70.	100.	55862.1
80.	100.	56052.5
90.	100.	56159.8
100.	100.	56103.7
110.	100.	56533.6
120.	100.	56199.3
130.	100.	56196.0
140.	100.	56016.6
150.	100.	56366.9
160.	100.	56489.7
170.	100.	56566.5
180.	100.	56716.0
190.	100.	56609.4
200.	100.	56387.0
210.	100.	56270.1
220.	100.	56310.4
230.	100.	56245.5
240.	100.	56135.9
250.	100.	56020.8
260.	100.	56020.2
270.	100.	56065.4
280.	100.	56006.9
290.	100.	55896.8
300.	100.	55810.1
310.	100.	56054.3
320.	100.	56383.5
330.	100.	56776.9
340.	100.	56403.6
350.	100.	55907.1
360.	100.	56653.6
370.	100.	57255.9
380.	100.	56957.0
390.	100.	56132.4
400.	100.	55674.9
410.	100.	54855.0
420.	100.	55568.6
430.	100.	56036.0
440.	100.	56420.1
450.	100.	56433.3
460.	100.	57143.0
470.	100.	56651.7
480.	100.	57806.0
490.	100.	59390.3
500.	100.	58933.6
510.	100.	58266.4
520.	100.	57746.1
530.	100.	57219.8
540.	100.	57108.7
550.	100.	56887.2
560.	100.	57057.8
570.	100.	57188.6
580.	100.	57334.9
590.	100.	57101.9
600.	100.	56532.1
610.	100.	55407.1
620.	100.	54487.7
630.	100.	53989.6
640.	100.	54044.9
650.	100.	54150.1
660.	100.	54296.4
670.	100.	54564.1
680.	100.	54347.4
690.	100.	54469.9
700.	100.	54751.3
710.	100.	55205.5
720.	100.	55814.9
730.	100.	55775.4
740.	100.	55374.1
750.	100.	54971.4
760.	100.	54648.2
770.	100.	55372.1
780.	100.	55413.3
790.	100.	54980.0
800.	100.	55336.1
810.	100.	55409.3
820.	100.	55190.8
830.	100.	55097.0
840.	100.	55548.1
850.	100.	54558.2
860.	100.	54282.6
870.	100.	55332.2
880.	100.	55866.4
890.	100.	55211.0
900.	100.	55950.8
910.	100.	55719.7

LINE 2

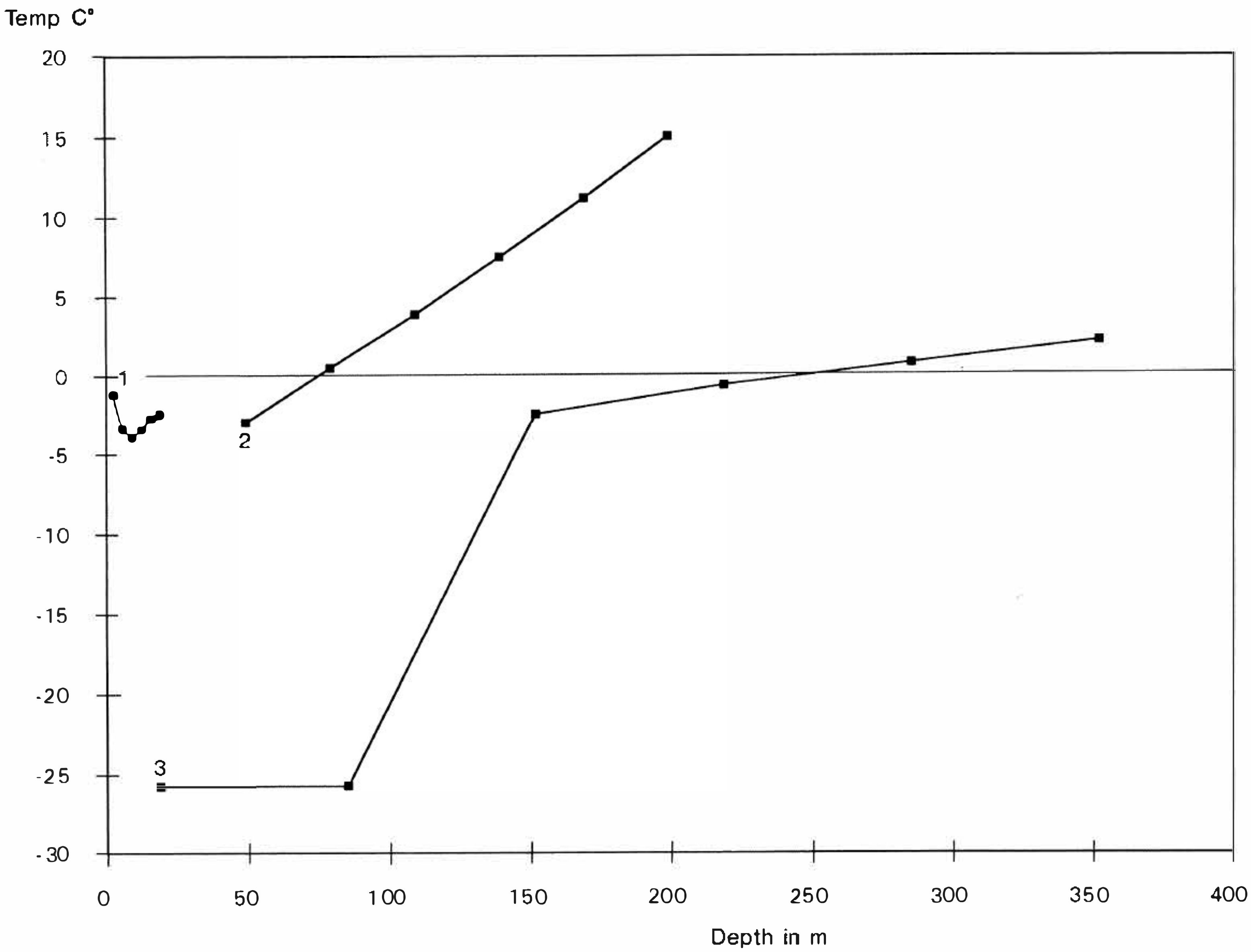
920.	200.	57277.3
930.	200.	57129.0
940.	200.	56476.3
950.	200.	56463.2
960.	200.	56484.3
970.	200.	56424.2
980.	200.	56342.2
990.	200.	56103.3
1000.	200.	55276.0
1010.	200.	54322.4
1020.	200.	56043.7
1030.	200.	57390.1
1040.	200.	57117.6
1050.	200.	56264.9
1060.	200.	55796.6
1070.	200.	56082.2
1080.	200.	56609.4
1090.	200.	56976.7
1100.	200.	57201.7
1110.	200.	57199.7
1120.	200.	56811.5
1130.	200.	56598.8
1140.	200.	56319.4
1150.	200.	55942.9
1160.	200.	55710.2
1170.	200.	55565.7
1180.	200.	55462.1
1190.	200.	55465.5
1200.	200.	55479.7
1210.	200.	55487.6
1220.	200.	55547.3
1230.	200.	55572.1
1240.	200.	55650.1
1250.	200.	55720.0
1260.	200.	55761.1
1270.	200.	55784.3
1280.	200.	55734.4
1290.	200.	55644.8
1300.	200.	55537.1
1310.	200.	55394.9
1320.	200.	55256.1
1330.	200.	55112.6
1340.	200.	54996.6
1350.	200.	54910.9
1360.	200.	54834.9
1370.	200.	54752.8
1380.	200.	54606.6
1390.	200.	54376.6
1400.	200.	54320.6
1410.	200.	54604.4
1420.	200.	54783.8
1430.	200.	54691.2
1440.	200.	54769.7
1450.	200.	54886.1
1460.	200.	54679.1
1470.	200.	54644.3
1480.	200.	54967.2
1490.	200.	55552.4
1500.	200.	55901.5
1510.	200.	55979.1
1520.	200.	56004.0
1530.	200.	55796.2
1540.	200.	55668.7
1550.	200.	55603.8
1560.	200.	55479.3
1570.	200.	54166.1
1580.	200.	53637.4
1590.	200.	54425.1
1600.	200.	54951.4
1610.	200.	55154.0
1620.	200.	54908.0
1630.	200.	53639.4
1640.	200.	56080.3
1650.	200.	57429.5
1660.	200.	57415.7
1670.	200.	57318.5
1680.	200.	56960.6
1690.	200.	56729.6
1700.	200.	56608.4
1710.	200.	56818.2
1720.	200.	56368.1
1730.	200.	56036.3
1740.	200.	55785.0
1750.	200.	55453.9
1760.	200.	55437.4
1770.	200.	55410.5
1780.	200.	55369.9
1790.	200.	55294.4
1800.	200.	55256.3
1810.	200.	55285.3
1820.	200.	55236.8
1830.	200.	55066.5
1840.	200.	54847.5
1850.	200.	54558.5
1860.	200.	54121.7
1870.	200.	55139.0
1880.	200.	56067.3
1890.	200.	55936.9
1900.	200.	56167.7
1910.	200.	56464.7
1920.	200.	56471.5
1930.	200.	56153.4
1940.	200.	55649.2
1950.	200.	55641.6
1960.	200.	55717.4
1970.	200.	55431.7
1980.	200.	58566.8
1990.	200.	58176.9
2000.	200.	58378.3
2010.	200.	58559.5
2020.	200.	58220.8
2030.	200.	57381.9
2040.	200.	57379.0
2050.	200.	56106.8
2060.	200.	54677.4
2070.	200.	54497.7
2080.	200.	54206.2
2090.	200.	54702.2
2100.	200.	55128.6
2110.	200.	55238.5
2120.	200.	55263.7
2130.	200.	55177.4


Baffin Bay
Greenland
Baffin Island
500 km
71°
Nuussuaq
50km
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Line 2
Marraat
Killiit
100
200
300
400
500
600
700
800
900
Line 1
500 m



Appendix 6 Echo-sounding profiles

Appendix 7 Temperature distribution in the borehole



R:målt (ohm)		Kabel læng (meter)	Dybde (meter)	TEMPERATUR (celcius)			
2827		20	2,53	-1,14966			
3116		20	5,86	-3,40539			
3189		20	9,2	-3,93759			
3119		20	12,53	-3,42754			
3027		20	15,86	-2,73701			
2986		20	19,2	-2,42153			
2827		20	2,53	-1,14966			
3071		200	49,2	-2,94816			
2647		200	79,2	0,53711			
2303		200	109,2	3,87293			
1986		200	139,2	7,49914			
1715		200	169,2	11,1741			
1476		200	199,2	15,0224			
8850		353	18,6	-25,7561			
8830		353	85,2	-25,7105			
3014		353	151,9	-2,40625			
2790		353	218,6	-0,58933			
2631		353	285,2	0,80556			
2481		353	351,9	2,2137			

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