GEUS
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# GANK-1
# GANK-1A

# Well summary GANK-1 and GANK-1A grønArctic Nuussuaq Kuussuaq, West Greenland. Report prepared for grønArctic energy inc., Calgary, Alberta, Canada, November 1995

**Dahl, K., Bate, K.J. & Dam, G.**

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DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1997/38

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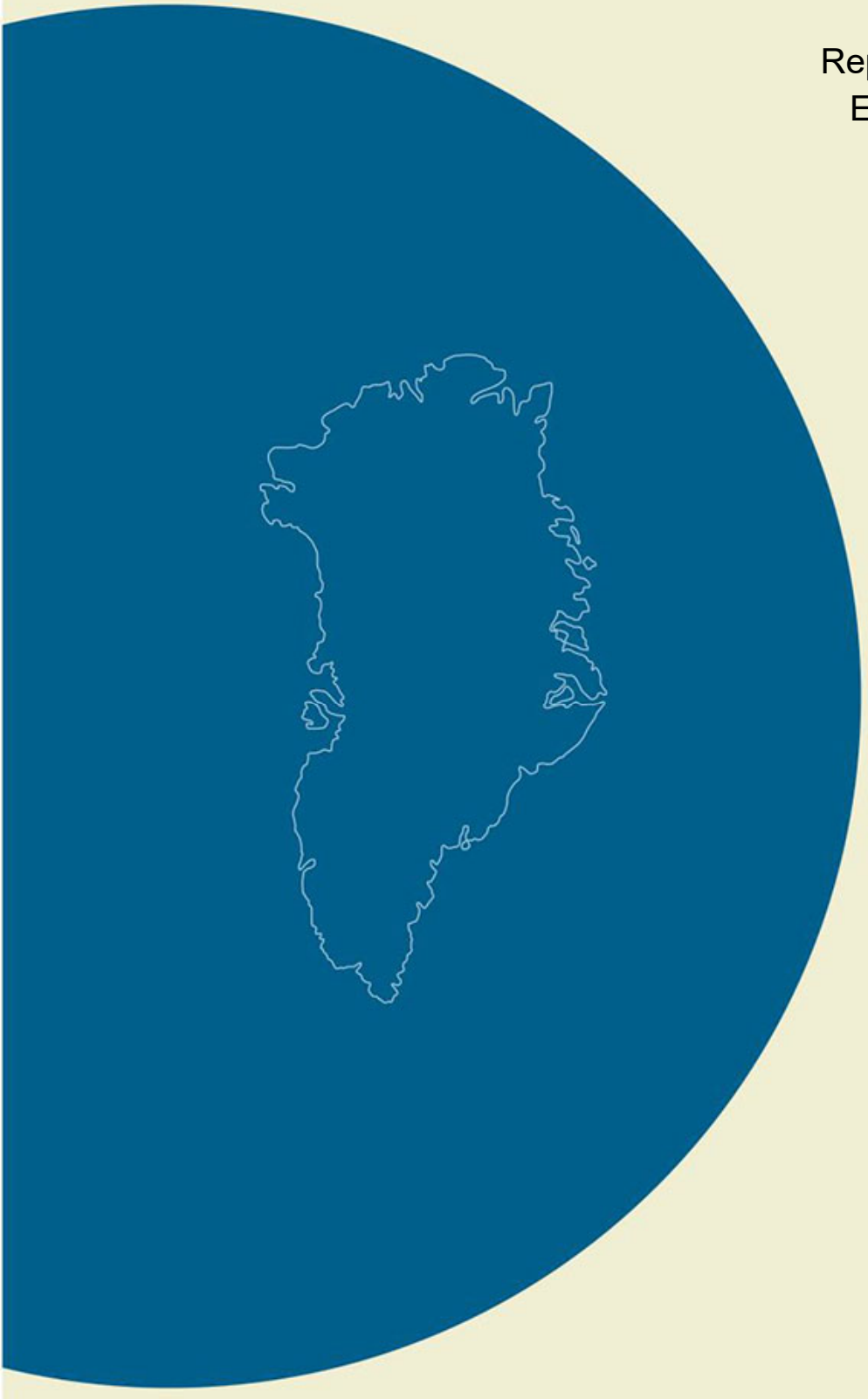

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF ENVIRONMENT AND ENERGY

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This report was originally prepared as a confidential report for grønArctic energy inc. Released April 1997

Karsten Dahl, Kevin J. Bate and Gregers Dam

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# 1.0 INTRODUCTION, PERTINENT WELL DATA, AND SUMMARY

## 1.1 Introduction

In May 1995 grønArctic Energy Inc. was awarded an exclusive licence (no. 06/95) to explore for hydrocarbons on the western part of Nuussuaq peninsula. As part of the work obligations under this licence a slim core hole drilling programme was carried out from June to September 1995. The programme included drilling of three wells GANK #1, GANE #1 and GANT #1 in the western part of Nuussuaq (Figs 1, 2).

An agreement (Ref. no. 93533-04/95) between the Mineral Resources Administration for Greenland (MRA) and grønArctic Energy Inc. concerning the 1995 drill cores states that the cores should be stored at GEUS in Copenhagen and that a geologist from GEUS should be at the drill site performing a preliminary sedimentological logging and sampling programme of the cores for analytical work on fluids, gases and cores. As part of the agreement all data from the well are confidential until April 1997 and GEUS is obliged to deliver reports to the operator including a geological log of the core, a preliminary sedimentological and stratigraphic analysis, and a description of geochemical results from analysis of samples.

### 1.1.1 Location

The surface location of the GANK #1 well is situated 6 km east of GANE #1 and approximately 500 m from the southern bank of the Kuussuaq river in the south-western part of Nuussuaq (Fig. 2). The well is also approximately 14 km east-south-east of the Marraat-1 well drilled in 1993 and 15 km east-south-east of the GANW-1 well drilled in 1994. The elevation is approximately 91 m above mean sea level and the coordinates are 70°28.35′N, 53°51.69′W.

### 1.1.2 Objective

The objective of the GANK #1 well was to explore for the presence of oil and/or gas in a structural prospect with a Marraat-type oil (generated from a Tertiary source rock) in Tertiary or Cretaceous sandstone reservoirs. The well would also provide information on the thermal maturity and pressure regime of the area.

## 1.2 Pertinent well data

| | |
|---|---|
| Well: | grønArctic Nuussuaq Kuussuaq #1<br>GANK #1 and GANK #1A (GGU 439201) |
| Well profile: | Vertical hole to 398.98 m (GANK #1)<br>Side-track from 218.55–332.84 m (GANK #1A) |
| Location: | Kuussuaq valley, approximately 500 m south of Kuussuaq river (Figs 1, 2), SW Nuussuaq |
| Coordinates: | 70°28.35′N, 53°51.69′W |
| Elevation: | Ground level: approximately 91 m above mean sea level |
| Depths: | All depths related to the core are measured from drill floor. Elevation of drill floor above ground level approximately 2 m. All other depths are measured from ground level, unless otherwise specified |
| Total depth, driller: | GANK #1: 398.98 m<br>GANK #1A: 332.84 m |
| Hole diameter: | GANK #1: 114.3 mm (HW) from 0–20 m,<br>96.0 mm (HQ) from 20–167.94 m,<br>75.7 mm (NQ) from 167.94–398.98 m<br>GANK #1A: 75.7 mm (NQ) from 218.55–332.84 m |
| Core diameter: | GANK #1: 63.5 mm (HQ) from 34.88–167.94 m,<br>47.6 mm (NQ) from 167.94–398.98 m<br>GANK #1A: 47.6 mm (NQ) from 218.55–332.84 m |
| Casing: | 20.00 m HW (114.3 mm) conductor casing<br>167.94 m NW (88.9 mm) casing |
| Drilling mud, fuel and additives: | Drill mud Quik-trol (GGU 439204)<br>Threadlube grease (Esso) (GGU 439209)<br>Rod/lubricating grease (GGU 439211)<br>Transmission oil (GGU 439210)<br>Turbofuel A-1 (GGU 439213) |

| | |
|---|---|
| | Water samples from Kuussuaq river (GGU 439212, 439215 and 439216) |
| Objective: | Structural prospect with Marraat-type oil (oil generated from Tertiary deltaic source rock and Tertiary or Upper Cretaceous reservoir sandstone) Drilled as part of grønArctic Energy Inc. licence no. 06/95 |
| DRILLING PROGRAMME | See time distribution chart (Fig. 3) |
| Date of helilifting the rig: | 9th August, 1995 |
| Date spudded, drilling: | 11th August, 1995 |
| Date rig released: | 28th August, 1995 |
| Date programme completed: | 28th August, 1995 |
| Days on drill site: | 18 |
| Well status: | Plugged and abandoned |
| Conventional cores: | The hole was cored throughout from 34.88 m with a recovery close to 100% |
| Drilling problems: | Several zones of highly fractured mudstone (faults) were intersected over depth range 300 m to 400 m resulting in high torque on the rods, jamming of core barrel and inability to progress any further. Due to the obstructions of the core barrel and cavings filling the hole, a side-track was drilled. Side-track GANK #1A, was spudded 23th August and extended in depth from 218.55–332.84 m. Continued bad hole conditions prevented any further progress. Inspection of the drill rods demonstrated that they had been machined offcentre. Drilling was terminated before the planned depth of 1200 m |

| | |
|---|---|
| Operator: | grønArctic energy Inc. |
| Drilling contractor: | Petro Drilling Limited |
| Drilling rig: | Diamond drill Longyear model 44 |

Personnel on drill site during drilling:

Cam Hanna, operation manager, grønArctic
Mark Renner, engineering student, grønArctic
Karsten Dahl, well site geologist, GEUS
Kim Zinck-Jørgensen, well site geologist, GEUS
Kevin Bate, well site geologist, GEUS
Helge Silvurberg, pilot, Greenland Air
Finn Lennard, mechanic, Greenland Air
Sivert Olsen, mechanic, Greenland Air
Barry Mathews, foreman, Petro Drilling
Lavern Pynn, driller, Petro Drilling
Geoffrey Upwards, driller, Petro Drilling
Ken Piercey, helper, Petro Drilling
Bronson Webber, helper, Petro Drilling
Darin Oxford, mechanic, Petro Drilling
Ina Rosing, cook, Greenland Contractors

Addresses of companies involved:

*grønArctic Energy Inc.*, Suite 800,
407 – 2nd Street, Calgary, Alberta T2P 2Y3,
Canada
*GEUS, The Geological Survey of Denmark and Greenland*, Øster Voldgade 10, DK-1350
Copenhagen K, Denmark
*Petro Drilling Company Ltd.*, P.O. Box 1021,
Armdale, Halifax, Nova Scotia B3L 4K9, Canada
*Greenland Air*, 3900 Nuuk, Greenland
*Greenland Contractors*, Kristianiagade 1,
DK-2100 Copenhagen Ø, Denmark

| | |
|---|---|
| External communication: | Inmarsat B portable |
| Internal communication: | VHF radio |

## 1.3 Summary

A total of 478.39 m of core (364.10 m from GANK #1 and 114.29 m from the side-track, GANK #1A) with a recovery close to 100% was sampled, described and shipped to GEUS in Copenhagen. The rock at termination depth (398.98 m) consists of fractured mudstone.

The lithology of the core consists of an upper volcanic succession, from 34.9 m to 114.9 m, and a succession of mudstones and sandstones from 114.9 m to termination depth. The overburden is composed of glacial deposits. The sediments are intruded by two thin volcanic intrusions at 323.5–324.3 m and 336.8–346.9 m constituting 3.2 % of the penetrated rock volume.

The volcanic succession is composed of picritic hyaloclastites with poorly developed porosity and permeability. In the lower part of the succesion the volcanics contain liquid oil in pores and fractures. From 86 m to 98 m several core intervals show oil staining (American Petroleum Index, API approximately 35–40 based on fluorescence only).

The greater part of the sediments consists of dark grey to black mudstones with minor sandstone and conglomerate interbeds. The following four facies associations are recognised: 1) mudstone, 2) thinly interbedded sandstone and mudstone, 3) bioturbated thinly interbedded sandstone and mudstone, and 4) sandstone and conglomerate.

The mudstones have been strongly affected by pressure, probably of tectonic origin, resulting in abundant slickensides and fracturing. Small gas/air bubbles were observed in the drilling fluid when connecting the rods, suggesting a relatively high gas pressure.

Due to the heavily fractured nature of the rocks, drilling problems were encountered at several levels, resulting in jammed/stuck core barrel, severe wear and cutting and parting of rods. Due to a combination of lost circulation, parting of rods and a stuck fish, the hole was abandoned at 398.98 m and cemented from 165–217 m. Furthermore an inspection of the NQ rods revealed that they had been machined offcentre, resulting in weakness and therefore poor efficiency.

It was decided to side-track the hole at a depth of 218.55 m and the hole was cemented from 165–217 m. Due to gas pressure the cement was gas contaminated (hard gas cut) and was displaced up the hole. While drilling the side-track similar

problems were soon encountered. High torque on the drill rods was experienced due to a tight hole and later the core tube became plugged with formation. Side-track drilling was terminated at a depth of 332.84 m. The formation intersected in the side-track has a close correlation with that drilled in GANK #1.

The problems were probably the result of cavings from the upper part of the hole plugging the core tube, combined with the reduced efficiency of the NQ rod connections being machined offcentre.

## 2.0 OPERATIONS

### 2.1 Drilling history

Until 1992, the Disko–Nuussuaq–Svartenhuk Halvø region had a reputation as being gas-prone. In order to assess the petroleum prospectivity of the basin, field expeditions to the region were carried out by the Geological Survey of Greenland (GGU) in the period 1990–1992 (Christiansen, 1993). Field work was carried out in cooperation with the Geological Museum, Copenhagen and the University of Copenhagen.

Detailed field work on the volcanic exposures in the western part of Marraat area was carried out by GGU in the summers of 1992–94. The break-through concerning the exploration for hydrocarbons was the discovery of live oil at Marraat in 1992 (Christiansen, 1993). The presence of the biomarkers oleanane and bisnorlupane suggests that the oil was generated from a Tertiary (or latest Cretaceous) source rock. Geochemical evidence indicates that the oil-prone material in the source rock is terrestrial in origin but deposited under marine conditions, probably in a deltaic environment. The Marraat oil has only suffered minor biodegradation and no thermal alteration (Christiansen *et al.*, 1994a).

Prior to the discovery of live oil in vesicular basalts 1992 only a few occurrences of solid bitumens and carbonaceous residuals had been reported in West Greenland (Henderson, 1969; Pedersen, 1986).

Previous observations concerning oil and gas seepage in the Nuussuaq and Svartenhuk Halvø area are mentioned by A. Rosenkrantz and A. Mikkelsen (see review by Christiansen, 1994). These descriptions of oil and gas seepage and local rumours on oil seepage have been difficult to confirm.

To investigate the oil impregnation at Marraat in greater detail, field work and a slim core drilling programme including a subsequent logging and geophysical programme was carried out by GGU in 1993 (Christiansen *et al.*, 1994b). The Marraat-1 well penetrated 446.85 m of Tertiary volcanics and in the uppermost 86 m of the core a series of vesicular zones with liquid oil was discovered (Dam & Christiansen, 1994).

In 1994 GGU carried out geophysical programmes in the Marraat area, along the south coast of Nuussuaq and the south-west coast of Umiivik bay on Svartenhuk Halvø to obtain information on the total sedimentary thickness. The seismic data have documented that the thickness of the succession is more than 7 km (Christiansen *et al.*, 1995b).

The oil company grønArctic Energy Inc. started prospecting in the Maaraat area in 1994. The GANW #1 well was drilled in the period from 11th September to 5th October and was located approximately 900 m north-west of the Marraat-1 well site. The GANW #1 well had a termination depth of 800 m and penetrated a volcanic succession of picrite with small occurrences of olivine-phyric basalt (Christiansen *et al.*, 1995a). The volcanics were developed in three facies: subaerial lava flows, hyaloclastite breccias and intrusions. Sediments were recognised in three intervals with thicknesses from 8 to 33 m. The well confirmed the presence of oil impregnation in parts of the volcanic succession.

From 1992 to 1995 the area with oil impregnation on the south-western part of Nuussuaq has been extended and outcrops with live oil were also observed near the well site of GANE #1 (Fig. 2). The area with live oil in surface outcrops is now known to cover an area of at least 5 × 8 km in the Marraat area and 1 × 3 km near GANE #1 well site.

### 2.2 Position of drill site

The GANK #1 borehole was positioned in an area where it was believed that the volcanic succession was relatively thin. The actual site was further constrained by availability of water and the fulfillment of the requirements set-out by the MRA for containment of an oilspil should any occur.

## 2.3 Drilling programme

The drilling of the GANK #1 and side-track GANK #1A wells took place between 9th and 28th August, 1995 and was performed by grønArctic Energy Inc. with Petro Drilling Company Limited, Canada, acting as the drilling contractor. A wire-line diamond drilling rig (Longyear Fly-in model 44) was used. In Table 1 the design of the hole, casing and core barrel are summarised. The drilling rig has a capability to drill NQ (75.7 mm) hole to a depth of 1200 m. The drill was equipped with a blow-out preventer (BOP), and a mud and choke manifold for well control. The maximum pressure rating of the well head and BOP was 13800 kPa. Safety equipment on the rig included $H_2S$ and combustionable gas detection units.

The drilling rig was operated by the operation manager, two drillers and two helpers, working continuously in twelve hour shifts (two men in each shift). The base camp was located adjacent to GANE #1 (Figs 1, 2) and the crew change was made by helicopter. Helicopter charter services were provided by Greenland Air using a Bell 212.

*Table 1. Design of the hole, casing and core barrel tubes (OD: outside diameter; ID: inside diameter)*

| | **HW** | **HQ** | **NQ** | **BQ** |
|---|---|---|---|---|
| Core size, mm | 63.5 | 63.5 | 47.6 | 36.5 |
| Hole size, mm | 114.3 | 96.0 | 75.7 | 60.0 |
| Hole volume, l/100m | 1026 | 724 | 451 | 282 |
| Annulus volume, l/min | n/a | 1.03 | 0.66 | 0.40 |
| Drill rod size (OD), mm | 88.9 | 88.9 | 69.9 | 55.6 |
| Drill rod size (ID), mm | 77.8 | 77.8 | 60.3 | 46.0 |
| Casing size, mm | 114.3 | n/a | 88.9 | n/a |
| Casing (ID), mm | 101.6 | n/a | 76.6 | n/a |
| Bit set (OD), mm | | 95.6 | 74.6 | 59.5 |
| Bit set (ID), mm | | 63.5 | 47.6 | 36.5 |
| Outer tube (OD), mm | | 92.1 | 73.0 | 57.2 |
| Outer tube (ID), mm | | 77.8 | 60.3 | 46.0 |
| Inner tube (OD), mm | | 73.0 | 55.6 | 42.9 |
| Inner tube (ID), mm | | 66.7 | 50.0 | 38.1 |

From 9th to 11th August the rig was helilifted from GANE #1 to the drill site for GANK #1. Drilling started on 11th August with setting of the HW conductor casing

to a depth of 20 m. NW casing began to be drilled on the 12th August. Coring of the rock began at 34.88 m on the 13th of August. Drilling progressed to a depth of 168 m and the NW casing was run in the hole with the casing shoe set at 168 m on the 15th August in the morning.

The NW casing was pressure tested to 7000 kPa followed by fitting and testing of the mud and choke manifolds and the flareline.

Drilling with NQ rods began on the 16th August in the afternoon. After drilling 2 m of new formation a formation integrity test was performed. The leak-off pressure recorded at surface was 1550 kPa with a leak-off gradient 19.15 kPa/m at the surface casing shoe (equivalent mud weight (EMW) 1950 kg/m$^3$). Drilling progressed smoothly for 3 days with only minor problems. On the 19th August problems with the core tube arose and twice the core was lost in the hole. Hereafter progress was slow because of high torque and breaking of the drill rods. Cavings filled part of the hole resulting in high torque and broken rods and a stuck core barrel. A mill tooth bit was installled in order to attempt to remove the cavings in conjunction with circulation of high viscosity mud. However, the drill rods soon parted and an attempt to fish the rods was unsuccessful. It was decided to terminate hole at a depth of 398.98 m, which was reached on 20th August in the morning. At midnight between 21st and 22nd August the hole was cemented from 165 to 213 m.

Drilling of the side-track (GANK #1A) started at noon on 23th August and continued for 28 hours without difficulties. But again high torque on the drill string was observed at 326 m and the core tube were repeatedly plugged up with mudstone rubble and minor sand.

In an attempt to stabilise the hole ½ m$^3$ cement was squeezed into the hole at a depth of 300 m. At 20.00 on the 26th August the rods were ran back into the hole and firm cement was drilled from 300–330 m. Hereafter the hole packed off the core barrel and circulation was not possible. The drill rods parted on the pin connection at a depth of 300 m; fishing of the rods was unsuccessful. Finally, at 12.00 on the 27th August the hole was cemented and abandoned. See Appendix I for a detailed description of the drilling programme.

# 3.0 GEOLOGY

## 3.1 Setting and stratigraphy

The West Greenland margin is a rifted continental margin, developed during the opening of the Labrador Sea and Baffin Bay in late Mesozoic–early Cenozoic time. Along the continental break-up zone a number of rift basins developed in which Cretaceous and Tertiary sediments were deposited (cf. Chalmers *et al.*, 1993; Chalmers & Pulvertaft, 1993). On the mainland Cretaceous–Tertiary sediments overlain by volcanic rocks outcrop in the Disko–Svartenhuk Halvø region (69°–72°N). The sediments were laid down in a basin, the Nuussuaq Basin, which is bounded to the east by an extensional fault system (Rosenkrantz & Pulvertaft, 1969). Recently acquired seismic data indicate that the maximum thickness of sediments in the basin exceeds 7 km (Christiansen *et al.*, 1995b), but the age and character of the deepest sediments are not known.

The exposed Cretaceous sediments, which are of Albian to late Campanian or early Maastrichtian age, were deposited in a fluvial- and wave-dominated delta environment (Pedersen & Pulvertaft, 1992). The delta fanned out to the west and north-west from a point east of Disko island, reaching into deeper water in the position of present-day northern Nuussuaq and Svartenhuk Halvø. Pre- and syn-rift fluvial sandstones with minor mudstone and coal characterise the south and east of the outcrop area. To the north-west these give way to stacked, typical deltaic, coarsening-upwards successions, each starting with interdistributary bay mudstones and ending with coal, while still farther north-west dark mudstones were deposited in a purely marine environment.

Towards the end of the Maastrichtian the area became tectonically unstable. Phases of uplift were followed by incision of valleys in the underlying sediments. Conglomerates and both turbiditic and fluvial sands and mudstones of Late Maastrichtian to middle Paleocene age filled the valleys, while on the fault-controlled slope to the west more than 2.5 km of turbidite sands alternating with marine mudstones were deposited (Dam & Sønderholm, 1994).

The eruption of Early Tertiary basalts began in a subaqueous environment, so that the earliest basalts, which occur to the west, consist of hyaloclastite breccias that build up Gilbert-type delta structures with cross-bedded sets up to 700 m

thick. The growing volcanic pile dammed up a lake to the east in which organic-rich lacustrine mudstones were deposited. As the volcanic edifice emerged above sea- or lake-level, eruption became sub-aerial, and plateau lavas spread into the east, finally overlapping onto Precambrian basement.

The GANK #1 well is situated close to Marraat and to date four wells have been drilled in this area since 1993 (Fig. 2). The Marraat area is situated south-east of a major fracture system, the Itilli Fault zone, which is centred in the Itiili valley.

The surface rocks consist of picritic hyaloclastites belonging to the oldest part of the Vaigat Formation (Pedersen, 1985). The volcanic rocks were extruded from local submarine eruption sites and redeposited by sedimentary processes in an aqueous environment during Early Paleocene (Pedersen, 1986; Christiansen *et al.*, 1995a).

The marine sediments exposed at Marraat Killiit contain a Late Danian fauna composed of bryozoans, gastropods, pelecypods and spines of echinoderms (Rosenkrantz, 1970). Palynostratigraphy of the lower sedimentary unit in the GANW #1 well gave indications of an age not older than middle Danian (Christiansen *et al.*, 1995a). The age of the sediments penetrated immediately below the volcanic unit in GANE #1 and GANK #1 is therefore probably Late Danian.

In the surroundings of GANK #1 field investigations were performed periodically throughout the drilling. The hyaloclastites are easily recognized in the field and constitute the only exposed rocks in the area, except for occasional dykes. Neither oil impregnation nor bitumen were discovered in the outcrops around GANK #1, although to the west near GANE #1 several showings have been recorded.

### 3.2 Lithology

A preliminary geological/sedimentological description of the core was prepared on the well site. A log of the core was made at a scale of 1:50. This was later summarized at a scale of 1:1250 (Fig. 4).

The API of the oil and bitumen was identified by use of a UV-light with the colour of the fluorescence characteristic of the API gravity of the oil. Generally the darker colours are associated with the heavier crudes, while the lighter colours are indication of lighter oils. Detection of gas seepage from the cores was done by the

drillers and/or the GEUS personnel when the core was unloaded from the core barrel.

The drilled succession can be divided into a volcanic unit and a sedimentary unit (Fig. 4). The volcanic unit extends to a depth of 114.90 m and consists of hyaloclastites. The sedimentary unit was drilled from 114.90 m to the bottom of the hole at 398.98 m. It consists of four main facies: 1) mudstone, 2) thinly interbedded sandstone and mudstone, 3) bioturbated thinly interbedded sandstone and mudstone, and 4) sandstone and conglomerate.

Diagenetic features observed in the sedimentary unit include two types of concretions. One type is typically dark green grey and ball-shaped, 2–40 mm across, with mudstone lamina surrounding the concretions. The other type is pale red brown, irregular, and contains fractures post-dating part of the tectonic activity. Both types are soluble in 5% HCl. Pyrite is common in the mudstone between the two volcanic intrusions and occurs scattered in the rest of the succession. A lithological summary is presented in Appendix II.

### 3.3 Facies description

*Facies association 1: Mudstone*

Description: This facies association constitutes the most abundant part of the drilled succession of sediments and consists of dark grey to black, parallel to irregular laminated mudstone. The amount of organic matter is in the range 1–3%. Interlayered within the mudstone are minor beds of light grey fine-grained sandstones, 1–100 mm thick. The laminated thin sandstone beds often have slumped or disturbed bedding.

Interpretation: Lack of bioturbation and the preserved organic material suggests that the water at the sea bottom was oxygen-depleted. The mudstones were probably mainly deposited from suspension. The dewatering structures of the sandstone lamina arise from rapid deposition, suggesting that the sandstones are deposited from distal turbidite currents.

*Facies association 2: Thinly interbedded sandstone and mudstone*

Description: This facies is rather similar to the mudstone of facies association 1, but the density of sandstone beds is larger. The sandstones are very fine to

medium-grained and show parallel and irregular lamination. Thickness ranges from a few mm to 50 cm; graded bedding is common.
Interpretation: The sandstone beds were deposited from low-density turbidity currents.

*Facies association 3: Bioturbated thinly interbedded sandstone and mudstone*
Description: This facies association is observed in the lower part of the succession. The lithology of the mudstone and sandstone is rather similar to facies associations 1 and 2. However, the thin sandstone beds show structures that could be related to burrowing organisms. Exact identification of the trace fossils has not been possible. The sandstone is generally irregular laminated.
Interpretation: The bioturbation suggests a similar depositional environment to that of facies association 2 but more oxygenated conditions.

*Facies association 4: Sandstone and conglomerates*
Description: This facies association is interlayered with sediments of facies association 2 in the lower part of the drilled succession, at 290 m and 274 m. In the upper part of the succession this facies is interlayered with mudstone (facies association 1) at 203 m and 175 m. At 175, 274 and 290 m the association consists of amalgamated sandstone beds occurring in coarsening-upward units up to 4 m thick. Each bed is 10–100 cm thick, sharply based and composed of parallel-laminated poorly sorted fine to coarse sandstone. The lamination is often disturbed. The conglomerates are mud-supported and contain subangular to rounded volcanic clasts and subangular mudstone clasts. At 203 m the association shows fining-upward grading with parallel and irregular lamination.
Interpretation: The occurrence of mudstone clasts in the conglomerates indicates redeposition of previously lithified mudstone. The disturbed bedding in the sandstone is probably due to dewatering of the underlying sediments due to rapid deposition. Together these observations suggest deposition from proximal low-density turbidite flow.

### 3.4 Lateral correlation and depositional environment

The base of the volcanic units has been used as the base line for a lateral correlation between the sedimentary units in the GANE #1 and #1A (210 m) and GANK #1 (285 m) wells (Fig. 5). The distance between the two wells is approximately 6 km. This correlation should, however, be taken with some reservations as the base of the volcanic unit is not necessarily synchronous. The sediments in the lower part of the GANE #1A well are obviously more coarse-grained and may have been deposited in a deltaic environment (Atane Formation?). They are overlain by a succession dominated by sandstone and thinly interbedded sandstone and mudstone, deposited from turbidite currents and debris flows (Kangilia Formation or the "Itilli succession").

The sediments of GANK #1 well is much more fine-grained than those of GANE #1A and consist mainly of mudstone and thinly interbedded sandstone and mudstone, deposited from suspension and distal turbidite currents. Lithostratigraphically the sediments of the GANK #1 well most likely correspond to the Kangilia Formation. No major cyclic variations of facies associations are present in the two wells, which is also characteristic of the heterolithic deposits of both the Kangilia Formation and the "Itilli succession". At Ataata Kuua, 40 km to the east, marked lateral variation can be seen in the Kangilia Formation, so that one cannot expect to be able to correlate from well to well on the basis of lithology alone.

### 3.5 Summary of hydrocarbon shows

| | |
|---|---|
| 86–96 m | Oil impregnation of hyalocastite. Scattered oil impregnation of vesicles and microfractures within both clasts and matrix. Oil occasionally bleeding from the rock, red to light brown colour, light API (35–40). Creosote odour. |
| 158–168 m | Mudstone, smell of oil from 158–168 m, most obviously along the glassy fractures or slickensides. Smell is due to contamination by diesel/jet fuel. |
| 191–197 m | Oil film on water when wetting the core; probably contamination. |
| 204.3 m | Coal fragment? |
| 327.2 m | Coal fragment? |

| | |
|---|---|
| 361.8 m | $H_2S$ detected. |
| 380–386 m | Contamination by jet fuel. |
| 384 m | Gas burned in flareline. |
| 244–290 m | GANK #1A, small bubbles of air/gas in the drilling fluid were observed by the driller when connecting and breaking down the rods. |

### 3.6 Cores

478.39 m of conventional core was cut, with a recovery close to 100%. Poor recovery in certain intervals, was due to the heavily fractured nature of the rocks. As a consequence parts of the retrieved core consist of rubble. A list of the core boxes is provided in Appendix III.

### 3.7 Samples

Sampling density of the cores was approximately two samples every 3 m, which included one sealed tin sample (8 cm core piece wrapped in aluminium foil) for later gas evaluation and detailed petrography, and one chip sample (1 cm core pieces) for reference/lithology. A list of core samples taken at the drill site is provided in Appendix IV.

*Table 2. Summary of samples taken at drill site GANK #1 and #1A.*

| | |
|---|---|
| **GANK #1** | |
| **Core box no:** (1-122), from 34.90–398.98 m | **122** |
| **Number of chip samples:** (subno. 501-519, 521-522, 524-536, 538-544, 547-548, 550-559, 561-631) | **124** |
| **Number of tinned samples (gas sealed):** (subno. 20-125) | **106** |
| **Number of foil samples (plastic or tin):** (subno. 1-17, 520, 523, 537, 545, 546, 549, 560) | **24** |
| **Number of gas samples:** | **0** |
| **Number of water samples:** | **5** |
| **Number of miscellaneous samples:** | **9** |
| **GANK #1A** | |
| **Core box no:** (123-154), from 218.6–332.8 m | **32** |
| **Number of chip samples:** (subno. 636–668) | **33** |
| **Number of tinned samples:** (subno. 126-155) | **30** |
| **Number of foil samples:** (subno. 632-635) | **4** |

Water samples, both from the Kuussuaq river and the circulation system, were collected in 500 ml Duran glass bottles and plastic bottles. Additionally, potential and actual contaminants were sampled, e.g rod grease, jet-fuel, transmission oil, drilling mud. Additional samples from the drill site are listed in Appendix V.
A summary of the samples is provided in Table 2.

### 3.8 Analytical methods

Part of the sample material is being analysed at GEUS, including the following analyses:

1) Leco/RockEval pyrolysis
2) Vitrinite reflectance
3) Extraction with subsequent desaphalting and column separation into saturated and aromatic hydrocarbons and NSO compounds
4) Gas chromatography and gas chromatography/mass spectrometry of saturated hydrocarbons
5) Head space gas composition, C and H isotopes
6) Conventional core analysis, porosity and permeability
7) Water geochemistry, pH, alkalinity

Preliminary results (F. G. Christiansen, personal communication, Nov. 1995) appear to indicate that the oil encountered in the hyaloclastites is of a similar character to that intersected in the Marraat-1 well, i.e. is derived from a source rock of Tertiary age deposited within a deltaic environment. However the high levels of plant biomarkers suggests a higher terrigenous input in the organic matter which may in turn indicate a more proximal position of the source rock for the GANK #1 oil. Furthermore, the geochemical analysis suggests that the degree of maturity at GANK #1 well site is slightly lower than that at the GANE #1 and lower than that at Marraat-1.

With regards the gas encountered in the deeper sections of the hole the preliminary results of the gas analysis indicate a high abundance of methane with only minor indications of the heavier gas. Therefore it would appear that the gas is of a dry nature suggesting that it has been generated within the gas window at a higher thermal maturity than that which generated the oil. The conclusion to be

drawn from this is that the gas has been generated from a separate source rock to that of the oil, at a much higher temperature (greater depth).

The results of these analyses will be presented in separate reports.

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**FIGURES**

Fig. 1
Geological map of central West Greenland showing location of well sites. Map based on Pedersen & Pulvertaft (1992) and Dam & Sønderholm (1994).

Fig. 2
Topographical map of west Nuussuaq showing location of well sites and areas of oil-impregnation within volcanic rocks. Map based partly on Christiansen *et al.* (1995b).

Fig. 3
Plot of time vs progress of drilling, GANK #1 and 1A.

Fig. 4
Simplified sedimentological log of the GANK #1 and #1A cores. Scale 1:1250.

Fig. 5
Simplified sedimentological log of the GANE #1, #1A and GANK #1 cores.

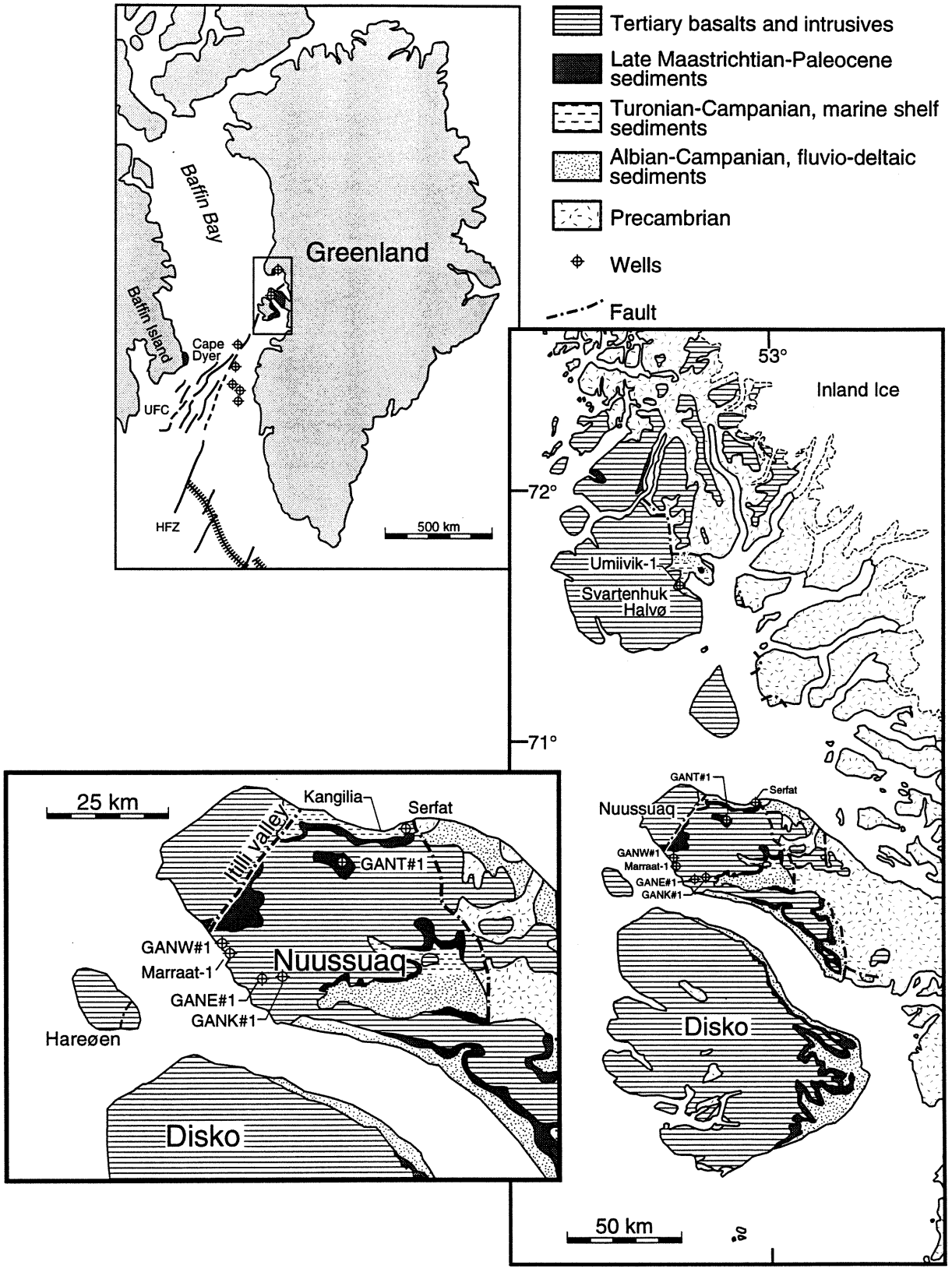


Figure 1. Geological map of central West Greenland showing location of well sites.

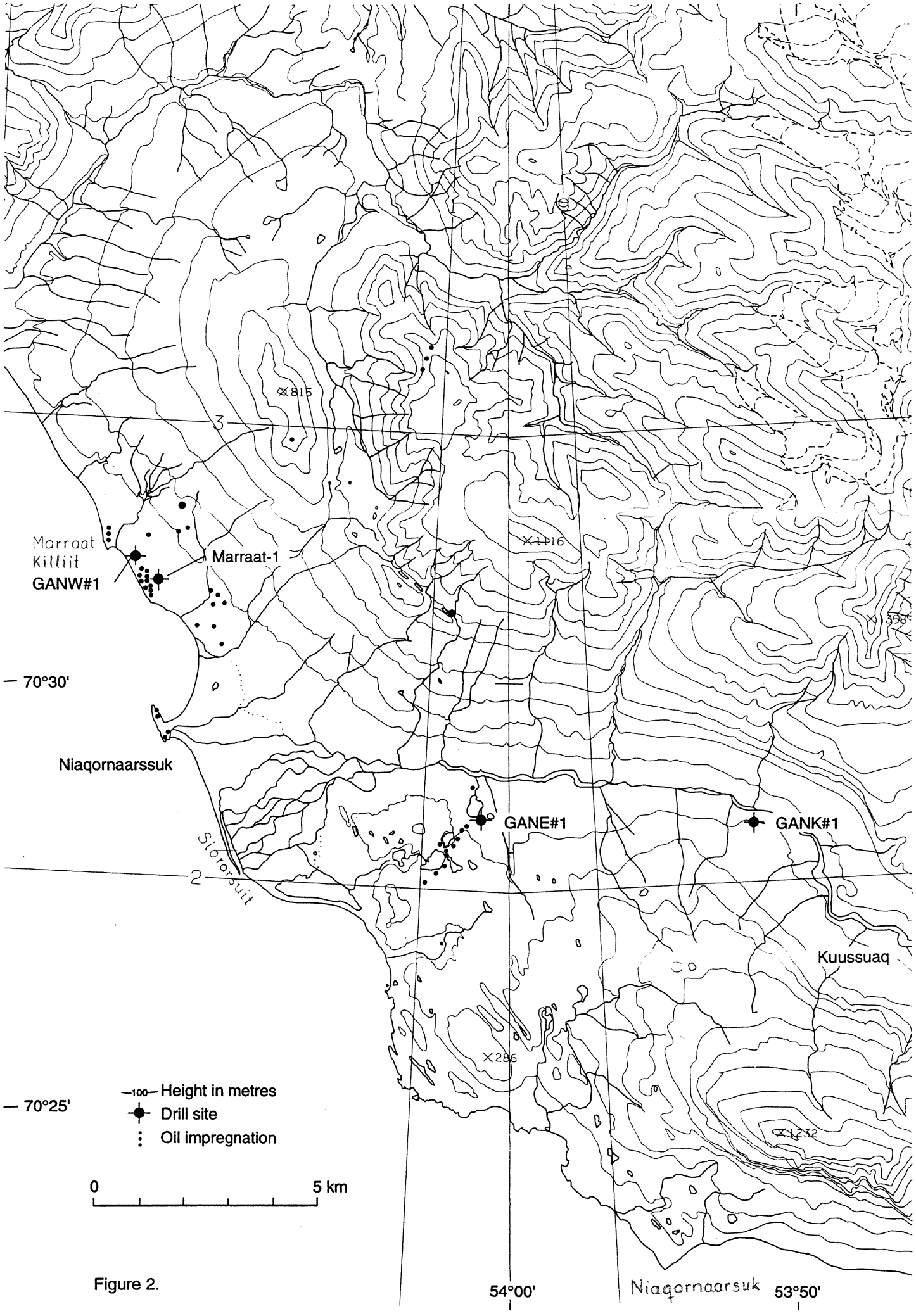
Marraat
Killiit
GANW#1
Marraat-1
70°30'
Niaqornaarssuk
GANE#1
GANK#1
Kuussuaq
70°25'
Height in metres
Drill site
Oil impregnation
0
5 km
54°00'
Niaqornaarsuk
53°50'

Figure 2.

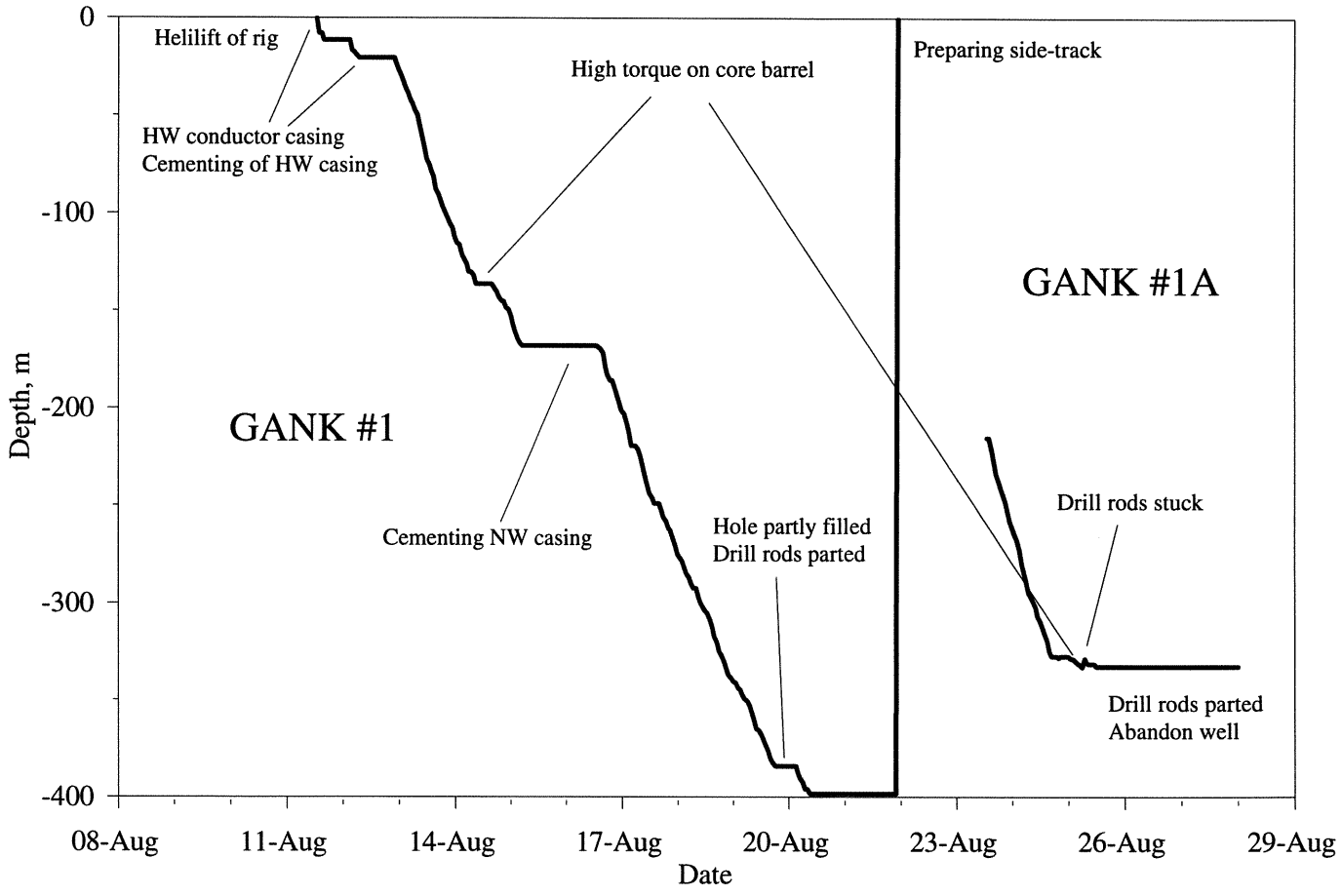


Figure 3. Plot of time vs progress of drilling, GANK#1 and #1A wells.

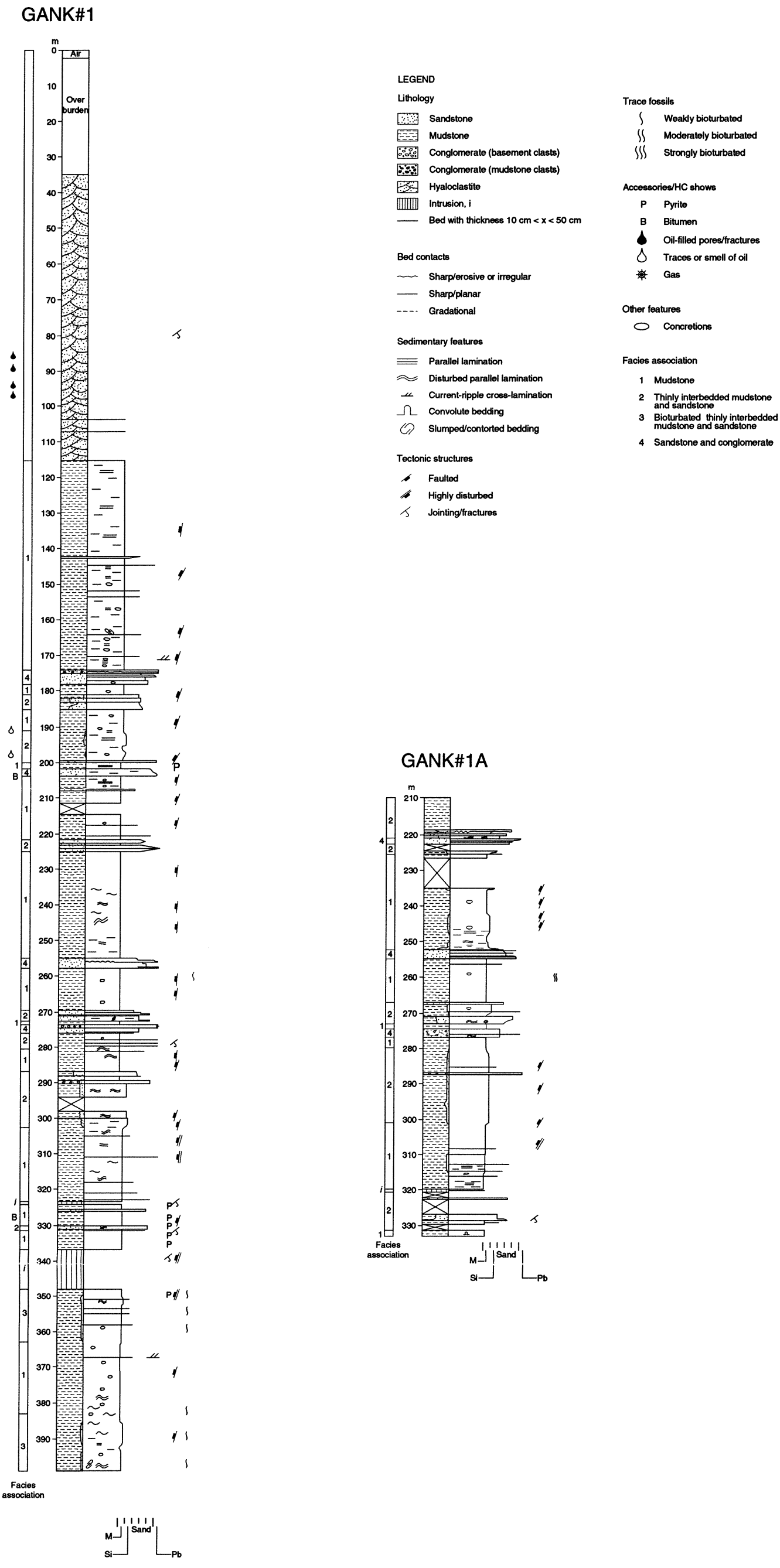


Figure 4. Simplified sedimentological log of the GANK#1 and #1A cores.

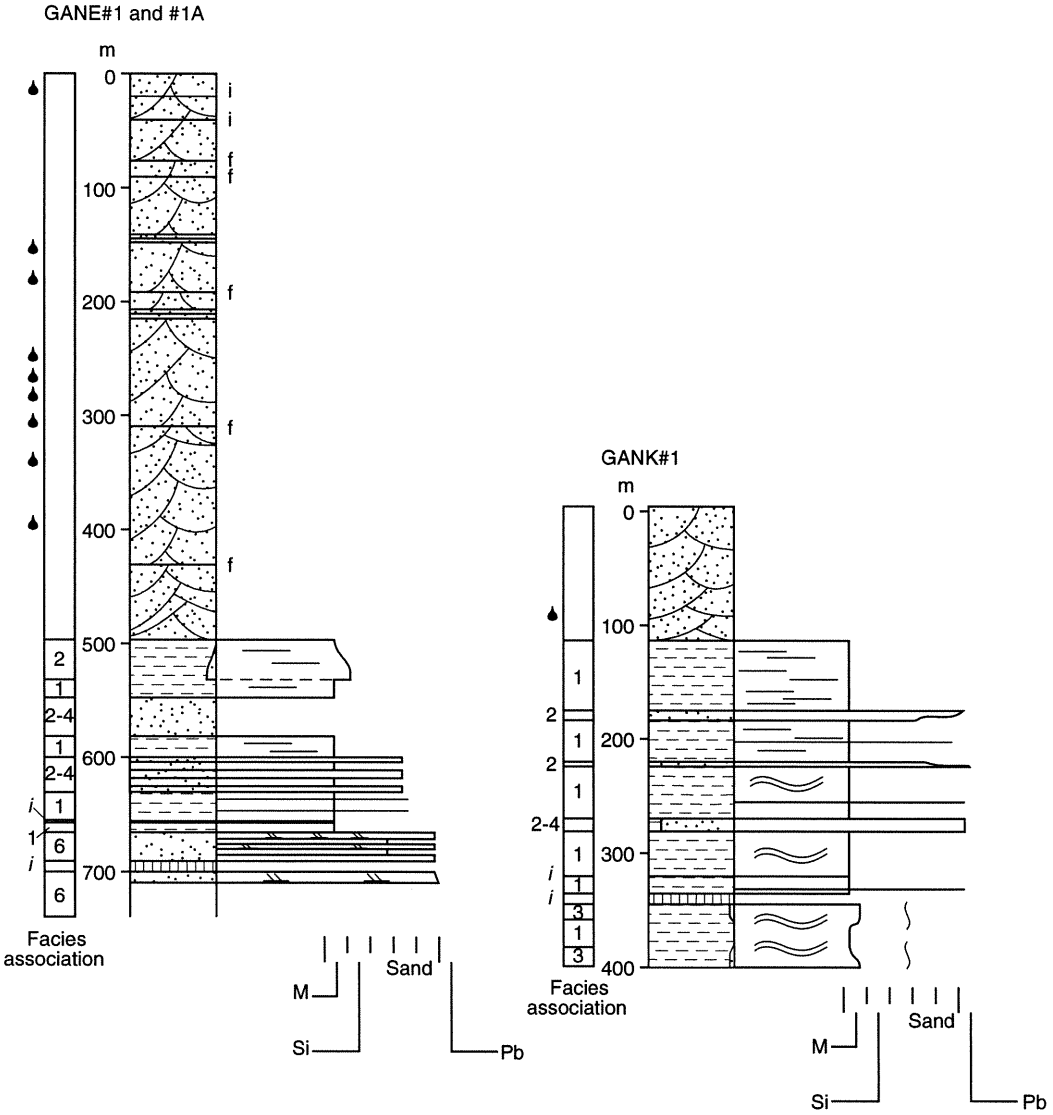


Figure 5. Simplified sedimentological logs of the GANE#1, GANK#1 and GANK#1A cores.

## APPENDICES

Appendix I: Drilling programme

Appendix II: Lithological summary

Appendix III: Core box list

Appendix IV: Core sample list

Appendix V: Additional samples, water, contaminants etc.

## Appendix I

## Drilling programme

**Drilling programme**

| Date | Time | Activities |
|---|---|---|
| 09-Aug | 20:00-24:00 | Helilift drilling rig to GANK #1 |
| 10-Aug | 00:00-20:00 | Helilift drilling rig to GANK #1 |
| | 20:00-24.00 | Helilift and assemble drilling rig |
| 11-Aug | 00:00-12:00 | Helilift and assemble drilling rig |
| | 12:00-20:00 | Drill HW conductor casing to 10 m |
| | 20:00-24:00 | Drill HW conductor casing to 20 m |
| 12-Aug | 00:00-20:00 | Drill HW conductor casing to 20 m |
| | 20:00-24:00 | Drill NW casing to 103 m |
| 13-Aug | 00:00-20:00 | Drill NW casing to 103 m |
| | 20:00-24:00 | Drill NW casing to 145 m |
| 14-Aug | 00:00-20:00 | Drill NW casing to 145 m |
| | 20:00-24.00 | Drill NW casing to 168 m, high torque and core barrel |
| 15-Aug | 00:00-06:00 | sticking in drill rods. Engine transmission overheating<br>Pumped two 20 l sweeps of jet fuel |
| | 06:00-08:00 | Circulate NW casing and prepare to cement |
| | 08:00-09:00 | Mix 20 sacks (800 kg) of Class 'A' cement. Slurry volume 0.6 $m^3$. Mix 3% (24 kg) of $CaCl_2$ and 0.5% (4 kg) of T-10 turbulence inducer<br>Displaced cement with 0.44 $m^3$ of water to 165 m |
| | 09:00-21:00 | Waiting on cement |
| | 21:00-24:00 | Pressure tested casing to 7000 kPa. Headed up and pressure tested BOP, mud and choke manifolds and flare lines to 7000 kPa<br>Pressure dropped to 6200 kPa and holding |
| 16-Aug | 00:00-05:00 | Run drill rods in hole and drill cement from 160 m to 168 m<br>Drill out landing ring and bit in core barrel |
| | 05:00-08:00 | Pull drill rods and replace bit |
| | 08:00-10:00 | Drill NQ hole from 168 m to 170 m |

| | | |
|---|---|---|
| 16-Aug | 10.00-10:30 | Conduct formation pressure integrity test. Leak off pressure at surface 1550 kPa. Equivalent mud weight at surface casing shoe 1950 kg/m$^3$ |
| | 10:30-13:30 | Replace transmission on drill rig |
| | 13:00-20:00 | Drill NQ hole from 170 m to 186 m |
| | 20:00-24:00 | Drill NQ hole from 186 m to 260 m |
| 17-Aug | 00:00-20:00 | Drill NQ hole from 186 m to 260 m |
| | 20:00-24:00 | Drill NQ hole from 260 m to 329 m |
| 18-Aug | 00:00-20:00 | Drill NQ hole from 260 m to 329 m |
| | 20:00-24:00 | Drill NQ hole from 329 m to 384 m |
| 19-Aug | 00:00-20.00 | Drill NQ hole from 329 m to 384 m |
| | 20:00-24:00 | Core tube stuck in core barrel. Pull drill rods to remove core tube. Bearing on core tube damaged |
| 20-Aug | 00:00-08:00 | Run drill rods in hole. Hole sluffing 67 m of fill in hole. Try to circulated fill from hole with high viscosity polymer mud. Unsuccessful<br>Core tube plugging and losing circulation |
| | 08:00-12:00 | Pull drill rods and unplug core barrel<br>Layout 2 drill rods due to severe wear and cutting |
| | 12:00-16:00 | Run drill rods in hole without core tube and try to circulate fill from hole. Unsuccessful |
| | 16:00-20:00 | Pull drill rods and remove core barrel and install mill tooth bit and run drill rods in hole |
| | 20:00-24:00 | Circulate drill rods to 396 m. Drill rods parted at 213 m |
| 21-Aug | 00:00-05:00 | Circulate drill rods to 396 m. Drill rods parted at 213 m |
| | 05:00-08:00 | Attempt to fish drill rods from hole. Unsuccessfull<br>Fish stuck in hole, unable to pull free |
| | 08:00-12:00 | Pull drill rods and inspect all connections |
| | 12:00-20:00 | Inspect all drill rod connections |
| | 20:00-22:00 | Inspect drill rods connections. NQ drill rod connections are visially machined offcentre |
| | 22:00-23:00 | Run drill rods to 165 m |

| | | |
|---|---|---|
| 21-Aug | 23:00-24:00 | Mix and pump 7 sacks (280 kg) class cement with 3% $CaCl_2$ and 0.5% T-10 |
| | | Squeeze cement from 165 m to 213 m |
| 22-Aug | 00:00-24:00 | Waiting on cement |
| 23-Aug | 00:00-09:00 | Waiting on cement |
| | 09:00-12:00 | Pull drill rods from hole. Gas perculating from well |
| | | Hard gas cut cement 30 m inside drill rods due to increasing gas pressure pushing cement up hole |
| | 12:00-14:00 | Run drill rods in hole and drill gas cut hard cement from 165 m to 180 m |
| | 14:00-20:00 | Run drill rods to 212 m and drill NQ hole from 212 m to 244 m. Drill rods kickoff top of fish at 212 m. |
| 24-Aug | 20:00-24:00 | Drill NQ hole from 244 m to 326 m |
| | 00:00-17:00 | Drill NQ hole from 244 m to 326 m |
| | 17:00-20:00 | Drill NQ hole from 326 to 327 m. Severe faulting at 326 m Unable to circulate and high torque on drill rods |
| | 20:00-24:00 | Drill NQ hole from 327 m to 333 m |
| | | Mix and pump 2 $m^3$ of high viscosity drilling fluid |
| 25-Aug | 00:00-12:00 | Severe faulting at 326 m. Unable to circulate and high torque on drill rods. Chuck jaws slipping on drill rods and engine overheating |
| | | Drill rods stuck in hole several times |
| | 12:00-15:00 | Pull drill rods and check core barrel for damage. Core barrel cut and severely worn |
| | | Lay out 2 joints of drill rods due to wear |
| | 15:00-17:00 | Run drill rods to 300 m and squeeze 0.5 $m^3$ (16 sacks) of class A cement with 3% (20 kg) of $CaCl_2$ and 0.5% (3 kg) of T-10. Pull drill rods to 165 m and shut-in well |
| | 17:00-24:00 | Waiting on cement |
| 26-Aug | 00:00-20:00 | Waiting on cement |
| | 20:00-22:00 | Pull drill rods and pick up core barrel and run in hole |
| | 22:00-24:00 | Tag cement at 300 m. Drill firm cement from 300 m to 330 m. Drill rods sticking and excessive high torque |

| | | |
|---|---|---|
| 26-Aug | 22:00-24:00 | Unable to circulate. Hole packing off around core barrel |
| | | Work drill rods and mix and pump high viscosity mud |
| 27-Aug | 00:00-01:00 | Drill NQ hole from 330 m to 333 m. Unable to circulate |
| | | Hole packing off around core barrel |
| | | Drill rods sticking and excessive high torque |
| | | Drill rods stuck at 333 m |
| | 01:00-01:30 | Drill rods stuck, work drill rods |
| | | Drill rods parted at 300 m |
| | 01:30-03:00 | Pull drill rods. Drill rods parted on pin connection |
| | 03:00-12:00 | Waiting on cement |
| | 12:00-13:00 | Mix and squeeze 1 $m^3$ (32 sacks) 1280 kg class A cement with 1% $CaCl_2$ and 0.5% T-10. Squeeze cement 20 m below well head. Shut-in well |
| | | Maximum pumping pressure was 2800 kPa at 20 l/min |
| | 13:00-24:00 | Waiting on cement. Tear out drilling rig. Clean drill site |
| 28-Aug | 00:00-20:00 | Waiting on cement. Tear out drilling rig. Clean drill site |

## Appendix II

## Lithological summary

The following is a summary of the description of the core at the drill site.

0–34.9 m Overburden.

34.9–114.9 m Hyaloclastite. The clasts are grey to yellow brown, angular, vesicular and matrix supported. The size of the clasts is up to 16 cm. Matrix is green to very dark green micro- to mesocrystalline occasionally with mafic minerals up to 2 mm across, non-calcareous with abundant white quartz and calcite veining. From 103.6 m to 114.9 m two thin beds (10 and 15 cm) of dark grey mudstone occur.

114.9–173.9 m Mudstone, dark grey, non-calcareous, non-swelling, platey. Glassy along fractures (slickensides), finely laminated. From 150 m ball-shape carbonate concretions occur. Between 141 m and 153 m the mudstone has a higher content of sand and is interbedded with 10–30 cm thick laminated, fine- to medium-grained sandstone.

173.9–177.8 m Sandstone, in the uppermost section consists of poorly sorted very coarse and pebbly sandstone, with subangular to subrounded clasts. Towards the base it consists of well-sorted medium-grained sandstone.

177.8–180.9 m Mudstone, dark grey, almost black, faulted with glassy fractures, slickensides.

180.9–185.1 m Sandstone, fine- to medium-grained, poorly sorted, disturbed bedding.

185.1–199.2 m Mudstone, dark grey, almost black, few 2–5 cm layers of soft clay. Fractured core due to faulting. Partly sandy.

199.2–203.5 m Sandstone, poorly sorted and coarse-grained to pebbly in top with clasts of siltstone and mudstones 1–20 mm across.

203.5–220.5 m Mudstone, dark grey, fractured. Interbedded with two sandstone beds, approx. 15 and 40 cm thick, poorly sorted, fine-grained. Coal? fragment recognised in the upper part of the mudstone.

220.5–225.1 m Sandstones interlayered with mudstones. The sandstones are poorly sorted and have disturbed bedding and coarsening-upward grading in the uppermost part. Some beds contain pebbles.

225.1–255.1 m Mudstone, dark grey to black, very fractured core due to faulting.

255.1–257.8 m Sandstones, fine to coarse-grained. Single bed of well-sorted medium-grained sandstone, approximately 1 m thick. Other beds are poorly sorted.

257.8–269.8 m Mudstone, dark grey to black with abundant slickensides, broken core, few concretions.

269.8–280.9 m Sandstones and conglomerates alternating with mudstones. Sandstones, poorly sorted, very fine to coarse-grained, thickness of beds from 10 to 100 cm. Conglomerates are mud-supported and contain mostly subangular to rounded yellow brown volcanic clasts and subangular mudstone clasts. Thickness from 10 to 70 cm. Mudstone, dark grey to black, hard, with slickensides. Thickness ranges from 15 to 190 cm.

280.9–302.5 m Mudstone, sandy, dark grey, faulted with slickensides. Rare sandstone beds and poorly sorted mud-supported conglomerates.

302.5–323.5 m Mudstone, dark grey, faulted. Few thin sandstone beds, 10–30 cm thick with disturbed bedding, fine-grained.

323.5–324.3 m Volcanic intrusion, pale green.

324.3–332.2 m Mudstone interlayered with sandstone beds. Mudstone, dark grey to black, laminated, pyrite common, faulted with slickensides. 3 cm thick coal? fragment recognised in the mudstone. Sandstone, fine- to coarse-grained, poorly sorted with mudstone clasts 2–50 mm across. Thickness of beds from 5–80 cm.

332.2–336.8 m Mudstone, black, with slickensides. A few occurrences of pyrite.

336.8–346.9 m Volcanic intrusion, vein-fillings with quartz.

346.9–399.0 m Mudstone, dark grey, laminated. Occasional pyrite and concretions. Slickensides. Few and thin sandstone beds of very fine- to fine-grained sand, thickness ranges from 2 to 100 mm. The sandstone beds appear bioturbated.

## Appendix III

## Core box list

| Box no | Top of box, m | Bottom of box, m |
|---|---|---|
| 1 | 34.88 | 38.10 |
| 2 | 38.10 | 41.06 |
| 3 | 41.06 | 44.30 |
| 4 | 44.30 | 47.72 |
| 5 | 47.72 | 50.97 |
| 6 | 50.97 | 52.96 |
| 7 | 52.96 | 57.00 |
| 8 | 57.00 | 60.15 |
| 9 | 60.15 | 63.28 |
| 10 | 63.28 | 66.41 |
| 11 | 66.41 | 69.58 |
| 12 | 69.58 | 72.77 |
| 13 | 72.77 | 75.92 |
| 14 | 75.92 | 79.06 |
| 15 | 79.06 | 82.25 |
| 16 | 82.25 | 85.30 |
| 17 | 85.30 | 88.41 |
| 18 | 88.41 | 91.66 |
| 19 | 91.66 | 94.82 |
| 20 | 94.82 | 97.98 |
| 21 | 97.98 | 101.80 |
| 22 | 101.80 | 104.19 |
| 23 | 104.19 | 107.25 |
| 24 | 107.25 | 109.92 |
| 25 | 109.92 | 112.98 |
| 26 | 112.98 | 115.81 |
| 27 | 115.81 | 118.80 |
| 28 | 118.80 | 121.51 |
| 29 | 121.51 | 124.20 |
| 30 | 124.20 | 127.10 |
| 31 | 127.10 | 129.54 |
| 32 | 129.54 | 132.50 |
| 33 | 132.50 | 135.14 |
| 34 | 135.14 | 137.75 |
| 35 | 137.75 | 142.04 |
| 36 | 142.04 | 144.43 |
| 37 | 144.43 | 147.59 |
| 38 | 147.59 | 150.19 |
| 39 | 150.19 | 153.34 |
| 40 | 153.34 | 156.03 |
| 41 | 156.03 | 158.90 |
| 42 | 158.90 | 161.91 |
| 43 | 161.91 | 164.63 |
| 44 | 164.63 | 167.11 |
| 45 | 167.11 | 167.94 |
| 46 | 167.94 | 170.79 |
| 47 | 170.79 | 173.01 |
| 48 | 173.01 | 175.89 |
| 49 | 175.89 | 178.40 |
| 50 | 178.40 | 182.11 |
| 51 | 182.11 | 186.06 |
| 52 | 186.06 | 188.98 |
| 53 | 188.98 | 189.28 |
| 53 | 189.28 | 191.41 |
| 54 | 191.41 | 194.77 |
| 55 | 194.77 | 197.53 |
| 56 | 197.53 | 200.08 |
| 57 | 200.08 | 202.82 |
| 58 | 202.82 | 205.97 |
| 59 | 205.97 | 206.35 |
| 59 | 206.35 | 208.84 |
| 60 | 208.84 | 211.53 |
| 61 | 211.53 | 218.01 |
| 62 | 218.01 | 220.99 |
| 63 | 220.99 | 224.07 |
| 64 | 224.07 | 226.24 |
| 65 | 226.24 | 228.35 |
| 66 | 228.35 | 230.52 |

| Box no | Top of box, m | Bottom of box, m |
|---|---|---|
| 67 | 230.52 | 233.58 |
| 68 | 233.58 | 235.94 |
| 69 | 235.94 | 239.13 |
| 70 | 239.13 | 241.65 |
| 71 | 241.65 | 244.60 |
| 72 | 244.60 | 247.28 |
| 73 | 247.28 | 252.71 |
| 74 | 252.71 | 255.89 |
| 75 | 255.89 | 259.18 |
| 76 | 259.18 | 262.44 |
| 77 | 262.44 | 265.39 |
| 78 | 265.39 | 267.69 |
| 79 | 267.69 | 270.61 |
| 80 | 270.61 | 273.59 |
| 81 | 273.59 | 276.01 |
| 82 | 276.01 | 279.38 |
| 83 | 279.38 | 281.94 |
| 84 | 281.94 | 284.98 |
| 85 | 284.98 | 287.45 |
| 86 | 287.45 | 290.55 |
| 87 | 290.55 | 293.10 |
| 88 | 293.10 | 299.92 |
| 89 | 299.92 | 301.01 |
| 90 | 301.01 | 305.41 |
| 91 | 305.41 | 308.61 |
| 92 | 308.61 | 311.51 |
| 93 | 311.51 | 314.93 |
| 94 | 314.93 | 317.62 |
| 95 | 317.62 | 320.97 |
| 96 | 320.97 | 323.83 |
| 97 | 323.83 | 326.42 |
| 98 | 326.42 | 329.47 |
| 99 | 329.47 | 332.15 |
| 100 | 332.15 | 335.23 |
| 101 | 335.23 | 337.28 |
| 102 | 337.28 | 340.12 |
| 103 | 340.12 | 342.52 |
| 104 | 342.52 | 345.57 |
| 105 | 345.57 | 348.80 |
| 106 | 348.80 | 351.33 |
| 107 | 351.33 | 354.20 |
| 108 | 354.20 | 357.66 |
| 109 | 357.66 | 360.50 |
| 110 | 360.50 | 364.00 |
| 111 | 364.00 | 367.46 |
| 112 | 367.46 | 370.33 |
| 113 | 370.33 | 373.47 |
| 114 | 373.47 | 376.43 |
| 115 | 376.43 | 379.64 |
| 116 | 379.64 | 382.71 |
| 117 | 382.71 | 386.02 |
| 118 | 386.02 | 388.91 |
| 119 | 388.91 | 392.10 |
| 120 | 392.10 | 395.28 |
| 121 | 395.28 | 398.39 |
| 122 | 398.39 | 399.28 |
| 123 | 218.55 | 221.74 |
| 124 | 221.74 | 235.67 |
| 125 | 235.67 | 239.36 |
| 126 | 239.36 | 242.19 |
| 127 | 242.19 | 245.58 |
| 128 | 245.58 | 248.57 |
| 129 | 248.57 | 251.36 |
| 130 | 251.36 | 254.50 |
| 131 | 254.50 | 257.34 |
| 132 | 257.34 | 260.83 |
| 133 | 260.83 | 263.91 |
| 134 | 263.91 | 267.65 |

| Box no | Top of box, m | Bottom of box, m |
|---|---|---|
| 135 | 267.65 | 270.34 |
| 136 | 270.34 | 273.25 |
| 137 | 273.25 | 276.36 |
| 138 | 276.36 | 279.61 |
| 139 | 279.61 | 282.51 |
| 140 | 282.51 | 285.82 |
| 141 | 285.82 | 288.34 |
| 142 | 288.34 | 292.66 |
| 143 | 292.66 | 296.46 |
| 144 | 296.46 | 298.94 |
| 145 | 298.94 | 301.59 |
| 146 | 301.59 | 304.11 |
| 147 | 304.11 | 306.80 |
| 148 | 306.80 | 309.75 |
| 149 | 309.75 | 312.82 |
| 150 | 312.82 | 315.49 |
| 151 | 315.49 | 318.62 |
| 152 | 318.62 | 325.71 |
| 153 | 325.71 | 331.52 |
| 154 | 331.52 | 332.84 |

## Appendix IV

## Core sample list

| Sub no | Depth, m | Date | Time | Type | Core box no |
|---|---|---|---|---|---|
| -1 | 35.35 | 14-Aug | 08:00 | Canned | 1 |
| -2 | 38.93 | | 08:15 | Canned | 2 |
| -3 | 43.14 | | 08:50 | Canned | 3 |
| -4 | 46.39 | | 09:05 | Canned | 4 |
| -5 | 49.69 | | 09:15 | Canned | 5 |
| -6 | 50.91 | | 09:30 | Canned | 6 |
| -7 | 55.95 | | 09:45 | Canned | 7 |
| -8 | 59.12 | | 10:05 | Canned | 8 |
| -9 | 63.02 | | 10:15 | Canned | 9 |
| -10 | 64.29 | | 10:30 | Canned | 10 |
| -11 | 68.52 | | 10:45 | Canned | 11 |
| -12 | 72.11 | | 11:10 | Canned | 12 |
| -13 | 75.22 | | 11:20 | Canned | 13 |
| -14 | 76.89 | | 11:45 | Canned | 14 |
| -15 | 79.98 | | 12:00 | Canned | 15 |
| -16 | 84.41 | | 12:15 | Canned | 16 |
| -17 | 85.82 | | 12:40 | Canned | 17 |
| -20 | 89.42 | 13-Aug | 16:20 | Canned | 18 |
| -21 | 90.54 | | 17:40 | Canned | 18 |
| -22 | 96.23 | | 18:25 | Canned | 20 |
| -23 | 97.73 | | 19:05 | Canned | 20 |
| -24 | 102.64 | | 21:30 | Canned | 22 |
| -25 | 105.87 | | 22:15 | Canned | 23 |
| -26 | 108.25 | | 23:30 | Canned | 24 |
| -27 | 111.36 | 14-Aug | 00:00 | Canned | 25 |
| -28 | 114.82 | | 01:00 | Canned | 26 |
| -29 | 117.95 | | 02:10 | Canned | 27 |
| -30 | 120.93 | | 03:00 | Canned | 28 |
| -31 | 123.98 | | 03:45 | Canned | 29 |
| -32 | 127.02 | | 04:45 | Canned | 30 |
| -33 | 130.06 | | 06:00 | Canned | 32 |
| -34 | 131.71 | | 07:30 | Canned | 32 |
| -35 | 133.90 | | 09:10 | Canned | 33 |
| -36 | 136.17 | 14-Aug | 17:25 | Canned | 34 |
| -37 | 142.34 | | 18:20 | Canned | 36 |
| -38 | 144.06 | | 20:00 | Canned | 36 |
| -39 | 148.44 | | 22:00 | Canned | 38 |
| -40 | 151.49 | | 22:45 | Canned | 39 |
| -41 | 154.53 | | 23:45 | Canned | 40 |
| -42 | 157.58 | 15-Aug | 00:30 | Canned | 41 |
| -43 | 160.63 | | 01:50 | Canned | 42 |
| -44 | 163.08 | | 02:40 | Canned | 43 |
| -45 | 166.08 | | 03:50 | Canned | 44 |
| -46 | 167.61 | | 05:00 | Canned | 45 |
| -47 | 170.14 | 16-Aug | 15:15 | Canned | 46 |
| -48 | 174.71 | | 16:30 | Canned | 48 |
| -49 | 175.89 | | 17:10 | Canned | 49 |
| -50 | 180.84 | | 17:30 | Canned | 50 |
| -51 | 184.95 | | 18:40 | Canned | 51 |
| -52 | 188.90 | | 21:05 | Canned | 52 |
| -53 | 190.83 | | 21:40 | Canned | 53 |
| -54 | 194.47 | | 22:25 | Canned | 54 |
| -55 | 195.30 | | 22:30 | Canned | 55 |
| -56 | 198.74 | | 23:15 | Canned | 56 |
| -57 | 201.34 | 17-Aug | 00:15 | Canned | 57 |
| -58 | 203.22 | | 01:45 | Canned | 58 |
| -59 | 206.35 | | 01:50 | Canned | 59 |
| -60 | 208.48 | | 02:50 | Canned | 59 |
| -61 | 211.53 | | 03:00 | Canned | 60 |
| -62 | 217.93 | | 03:55 | Canned | 61 |
| -63 | 220.42 | | 07:20 | Canned | 62 |
| -64 | 223.96 | | 07:30 | Canned | 63 |
| -65 | 225.10 | | 08:15 | Canned | 64 |
| -66 | 229.38 | | 09:05 | Canned | 66 |
| -67 | 233.50 | | 09:35 | Canned | 67 |
| -68 | 235.08 | | 10:50 | Canned | 68 |
| -69 | 238.28 | | 11:10 | Canned | 69 |
| -70 | 240.25 | | 11:40 | Canned | 70 |

| Sub no | Depth, m | Date | Time | Type | Core box no |
|---|---|---|---|---|---|
| -71 | 242.97 | | 12:45 | Canned | 71 |
| -72 | 247.74 | | 14:10 | Canned | 73 |
| -73 | 252.25 | | 16:50 | Canned | 73 |
| -74 | 253.78 | | 17:40 | Canned | 74 |
| -75 | 258.93 | | 18:20 | Canned | 75 |
| -76 | 259.29 | | 18:55 | Canned | 76 |
| -77 | 262.74 | | 19:00 | Canned | 77 |
| -78 | 268.74 | | 20:45 | Canned | 78 |
| -79 | 270.36 | | 22:00 | Canned | 79 |
| -80 | 272.19 | | 23:45 | Canned | 80 |
| -81 | 275.54 | 18-Aug | 00:15 | Canned | 81 |
| -82 | 278.59 | | 00:30 | Canned | 82 |
| -83 | 281.64 | | 02:55 | Canned | 83 |
| -84 | 284.68 | | 03:00 | Canned | 84 |
| -85 | 286.60 | | 04:00 | Canned | 85 |
| -86 | 290.47 | | 05:10 | Canned | 86 |
| -87 | 292.05 | | 06:00 | Canned | 87 |
| -88 | 293.00 | | 07:00 | Canned | 87 |
| -89 | 298.72 | | 09:15 | Canned | 88 |
| -90 | 301.16 | | 10:00 | Canned | 89 |
| -91 | 304.50 | | 11:15 | Canned | 90 |
| -92 | 308.10 | | 12:20 | Canned | 91 |
| -93 | 310.24 | | 13:30 | Canned | 92 |
| -94 | 313.18 | | 14:45 | Canned | 93 |
| -95 | 316.51 | | 15:10 | Canned | 94 |
| -96 | 318.77 | | 16:10 | Canned | 95 |
| -97 | 321.78 | | 17:10 | Canned | 96 |
| -98 | 323.83 | | 17:40 | Canned | 97 |
| -99 | 326.87 | | 20:10 | Canned | 98 |
| -100 | 330.94 | | 20:15 | Canned | 99 |
| -101 | 332.23 | | 21:45 | Canned | 100 |
| -102 | 335.30 | | 22:00 | Canned | 101 |
| -103 | 337.96 | | 22:30 | Canned | 102 |
| -104 | 340.22 | | 23:45 | Canned | 103 |
| -105 | 343.28 | 19-Aug | 02:00 | Canned | 104 |
| -106 | 346.57 | | 04:20 | Canned | 105 |
| -107 | 349.61 | | 05:00 | Canned | 106 |
| -108 | 352.13 | | 07:00 | Canned | 107 |
| -109 | 355.70 | | 08:00 | Canned | 108 |
| -110 | 357.28 | | 08:35 | Canned | 108 |
| -111 | 359.86 | | 09:15 | Canned | 109 |
| -112 | 363.40 | | 10:15 | Canned | 110 |
| -113 | 365.88 | | 12:00 | Canned | 111 |
| -114 | 368.12 | | 12:40 | Canned | 112 |
| -115 | 371.81 | | 13:30 | Canned | 113 |
| -116 | 373.47 | | 14:30 | Canned | 114 |
| -117 | 375.85 | | 15:15 | Canned | 114 |
| -118 | 379.46 | | 16:10 | Canned | 115 |
| -119 | 380.37 | | 22:50 | Canned | 116 |
| -120 | 384.35 | 20-Aug | 03:10 | Canned | 117 |
| -121 | 386.96 | | 04:00 | Canned | 118 |
| -122 | 389.53 | | 05:55 | Canned | 119 |
| -123 | 392.58 | | 06:00 | Canned | 120 |
| -124 | 395.82 | | 07:00 | Canned | 121 |
| -125 | 396.50 | | 10:20 | Canned | 121 |
| -126 | 243.27 | 23-Aug | 20:00 | Canned | 127 |
| -127 | 245.60 | | 20:45 | Canned | 128 |
| -128 | 250.06 | | 21:15 | Canned | 129 |
| -129 | 252.36 | | 22:00 | Canned | 130 |
| -130 | 255.50 | | 22:30 | Canned | 131 |
| -131 | 258.19 | | 23:15 | Canned | 132 |
| -132 | 262.08 | | 23:50 | Canned | 133 |
| -133 | 263.02 | 24-Aug | 01:45 | Canned | 133 |
| -134 | 268.25 | | 02:15 | Canned | 135 |
| -135 | 270.89 | | 02:45 | Canned | 136 |
| -136 | 274.82 | | 03:15 | Canned | 137 |
| -137 | 276.60 | | 03:45 | Canned | 138 |
| -138 | 279.76 | | 04:20 | Canned | 139 |

| Sub no | Depth, m | Date | Time | Type | Core box no |
|---|---|---|---|---|---|
| -139 | 282.85 | | 04:50 | Canned | 140 |
| -140 | 285.46 | | 05:20 | Canned | 140 |
| -141 | 288.47 | | 05:50 | Canned | 142 |
| -142 | 290.36 | | 06:15 | Canned | 142 |
| -143 | 293.15 | | 06:50 | Canned | 143 |
| -144 | 296.44 | | 07:25 | Canned | 143 |
| -145 | 297.47 | | 08:20 | Canned | 144 |
| -146 | 299.79 | | 09:00 | Canned | 145 |
| -147 | 302.47 | | 10:00 | Canned | 146 |
| -148 | 304.31 | | 10:30 | Canned | 147 |
| -149 | 306.80 | | 11:05 | Canned | 148 |
| -150 | 309.89 | | 11:45 | Canned | 149 |
| -151 | 312.88 | | 13:00 | Canned | 150 |
| -152 | 315.55 | | 14:00 | Canned | 151 |
| -153 | 318.77 | | 14:30 | Canned | 152 |
| -154 | 320.47 | | 15:00 | Canned | 152 |
| -155 | 326.44 | | 17:40 | Canned | 153 |
| -501 | 38.01 | 14-Aug | 08:00 | Chip | 1 |
| -502 | 39.02 | | 08:20 | Chip | 2 |
| -503 | 43.23 | | 08:55 | Chip | 3 |
| -504 | 46.48 | | 09:10 | Chip | 4 |
| -505 | 49.78 | | 09:15 | Chip | 5 |
| -506 | 51.00 | | 09:35 | Chip | 6 |
| -507 | 55.93 | | 09:50 | Chip | 7 |
| -508 | 59.10 | | 10:06 | Chip | 8 |
| -509 | 63.00 | | 10:20 | Chip | 9 |
| -510 | 64.38 | | 10:35 | Chip | 10 |
| -511 | 68.61 | | 10:50 | Chip | 11 |
| -512 | 72.09 | | 11:15 | Chip | 12 |
| -513 | 75.20 | | 11:21 | Chip | 13 |
| -514 | 76.87 | | 11:50 | Chip | 14 |
| -515 | 79.96 | | 12:05 | Chip | 15 |
| -516 | 84.39 | | 12:20 | Chip | 16 |
| -517 | 85.80 | | 12:45 | Chip | 17 |
| -518 | 89.41 | | 12:51 | Chip | 18 |
| -519 | 90.63 | | 12:56 | Chip | 18 |
| -520 | 88.42 | | 13:00 | Foil | 18 |
| -521 | 96.21 | | 13:40 | Chip | 20 |
| -522 | 97.71 | | 13:45 | Chip | 20 |
| -523 | 96.63 | | 13:50 | Foil | 20 |
| -524 | 102.73 | | 14:45 | Chip | 22 |
| -525 | 105.78 | | 15:00 | Chip | 23 |
| -526 | 108.34 | | 15:10 | Chip | 24 |
| -527 | 111.34 | | 15:20 | Chip | 25 |
| -528 | 114.80 | | 15:40 | Chip | 26 |
| -529 | 115.01 | | 15:55 | Chip | 27 |
| -530 | 120.91 | | 16:05 | Chip | 28 |
| -531 | 124.07 | | 16:20 | Chip | 29 |
| -532 | 127.00 | | 16:26 | Chip | 30 |
| -533 | 130.04 | | 16:40 | Chip | 32 |
| -534 | 131.80 | | 16:46 | Chip | 32 |
| -535 | 133.99 | | 16:52 | Chip | 33 |
| -536 | 136.15 | | 17:00 | Chip | 34 |
| -537 | 140.20 | 15-Aug | 09:00 | Canned | 35 |
| -538 | 140.19 | | 09:00 | Chip | 35 |
| -539 | 142.34 | | 09:50 | Chip | 36 |
| -540 | 143.34 | | 09:50 | Chip | 36 |
| -541 | 148.61 | | 10:40 | Chip | 38 |
| -542 | 151.57 | | 10:40 | Chip | 39 |
| -543 | 154.53 | | 11:20 | Chip | 40 |
| -544 | 157.75 | | 11:20 | Chip | 41 |
| -545 | 158.59 | | 12:55 | Canned | 41 |
| -546 | 158.97 | | 12:55 | Canned | 42 |
| -547 | 160.71 | | 13:05 | Chip | 42 |
| -548 | 163.08 | | 13:20 | Chip | 43 |
| -549 | 164.15 | | 13:40 | Canned | 43 |
| -550 | 166.16 | | 14:00 | Chip | 44 |
| -551 | 167.99 | | 14:00 | Chip | 45 |

| Sub no | Depth, m | Date | Time | Type | Core box no |
|---|---|---|---|---|---|
| -552 | 170.14 | 16-Aug | 18:15 | Chip | 46 |
| -553 | 174.71 | | 19:00 | Chip | 48 |
| -554 | 175.89 | | 19:00 | Chip | 49 |
| -555 | 180.84 | 17-Aug | 08:30 | Chip | 50 |
| -556 | 184.95 | | 08:45 | Chip | 51 |
| -557 | 188.90 | | 09:00 | Chip | 52 |
| -558 | 190.83 | | 09:20 | Chip | 53 |
| -559 | 194.47 | | 09:45 | Chip | 54 |
| -560 | 190.30 | | 09:50 | Canned | 53 |
| -561 | 195.30 | | 10:30 | Chip | 55 |
| -562 | 198.74 | | 10:45 | Chip | 56 |
| -563 | 201.34 | | 11:15 | Chip | 57 |
| -564 | 203.22 | | 11:45 | Chip | 58 |
| -565 | 204.28 | | 11:45 | Chip | 58 |
| -566 | 206.35 | | 12:15 | Chip | 59 |
| -567 | 208.48 | | 12:15 | Chip | 59 |
| -568 | 211.53 | | 12:30 | Chip | 60 |
| -569 | 217.93 | | 13:30 | Chip | 61 |
| -570 | 220.42 | | 13:40 | Chip | 62 |
| -571 | 223.96 | | 14:00 | Chip | 63 |
| -572 | 225.10 | | 14:10 | Chip | 64 |
| -573 | 227.08 | | 14:20 | Chip | 65 |
| -574 | 229.38 | | 14:20 | Chip | 66 |
| -575 | 233.50 | | 15:15 | Chip | 67 |
| -576 | 234.98 | | 15:15 | Chip | 68 |
| -577 | 238.28 | | 15:40 | Chip | 69 |
| -578 | 240.25 | | 15:45 | Chip | 70 |
| -579 | 242.97 | | 16:00 | Chip | 71 |
| -580 | 246.58 | | 16:45 | Chip | 72 |
| -581 | 247.74 | | 18:15 | Chip | 73 |
| -582 | 252.25 | | 18:15 | Chip | 73 |
| -583 | 253.78 | 18-Aug | 08:15 | Chip | 74 |
| -584 | 258.93 | | 08:15 | Chip | 75 |
| -585 | 259.29 | | 08:50 | Chip | 76 |
| -586 | 262.74 | | 09:00 | Chip | 77 |
| -587 | 268.82 | | 09:30 | Chip | 78 |
| -588 | 270.36 | | 09:30 | Chip | 79 |
| -589 | 272.19 | | 09:45 | Chip | 80 |
| -590 | 275.54 | | 09:45 | Chip | 81 |
| -591 | 278.59 | | 10:30 | Chip | 82 |
| -592 | 281.64 | | 10:30 | Chip | 83 |
| -593 | 284.68 | | 11:00 | Chip | 84 |
| -594 | 286.68 | | 11:00 | Chip | 85 |
| -595 | 290.47 | | 11:15 | Chip | 86 |
| -596 | 293.00 | | 11:15 | Chip | 87 |
| -597 | 298.72 | | 12:05 | Chip | 88 |
| -598 | 301.16 | | 12:05 | Chip | 89 |
| -599 | 303.37 | | 16:00 | Chip | 90 |
| -600 | 308.10 | | 16:00 | Chip | 91 |
| -601 | 310.24 | | 16:30 | Chip | 92 |
| -602 | 313.18 | | 17:00 | Chip | 93 |
| -603 | 316.51 | | 17:30 | Chip | 94 |
| -604 | 318.77 | | 18:15 | Chip | 95 |
| -605 | 321.78 | | 18:15 | Chip | 96 |
| -606 | 323.91 | 19-Aug | 08:10 | Chip | 97 |
| -607 | 326.87 | | 08:10 | Chip | 98 |
| -608 | 330.94 | | 08:50 | Chip | 99 |
| -609 | 332.23 | | 09:15 | Chip | 100 |
| -610 | 335.30 | | 10:00 | Chip | 101 |
| -611 | 337.96 | | 10:00 | Chip | 102 |
| -612 | 340.20 | | 10:20 | Chip | 103 |
| -613 | 343.28 | | 10:20 | Chip | 104 |
| -614 | 346.57 | | 10:55 | Chip | 105 |
| -615 | 349.61 | | 10:55 | Chip | 106 |
| -616 | 352.13 | | 11:30 | Chip | 107 |
| -617 | 355.70 | | 11:30 | Chip | 108 |
| -618 | 359.86 | | 13:05 | Chip | 109 |
| -619 | 363.40 | | 13:05 | Chip | 110 |

| Sub no | Depth, m | Date | Time | Type | Core box no |
|---|---|---|---|---|---|
| -620 | 365.88 | | 13:30 | Chip | 111 |
| -621 | 368.12 | | 15:00 | Chip | 112 |
| -622 | 371.81 | | 15:00 | Chip | 113 |
| -623 | 375.84 | | 17:00 | Chip | 114 |
| -624 | 377.04 | | 17:00 | Chip | 115 |
| -625 | 380.37 | 20-Aug | 08:20 | Chip | 116 |
| -626 | 384.35 | | 08:20 | Chip | 117 |
| -627 | 386.96 | | 09:40 | Chip | 118 |
| -628 | 389.61 | | 09:40 | Chip | 119 |
| -629 | 392.66 | | 10:40 | Chip | 120 |
| -630 | 396.50 | | 10:40 | Chip | 121 |
| -631 | 398.84 | 23-Aug | 20:40 | Chip | 122 |
| -632 | 219.90 | | 22:00 | Canned | 123 |
| -633 | 225.46 | | 22:00 | Canned | 124 |
| -634 | 235.81 | | 22:00 | Canned | 125 |
| -635 | 241.54 | | 22:00 | Canned | 126 |
| -636 | 219.90 | | 22:00 | Chip | 123 |
| -637 | 225.82 | | 22:00 | Chip | 124 |
| -638 | 235.79 | | 22:00 | Chip | 125 |
| -639 | 241.70 | | 22:00 | Chip | 126 |
| -640 | 243.27 | 24-Aug | 08:30 | Chip | 127 |
| -641 | 245.97 | | 08:30 | Chip | 128 |
| -642 | 250.14 | | 08:30 | Chip | 129 |
| -643 | 252.94 | | 09:30 | Chip | 130 |
| -644 | 256.36 | | 09:30 | Chip | 131 |
| -645 | 259.53 | | 09:30 | Chip | 132 |
| -646 | 263.16 | | 10:30 | Chip | 133 |
| -647 | 266.67 | | 10:30 | Chip | 134 |
| -648 | 268.25 | | 10:30 | Chip | 135 |
| -649 | 271.03 | | 12:00 | Chip | 136 |
| -650 | 274.77 | | 12:00 | Chip | 137 |
| -651 | 276.60 | | 12:00 | Chip | 138 |
| -652 | 279.76 | | 12:00 | Chip | 139 |
| -653 | 285.42 | | 13:30 | Chip | 140 |
| -654 | 286.82 | | 13:30 | Chip | 141 |
| -655 | 290.26 | | 13:30 | Chip | 142 |
| -656 | 293.23 | | 14:30 | Chip | 143 |
| -657 | 297.33 | | 14:30 | Chip | 144 |
| -658 | 299.79 | | 14:30 | Chip | 145 |
| -659 | 302.64 | | 16:00 | Chip | 146 |
| -660 | 304.50 | | 16:00 | Chip | 147 |
| -661 | 306.99 | | 16:00 | Chip | 148 |
| -662 | 309.98 | | 17:00 | Chip | 149 |
| -663 | 313.03 | | 17:00 | Chip | 150 |
| -664 | 316.08 | | 17:00 | Chip | 151 |
| -665 | 322.19 | 27-Aug | 13:10 | Chip | 152 |
| -666 | 326.28 | | 13:30 | Chip | 153 |
| -667 | 331.22 | | 13:30 | Chip | 153 |
| -668 | 332.36 | | 13:30 | Chip | 154 |

## Appendix V

## Additional samples, water, contaminants etc.

| GGU no | Depth, m | Time | Date | Type | Container | Comments |
|---|---|---|---|---|---|---|
| 439201 | | | 08/13 | Core | | GANK #1 and #1A |
| 439202 | 233.78 | 09:30 | 08/17 | Water | Bottle | Water sampled from circulation system, thin oil film on surface |
| 439203 | 364.85 | 11:45 | 08/19 | Water | Bottle | Water sampled from circulation system, H2S detector has been activiated at 11:15 to 11:30 |
| 439204 | 395.33 | 08:20 | 08/20 | Mud | Tin | Drilling mud |
| 439205 | | 08:40 | 08/20 | Rock | Plastic bag | Rubbles, outfall from the hole, not depthmarked |
| 439206 | | 08:40 | 08/20 | Rock | Plastic bag | Probably located between 1247-1297' |
| 439207 | | 08:40 | 08/20 | Rock | Plastic bag | and contaminated by fuel |
| 439208 | 398.98 | 15:30 | 08/20 | Rock | Plastic bag | Poor recovery from core tube, rubbles with pyrite |
| 439209 | | | 08/21 | Grease | Tin | Threadlube, ESSO, used when connecting the rods |
| 439210 | | | 08/21 | Oil | Tin | Transmission oil |
| 439211 | | | 08/27 | Grease | Tin | Rod grease |
| 439212 | | 21:00 | 08/23 | Water | Bottle | River water |
| 439213 | | 13:30 | 08/24 | Fuel | Tin | Turbofuel A-1 |
| 439214 | 328.27 | 17:30 | 08/24 | Water | Bottle | Water sampled from circulation system, GANK #1A |
| 439215 | | 14:30 | 08/27 | Water | Bottle | River water sampled from supply tank at the rig |
| 439216 | | 12:00 | 34939 | Water | Bottle | River water |