1981 OFFSHORE GEOTECHNICAL SITE INVESTIGATION IRKALUK B-35 BEAUFORT SEA

Report to
DOME PETROLEUM LTD.
Calgary, Alberta

by

EBA Engineering Consultants Ltd.

and

McClelland engineers, inc.

EBA Engineering Consultants Ltd.

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1982 06 18

Dome Petroleum Ltd.
5th Floor, Roslyn Building
400 - 5th Avenue S.W.
CALGARY, Alberta
T2P 2H8

OUR FILE: 101-3210

Attention: Mr. M.U. Gajtani
Senior Geotechnical Engineer

Dear Muharrem:

Re: Final Report - "1981 Offshore Geotechnical Site Investigation: Irkaluk" B-35, Beaufort Sea"

We are pleased to submit 10 copies of the subject report which are attached herewith. This constitutes our final transmittal for the Irkaluk foundation investigation. The project team of EBA and McClelland Engineers, Inc. has appreciated the opportunity to work on this Offshore Geotechnical Site Investigation program, and we hope that our contribution has been of value to Dome.

We would also like to thank you and your colleagues for the assistance and cooperation that was extended during the planning, execution, and reporting stages of this project. Should you have any questions or comments that arise regarding our final report, please do not hesitate to contact us.

Very truly yours,

EBA Engineering Consultants Ltd.

W.D. Roggensack, P.Eng.
Senior Project Engineer
Arctic Geotechnical Group

WDR/emb

Encl.

cc: Mr. C. Ehlers, P.E. - MEI

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Report No. 0181-0077
May 28, 1982

Dome Petroleum Limited
Beaufort Sea Operations Division
800 6th Avenue SW
Place 800 - ATCO Building
Calgary, Alberta
Canada T2P 2M7

Attention: Mr. Muharrem Gajtani

Geotechnical Investigation
Irkaluk B-35
Beaufort Sea

Gentlemen:

This report presents the results of our geotechnical investigation of soil and foundation conditions at the above offshore location. EBA Engineering Consultants Ltd. and McClelland Engineers, Inc. jointly performed this investigation under your General Agreement for Coring Services dated June 1, 1981.

We appreciate the opportunity to be of service to you in this interesting project. Please call us when we can be of further assistance.

Very truly yours,

McCLELLAND ENGINEERS, INC.

Clarence J. Ehlers

Clarence J. Ehlers, P.E.
Senior Engineer Manager

CJE/mmt

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS
OF ALBERTA
PERMIT NUMBER
P 245
E B A ENGINEERING
CONSULTANTS LTD.

1981 OFFSHORE GEOTECHNICAL
SITE INVESTIGATION
IRKALUK B-35
BEAUFORT SEA

Report to
DOME PETROLEUM LTD.
CALGARY, ALBERTA

by

EBA ENGINEERING CONSULTANTS LTD.

and

McCLELLAND ENGINEERS, INC.

EXECUTIVE SUMMARY

A geotechnical investigation of soil and foundation conditions was performed for Dome Petroleum Ltd. at the Irkaluk B-35 exploratory drilling site in the Beaufort Sea. The study consisted of a foundation boring drilled to 45.8 m (-104.0 m Elevation) below the seafloor in 58.2 m of water. Operational problems caused early termination of the borehole at 45.8 m penetration (-104.0 m Elevation). Laboratory tests were subsequently performed on samples recovered from the borehole. Geophysical logging was performed following completion of the borehole.

The soils encountered generally consist of five metres of interbedded dense silt and sand overlying dense fine sands. Well bonded frozen sands with little or no visible ice were encountered below 16.5 m penetration (-74.7 m Elevation).

Field laboratory tests were peformed on most soil samples. Field tests included determination of moisture contents, core temperatures, core photography and the measurement of the undrained shear strength with a Torvane or Pilcon hand vane. The laboratory program conducted in Edmonton consisted of additional classification, index, strength and consolidation tests.

The principal recommendations developed by the study are listed below:

1. Care should be taken to control washout and sloughing of the sands during drilling and cementing operations.

2. The seabed soils comprise 5 metres of interbedded clay and fine sand whose lowest measured shear strength is still in the firm to stiff range.

3. Sands estimated to be dense to very dense but more fieldwork is recommended to verify this preliminary assessment.

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LIST OF FIGURES

1.0 INTRODUCTION

One borehole was completed to 45.8 m (-104.0 m Elevation) depth at the Irkaluk B-35 location, as designated by Dome Petroleum Ltd., in the period 13th and 14th October 1981. The borehole location shown on Figure 1 was 7 828 103 m N 530 123 m E (70° 34' 28"N 134° 10' 21"W) in a water depth of 58.2 m. The drilling was terminated before the stipulated 120 m target depth due to an extremely slow drilling rate in well bonded sands and exhaustion of the drilling mud stocks. The borehole was primarily intended to determine geotechnical conditions of the seabed prior to the drilling of an exploratory well. Field time spent on the Irkaluk boring is summarized in an operational calendar, Figure 2.

Several different participants were actively involved in the fieldwork operations; these are summarised below:

- McClelland Engineers Inc., Houston Texas

  provided two drillers, one geotechnical engineer and one technician who were responsible for the rotary drilling and in situ testing equipment, and were jointly responsible with EBA for the field operations.

- EBA Engineering Consultants Ltd., Edmonton, Alberta

  provided one site engineer, two junior engineers and an engineering assistant who were responsible for the logging, handling and subsequent laboratory testing of the samples recovered, and also, were jointly responsible, with

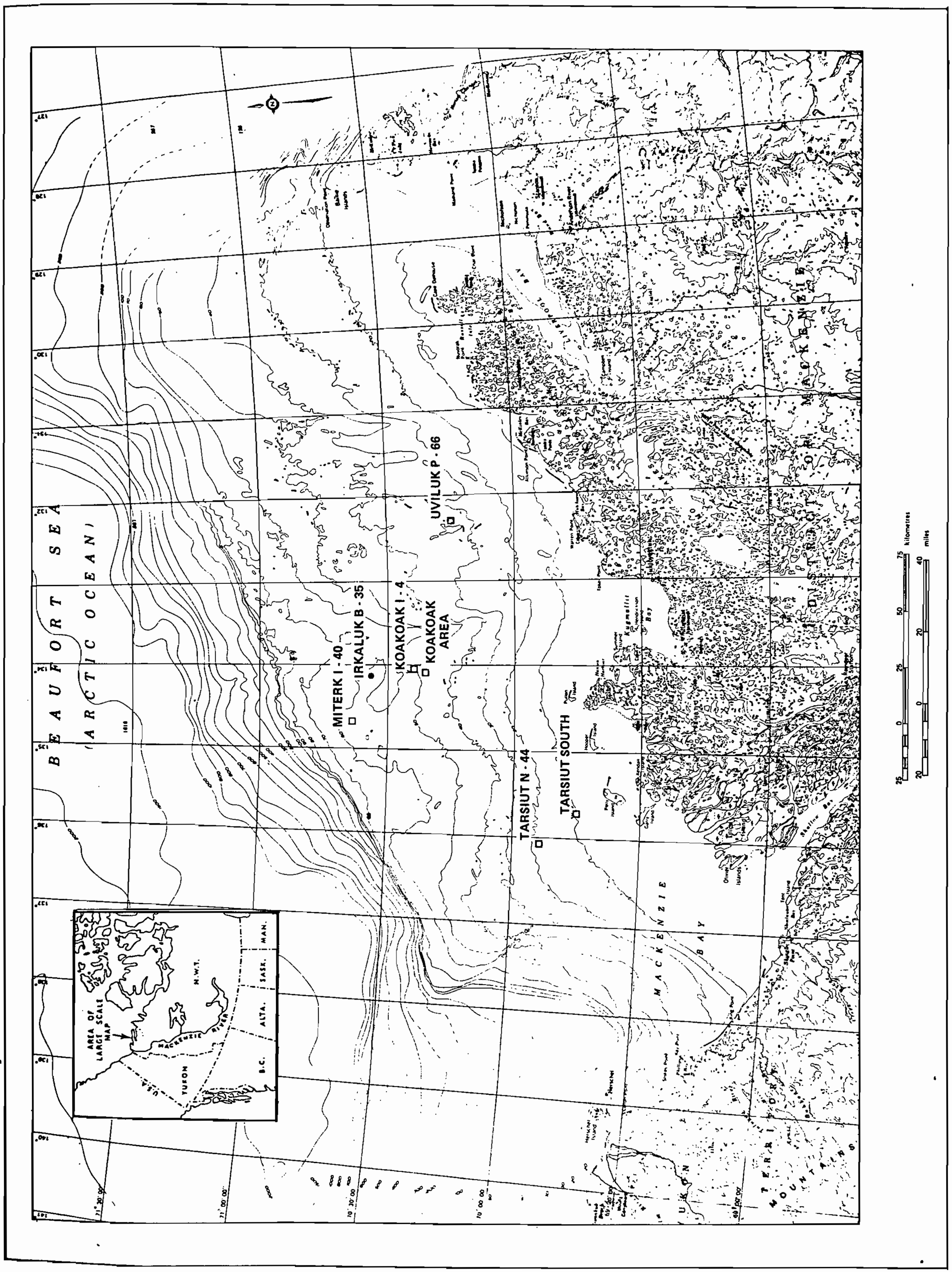


FIGURE 1 BOREHOLE LOCATION MAP

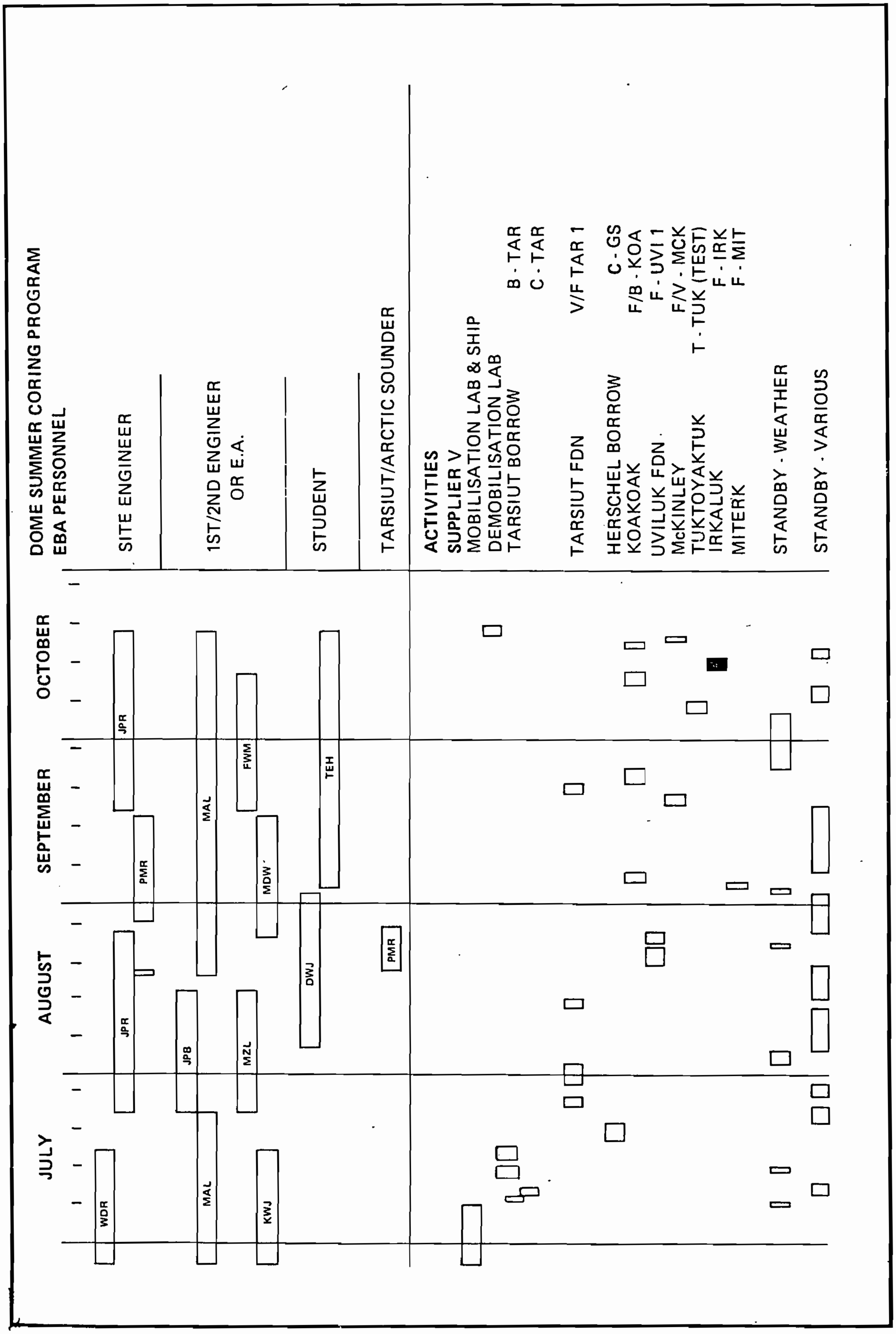


FIGURE 2 OPERATIONAL CALENDAR

McClelland for the field operations. EBA produced this report.

- Geocon Offshore Ltd., Toronto, Ontario

  provided two drillers/driller's assistants to act as roughnecks in the rotary drilling operation and also to operate the vibrocoring equipment.

- BPB Instruments (Canada) Ltd., Calgary, Alberta

  provided one logging technician and associated logging equipment for the geophysical logging of the boreholes.

- ONCL/Dome Survey

  provided one surveyor and "ARGO" surveying equipment for positioning and surveying operations.

- Canadian Marine Drilling Ltd. (CANMAR), of Calgary, Alberta

  provided all marine plant and services, the drilling system, and in addition, provided one crew member per shift for roughnecking duties.

2.0 FIELD INVESTIGATION

2.1 Equipment and Operations

The fieldwork was executed from the CANMAR (Canadian Marine Drilling Ltd.) Supplier V, a 40 m long shallow-draught vessel specially converted for geotechnical investigations. The vessel was placed in the correct position by means of a microwave ARGO range-range positioning system operated by ONCL/Dome Surveys. It was held on location by deploying a four-point anchor system; accuracy of the positioning and anchoring system is not thought to vary by more than 5 m from the location as stated in the logs.

The boreholes were effected by a Failing 1500 rotary drilling rig mounted amidship at the stern of the vessel, working through a moonpool situated approximately at the centre of the ship. The rig itself was mounted on a platform 3.2 m above the deck to facilitate the handling of pipe on the drill floor.

Boring was carried out using a drag bit with tungsten carbide inserts which cuts a hole of 228 mm nominal diameter. The drill string comprised "NC50" drill pipe of 114 mm -ID and 156 mm -OD at the tool joints. Sea water mixed with "Zeogel" attapulgite mud and "Baroid" barite weight component in varying ratios (dependant on the formations encountered) was used as the flushing medium. The mud mixture was kept as cool as possible by drawing water from well below the warmer surface waters. As no conductor casing was employed during the boring, no mud was recovered after circulation and the return was discharged freely on the seabed.

2.2 Soil Samples

Sampling was carried out in unfrozen soils by percussion techniques, semi-continuously at 1 m intervals to 15 m and at 3 m intervals thereafter using 54 mm -ID and 57 mm -OD thin-walled tubes. In frozen soils, samples were recovered by percussion techniques at 3 m intervals using a thick-walled tube of 54 mm -ID and 63 mm-OD. These samplers were operated on a wire line through the drill pipe, and were driven with a 79.4 kg sliding weight. Normally, the weight was dropped between 20 and 30 times through approximately 1.5 m to achieve the desired 0.6 m penetration of the sampler. It should be noted that, as neither the length of the drop of the weight nor the penetration of the sampler can be determined during normal sampling practice, accurate measure of the penetration resistance of the soil cannot be made by utilizing blow count/penetration values.

2.3 Sample Handling and Packaging

Soil samples were designated as frozen or unfrozen for testing and packaging purposes. The soil was considered frozen only if visible ice and/or ice bonding was encountered concurrent with core temperatures less than 0°C.

The temperature of all soil samples was measured prior to extrusion. A hand-held thermistor probe, with a one-tenth of a degree Celcius resolution, was used to measure temperature. The probe was inserted into the end of the sample and the temperature was allowed to stabilize.

Unfrozen soils were extruded and prepared for logging and sample photography. Subsamples were split from the main sample for on board laboratory testing. Representative noncohesive samples were sealed in plastic bags and cohesive soils were wrapped in concentric layers of thin plastic film and aluminum foil. The wrapped core sample was then placed in a cardboard tube that was filled with dry sand and sealed at both ends with wax. Care was taken during waxing to minimize thermal disturbance. Additional subsamples were selected on the basis of organic content for sedimentological and sample dating purposes. Samples were also taken at 10 m intervals for porewater chemistry and gas analysis.

All soil samples were photographed immediately after extrusion. An index to core photography is presented in Appendix G. Photographs will be presented in a separate report.

In frozen soils, the soil sample was partially extruded to allow a 50 mm disc to be placed in a cool bath maintained at -2°C for calorimeter testing at a later time. In addition time domain reflectometry (TDR) tests were performed while the sample remained in the tube, to provide a measure of the unfrozen moisture content. The sample was then extruded, photographed and logged, again removing sub-samples for onboard laboratory testing. If sufficient core was obtained, the core was split into two sections: the first was wrapped in thin plastic film and thick plastic core sleeving for storage in a freezer at temperatures below -10°C. The second was stored in a manner identical to that described above for unfrozen cohesive materials. Sample handling was performed as quickly as possible to reduce unnecessary thermal disturbance of the sample.

Unfrozen wrapped core samples, bag samples, and canned gas analysis samples were stored and shipped in pails with sealed lids accompanied by a max-min thermometer to record the extremes of temperature to which the samples were subjected during transit. Frozen core and porewater chemistry samples were stored in a commercial freezer which maintained the samples at temperatures colder than -10°C. The samples were shipped in insulated core-boxes packed with gel freezer packs. Samples were shipped with dispatch and maintained in a frozen state. Max-min thermometers also accompanied these samples.

2.4 Field Laboratory Testing

Field laboratory testing, other than that mentioned above, was limited to the measurement of bulk density and shear strength. In semi-cohesive and cohesive unfrozen materials, the shear strength was determined using a "Pilcon" hand vane inserted to various penetrations into the end of the sample prior to extrusion. Estimates of shear strength were also made during the logging of the sample using a "Torvane" and "Pocket Penetrometer". An estimate of the in situ state of packing of non-cohesive materials was made on the basis of the recovery length of the sample, the state of the sample upon extrusion, drilling rate, and moisture content of the sample. The bulk density of frozen material was determined from the weight of intact core cylinders divided by volume as determined from external dimensions obtained from caliper measurements. These densities are considered to be accurate to the nearest 0.1 t/m^3.

3.0 LABORATORY TESTING OF SAMPLES

3.1 Particle Size Distribution

3.1.1 Sieving Method

This test was performed on 17 samples in accordance with ASTM standard designation D 422-63 (Reapproved 1972). Where necessary, the samples were divided by riffle-box to produce samples of standard mass. All samples were prepared in accordance with ASTM designation D2217-66 (Reapproved 1972) if hydrometer method tests were not required. The particle size distribution curves obtained are presented in Appendix C.

3.1.2 Hydrometer Method

This test was performed on one sample in accordance with ASTM standard designation D-422-63 (Reapproved 1972) if in the opinion of the engineer, the sample displayed a significant percentage of particles finer than 75 microns. Pretreatment of the sample using hydrogen peroxide was carried out to remove organic matter. The results of these analyses are presented in Appendix C.

3.2 Atterberg Limits

Atterberg limits were determined for three samples, and results including the calculated Plasticity Index, are presented in Appendix C.

3.2.1 Liquid Limit

Liquid limits were determined in accordance with ASTM standard designation D-423-66 (Reapproved 1972), utilising a three-point method.

3.2.2 Plastic Limit

The plastic limit test was carried out in accordance with ASTM standard designation D-424-59 (Reapproved 1971).

3.3 Natural Bulk Density and Dry Density

Densities were calculated for the triaxial and oedometer specimens by obtaining the weight of a known volume of soil and its associated moisture content. The results of these determinations are presented in Appendix C and also, separately with the respective shear strength and consolidation test results.

3.4 Strength Testing

3.4.1 Triaxial Shear Testing

Unconsolidated-undrained triaxial testing of two "undisturbed" unfrozen samples of diameters between 30 mm and 50 mm were conducted according to the procedures as described in Appendix H. Results for this test are presented in Appendix D.

3.5 Compressibility Testing

One sample was subjected to a standard oedometer/consolidation test, following procedures outlined in Appendix H. Test results are presented in Appendix E.

3.6 Porewater and Gas Analyses

3.6.1 Porewater Salinity/Chemistry Tests

A total of 6 samples were subjected to porewater salinity analysis. The samples were frozen immediately upon extrusion in the field. Four of these samples were wrapped in several layers of airtight bags, and were shipped on ice to Carbon Systems Inc. of Baton Rouge, Louisiana, for complete porewater chemistry analysis in their laboratories. The salinity data is presented on Figure B.2 in Appendix B, and appears in tabular form on Table 1 in Appendix F.

3.6.2 Dissolved Gas Analysis

Samples for gas analysis were sealed in 500 ml cans in the field with 450 ml of deaired brine, and were shipped to Carbon Systems Inc., as noted above. Four samples were subjected to this analysis, and test results are presented in Appendix F.

4.0 SITE STRATIGRAPHY

4.1 General Geological History (Swan-Wooster, 1982)

The sediments encountered in this geotechnical exploration of part of the MacKenzie Delta are probably of the Illinoisan and Wisconsin stages of the

Quaternary period. The oldest units penetrated are a glaciofluvial deltaic sequence which occupies a glacially-scoured structural depression developed by late Cretaceous block faulting. The sequence consists of pro-deltaic and marine clay-silt-sand rhythmic units, and is probably of Illinoisan age. The general distribution and nature of the overlying sediments has been most strongly influenced by two major sea level fluctuations in the Wisconsin stage, the latter event depressing sea level to at least one hundred metres below the present level, and exposing the shelf to a periglacial climate and consequent permafrost aggradation. The exposure of the shelf also allowed subaerial erosion and aeolian deposition to take place. The thick layer of uniform fine-grained sand deposited during this period appears to be fluvio-deltaic in origin and lies unconformably on the eroded older deltaic sequence. During this period of depressed sea levels, a significant distributary of the prehistoric Mackenzie River cut a deep channel (Kugmallit Trough) through these fine-grained sands, establishing a route for drainage and imposing a deposition control that remains active to the present.

As sea levels rose during the late Wisconsin marine transgression, an influx of relatively warm, shallow water thawed parts of the frozen land surface. Reworking of surfacial material also took place during the transgression, redepositing the material in sequences reflecting the uneven advance of the sea over the land surface. A sustained influx of fine-grained sediment from the Mackenzie River concurrently filled local drainage channels that had developed during periods of depressed sea level and blanketed regions of low current activity.

The Irkaluk site is situated on the Pullen Plain, an extensive sand plain that forms the western part of the glaciofluvial delta of the MacKenzie River. This site is sufficiently distant from the Kugmallit Trough margin for Holocene clays and silts to have been deposited overlying a substantially greater thickness of early Wisconsin stage sands. The geomorphological setting at this site is quite similar to conditions encountered at Miterk I-40.

4.2 Stratigraphy

Subsurface stratigraphy consists of a surficial layer of interbedded clay and fine sand underlain by predominantly granular soils. Frozen soil was encountered below 16.5 m penetration (-74.7 m Elevation). Detailed descriptions that include color and textural variations, inclusions and ground ice for each stratum are noted on the boring log in Appendix A. A general description of the soils follows.

The uppermost stratum was present from the seafloor to 4.6 m (-62.8 m Elevation) and consisted of interbedded:

ii CLAY [CL]; silty, firm to stiff, high plasticity, dark grey [2.5Y 4/0], and

iii SAND [SP], fine-grained with a trace of SILT; subrounded, dark olive grey [5Y 4/3].

This unit, attaining a total thickness of 4.6 m, was split into three sections during the logging, as thicknesses of the clay sub-units increase toward the middle of the stratum. A clay bed with an inferred thickness of 1.5 m is present at this level. The proportion of clay decreases with depth as the sand percentage increases, grading into the underlying sand unit. The material in this uppermost unit is probably of Holocene age reflecting periods of high and low current activity in the Kugmallit Trough.

Directly underlying the clay/sand sequence was a unit exceeding 41.2 metres in thickness which consists of:

IIi SAND [SP], fine-grained with a trace of SILT; even, parallel, continuous laminations of black fine-grained silty SAND, subrounded, dense (estimated), dark olive grey [5Y 4/3].

Frozen conditions were encountered at 16.5 m penetration (-74.7 m Elevation). The sand is well bonded, with ground ice conditions being described as Nbn to Vx trace. Also, between 28.3 m and 40.8 m penetration (-86.5 m Elevation and -99.0 m Elevation) the sand undergoes a colour change to light brown [10YR 6/3] without significant changes being noted in either grading or density. This transition was marked at its upper extent by significant thin, parallel even bands of the different coloured sands, indicating a probable lowering of the sea level and a more active storm/ebb or summer/winter controlled depositional environment. In more westerly areas of the delta, it has been suggested this brown sand is indicative of lower sea levels during the late Illinoisan stage.

5.0 ENGINEERING PROPERTIES OF SOILS

5.1 Permafrost

Soil temperature prior to extrusion (in practice, directly after recovery from the hole) was measured using a hand-held thermistor probe, with a one-tenth of a degree Celcius resolution, inserted as far as possible up to a maximum penetration of 150 mm into the end of the sample. In connection with this program, soil was described as being "frozen" only if visible ice and/or ice bonding was encountered concurrent with core temperatures of less than 0°C. Permafrost is defined as any earth material that has been below 0°C for a prolonged period of time without regard to the phase composition of moisture present in the pore spaces. Typical marine sediments from the Beaufort Sea have porewater salinities of 30 to 40 ppt resulting in a freezing point depression of 1.5C°. As a result, soil can exist at temperatures below 0°C ("permafrost") but exhibit no ice bonding or segregated ice until soil temperatures drop to -1.5°C or colder. "Frozen" soil is therefore distinguished from permafrost, because permafrost conditions in the seabed may not necessarily be of engineering significance.

Core temperatures measured in this borehole were consistently below 0°C. In response to heat extraction by seawater near its freezing temperature, the upper portion of the sands has been cooled to near -1°C while sediments, at greater depths exhibit temperatures closer to -0.5°C. Salinities measured in the type [IIi] sands averaged 30 ppt and to a level of 16.5 m penetration (-74.7 m Elevation), these sands were described as "not frozen".

Below the 16.5 m penetration (-74.7 m Elevation) level, the soils were described as well bonded (Nbn) with occasional traces of ice crystals (Vx). The core temperatures below 16.5 m penetration (-74.7 m Elevation) fell uniformly between -1.0°C and -1.5°C. These temperatures, accompanied by salinities below 10 ppt, would allow the soil porewater to freeze. Figure B-3 (Appendix B) presents unfrozen water contents measured with the TDR apparatus. These average around 13%, thus implying a frozen moisture content of close to 15%. With the exception of one result, calorimetry determinations of unfrozen water content varied considerably, and are not judged to be reliable.

While the borehole was being drilled, mud temperatures were generally below 0°C, reflecting freezing point depression in the near-freezing seawater used to prepare mud.

5.2 Geotechnical

The soil profile encountered in this borehole can be separated into two distinct units on the basis of soil properties.

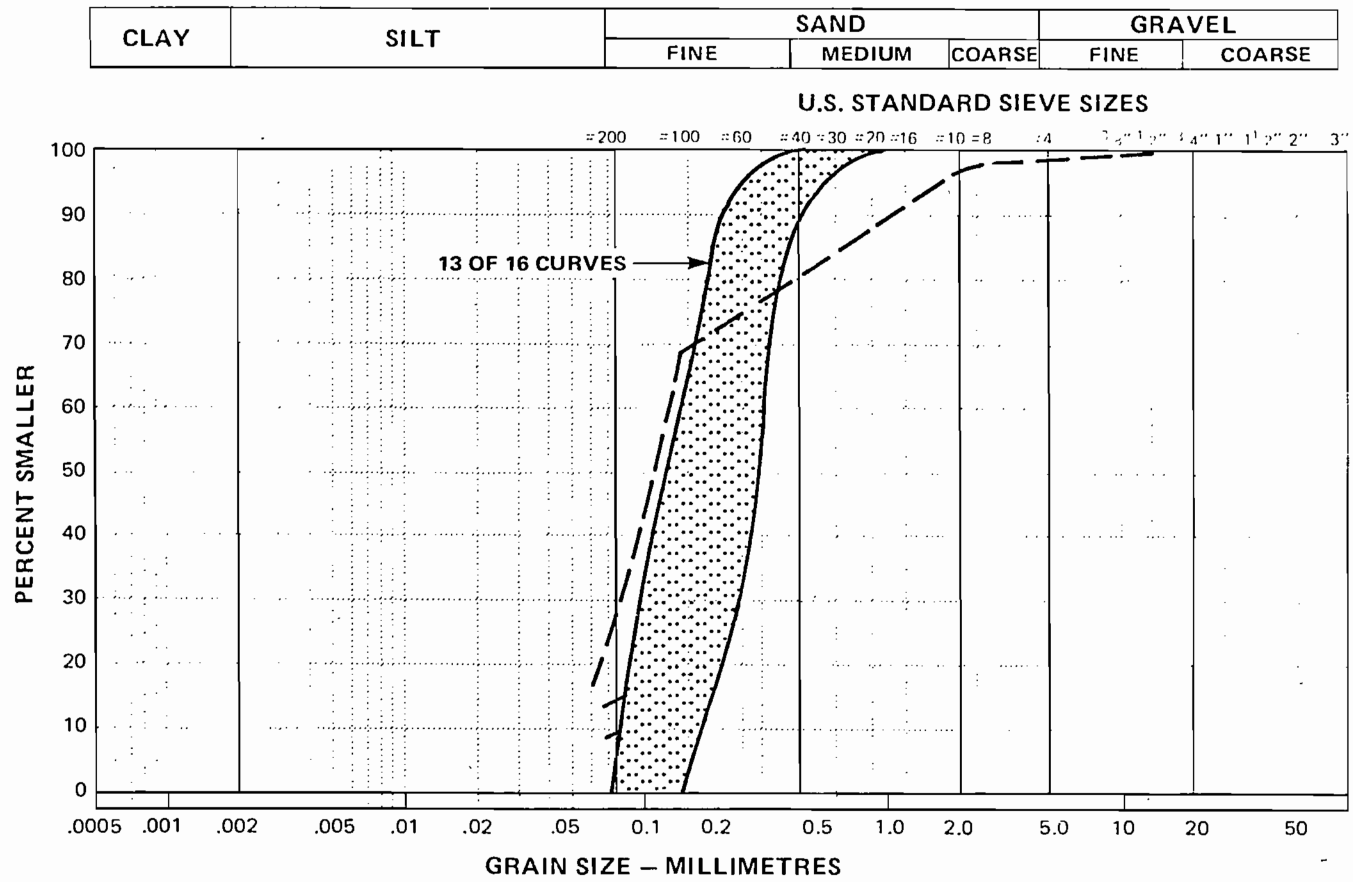
The upper unit extends from seabed to 4.6 m penetration (-62.8 m Elevation), comprised of interbedded sand and clay types [Ii and Iii], grades from a sand with 5% silt to a silt with 33% clay. Atterberg limits place the material close to the A-line, so material could fall in either the ML or CL classifications. Moisture contents in the silt are all below the liquid limit (averaging 30%), and are about 20% in the sand. Measured densities in these units 1.97 and 2.13 Mg/m^3, respectively. The undrained shear strength of the sand unit was also highly dependent on the lithology ranging from over 400 kPa in the sand to close to 50 kPa in the clay for similar confining pressures. The clayey silt member exhibits moderate compressibility and light overconsolidation, with a Compression Index (C_c) in the range of 0.23 and 0.27 and Overconsolidation Ratio of close to three.

As mentioned previously, the underlying type [II] sands appear uniformly graded to the termination depth of the borehole. The grading envelope for the sands is presented in Figure 3. The sand is generally fine-grained with the median grain diameter (D_{50}) ranging between 125 microns and 300 microns. Fines contents (combined silt and clay) varied to a maximum of 12%, but were generally close to 6%. Measured moisture contents averaged 27% throughout the unit, and exhibited no marked increase with depth. This moisture content corresponds to a saturated bulk unit weight of 19.5 kN/m^3, and agrees well with the field estimation that the sands are in a 'dense' state.

5.3 Sediment Gases

Methane, ethene, ethane, propene, propane, N-butane and I-butane are the hydrocarbon gases detected in this borehole. Methane concentrations were measured up to 174 ppm. Although concentrations at Irkaluk are higher than those found at other boreholes sampled during the 1981 field program, they are still low. This suggests a correspondingly low probability of geologic hazard associated with petrogenic gases in the 4.6 metres of sediments penetrated at this location.

PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
	F-IRK 1:1	4.6 - 45.8		1 - 7	99 - 93		1.5 - 3.0	.9 - 1.3	SP - SM
	F-IRK 1:1	Individual grading curve							

JOB NO. 101-3210 **DATE** 09-02-82

FIGURE 3 GRADING ENVELOPE FOR SANDS, IRKALUK B-35

6.0 GEOTECHNICAL CONSIDERATIONS

6.1 Seabed Soils

The seabed soils at this location appear more competent than the softer clays found at the Miterk I-40 or Uviluk P-66 locations. The upper five metres comprise varying mixtures of clay and fine sand whose lowest measured shear strength is still in the firm to stiff range.

6.2 In Situ Density of Sands

The in situ density of sands was not measured directly but has been estimated as dense to very dense. Therefore, settlements due to thawing of frozen sands, causing well casing downdrag and liquefaction of unfrozen sands due to earthquake loading are considered unlikely at this site. However, we recommended that the frozen sands should be cored or other in situ testing performed so that a more precise estimate of in situ density can be made to verify this preliminary assessment.

6.3 Permafrost

Frozen sand was encountered at 16.5 m penetration (-74.7 m Elevation) and was observed to the base of the hole. No significant amounts of visible ice were observed in the samples, indicating that the soils are expected to be relatively thaw stable. No core of sufficient quality was recovered to permit quantitative assessment of the sand's in situ properties. Naturally, washout will be a concern while drilling through sand; however, when frozen sand is exposed to circulation, efforts should be taken to maintain cold mud temperatures to reduce sloughing in frozen soils. The drilling process should be monitored closely while drilling through sand to prevent excessive washout and sloughing. Since thaw and sloughing will continue as long as circulation is maintained through the permafrost, elapsed time between drilling and cementing should be kept to a minimum.

Respectfully Submitted,

EBA Engineering Consultants Ltd.

PREPARED BY:

P.M. Romeril, P.Eng.

J.P. Ruffell

REVIEWED BY:

W.D. Roggensack, P.Eng.
Senior Project Engineer
Arctic group

WDR/dmt

REFERENCES

SWAN-WOOSTER Engineering Co. Ltd., 1982. Environmental Impact Statement Study of Production Structures Beaufort Sea Oil Development. Draft Engineers Report submitted to Dome-ESSO-Gulf.

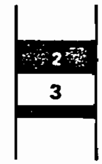
APPENDIX A

BOREHOLE LOGS

SYMBOLS AND ABBREVIATIONS USED ON BOREHOLE LOGS

SOIL SAMPLE

- represented by sample identification number which increase sequentially from the top of the hole; thickness of block is equivalent to sample recovery



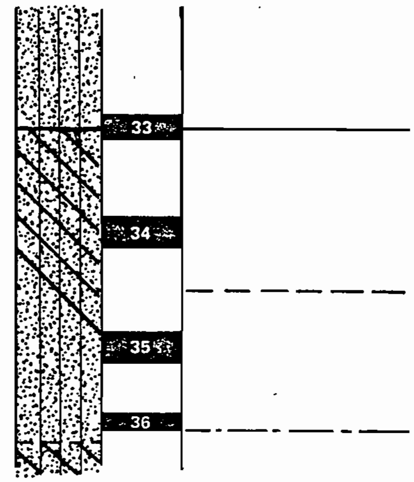
SOIL BOUNDARIES

- have been indicated using the following system

- stratum boundary observed within sample

- stratum boundary assumed to occur within ± 0.5m of the marked level and is probably gradational between the two samples

- stratum boundary assumed to occur within ± 1.0m of the marked level



- stratum boundary notation for both depth below seabed (41.5 metres) and elevation below sealevel (uncorrected for tides) (-64.6 metres El.)

41.5 (-64.6 El.)

SOIL DESCRIPTION

UNIFIED SOIL CLASSIFICATION — USC

- determined in accordance with chart on following page

TEXTURAL DESCRIPTION

- determined in accordance with attached sheet and used to augment Unified Soil Classification

Special terms used include:

e.g. - "becoming trace of/with some CLAY" indicating an overall change in a feature of the stratum not sufficient to change the total description

- "trace of/with some CLAY" indicating small feature displayed in that sample only

MUNSELL COLOUR DESIGNATION

- describing wet grey soil, e.g. — (5Y 4/2)

- describing dry grey soil, e.g. — (10YR 6/1)

GROUND ICE DESCRIPTION

- determined in accordance with chart on following page; extra effort has been made to better describe the degree and extent of soil bonding and also a value of core temperature (°C) at that level

- see also definition of terms in text

e.g. FROZEN - 2.3
- Nf - Nbn
- poorly to slightly bonded

SAND: Nbn - 2.8

CLAY: not frozen

TEST RESULTS

- see legend at bottom of borehole log

CONSISTENCY

Fine-Grained Soils

Major portion passing No. 200 Sieve. Includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silt. Consistency is rated according to shear strength, as indicated by penetrometer readings or vane shear readings.

Descriptive Term	Unconfined Compressive Strength kPa	Equivalent Blows per Foot (N)
Very Soft	less than 25	0 - 2
Soft	25 to 50	2 - 4
Firm	50 to 100	4 - 8
Stiff	100 to 200	8 - 16
Very Stiff	200 to 400	15 - 50
Hard	400 and higher	>50

Coarse-Grained Soils

Major portion retained in No. 200 Sieve. Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Condition is rated according to relative density, as determined by laboratory tests.

Descriptive Term	Relative Density	Equivalent Blows per foot (N)
Very Loose	0 - 20%	0 - 4
Loose	20 - 40%	4 - 10
Compact or Medium	40 - 75%	10 - 30
Dense	75 - 90%	30 - 50
Very Dense	90 - 100%	50 +

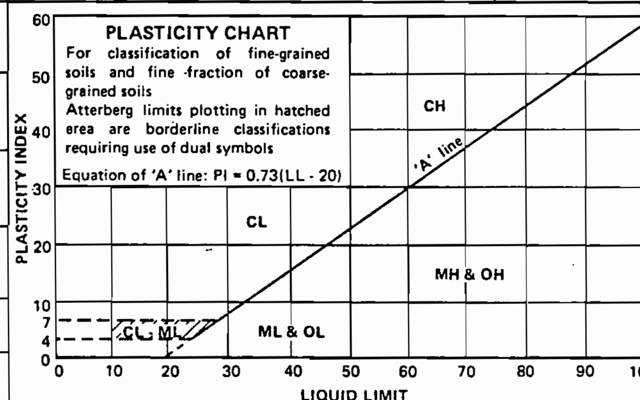
The number of blows (N) on a 2" O.D. split spoon sampler by a 140 lbs. weight falling 30" required to drive the sample a distance of 1' (in accordance with ASTM D1586).

PLASTICITY

Low - Liquid limit less than 50
High - Liquid limit greater than 50

UNIFIED SOIL CLASSIFICATION†

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES	CLASSIFICATION CRITERIA		
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines: Less than 5% pass No. 200 sieve: GW, GP, SW, SP; More than 12% pass No. 200 sieve: GM, GC, SM, SC; 5% to 12% pass No. 200 sieve: Borderline classification requiring use of dual symbols	$C_u = D_{60}/D_{10}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly-graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW	
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits plot below 'A' line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand clay mixtures		Atterberg limits plot above 'A' line and plasticity index greater than 7	
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines		$C_u = D_{60}/D_{10}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly-graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW	
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures		Atterberg limits plot below 'A' line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits plot above 'A' line and plasticity index greater than 7	
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands			
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts			
			CH	Inorganic silts of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity			
HIGHLY ORGANIC SOILS			PT	Peat, muck and other highly organic soils			



*Based on the material passing the 3 in. (75 mm) sieve
†ASTM Designation D 2487, for identification procedure see D 2488

GROUND ICE DESCRIPTION

ICE NOT VISIBLE

GROUP SYMBOLS	SYMBOLS	SUBGROUP DESCRIPTION	
N	Nf	Poorly-bonded or friable	
	Nbn	No excess ice, well-bonded	
	Nbe	Excess ice, well-bonded	

NOTE:

1. *Dual symbols are used to indicate borderline or mixed ice classifications*
2. *Visual estimates of ice contents indicated on borehole logs ± 5%*
3. *This system of ground ice description has been modified from NRC Technical Memo 79, Guide to the Field Description of Permafrost for Engineering Purposes*

LEGEND

Soil   Ice

VISIBLE ICE LESS THAN 50% BY VOLUME

GROUP SYMBOLS	SYMBOLS	SUBGROUP DESCRIPTION	
V	Vx	Individual ice crystals or inclusions	
	Vc	Ice coatings on particles	
	Vr	Random or irregularly oriented ice formations	
	Vs	Stratified or distinctly oriented ice formations	

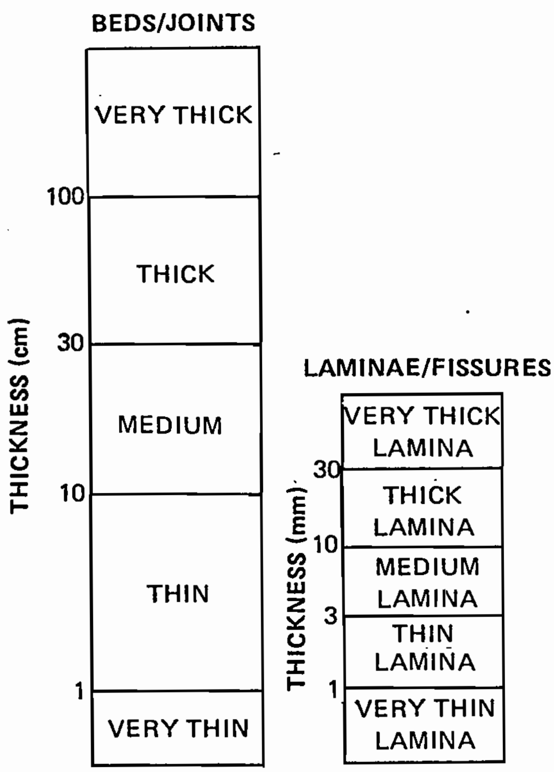
VISIBLE ICE GREATER THAN 50% BY VOLUME

ICE	ICE + Soil Type	Ice with soil inclusions	
	ICE	Ice without soil inclusions (greater than 25 mm (1 in.) thick)	

DESCRIPTION OF SEDIMENTARY STRUCTURES

BEDS SEDIMENTATION UNITS DEPOSITED UNDER ESSENTIALLY CONSTANT PHYSICAL CONDITIONS, SEPARATED BY BEDDING PLANES WHICH ARE RECOGNIZABLE BY TEXTURAL OR COMPOSITIONAL CHANGES RESULTING FROM PERIODS OF NON-DEPOSITION OR EROSION, OR ABRUPT CHANGES IN DEPOSITIONAL CONDITIONS. BEDS MAY BE INTERNALLY HOMOGENEOUS, OR COMPOSED OF SMALLER UNITS-LAMINAE

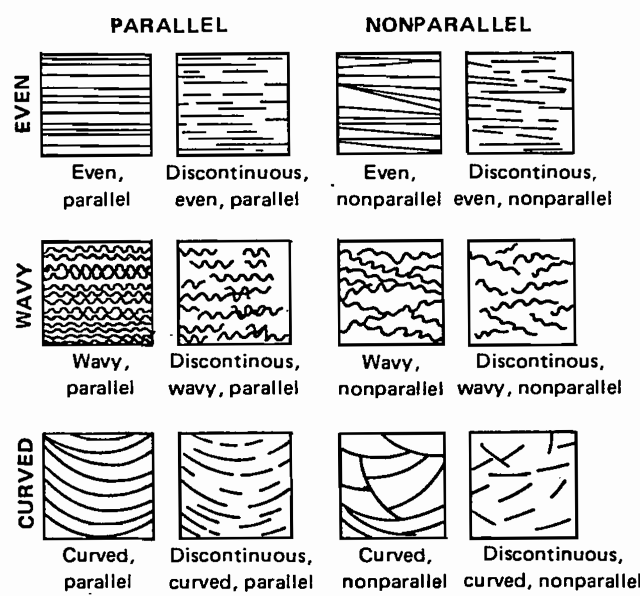
LAMINAE THE SMALLEST MEGASCOPIC LAYERS IN A SEDIMENTARY SEQUENCE, REPRESENTING MINOR FLUCTUATIONS IN PHYSICAL CONDITIONS DURING THE DEPOSITION OF BEDS. LAMINAE ARE RELATIVELY UNIFORM IN TEXTURE AND COMPOSITION AND GENERALLY LACK MEGASCOPIC INTERNAL LAYERING.



e.g. Thick bed
Thickly spaced joint

e.g. Thin lamina
Thinly spaced fissures

(Modified after Ingram, 1954 and Campbell, 1967)



(After Campbell, 1967)

SYSTEM INTERNATIONAL UNITS

QUANTITY	NAME	SYMBOL	EXPRESSED IN TERMS OF OTHER SI UNITS	EXPRESSED IN TERMS OF BASE AND SUPPLEMENTARY UNITS
SI UNITS				
length	metre	m		
mass	kilogram	kg		
time	second	s		
electric current	ampere	A		
thermodynamic temperature	kelvin	K		
amount of substance	mole	mol		
luminous intensity	candela	cd		
SI SUPPLEMENTARY UNITS				
plane angle	radian	rad		
solid angle	steradian	sr		
EXAMPLES OF SI DERIVED UNITS WITH SPECIAL NAMES				
frequency	hertz	Hz	1/s	s^{-1}
force	newton	N	$m \cdot kg/s^2$	$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
EXAMPLES OF SI DERIVED UNITS WITHOUT SPECIAL NAMES				
velocity - linear	metre per second		m/s	$m \cdot s^{-1}$
- angular	(radian per second)		rad/s	$rad \cdot s^{-1}$
acceleration - linear	(metre per second) per second		m/s^2	$m \cdot s^{-2}$
- angular	(radian per second) per second		rad/s^2	$rad \cdot s^{-2}$
concentration (of amount of substance)	mole per cubic metre		mol/m^3	$mol \cdot m^{-3}$
dynamic viscosity	pascal second		$Pa \cdot s$	$m^{-1} \cdot kg \cdot s^{-1}$
moment of force	newton metre		$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
surface tension	newton per metre		N/m	$kg \cdot s^{-2}$
heat flux density, irradiance	watt per square metre		W/m^2	$kg \cdot s^{-3}$
heat capacity, entropy	joule per kelvin		J/K	$m^2 \cdot s^{-2}\ K^{-1}$
specific heat capacity, specific entropy	joule per kilogram kelvin		$J/(kg \cdot K)$	$m^2 \cdot s^{-2} \cdot K^{-1}$
specific energy	joule per kilogram		J/kg	$m^2 \cdot s^{-2}$
thermal conductivity	watt per metre kelvin		$W/(m \cdot K)$	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$

OTHER UNITS PERMITTED FOR USE WITH SI

QUANTITY	NAME	SYMBOL	DEFINITION
time	minute	min	1 min = 60 s
	hour	h	1 h = 3,600 s
	day	d	1 d = 86,400 s
	year	a	
plane angle	degree	°	1° = (π/180) rad
	minute	′	1′ = (π/10,800) rad
	second	″	1″ = (π/648,000) rad
area	hectare	ha	1 ha = 10,000 m^2
volume	litre	L	1,000 L = 1 m^3
temperature	degree Celsius	°C	0° C = 273.15° K temperature interval 1 C° ≡ 1 K°
mass	tonne	t	1 t = 1,000 kg = 1 Mg

MULTIPLYING FACTOR	PREFIX	SYMBOL	MULTIPLYING FACTOR	PREFIX	SYMBOL
1,000,000,000,000,000,000 = 10^{18}	exa	E	0.1 = 10^{-1}	deci*	d
1,000,000,000,000,000 = 10^{15}	peta	P	0.01 = 10^{-2}	centi*	c
1,000,000,000,000 = 10^{12}	tetra	T	0.001 = 10^{-3}	milli	m
1,000,000,000 = 10^{9}	giga	G	0.000,001 = 10^{-6}	micro	µ
1,000,000 = 10^{6}	mega	M	0.000,000,001 = 10^{-9}	nano	n
1,000 = 10^{3}	kilo	k	0.000,000,000,001 = 10^{-12}	pico	p
100 = 10^{2}	hecto*	h	0.000,000,000,000,001 = 10^{-15}	femto	f
10 = 10^{1}	deca*	da	0.000,000,000,000,000,001 = 10^{-18}	atto	a

* *to be avoided where possible*

SYSTEM INTERNATIONAL CONVERSIONS

AREA

1 km^2	= 3.861×10^{-1} mi^2	1 km^2 = 100 hectares
1 km^2	= $2.471 \times 10^{+2}$ acre	
1 m^2	= 1.196 yd^2	
1 m^2	= $1.076 \times 10^{+1}$ ft^2	
1 mm^2	= 1.550×10^{-3} in^2	see note 1

DENSITY

1 Mg/m^3	= $6.243 \times 10^{+1}$ lb_m/ft^3	see note 2
1 kg/m^3	= 6.243×10^{-2} lb_m/ft^3	

FORCE

1 N	= 2.248×10^{-1} lb_f	

HEAT

ENERGY (E)		
1 kJ	= 9.478×10^{-1} BTU (IST)	1 BTU = 252 cal
1 J	= 2.388×10^{-1} cal (IST)	
HEAT FLUX (Q)		
1 W/m^2	= 3.170×10^{-1} BTU/(ft^2 · hr)	
SPECIFIC HEAT CAPACITY (c)		
1 kJ/(kg · C°)	= 2.388×10^{-1} BTU/(lb_m · F°)	
THERMAL CONDUCTIVITY (k)		
W/(m · C°)	= 5.778×10^{-1} BTU/(ft · hr · F°)	
COEFFICIENT OF HEAT TRANSFER (c_s)		
1 W/(m^2 · C°)	= 1.761×10^{-1} BTU/(ft^2 · hr · F°)	see note 3

LENGTH

1 km	= 6.214×10^{-1} mi (statute)	
1 m	= 1.094 yd	
1 m	= 3.281 ft	
1 mm	= 3.937×10^{-2} in	

MASS

1 Mg	= 1.102 T	1 T = 2000 lb_m
1 Mg	= 2.205×10^{3} lb_m	Mg is equivilant to tonne
1 kg	= 2.205 lb_m	

POWER

1 W	= 1.341×10^{-3} HP	1 HP = 550 ft · lb_f/s

PRESSURE, STRESS or ELASTIC MODULI

1 MPa	= $1.044 \times 10^{+1}$ T_f/ft^2 [TSF]	see note 4
1 kPa	= 1.044×10^{-2} T_f/ft^2 [TSF]	
1 kPa	= 1.450×10^{-1} lb_f/in^2 [psi]	
1 kPa	= 3.346×10^{-1} ft of water	hydrostatic pressure of water at 1 ft. depth
1 Pa	= 2.089×10^{-2} lb_f/ft^2 [psf]	

TEMPERATURE

°C	= (°F - 32)/1.8	0°C = 273.15° K
C°	= 1.8 F°	1 C° = 1 K°

TIME

1 Ms	= 3.171×10^{-2} yr	for one year equal to 365 days
1 ks	= 1.157×10^{-2} day	
1 s	= 3.171×10^{-8} yr	

VISCOSITY

DYNAMIC (η)		
1 Pa · s	= $1.000 \times 10^{+3}$ centipoise	
KINEMATIC (ν)		
1 mm^2/s	= 1.000 cenistoke	

VOLUME

1 m^3	= 8.107×10^{-4} acre · ft	
1 m^3	= 1.308 yd^3	
1 m^3	= $3.531 \times 10^{+1}$ ft^3	
1 m^3	= $2.200 \times 10^{+2}$ gal (Imperial)	1 m^3 = 1000 L
1 cm^3	= 3.520×10^{-2} fl oz	see note 1
1 cm^3	= 6.102×10^{-2} in^3	

VOLUME RATE OF FLOW

1 m^3/s	= 1.901×10^{-1} mgpd (Imperial)	
1 m^3/s	= $3.531 \times 10^{+1}$ ft^3/s	

COEFFICIENTS

VOLUME COMPRESSIBILITY OR SWELLING (m_v or m_s)		
1 m^2/MN;	= 9.579×10^{-2} ft^2/T_f	
CONSOLIDATION OR SWELLING (c_v or c_s)		
1 m^2/yr	= $1.076 \times 10^{+1}$ ft^2/yr	
1 m^2/yr	= 2.949×10^{-2} ft^2/day	
1 m^2/yr	= 3.171×10^{-4} cm^2/s	
HYDRAULIC CONDUCTIVITY (k)		
1 m/s	= $2.835 \times 10^{+5}$ ft/day	see note 5

NOTES

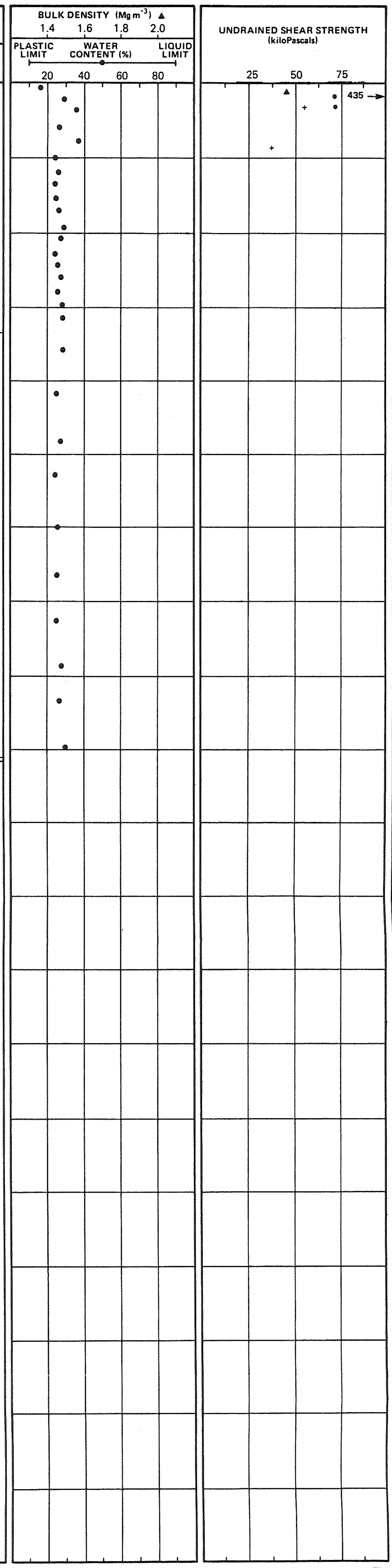
1. *The use of cm^2 and cm^3 for area and volume is permissible.*
2. *To convert mass density (ρ) to weight per unit volume use:*
   $F = ma_g$
   i.e. $\rho Mg/m^3 \times 9.807\ m/s^2 = 9.807\rho \frac{Mg \cdot m}{s^2 \cdot m^3} = 9.807\rho \frac{kN}{m^3}$
   kg_f/m^3 is not a valid SI density unit.
3. *The inverse of the 'coefficient of heat transfer' is 'thermal resistance' or the 'R' value.*
4. *kg_f/m^2 is not a valid SI stress unit.*
5. *Hydraulic conductivity is a proportionality coefficient defined in Darcy's Law* $v = k_w \frac{\partial h}{\partial s}$, *where* v = *velocity of flow*, $\frac{\partial h}{\partial s}$ = *hydraulic gradient*
6. *All conversion factors have been rounded to four significant figures.*

BOREHOLE LOG AND LABORATORY TEST RESULTS

LOCATION: IRKALUK B - 35
UTM COORDINATES: 7 828 103 m N 530 123 m E WATER DEPTH: 58.2 m

DEPTH BELOW SEABED (metres)

Sample NO.	SOIL DESCRIPTION	GROUND ICE	SPECIALIZED TESTS
1–3	CLAY (CL/SP) - stiff, low plasticity, dark grey (2.5YN 4/0) interbedded with: SAND, fine-grained, with a trace of SILT subrounded, dark olive grey 1.5 (-59.7 El.)	NOT FROZEN -0.9	T, T C
4–5	CLAY (CL) - massive, firm-stiff, of low plasticity, dark grey (2.5YN 4/0) 3.0 (-61.2 El.)	-0.8	
6	CLAY (CL/SP) - interbedded (as above), SAND is (5Y 4/3) 4.6 (-62.8 El.)		S, G
7–18	SAND (SP) - fine-grained with a trace of SILT and laminations of black, fine-grained silty SAND, subrounded, dark olive grey (5Y 4/3)	-0.3 -0.5	
	- trace of lithified wood fragments of medium sand size	-0.6	
	- trace of medium-grained SAND	-0.4	
	- becoming slightly finer with no trace of medium	-0.7	
	16.5 (-74.7 El.)	-0.6	S, G, TD Ca
19		FROZEN - 1.2 Nbn to Vx trace	
20	- trace of lithified wood fragments of fine sand size	-0.7	TD
21	- becoming significantly banded, thin, parallel, even light brown/dark olive grey with no change in grading	-1.0	TD
22	28.3 (-86.5 El.)	-1.4	TD
23	SAND (SP) - fine-grained with a trace of SILT and occasional parallel laminations of black, silty, fine-grained SAND, subrounded to rounded, light brown (10YR 6/3)	Nbn to Vx trace -1.3	Ca TD
24		-1.4	S, G, TD Ca
25		-1.1	TD, Ca
26	40.8 (-99.0 El.)	-1.1	G, S
27	SAND (SP) - fine-grained with a trace of SILT and faint parallel thin laminae throughout, dark olive grey (5Y 4/3)	Nbn to Vx trace -1.4	
28	45.8 (-104.0 El.)	-1.1	G, S, TD
	END OF BOREHOLE		



JOB No.: 101 - 3210
DRILLING COMPLETED: 81/10/14
BOREHOLE DEPTH: 45.8 m
DRILLING RIG: F 1500/SUPPLIER V
LOG COMPILED BY: JPR.

SOIL SYMBOLS: SAND, SILT, CLAY

LEGEND

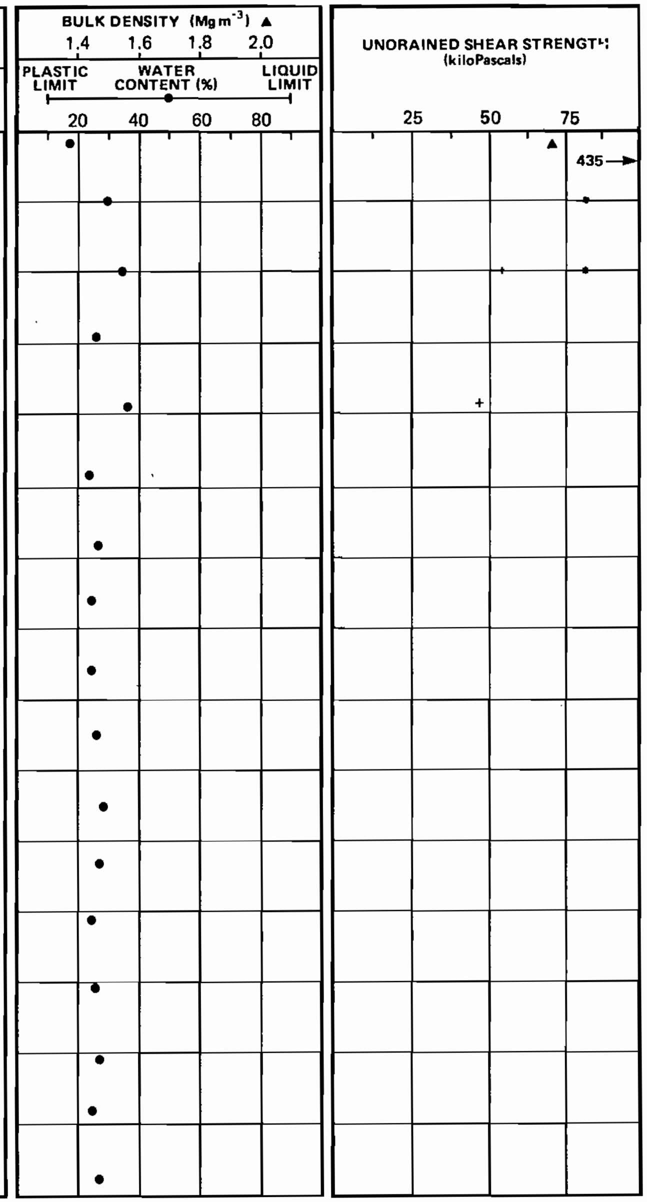
SHEAR STRENGTH: + Torvane; × Min. Vane; ⊕ Pilcon Vane; ○ Halibut Vane; ● Fall Cone; ▲ UU Triaxial; ■ CU Triaxial

TEST IDENTIFICATION: C - Consolidation; DS - Direct Shear; TD - TDR; Ca - Calorimetry; T - Triaxial Shear; S - P.W. Salinity; G - Gas Analysis

BOREHOLE NUMBER F-IRK 1:1

LOCATION: IRKALUK B - 35
UTM COORDINATES: 7 828 103 m N 580 123 m E WATER DEPTH: 55.2 m

DEPTH BELOW SEABED (metres)	SYM.	NO.	SOIL DESCRIPTION	GROUND ICE T	SPECIALIZED TESTS
0	CLAY/SAND	1	Interbedded: CLAY (CL/SP) - stiff, high plasticity, dark grey (2.5YN 4/0) and: SAND - fine grained with a trace of SILT, subrounded, dark olive grey (5Y 4/3) 1.5 (-56.7 El.)	NOT FROZEN -0.9	T, T
1		2		-1.1	C
2	CLAY	3	CLAY (CL) - massive, firm-stiff, of high plasticity, dark grey (2.5YN 4/0) 3.0 (-58.2 El.)	-0.9	
3	CLAY/SAND	4	Interbedded: CLAY (CL/SP) - stiff, of high plasticity, dark grey (2.5YN 4/0) and: SAND - fine grained with a trace of SILT, subrounded, dark olive grey (5Y 4/3) 4.6 (-59.8 El.)	-0.5	
4		5		-0.8	
5	SAND	6	SAND (SP) - fine grained, with a trace of SILT and laminations of black fine grained silty SAND, subrounded, dark olive grey (5Y 4/3)	-0.7	G, S
6		7		-0.3	
7		8		-0.3	
8		9	- with fine gravel sized clast of white igneous material	-0.5	
9		10	- with trace of fine gravel sized clasts of DOLERITE	-0.7	
10		11		-0.6	
10		12		-0.6	
11		13	- trace of medium grained SAND	-0.5	
12		14	- becoming slightly finer with no trace of medium	-0.4	
13		15		-0.0	
14		16			
15		17		-0.7	



JOB No.: 101 - 3210
DRILLING COMPLETED: 81/10/14
BOREHOLE DEPTH: 45.8 m
DRILLING RIG: F 1500/SUPPLIER V
LOG COMPILED BY: JPR

LEGEND

SOIL SYMBOLS: SAND, SILT, CLAY

SHEAR STRENGTH:
+ Torvane
● Fall Cone
× Min. Vane
▲ UU Triaxial
* Pilcon Vane
■ CU Triaxial
○ Halibut Vane

TEST IDENTIFICATION:
C - Consolidation
T - Triaxial Shear
DS - Direct Shear
S - P.W. Salinity
TD - TDR
G - Gas Analysis
Ca - Calorimetry

BOREHOLE NUMBER F-IRK 1:1

PAGE 2 OF 2

BOREHOLE LOG AND LABORATORY TEST RESULTS

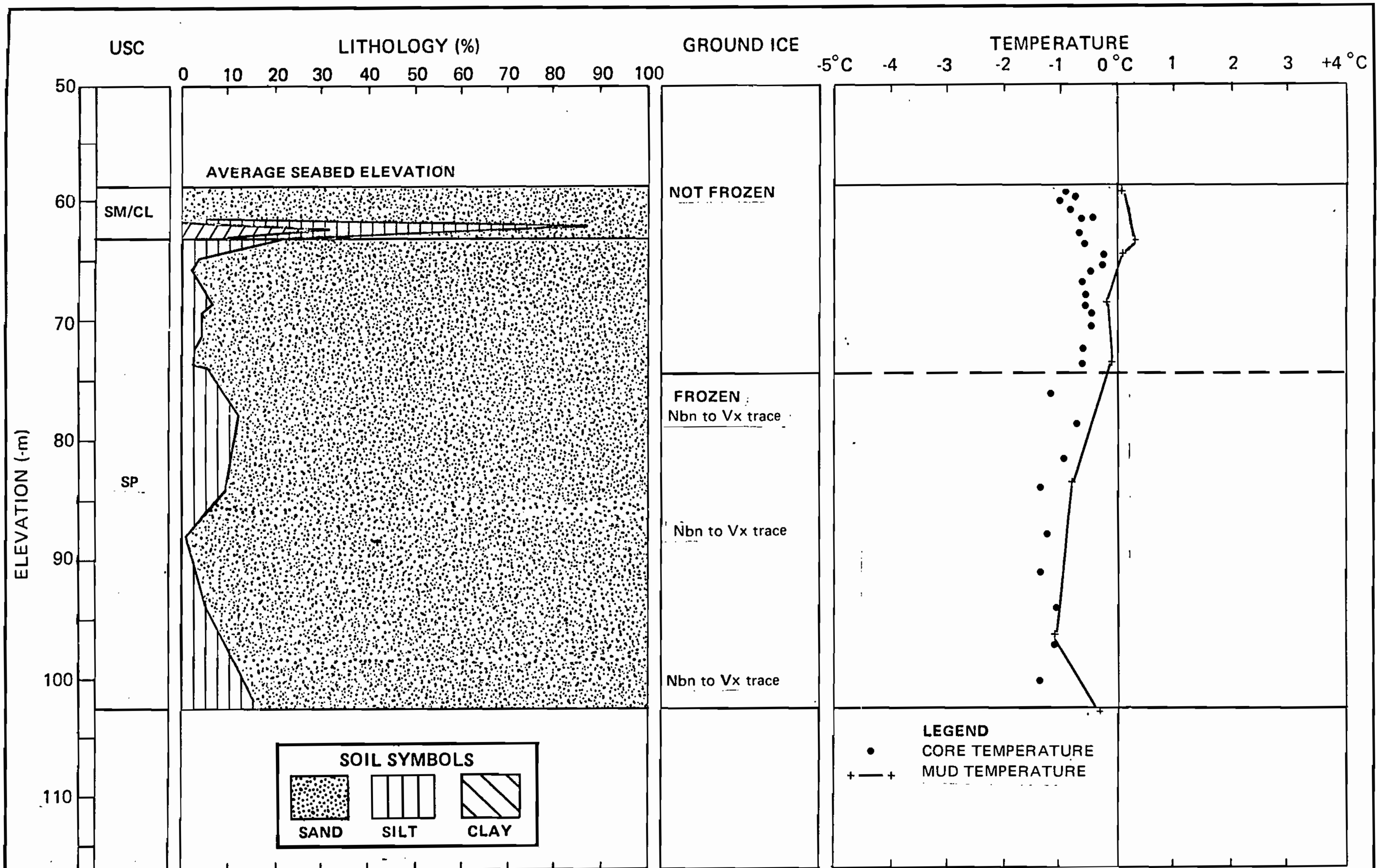
APPENDIX B

APPENDIX B

DIAGNOSTIC PROFILES

APPENDIX B

DIAGNOSTIC PROFILES



NOTE: **FROZEN** *indicates that ice bonding was distinguished.*

FIGURE B.1 TEMPERATURE PROFILE, IRKALUK B - 35

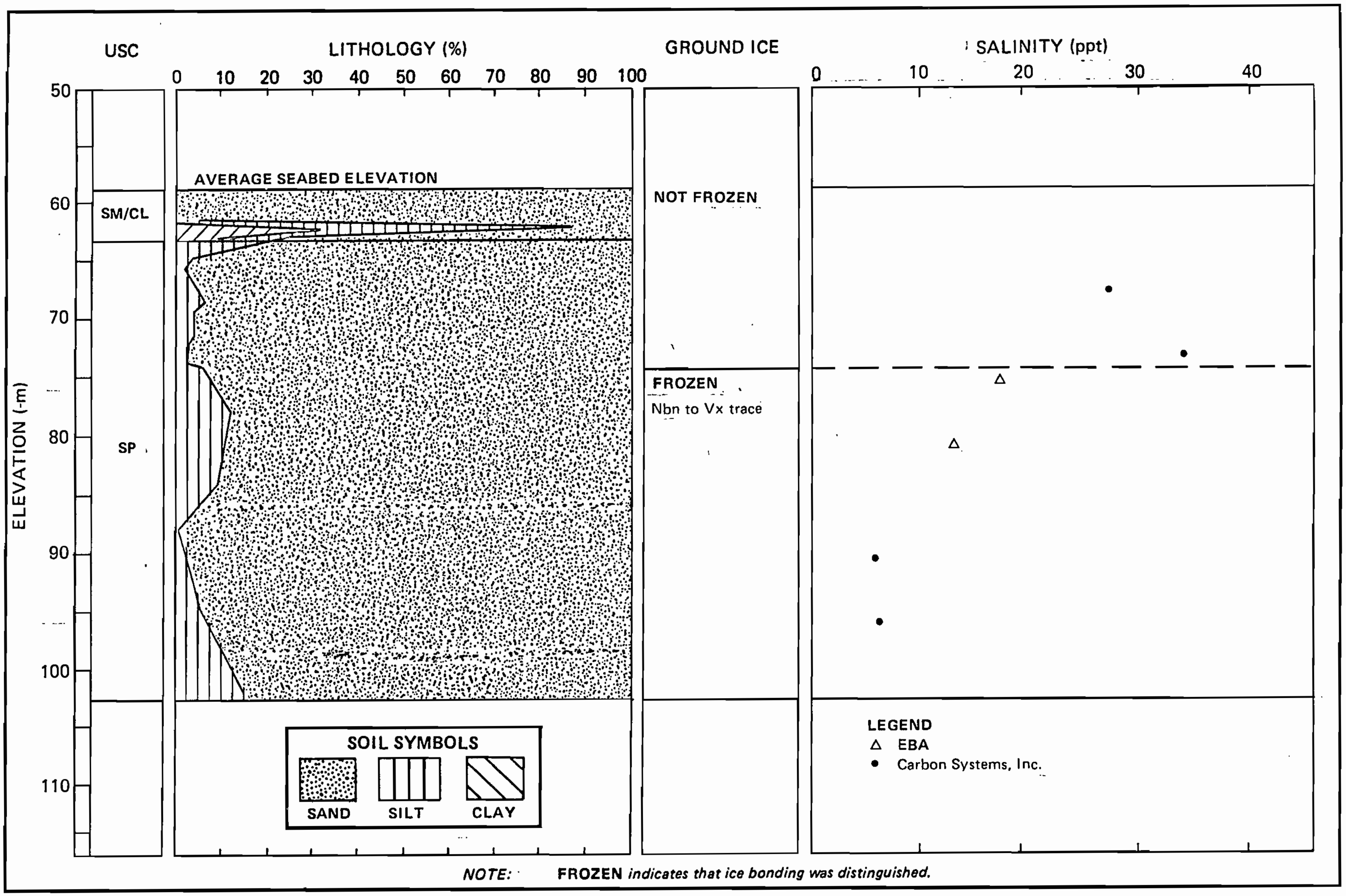


FIGURE B.2 SALINITY PROFILE, IRKALUK B - 35

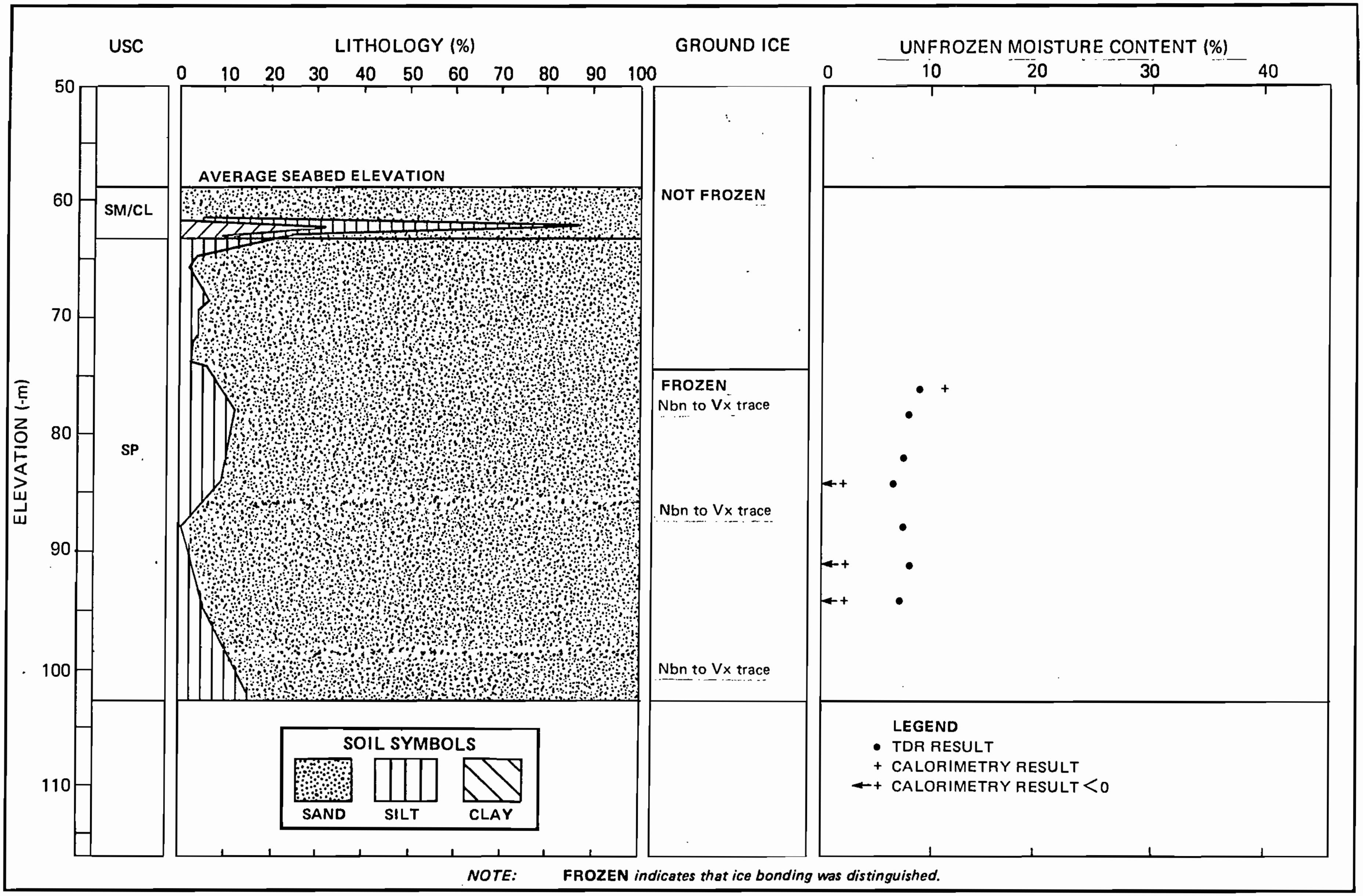


FIGURE B.3 UNFROZEN MOISTURE CONTENT PROFILE, IRKALUK B - 35

TABLE B-1 UNFROZEN MOISTURE CONTENT FROM TDR DATA

Sample No.	ϕuf cm^3/cm^3%	Dry density t/m^3	$\phi uf2$ gm/gm%
19	23.0	1.53	15
20	20.9	1.59	13
21	19.8	1.55	13
22	17.2	1.59	12
23	20.9	1.59	13
24	20.9	1.59	13
25	20.9	1.59	13
28	14.5	1.52	10

Note:

1. Dry density calculated from total m/c assuming saturated bulk density equals 1.99 t/m^3 for the stratum.

2. ϕuf [gm/gm] = ϕuf [cm^3/cm^3] ÷ Dry density

APPENDIX C

CLASSIFICATION AND INDEX TEST RESULTS

APPENDIX C
CLASSIFICATION

SAMPLE TYPES

B - bag sample

W - waxed unfrozen core sample

PF - permafrost core sample

G - gas sample canned

PW - porewater sample frozen

TDR - sample used up in time domain reflectometry testing

CA - sample used up in calorimetry testing

SUMMARY OF LABORATORY TESTING RESULTS — PERMAFROST

SAMPLE NO.	SAMPLE TYPE	DEPTH INTERVAL (metres)	MOIST. CONT. (%)	BULK DENS. (Mg/m³)	GROUND ICE DESCRIPTION (%)	ATTERBERG LIMITS LL (%)	PL (%)	PI (%)	GRAIN SIZE DISTRIBUTION CLAY (%)	SILT (%)	SAND (%)	GRAV. (%)	ORGANIC CONTENT (%)	SOIL DESCRIPTION
1A	B	SB-0.25	19		NOT FROZEN	Non	Plast	c						(SM) SAND
1B	W	0.25-0.40	17	2.13	NOT FROZEN									
2A	B	0.91-1.06	30		NOT FROZEN	37	25	12						(ML) SILT
2B	W	1.06-1.21	28	1.97	NOT FROZEN									
2C	B	1.21-1.26			NOT FROZEN									
3A	W	1.82-1.95			NOT FROZEN									
3B	B	1.95-2.13	36		NOT FROZEN									
4A	B	2.74-2.84	25		NOT FROZEN	39	31	8						(ML) SILT
4B	B	2.84-3.09			NOT FROZEN				--	5	95	0		(SP) SAND
5	B	3.66-4.06	37		NOT FROZEN				33	54	13	0		(ML-CL) CLAY AND SILT
6	B	4.57-5.17	24		NOT FROZEN				--	23	77	0		(SP) SAND
7	B	5.49-5.99	26		NOT FROZEN									
8	B	6.40-6.70	24		NOT FROZEN				--	3	97	0		(SP) SAND
9	B	7.32-7.82	24		NOT FROZEN				--	2	98	0		(SP) SAND
10	B	8.23-8.83	27		NOT FROZEN									
11	B	9.14-9.79	30		NOT FROZEN									
12	B	10.06-10.54	29		NOT FROZEN				--	6	94	0		(SP-SM) SAND
13	B	10.97-11.27	25		NOT FROZEN				--	4	96	0		(SP) SAND
14	B	11.89-12.20	25		NOT FROZEN				--	4	96	0		(SP) SAND
15	B	12.80-13.20	27		NOT FROZEN				--	4	96	0		(SP) SAND
16	B	13.72-13.95	25		NOT FROZEN				--	3	97	0		(SP) SAND
17	B	14.63-15.08	27		NOT FROZEN				--	3	97	0		(SP) SAND
18	B	15.54-15.84	28		NOT FROZEN				--	6	94	0		(SP-SM) SAND
19A	B	17.64-17.69	30		FROZEN									
19B	PF	17.69-17.81			Nbn to Vx trace									

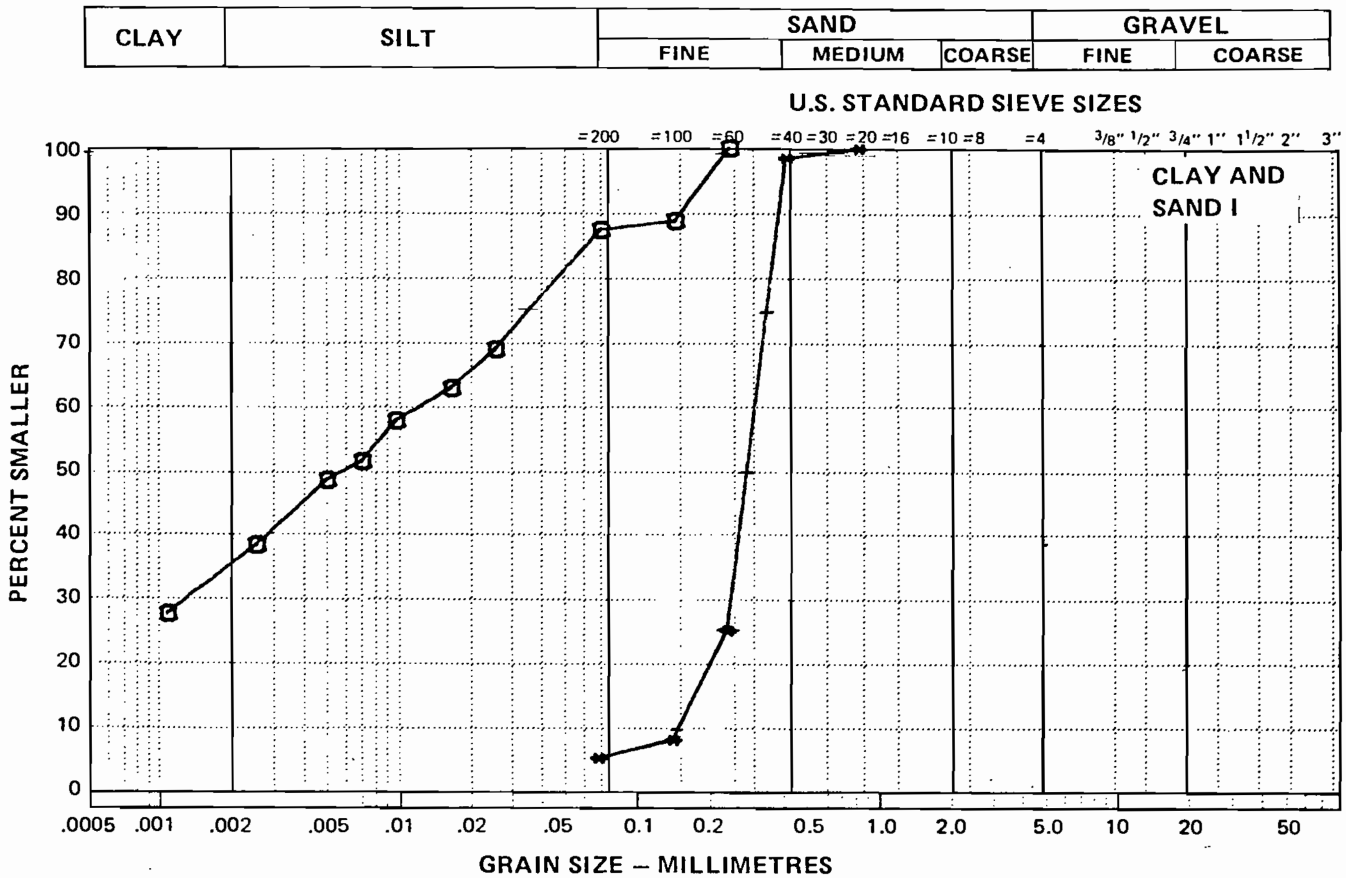
PROJECT NUMBER 101-3210 SITE NUMBER F-IRK 1:1

SUMMARY OF LABORATORY TESTING RESULTS – PERMAFROST

SAMPLE NO.	SAMPLE TYPE	DEPTH INTERVAL (metres)	MOIST. CONT. (%)	BULK DENS. (Mg/m^3)	GROUND ICE DESCRIPTION (%)	ATTERBERG LIMITS LL (%)	ATTERBERG LIMITS PL (%)	ATTERBERG LIMITS PI (%)	GRAIN SIZE DISTRIBUTION CLAY (%)	GRAIN SIZE DISTRIBUTION SILT (%)	GRAIN SIZE DISTRIBUTION SAND (%)	GRAIN SIZE DISTRIBUTION GRAV. (%)	ORGANIC CONTENT (%)	SOIL DESCRIPTION
20	B	20.74-20.89	24		FROZEN				--	11	88	1		(SP-SM) SAND
21A	PF	23.79-23.94	29		Nbn to Vx trace									
22A	PF	26.04-26.11			Nbn to Vx trace									
22B	B	26.11-26.29	25		Nbn to Vx trace				--	8	93	0		(SP-SM) SAND
23A	B	29.89-30.04	25		Nbn to Vx trace				--	1	99	0		(SP) SAND
24	G	32.94-33.14	26		Nbn to Vx trace									
25	B	35.99-36.24	26		Nbn to Vx trace				--	5	95	0		(SP) SAND
26	B	39.04-39.22	28		Nbn to Vx trace									
27	PF	42.06-42.26	27		Nbn to Vx trace									
28	PF	45.60-45.80	31		Nbn to Vx trace				--	15	85	0		(SP) SAND

PROJECT NUMBER 101-3210 SITE NUMBER F-IRK1:1

PARTICLE - SIZE ANALYSIS OF SOILS

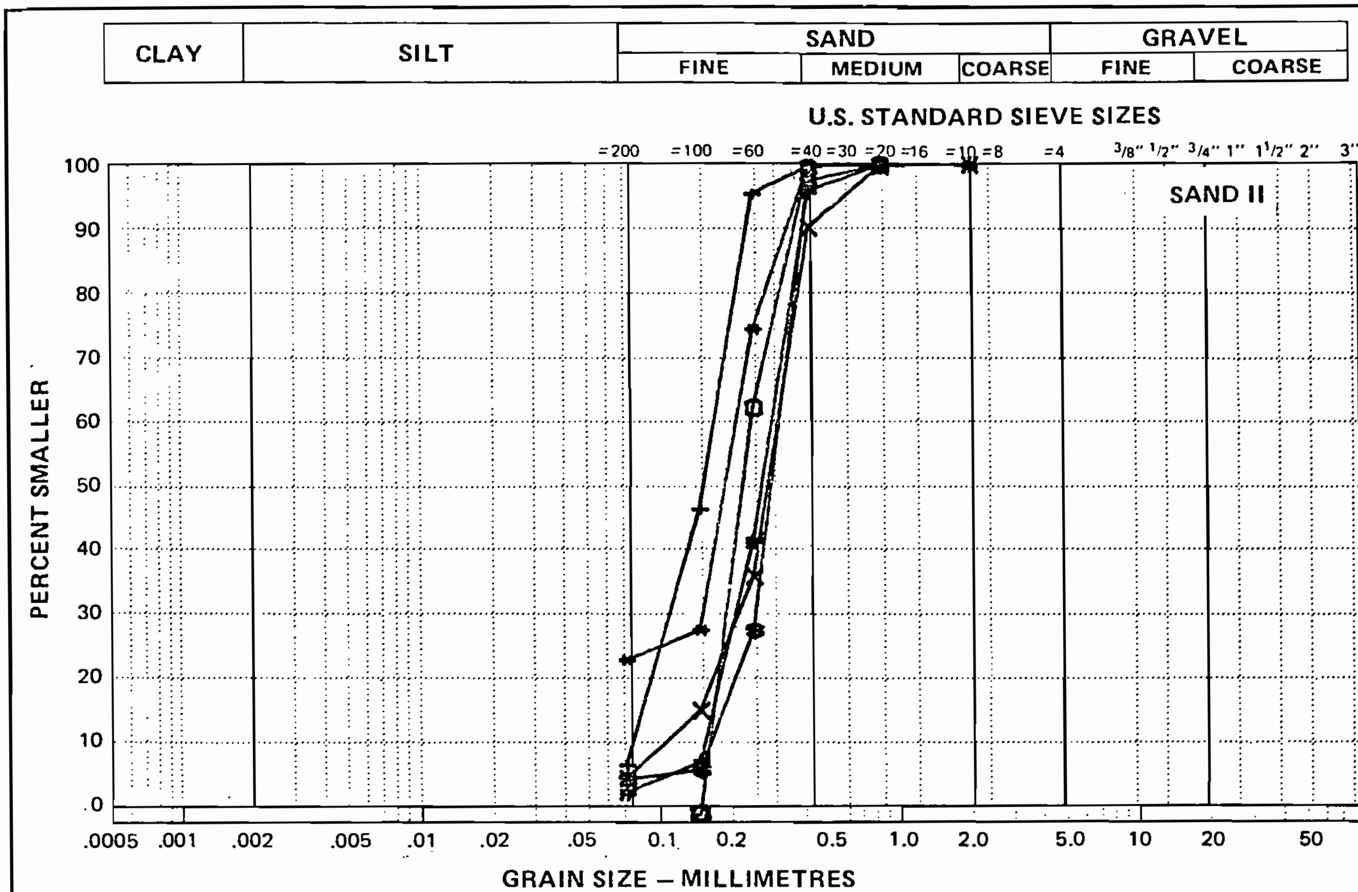


SYMBOL	BOREHOLE NUMBER	DEPTH (m)	CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
			DESCRIPTION						
*	F-IRK1:1	~~2.74- 2.84~~ 2.89 - 3.09	–	4.7	95.3	0.0	2.0	1.3	SP
▫	F-IRK1:1	3.88- 4.08	33.8	53.4	12.8	0.0	–	–	–

2
3

JOB NO. 101-3210 DATE 82-02-10

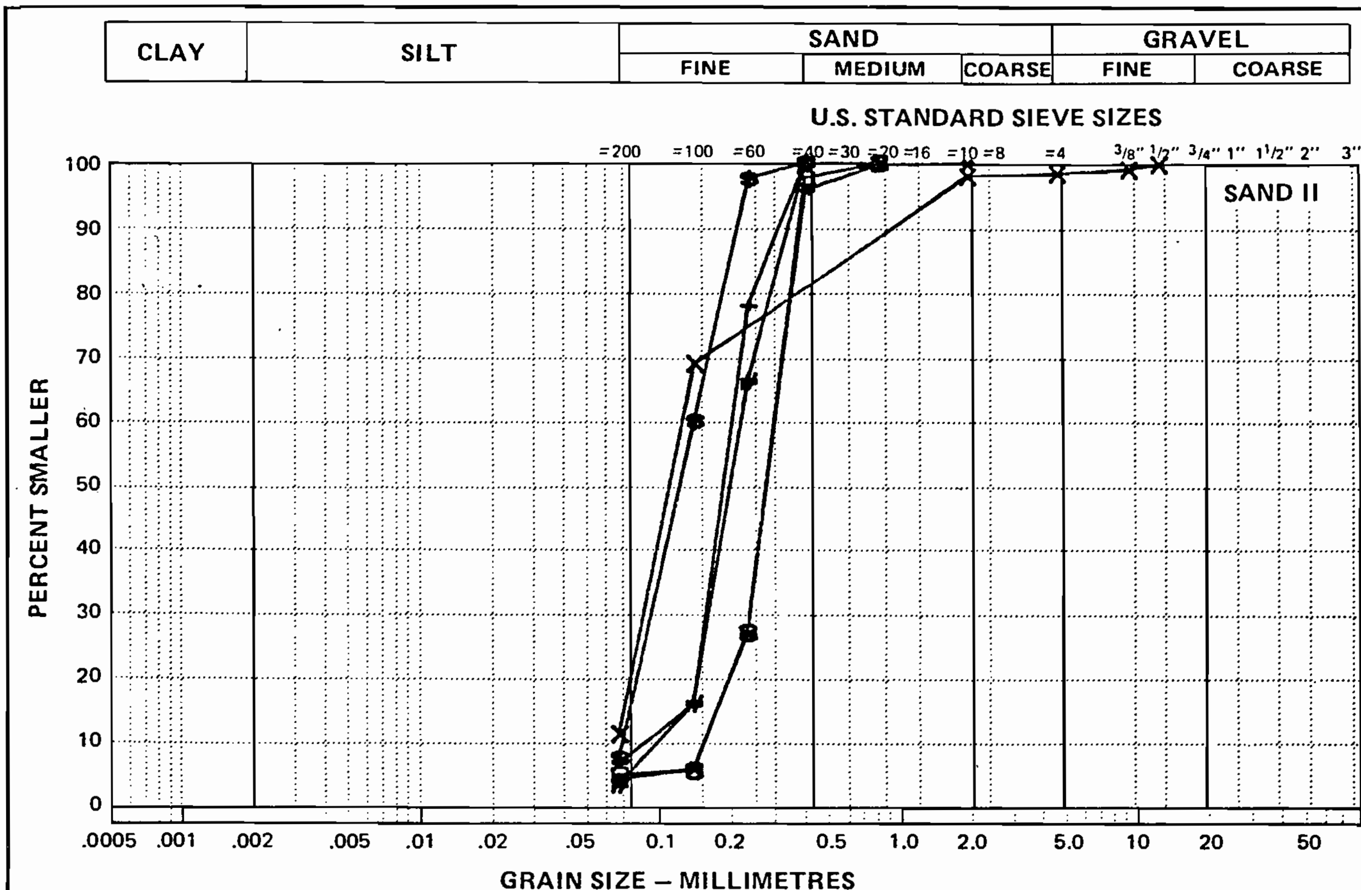
PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
*	F-IRK1: 1	4.57– 5.17	–	22.7	77.3	0.0	–	–	–
◻	F-IRK1: 1	8.40– 8.70	–	0.0	100.	0.0	1.5	.9	SP
#	F-IRK1: 1	7.32– 7.82	–	2.0	98.0	0.0	1.9	.9	SP
+	F-IRK1: 1	10.08– 10.54	–	6.2	93.8	0.0	2.2	.9	SP-SM
×	F-IRK1: 1	10.97– 11.27	–	4.2	95.8	0.0	2.9	1.4	SP
✱	F-IRK1: 1	11.89– 12.20	–	4.0	96.0	0.0	1.9	1.2	SP

JOB NO. 101–3210 DATE 81–12–14

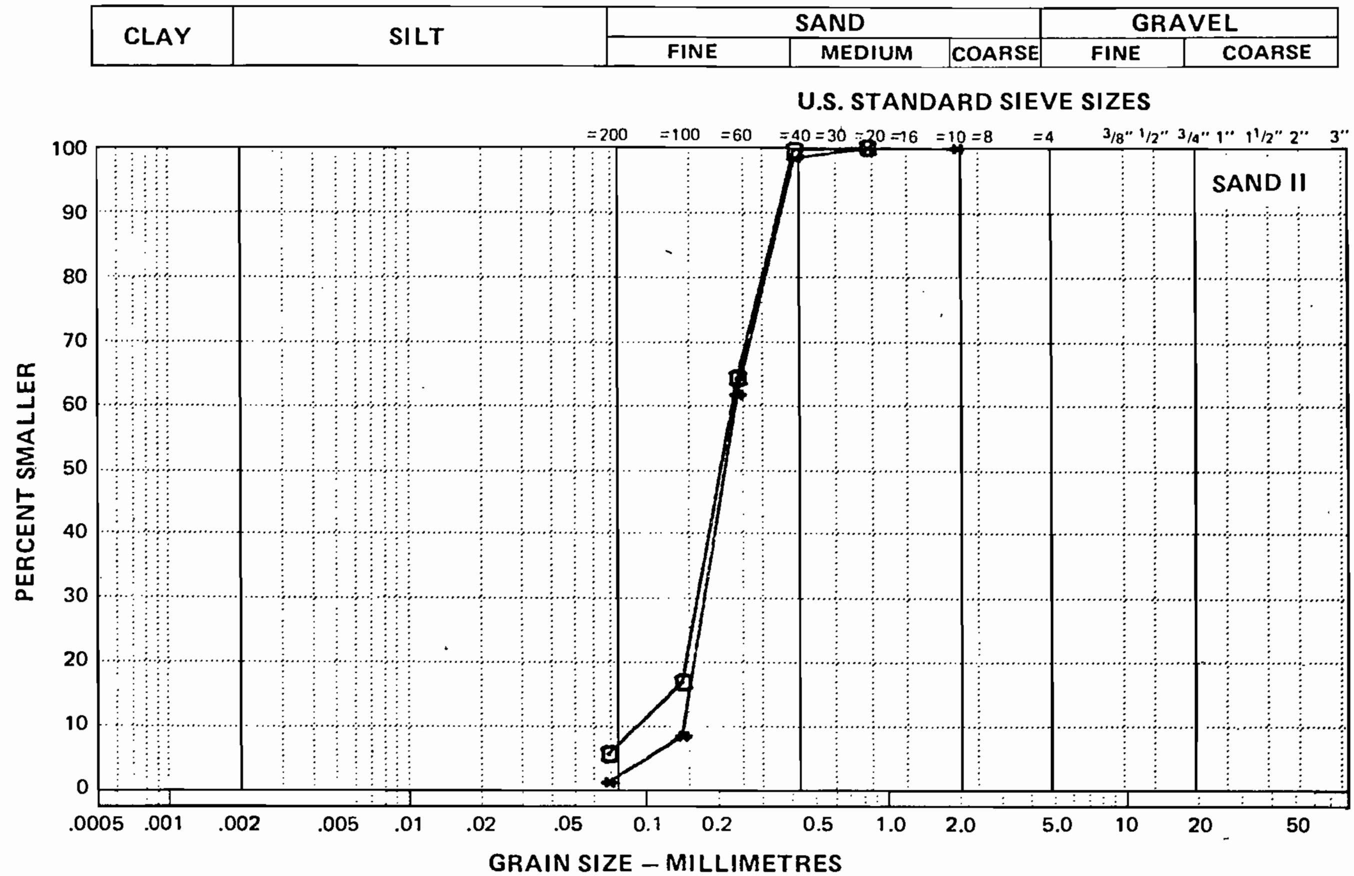
PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
●	F-IRK1: 1	12.80- 13.20	–	3.8	96.2	0.0	1.9	1.2	SP
□	F-IRK1: 1	13.72- 13.95	–	4.5	95.5	0.0	1.9	1.2	SP
#	F-IRK1: 1	14.83- 15.08	–	3.0	97.0	0.0	2.2	1.2	SP
+	F-IRK1: 1	15.54- 15.84	–	6.2	93.8	0.0	2.2	1.3	SP-SM
×	F-IRK1: 1	20.74- 20.89	–	10.8	87.8	1.4	–	–	–
$	F-IRK1: 1	28.11- 28.29	–	7.1	92.9	0.0	2.0	.9	SP-SM

JOB NO. 101-3210 DATE 81-12-14

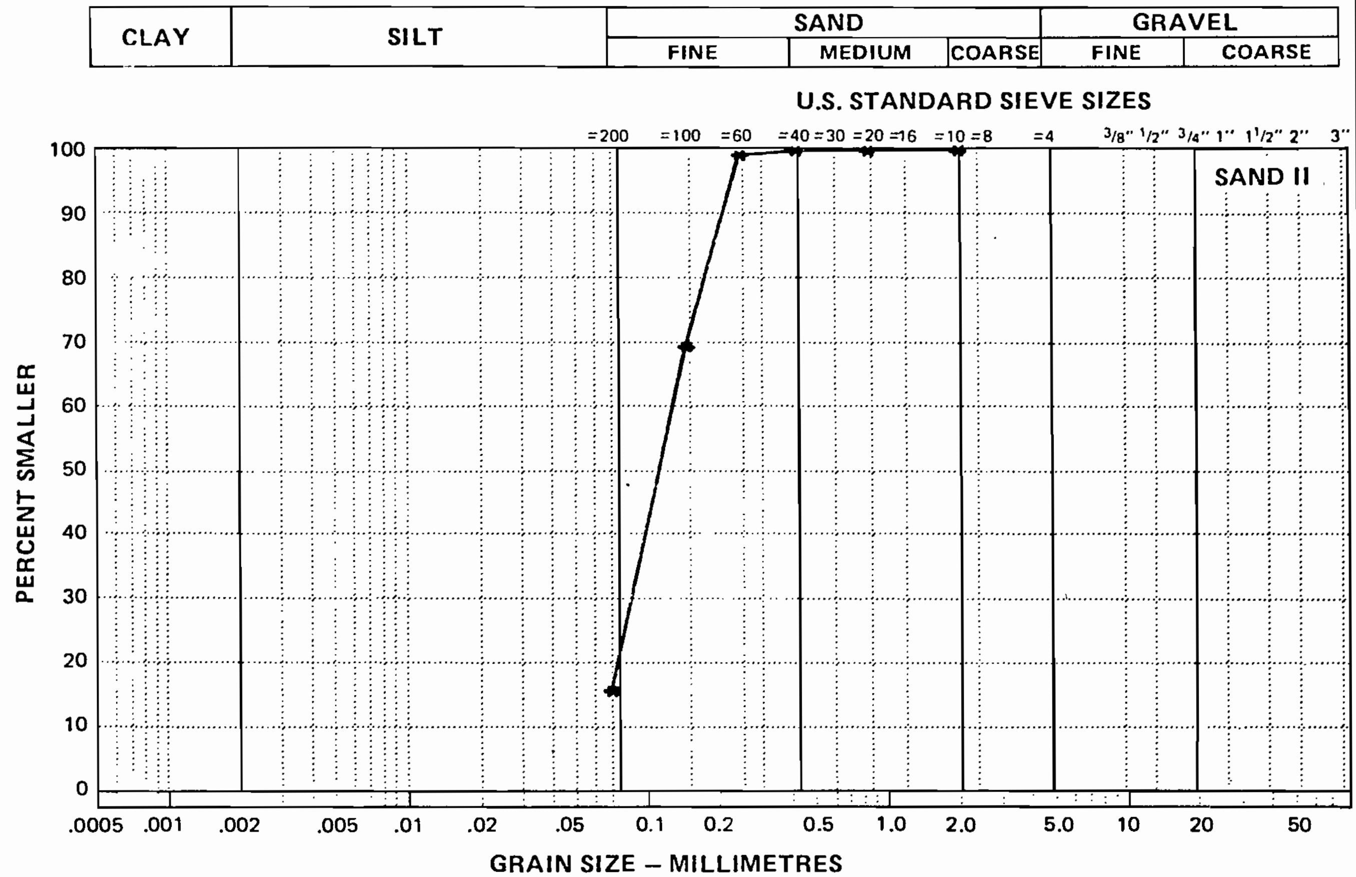
PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
*	F-IRK1: 1	29.99- 30.04	–	.7	99.3	0.0	1.6	.9	SP
□	F-IRK1: 1	35.99- 36.24	–	5.1	94.9	0.0	2.4	1.3	SP-SM

JOB NO. 101-3210 DATE 81-12-14

PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
*	F-IRK1: 1	45.80– 45.80	–	15.5	84.5	0.0	–	–	–

JOB NO. 101–3210 DATE 81-12-14

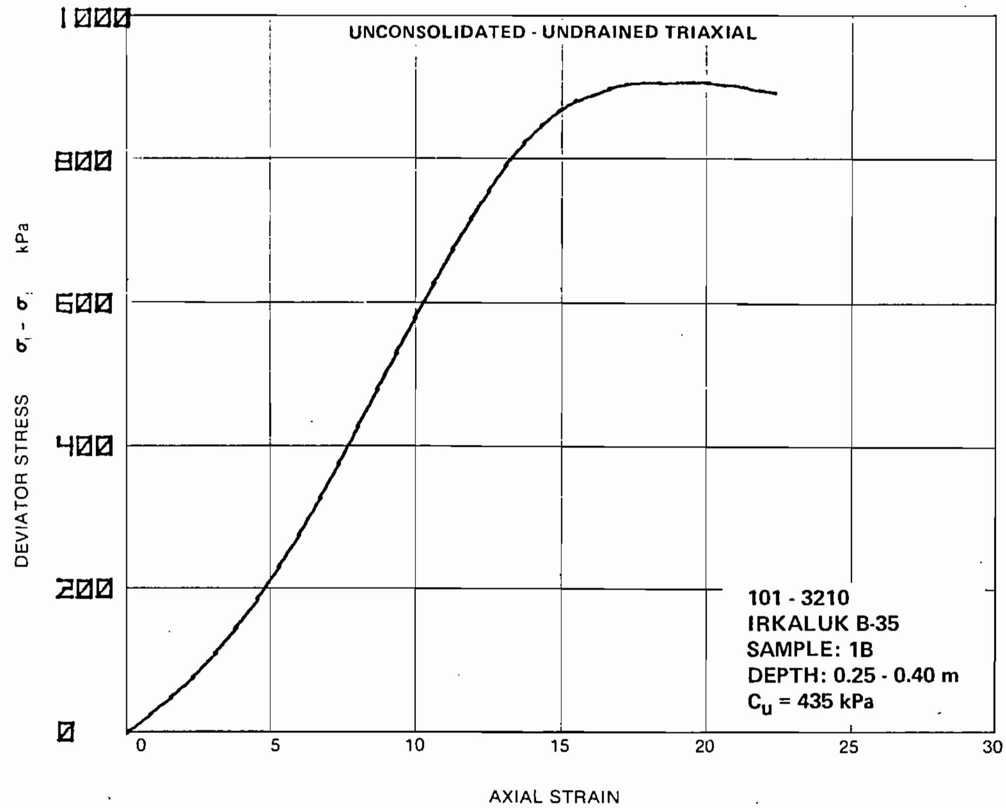
APPENDIX D
SHEAR STRENGTH

APPENDIX D

SHEAR STRENGTH TEST RESULTS

TABLE D-1 SUMMARY OF UNCONSOLIDATED - UNDRAINED TRIAXIAL TESTS, IRKALUK B-35

Borehole No.	Depth Interval (m)	USC	Water Content (%)	Wet Density (Mg/m^3)	Confining Pressure (kPa)	Axial Strain at Failure (%)	Undrained Shear Strength (kPa)	Mode of Failure
F-IRK 1:1	0.25-0.40	SM-ML	17	2.13	340	15	435	Barreling
	1.06-1.21	ML-SM	28	1.97	350	14.5	46.5	Shear Plane



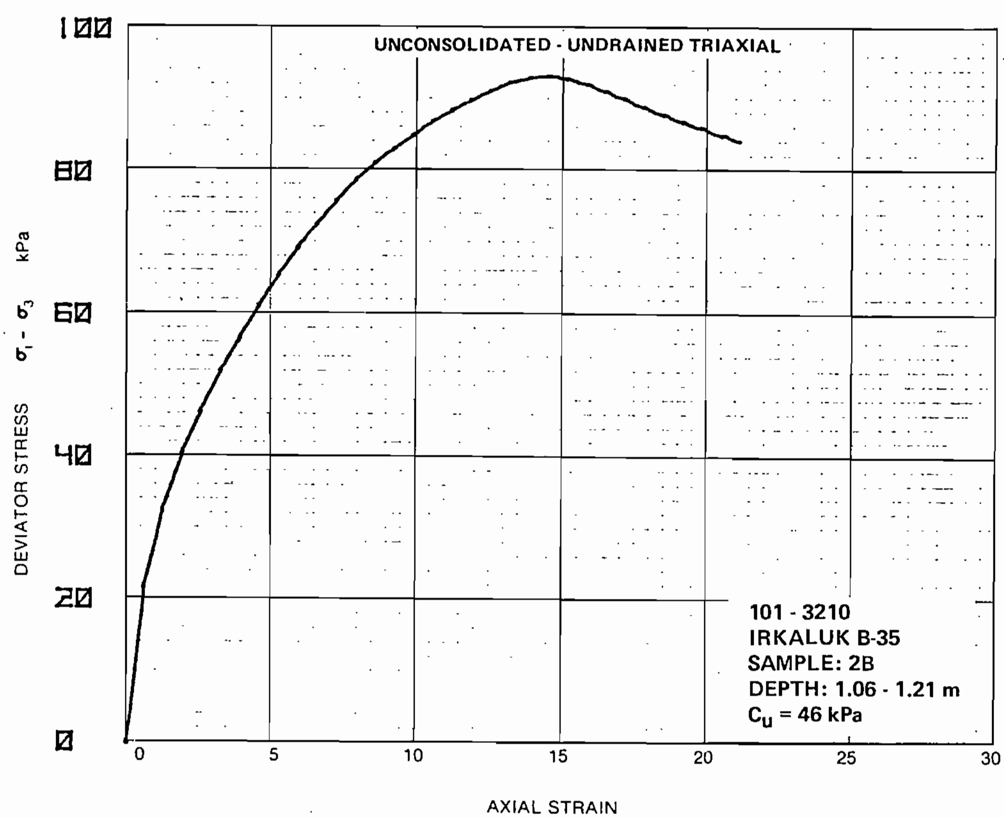


FIGURE D.1 SHEAR STRENGTH TEST RESULTS

APPENDIX E
CONSOLIDATION

APPENDIX E

CONSOLIDATION TEST RESULTS

TABLE E.1 CONSOLIDATION TEST RESULT, IRKALUK B-35

SAMPLE NUMBER	DEPTH (metres)	USC	MOISTURE CONTENT INITIAL (%)	MOISTURE CONTENT FINAL (%)	BULK DENSITY INITIAL (Mg/m^3)	BULK DENSITY FINAL (Mg/m^3)	EFFECTIVE OVERBURDEN PRESSURE (kPa)	ESTIMATED PRECONSOLIDATION PRESSURE (kPa)	c_c	NORMAL STRESS (kPa)	e	c_v (m^2/yr)	m_v (1/MPa)	k (m/s)
3A	1.83-1.95	CL	31	27	1.95	2.04	20	62-66	0.23-0.27	0				
											0.867			
										10				
											0.863	7.07E 01	2.19E-01	4.82E-09
										16				
											0.857	3.44E 01	5.26E-01	5.63E-09
										20				
											0.854	6.37E 01	4.94E-01	9.79E-09
										UNLOADED to 10 kPa with e = 0.864				
										20				
											0.861	8.93E 00	1.58E-01	4.39E-10
										30				
											0.859	1.53E 01	8.65E-02	4.12E-10
										45				
											0.854	6.12E 00	1.97E-01	3.74E-10
										70				
											0.842	1.90E 01	2.53E-01	1.50E-09
										100				
											0.827	4.34E 00	2.70E-01	3.64E-10
										225				
											0.779	1.05E 01	2.11E-01	6.87E-10
										500				
											0.717	3.04E 00	1.27E-01	1.20E-10
										1000				
											0.665	4.39E 00	6.00E-02	8.20E-11
										2000				
											0.588	2.38E 00	4.66E-02	3.44E-11
										3200				
											0.539	4.53E 00	2.57E-02	3.62E-11
										UNLOADED to 500 kPa with e = 0.560				
										UNLOADED to 45 kPa with e = 0.620				
										UNLOADED to 10 kPa with e = 0.649				
										UNLOADED to 0 kPa with e = 0.727				

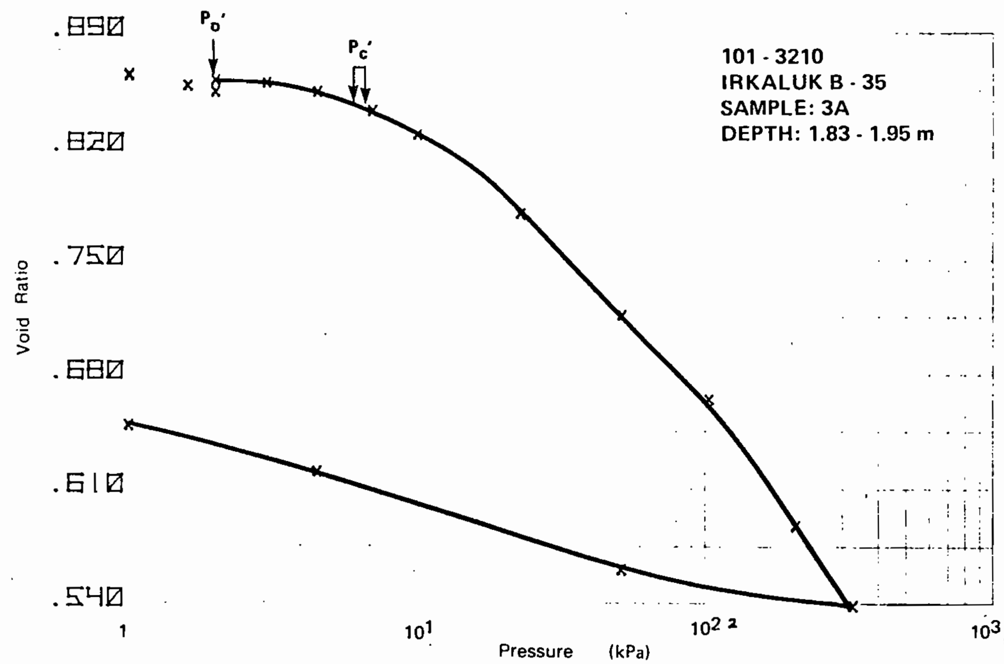


FIGURE E.1 CONSOLIDATION TEST RESULTS

APPENDIX F
SUBCONSULTANTS

APPENDIX F

SUBCONSULTANTS RESULTS

APPENDIX F

SUBCONSULTANTS RESULTS

General

Tests performed outside the confines of EBA's laboratory were restricted to a geochemical investigation consistent with previous years work. These services were provided by subconsultants.

Geochemical analyses were performed by Carbon Systems Inc. (CSI) in Baton Rouge, Louisiana. Dr. Whelan of CSI prepared a separate interpretative report discussing the results from all the 1981 borings. Results for the 4 samples taken at the Irkaluk B-35 location have been excerpted from that report, and are presented in this Appendix. Porewater salinities extracted from the CSI report are presented elsewhere as a diagnostic profile (see Figure B.2, Appendix B).

The complete CSI interpretative report was bound separately by EBA and is included with the package of reports from the 1981 Offshore Geotechnical Site Investigations.

Discussion of Results

The IRKALUK borehole was drilled in 58.2 m of water to a depth of 45.8 m below the mudline. The geochemical data are similar in this boring to the other 1981 borings. The most striking feature of these data was the sharp lowering of salinity in the 33.2 m penetration (-91.4 m Elevation) and 39.3 m penetration (-97.5 m Elevation) samples. Salinities fell to below 6 ppt. This result was also observed in both UVILUK and MITERK locations. KOAKOAK 2:3 also demonstrated a lower salinity at 29.1 m penetration (-75.4 m Elevation).

The average content of petrogenic gases was slightly higher in this boring than the others. Again, the concentrations were too low to indicate a potential drilling or foundation hazard.

Presentation of Results

The results of laboratory analyses are listed in Tables 1 to 5. The tabular data is listed in tables for each parameter set. For example, water content, salinity, sulfate, etc. are organized into Table 1. Table 2 contains hydrocarbon gas concentrations. Tables 3, 4 and 5 give theoretical values, pressure calculations and carbonate content respectively. On these tables, depths for samples within the boring are represented by the deepest depth designation of the metric interval of penetration below the mud line.

Table 1. Results of pore water and bulk sediment analyses for each sample.

CLIENT: EBA ENGINEERING
JOB NO: 101-3210
BORING: F-IRK 1:1
SITE : BEAUFORT SEA

DEPTH OF WATER = 191. m
TEMP SEDIMENT = 293 DEG. K
DENSITY SEDIMENT = 2.70 GM/CC
SOLUBILITY METHANE= 25.0 ML/L.ATM.
NUMBER OF SAMPLES = 4

OBSERVATIONS FOR EACH SAMPLE

DEPTH m	WATER CONT. (WC) WT. PERCENT	SALINITY (C) PPT W/W	OBS. SULFATE (SO) PPT W/W	CONDUCTIVITY MICRO-MHOS	PH	TOT. ORG. C (TOC) WT. PERCENT	DIOC M-MOL/L
5.2	19	27.27	1.87	40600.	0.14	0.41	3.92
15.8	22	33.79	1.99	49100.	0.07	0.08	4.00
33.2	21	5.72 24	0.55	8650.	0.80	0.13	2.42
39.3	22	5.90 26	0.37	8690.	0.89	0.11	2.75

Table 2. Observed total light hydrocarbon concentrations in ppm (v/v). Sum sat. represents the sum of the concentrations of the "petrogenic saturated hydrocarbons: ethane, propane, iso-butane and normal butane.

DEPTH DISTRIBUTIONS OF GAS PRESSURE DERIVED FROM OBSERVED AND THEORETICAL METHANE CONCENTRATIONS
(PRESSURES ARE GIVEN IN BOTH ATM. AND PSI)

DEPTH	PRESSURE			
	PSI		ATMOS.	
m	OBSERVED	MAXIMUM	OBSERVED	MAXIMUM
5.2	-2.88	-1.89	-0.20	-0.13
15.8	-3.29	0.70	-0.22	0.05
33.2	-3.97	-5.52	-0.27	-0.38
39.3	-4.22	-4.41	-0.29	-0.30

F-IRK 1:1

Table 3. Calculated values for theoretical methane compared with measured methane values. Observed sulfate concentrations are listed as a comparison with the associated calculated sulfate deficit (corrected for salinity).

COMPARISON OF METHANE CONTENT PER UNIT VOLUME OF PORE WATER
WITH THE MAXIMUM POSSIBLE IN DISSOLVED AND BUBBLE PHASES

DEPTH	WATER CONTENT	POROSITY	METHANE ML/L		
m	PERCENT		TOTAL	MAX. DISSOLVED	BUBBLE
5.2	19	0.38	0.0	182.7	-182.6
15.8	22	0.43	0.3	208.9	-208.6
33.2	21	0.41	0.4	252.3	-251.9
39.3	22	0.43	0.0	267.4	-267.4

F-IRK 1:1

Table 4. Comparison of the observed methane content, converted to concentration per unit volume of pore water, with the maximum value of dissolved methane which could be present in each sample. Maximum values of dissolved methane are calculated from the pressure-solubility relationships discussed in the text. Bubble concentrations are equal to the difference between total observed and max. dissolved.

Table 5. Gas pressure calculations, for each sample, derived from both observed methane values and theoretical methane values. Pressures are listed in psi and atmospheres. Negative values have no physical significance and indicate that methane concentrations are insufficient to saturate the pore water and form bubbles.

OBSERVED HYDROCARBON CONCENTRATIONS
MICRO-L/L WET SEDIMENT

DEPTH	METHANE	ETHENE	ETHANE	PROPENE	PROPANE	I-BUTANE	N-BUTANE	SUM SAT.
5.2	12.	0.70	1.10	0.20	1.00	0.00	0.10	2.20
15.8	132.	0.60	1.10	0.20	0.90	0.20	0.20	2.40
33.2	174.	1.20	3.50	0.40	1.90	0.40	0.40	6.20
39.3	5.	0.50	2.60	0.20	1.80	0.30	0.40	5.10

F-IRK 1:1

APPENDIX G
PHOTO INDEX

APPENDIX G

INDEX TO CORE PHOTOGRAPHY

TABLE G.1 SUMMARY OF CORE PHOTOGRAPHY, IRKALUK B-35

SAMPLE NO.	SAMPLE TYPE	DEPTH INTERVAL (m)	USC	NUMBER OF PHOTOS (if more than one)
1A	B	SB-0.25	SM	
2A	B	0.91-1.06	ML	
3B	B	1.95-2.13		
4B	B	2.84-3.09	SP	
5	B	3.66-4.06	ML-SP	
6	B	5.47-5.17	SP	
7	B	5.49-5.99	SP	
8	B	6.40-6.70	SP	
9	B	7.32-7.82	SP	
10	B	8.23-8.83	SP	
11	B	9.14-9.79	SP	
12	B	10.06-10.54	SP-SM	
13	B	10.97-11.27	SP	
14	B	11.89-12.20	SP	
15	B	12.80-13.20	SP	
16	B	13.72-13.95	SP	
17	B	14.63-15.08	SP	
18	B	15.54-15.84	SP-SM	
19A	B	17.64-17.81		
20	B	20.74-20.89	SP-SM	
21A	PF	23.79-23.94		
22B	B	26.11-26.29	SP-SM	
23A	B	29.89-30.04	SP	
24	B	32.94-33.14	SP	
25	B	35.99-36.24	SP	
26	B	39.04-39.22		
27	PF	42.06-42.26		
28	PF	45.60-45.80	SM	

APPENDIX H
LAB PROCEDURES

APPENDIX H

LABORATORY TEST PROCEDURES

LABORATORY TEST PROCEDURES

Procedures Specified

1. Classification and Index Tests
2. Triaxial Shear Tests
3. Direct Shear Tests
4. Laboratory Miniature Vane
5. Swedish Fall Cone Shear Strength Determination
6. Consolidation Tests
7. Porewater Salinity Tests
8. Organic Content Determination
9. Radiography
10. Petrographic Analysis of Sands
11. Angle of Repose

LABORATORY TEST PROCEDURES

1. CLASSIFICATION AND INDEX TESTS

These tests are quite routine and the standard ASTM procedures employed are listed below:

TEST	ASTM DESIGNATION
Moisture Content	D 2216
Liquid Limit (1)	D 423
Plastic Limit and Plasticity Index	D 424
Grain Size	D 421 & 422
Specific Gravity	D 854
Relative Density	D 2049
Unified Soil Classification	D 2487

NOTE: 1. All liquid limit determinations reported were 3 point determinations.

2. TRIAXIAL SHEAR TESTS

UNCONSOLIDATED-UNDRAINED TRIAXIAL TESTS

Procedure 1* - Standard unconfined compression test procedure. Stress-strain curve produced.

Procedure 2* - Sample mounted in triaxial cell and jacketed. A pore pressure response test is carried out prior to shearing. If further saturation is required, back pressure can be applied to the sample. Cell pressure equivalent to estimated total horizontal stress applied without sample drainage. Sample sheared by increasing axial stress at controlled rate of strain. Frozen samples permitted to thaw (undrained) before commencing pore pressure response test. Stress-strain curve produced.

Procedure 3* (Multi-Stage Test) - As procedure 2. Samples taken to yield (5% - 7% strain) so maximum deviatoric can be estimated or to failure, whichever is the smaller. Shearing is stopped temporarily and the cell pressure then set to second highest value and test proceeds. If sample has not already failed or exceeded 20% strain the shearing is stopped and the cell pressure is then set to the third highest value and the test proceeds. Full Mohr's Circle plot produced or only stress-strain curve produced if failure occurs in the first stage or no real change in the curve is produced.

* This test may be specified with porewater pressure measurement.

CONSOLIDATED-UNDRAINED TRIAXIAL TESTS

Procedure 1 - Sample mounted in triaxial cell and jacketed. A pore pressure response test is carried out prior to shearing. If further saturation is required, back pressure can be applied to the sample. Frozen samples are placed in a pre-chilled triaxial cell and permitted to thaw before commencing consolidation. Cell pressure equivalent to estimated total horizontal stress applied allowing drainage. Once consolidation is complete, drainage is shut off. Samples are sheared by increasing axial stress at controlled rate of strain. Stress-strain curve and other diagnostic plots are produced.

CONSOLIDATED-DRAINED TRIAXIAL TESTS

Procedure 1 - Sample mounted in triaxial cell and jacketed, and then thawed under nominal pressure of 35 kPa. A pore pressure response test is carried out prior to shearing. If further saturation is required, back pressure can be applied to the sample. Consolidated to cell pressure equivalent to estimate horizontal in situ effective stress. With drainage open, sample is sheared by increasing the axial stress at a controlled rate of strain. The rate of strain used is selected based on the consolidation properties of the soil determined during the consolidation phase of this test. Stress-strain curve and other diagnostic plots are produced.

Procedure 2 - Lack of undisturbed samples of sand from certain strata required reconstituting disturbed samples for strength testing. Relative density test conducted on the sand and reconstituted samples are prepared to approximately 70% relative density. A pore pressure response test is carried out prior to shearing. If further saturation is required, back pressure can be applied to the sample. Sample is consolidated to cell pressure equivalent to estimated in situ horizontal effective stress. With the drainage open, the sample is sheared by increasing the axial stress at a controlled rate of strain.

Stress-strain curve and other diagnostic plots are produced.

NOTES: 1. Standard UU Triaxial procedure ASTM D2850.

2. Standard CU and CD triaxial procedures taken from Bishop & Henkel (1969).

3. Samples reconstituted according to procedures outlined in Bjerrum, Kringstad, and Kummeneje (1961).

3. DIRECT SHEAR TESTS

Procedure 1 - Standard direct shear procedure. Frozen samples permitted to thaw and consolidate under applied normal pressure before commencing shear. Resheared strength measured on plane cut after peak strength has been determined. Generally perform minimum of 3 tests on each material type to define effective stress parameters c' and Ø'. Shear stress - deformation curve and other diagnostic plots produced.

Procedure 2 - If no undisturbed sample was available an appropriate sample was reconstituted for testing and the same general procedure was utilized as indicated above.

NOTES: 1. Standard direct shear procedure ASTM D 3080.

2. Samples reconstituted according to procedures outlined in Bjerrum, Kringstad, and Kummeneje (1961).

4. LABORATORY MINIATURE VANE

Procedure 1 - Sample either retained in shelby tube or extruded into split ring. Vane lowered into sample ensuring total submergence of the vane. Vane rotated at 10 degrees/min. Test run until steady post-peak value is reached. Stress-strain curves, peak and post-peak shear strengths produced.

5. "SWEDISH" FALL CONE SHEAR STRENGTH DETERMINATION

Procedure 1 - Small portion of sample is extruded into a small cup. Cone is selected with reference to expected shear strength of soil. Cone is lowered to just touch the surface of the sample and released. Depth of penetration of cone is measured. Shear strength is inferred from cone charts.

6. STANDARD OEDOMETER/CONSOLIDATION TESTS

Procedure 1 - Sample set up in oedometer with dry stones. Standard incremental loading is done to a specified vertical effective stress that exceeds the in situ effective overburden pressure. The oedometer is then flooded unloaded and permitted to rebound. After rebound, the specimen is reloaded in 50% increments until a vertical effective stress, as specified, is reached. Thereafter, the standard doubling of pressures is resumed to test completion. All load increments are left on for a time interval determined by the root time method (Craig, 1974). e-log-p' curve, c_v, k, m_v, and P_c data produced.

Procedure 2 - Sample set up frozen in oedometer, then moved from cold room to standard apparatus. Stress is applied to seat load cap and sample is then thawed under nominal pressure. Procedure continues as for Procedure 1. e-log-p' curve, c_v, k, m_v, and p'c data produced.

NOTE: 1. Modifications made to standard procedure (ASTM D 2435) are taken from Andresen et al. (1979) and Broms (1980) recommended for overconsolidated soils.

In addition to the specific procedures described above, all samples programmed for testing will have other basic tests performed as follows:

1. Moisture content
2. Bulk density
3. Core photography (where practical)
4. Detailed description of sedimentological features, and
5. Identification and preservation of discrete organic matter when present.

7. POREWATER SALINITY TESTS

Procedure 1 - Samples trimmed to remove disturbed material. Porewater extruded from thawed sample and chloride titration is performed to establish equivalent salinity (NaCl).

NOTES: 1. A silver nitrate titration was performed to determine the chloride ion content (ASTM D 512 Method B).

2. Chloride ion content was converted to an equivalent salinity using the following empirical relation.

Salinity (o/oo) = 0.03 + (1.805 x Chlorinity (o/oo))

8. ORGANIC CONTENT DETERMINATION

Procedure 1 - Small portion of sample weighed then oven dried. Dried sample mixed with Hydrogen Peroxide solution (H202) and boiled. After all reaction ceases sample is oven dried and reweighed. Loss in weight is inferred as organic content.

9. RADIOGRAPHY

Procedure 1 - Samples transported to radiography subcontractor to be exposed and developed on their premises. Samples returned with film negatives.

Procedure 2 - Samples radiographed at EBA. Samples removed from storage area and replaced immediately. Film processed immediately and results reviewed.

NOTE: 1. Radiography subcontractor can for report presentation preparation make high quality B/W prints from film negatives.

10. PETROGRAPHIC ANALYSIS STUDY OF SANDS

Prior to wet sieve separation into #60, #100 and #200 fractions, the sand samples were thoroughly washed to remove any surface coatings such as organics or soils. Each of the sieve fractions was then oven dried in preparation for the petrographic analyses.

The petrographic analyses was carried out using a Bausch and Lomb Stereozoom 7 with a maximum magnification of seven times (7x). The overall petrographic analyses consists of four sections:

1. Surface topography
2. Surface shape
3. Mineralogical make-up of the various fractions
4. Quantification by process of estimation or individual counting.

The first step was to elucidate the mineralogical make of the sand which was carried out on the #60 fraction. The mineralogical examination was carried out by the examination of the individual particles under the following major characteristics.

1. Crystal form
2. Crystalline aggregate
3. Cleavage and fracture
4. Tenacity
5. Hardness
6. Lustre
7. Colour
8. Streak
9. Density

Also, several other properties such as refractive index and chemical reaction are called upon if necessary.

The complete characteristics of individual mineral types is presented in 'Elements of Mineralogy' by Mason and Berry (1967) and as such was used as the standard reference book.

The surface topography was carried out on the #60 sieve fraction utilizing the six class system of visual estimation and roundness as shown in Figure H.1 after Shepard and Young (1961). Surface shape of the particles which was examined for all of the three fractions was characterized through a sphericity versus roundness visual correlation chart presented in Figure H.2 originated by Krumbein and Sloss (1963).

11 ANGLE OF REPOSE

The angle of repose was measured by the method described by Cornforth (1972). A large flat glass plate was placed upon a level surface. Dry sand then deposited through a funnel into a conical heap of approximately three inches (8 cm) in height. The heap was then undercut by scraping away sand grains from the heap in small quantities until the sand grains travelled down the face of the slope. The heap was then photographed using a polaroid camera and the angle measured from the positive print.

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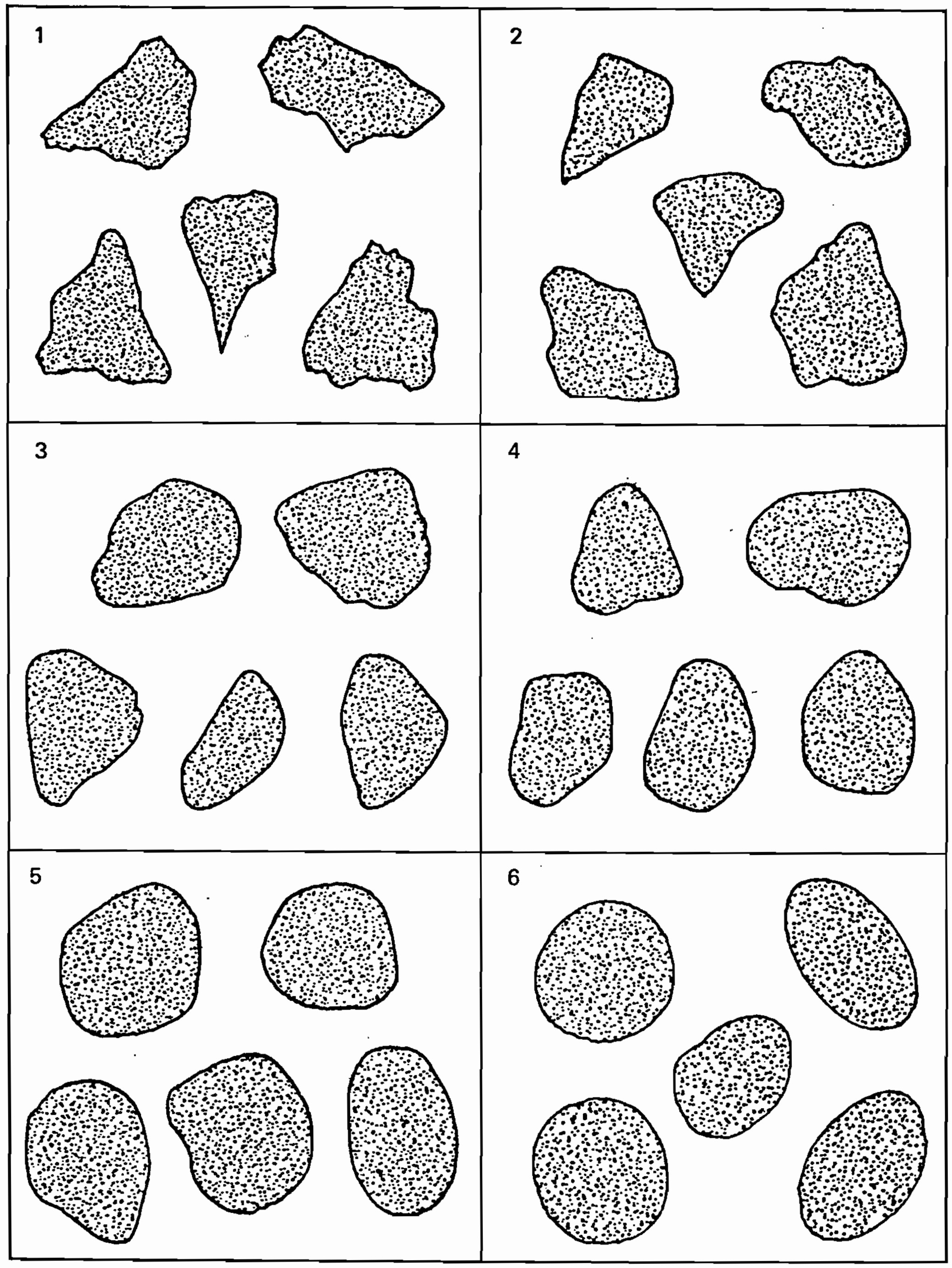


FIGURE H - 1 VISUAL ESTIMATION OF PARTICLE ROUNDNESS (SHEPHARD AND YOUNG, 1961)

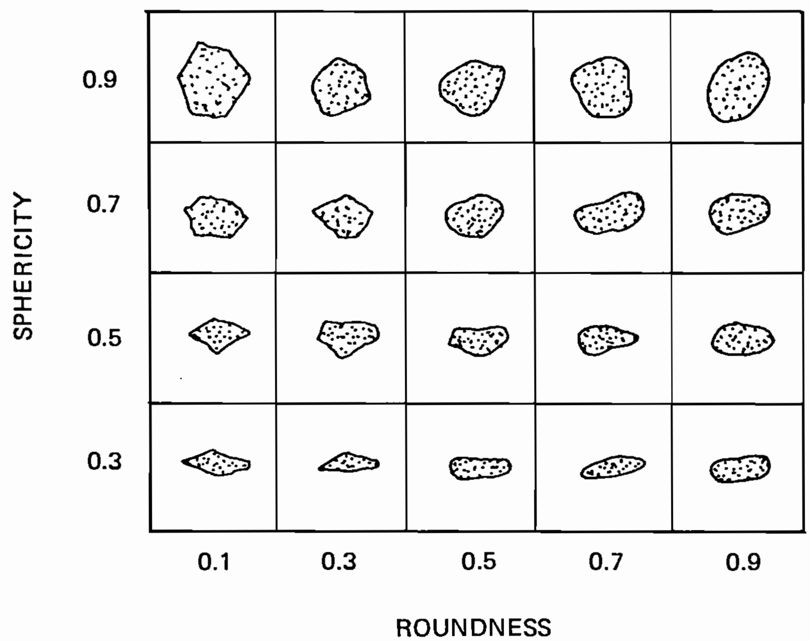


FIGURE H - 2 SPHERICITY VERSUS ROUNDNESS CORRELATION (KRUMBEIN AND SLOSS, 1963).

APPENDIX I
GEOPHYSICAL LOGS

APPENDIX I

GEOPHYSICAL BOREHOLE LOGS (BPB)

GAMMA RAY LOG.

BOREHOLE F [illegible] 1.1

CLIENT Dome Petroleum Ltd.

AREA [illegible]

COUNTRY Canada

DATE LOGGED [illegible]

DEPTH SCALE 1.100

4 OF 4 LOGS

BOREHOLE DATA	REFER TO 1 of 4	LOG
OPERATION DATA	REFER TO 1 of 4	LOG

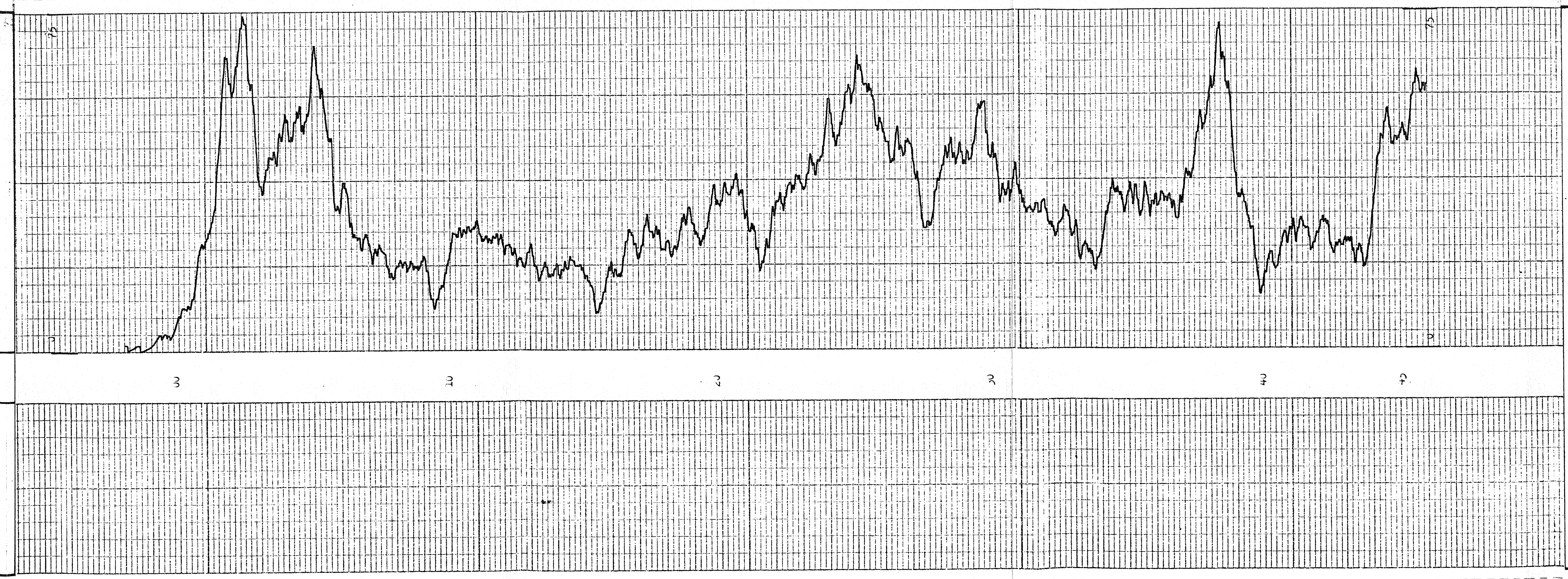
EQUIPMENT AND RECORDING DATA

LOG	TAPING: LOG TAPED	TAPING: RECORD SPEED	TAPING: DIRECT or REPLAY	PANEL: SPEED	PANEL: T C SECS	PANEL: NORM	CAL COEFF
gamma	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SONDE NO | SOURCE NO

REMARKS

DEPTH



DEPTH

BOREHOLE [illegible]

CLIENT [illegible]

AREA [illegible]

COUNTRY [illegible]

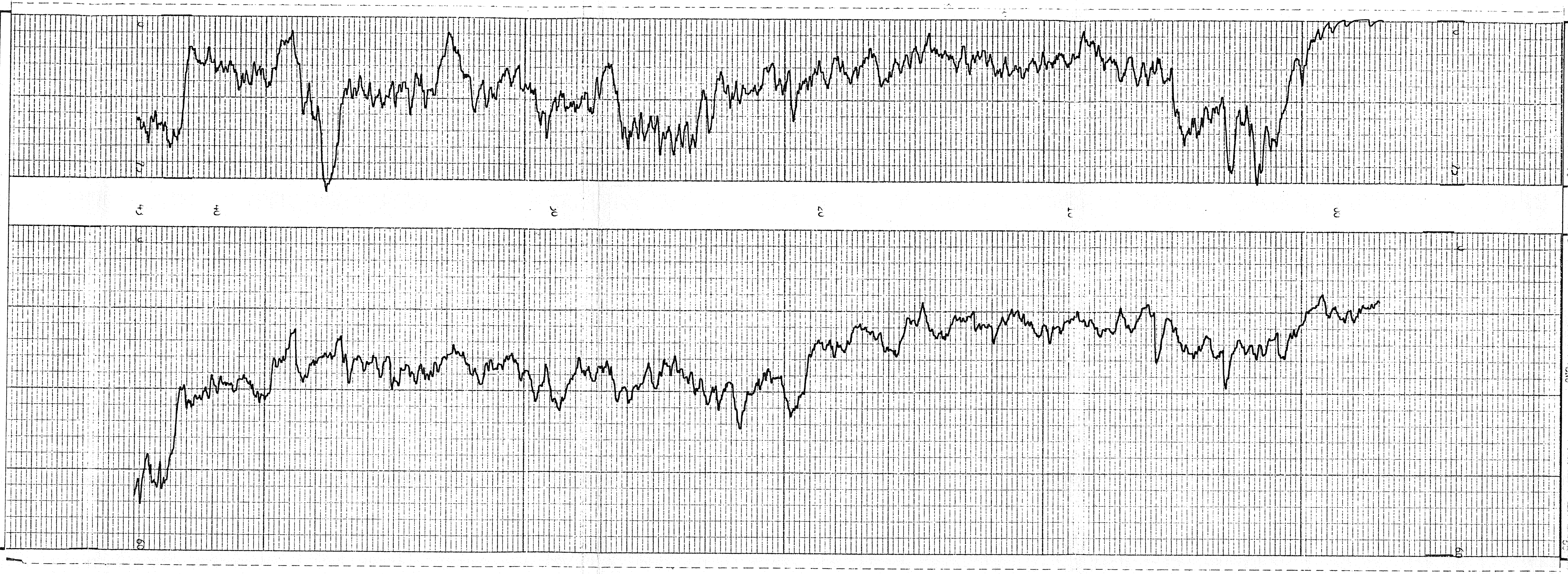
BOREHOLE

CLIENT

AREA

COUNTRY

DEPTH



DEPTH

BOREHOLE

CLIENT

AREA

COUNTRY

DATE LOGGED

DEPTH SCALE

BOREHOLE DATA REFER TO LOG

OPERATION DATA REFER TO LOG

EQUIPMENT AND RECORDING DATA

LOG	TAPING			PANEL		CAL COEFF
	LOG TAPED	RECORDED SPEED	DIRECT REPLAY	SPEED	T.C. SECS	NORM

REMARKS

BPB

BOREHOLE
CLIENT
AREA
COUNTRY
DATE LOGGED

DEPTH SCALE

OF ___ LOGS

BOREHOLE DATA

PERMANENT DATUM				
ELEVATION OF P.D.				
	B.P.B.		DRILLER	
MEASUREMENTS FROM				
DEPTH REACHED				
CASING SHOE				
BIT SIZES	1	TO	2	TO
	3	TO	4	TO
CASING SIZES	1	TO	2	TO

FLUID DATA

NATURE	
S.G.	
LEVEL	
VISCOSITY	
Rm at meas temp	
B H T	

OPERATION DATA

FIRST READING	
LAST READING	
INTERVAL LOGGED	
UNIT–TRUCK No.	
ENGINEER	
WITNESS	

EQUIPMENT AND RECORDING DATA

LOG	EQUIPMENT			TAPING			PANEL		CAL COEFF	DEPTHS		
	SONDE	SOURCE	CALIBRATOR	LOG TAPED	RECORD SPEED	DIRECT or REPLAY SPEED	T.C. SECS	NORM		FROM	TO	INTERVAL

REMARKS

ADDITIONAL SONDES RUN

SONDE	LOG	GENERAL SCALE LOG	DETAIL SCALE LOG	
				REFER TO ADDITIONAL HEADINGS

DEPTH

DEPTH

BOREHOLE
CLIENT
AREA
COUNTRY

BPB

MY 95160 B

BPB

GAMMA RAY LOG
LONG SPACED DENSITY LOG
CALIPER LOG

BOREHOLE	F.1AK 1.1
CLIENT	Dome Petroleum Ltd.
AREA	Iterk
COUNTRY	Canada
DATE LOGGED	[illegible]
DEPTH SCALE	1.100
1 OF [illegible] LOGS	

BOREHOLE DATA

	B.P.B.	DRILLER
PERMANENT DATUM	Moon Pool of vessel	
ELEVATION OF P.D.	50.5m above seabed.	
MEASUREMENTS FROM	Moon Pool	Moon Pool
DEPTH REACHED	[illegible]	[illegible]
CASING SHOE	None set	None set
BIT SIZES 1	[illegible] TO [illegible]	2 TO
3	TO	4 TO
CASING SIZES 1	TO	2 TO

FLUID DATA

NATURE	[illegible]
S.G.	[illegible] gms/cc.
LEVEL	
VISCOSITY	
Rm at meas temp	
B H T	

OPERATION DATA

FIRST READING	[illegible]
LAST READING	[illegible]
INTERVAL LOGGED	[illegible]
UNIT-TRUCK No.	Unit on board ship
ENGINEER	[illegible]
WITNESS	

EQUIPMENT AND RECORDING DATA

LOG	SONDE	SOURCE	CALIBRATOR	LOG TAPED	RECORD SPEED	DIRECT or REPLAY	SPEED	T.C. SECS	NORM	CAL. COEFF.	FROM	TO	INTERVAL
Gamma	[illegible]	[illegible]	[illegible]	"	/	/	/	1	•	[illegible]	[illegible]	[illegible]	[illegible]
LSD		[illegible]	[illegible]	"	/	"	/	[illegible]	2.15	•	[illegible]	[illegible]	[illegible]
Caliper			[illegible]	"	/	"	/	[illegible]	•	•	[illegible]	[illegible]	[illegible]

ADDITIONAL SONDES RUN

SONDE	LOG	GENERAL SCALE LOG	DETAIL SCALE LOG
[illegible]	[illegible]	1.100	

REFER TO ADDITIONAL HEADINGS

REMARKS

Hole was logged through the rods. On the second run the pipe was raised 1.0m to facilitate overlapping of tool joints.

DEPTH

DEPTH

BOREHOLE	F.1AK 1.1
CLIENT	Dome Petroleum Ltd.
AREA	Iterk
COUNTRY	Canada

BPB

MY 95160 R