UPDATE OF WELL LOG STUDIES
MACKENZIE DELTA/BEAUFORT SEA AREA, ARCTIC ISLANDS AND OFFSHORE EAST COAST
VOLUME 1: ARCTIC CANADA

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SUMMARY

Several recent contracted projects, based largely on petrophysical interpretation of downhole logs, have investigated the occurrence of permafrost and natural gas hydrate in Arctic Canada and the distribution of marine gas hydrate in offshore Eastern Canada. Objectives of the present study were two-fold: to update the previous Arctic well log investigations, based on interpretation of logs from recent off-confidential wells, and to review available evidence relative to hydrate occurrence in the Hibernia-Terra Nova area, offshore Newfoundland. This is the first volume of the study report, concerned with permafrost and gas hydrate in Northern Canada.

In the main, the diagnostic criteria used to log the distribution of permafrost and gas hydrate were the same as those developed during previous contracted studies. The occurrence of ice bearing permafrost was interpreted based on analysis of the resistivity and spontaneous potential logs primarily, with support from the sonic and gamma ray logs. In most instances, a transition zone was observed below the base of ice-bearing permafrost. A combination of the sonic, gamma ray and spontaneous potential log responses was used to interpret the occurrence of natural gas hydrate intervals; in general, the density and neutron porosity logs are of little value for identification of permafrost and gas hydrate in the Arctic environment.

A number of maps and tables are used to sumarize the study results. Details of the analyses and reduced-scale side by side log presentations are appended. Logs from a total of 13 Arctic Islands wells were reviewed. Onshore, from 300 m to 755 m of ice-bearing permafrost is interpreted (with transitions extending to 465 m to 850 m); gas hydrate is interpreted in two of the four wells. Permafrost appears, with very low reliability, to extend in the offshore to as much as 795 m depth (at most sites it is absent or above the log tops), with gas hydrate interpreted to exist in approximately half of the wells. In the Mackenzie Delta-Tuktoyaktuk Peninsula area, some 340 m to 675 m of permafrost (transitions from 425 m to 745 m) is interpreted at nine onshore sites. Again, about half of the wells are interpreted to intersect gas hydrate-bearing intervals. In all, 15 offshore Beaufort wells were included. Interpreted permafrost and transition base depths range from 280 m to 790 m and 370 m to 900 m

respectively. Hydrate-bearing intervals are interpreted to exist, with reasonable reliability, at 7 of the 15 sites.

Completion of this (second) Arctic well log update provides an opportunity to re-evaluate available information on ice-bearing permafrost thickness and natural gas hydrate in Northern Canada. Recent results from seventeen, generally widely distributed, Arctic Island wells are considered to add relatively little to our understanding of overall conditions in this area. Data from wells in the Mackenzie Delta-Tuktoyaktuk Peninsula and Offshore Beaufort areas, however, have been used to compile a preliminary map of permafrost thickness and likely gas hydrate occurrence. Permafrost in excess of 600 m thick is shown to be extensive, in particular in and to the north of Richards Islands, while seven areas (and a further six isolated, single well, occurrences) where gas hydrate is expected to exist are identified. The distribution of thick permafrost and, to some degree, gas hydrate appears to be related to glacial limits in the area.

SECTION 1

INTRODUCTION

1.1 General

Several recent projects have investigated the occurrence of permafrost and natural gas hydrates in Arctic Canada and of marine gas hydrates in offshore Eastern Canada. These studies were based in large part, on petrophysical interpretation of downhole logs from oil and gas exploration wells. Thurber Consultants Ltd. was retained, by Supply and Services Canada (SSC) on behalf of the Geological Survey of Canada, to update these previous studies.

Authorization to proceed with a review of recently off-confidential logs from 37 wells in the Arctic Islands, Mackenzie Delta-Tuktoyaktuk Peninsula area and offshore Beaufort Sea was received from Mr. P.J. Monnelly of SSC, in a contract dated August 24, 1987. Subsequently, the project was expanded to include a review of the logs from a further 29 wells in the Hibernia and Terra Nova areas of the Grand Banks, offshore Newfoundland. A contract amendment, dated November 20, 1987, was issued to cover the study of East Coast wells. The overall assignment was carried out under SSC Contract No 69SZ.23233-7-0925.

Since the modes of gas hydrate occurrence (and observed petrophysical responses) are different in the permafrost and (non-permafrost) offshore environments, the final study report has been organized in several parts. This is Volume 1, concerned with permafrost and gas hydrates in the Arctic wells. Volume 2 (bound separately) addresses marine gas hydrate occurrence in the Hibernia and Terra Nova areas. Side-by-side reduced scale log presentations are appended in Volume 3.

1.2 Scope of Work - Arctic Wells

Previous contracted studies have indicated that the occurrence of permafrost and natural gas hydrates in Arctic oil and gas exploration wells may be identified based on petrophysical interpretation of downhole logs. Logs from over 550 wells have been examined in this way over the past five years (D & S Petrophysical, 1983; Hardy Associates, 1984a; 1984b; Thurber Consultants, 1986). During the present study, the primary objective was to update the results of these previous studies, based on analysis of the logs from recent off-confidential wells.

The study area comprises two main areas: the Arctic Islands and the Mackenzie Delta-Beaufort Sea area. In turn, the latter area may be subdivided into onshore (Mackenzie Delta-Tuktoyaktuk Peninsula) and offshore (Beaufort Sea) sections. The locations of the study area, and areas of prime interest, are shown on Drawing 1, Appendix A.

1.3 Terms of Reference

Terms of reference for the update study of Arctic wells were essentially the same as those developed during previous contracted studies. They were established during telephone conversations between Mr. I.G. Jones of Thurber Consultants Ltd., Dr. A.S. Judge of the Geological Survey of Canada, EMR, and Mr. P.J. Monnelly of SSC, as follows:

- examine downhole logs of recent off-confidential onshore and offshore wells, using best currently accepted criteria, to outline permafrost thickness and hydrate occurrence to a depth of 2000 m, and

- prepare a brief report describing the study, presenting its results and comparing the results with available information from previous investigations.

1.4 Personnel and Responsibilities

The investigation was carried out by Thurber Consultants, with petrophysical logging expertise provided by Petrophysical Consultants International Ltd. Messrs. I.G. Jones, P.Geol. and G.E. Dawson-Grove, P.Eng., P.Geol., were responsible for the input of the respective firms. Mr. L.B. Smith, P.Eng. of Thurber Consultants was assigned as Review Principal.

1.5 Acknowledgements

Reduced-scale well logs were obtained on a commercial basis, from Riley's Datashare International Ltd. As in the past, the preparation of this material was facilitated by Mr. Ken Brown of Riley's.

Access to well history reports, on file at the Institute of Sedimentary and Petroleum Geology (ISPG) in Calgary, was provided by Mr. W. Banning.

Dr. A.S. Judge, Geological Survey of Canada was the Scientific Authority for the project. Mr. P.J. Monnelly was the Science Branch Contracting Officer for Supply and Services Canada.

SECTION 2

METHOD OF INVESTIGATION

2.1 Information Review

Available data on permafrost and gas hydrate conditions in the Arctic Islands, onshore Mackenzie Delta-Tuktoyaktuk Peninsula and offshore Beaufort Sea areas were reviewed as the first phase of the study. Reference was made primarily to the reports of previous contracted permafrost/gas hydrate studies (D & S Petrophysical, 1983; Hardy Associates, 1984a; Thurber Consultants, 1986).

Results of the information review have been incorporated, as appropriate, into this report.

2.2 Interpretation of Petrophysical Logs and Other Data

This major component of the investigation was carried out in three stages.

Firstly, wells were selected for detailed study, by reference to the 1984 and 1985 Annual Reports of the Canada Lands Oil and Gas Administration (COGLA). A total of 37 wells were identified, including 27 wells that became "off confidential" between March 31, 1986 (when Thurber Consultants' previous update study was completed) and December 31, 1987 and 10 wells for which logs were not available at the time of the Thurber Consultants (1986) study. Reduced-scale blowdowns of the appropriate logs for each well were then obtained from Riley's Datashare International Ltd. Table 1 provides a listing of wells included in the study; locations are shown on Drawings 3 and 4, Appendix A.

The second stage involved detailed petrophysical analysis and interpretation. In carrying out the interpretation for each well, reference was made primarily to the resistivity and sonic logs (and accompanying spontaneous potential, gamma ray and caliper logs), since previous experience has shown these to be the most diagnostic logs for permafrost and gas hydrate delineation in the arctic environment (Section 3.2). Formation density, neutron porosity and temperature logs were also reviewed as available.

TABLE 1

ARCTIC ISLANDS AND BEAUFORT-MACKENZIE WELLS

A. Arctic Islands

Well No.[1]	Drilling[2] Authority	Well Name	Year Completed	Location
162	1099	Panarctic Sherard Bay F-34	1984	76°13'N,108°44'W
153*	979	Panarctic et al W. Bent Horn G-02	1981	76°21'N,104°01'W
154*	1012	Panarctic et al Marryatt K-71	1982	76°21'N,108°58'W
163	1217	Panarctic et al East Drake L-06	1985	76°26'N,107°33'W
164	1133	Panarctic et al Buckingham B-69	1984	77°08'N, 91°24'W
165	--	Panarctic et al Skybattle Bay M-11	1985	77°11'N,105°07'W
155*	988	Panarctic et al Whitefish A-26	1982	77°15'N,106°38'W
156*	989	Panarctic et al Cisco C-42	1982	77°21'N,106°17'W
166	1132	Panarctic et al Cisco M-22	1984	77°22'N,106°11'W
157*	1031	Panarctic et al Grenadier A-26	1983	77°24'N, 99°35'W
158*	--	Panarctic et al Cisco K-58	1983	77°28'N,106°21'W
167	--	Panarctic et al Cape Alison C-47	1985	77°46'N,100°17'N
168	1131	Panarctic et al Skate C-59	1984	77°48'N,104°51'W

B. Mackenzie Delta-Tuktoyaktuk Peninsula

Well No.[1]	Drilling[2] Authority	Well Name	Year Completed	Location
182	1226	Gulf et al Skakgatlatachig D-50	1985	68°39'N,133°57'W
183	--	Gulf et al Onigat D-52	1985	68°41'N,133°44'W
184	--	Esso PCI Home et al Tuk J-29	1985	69°18'N,133°06'W
163*	1119	Esso PCI Home et al Tuk M-09	1984	69°19'N,133°02'W
185	--	Esso PCI Home et al Tuk H-30	1985	69°19'N,133°05'W
164*	1041	Esso Pex Home et al Pikiolik G-21	1983	69°20'N,132°36'W
186	1200	Chevron Trillium Upluk L-42	1985	69°22'N,135°27'W
187	--	Esso Home et al Taglu West H-06	1985	69°25'N,135°00'W
188	--	Esso PCI Home et al Itkrilek B-52	1985	69°31'N,131°59'W

C. Offshore Beaufort

Well No.[1]	Drilling[2] Authority	Well Name	Year Completed	Location
189	1195	Esso Trillium Adgo H-29	1985	69°28'N,135°50'W
190	--	Dome et al Adlartok P-09	1985	69°39'N,137°45'W
191	1251	Dome et al Edlok N-56	1985	69°46'N,140°14'W
192	1098	Esso Home et al Kadluk O-07	1984	69°47'N,136°01'W
193	--	Esso PCI Home et al Nipterk A-19	1985	69°49'N,135°20'W
194	1080	Gulf et al Pitsiulak A-05	1984	69°54'N,136°46'W
195	1199	Gulf et al Tarsiut P-45	1984	69°55'N,136°25'W

TABLE 1

ARCTIC ISLANDS AND BEAUFORT-MACKENZIE WELLS
(CONTINUED)

C. Offshore Beaufort (continued)

Well No.[1]	Drilling[2] Authority	Well Name	Year Completed	Location
196	1194	Esso Home PCI et al Amerk O-09	1985	69°59'N,133°31'W
197	1029	Dome et al Natiak O-44	1984	70°04'N,137°13'W
198	1201	Gulf et al Akpak 2P-35	1985	70°15'N,134°09'W
199	1073	Dome et al Arluk E-90	1985	70°19'N,135°26'W
175*	946	Dome Koakoak O-22	1981	70°23'N,134°07'W
200	985	Dome et al Siulik I-05	1984	70°25'N,134°31'W
178*	1040	Dome et al Aiverk 2I-45	1982	70°25'N,132°42'W
201	1126	Dome et al Nerlerk J-67	1985	70°27'N,133°19'W

NOTES: 1 Well numbers were assigned, for purposes of this study only, to run consecutively with those used in previous studies by Hardy Associates (1984a), D & S Petrophysical (1983) and Thurber Consultants (1986).

2 Drilling Authority Numbers are assigned by COGLA, on a site-specific basis, to each well.

* Well included in Thurber Consultants' previous update study, for which logs were not available at that time.

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Finally, geological information and available mud gas logs, contained in the well history files at the Institute of Sedimentary and Petroleum Geology, were reviewed. Observed mud gas peaks were recorded for comparison with the natural gas hydrate interpretation.

As detailed below, results of the analysis have been compiled onto a series of tables and maps for final presentation.

2.3 Presentation of Results

The results of the study of Arctic wells are presented in this report, with supporting documentation attached in a number of appendices. This volume consists of the report text, describing the investigation and summarizing its results, together with Appendices A and B (which present drawings and analysis details relative to each well). Side-by-side presentations of the petrophysical logs for each well are presented in Appendix C (Volume 3).

SECTION 3

DETERMINATION OF PERMAFROST THICKNESS AND GAS HYDRATE OCCURRENCE

3.1 Definitions

3.1.1 Permafrost

Permafrost, or perenially frozen ground, is the thermal condition that exists when the ground remains at a temperature below 0°C for two or more years.

Such a temperature-based definition, it should be noted, does not imply that the ground necessarily contains ice or that it exhibits ice-bonding. It is convenient for this reason, since the application of petrophysical techniques depends on the recognition of log responses to the presence of frozen (i.e. bonded) material, to differentiate between permafrost per se and ice-bearing permafrost (IBPF). The former is defined solely on the basis of temperature, while the base of IBPF reflects physical changes related to the phase change from water to ice (Osterkamp and Payne, 1981).

At any given site, the base of permafrost (as defined by the 0°C isotherm) rarely, if ever, corresponds to that of ice-bearing permafrost. This difference is due to freezing point depression which is, in turn, a function of pressure, chemical and soil particle effects. As an example, assuming typical Arctic Island subsurface conditions, freezing point depression can result in differences between the bases of IBPF and of permafrost ranging from about 40 m in clean sand to in excess of 275 m in shale (Hardy Associates, 1984a).

A transition zone is observed in most wells below the interpreted IBPF base. The transition is characterized by gradual changes in petrophysical response, primarily resistivity and sonic travel times. Transition zone development is believed to be related, in part, to lithology (ie. shale percentage) and, in part, to an increase in unfrozen water content as the melting point is approached (Desai and Moore, 1968).

3.1.2 Natural Gas Hydrate

Natural gas hydrate, or clathrate, is a solid, ice-like mixture of natural gas and water that, in the presence of a saturated concentration of gas and under appropriate pressure conditions, may exist at temperatures above the freezing point of water. In arctic and antarctic regions, hydrate exists both within and below permafrost, and onshore and offshore. It may also occur in marine sediments on offshore continental margins in other areas, including the Canadian East Coast (as discussed in Volume 2 of this report).

The hydrate structure comprises a latticework of water molecules, held together by hydrogen bonds, with gas molecules filling the voids. Gas hydrates may be of two main types: Structure I (including "small" gas molecules) and Structure II, containing larger molecules (Davidson et al, 1978). Experience indicates that Structure I methane hydrates are most frequently present in northern wells.

A phase diagram for the methane-water system is presented on Drawing 2, Appendix A.

3.2 Petrophysical Log Responses

Typically, well logs run through ice-bearing permafrost and intervals containing gas hydrate exhibit characteristic petrophysical responses.

3.2.1 Determination of Permafrost Thickness

The log responses associated with the presence of ice-bearing permafrost are now well documented (e.g. Desai and Moore, 1968; Pollard and Nash, 1971; Hnatiuk and Randall, 1977; Osterkamp and Payne, 1981; D & S Petrophysical, 1983; Hardy Associates, 1984a; Thurber Consultants, 1986). Table 2 summarises the previously reported petrophysical responses to the presence of ice-bearing permafrost.

Petrophysical responses used in this study to interpret the base of ice-bearing permafrost and identify a transition zone, if present, were:

a) a relatively abrupt increase in resistivity,

b) a negative drift of the S.P. log,

TABLE 2

PETROPHYSICAL INDICATIONS OF THE BASE OF ICE-BEARING PERMAFROST (IBPF)

Log	Observed Response
Spontaneous Potential (S.P.)	. negative drift within IBPF[1,2,4,5,6]
Gamma Ray	. non-correspondence with S.P.[5,6]
Caliper	. hole washout[1,2,3,4,5,6]
Resistivity (Dual Induction, Dual Laterolog)	. abrupt increase in resistivity (provided tool interpretive depth exceeds thickness of thermally invaded zone)[1,2,3,4,5,6]
Sonic (Acoustic Velocity)	. high velocity in to gauge hole[1,2,3,4] . cycle skipping (low velocity) in washed out hole[1,2,3,4,5,6]
Density	. little response[5]
Neutron Porosity	. little response[5]
Temperature	. "plateau" corresponding to IBPF base[5]

SOURCES

1 Pollard and Nash (1971)
2 Hnatiuk and Randall (1977)
3 Osterkamp and Payne (1981)
4 D & S Petrophysical (1983)
5 Hardy Associates, (1984a)
6 Thurber Consultants (1986)

c) hole washout, shown by the caliper log (rarely),

d) non-correspondence between the S.P. and gamma ray logs, and

e) cycle skipping on the sonic log, due to hole washout.

To date, little or no direct evidence of permafrost has been observed on formation density and neutron porosity logs (Table 2).

Log interpretation typically involved a number of steps. Firstly, available information on permafrost conditions in the general area of the well (for example, published ground temperature data, previous petrophysical study results, etc.) was reviewed, to provide a preliminary assessment of the conditions likely to be encountered. The resistivity and S.P. logs were then examined to identify the base of ice-bearing permafrost (i.e. the point at which, moving uphole, a relatively abrupt increase in resistivity was associated with a negative drift in S.P). Similar evidence for the presence of a transition zone was then reviewed. The initial IBPF base and transition picks were confirmed by reference to other available logs; secondary indications included: non-correspondence between the S.P. and gamma ray logs, hole washout (shown on the caliper log) and cycle skipping on the sonic log (Table 2). A reliability factor was assigned to each pick, ranging from 1 (good) to 3- (faintly possible), as the final stage of the interpretation procedure.

Table 4 (presented in Section 4) provides a summary of the log interpretation results. These are briefly described for each area of interest in Sections 4.1 to 4.3. Analysis detail sheets for the individual wells are presented in Appendix B, and reduced side-by-side log presentations in Appendix C (Volume 3).

3.2.2 Identification of Gas Hydrate Occurrence

Gas hydrate-bearing intervals in the arctic environment give rise to related but somewhat different petrophysical responses to those observed in ice-bearing permafrost. These have been documented by Bily and Dick (1974), Weaver and Stewart (1982), Collett (1983), D & S Petrophysical (1983), Hardy Associates (1984a, b) and Thurber Consultants (1986).

Petrophysical responses previously associated with gas hydrate occurrence in permafrost regions are summarized on Table 3.

In this study, the occurrence of natural gas hydrates was interpreted based on the following:

a) non-correspondence between the S.P. and gamma ray logs,

b) cycle skipping on the sonic log,

c) a low gamma ray reading, indicating sand, together with a slight increase in resistivity,

d) some degree of hole washout (on caliper),

e) location in sand bodies (throughout or at the top), and

f) "tracking" of the gamma ray and sonic logs and a tendency for the caliper and sonic to "hourglass".

Although previous experience suggests that there is little or no correlation with hydrate occurrence in the permafrost environment, reference was also made to density and neutron porosity logs as available. In the (non-permafrost) offshore environment, these logs may be primary indicators of hydrate occurrence (Thurber Consultants, 1985).

Interpretation of gas hydrate from the downhole logs was carried out in stages, generally in conjunction with the permafrost interpretation. Following a review of available information from wells in the same general area (to provide a preliminary assessment of likely hydrate occurrence), the presence of possible hydrate-bearing (sand) intervals was determined, based on a review of the gamma ray log. Next, the likely distribution of hydrate within each sand interval was determined. Log indications include: non-correspondence between S.P. and gamma ray logs, caliper evidence of hole washout, cycle skipping on the sonic (acoustic) log and, rarely, "tracking" of the gamma ray and sonic and/or "hour-glassing" of the caliper and sonic (Table 3). Finally, a reliability rating was assigned to each pick.

TABLE 3

PETROPHYSICAL RESPONSES TO GAS HYDRATE OCCURRENCE IN THE PERMAFROST ENVIRONMENT

Log	Observed Response
Spontaneous Potential (S.P.)	. non-correspondence with gamma ray[5,6] relatively low (ie. less negative) deflection[4]
Gamma Ray	. low reading (indicating sand)[5,6]
Caliper	. hole washout[1,4,5,6]
Resistivity (Dual Induction, Dual Laterolog)	. relatively high resistivity deflection[2,3,4] . little response[5,6]
Sonic (Acoustic Velocity)	. higher velocity (lower travel time) in "to gauge" hole[1,2,3,4,5,6] . cycle skipping (low velocity/long travel time) in rough hole related to hydrate decomposition[5,6]
Density	. little response[1,2,3,4,5,6]
Neutron Porosity	. little response[1,5,6] . increase opposite hydrate (relative to gas and water saturated zones)[4]
Mud Gas	. significant increases in total mud gas[2,4] . variable correlation between mud gas peaks and hydrate occurrences[5,6]

SOURCES

1 Bily and Dick (1974)
2 Osterkamp and Payne (1981)
3 Weaver and Stewart (1982)
4 Collett (1983)
5 Hardy Associates, (1984a)
6 Thurber Consultants (1986)

The hydrate interpretation results are summarised on Table 4 (presented in Section 4), and described in Sections 4.1 to 4.3. These data are also shown on analysis detail sheets and side-by-side log presentations, in Appendices B and C (Volume 3), respectively.

3.3 Mud Gas Log Indications

As expected, there is a correlation between the interpreted occurrence of hydrate-bearing intervals and peaks on mud gas logs. Experience to date suggests that the significance of this relationship may vary. In the Mackenzie-Beaufort region, a relatively good correlation has been reported (e.g. Bily and Dick, 1974; Weaver and Stewart, 1982); however, in the Arctic Islands it appears to be less reliable (Hardy Associates, 1984a).

Available mud gas logs, contained in the well history files at the Institute of Sedimentary and Petroleum Geology, were reviewed as part of the study. The Analysis Details sheets, in Appendix B, present summaries of the mud gas data.

SECTION 4

PERMAFROST THICKNESS AND GAS HYDRATE OCCURRENCE

4.1 General

Table 4 presents the study results, in terms of interpreted ice-bearing permafrost thicknesses, depths to the transition base and the occurrence of natural gas hydrate for the 37 northern wells. Sections 4.2 to 4.4 detail conditions in the Arctic Island, Mackenzie Delta-Tuktoyaktuk Peninsula and offshore Beaufort Sea areas respectively, and compare these results with previous interpretations. Finally, Section 4.5 summarizes and updates available information on permafrost and the likely distribution of gas hydrate distribution in these areas.

4.2 Arctic Islands

Logs from a total of 13 Arctic Islands wells were reviewed; locations, in the Sverdrup Basin, are shown on Drawing 3, Appendix A. Four wells were drilled onshore (on the Sabine Peninsula and Cameron Island), while the remaining nine wells were drilled offshore. Five wells are included for which logs were not available during the previous update study (Thurber Consultants, 1986).

4.2.1 Permafrost

At three of the onshore sites, interpreted permafrost thicknesses range from 300 m (W. Bent Horn G-02) to 755 m (Skybattle Bay M-11), with transitions extending to 465 m and 850 m (Table 4). In the fourth onshore well (Sherard Bay F-34), no evidence of permafrost was observed within the logged interval (i.e. below 368 m).

As in previous studies (e.g. Hardy Associates, 1984a; Thurber Consultants, 1986), the bases of the ice-bearing permafrost and transition (if present) are apparently above the log tops in the majority of offshore Arctic Island wells. At East Drake L-06 and Skate C-59, thick permafrost is interpreted to be present; however, these picks are assigned a very low reliability. Somewhat more confidence is placed in the permafrost and transition base picks of 470 m and 540 m (respectively 307 m and 377 m below sea bed) at Grenadier A-26.

TABLE 4

INTERPRETED ICE-BEARING PERMAFROST THICKNESSES
AND GAS HYDRATE OCCURRENCE

A. ARCTIC ISLANDS

Well No.	Well Name	Permafrost Base (m)	Permafrost Trans. (m)	Hydrate Occurrence Interval (m)	Hydrate Occurrence Thickness (m)	Comments
162	Sherard Bay F-34	<368	--	--	--	IBPF base above log tops; no hydrate interpreted
153*	W. Bent Horn G-02	300	465	605-835	220	
154*	Marryatt K-71	550	850	510-1655	1145	Hydrate interpreted to be thin and scattered; very thick transition indicated
163	East Drake L-06	795	845	410-1145	735	Offshore well; low quality IBPF picks
164	Buckingham B-69	<435	--	455-825	370	Offshore well; IBPF base, if present, above RES log top; scattered hydrate
165	Skybattle Bay M-11	755	815	--	--	Good quality IBPF picks; no hydrate interpreted
155*	Whitefish A-26	<583	--	1008	1+/-	Offshore well; IBPF base, if present, above RES log top; hydrate likely absent
156*	Cisco C-42	<500	--	--	--	Offshore well; IBPF base, if present, above RES log top; no hydrate interpreted

TABLE 4

INTERPRETED ICE-BEARING PERMAFROST THICKNESSES
AND GAS HYDRATE OCCURRENCE
(CONTINUED)

166	Cisco M-22	<500	--	625-1475	850	Offshore well; IBPF base, if present, above RES log top
157*	Grenadier A-26	470	540	540-1135	595	Offshore well; relatively good IBPF base pick
158*	Cisco K-58	<605	--	625-690	65	Offshore well; IBPF base, if present, above RES log top
167	Cape Allison C-47	<595	--	660-975	315	Offshore well; IBPF base, if present, above RES log top
168	Skate C-59	755	955	775-1980	1205	Offshore well; low reliability IBPF picks

B. MACKENZIE DELTA-TUKTOYAKTUK PENINSULA

Well No.	Well Name	Permafrost Base (m)	Permafrost Trans. (m)	Hydrate Occurrence Interval (m)	Hydrate Occurrence Thickness (m)	Comments
182	Skakgatlatachig D-50	675	745	565-990	425	IBPF somewhat thicker than expected
183	Onigat D-52	580	650	--	--	No hydrate interpreted; IBPF somewhat thicker than expected
184	Tuk J-29	370	450	--	--	No hydrate interpreted

TABLE 4

INTERPRETED ICE-BEARING PERMAFROST THICKNESSES
AND GAS HYDRATE OCCURRENCE
(CONTINUED)

163*	Tuk M-09	355	450	840-990	150	Relatively good IBPF picks
185	Tuk M-30	<385	--	--	--	Transition base within log gap: no hydrate interpreted
164*	Pikiolik G-21	400	650	--	--	No hydrate interpreted
186	Upluk L-42	460	550	510-870	360	Relatively good IBPF and hydrate picks
187	Taglu West H-06	525	640	660-690	30	Relatively good IBPF picks
188	Itkrilek B-52	340	425	915-1010	95	Hydrate interpreted on litho-density log only

C. OFFSHORE BEAUFORT

Well No.	Well Name	Permafrost Base (m)	Permafrost Trans. (m)	Hydrate Occurrence Interval (m)	Hydrate Occurrence Thickness (m)	Comments
189	Adgo H-29	280	370	440-980	540	Most hydrate interpreted on RES (not sonic)
190	Adlartok P-09	400	450	475-740	265	Few sands to provide hydrate reservoirs
191	Edlok N-56	405	560	--	--	No hydrate interpreted
192	Kadluk O-07	740	820	--	--	No hydrate interpreted

TABLE 4

INTERPRETED ICE-BEARING PERMAFROST THICKNESSES
AND GAS HYDRATE OCCURRENCE
(CONTINUED)

193	Nipterk L-19	520	615	620-1395	775	Very low reliability hydrate picks; likely absent
194	Pitsiulak A-05	750	830	--	--	No hydrate interpreted
195	Tarsiut P-45	610	695	--	--	No hydrate interpreted
196	Amerk 0-09	745	835	1275-1600	325	Good IBPF picks; thin scattered hydrate at considerable depth (may be absent)
197	Natiak 0-44	320	400	720-740	20	Low reliability IBPF picks
198	Akpak 2P-35	790	900	750-1740	990	Thick IBPF interpreted; hydrate apparently extensive, yet little reservoir
199	Arluk E-90	--	440	500-1180	680	IBPF not logged; relatively extensive hydrate interpreted, yet little reservoir
175	Koakoak O-22	640	720	745-1160	415	----
200	Siulik I-05	300	345	--	--	No hydrate interpreted
178*	Aiverk 2I-45	625	770	615-1820	1205	Hydrate interpreted to be extensive
201	Nerlerk J-67	<680	--	703-1615	912	IBPF base above log tops

* Well included in previous well update study (Thurber Consultants, 1986), for which logs were not available at that time.

4.2.2 Gas Hydrate

Petrophysical evidence for the occurrence of gas hydrate exists in two of the onshore wells and the majority (eight) of the offshore wells. In most instances, the hydrate appears to be thin and/or scattered in its occurrence. Further, the reliability of the hydrate picks is generally considered to be poor to very poor.

4.2.3 Comparison with Previous Interpretations

Permafrost and gas hydrate conditions in Arctic Island wells have been discussed previously by Hardy Associates (1984a) and Thurber Consultants (1986). In most instances, the results presented on Table 4, are consistent (in terms of both permafrost and interpreted gas hydrate). Two possible inconsistencies may be noted:

- in the Cisco area wells, hydrate is interpreted to exist yet was not observed previously, and
- at Skybattle Bay, the ice-bearing permafrost is apparently considerably thicker than interpreted previously, at Skybattle Bay C-15 (possibly related to distance from the shoreline).

4.3 Mackenzie Delta and Tuktoyaktuk Peninsula

Nine wells from this area were included; all were drilled onshore. Locations are shown on Drawing 4, Appendix A.

Five of the wells were located to the south and east of Tuktoyaktuk, two in the Caribou Hills and two in the northern (outer) part of the Delta. The Tuk M-09 and Pikiolik G-21 wells, were included in the previous update study but not reviewed at that time, since logs were not available.

4.3.1 Permafrost

Interpreted permafrost and transition base depths are quite consistent within each of the above areas (Drawing 4). In the Tuktoyaktuk area, depths to the base of ice-bearing permafrost range from 340 m to 400 m, with transitions extending to 425 m to 650 m. At Skakgatlatachig and Onigat, in the Caribou Hills,

some 675 m and 580 m of permafrost is interpreted to be present, with transition bases at 745 m and 650 m respectively. Finally, in the outer Delta area at Taglu West and Upluk, 460 m to 525 m of ice-bearing permafrost is interpreted, with transitions extending to 550 m and 640 m.

4.3.2 Gas Hydrate

Natural gas hydrate is interpreted to be present in five of the nine Mackenzie Delta-Tuktoyaktuk Peninsula area wells (Table 4). The distribution is such that wells in the outer Delta area (e.g. Taglu West, Upluk) apparently contain hydrate while it exists in only a limited number of those in the other areas. As noted in Section 4.5, this is consistent with previous results (Bily and Dick, 1978; D & S Petrophysical, 1983; Thurber Consultants, 1986).

4.3.3 Comparison with Previous Interpretations

Interpreted ice-bearing permafrost thicknesses are consistent with earlier results for the Tuktoyaktuk and outer Delta areas; however, permafrost is interpreted to be somewhat thicker in the two Caribou Hills wells than reported previously (D & S Petrophysical, 1983). As with the previous update study (Thurber Consultants, 1986), natural gas hydrate is interpreted to be more extensive than reported previously by D & S Petrophysical.

4.4 Offshore Beaufort

Locations of the fifteen offshore Beaufort Sea wells are shown on Drawing 4, Appendix A. Two wells (Koakoak 0-22 and Aiverk 2I-45) are included that were not reviewed in detail (since logs were not available) in the earlier Thurber Consultants (1986) update study.

4.4.1 Permafrost

Interpreted depths to the base of ice-bearing permafrost range from 280 m to 750 m, with associated transitions extending to 345 m to 835 m (Table 4). At Nerlerk J-67, the base of permafrost apparently occurs above the log tops (i.e. at a depth of less than 680 m).

As shown on Drawing 4, Appendix A, a trend of increasing permafrost thickness to the east and north

is apparent within the area of interest. This is consistent with previous results for the area (detailed in Section 4.5.2).

4.4.2 Gas Hydrate

Well log interpretation suggests that hydrate exists in 6 of the 15 offshore Beaufort wells. Gas hydrate appears to be confined to wells located in the eastern section of the area (Drawing 4). This distribution is consistent with other results reported to date.

4.4.3 Comparison with Previous Interpretations

Considerable data now exist relative to permafrost and gas hydrate conditions beneath the Beaufort Sea, much of it consisting of well log interpretation study results (D & S Petrophysical, 1983; Thurber Consultants, 1986). These results are discussed in detail in Section 4.5.2. In addition, permafrost/gas hydrate data for a number of locations have been reported by Weaver and Stewart (1982).

The results presented on Table 4 are generally consistent with the previous interpretations. As noted previously by Thurber Consultants (1986, p18), however, ice-bearing permafrost is interpreted to be considerably thicker in most Tarsiut area wells than observed, during drilling, by Weaver and Stewart (1982). Gas hydrate occurrence is also interpreted to be more widespread in the offshore Beaufort than reported by D & S Petrophysical (1983).

4.5 Discussion

Completion of this second Arctic well log update study provides an opportunity to summarize and discuss available information on the distribution of ice-bearing permafrost and occurrence of natural gas hydrates in Northern Canada. Sections 4.5.1 and 4.5.2 update the initial findings for the Arctic Islands and Mackenzie Delta-Beaufort Sea areas, earlier addressed by Hardy Associates (1984a) and D & S Petrophysical (1983) respectively.

4.5.1 Arctic Islands

A total of 151 wells were included in the initial investigation of permafrost and gas hydrate

conditions by Hardy Associates (1984a). An additional 17 wells have since been addressed in this and the previous update study.

The initial study concluded that ice-bearing permafrost in excess of 600 m thick is widespread in interior areas of the larger Arctic Islands, in particular Banks, Melville, Ellef Ringnes, Bathurst and Cornwallis. Most other onshore areas (excepting the extreme southern mainland areas) are apparently underlain by 300 m to 600 m of frozen ground (Hardy Associates, 1984a, Figure 3). With respect to natural gas hydrate, it was concluded that hydrate is widespread in most areas of the onshore Arctic Islands but sparsely distributed or absent in much of the Sverdrup Basin (Hardy Associates, 1984a, Figure 4). Although data are limited, it appeared that permafrost is absent beneath most of the inter-island offshore areas (except close to shoreline), but that gas hydrate may be present in some isolated areas, e.g. beneath Bryam Martin Channel.

As noted, logs from an additional 17 wells have been reviewed since the 1984 study was completed (13 as part of the present investigation). In most instances, the more recent wells were drilled close to existing wells (often to delineate reserves) and permafrost/gas hydrate conditions are generally similar to and consistent with those reported earlier. Overall, in the Arctic Islands, the results of the update studies have tended to confirm, yet add relatively little new to, the initial interpretation (presented in Hardy Associates, 1984a).

4.5.2 Mackenzie-Beaufort Region

Permafrost and natural gas hydrate conditions in this area were first addressed, in a study of logs from 161 onshore and offshore wells, by D & S Petrophysical (1983). A further 40 wells have since been included in the two update studies (Thurber Consultants, 1986; this study). Data from these 201 wells now provide a basis for detailing ice-bearing permafrost thicknesses and approximating the likely occurrence of natural gas hydrate in the region. Available information is shown on Drawing 5, Appendix A.

Salient features of the distribution of ice-bearing permafrost in the Mackenzie Delta-Tuktoyaktuk

Peninsula/offshore Beaufort Sea area, inferred based on the results of petrophysical studies, include (Drawing 5):

- permafrost is thickest on and offshore to the north of Richards Island, where it extends to greater than 600 m below ground surface/sea bed (and, locally, exceeds 700 m in thickness),

- very thick permafrost (exceeding 600 m) apparently also exists in the offshore Tarsuit area,

- in onshore areas of the Tuktoyaktuk Peninsula, permafrost ranges in thickness from less than 200 m to about 600 m, generally increasing to the north and west,

- permafrost thicknesses decrease rapidly in the west, along the edge of the Pleistocene Delta, but more gradually towards the south and east, and

- information on permafrost thicknesses is very limited in areas to the north of 70°N and east of 132°W, and to the west of 137°W.

The results shown on Drawing 5 are consistent with an earlier compilation, including some of the same data for a portion of the study area by Judge (1986, Figure 16.1). As noted in Section 4.4.3, the thick permafrost interpreted in the Tarsuit area is somewhat at variance with the results of Weaver and Stewart (1982), who report permafrost thicknesses of 400 m to 500 m in this area. As noted by Judge (1986), it appears that the occurrence of thick permafrost is related to the limits of late-Wisconsin glaciation in the area.

Seven main areas of gas hydrate occurrence are identified in the Beaufort-Mackenzie region, based on well log interpretation (Drawing 5). A further six, isolated single-well, occurrences are also shown. The "major" gas hydrate areas are:

- offshore to the north of Richards Island (north of 69°50'N, between 131°W and 135°W), where a total of 20 wells apparently intersected hydrate,

- offshore to the north and east of Tarsiut (with 5 wells),

- in the offshore Adgo area (5 wells), to the south and west of Garry Island,

- in the Niglintgak-Taglu West-Pelly Island area of the outer Delta (6 wells, mostly onshore),

- in the Toapolok area (2 onshore wells), and

- in the Caribou Hills (4 wells).

In addition to the above, hydrate is interpreted to exist in the following onshore wells (Drawing 5):

- Ivik J-26 and Malik L-38 (as reported by Bily and Dick, 1976),

- Kipnik 0-20 (in the Modern Delta), and

- Itkrilek B-52, Tuk M-09 and Nuna A-10 (to the south and east of Tuktoyaktuk).

The above summary suggests that natural gas hydrate exists in 51 of the 201 wells reviewed to date (i.e. approximately 25 percent of the total). It appears from Drawing 5 that, with the possible exception of Kipnik 0-20, natural gas hydrate occurs within the Pleistocene Delta area and, thus, outside the limits of late-Wisconsin glaciation.

SECTION 5

CLOSURE

Petrophysical well log interpretation results and other available data have been used to update previous studies of ice-bearing permafrost thickness and gas hydrate occurrence in Northern Canada. Logs for 37 recently off-confidential wells from the Arctic Islands, onshore Mackenzie Delta-Tuktoyaktuk Peninsula and offshore Beaufort Sea areas have been reviewed. The study results are consistent with previous interpretations, suggesting that the interpretive procedures may have reasonably wide application.

As part of this, the second, northern well update presently available information has been reviewed and compared with the preliminary regional interpretations presented in the initial studies. In the Arctic Islands, it appears that the recent (widely distributed) results add relatively little to, yet are consistent with, the preliminary assessment. Available data for the Mackenzie-Beaufort region are now adequate to provide a relatively detailed interpretation of ice-bearing permafrost thickness and likely gas hydrate occurrence.

It is recommended that further updates be carried out in the future, as the availability of new well log information warrants. This will be particularly important in the offshore Beaufort Sea and Tuktoyaktuk Peninsula areas, where full-scale oil and gas production is likely in the near future. At that time it will also be important to monitor field evidence for the occurrence of natural gas hydrate, to provide site-specific control for the interpretations presented.

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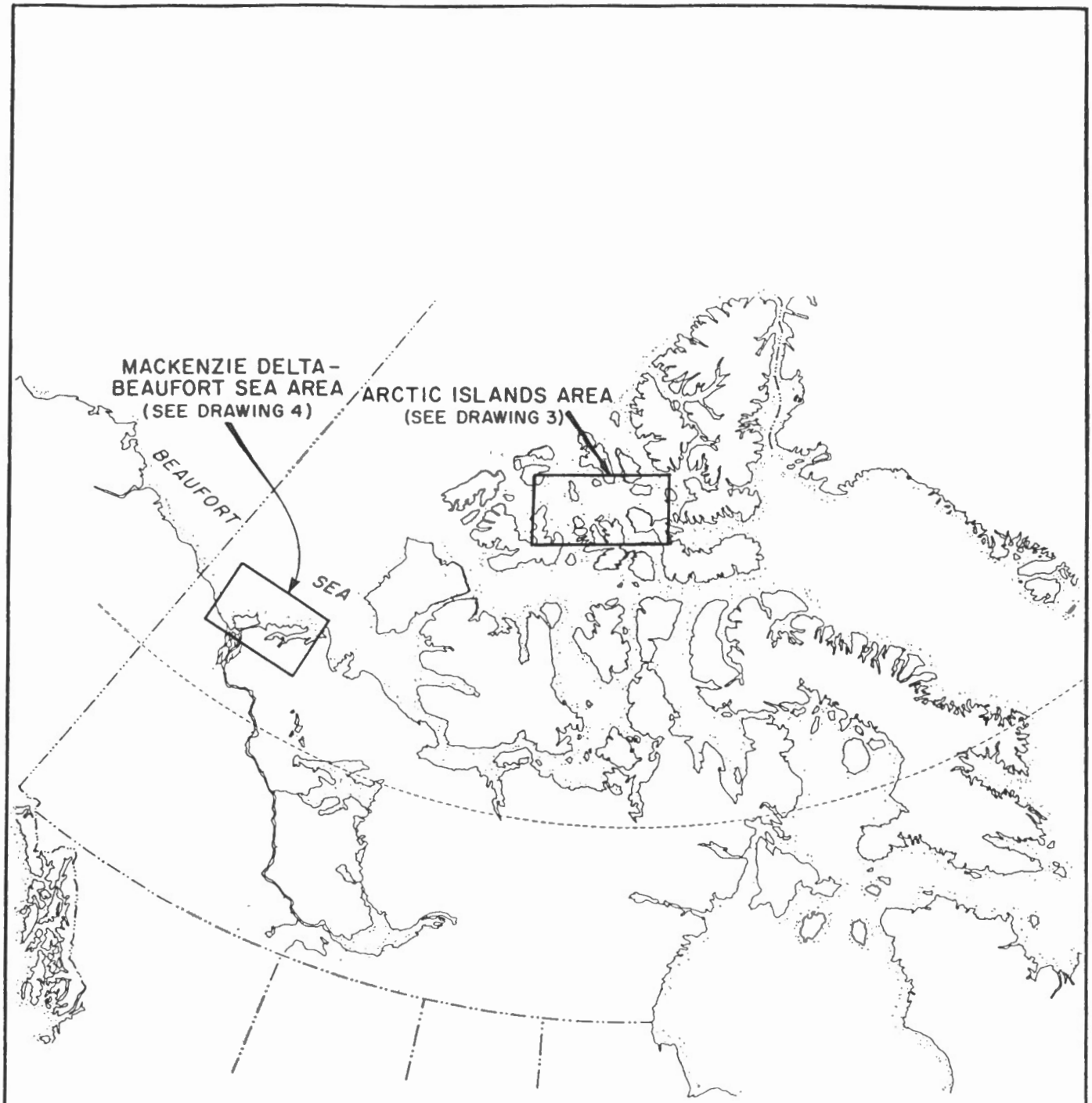
APPENDIX A

APPENDIX A

Drawings

Drawing 1	Study Area Location Plan
Drawing 2	Phase Diagram for Methane-Water System
Drawing 3	Permafrost Thickness and Gas Hydrate Occurrence, Arctic Island Wells
Drawing 4	Permafrost Thickness and Gas Hydrate Occurrence, Mackenzie Delta-Tuktoyaktuk Peninsula and Offshore Beaufort Wells
Drawing 5	Permafrost and Gas Hydrate Distribution, Beaufort-Mackenzie Region



DEPT. OF SUPPLY AND SERVICES

STUDY AREA
LOCATION PLAN

WELL LOG UPDATE

THURBER CONSULTANTS LTD., Geotechnical Engineers

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DATE	MARCH, 1988
APPROVED	I/RHS
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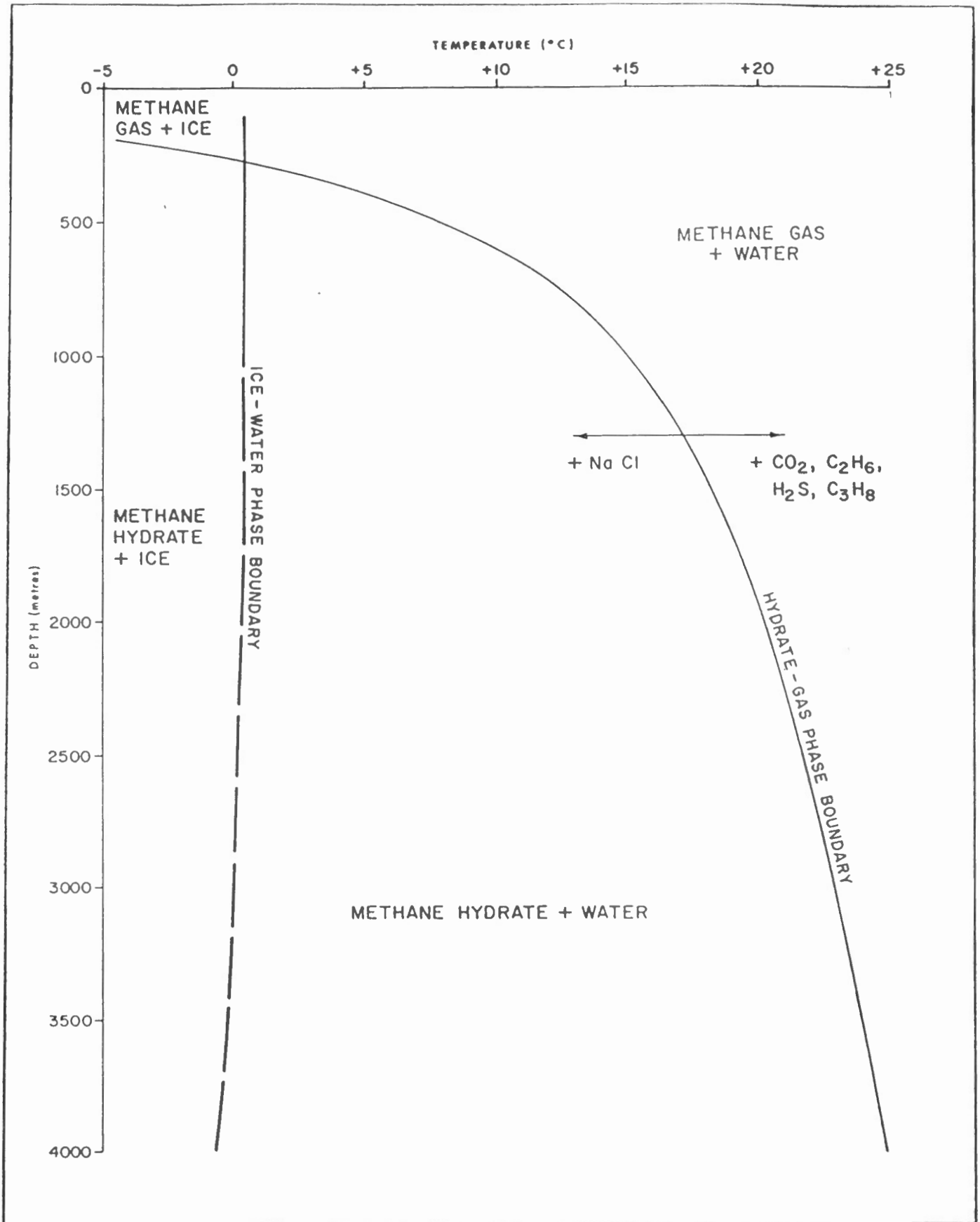

DEPARTMENT OF SUPPLY AND SERVICES

PHASE DIAGRAM FOR METHANE - WATER SYSTEM

WELL LOG UPDATE

THURBER CONSULTANTS LTD., Geotechnical Engineers

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DATE	MARCH, 1988
APPROVED	J. Jones
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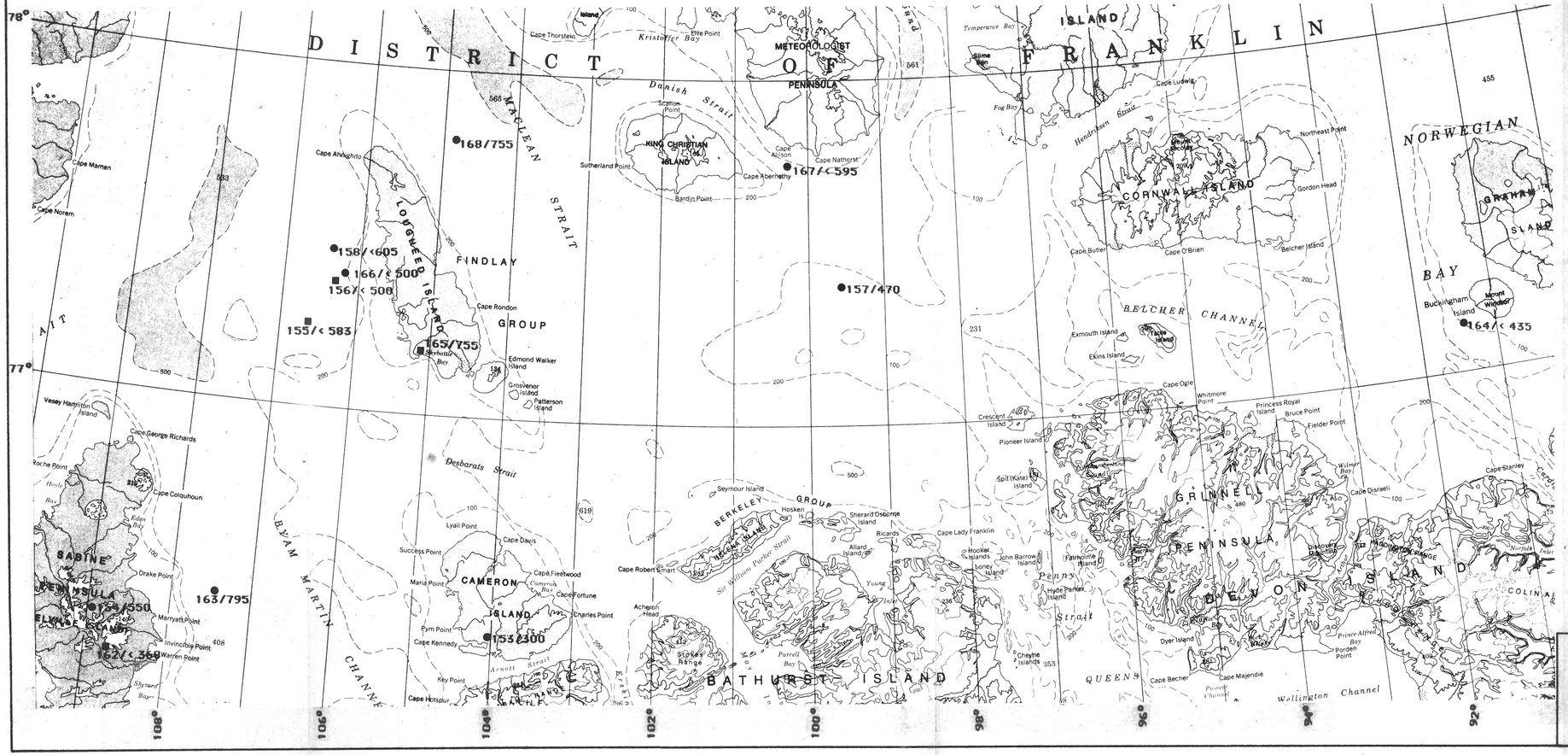

LEGEND

154/550 ● WELL No./IBPF BASE
HYDRATES INTERPRETED

156/< 500 ■ WELL No./IBPF BASE
NO HYDRATES INTERPRETED
(OR TRACES ONLY)

SUPPLY AND SERVICES CANADA

PERMAFROST THICKNESS AND GAS HYDRATE OCCURENCE ARCTIC ISLANDS

WELL LOG UPDATE STUDY

THURBER CONSULTANTS LTD., Geotechnical Engineers

DRAWN IGJ/VV
DATE MARCH, 1988
APPROVED
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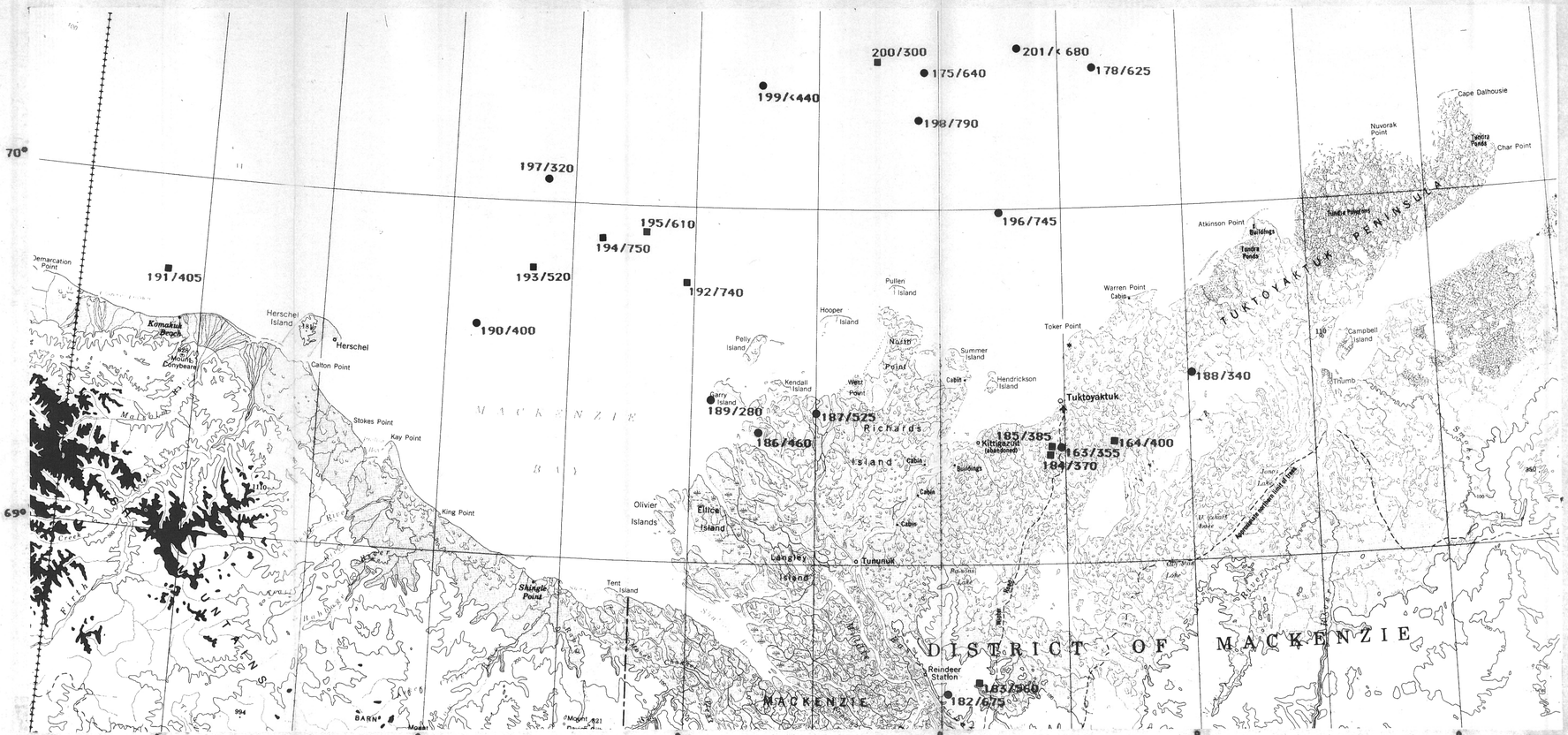

LEGEND

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HYDRATES INTERPRETED

183/560 ■ WELL No./IBPF BASE
NO HYDRATES INTERPRETED
(OR TRACES ONLY)

SUPPLY AND SERVICES CANADA

PERMAFROST THICKNESS AND GAS HYDRATE OCCURENCE MACKENZIE DELTA - OFFSHORE BEAUFORT

WELL LOG UPDATE STUDY

THURBER CONSULTANTS LTD., Geotechnical Engineers

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DATE	MARCH, 1988
APPROVED	
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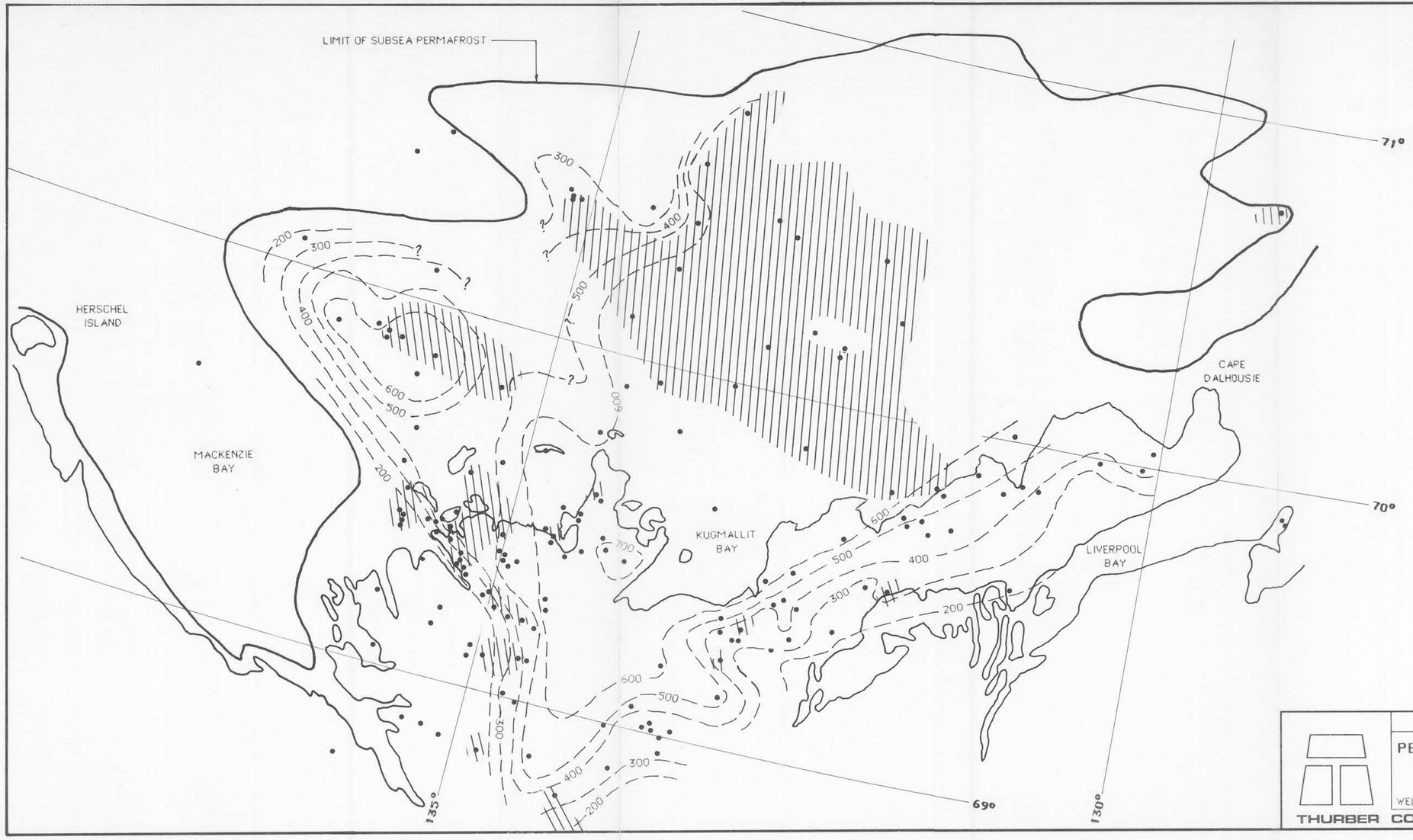

NOTES
1. Data from well log interpretation studies by D & S Petrophysical (1983) and Thurber Consultants (1986, this study)
2. Limit of subsea permafrost after Judge (1986)

SUPPLY AND SERVICES CANADA

PERMAFROST AND GAS HYDRATE DISTRIBUTION BEAUFORT - MACKENZIE REGION

WELL LOG UPDATE STUDY

THURBER CONSULTANTS LTD., Geotechnical Engineers

DRAWN	IGJ/VV
DATE	MARCH, 1988
APPROVED	Jones
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FILE No.	16-5-41
DRAWING No.	5

APPENDIX B

APPENDIX B

Analysis Details

ARCTIC ISLANDS

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 162
D.A. NO: 1099

NAME: Panarctic et al Sherard Bay F-34
AREA: Arctic Islands

K.B.: 72.5 m G.L.: 62.0 T.D.: 5,449.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL	368	2000	<368	-	-	-	-	-
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	330	2000						
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	DENS	368	2000						
Neutron	-								
Temperature	-								
Mud Gas	X	5	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

Increases in mud gas at 990 m - 1100 m and 1350 m - 1400 m.

E. COMMENTS

Permafrost base not observed on logs (apparently above log tops); no gas hydrates interpreted.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 168
D.A. NO: 1131

NAME: Panarctic et al Skate C-59
AREA: Arctic Islands

K.B.: 10.3 m

G.L.: -360.2 m

T.D.: 2,300.00 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DI-SFL	667	2000	755	955	3-3-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	667	2000				775	1980	2-3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	DENS	610	2000						
Neutron	-								
Temperature	-								
Mud Gas	X	436	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability	Interval (m)	Reliability
775±	2	1475-1570	3
800-900	3	1675-1725	3
900-920	3	1850-1980	3
920-1010	3		

D. MUD GAS LOG INDICATIONS

Increases in mud gas at 515 m - 680 m (shale section) and 985 m - 1,025 m; otherwise steady background.

E. COMMENTS

Low reliability IBPF picks; IBPF probably unlikely in this depth of water.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 167
D.A. NO: --

NAME: Panarctic et al Cape Allison C-47
AREA: Arctic Islands

K.B.: 11.7 m G.L.: -243.9 m T.D.: 2,100.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DI-SFL	595	2000	<595	-	-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	595	2000				660	975	2-3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	460	2000						
Neutron	CN	460	2000						
Temperature	-								
Mud Gas	X								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
660-770	2
800-975	3

D. MUD GAS LOG INDICATIONS

Slight increase in mud gas at 1030 m.

E. COMMENTS

IBPF, if present, above log tops.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 158
D.A. NO:

NAME: Panarctic et al Cisco K-58
AREA: Arctic Islands

K.B.: 10.4 m

G.L.: -283.5 m

T.D.: 2,240.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL	605	2000	<605	-	-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	565	2000				625	690	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	-								
Neutron	-								
Temperature	-								
Mud Gas	X								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
625-690	3

D. MUD GAS LOG INDICATIONS

Increases in mud gas at 425 m and 555 m; strong increase at 600 m - 660 m.

E. COMMENTS

IBPF may be absent (in view of water depth).

THURBER

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 157
D.A. NO: 1031

NAME: Panarctic et al Grenadier A-26
AREA: Arctic Islands

K.B.: 10.0 m

G.L.: -163.0 m

T.D.: 2,766.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DI-SFL	225	2000	470	540	2-3			
Sonic (Acoustic)	BHCS	135	2000				540	1135	2-3
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	450	2000						
Neutron	CN	450	2000						
Temperature	-								
Mud Gas	X	240	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
540-645	2
745-790	2
955-1135	3 (scattered)

D. MUD GAS LOG INDICATIONS

Increased mud gas at 500 m, 690 m - 710 m, 715 m - 945 m, 1160 m - 1310 m and below 1420 m.

E. COMMENTS

Relatively good IBPF pick (for an offshore Arctic Islands location).

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 166
D.A. NO: 1132

NAME: Panarctic et al Cisco M-22
AREA: Arctic Islands

K.B.: 11.7 m

G.L.: -174.9 m

T.D.: 2,367.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DI-SFL	500	2000	<500	-	-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	125	2000				625	1475	2-3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	1500	2000						
Neutron	CNL, CN	150	2000						
Temperature	X								
Mud Gas	X								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability	Interval (m)	Reliability
625-670	2	1250-1340	2
715-720	3	1380-1475	3
750-760	3		

D. MUD GAS LOG INDICATIONS

Slight increase in mud gas at 630 m - 830 m, 1235 m - 1330 m and 1410 m±.

E. COMMENTS

IBPF could be absent (in view of water depth).

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 156
D.A. NO: 989

NAME: Panarctic et al Cisco C-42
AREA: Arctic Islands

K.B.: 7.5 m

G.L.: -323.4 m

T.D.: 1,750.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To (m)	Reliability
Resistivity	DLL	500	1725	<500	-	-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	685	1735				-	-	-
S.P.	X								
Gamma Ray	GR	375	1750						
Caliper	X								
Density	-								
Neutron	N	375	1750						
Temperature	-								
Mud Gas	X	400	1725						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

Increases in mud gas at 555 m - 615 m, 695 m - 755 m (mostly behind casing).

E. COMMENTS

IBPF may be absent (in view of water depth); hydrate not interpreted.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 155
D.A. NO: 988

NAME: Panarctic et al Whitefish A-26
AREA: Arctic Islands

K.B.: 10.2 m

G.L.: -351.0 m

T.D.: 2,817.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL	583	2000	< 583	-	-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	533	2000				1008	-	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	212	2000						
Neutron	CN	212	2000						
Temperature	-								
Mud Gas	X	445	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
1008±	3

D. MUD GAS LOG INDICATIONS

Steady background mud gas; no peaks.

E. COMMENTS

IBPF may be absent (in view of water depth); hydrate possibly absent.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 165
D.A. NO: --

NAME: Panarctic et al Skybattle Bay M-11
AREA: Arctic Islands

K.B.: --

G.L.: --

T.D.: 2,785.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DI-SFL	15	2000	755	815	1			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	440	2000				-	-	
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	440	2000						
Neutron	-								
Temperature	X								
Mud Gas	X								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

Low background throughout; no peaks.

E. COMMENTS

No hydrate interpreted; however, non-correspondence of S.P. and GR down to 1,300m. Inflection in TEMP at 785 m. D.A., K.B. and G.L. information not available.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 164
D.A. NO: 1133

NAME: Panarctic et al Buckingham B-69
AREA: Arctic Islands

K.B.: 11.2 m

G.L.: -79.3 m

T.D.: 2,772.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL	435	2000	<435	-	-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	383	2000				455	825	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	75	2000						
Neutron	CN	75	2000						
Temperature	-								
Mud Gas	X	152	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
455-825	3 (thin, scattered)

D. MUD GAS LOG INDICATIONS

Mud gas increases at 460 m - 480 m, 515 m - 665 m and below 700 m.

E. COMMENTS

Cyber lithology log indicates high proportion of sand at 460 m - 805 m and 850 m - 1190 m.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 163
D.A. NO: 1217

NAME: Panarctic et al East Drake L-06
AREA: Arctic Islands

K.B.: 10.0 m

G.L.: -347.0 m

T.D.: 1,300.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL	345	1300	795	845	3-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	346	1300				410	1145	2-3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	DENS	735	1300						
Neutron	-								
Temperature	-								
Mud Gas	X		1300						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
410-600	3
920-945	2
1145+	3

D. MUD GAS INDICATIONS

Increases in mud gas at 460 m - 620 m, 900 m - 1015 m, 1060 m - 1100 m; peak at 1130 m - 1160 m.

E. COMMENTS

Low reliability IBPF picks; "ice" indications on LSS at 410 m - 600 m and 630 m - 750 m.

THURBER

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 154
D.A. NO: 1012

NAME: Panarctic et al Marryatt K-71
AREA: Arctic Islands

K.B.: 91.0 m G.L.: 80.5 m T.D.: 5,467.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL	395	2000	550	850	3-3-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	326	2000				510	1655	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	0	2000						
Neutron	CN	0	2000						
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability	Interval (m)	Reliability
510-850	3 (thin, scattered)	1330-1655	3 (scattered)
950-970	3		
970-1150	3 (thin, scattered)		

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

Hydrate generally interpreted to be thin and scattered.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 153
D.A. NO: 979

NAME: Panarctic et al W. Bent Horn G-02
AREA: Arctic Islands

K.B.: 19.0 m

G.L.: 9.4 m

T.D.: 3,220.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To (m)	Reliability
Resistivity	DI-SFL	36	2000	300	465	2-3			
Sonic (Acoustic)	BHCS	25	2000				605	835	3-3-
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	25	2000						
Neutron	CN	25	2000						
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
605-820	3⁻ (thin, scattered
820-835	3

D. MUG GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

Interpreted IBPF thickness appears shallow but is consistent with some other Bent Horn area wells.

MACKENZIE DELTA-TUKTOYAKTUK PENINSULA

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 182
D.A. NO: 1226

NAME: Gulf et al Skakgatlatachig D-50
AREA: Mackenzie Delta-Tuktoyaktuk Peninsula

K.B.: 151.0 m

G.L.: 147.0 m

T.D.: 2,061.00 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DIL	540	2000	675	745	2-3			
Sonic (Acoustic)	BHCS	540	2000				565	990	3
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	DENS	555	2000						
Neutron	-								
Temperature	-								
Mud Gas	X	0	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
565-625	3
690-920	3 (scattered)
960-990	3

D. MUD GAS LOG INDICATIONS

Increases in mud gas at 550 m, 675 m - 745 m, 760 m; peak at 810 m - 865 m.

E. COMMENTS

Interpreted IBPF thickness seems high; other data in areas suggest IBPF base could be above log tops.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 183
D.A. NO: --

NAME: Gulf et al Onigat D-52
AREA: Mackenzie Delta-Tuktoyaktuk Peninsula

K.B.: 129.4 m G.L.: 125.0 m T.D.: 1,409.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Reliability
Resistivity	DIL	465	1409	580	650	3			
Sonic (Acoustic)	BHCS	465	1409				-	-	-
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	DENS	500	1409						
Neutron	-								
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

No hydrate interpreted; IBPF base seems deep (data from other wells in the area suggest IBPF base could be above log tops).

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 184 NAME: Esso PCI Home et al Tuk J-29
D.A. NO: 1211 AREA: Mackenzie Delta-Tuktoyaktuk Peninsula

K.B.: 16.9 m G.L.: 10.6 m T.D.: 3,176.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To (m)	Reliability
Resistivity	DI-SFL	10	2000	370	450	2-3			
Sonic (Acoustic)	BHCS	792	2000				-	-	-
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	920	1220						
Neutron	-								
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

No hydrate interpreted; some hashy zones on BHCS (not logged as hydrate).

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 163
D.A. NO: 1119

NAME: Esso PCI Home et al Tuk M-09
AREA: Mackenzie Delta-Tuktoyaktuk Peninsula

R.T.: 31.2 m

G.L.: 24.0 m

T.D.: 3,030.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DLL, DI-SFL	0	2000	355	450	2-3			
Sonic (Acoustic)	BHCS	765	2000				840	990	2-3
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	725	1910						
Neutron	CN	725	1910						
Temperature	-								
Mud Gas	X								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
840-870	2
900-920	3
975-990	3

D. MUD GAS LOG INDICATIONS

Low background mud gas; no peaks.

E. COMMENTS

Relatively good IBPF picks.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 185
D.A. NO: --

NAME: Esso PCI Home et al Tuk H-30
AREA: Mackenzie Delta-Tuktoyaktuk Peninsula

K.B.: --

G.L.: --

T.D.: 1,399.00 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DI-SFL	15	1399	385	-	2			
Sonic (Acoustic)	Sonic	600	1399				-		-
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	GR	600	1399						
Caliper	X								
Density	-								
Neutron	NEUT	600	1399						
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

Transition base within RES log gap; no hydrate interpreted; non-correspondence in S.P. and GR to 685 m. D.A., K.B. and G.L. information not available.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 164
D.A. NO: 1041

NAME: Esso Pex Home et al Pikiolik G-21
AREA: Mackenzie Delta-Tuktoyaktuk Peninsula

K.B.: 74.8 m

G.L.: 67.6 m

T.D.: 1,429.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Reliability
Resistivity	DLL, DIL	10	1429	400	650	2-3			
Sonic (Acoustic)	BHCS	533	1429				-	-	-
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	485	1429						
Neutron	CN	485	1429						
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

Well history report indicates "base of permafrost" at -323.0 m (K.B.); no hydrate interpreted.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 186
D.A. NO: 1200

NAME: Chevron Trillium Upluk L-42
AREA: Mackenzie Delta-Tuktoyaktuk Peninsula

K.B.: 31.5 m G.L.: 20.7 m T.D.: 3,350.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To (m)	Reliability
Resistivity	DLL	256	2000	460	550	2-3			
Sonic (Acoustic)	BHCS	220	2000				510	870	2-3
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FDEN	35	2000						
Neutron	-								
Temperature	-								
Mud Gas	X	200	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
510-520	2
800-810	3
835-870	3

D. MUD GAS LOG INDICATIONS

Increases in mud gas at 480 m - 530 m, 765 m - 795 m, 810 m - 840 m and 1095 m - 1465 m.

E. COMMENTS

Well history report estimates "permafrost base" at 355 m.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 187
D.A. NO: --
NAME: Esso Home et al Taglu West H-06
AREA: Mackenzie Delta-Tuktoyaktuk Peninsula

K.B.: 11.0 m
G.L.: 1.7 m
T.D.: 4,200.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To (m)	Reliability
Resistivity	DLL	25	2000	525	640	2			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	615	2000				660	690	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FDEN	630	2000						
Neutron	-								
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
660-690	3

D. MUD GAS LOG INDICATIONS

No mud gas log available; drilling well history report indicates low background throughout.

E. COMMENTS

Well history report suggests mud gas peak at 43 m "probably due to presence of small pocket of gas hydrate".

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 188
D.A. NO: 1229

NAME: Esso PCI Home et al Itkrilek B-52
AREA: Mackenzie Delta-Tuktoyaktuk Peninsula

K.B.: 10.4 m G.L.: 6.3 m T.D.: 1,284.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To (m)	Reliability
Resistivity	DI-SFL	19	1284	340	425	2-3			
Sonic (Acoustic)	BHCS	619	1284				-		-
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	595	1284				915	1010	3
Neutron	-								
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
915-1010	3

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

Hydrate interpreted on litho-density log but not on BHCS.

OFFSHORE BEAUFORT

THURBER

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 189
D.A. NO: 1195

NAME: Esso Trillium Adgo H-29
AREA: Offshore Beaufort

K.B.: 10.2 m

G.L.: -2.8 m

T.D.: 3,314.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Reliability
Resistivity	DIL	50	2000	280	370	3	440	890	3
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	900	2000				950	980	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	900	2000						
Neutron	CN	900	2000						
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
440-475	3
745-775	3
855-890	3
950-980	3

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

Hydrate in upper section of well interpreted on RES; cycle skipping on LSS at 950 m - 980 m.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 190
D.A. NO: --

NAME: Dome et al Adlartok P-09
AREA: Offshore Beaufort

K.B.: --

G.L.: --

T.D.: 2,647.00 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Reliability
Resistivity	DLL, DI-SFL	55	2000	400	450	2-3			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	190	2000				475	740	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	785	2000						
Neutron	CN	785	2000						
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
475-515	3
550-570	3
715-740	3

D. MUD GAS LOG INDICATIONS

Increased mud gas between 360 m - 665 m, 800 m - 975 m, and below 1,000 m; no major peaks.

E. COMMENTS

Few sands to provide hydrate reservoirs. DI-SFL log and D.A., K.B. and G.L. data not available.

THURBER

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 191
D.A. NO: 1251

NAME: Dome et al Edlok N-56
AREA: Offshore Beaufort

K.B.: 12.0 m

G.L.: -44.0 m

T.D.: 2,530.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL, DI-SFL	45	2000	405	460	3			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	390	2000				-	-	-
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	850	2000						
Neutron	CN	850	2000						
Temperature	-								
Mud Gas	X	162	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

No hydrate interpreted.

THURBER

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 192
D.A. NO: 1098

NAME: Esso Home et al Kadluk O-07
AREA: Offshore Beaufort

K.B.: 16.1 m

G.L.: -29.1 m

T.D.: 3,896.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Reliability
Resistivity	DLL	200	2000	740	820	3	-	-	-
Sonic (Acoustic)	BHCS	515	2000						
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	980	2000						
Neutron	CN	980	2000						
Temperature	-								
Mud Gas	X	29	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

Background mud gas throughout.

E. COMMENTS

Noisy sonic below 1390 m but not interpreted as hydrate; no hydrate interpreted.

THURBER

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 193
D.A. NO: 1198

NAME: Esso PCI Home et al Nipterk L-19
AREA: Offshore Beaufort

K.B.: 15.3 m

G.L.: -11.0 m

T.D.: 3,879.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To (m)	Reliability
Resistivity	DLL	70	2000	520	615	2-3			
Sonic (Acoustic)	BHCS	50	2000				620	1395	3-
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	1180	2000						
Neutron	CN	1180	2000						
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
620-820	3-
1305-1395	3-

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

Very low reliability hydrate picks; may be absent.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 194
D.A. NO: 1080

NAME: Gulf et al Pitsiulak A-05
AREA: Offshore Beaufort

R.T.: 20.0 m

G.L.: -27.0 m

T.D.: 2,192.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL	40	2000	750	830	3			
Sonic (Acoustic)	BHCS	1550	2000				-	-	-
Long-spaced Sonic	LSS	670	2000				-	-	-
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FDEN	690	2000						
Neutron	-								
Temperature	-								
Mud Gas	X	60	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

Increase in mud gas at 250 m - 950 m.

E. COMMENTS

No hydrate interpreted. RES increase at 300 m could be IBPF, with transition to 435 m; however, above 750 m IBPF base is preferred.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 195
D.A. NO: 1199

NAME: Gulf et al Tarsiut P-45
AREA: Offshore Beaufort

R.T.: 22.8 m

G.L.: -25.5 m

T.D.: 3,042.0 m (2254.0 TVD)

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DLL, DI-SFL	201	2000	610	695	3			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	645	2000				-	-	-
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	600	2000						
Neutron	CN	600	1270						
Temperature	-								
Mud Gas	X	60	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability

D. MUD GAS LOG INDICATIONS

High gas flows out of casing suggest hydrate may be present above 200 m; mud gas peak at 890 m to 900 m.

E. COMMENTS

No hydrate interpreted below 200 m.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 196
D.A. NO: 1194

NAME: Esso Home PCI et al Amerk O-09
AREA: Offshore Beaufort

K.B.: 16.4 m

G.L.: -26.0 m

T.D.: 5,000.00 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL	42	2000	745	835	1-2			
Sonic (Acoustic)	BHCS	995	2000				1275	1600	3
Long-spaced Sonic	-								
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	990	2000						
Neutron	CN	990	2000						
Temperature	-								
Mud Gas	X	42	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
1275-1600	3 (thin scattered)

D. MUD GAS LOG INDICATIONS

Increased mud gas at 810 m, 1080-1085 m and 1345 m - 1355 m.

E. COMMENTS

Good IBPF picks.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 197
D.A. NO: 1029
NAME: Dome et al Natiak O-44
AREA: Offshore Beaufort

R.T.: 11.9 m
G.L.: -43.0 m
T.D.: 4,650.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL, DILL	45	2000	320	400	3-3-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	680	2000				720	740	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FDEN	680	2000						
Neutron	-								
Temperature	-								
Mud Gas	X	206	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
720-740	3

D. MUD GAS LOG INDICATIONS

No mud gas log available; well history report indicates gas peaks at 392 m - 408 m, 415 m - 430 m, 603 m - 613 m and 735 m - 738 m.

E. COMMENTS

Low reliability IBPF picks.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 198
D.A. NO: 1201

NAME: Gulf et al Akpak 2P-35
AREA: Offshore Beaufort

K.B.: m

G.L.: -45.0 m

T.D.: 3,673.00 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DI-SFL	750	2000	790	900	2-3			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	750	2000				750	1740	2-3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	-								
Neutron	-								
Temperature	-								
Mud Gas	X								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability	Interval (m)	Reliability
750-1125	2	1320-1360	3
1175-1210	3	1450-1535	3
1230-1250	3	1605-1640	3
		1715-1740	3

D. MUD GAS LOG INDICATIONS

Mud gas increases at 405 m - 490 m, 570 m - 670 m, 750 m - 900 m, 930 m - 1,140 m, 1,195 m - 1,225 m, 1,310 m - 1,360 m, 1,625 m - 1,650 m, and 1,720 m - 1,750 m; reasonable agreement with interpreted hydrate; little in the way of reservoir sands.

E. COMMENTS

Thick IBPF and transition interpreted.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 199
D.A. NO: 1073

NAME: Dome et al Arluk E-90
AREA: Offshore Beaufort

R.T.: 12.2 m

G.L.: -58.0 m

T.D.: 4,300.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DLL, DI-SFL	70	2000	-	440	2			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	375	2000				500	1180	2-3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FD	375	2000						
Neutron	CN	375	2000						
Temperature	-								
Mud Gas	X								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability	Interval (m)	Reliability
500-600	2	930-950	2
700-800	3 (scattered)	1010-1025	2
860-920	3	1050-1065	2
		1160-1180	2

D. MUD GAS LOG INDICATIONS

Relatively good correlation of mud gas peaks with interpreted hydrate occurrence.

E. COMMENTS

Relatively extensive hydrate interpreted, yet little in the way of reservoir sands. Base IBPF not logged.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 175
D.A. NO: 946

NAME: Dome Koakoak O-22
AREA: Offshore Beaufort

K.B.: 11.9 m

G.L.: -49.2 m

T.D.: 4,365.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Reliability
Resistivity	DLL-MSFL	195	2000	640	720	2-3			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	630	2000				745	1160	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	FDEN	630	2000						
Neutron	-								
Temperature	-								
Mud Gas	-								

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
745-1160	3

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

Drilling report indicates "top of permafrost" at 158 m, "base of permafrost" at 592 m and "base of transition" at 660 m; cycle skipping on sonic at 745 m - 1160 m.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 200
D.A. NO: 985

NAME: Dome et al Siulik I-05
AREA: Offshore Beaufort

K.B.: 12.2 m

G.L.: -52.0 m

T.D.: 4,824.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Bottom (m)	Permafrost Base (m)	Trans. (m)	Reliability	Gas Hydrates From (m)	To	Reliability
Resistivity	DLL, DI-SFL	52	2000	300	345	3			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	635	2000				870	1120	3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	600	2000						
Neutron	-								
Temperature	-								
Mud Gas	X	208	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
870-1120	3 (scattered)

D. MUD GAS LOG INDICATIONS

Increasing mud gas from 500 m, with peak at 725 m to 1120 m.

E. COMMENTS

Well history report states "background gas increased rapidly once base of permafrost was reached at 650 m".

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 178
D.A. NO: 1040

NAME: Dome et al Aiverk 2I-45
AREA: Offshore Beaufort

K.B.: 11.5 m

G.L.: -61.9 m

T.D.: 5,034.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Reliability
Resistivity	DLL, DI-SFL	55	2000	625	770	2-3			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	695	2000				615	1820	2-3-
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	DENS	695	2000						
Neutron	-								
Temperature	-								
Mud Gas	X	634	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability	Interval (m)	Reliability	Interval (m)	Reliability
615(csg)-635	3	1185-1195	2	1435-1500	2
795-815	2	1230-1240	3	1570-1725	3 (scattered)
835-845	3	1290-1295	3	1820 ±	3-
845-1025	3 (scattered)	1300-1370	2		

D. MUD GAS LOG INDICATIONS

Mud gas peaks at 715 m - 735 m, 790 m - 820 m, 1,190 m - 1,200 m, 1,220 m - 1,240 m, 1,260 m - 1,290 m, 1,435 m - 1,490 m, 1,635 m ±, 1,705 m; correlation with interpreted hydrate is relatively good.

E. COMMENTS

Hydrate interpreted to be extensive.

PERMAFROST/GAS HYDRATE UPDATE: ANALYSIS DETAIL

A. WELL INFORMATION

WELL NO: 201
D.A. NO: 1126

NAME: Dome et al Nerlerk J-67
AREA: Offshore Beaufort

K.B.: 20.0 m

G.L.: -45.0 m

T.D.: 4,904.0 m

B: PERMAFROST AND GAS HYDRATE DATA

Log Name	Avail/Type	Logged Interval Top (m)	Logged Interval Bottom (m)	Permafrost Base (m)	Permafrost Trans. (m)	Permafrost Reliability	Gas Hydrates From (m)	Gas Hydrates To (m)	Gas Hydrates Reliability
Resistivity	DI-SFL	680	2000	680	-	-			
Sonic (Acoustic)	-								
Long-spaced Sonic	LSS	680	2000				703	1615	2-3
S.P.	X								
Gamma Ray	X								
Caliper	X								
Density	LD	680	2000						
Neutron	-								
Temperature	-								
Mud Gas	X	200	2000						

C. DETAILED GAS HYDRATE INTERPRETATION

Interval (m)	Reliability
703-795	2
1020-1120	3
1120-1250	2
1250-1575	3
1575-1615	2

D. MUD GAS LOG INDICATIONS

No mud gas log available.

E. COMMENTS

IBPF apparently above RES log top.
Well history report indicates gas peak at 650-700 m "likely due to hydrates at base of permafrost".