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GEOLOGY AND RESOURCE POTENTIAL OF A PROPOSED NATIONAL MARINE PARK LANCASTER SOUND

NORTHWEST TERRITORIES

D.R. Smith, R.J.Gowan, M. McComb

Canada

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SUMMARY

The proposed national marine park in Lancaster Sound is located within one of the least explored areas on Canada's frontier lands. The data base however, is sufficient to make several qualitative statements as to the proposed park's non-renewable resource potential.

The potential for oil and/or gas accumulation has been rated as high (2) for the east-central portion of Lancaster Sound. It must be emphasized that interpretation of seismic data has indicated that source and reservoir beds may be present, but this cannot be documented until a well has been drilled. Within the area of high potential, several large structures have been delineated, each theoretically capable of containing more than ten billion barrels of oil in place. The type of geological basin and inferred age of its sedimentary rocks, are similar to some prolific hydrocarbon producing basins elsewhere in the world.

Data on mineral resources are insufficient to allow detailed analysis to be done. Placer mineral potential does exist although no deposits have been discovered so far, and the potential for finding them is generally considered to be low. Aggregates capable of being used locally for construction purposes occur along most of the shoreline and in some parts of the basin, but specialty aggregates such as high silica or carbonate sands have not yet been identified.

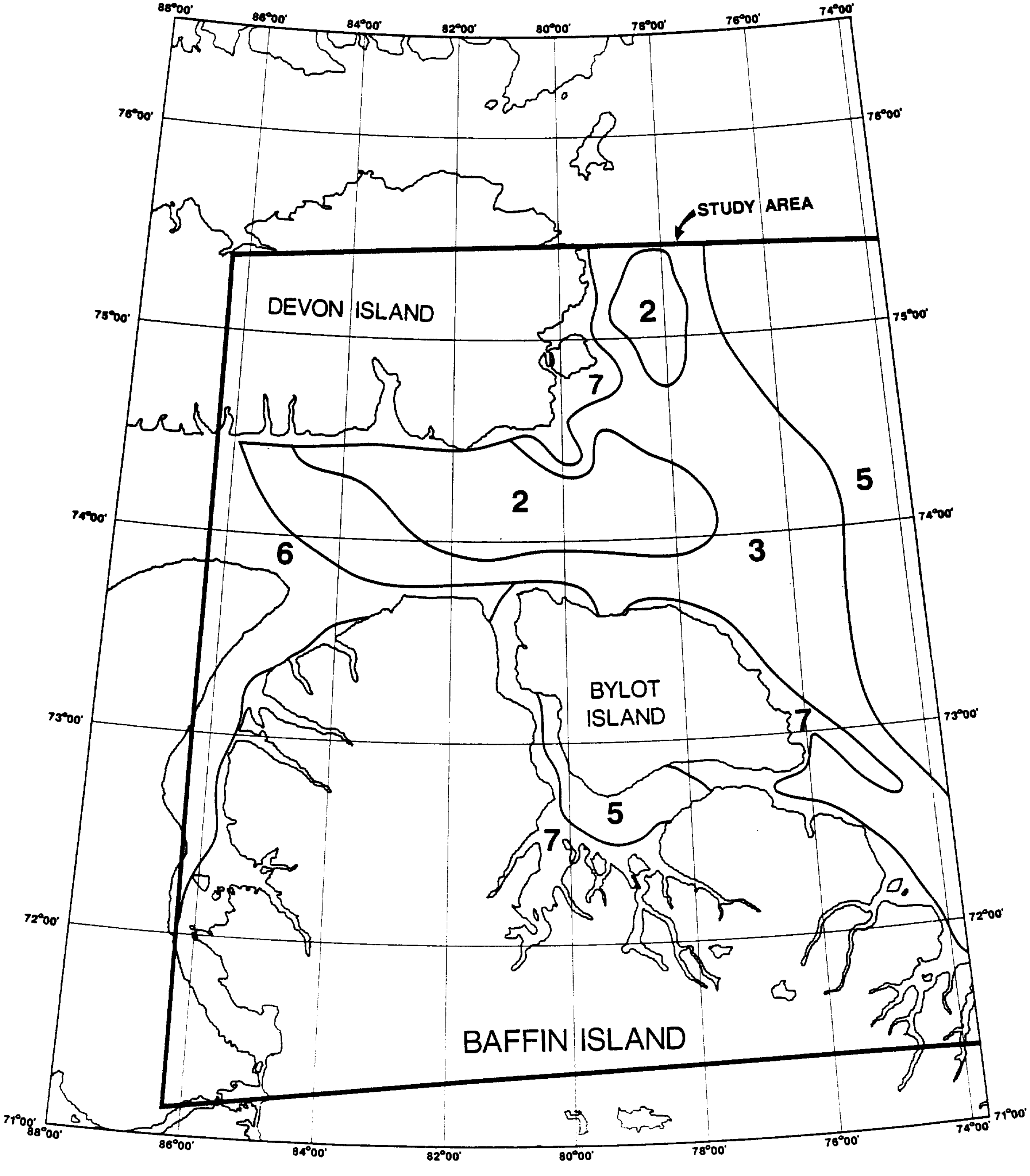

Fig. 10. Overall resource potential map. See Table 3 for rating criteria, ranging from very high (1) to very low (7).

INTRODUCTION

Purpose of the Study

The Canadian Parks Service co-ordinates a detailed assessment of the feasibility of establishing any proposed national marine park. As part of the feasiblility assessment, the non-renewable natural resource potential of the proposed park area is examined. Mineral and gas and oil exploration and development are prohibited activities within established national marine parks and so this non-renewable resource information is required in order to help all interested parties decide whether a park is desirable, and if so, where the boundary should be located. This report describes the non-renewable resource potential of a proposed national marine park in Lancaster Sound, at the eastern entrance to the Northwest Passage in Arctic Canada. A separate report has already been completed for the land area of a proposed adjacent national park.

This initial non-renewable resource assessment is based on available geoscience information. Depending upon the outcome of a review of the recommendations by appropriate Associate Deputy Ministers in the Departments of Energy Mines and Resources, Indian Affairs and Northern Development, Environment Canada, and the Government of the Northwest Territories, the assessment may end at this stage. Alternatively, if funds are available, these decision makers may request more non-renewable resource information to help with the decision on whether or not to establish the park or where to locate the boundary.

The rationale for the park and a map of the park area of interest are located in the public information booklet prepared by the Canadian Parks Service, and appended to this report.

Study Area

This study encompasses the marine component of the area outlined in Figure 1 and described in greater detail in the attached park proposal booklet. The land portions of the study area on Bylot and Baffin Islands were recently assessed by the Geological Survey of Canada in GSC paper 87-17 by Jackson and Sangster (1987) and the sedimentary geology of Devon Island has recently been discussed in GSC Memoir 411 by Thorsteinsson and Mayr (1987).

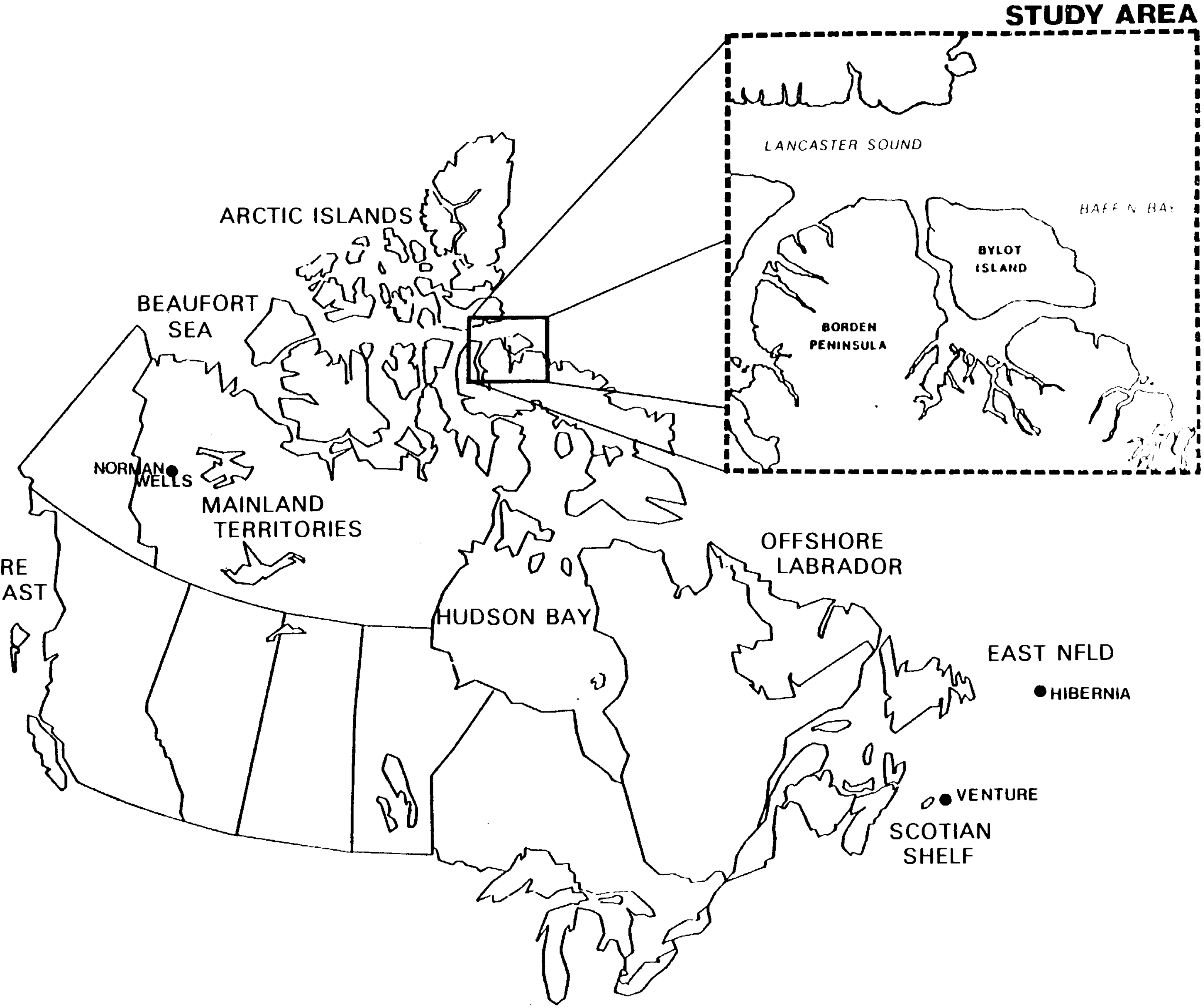

Fig. 1. Location map of study area.

Data Base

Information on sediments and sedimentary rocks within the study area is fairly sparse, and comes mainly from results of exploration by oil companies and by research conducted by officers of the Geological Survey of Canada. Oil exploration permits in the area were first issued in 1968-1969. More than 60,000 line-km of marine seismic data have been collected by petroleum exploration companies. The quality of seismic data ranges from poor to good, and provides a framework for identifying structural anomalies and the sedimentary packages within the Lancaster and north Baffin basins. No wells have been drilled.

Both Oakwood, Consolidex et al (CMO) and Petro-Canada have undertaken assessment of bottom sediments at possible drilling sites. Some surficial geological studies have been conducted by officers of the Atlantic Geoscience Centre, Geological Survey of Canada.

Acknowledgements

The study has been prepared by representatives of the Canada Oil and Gas Lands Administration (COGLA) and the Natural Resources and Economic Development Branch, Department of Indian Affairs and Northern Development. Input and advice from the Atlantic Geoscience Centre, the Institute of Sedimentary and Petroleum Geology and the Ocean Mining Division (DEMR) has been important. This text has been critically reviewed by Al Grant, Brian MacLean, and Graham Williams of the Atlantic Geoscience Centre, Jim Dietrich of the Institute of Sedimentary and Petroleum Geology, Peter Hale of the Ocean Mining Division, Mineral Policy Sector, and Charlie Jefferson of the Continental Geoscience and Mineral Resources Branch, Geological Survey of Canada. Their comments and constructive criticisms were very much appreciated.

HISTORY OF NON-RENEWABLE RESOURCE EXPLORATION WITHIN THE STUDY AREA

As of February 1989, three companies had petroleum exploration rights in the form of permits or exploration licences (see Figure 2, Table 1). The companies hold rights to approximately 3,400,581 hectares, down from a high of greater than 6,000,000 hectares in the 1970's. No mining leases or permits have been issued in the offshore. A moratorium precluding drilling and mining is currently in force over the entire study area.

Oakwood, Consolidex et al (CMO), a consortium holding petroleum exploration rights in Lancaster Sound, is one of the major operators in the area. This group although still evolving has been referenced to as CMO and is the successor to Norlands Petroleum Ltd., the company that received approval-in-principle to drill a well in Lancaster Sound in 1974. Drilling approval was delayed and the approval-in-principle terminated in 1977 due to environmental concerns. A 1978 Environmental Assessment Review Panel reviewed Norland's proposal for exploratory drilling and recommended that this activity not take place until a study answers the question - is exploratory drilling compatible with current and future uses in Lancaster Sound? A moratorium was subsequently placed on exploration activity, and is still in place. This issue of oil exploration and development is unresolved though it has been the subject of a regional study and is now a major focus of a regional land use planning process.

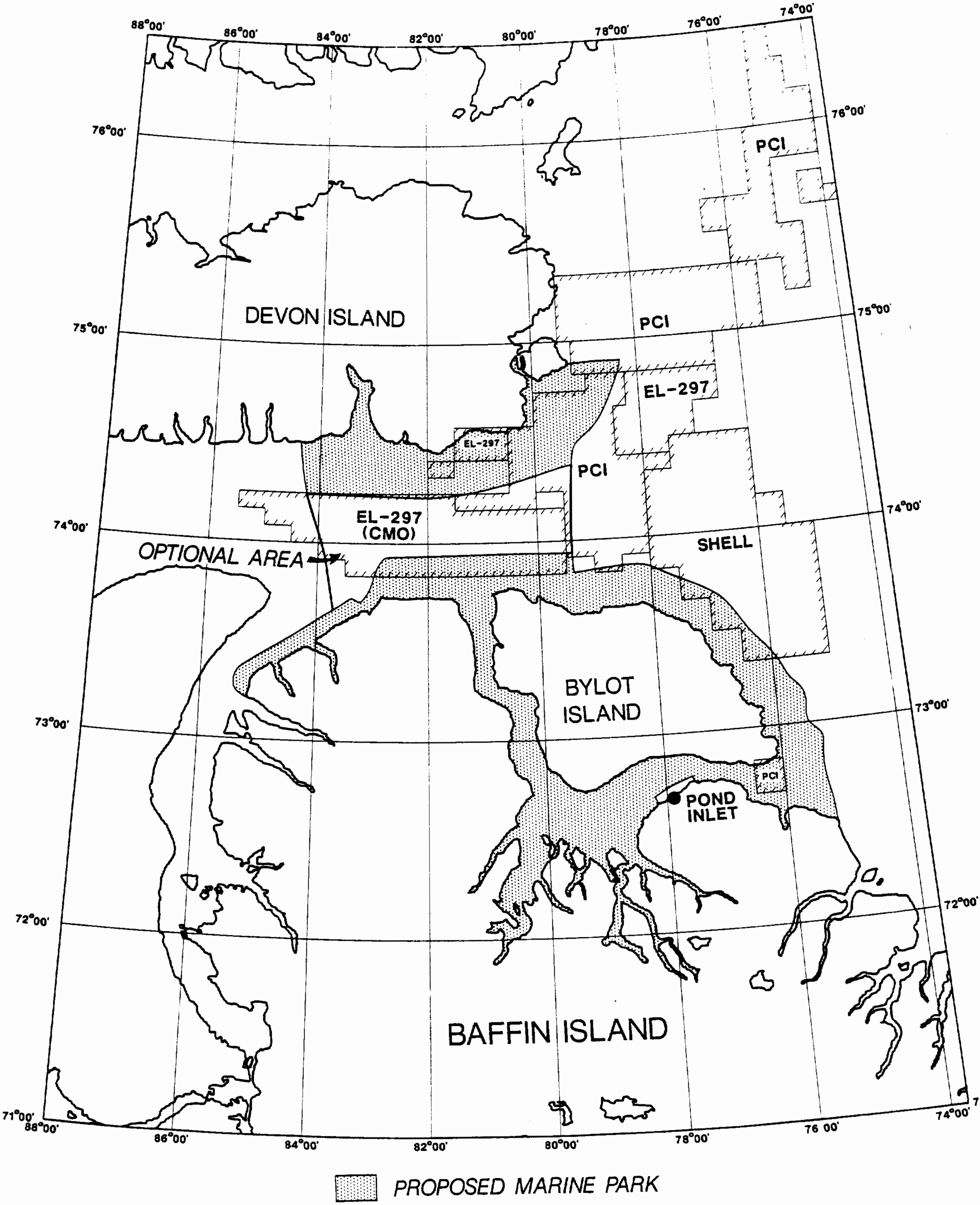

Fig. 2. Map showing currently held exploration permits and exploration agreements, and the area of interest of the proposed marine park.

COMPANY	CURRENT LAND HOLDINGS	TOTAL GEOLOGICAL AND GEOPHYSICAL EXPENDITURES	COMMENTS
PETROCAN	EAP No.1: 399,934 ha Baffin Bay 1,206,627 ha TOTAL: 1,606,561 ha	$ 5,086,757	EA's under negotiation.
OAKWOOD CONSOLIDEX ET AL	931,641 EL 297	$ 7,012,245	EL 247 expires July 15, 1994. Land Held: Oakwood: 12.5% Consolidex: 12.5% Magnorth: 75% (Owned 38% by BP).
GULF	NIL	$ 528,954	Had entered into EA negotiations, but relinquished land in March, 1983.
SHELL	862,380 ha.	$ 1,500,716	EA under negotiation. Shell 100% PetroCan is operator and can earn 50% with the drilling of two wells.
OTHERS	NIL	Approximately $7,000,000	Includes Esso, Taxaco, Mobil, Aquitaîne and the estimated percentages of regional "participation" projects of Kenting, GSI, and Eureka.
TOTAL	**3,400, 581 ha.**	**$21,128,672**	

TABLE I: Listing of current land holdings in the Lancaster Sound - North Baffin Bay area (See Fig. 7).

REGIONAL GEOLOGY

The park area of interest is centered around Lancaster Sound where it enters into the northern part of Baffin Bay (Fig 1). This is the eastern limit of the famed Northwest Passage, and is adjacent to and along the passive continental margin of the the North American crustal plate.

Of primary interest in this assessment are sedimentary rocks of Mesozoic and Tertiary age and the thin veneer of overlying unconsolidated sediment. As a consequence of lack of data, the study area was not divided into domains as was done by Jackson and Sangster (1987) in their study of the adjacent land area. Instead, areas of greater or lesser resource potential were identified through analysis of the existing geoscience database.

Evolution of Lancaster Sound-Baffin Bay

The physiographic feature known as Lancaster Sound coincides with a long narrow sedimentary basin commonly referred to as the Lancaster Basin (Fig. 3). The evolution of the Lancaster and Baffin Bay basins has been the subject of much controversy in recent years with many different hypotheses being proposed. It is generally considered that the development of the Lancaster Basin is intimately related to the development of Baffin Bay Basin which is, in turn, related to the opening up of the North Atlantic Ocean due to continental drift. Many variations on this theme have been put forward and the exact relationships are as yet unclear.

One plate tectonic model proposed by Srivistava (1978), Kerr (1981, 1982), Daae (1983) and others, is that as the North Atlantic continued to open, a spreading axis developed between Greenland and Canada during Late Cretaceous-Early Tertiary time, with actual sea floor spreading occurring between Greenland and Canada to form the Baffin Bay Basin. As rifting commenced, Lower Cretaceous sediments may have been deposited in grabens developed along the continental margin from Labrador as far north as Jones Sound. Kerr (1981, 1982) proposed that as drifting started, northeast trending faults appeared as Greenland started to rotate away from Baffin Island about a rotational pole in the Lancaster Sound-Jones Sound area. This caused compression farther to the north and is documented as the Eurekan Orogeny which has deformed much of the eastern Sverdrup Basin. McWhae (1979) documents 20 km of crustal shortening in southern Ellesmere

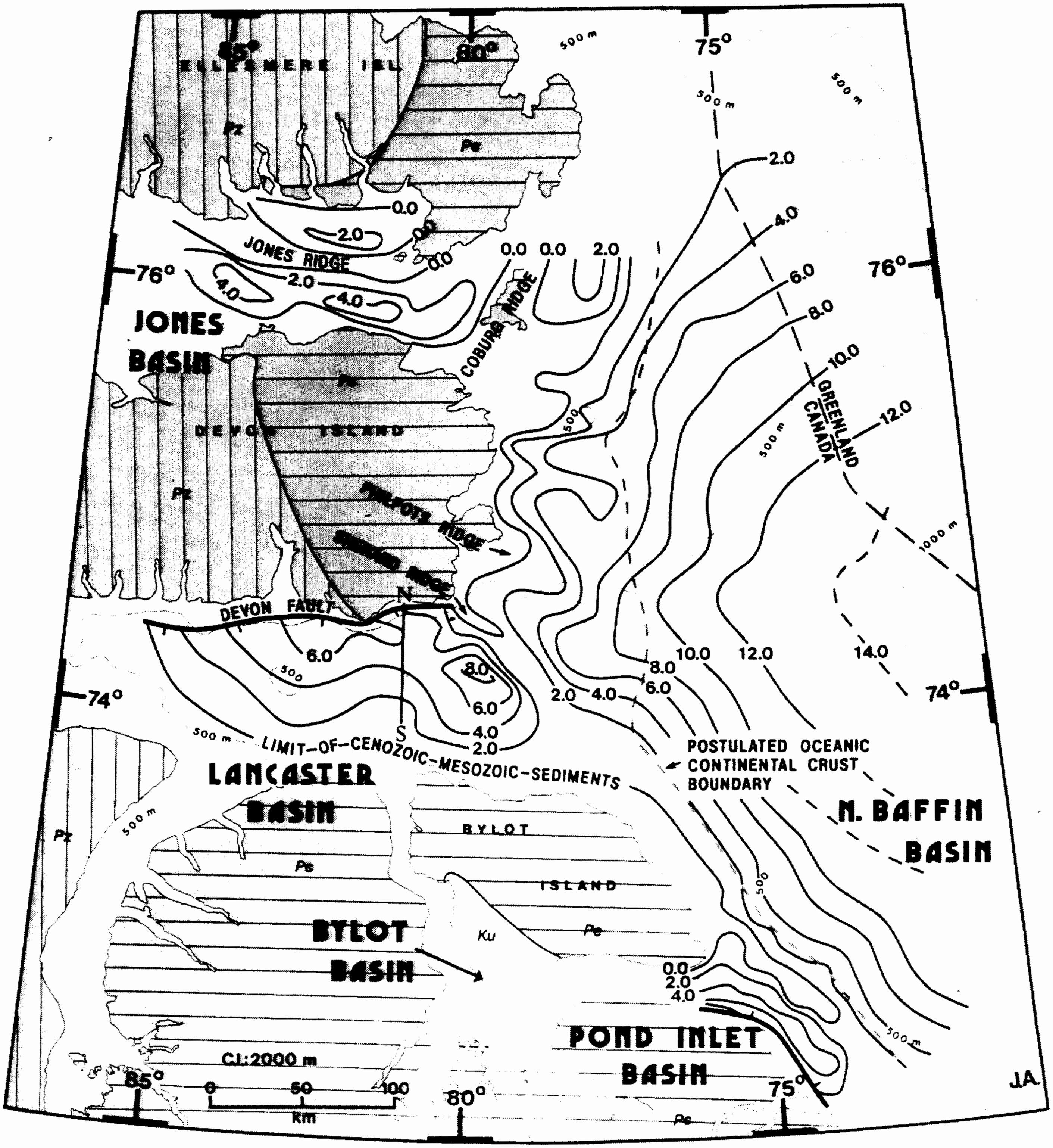

Fig. 3. Isopachous map of Cenozoic and Mesozoic sediments (from Hea et al 1980).

Island and up to 40 km further north. This is supported by Balkwill (1978). The rotational pole may have been a triple junction with Lancaster Basin being one arm, the Baffin Bay spreading axis another and Nares Strait the third. According to this model, Lancaster Basin became the failed aulocogenic arm, when left lateral movement occurred along Nares Strait and the remainder of Baffin Bay opened with the onset of active sea floor spreading approximately 50 - 30 mya, (McWhae, 1981). Kerr (1981) considered that less than 25 km of transcurrent movement has occurred along Nares Strait, with most of the opening due to rotation, but others such as Srivastava and Falconer (1982) interpret as much as 250 km of movement. Correlation of geological features across Nares Strait as described by Dawes and Kerr (1982) and others indicate little or no strike-slip movement along Nares Strait, and Grant (1980, 1982) has indicated the possibility that the crust has merely foundered, perhaps with some attenuation, but no continental drift has taken place.

The various hypotheses for the origin of Lancaster Sound basin highlight the fact that there are many unanswered geological questions in this area, and as McMillan (1982) indicates, the resolution of some of these regional questions may have a direct impact on determining the hydrocarbon potential of the Lancaster Sound Area.

Deformation

Seismic data acquired in the Lancaster Sound - Baffin Bay area does not definitively support any particular plate tectonic model but does reveal a lot of tensional deformation dominated by large normal faults and horst and graben structures (Fig. 4). Some evidence does point to minor transcurrent faults particularly in the northeastern part of the area of interest.

Draping (and onlap) over and onto basement highs and some anticlinal folding along transcurrent faults also appear to be present. No diapirs or thrust faults have been identified. The geological environment does not appear to be conducive to salt tectonics although shale diapirism may be a possibility. No growth faults have been mapped although it is almost certain that they do exist, particularly in the eastern part of the area.

Two structural elements, the Sherard ridge and the Philpots ridge (Fig. 7) are oriented north-west to south-east as are many of the major faults. This seems to be consistent with older structuring where north-west to south-east trending faulting of Helikian age has been documented by

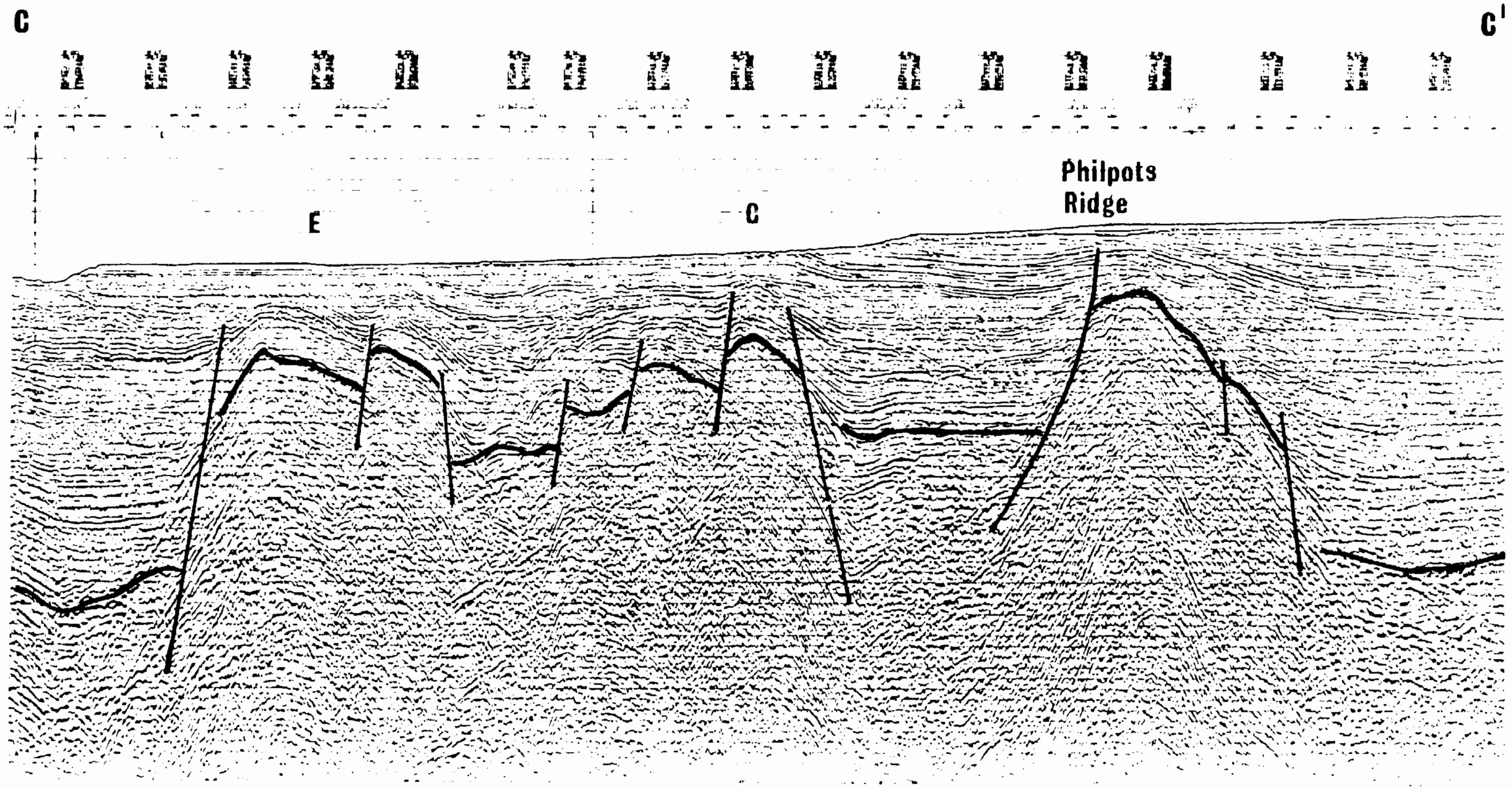

Fig. 4 . Seismic Section showing blocked faulted sediments.

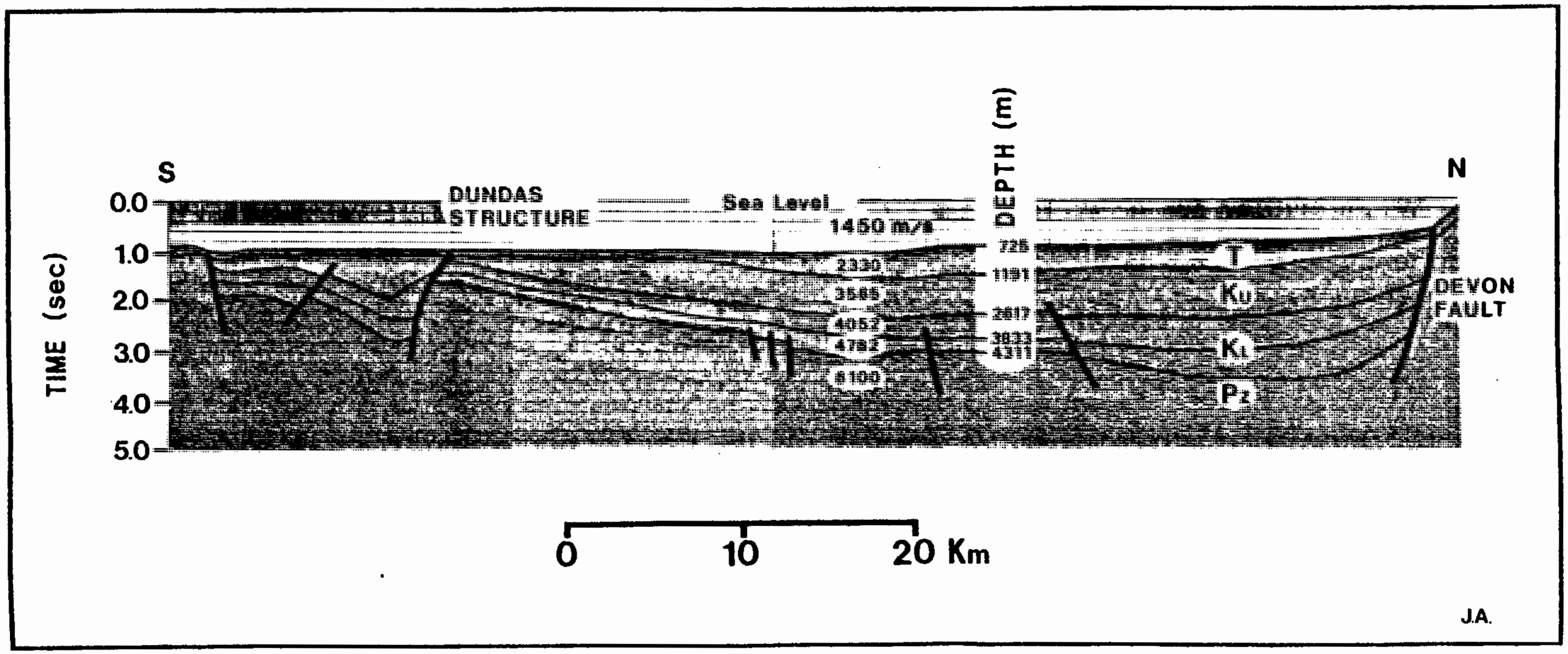

Fig. 5. Seismic section over Dundas Structure Lancaster Sound.
(From Hea et al 1980).

various authors (see Jackson and Sangster, 1987). A majority of movement on these faults appears to have taken place during deposition of the Neohelikian Bylot Supergroup with minor movements occurring right up until Recent time. Diabase dikes emplaced along these fault zones have been mapped and age dated as ranging between 470 and 819 mya. These tend to highlight the long lasting nature of the NW-SE trending fault system. Thorsteinsson and Mayr (1987) also indicate that a NW-SE trending fault system is present in the southeastern portion of Devon Island.

The major E-W trending faults which bound the Lancaster Basin were formed either as continental drift was initiated between Greenland and North America or triggered by development of the Sverdrup Rift Basin to the north-west. Various elements of the E-W trend have been superimposed on the existing structure (such as the south bounding fault of the Dundas structure as seen on Fig. 5). Daae (1983) indicates at least three periods of vertical movement on this fault during Mesozoic time, the latest one occurring after most of the sediments had been deposited.

In the Eclipse Trough on Bylot Island, three distinctive unconformities have been identified by McWhae (1979) and others in the Mesozoic-Tertiary sections. Harper and Woodcock (1980) indicated at least three major unconformities from seismic data. Erosion of structural highs at the time of these unconformities may have caused these structures to be devoid of potential reservoir rocks or alternatively may have allowed for a better developed reservoir through winnowing.

Modification by Glaciation and Sea Level Change

The basins have been structurally stable since Early Tertiary time, with only compaction of sediments and minor re-activation along some faults occurring. The near-surface morphology of the basin has been altered, by recent fluvial, glacial, and marine processes. The most important features of the regional surficial geology, with regard to the resource potential of the study area, are related to the deposition of glacial, glacio-fluvial, and, glacio-marine sediments, and their subsequent reworking into beach and bar deposits.

The glacial history of eastern Lancaster Sound and adjacent channels is relatively complex because the Sound was the main pathway for ice derived from the Arctic Islands, from a series of relatively thin localized ice caps, and from the northeastern margins of formerly extensive continental ice sheets. The chronology of glacial events within the marine area has not been determined, but it appears from the terrestrial record that several episodes are represented. The glacial history of Bylot Island, which is a key to the adjacent marine areas, has been outlined by Klassen (1985).

Continental ice from the southwest may have overridden northern Baffin Island and much of Bylot Island, and coalesced with ice which flowed from the west, and fully occupied Lancaster Sound, prior to the mid-Wisconsin. Subsequent advances of the Laurentide ice sheet, as indicated by glacial evidence and interglacial organic and marine units, were successively less extensive in this area. The last major flow of continental ice onto Bylot Island, which occurred at least 43,000 (radiocarbon) years ago, is clearly shown by lateral moraines near the coast on northeastern Bylot Island and along Pond Inlet on both Bylot and Baffin Islands. During this advance, named the Eclipse glaciation (Klassen, 1982), grounded glacier ice occupied the channels around Bylot Island, with flow eastward through Eclipse Sound and Pond Inlet, and northward through Admiralty Inlet. The Admiralty Inlet lobe merged with the larger glacier flowing eastward through Lancaster Sound, but likely did not displace it to form any significant offshore lateral moraine. Much of the drift from the Eclipse glaciation on Bylot Island is covered with marine sediment of probable Holocene age.

Continental ice is thought to have been almost entirely confined to the channels around Bylot Island in subsequent advances since the Eclipse glaciation (Klassen, 1982). Minor moraines associated with post-Eclipse advances of the Laurentide ice occur at a few locations on the present coast. The Bylot ice cap has not changed significantly since the Eclipse glaciation, but post-Eclipse maxima have extended to the present coast in a few valleys. Glaciomarine sediments, which represent deposition in a marine environment adjacent to the glacial ice front, including deposition beneath a floating ice shelf, are likely to have been deposited in association with interglacial periods and deglaciation as the ice withdrew from the inter-island channels (MacLean et al, in preparation). All of the major channels were likely free of ice by at least 8,000 years before present (Dyke and Prest, 1987).

Sea level changes also play a role in basin modification and are important because long periods of relatively constant sea level are required for extensive reworking and concentration of coarse grained sea bed sediments.

Relative sea-level changes in the eastern Arctic Islands have been determined accurately and in detail for southern Ellesmere Island (Blake and Lewis, 1975) and northern Somerset Island (Dyke, 1979). Initial emergence following deglaciation (8000 - 9000 years before present) was relatively rapid, and the rate has slowed and remained nearly constant since about 4000 to 5000 years ago. A similar trend is indicated for northern Devon Island (England, 1976). Total emergence ranges from about 60 m to 130 m.

The sea level record for eastern Baffin Island is believed to be more complex, in that a number of earlier oscillations in sea-level, and a rise in relative sea-level of at least 2 m over the last 1500 years, are suggested (Andrews and Miller, 1985). Although there are no quantitative data for Bylot Island, coastal features such as barrier beaches indicate that recent submergence is likely. The absence of Holocene deposits on northern Bylot Island suggests little or no emergence in this area; therefore, ice marginal features similar to those found on the emergent coastal areas elsewhere on Bylot Island may be present in the adjacent nearshore zone.

Relationship to Adjacent Archean Basement Complex

Most of the area mapped south of Lancaster Sound is underlain by a variable complex of high grade acidic to intermediate gneisses that are mostly migmatites. They are discussed in detail by Jackson and Sangster (1987) and will not be described here. The Mesozoic-Tertiary section on Bylot Island as described by McWhae (1979), Miall et al (1980), and Jackson and Sangster (1987) sits directly on Archean basement rocks (Fig. 7). It is inferred that this unconformable relationship also occurs in the eastern portion of Lancaster Basin and in Baffin basin. Most of the structures outlined by seismic data occur in the eastern part of the area, and the lineaments may well be related to older structures within the Archean.

Relationship to Adjacent Paleozoic Sediments

Up to 1040 m of Early Paleozoic sediments are preserved in the Borden Peninsula area as described by Jackson and Sangster (1987), and the exposed thickness of Paleozoic sediments on Devon Island is approximately 3700 m (Thorsteinsson and Mayer, 1987). Neither Thorsteinsson and Mayr, nor Jackson and Sangster have observed Mesozoic and/or Tertiary rocks lying directly on Paleozoic strata but in the western portion of the

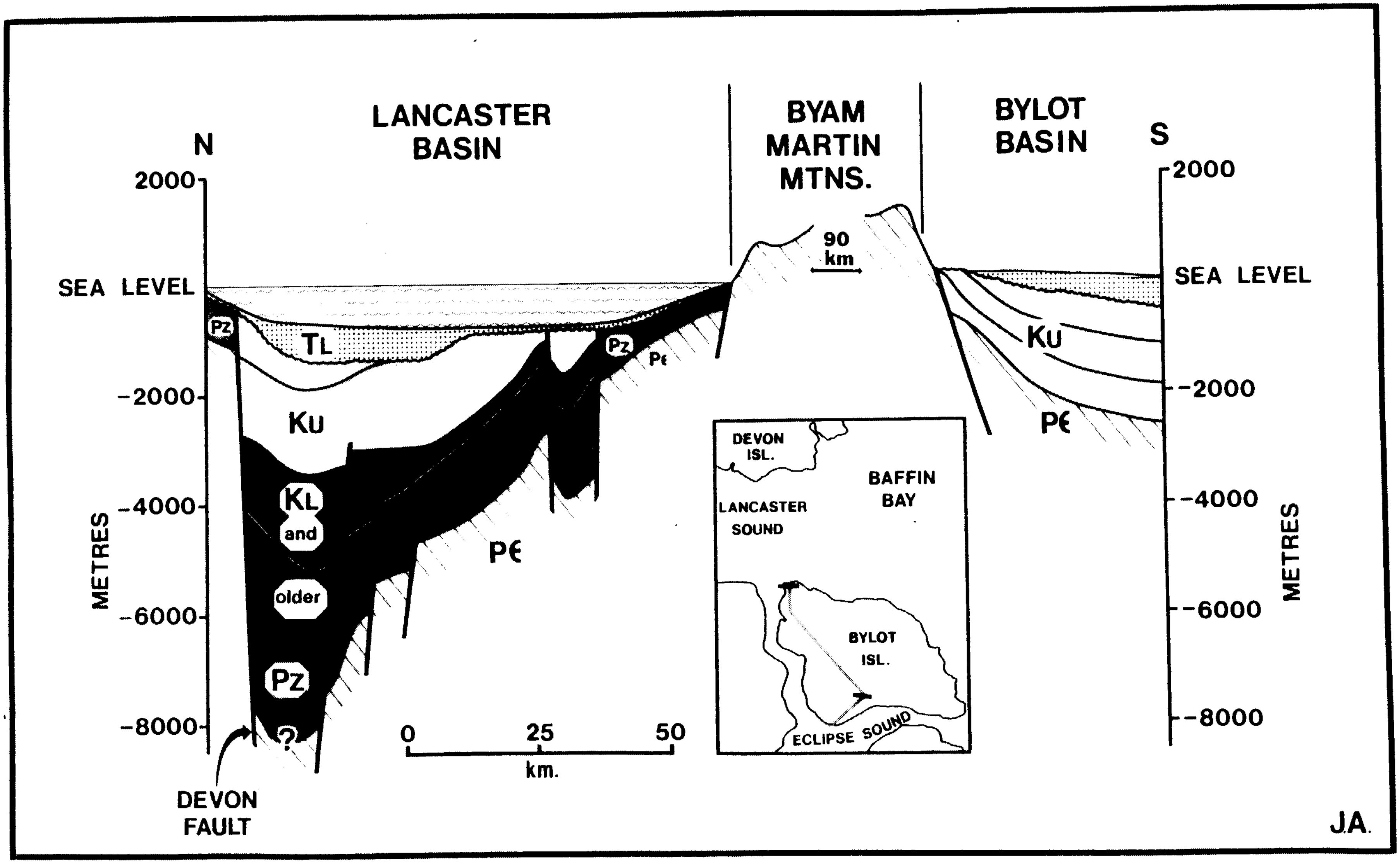

Fig. 6. Interpreted geological cross-section across Lancaster Sound and Bylot Island (from Hea et al 1980).

Lancaster Basin, it is presumed that a variety of Paleozoic rocks unconformably underly the wedge of Mesozoic-Tertiary sediments. Paleozoic strata have been separated into three major units by Jackson and Sangster (1987). Cambrian and/or Ordovician units comprise mainly clastic rocks of the Gallery Formation and the overlying interspersed sandstone, conglomerate and dolostone of the Turner Cliffs Formation. The Early to Middle Ordovician unit comprising of the Ship Point formation, consists mainly of dolostone with minor sandstones. The Middle Ordovician to Middle Silurian unit consists mainly of interlayered mixtures of limestone and dolostone. For more detail, refer to Jackson and Sangster (1987).

Stratigraphy of Lancaster - Baffin Bay Basins

Figures 3 and 6 illustrate that great thicknesses of consolidated sediments occur in the Lancaster and northern Baffin basins. Upper Cretaceous and Tertiary bedrock has been sampled on the adjacent Baffin Bay Shelf (MacLean et al., 1981, MacLean and Williams, 1983), but it must be emphasized that until a well has been drilled in the area, the age, lithology, and reservoir parameters of most subsurface rocks of Mesozoic-Tertiary age, can only be inferred.

Since the sediments which fill the Lancaster and Baffin basins do not outcrop, the interpretations of subsurface stratigraphy are based on descriptions of isolated Mesozoic-Tertiary outliers on Bylot, Baffin and Devon Islands, shallow corehole and dredge samples from the Baffin Bay shelf (Maclean et al 1981, Maclean and Williams, 1982) and stratigraphic analysis of marine seismic data. In general, the authors believe that most of the sediment fill in the Lancaster basin is of Cretaceous and Tertiary age. This is consistent with the majority of theories of basin evolution, with the outcrops that occur onshore and with the age of rocks on the north-east Baffin Island Shelf. This differs from the conclusions of Harper and Woodcock (1980) who undertook a seismic stratigraphic study over the Dundas anomaly in the Lancaster Basin. While they admit to a variety of possibilities, their preferred interpretation identifies a large portion of the deeper strata in the basin as Middle and Upper Jurassic in age. The primary reason for this is because the interpreted interval velocities from the seismic data are similar to the measured velocities in the Jurassic interval for the Hoodoo Dome H-37 well in the Sverdrup Basin. It can be shown however that these velocities are also similar to the Paleocene interval in the Canterra et al Hekja O-71 well on the southeastern Baffin Island shelf. Although there is some potential for rocks of Jurassic and Triassic age, they are probably not extensive

Table 2: Cretaceous - Tertiary Eclipse Group (from Jackson & Sangster, 1987)

Age	Formation	Member	Thickness (m)	Lithology
Late Paleocene-Early Eocene	Eureka Sound	Upper mudstone	200+	mudstone, minor sandstone
		Upper sandstone	1370+	immature sandstone, minor siltstone, mudstone
		Lower mudstone	80-500+	mudstone, jarositic, minor sandstone
		Lower sandstone	0-200	glauconitic quartzarenite
		Disconformity		
Campanian-Maastrichtian	Kanguk	Sandstone	0-540	immature sandstone, mudstone
		Mudstone	560-590	mudstone
		Disconformity		
Albian-Cenomanian (Middle Cretaceous)	Hassel		10-120	quartz arenite, minor mudstone

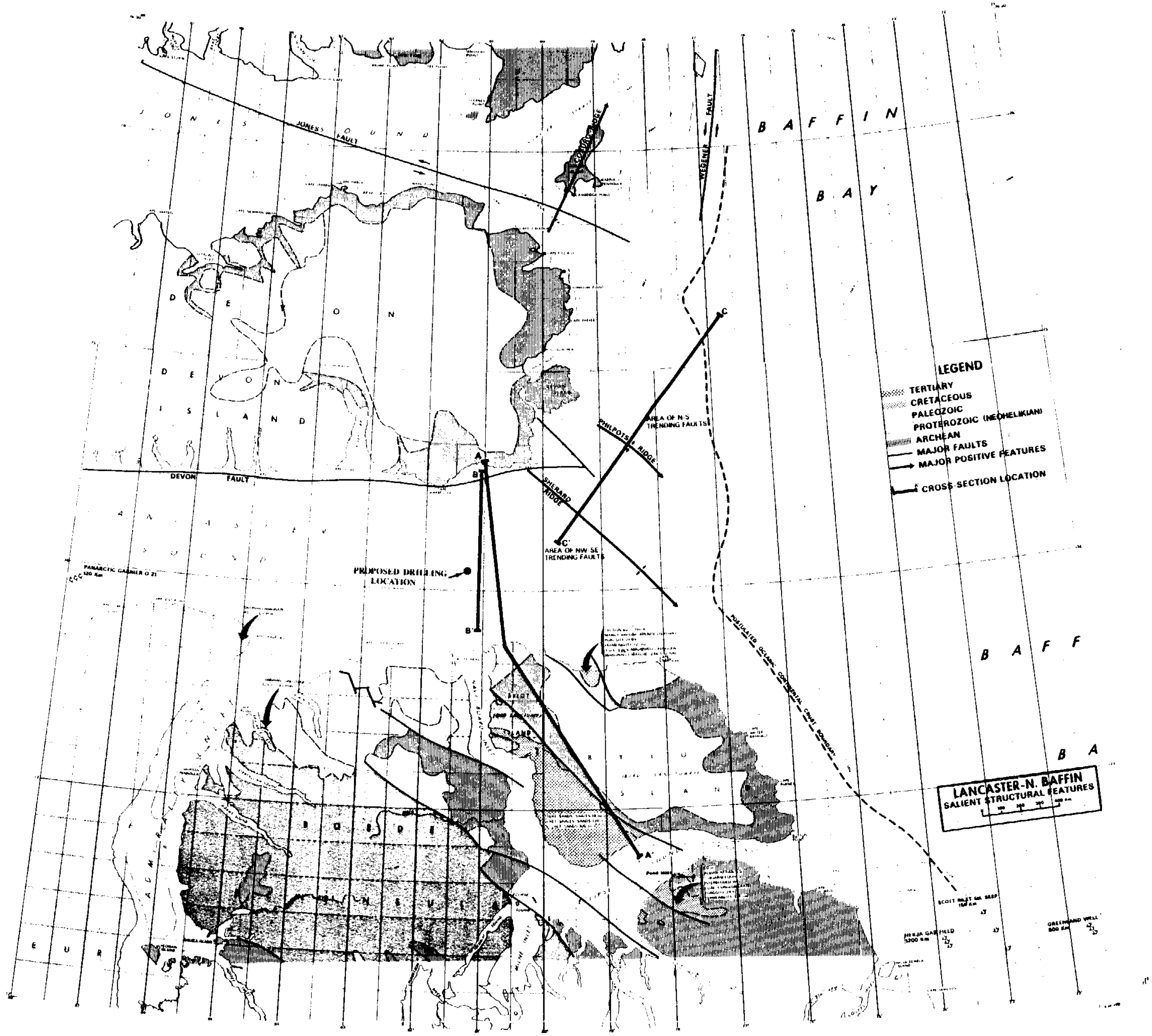

Fig. 7. Map showing regional geology, structural elements, and location of cross-sections.

and the basin fill has been assessed on the assumption that the deeper portion of the basin fill is primarily Cretaceous in age, unconformably overlying either Archean basement or lower Paleozoic rocks.

Outcropping of Mesozoic-Tertiary clastics occurs in several locations in the study area (Fig. 7), including Pond Inlet on Baffin Island, Eclipse Trough and Cape Liverpool area of Bylot Island and in several small grabens on Devon Island. The Mesozoic-Tertiary strata have been described in detail by a number of authors, including Miall et al (1980), McWhae (1979) Jackson and Sangster (1987) and Thorsteinsson and Mayr (1987). In all areas, Cretaceous or Tertiary clastic rocks lie unconformably on Archean basement. In no areas have rocks been dated as Triassic in age. The most extensive Cretaceous-Tertiary outlier is in the Eclipse Trough of Bylot Island where over 3 000 m of clastic sediments have been described by Miall et al (1980) and McWhae (1979). These strata have been correlated by Miall et al (1980) to the Hassel, Kanguk and Eureka Sound formations of the Sverdrup Basin over 400 km to the northwest. McWhae (1979) came to similar conclusions although he related the lowermost Cretaceous sediments to the slightly older Bjarni Formation as observed on the Labrador Shelf (Fig. 8). Miall et al (1980) placed the age of the rocks as ranging from Albian-Cenomanian for the mainly sandy Hassel Formation, through Campanian-Maastrichtian for the sandy Kanguk Formation, to Late Paleocene-Early Eocene for the very thick Eureka Sound Member which consists of alternating mudstone and sandstone facies (Table 2). These ages are comparable with independent studies by industry (McWhae, 1979) and recently by the Geological Survey of Canada. Ioannides (1986) noted a striking similarity with the lowermost section sampled along the south coast sections of Bylot Island to the samples from Devon Island and a similar age is inferred (Santonian to Early Campanian). Campanian rocks sampled at Buchan Gulf and Home Bay, and late Eocene to early Oligocene rocks sampled off Scott Inlet indicate that Upper Cretacious marine strata occur extensively on the northeast Baffin Island Shelf beneath a variable cover of Tertiary and Quaternary sediments (MacLean and Williams, 1983). McWhae (1979) noted major unconformities within the Eclipse Trough strata which he related to regional unconformities on the east coast of Canada (eg. Avalon unconformity) (Fig. 8). Major unconformities of similar age are also noted in the seismic analysis of Harper and Woodcock (1980).

Harper and Woodcock's stratigraphic analysis was undertaken in the area of the Dundas anomaly of the central Lancaster Basin, and provides good insight into the sedimentary basin fill. Although the authors do not agree with Harper and Woodcocks age assignments, their valuable

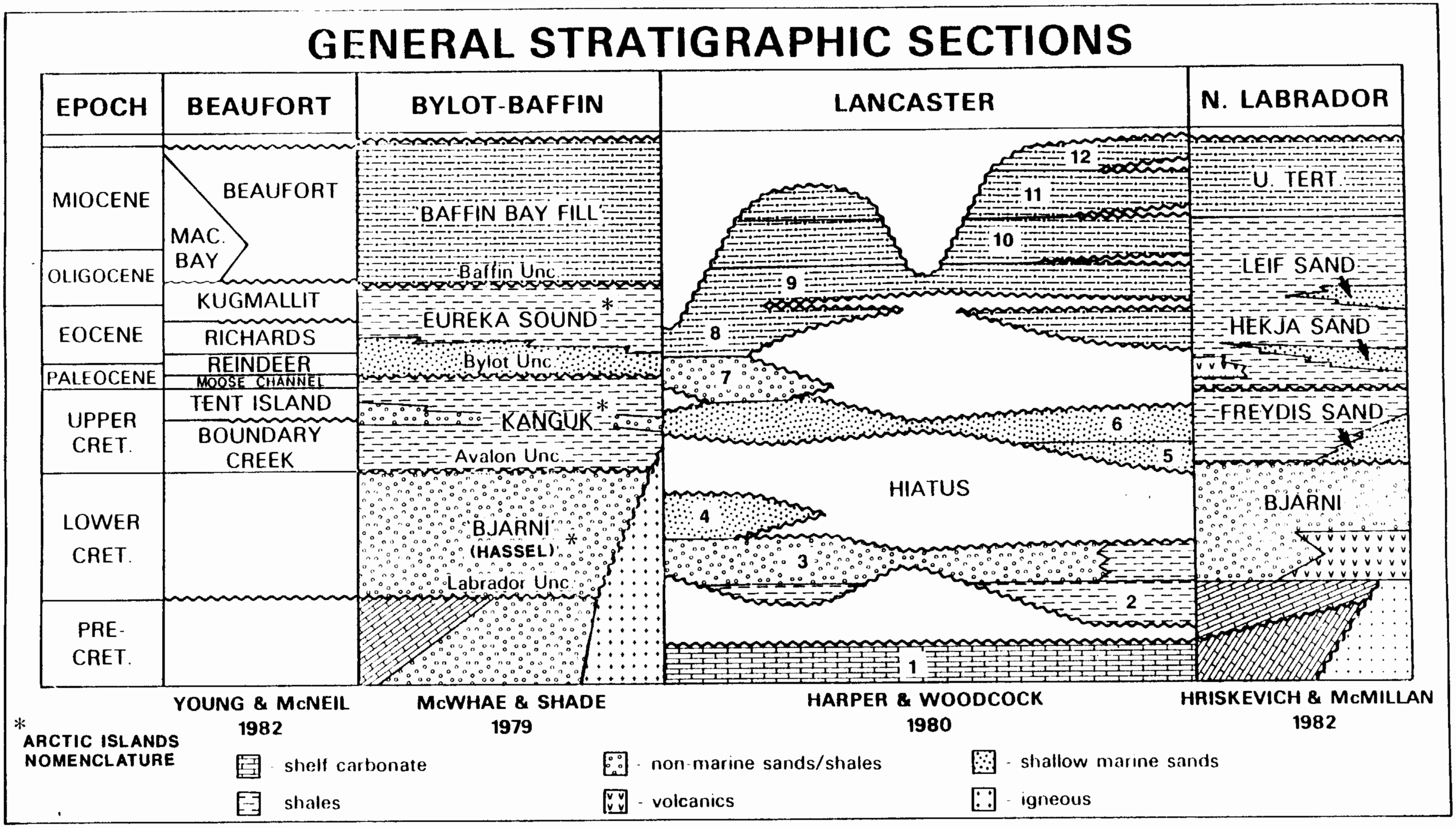

Fig. 8. Comparison of various stratigraphic columns with interpreted seismic stratigraphic sequences for Lancaster Basin.

description of sequences and depositional history are summarized below. Fig. 8 is an attempt to correlate Harper and Woodcock's analysis (age adjusted) with McWhae's findings on Bylot Island and compare them to the stratigraphic columns for the Beaufort and Labrador Seas.

Harper and Woodcock (1980) denoted twelve seismic sequences in the Dundas area. Sequence 1, the oldest, commonly has a thickness of about 300-500 m and based on velocity analysis is indicated by Harper and Woodcock to be carbonates, probably of Paleozoic age.

The sequences designated 2 to 7 (Fig. 8) are interpreted to be Cretaceous in age with a major unconformity between sequences 4 and 5 separating sediments correlated with the Albian Hassel (2, 3, 4) and Maastrichtian Kanguk (5, 6, 7) Formations.

Based on character and velocity analysis, sequence 2 is described as a transgressive shallow marine unit of interbedded sands and shales overlain by a fairly homogeneous sequence (3) which could either be sand or shale. Downlapping relationships suggest it is a regressive sand and probably has greater lateral extent then the underlying section. Sequence 3 in turn is overlain by a fairly thin sequence 4 which has been eroded off to the east beneath a regional unconformity which may correlate to the Avalon unconformity in the Eclipse Trough. (McWhae, 1979)

The overlying sequence 5 is areally restricted, and is interpreted to be a transgressive coastal marine section. It is overlain and overstepped by sequence 6 which probably can also be interpreted as transgressive deposits. The data appear to be consistent with Maastrichtian age sedimentation being restricted to the present area of Lancaster Sound and the more proximal, sandier facies occurring to the east, indicating an eastern source. Sequence 7 is a thin, possibly lacustrine unit, found only in the west, that was either not deposited in the east or was completely eroded beneath a regional unconformity that may relate to McWhae's (1979) Bylot Unconformity, above which Tertiary sediments were deposited.

Depositional sequences 8, 9 and 10 may be equivalents of the Eureka Sound Formation. Sequences 8 and 9 are onlapping units representing progressive marine transgression. The seismic signature of sequence 9 becomes more transparent to the east, possibly indicating a shalier section deposited in a deeper marine environment. Sequence 10 is mainly transparent seismically and is interpretated as a predominantly shale succession

Marine Sediments • ᐃᖅᑳᓪᓚᓂ ᑐᐊᐹᔭᑦ • Sédiments marins

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Sable (1/16 - 2 mm) et gravier (>2 mm)

☐ Silt (1/256 - 1/16 mm) • ᓴᓇ (1/256 - 1/16 ᒥᓕᒦᑐᑦ) • Limon (1/256 - 1/16 mm)

☐ Clay (<1/256 mm) • ᒫᖅᑲᐃᑦ (1/256 ᒥᓕᒥᑐ ᐅᓪᓚᑖᓂ) • Argile (<1/256 mm)

Limit of Area Surveyed • ᖃᐅᔨᓴᖅ ᐱᐅᕙᖅ • Limite de la région étudiée

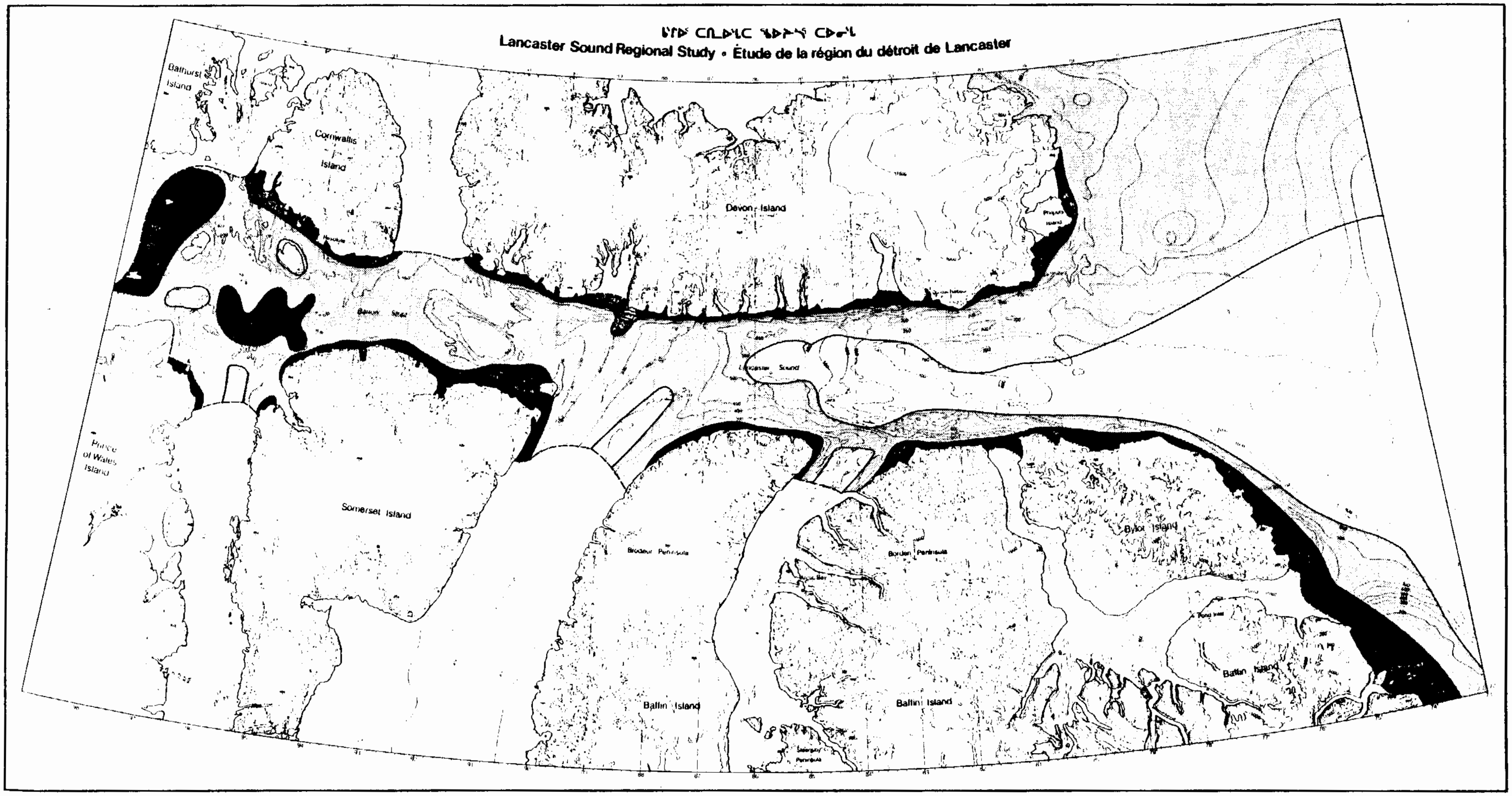

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Fig. 9. Distribution of surficial sediments. From the Lancaster Sound Region: Data Atlas.

deposited during a period of maximum transgression. Sequences 11 and 12 suggest regressive conditions with eastward progradation of sediment wedges that comprise most of the Baffin basin fill.

Unconsolidated sediments in the Lancaster Sound Basin are believed to be derived from erosion of poorly consolidated bedrock, glacial deposition and post-glacial marine sedimentation. Nearshore areas received recent sediment from localized alluvial and glacio marine processes, as well as ice rafting and reworking by waves and currents.

The accumulation of unconsolidated basin fill during the Cenozoic has been outlined by Pelletier (1980). The underlying sedimentary bedrock surface was shaped by Tertiary fluvial erosion and by Pleistocene glacial erosion. The distribution and character of surficial sediments in the present-day marine areas of eastern Lancaster Sound and the adjacent inter-island channels has been controlled by the above events, by changes in relative sea level, and by glacio-marine and marine depositional processes. The following general outline of the surficial sediments, where not specifically referenced otherwise, has drawn upon a summary provided by MacLean (1987).

The steep sided channels of the marine area of interest may locally expose sedimentary bedrock. Sediment eroded from poorly consolidated Tertiary conglomerates and sandstones may have been reworked by Quaternary fluvial, glacial and marine processes. There is also evidence of input of material derived from Precambrian rock in sediments obtained from northern Prince Regent Inlet and eastern Barrow Strait (MacLean et al, in preparation), and in Lancaster Sound (Buckley, 1971). Deposits of clean, uniform Tertiary silica sand are relatively extensive on southern Bylot Island (Klassen, personal communication) and sands in adjacent Eclipse Sound (McLaren et al., 1981) are generally similar in gradation.

The glacial history of the Bylot area suggests that only limited, and primarily older, glacial debris eroded from Bylot Island during the Wisconsinan is present in the adjacent marine channels. Most of the glacially derived Wisconsinan sediment in the inter-island channels has originated from adjacent Shield and the Arctic Islands areas to the south and west.

Marine sedimentation has continued in Lancaster Sound since the retreat of the glaciers and the relative rise of sea level. Fine grained sediments, derived from the adjacent channels and islands, were deposited along

Lancaster Sound. These deposits exceed 30 m east of Barrow Strait and reach a thickness of more than 200 m near Baffin Bay (Pelletier, 1980). Modern sources of sediment to the basin fill of Lancaster Sound and adjacent channels include outwash and modern glacio-marine deposits from active glaciers on Devon, Bylot and Baffin Islands, alluvium from the numerous streams and rivers in the area, erosion of coastal bluffs and beaches by marine processes, plucking of talus from rock cliffs by drifting ice, and ice-rafting of debris by icebergs and pack ice. Buckley (1971) determined, on the basis of heavy mineral concentration, that much of the most recent surficial sediment is derived from local streams and active glaciers in the eroded valleys on the surrounding islands, and that ice-rafting and marine currents are the main agents of present-day marine sediment dispersal.

Most of the beaches of the marine area of interest contain coarse surficial sediment (sand, gravel, cobbles and boulders) and vary in shape from small narrow pocket beaches at the base of coastal rock cliffs, to continuous, complex barrier beach systems (Sempels, 1982). Although there are few direct field measurements, similar coarse sediments may extend to the narrow nearshore zone along most of the coastline, (Indian and Northern Affairs Canada, 1982). Farther from shore, the surficial deposits are composed of sands, silts and clays. Marine silts and clays predominate in deeper basins. The general trend in the distribution of seabed sediments from coarse sediments along the coast to marine clays in the basins is shown in Figure 9.

The stratigraphy of surficial sediments in the Lancaster Sound marine area is poorly documented due to a general lack of field observations and high resolution shallow seismic reflection data. Stratigraphic sequences are known for only a few isolated locations and these data are inadequate to develop a regional stratigraphic model which is needed to quantify surficial resource potential. The following general interpretation was prepared by MacLean (1987), based mainly on widely separated seismic reflection (airgun) and 12 kHz profiler records, limited sample data, and comparison of probable conditions with other marine areas. More data are available in the western part of Lancaster Sound, notably west of Navy Board Inlet and north of Admiralty Inlet to Croker Bay, where data from a grid of samples are available (Buckley, 1971). More detailed data from recent surveys further to the west, (MacLean et al. in preparation) were used also in the interpretation.

Glacial drift deposits variably overlie the bedrock, representing deposition beneath grounded glacial ice. Elsewhere in the channels of the Arctic Islands, the glacial drift is typically a massive cohesive mixture of clay, silt, sand and gravel. This is the most widespread of the surficial units. Its thickness ranges from less than 10 m in the eastern part of the Sound to about 115 m north of Brodeur Peninsula and up to 200 m locally in Eclipse Sound (MacLean, 1987). East of Bylot Island, a series of moraine-like ridges, which trend southeast from the mouth of Lancaster Sound, contain up to 15 m of sediment interpreted from acoustic profiles to be glacial drift (Praeg, 1987). In Pond Inlet, glacial drift is interpreted from acoustic data to be generally in the order of 10 m, and locally, 20 m thick.

The drift is overlain by glaciomarine sediments typically composed of stratified silt and clay and variable amounts of sand and gravel. These deposits are generally only a few metres thick, and overlie the drift at least locally in the central part of the area, as determined from a high-resolution seismic reflection profile located north of Bylot Island (MacLean, 1987). East of Bylot Island, this unit may be up to 10 m thick (Praeg, 1987). The lack of adequate high resolution data for most of the area prevents delineation of these units. Up to 9 m of post-glacial marine sediments are detected from 12 kHz echo sounder profiles along much of the deep central part of Lancaster Sound. This unit is about 3 m thick in deeper waters east of Bylot Island. These deposits variably overlie the glacial drift and glaciomarine deposits, but are either absent, or thinner than the limits of resolution of the acoustic systems in many areas, where "hard bottom" reflectors on the echosounder profiles are thought to indicate seabed sediments composed mainly of glacial drift with little or no younger sediment cover.

Post-glacial marine sediments in an Arctic marine environment include the typical fine-grained (silt and clay sized) particles dispersed by currents, as well as variable amounts of a wide range of particle sizes which are dispersed through ice-rafting. East of Bylot Island, the post-glacial sediments consist of muddy sand to sandy mud with gravel. Buckley (1971) reported that although ice-rafting is capable of distributing fine or coarse sediment throughout the marine area, the distribution of ice-rafted sediments is concentrated along the shore where the accumulation and melting of drifting shore ice is prevalent. Modern outwash has provided abundant post-glacial coarse sediment to the coastal and nearshore areas and the active glaciers continue to supply alluvium to the marine environment.

Table 3: Rating criteria used in hydrocarbon and mineral assessment (from Jackson & Sangster, 1987)

Rating Scale	Rating	Criteria
1	Very High	Geological environment very favourable. Significant deposits present. Additional undiscovered deposits very likely.
2	High	Geological environment very favourable. Mineral or hydrocarbon occurrences present but no significant deposits known.
3	High-Moderate	
4	Moderate	Geological environment favourable. Mineral or hydrocarbon occurrences may not be present.
5	Low-Moderate	
6	Low	Aspects of the geological environment may be favourable, but limited in scope. Few, if and, mineral or hydrocarbon occurrences known. Undiscovered deposits unlikely.
7	Very Low	Gelological environment unfavourable. No mineral or hydrocarbon occurrences known. Undiscovered deposits very unlikely.

MINERAL AND HYDROCARBON POTENTIAL

Methods of Assessment

The objective of this study was to identify areas that have mineral and hydrocarbon resource potential, based on an evaluation of the presently known geological information. The evaluation was carried out without consideration of the present or future economic viability of any such predicted deposits, although in the case of construction materials, where the primary use will be local, some comment was made on relationship to development projects. This evaluation process places the study area's overall potential in the national context, and highlights areas of greater and lesser potential within the study area. As has already been noted, rather than dividing the area into domains as was done by Jackson and Sangster (1987), geological variations within the study area as a whole have been looked at in an attempt to highlight areas of higher potential.

Assessment Rating Categories

Each portion of the study area was rated for its potential to contain deposits of hydrocarbons or minerals. The possible rating categories range from very high to very low depending on the number and kinds of geological, geophysical and geochemical data present (Table 3). A map outlining the areas of various hydrocarbon potential was constructed (Fig. 10). Mineral and coal potential in the bedrock has been discussed by Jackson and Sangster (1987) for the on land portion and although these trends could be extended offshore for a certain distance no attempt has been made to do so and a rating of 6 has been assigned. Some mineral and coal potential may also exist in the Mesozoic sediments but again the offshore is considered as having a low potential and is rated as 6.

Hydrocarbon Potential

In order for an accumulation of hydrocarbons to occur, five criteria must be present. They are; presence of source, trap, reservoir, seal, and correct timing of migration versus structuring. The potential and likelihood of each of these criteria being present within the study area are discussed below based on the regional geology.

AGE/FM	T.O.C.	ORGANIC TYPE	MATURITY
Paleozoic Turner Cliffs	poor	exinous (gas)	TAI 2^{+} - 3 (mature)
L. Cret. Bjarni	v. good	exinous (gas)	V.R. .48 (marginal mature)
U. Cret. Kanguk	2.2% (good)	20-50% amorphous (oil)	V.R. .45 (immature)
Tert. (Maude Bight Section)	1.8% (good)	40-50% amorphous (oil)	low ro. (immature)
Tert. (Eclipse Sound Section)	up to 2.2% (good)	60% exinous (gas)	V.R. .49 (marginal mature)

from McWhae 1980 (246-1-12-100)

Table 4: Geochemical results from outcrop samples on Baffin and Bylot Islands

Source of Hydrocarbons

There are good indications that source beds of sufficient organic richness and thermal maturity exist within the Basin. Direct hydrocarbon indicators support the presence of hydrocarbons within the sedimentary section.

Hydrocarbon source beds in Paleozoic strata are not apparent although Thorsteinsson and Mayr (1987) state that rocks correlative with the Allen Bay Formation are fetid and exhibit bituminous residues. Laterally the Allen Bay Formation grades into graptolitic shales and limestones of the Cape Phillips Formation which may be a source rock, particularly in the western part of the study area. Conodont Colour Indices (CAI) on Devon Island (Thorsteinsson and Mayr, 1987) range in most part from 1 to 1.5, somewhat below the level of 2 which Mayr (1978) concluded was the boundary between mature and overmature organic matter. With the deeper burial in the Lancaster Basin, organic rich Paleozoic rocks may generate liquid hydrocarbons.

Within the Mesozoic-Tertiary section, seismic stratigraphy has interpreted at least two transgressive coastal marine deposits and also a possible lacustrine sequence which may contain potential source beds. The occurence of an oil seep off of Scott Inlet on the Baffin Island shelf has been documented by the Geological Survey of Canada (MacLean et al, 1981, Grant et al, 1988). The oil would seem to be coming from rocks at Upper Cretaceous or Tertiary age along or near the contact with a Precambrian outlier and that these sedimentary rocks could be reasonably thick and mature. Organic-rich Campanian-age mudstones have also been sampled from Home Bay south of the area of interest (MacLean and Williams, 1983). Depth of burial should have been sufficient to put these into the oil window, particularly if Daae's (1983) assessment that up to 1 500 m of sediment has been eroded off in Pleistocene time is correct. Geochemical analysis carried out by Petro-Canada (McWhae, 1979) indicate that outcropping of several of the Cretaceous-Tertiary shales contain sufficient organic content to be considered as source rocks (Table 4). Vitrinite reflectance measurements would indicate these samples to be immature to marginally mature but given the increased depth of burial within the basins proper, these shales may be capable of generating liquid hydrocarbons. It should be noted that a direct hydrocarbon indicator (flat spot) has been identified on a seismic profile over one of the anomalies. Through seismic velocity analysis, this has been interpreted as indicating a hydrocarbon-water interface, although there are other explanations (eg. facies change) for this phenomenon.

Trapping Mechanisms

More than 30 structural traps have been identified from the seismic grid and the 5 largest of these are each capable of containing 1.5 billion m^3 of oil in place. The most obvious type of structures are upthrown and tilted fault blocks which developed during initial phase of basin rifting. Structural drape of Tertiary sediments has occurred over some of the fault blocks. Some anticlinal structures may have also developed due to transcurrent movement along faults. This is particularly obvious northeast of Philpots ridge (Fig. 7). Thorsteinsson and Mayr (1987) also believe that leaching and isostatic adjustment of halite in the Paleozoic may have deformed prospective Paleozoic reservoirs.

Although structural traps are the most easily identified and usually the first targets to be tested in the exploration of a basin, the potential for large stratigraphic traps is also very good. The seismic stratigraphic analysis undertaken by Harper and Woodcock (1980) over the Dundas structure indicates abundant onlapping, subunconformity truncation and depositional edges, all of which have potential to form large stratigraphic traps. The regional unconformities that are seen in outcrop and on seismic sections allow abundant opportunities for subunconformity traps in other parts of the basins. Facies changes are also indicated on the seismic stratigraphic analysis, and represent further potential stratigraphic traps. In the Paleozoic section biostromal and biohermal development in the Allen Bay and Douro formations (see Thorsteinsson and Mayr, 1987) may provide stratigraphic traps. Subunconformity traps within the Paleozoic also may exist.

Potential Reservoirs

Abundant thicknesses of permeable and porous sandstone capable of containing hydrocarbons, should be present at depth in the Lancaster, and western portion of the Baffin Bay basins.

Based on regional bedrock mapping, the Mesozoic strata (containing the primary reservoir targets) should lie unconformably on Archean basement (or oceanic crust) in the east, and on late Proterozoic clastics or Paleozoic carbonates in the west. The following assessment of potential reservoirs is based on geological investigations by the GSC and Petro-Canada and on a seismic stratigraphic interpretation by Harper and Woodcock (1980).

1. Proterozoic Clastics: Proterozoic quartz arenites up to 1500 m thick are present in outcrop on Baffin and Bylot Islands, preserved mainly in long standing grabens. Although this assemblage displays good porosity in outcrop, its potential offshore would be low due to its extreme depth of burial where compaction and diagenesis may significantly reduce porosity. Although it has been shown that diagenesis may in fact increase porosity through secondary porosity development, this could only be determined, by actually drilling into this section.

2. Paleozoic Clastics: The majority of the Paleozoic section is carbonate but locally spectacular developments of mature quartz arenites in the Gallery and Cass Fiord Formations have been seen in outcrop. One section in the Gallery formation, described by McWhae, (1979) was greater than 200 m thick with 125 m having greater than 9% porosity. Laboratory measurements by Petro-Canada (McWhae 1979) on outcrop samples have yielded porosities as high as 28% and permeability as high as 353 md. Evidence of quartz overgrowths would indicate porosity will be reduced at depth, and the offshore reservoir potential of these Paleozoic clastics must be viewed as low.

3. Paleozoic Carbonates: An assessment of the Paleozoic carbonates outcropping south of Lancaster Sound would indicate that they constitute a bonafide secondary objective in the western part of the study area. A majority of the carbonates are shallow water varieties and have been deposited in an oxygenated high energy environment. Regional mapping by both the GSC and Petro-Canada show that the Ordovician carbonates contain patches of vuggy porosity. The Silurian Cape Crauford formation has extensive intercrystalline and solution collapse breccia porosity with one section displaying 85 m of greater than 6% porosity (McWhae, 1979). The Allen Bay limestones exhibit some vuggy porosity generally developed about 1000 m above the basal unconformity. The middle Devonian Blue Fiord limestone may contain adequate vuggy porosity where it is truncated by the Labrador unconformity such as at the Dundas structure.

These observations are supported somewhat by Thorsteinsson and Mayr (1987) who recognized some potential Paleozoic reservoirs on Devon Island north of the Lancaster Sound, particularly in the Allen Bay Formation where solution breccias and intergranular porosity are present in the bioherms and biostromes. The maintenance of this porosity at depth is, however, questionable. Even though porosity may be enhanced or reduced by diagenesis, it should be noted, that wells to the west that have penetrated the equivalent Paleozoic sections have encountered very little porosity.

4. Lower Cretaceous Hassel Equivalent: this potential reservoir occurs in outcrop as a poorly sorted immature sand probably derived from the nearby shield. In some measured sections it displays up to 28% porosity, and 418 md permeability (McWhae, 1979). The comparable subsurface section as interpreted by Harper and Woodcock (1980) is that it is mainly non-marine sands overlain by shallow marine sands and shales. It is this type and age of reservoir that contains the gas in the Bjarni and North Bjarni discoveries in offshore Labrador, and in the Parsons field in the Mackenzie Delta, and this section represents excellent potential to contain reservoir quality rock.

5. Late Cretaceous Kanguk Equivalent: As seen in outcrop, this is an alternating sand shale sequence deposited mainly in a shallow marine environment with some fluvio-deltaic and lacustrine deposition. The basal portion of this sequence as seen in outcrop has excellent porosity, up to 28% and fair permeability (7.3 md). Seismic stratigraphic interpretation tends to support these conclusions, indicating a sequence of mainly interbedded shallow marine shales and sands.

6. Tertiary Eureka Sound Equivalent: This sequence is mainly interbedded sands and shales with the shales becoming quite thick and dominant. In outcrop, the typical sand lithology is a friable feldspathic arenite. An outcrop of this formation found on Maude Bight adjacent to Lancaster Sound, displays excellent porosity (21-22%) and good permeability (72 md average) according to McWhae (1979).

   In Lancaster Sound, the comparable sequence is interpreted to be non marine sands at the base with the remainder being interbedded marine sands and shales.

Potential Seal

The presence of an impervious layer of rock to act as a seal to vertical migration of hydrocarbons cannot be demonstrated until a well has been drilled, but some generalizations can be made from the Mesozoic outcrop in the surrounding islands, and from seismic stratigraphy.

A top seal for many of the potential Mesozoic reservoirs may be a problem, as both outcrop and seismic analysis indicate the Cretaceous section to be fairly sandy. Shale, which is a good seal, should increase easterly toward Baffin Bay; but there may not be a sufficient top seal until Tertiary age sediments which may be relatively unstructured, or would require late migration even if there is some structural development. Lateral seal across faults also becomes less likely in the Cretaceous section as the higher percentage of sand increases the chance of sand to sand juxtaposition. In addition, Daae (1983) has demonstrated that these faults have undergone several periods of movement and possibly act as conduits to the surface, along which hydrocarbons could escape. Seismic interpretation also indicates that many of the structures have undergone significant erosion at the crests, increasing the risk that the reservoirs may be breached.

Timing

If hydrocarbons were generated from source rocks of Paleozoic age, a majority of the structures seen on seismic interpretation, which appear to have developed in the Mesozoic, may have occured too late to trap these hydrocarbons. The Mesozoic section, however, has the highest potential for containing source beds. If hydrocarbons were generated from this section, it is likely that the primary structures would already be in place, allowing for entrapment of these hydrocarbons, since the generation would probably not occur until a sufficient sedimentary section had been deposited on top of the potential source beds.

The structuring involving Mesozoic sediments appears to have been initiated early on, providing a positive receptacle into which hydrocarbons may have migrated. If there is no seal until Tertiary however, sediment draping caused by compaction over these structures may not have occurred at time of migration. In addition, the timing of the primary structuring with the major unconformities highlights potential for breaching of hydrocarbon pools but also highlights potential for localized sediment source and reservoir enhancement through winnowing.

Summary of Hydrocarbon Potential

All the criteria necessary for hydrocarbon entrapment are likely to occur in the study area. The sand-prone sedimentary section is thick, and indicated to be porous and permeable, and some very large structures have been identified. Despite the potential risks on trap, seals, and source rocks, we consider part of the study area to have high potential to contain significant hydrocarbon assumulations. Until one or more wells are drilled within the basin, it will be very difficult to quantitatively estimate the basin's potential.

While the study area is generally rated as having considerable potential to yield hydrocarbons, there are some portions rated higher that others. The areas noted 2 on the map (Fig. 10) have concentrations of structures, and should have all the criteria needed to contain hydrocarbons. A lower rating (3) has been given areas where structures have not been seen, and even lower ratings (4)(5)(6), have been given areas where a mainly shale section is hypothesized (to the east) or where the Mesozoic section becomes quite thin (to the west). A rating of 7 was given to areas where thin sedimentary section is anticipated or where igneous rocks outcrop.

Analogous World Wide Basins

Basins of a size and type similar to Lancaster and Baffin elsewhere in the world have been shown to be contain large accumulations of both oil and gas. Daae (1983) compared the Lancaster Sound Basin to the prolific hydrocarbon-bearing Anadarko Basin in the southwestern United States. Although the Anadarko Basin fill is mainly Paleozoic in age, the basin type and size is very similar. Another example may be the Viking graben in the North Sea. Abundant gas has been discovered in Tertiary sands in fields such as Frigg and Odin and oil occurs in Jurassic sands in such fields as Brent, Statfjord, and Ninian. Again the size and type of basin are similar to the Lancaster basin.

Surficial Resource Potential

Surficial resources include consolidated (bedrock) deposits and unconsolidated (granular) deposits that could be exploited in the foreseeable future. The latter can be sub-divided into construction materials, industrial minerals and placer minerals. Based on the available geoscience information, this report deals primarily with granular resources which would likely be recovered by dredging. The assessment of the offshore surficial resources potential therefore requires consideration of regional bathymetry, seabed topographic features, surficial sediment data, concentrating processes, ice conditions and potential uses. Each of these topics is discussed below.

Regional Bathymetry

Water depths in eastern Lancaster Sound are generally in the range of 600 m to 800 m, but reach more than 1000 m off northeast Bylot Island. Typically, they exceed 500 m within about 4 km of the northern coasts of Bylot Island and Borden Peninsula and southeast of Devon Island. Dredge technology currently restricts the feasibility of large scale resource development to well within the 100 m isobath. These depths are present only within a very narrow (generally 1 km to 2 km) nearshore zone, which widens to as much as 15 km along the east coast of Bylot Island. Depths of 600 m to 800 m are also prevalent in Pond Inlet and Eclipse Sound, and locally they exceed 900 m. Depths in Navy Board Inlet range from 100 m to 200 m in the south and 300 m to 400 m farther north. Deep water extends very close to the shore in these channels also.

At best, only those areas within about 100 m water depth could be considered as prospective due to the practical extraction depth limitations of existing dredging plants. Additionally, the existing bathymetry is insufficiently detailed for most of the area to identify and delineate bathymetric anomalies or seabed features which potentially may contain aggregate deposits. Borrow pit development would be further complicated by the narrow width of this zone which would prevent establishment of a suitable dredging pattern in many areas.

Seabed Topographic Features

Physiographic sill features are found at the mouths of a number of fiords and inlets leading into Lancaster and Eclipse Sounds. Most significant is the sill at the mouth of Navy Board Inlet where water depths of as little as 24 m are present near the centre of the sill. A less pronounced sill is also detected at the mouth of Pond Inlet. These features are thought to be terminal moraines associated with former valley glaciers, which in some cases, overhang the sounds (Pelletier, 1980). These bathymetric anomalies are likely to have experienced relatively greater re-working and sorting of the sediment by seabed currents and by waves during periods of emergence and submergence associated with fluctuations in relative sea level.

Submerged drainage courses, such as the submarine troughs extending from major fiords and dissecting the continental shelf along the east coast of Baffin Island, southeast of the study area (MacLean, 1985), are typically of interest with regard to the location of potential placer deposits. Although the available bathymetry is not detailed, there do not appear to be significant submarine drainage courses within the study area.

Production dredging for aggregate resources generally requires a relatively even seabed. Much of the coastal zone of Lancaster Sound consists of eroded bedrock cliffs and ice-filled valleys (Harper et al, 1986). The seaward extension of the rugged topography of these areas is likely to further limit the suitability of the nearshore zone. The likelihood of bouldery material within these areas and in areas underlain by glacial drift further reduces aggregate prospectivity. Limited experience, from the area off the southwest coast of Banks Island, in the dredging of material derived from the re-working of tills indicates that boulder-sized material can block and potentially damage the draghead of suction dredges. Similarly, ice-rafted boulders may also contaminate sand and gravel deposits.

Surficial Sediment Data

The surficial resource potential of the Lancaster Sound area can be discussed only in a qualitive manner due to paucity of adequately detailed geophysical data and of seabed and subbottom sampling. Although composite trackplots of geophysical surveys for the marine area of interest (O'Connor, 1984) suggest considerable activity in the area, these surveys generally do not include the shallow, high-resolution subbottom profiling needed to determine the seismo-stratigraphy of surficial deposits.

Seabed sampling consists primarily of surface grab samples which are of limited value in preparation of a granular resource assessment. Potential resources may be undetected in the presence of a thin layer of recent fine-grained overburden, or may be considered unsuitable due to a matrix of muddy sediment at the seabed. Alternatively, sand and gravel recovered by seabed sampling may represent only a thin lag of coarse-grained sediment derived from underlying glacial drift. A few cores have been recovered with gravity soil samplers, mainly in deeper waters, where fine-grained sediments are present. These samplers are generally unable to penetrate, or retain samples of, the coarser sediments in the nearshore zone.

A first approximation of the offshore granular resource potential may be obtained from the general distribution of seabed sediments shown in Figure 9. Sand and gravel deposits are known to exist in the nearshore zone throughout the study area, but their gradational and mineralogical characteristics are not well documented. No detailed assessments of offshore construction materials, or industrial and placer minerals have been completed.

Concentrating Processes

Recent wave and current action and ice-rafting can result in the concentration of potential surficial resources.

In the deeper waters of Lancaster Sound and the adjacent channels, marine deposition and ice-rafting are the predominant modern processes, but there is evidence of slumping and turbidity flows originating from steep fiord walls (Harper et al, 1986). Nearshore regions are influenced by waves, currents and ice-scouring. The predominance of clean, coarse sediments off southeastern Devon Island, and elsewhere in the nearshore zone is indicative of winnowing out of fines by wave and current action. East of Bylot Island, samples collected in less than 250 m of water contained a thin (less than 100 mm) gravelly lag deposit (Praeg, 1987). Evidence of current scouring of glacial deposits in as much as 350 m of water is given by Lewis et al (1977).

Parts of the seabed have been subjected to modification through the scouring by keels of drifting ice which cut several (2-10) metres into the seabed. As in other parts of the Arctic Island channels, ice scours observed in deep water appear to be confined to the glacial drift and were probably formed by large bergs calved at the glacial front (MacLean, 1987). Lewis et al (1977) show an extensive pattern of ice scour tracks in about 140 m of water. In sands and gravels, the scouring process involves a ploughing action, which generally results in clearly defined scour tracks in the seabed sediments.

Ice Conditions

In arctic waters, long periods of ice cover limit the development potential of offshore surficial resources. Between October and late May, the Lancaster Sound area is essentially ice-covered (Harper et al, 1986). Open water appears first on the northern side of the sound, generally by mid-June, but drifting ice remains against the southern shore until mid-July, and does not clear from the adjacent channels until August. The dredges used in the Beaufort Sea are restricted to periods of open water, which typically does not exceed four months in Lancaster Sound. An additional challenge is presented by icebergs, which are common within Lancaster Sound, and also occasionally enter Pond Inlet and Navy Board Inlet.

Potential Uses

The assessment of aggregate resource potential requires consideration of their potential uses. Any major resource development in the Lancaster Sound region is likely to require large volumes of sand and gravel for use in construction of shore-base facilities. For example, the Dundas Harbour - Croker Bay area on southern Devon Island has been suggested (Indian and Northern Affairs Canada, 1982) as a possible support base for oil and gas development. Development of any mineral deposits which might be found in the areas of favourable geology on southwestern Bylot Island and southwest of Pond Inlet (op cit), or south of Milne Inlet (Harper et al, 1986), on Baffin Island, would also require new shore-base facilities.

Demands for offshore aggregates for use in these facilities would be largely dependant on the local availability of suitable onshore resources and the feasibility of dredging from adjacent offshore areas. The construction of loading weirs or breakwaters which extended a significant distance offshore may require localized dredging of nearshore granular resources.

The only large-scale exploitation of offshore surficial resources in the Canadian arctic has been that associated with the construction of hydraulic fill artificial islands and bottom-founded, caisson-retained hydrocarbon exploration structures in the Beaufort Sea. Significantly greater water depths in prospective hydrocarbon zones in the marine area of interest may preclude similar resource utilization in Lancaster Sound and the adjacent channels.

Potential Surficial Resources

1. Bedrock Deposits: No attempt has been made to delineate areas of non-hydrocarbon mineral potential for bedrock in the offshore portions of this area. The Cretaceous and Tertiary rocks do have some potential to contain non-hydrocarbon mineral deposits such as coal, at

levels similar to Domain 2 on Bylot Island (Jackson and Sangster, 1987), but neither data availability nor operating conditions (water depth, ice, etc.) make it practical to attempt further assessment.

Likewise, the prospectivity of the domains as outlined by Jackson and Sangster (1987) for the onshore portion should theoretically continue into the offshore underneath the Cretaceous and younger basin fill. However, it is not realistic to maintain these ratings into the offshore except in the immediate offshore zone. An exception to this would be if a defined ore body projected from shore into the offshore. This has not been observed on Bylot Island or Brodeur Peninsula (Jackson and Sangster, 1987) or on Devon Island (Thorsteinsson and Mayr, 1987) and for this reason, we have chosen to assign a rating of 6 to this category for all of the offshore.

2. Construction Materials: These are deposits whose engineering properties make them suitable for use in construction (e.g. earth fills). The potential utilization of seabed deposits as construction materials depends primarily on an abundance of coarse-grained particles (sand and gravel), preferably, in equal portions (well-graded) to increase their structural stability, and a limited fines (silt and clay) content to permit their rapid drainage during placement. However, these deposits have essentially no value unless there is local demand for their utilization.

   The presence of coarse granular sediments in virtually all beaches bordering the marine area of interest, and the widespread distribution of similar sediments in the nearshore zone give the appearance of an abundance of aggregate resources along the coasts of the Lancaster Sound marine area. Summaries of particle-size distribution analyses, presented in McLaren et al (1981) indicate that the surficial deposits consist of sands and gravels in varying proportions, with negligible fine-grained material. Beach deposits of sand and gravel with potential commercial value as construction materials have been identified along several portions of the coastline (Indian and Northern Affairs Canada, 1982). However, MacLean (personal communication) reports that most gravel beaches are underlain by bedrock or till at shallow depths, or consist of a mixture of gravel and fines.

Pelletier (1980) noted that seabed sampling was, at that time, insufficient to delineate seabed aggregate resources, and no specific assessments of the offshore aggregate potential have since been completed. The sediment descriptions and summaries of particle-size distribution analyses of limited seabed sampling in the nearshore zone (Buckley, 1971; McLaren et al, 1981; Sivitsky, 1984 and Sivitsky and Praeg, 1987) show that although clean sands and gravels are predominant in much of the nearshore zone, their distribution may be somewhat erratic. Sampling in the nearshore zones adjacent to Phoenix Head Glacier on southern Devon Island, and at the mouth of Oliver Sound on northeastern Baffin Island, for instance, revealed predominantly finer grained sediments with random samples of sand and gravel.

It is unlikely that exploitable quantities of construction materials are present in deeper waters, especially in the glacio-marine and post-glacial sediments. Fine-grained sediments are predominant in these areas.

3. Industrial Minerals: These include deposits, defined on the basis of their mineralogical content (type and purity) from which all, or almost all of the dredged sediment is utilized. Typical industrial minerals include silica sands or carbonate sands that could be used in the manufacture of glass or cement, respectively.

   Mineralogical analyses of seabed samples, needed to assess the potential for industrial materials, are essentially non-existent. The silica sands present within the poorly consolidated Tertiary sediments on Bylot Island could also conceivably constitute the uniform sands detected in Eclipse Sound. There is no indication of any significant deposits of carbonate sands or other industrial mineral deposits. Potential development of any significant seabed deposits of industrial products, such as high-purity silica sands, will be hindered by economic factors associated with the extraction and delivery of these relatively low value minerals to their generally distant markets.

4. Placer Deposits: These deposits typically contain rich concentrations of minerals such as gold, platinum, diamonds, cassiterite, magnetite and other heavy minerals that have been released from bedrock by chemical and mechanical weathering and concentrated by fluvial, coastal and marine processes. Dredging operations for placer minerals retain only the heavy mineral fractions of the deposit.

As for construction materials and industrial minerals, the assessment of placer mineral potential is hampered by the general lack of data on regional bathymetry, seabed topography, distribution and properties of the surficial sediments, including mineralogical analyses, and potential concentrating processes. The presence of potential source rock onland and close to shore and the effects of glaciation are also important considerations with respect to placer deposits (Hale and McLaren, 1984).

Aside from coal and gypsum, the only reported mineral occurrences on Bylot Island are minor malachite staining, thin beds of siderite, and veinlets and minor disseminated magnetite (Jackson and Sangster 1987), and the glacial history (Klassen, 1985) suggests very low potential for their near surface occurrence in the offshore. However, since the Precambrian uplands are a major source for the glacially-derived Wisconsinan sediment in the inter-island channels areas, the possibility exists for a full suite of minerals associated with igneous and metamorphic rocks. Potentially valuable sediments, which may be derived also from nearby Borden and Brodeur Peninsulas or northeastern Baffin Island, include a variety of heavy minerals including magnetite, ilmenite, sphalerite, galena, silver and others (Jackson and Sangster, 1987; Sempels, 1982). Jackson and Sangster (1987) report the occurrence of a single pebble of cassiterite of unknown origin, but are unaware of any concentration of economic minerals in the onland unconsolidated deposits.

It is speculated that placer gold may be present offshore of Baillarge Bay, northeast of Strathcona Sound (Hale and McLaren, 1984), based primarily on geologic conditions on Borden Peninsula. Garnets, derived from Precambrian gneisses are found in relatively high proportions along portions of the beaches of Bylot Island (Klassen, personal communication) and along the northwestern coastal area (Buckley, 1971). Titanium dioxide concentrations of 12.2% in Bylot Island barrier deposits have been reported (Emery-Moore, 1985; Syvitski, 1984; Syvitski and Praeg, 1987). To date, no specific placer mineral occurrences have been identified in the study area, but it must be emphasized that exploration specifically for this type of deposit has been negligible.

Summary of Surficial Resource Potential

Given the lack of suitable data for evaluation of regional seabed geology and surficial sediments, it is not possible to identify any specific areas of potential surficial resource deposits. While the inferred geological conditions suggest that localized areas of prospective occurrences are possible, a surficial geological framework for the area is needed to determine an overall resource potential, and more detailed site specific assessments are needed to verify the basic assumptions used.

It is possible that seabed construction materials could be developed in localized areas adjacent to possible shore-base facilities associated with any future hydrocarbon or mineral resource development. Potential sources of heavy minerals exist onland and glaciation may have liberated and transported them to the offshore, where, under certain conditions, they may have been concentrated into placer deposits. The potential for bedrock deposits and industrial minerals is even less certain since it is presently based only on the extrapolation of onland geologic conditions to the offshore.

Additional regional and site specific geological studies are required if the resource potential is to be expressed in terms of quality and quantity. Data needed includes high-resolution geophysics, seabed sampling, and textural and mineralogical analyses.

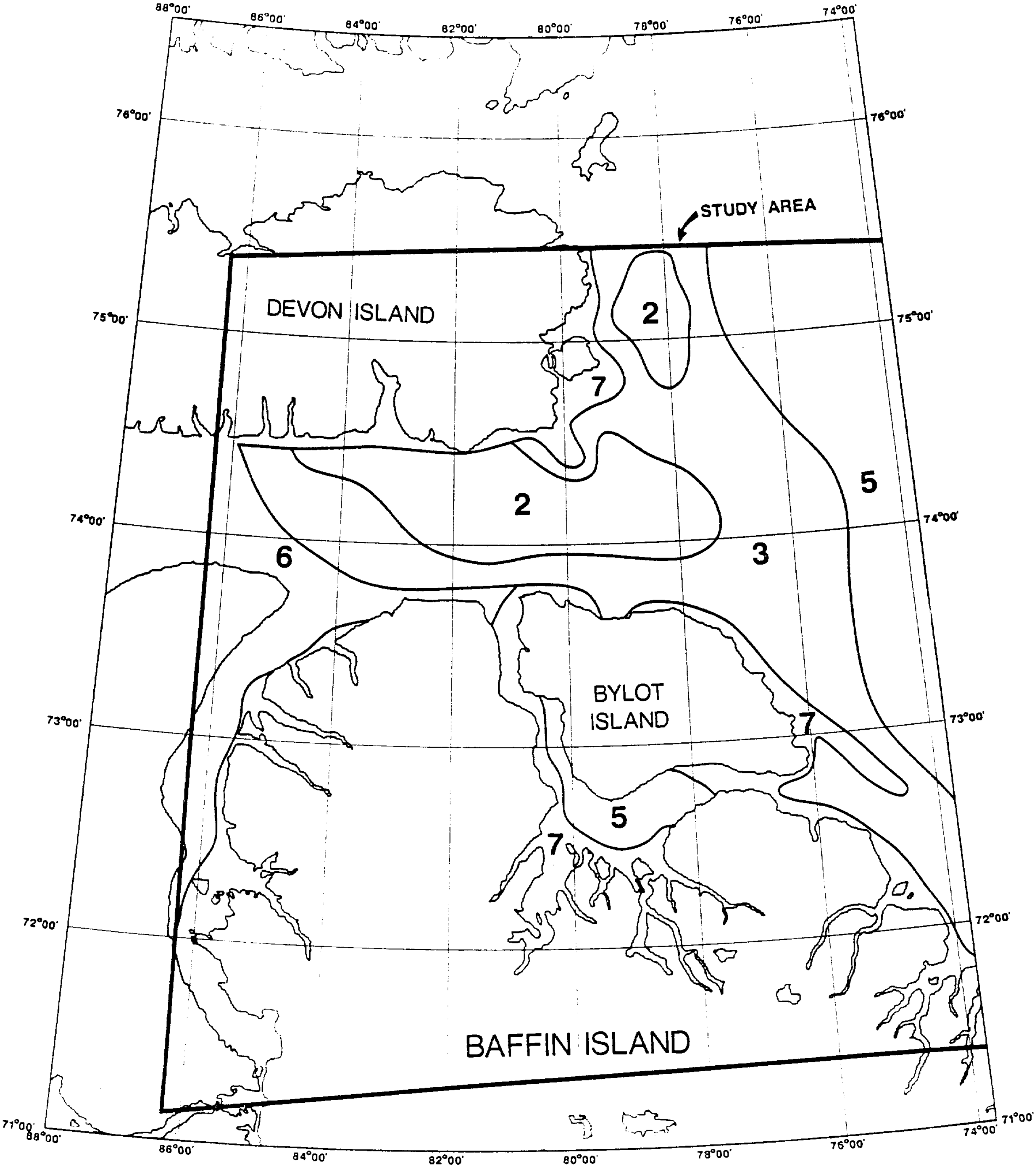

Fig. 10. Overall resource potential map. See Table 3 for rating criteria, ranging from very high (1) to very low (7).

CONCLUSIONS

1. From a non-renewable resource exploration point of view this region represents one of the last unknown frontiers in Canada.

2. This area may be comparable to the Jeanne d'Arc Basin or Beaufort Sea in terms of hydrocarbon potential, but the inherent difficulty in estimating this potential due to lack of information introduces a large amount of uncertainty in this assessment. Estimates of hydrocarbon occurrence are speculative and based on limited geological knowledge over a large area. Nevertheless it is believed that potential hydrocarbon resources are present in a portion of the study area, perhaps in sufficient quantities to impact on Canada's Energy Inventory.

3. The nature of the geology and the interpretation of the geophysical data indicates that parts of the study area have thick sequences of sediments capable of both generating hydrocarbons, and pooling them in accumulations of very large size.

4. There is some variation in prospectivity within the study area, with the higher potential for oil and gas being in the eastern middle portion of Lancaster Sound and the western portion of Baffin Bay (see Fig. 10.)

5. There appears to be potential for construction aggregates along most of the coast although no area has been documented as having specific deposits. There are insufficient data to document potential in surficial sediments away from the shoreline.

RECOMMENDATIONS FOR FURTHER WORK

1. Several questions need to be answered before firm conclusions can be reached about hydrocarbon potential, and most of these can only be answered by the drilling of a well (wells) at an estimated cost in excess of $50 million. This is not a feasible option for further work by the Federal Government.

2. The regional seismic grid is adequate and several structures have been defined to the point of drilling. Further seismic aquisition would not noticably enhance our assessment capabilities, although seismic stratigraphic analysis of the existing data base may be useful, particularly in the eastern portion of the study area.

3. There is potential for specific projects to be undertaken by Universities or the Geological Survey of Canada that would help supplement information on the unconsolidated surficial mineral occurrences. These options should be investigated, in order to improve knowledge about the study area, although the information may not be essential for refining the Government's position on the marine park proposal.

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