PROCEEDINGS OF THE BEAUFORT SEA GRANULAR RESOURCES WORKSHOP

FEBRUARY 13 AND 14, 1992

SPONSORED BY:

INDIAN AND NORTHERN AFFAIRS CANADA NATURAL RESOURCES AND ENVIRONMENT BRANCH

Part of the Northern Oil and Gas Action Program
(DSS File No. 038ST.A7134-0-0037)

eba

PROCEEDINGS OF THE
BEAUFORT SEA GRANULAR RESOURCES WORKSHOP
FEBRUARY 13 AND 14, 1992

Sponsored By:

INDIAN AND NORTHERN AFFAIRS CANADA
Natural Resources and Environment Branch
Part of the Northern Oil and Gas Action Program
(DSS File No. 038ST.A7134-0-0037)

Edited By:

Neil R. MacLeod, P.Eng.
EBA Engineering Consultants Ltd.
Calgary, Alberta

(EBA Project No. 0306-34786)

DECEMBER 1993

PREFACE

The major Beaufort Sea petroleum operators, in their 1983 submission to the Beaufort Environmental Assessment and Review Process, indicated a potential demand for up to 700 million cubic metres of granular material. Although it was known that substantial quantities of sand-sized material existed at the seafloor, the distribution of offshore gravel resources was less certain. At about the same time, a regional overview study of the supply/demand situation for offshore granular resources was undertaken by the Department of Indian Affairs and Northern Development (DIAND) with the co-operation of the industry. The main finding of the study was that proven resources fell far short of the forecast long-term demand for an estimated 35 million cubic metres of gravel.

In order to address this concern, a research project was initiated as part of the Northern Oil and Gas Action Program (NOGAP). NOGAP is intended to advance government preparedness for major hydrocarbon development in Canada's northern territories. This meant acquiring the knowledge and analytical capbility to make appropriate decisions concerning major northern development proposals. NOGAP funds have been used to accelerate work on current projects or to undertake new activities which existing budgets could not accommodate.

NOGAP Project A4, Granular Resources Inventory and Management, began in 1984/1985. Its objectives were to ensure that adequate geotechnical, hydrographic and other technical information is available for granular resources management and to provide detailed information on each significant borrow source in the region as is required for conservation and effective utilization. Following a three year hiatus, NOGAP was revived in 1990/1991 and is expected to continue until 1993/1994. A total of 17 sub-projects detailing with offshore granular resources in the Beaufort Sea have been completed, to date, under NOGAP. This work has been guided since 1985/1986 by an informal working group that included representatives of each of the three major Beaufort operators and the Geological Survey of Canada (GSC).

The NOGAP A4 project has worked towards a regional granular inventory by conducting several studies annually to improve the scientific and geotechnical data base. These studies were intended to complement the work of industry and government by focussing on the high quality granular deposits that might be in greatest demand and by tying-in these separate site specific studies to provide a better understanding of the regional inventory. A major effort has been made in this project to catalogue and compile most of the data previously collected by the main Beaufort petroleum operators into a series of computer data bases that have recently been linked with a digital mapping system to provide ready access. This information has been used to prepare several regional resource assessments of granular material sources in the Beaufort Sea. These studies have been conducted in co-operation with regional studies undertaken by the GSC to establish the geological framework for the Beaufort Region.

Since the initial studies, the Beaufort petroleum operators have expressed concern that much of the higher quality gravels have been used as general fill for island construction. In addition, there has been a greater demand for limited supplies of high quality sands and requests have been made for the exportation of Beaufort granular resources to Alaska. Meanwhile, there has been discussion about treating granular resources like mineral resources by allowing exclusive exploitation rights. These events have placed increased pressure on the department to effectively inventory and manage the remaining offshore deposits. With NOGAP winding down and industry activity in the region waning, there was perceived a need to bring together those who have been part of Beaufort exploration activities and those who may be future participants. This workshop was intended to provide a forum to review the existing information and to identify future research and study requirements.

This workshop could have not been possible without the co-operation of both industry and government. The kind offer of ESSO Resources Canada Ltd., through Jeff Weaver, to provide the comfortable meeting facilities is greatly appreciated. The support and encouragement of several representatives of ESSO, Gulf and Amoco and paticularly, the continuous involvement of Kevin Hewitt (Amoco/CanMar) over the years have been critical to any successes realized. In addition, Steve Blasco of the GSC has been a constant "sounding board" and advisor. Acknowledgement is given also the technical paper authors and presenters for the excellent efforts under a tight schedule. Finally, the skills and experiences of the workshop organizers, Neil MacLeod and John Lewis have been demonstrated in their crafting of a balanced and interesting program of technical papers and thoughtful discussion. To all of these, a sincere "thank you".

Robert J. Gowan P.Geol.
Geotechnical Advisor
Northern Granular Resources Program
Indian and Northern Affairs Canada
Ottawa, Ontario K1A 0H4

PART 3

INVITED PRESENTATIONS

Geological Constraints to Off-Shore Granular Resource Assessment in the Canadian Beaufort Sea

Presented By Steve Blasco
Geological Survey of Canada
Atlantic GeoSciences Centre
Dartmouth, Nova Scotia

Knowledge of the Late Quaternary geological history and depositional environments of unconsolidated sediments composing the Beaufort continental shelf provides the technical basis for guiding the search for granular resources, determining the origin of deposits and constraining inventory assessments.

Regional seabed geological mapping of the Beaufort shelf has resulted in the subdivision of the shelf into nine physiographic regions (Figure 1, O'Connor, 1982). The surficial geology is continuous within eachof th enine regions, but varies considerably among regions. This mapping lead to the further identification of five prospective areas with high potentials for sand and gravel deposits (Figure 1). As this figure illustrates, all source areas located and used to date by industry are found within four of the five identified areas.

Granular resource exploration and development has been focused on the high potential areas of the central shelf north of Richards Island and the Tuktoyaktuk Peninsula (Akpak Plateau and Tingmiark Plain). To the west, the Herschel sill and western Yukon shelf (Natsek Plain) represent potential sand and gravel source areas. The balance of the Beaufort shelf is dominated by extensive areas of exposed fine grained sediments on and underlying the sea floor. Figure 2 (Blasco et al, 1990) is a schematic east-west cross-section of the shelf showing the distribution of sands and clays in the near surface sediments. Lack of success in locating gravel deposits during early exploration phases on the shelf lead to the expansion of the search to the coast line of southwestern Banks Island.

The recent history of the shallow sediments of the Beaufort and Banks continental shelves is dominated by the effects of the last sea level rise, an event which has continued over the last 10,000 years (Hill et al, 1985). This transgression has resulted in the erosion, reworking, concentration and deposition of most of the sand and gravel bodies developed to date. However, the depositional setting varies among borrow sites. Geological models accounting for the origin of these deposits have evolved and changed over the last decade. Seven models have been used to constrain exploration and inventory evaluations of granular prospects. Each of these models is discussed below with appropriate examples.

Model 1A (Figure 3) represents the current view of central shelf stratigraphy (Blasco et al, 1990). Unit C sands represent a broad caostal outwash plain deposited during the retreat of the late Wisconsinan ice sheet. The exposed surface of this sand plain was reworked by rising sea level. Fine sediments were removed and coarse-grained sediments were concentrated as lag veneers, barrier islands, beaches or channel bar deposits. With continued rise in sea level, these deposits were covered with high energy near shore interbedded sands, silts and clays of Unit B. As water depths increased off shore, these Unit B interbedded sediments were, in turn, succeeded by Unit A marine clays. Units C, B and A strata were deposited as a succession over the last 20,000 years.

The Unit B/C contact represents a major regional unconformity and source of reworked sand and gravel. Borrow deposits are found on the seabed of the Akpak Plateau and Tingmiark Plain where Unit B and Unit A sediments are not present or form only a thin discontinuous overlying veneer. In addition to these reworked Unit B/C unconformity deposits, exposed Unit C sands have been dredged extensively as artificial island construction material. Model 1B, in-situ sand deposits, is illustrated as Figure 4. The southeast Isserk and centrak Erksak borrow sites are examples of Model 1A and 1B deposits, respectively (Meagher and Lewis, 1988a and 1988b).

Dredging of Unit C sands at depth is frequently limited or retarded by the presence of shallow permafrost. Well-bonded ice-bearing sands form an effective barrier to the dredging process. In other areas such as south of the Isserk site, ice-bearing Unit C sands have thawed under the influence of warm Mackenzie River waters. Thawed Unit C sands have consolidated and the resulting depression has infilled with thick Unit B deposits. This process, which may result in substantial overburden thicknesses, may preclude access to Unit C sands as a resource.

The surficial on-shore stratigraphy of Richards Island consists of basal sands of the Kidluit and Kittigazuit Formations overlain by Toker Point morraine. Rampton (1988) regards this sediment sequence to be early Wisconsinan or earlier in age (65,000 year minimum date). When the first off-shore stratigrpahic model was proposed on 1980 (O'Connor, 1980), stratigraphic continuity with the on-shore was assumed and Unit C sands were considered correlative with the Kidluit/Kittigazuit Formations. The overlying Toker Point morraine existed in the off-shore and was eroded and reworked during the last transgression, resulting in the deposition of coarse-grained lag deposits off shore. These lag deposits formed the basal part of Unit B. Unit B interbedded sands, silts and clays and Unit A clays were subsequently deposited and are mostly Holocene in age, as noted in Model 1a and 1b above.

Model 2 (Figure 5) illustrates this original model. The implication was that significant thin deposits of reworked Toker Point morraine existed as granular sources in the coastal zone north of Richards Island, at least as far off shore as Rampton's proposed ice limit. Fortin (1989) used this hypothesis in his granular assessment of this area.

The on-shore/off-shore stratigraphic correlation is not supported by chronologic evidence. Unit C appears to be younger than 21,000 (Blasco et al, 1990) and little evidence of the Toker Point has been documented in the off-shore.

To date, the geological mistie between the on-shore and off-shore remains unsolved. A compromise model which possibly accommodates the observed stratigraphy extneds the Richards Island sequence into the near shore zone (Model 2). This sequence ultimately dips beneath the more recent off-shore sequence (Models 1a and 1b). This Model 3 is illustrated in Figure 6 and sugests that inliers and outliers of the older and younger sequences may exist in the off-shore. However, recent work by Lewis (1991) suggests lateral continuity of Unit C and underlying strata from the off-shore to the near shore zone.

Sand and gravel deposits may also be found in Unit B transgressive sediments. As sea level rises, eroding and reworking the coast line in its path, sediments are exposed to high energy wave and current regimes. Coarse-grained coastal deposits are reworked and concentrated to form beaches and barrier islands. Model 4 (Figure 7) illustrates this stratigraphy. Shallow seismic and borehole evidence reveals the Unit B/C unconformity at depth and a Unit B of greater thickness. The Issigak borrow site on the southern Kringalik Plateau is this type of deposit (MacLeod, 1987) and forms an anomaly within the region dominated by fine-grained sediments, both on the seabed and with depth. Issigak is probably a barrier island generated during the last transgression, less than 3,000 years ago (sediments directly underlying the gravels have been dated at this age). Areas of morphologic relief during sea level rise may be exposed to high energy regimes for prolonged periods of time, leading to the reworking and concentration of granular sediments.

Little evidence exists on the Beaufort shelf of glacial ice action. Well defined tills and/or moraines have not been recognized to date, with the exception of the Herschel sill area. An early (possibly late) Wisconsinan ice tongue advancing northward down the axist of the Mackenzie Trough (Blasco et al, 1989), deposited a lateral moraine along the eastern ede of Herschel Basin. This morraine forms a ridge or sill from Kay Point on the mainland, north to Herschel Island. Fluctuating sea levels have eroded and reworked the crest of the Herschel sill, resulting in the concentration of coarse gravels on the seabed (O'Connor and King, 1985 and Gowan, 1984). The moraine origin for granular deposits is illustred in Model 5 (Figure 8).

The origin of granular resource deposits on the western Yukon shelf (Natsek Plain) is complex and poorly understood. In the near shore zone, coarse-grained alluvial fans, deposited at the mouths of northward draining river systems during low stands of sea level, form shallow water sources of sand and gravel (Meagher, 1986). Off-shore, progressing northward across the shelf, successively younger Neogene to Quaternary strata outcrop on the seabed (Lewis and Meagher, 1991 and Blasco et al, 1990). On the outer shelf, seabed sediments have been dated at 53,000 years BP or greater. This implies that surficial shelf sediments may have been exposed to at least two cycles of sea level lowering, sub-aerial exposure, erosion and reworking during sea level rise. Coarse-grained glacial, fluvial and transgression related sediments have been remobilized, reworked and concentrated as sand and gravel deposits which form thin discontinuous patches on a much older substrate. This geologic Model 6 used to account for the origin of western shelf granular deposits is illustrated in Figure 9.

Little data exist to clearly define the origin or extent of granular resources in the near shore and immediate off-shore of southwestern Banks Island. Mode 7)Figure 10) illustrates a schematic cross-section of the coastal zone. Underlying alluvial and glacial till deposits have been eroded, reworked and concentrated by wave and current action during a rising Holocene sea level. Thin coarse grained lag gravel deposits are exposed on the seabed in shallow waters. In the near off-shore, these deposits are covered with fine-grained sediments (Fortin, 1987).

Continued geological research is required to identify new granular sources and to more clearly define the origin and spatial extent of existing deposits. Significant quantities of sand appear to exist on the southern Akpak Plateau and Tingmiark Plain areas of the central shelf. However, few sand sources exist in close proximity to exploration and developments sites in the west central Beaufort area. Known gravel sources are limited in number and volume. Regional dna site specific geological studies are required to find strategically located sand deposits and to significantly expand on the supply of gravel. More specifically, the near shore stratigraphy of the Richards Island area needs to be resolved to define the appropriate geologic model and to clearly define the granular resource potential of this area

References

Blasco, S.M., Fortin, G., Hill, P.R., O'Connor, M.J. and Brigham-Grette, J.K., 1990. The Late Neogene and Quaternary Geology of the Canadian Beaufort Continental Shelf. Grantz, A., Johnson, L. and Sweeney, J.F., eds., The Arctic Region: Boulder, Colorado, Geological Society of Americ, vL, pp. 491 - 502.

Blasco, S.M., Brigham-Grette, J. and Hill, P.R., 1989. Off-Shore Constraints to the Late Pleistocene Glacial History fo the Mount of the Mackenzie River. United States GEological Survey Circular 1026, pp. 15 - 17.

Fortin, G., H.R. Seismic Interpretation Services Inc., 1987. Interpretation and Synthesis of High Resolution Reflection Seismic Data from the Banks Island Borrow Area. Indian and Northern Affairs Canada internal report, pp. 65.

Fortin, G., H.R. Seismic Interpretation Services Inc., 1989. Granular Resource Potential: Analysis Based on High Resolution Refraction Data, Southern Akpak Plateau. Indian and Northern Affairs Canada internal report, pp. 47.

Gowan, R.J., EBA Engineering Consultants Ltd., 1984. Off-Shore Geotechnical Site Investigation - Herschel Sill Sites, Yukon Territory. Indian and Northern Affairs Canada and the Geological Survey of Canada internal report, December 1984, pp. 20, Appendices A and B.

Hill, P.R., Mudie, P.J., Moran, K. and Blasco, S.M., 1985. A Sea Level Curve for the Canadian Beaufort Shelf. Canadian Journal of Eearth Sciencies, v. 22, pp. 1,383 - 1,393.

Lewis, J.F., 1991. Regional Surficial Geology: South Central Beaufort Shelf Beaufort Sea, Northwest Territories. Geological Survey of Canada internal report (draft).

Lewis, J.F. and Meagher, L., 1991. Upper Tertiary and Quaternary Geology and Morphology of the Western Beaufort (Yukon) Continental Shelf and Slope. Geological Survey of Canada internal report (draft).

MacLeod, N.R., EBA Engineering Consultants Ltd., 1987. Synthesis and Interpretation of Bathymetric, Geophysical and Geotechnical Data from the Issigak Borrow Block. Indian and Northern Affairs Canada internal report, pp. 42.

Meagher, L., Earth & Ocean Research Ltd., 1986. Overview of Granular Resources Potential for the Western Beaufort (Yukon) Continental Shelf. Indian and Northern Affairs Canada internal report, pp. 97, enclosures.

Meagher, L.J. and Lewis, J.F., Earth & Ocean Research Ltd., 1988a. Synthesis and Interpretation of Bathymetric, Geophysical, Geological and Geotechnical Data: Isserk Borrow Block - South Central Beaufort Sea. Indian and Northern Affairs Canada internal report (revised August 1989), pp. 70, Appendices 1 to 3 (unpaged), 6 enclosure.

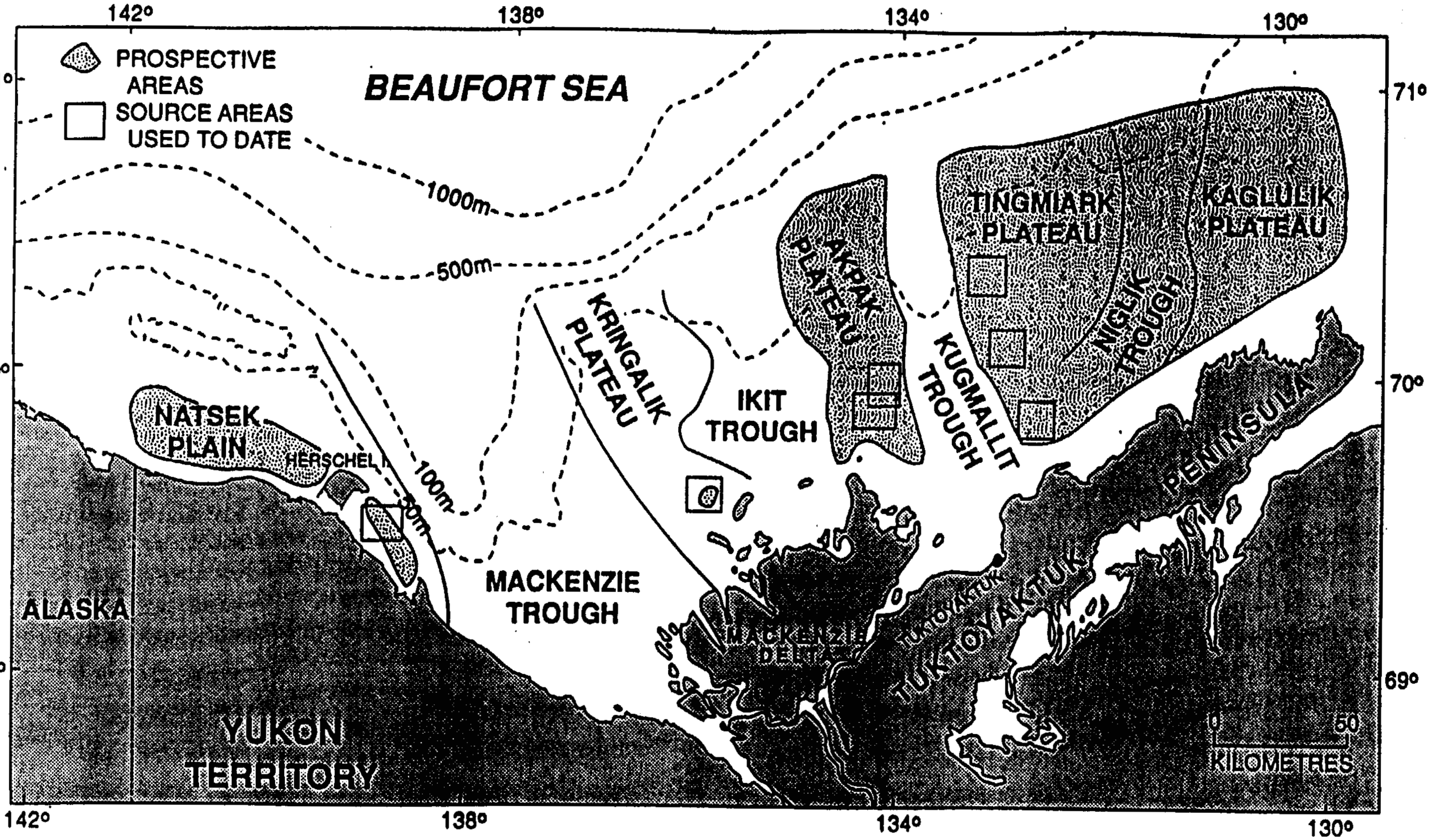
Meagher, L.J. and Lewis, J.F., Earth & Ocean Research Ltd., 1988a. Synthesis and Interpretation of Bathymetric, Geophysical, Geological and Geotechnical Data: Isserk Borrow Block - South Central Beaufort Sea. Indian and Northern Affairs Canada internal report (revised August 1989), pp. 128, Appendices 1 to 3 (unpaged), 7 enclosure.

O'Connor, M.J., M.J. O'Connor and Associates Ltd., 1982. Regional Surficial Geology of the Southern Beaufort Sea. Geological Survey of Canada internal report, pp. 137.

O'Connor, M.J., M.J. O'Connor and Associates Ltd., 1980. Development of a Proposed Model to Account for the Surficial Geology of the Southern Beaufort Sea. Geological Survey of Canada open ile report 953, pp. 128.

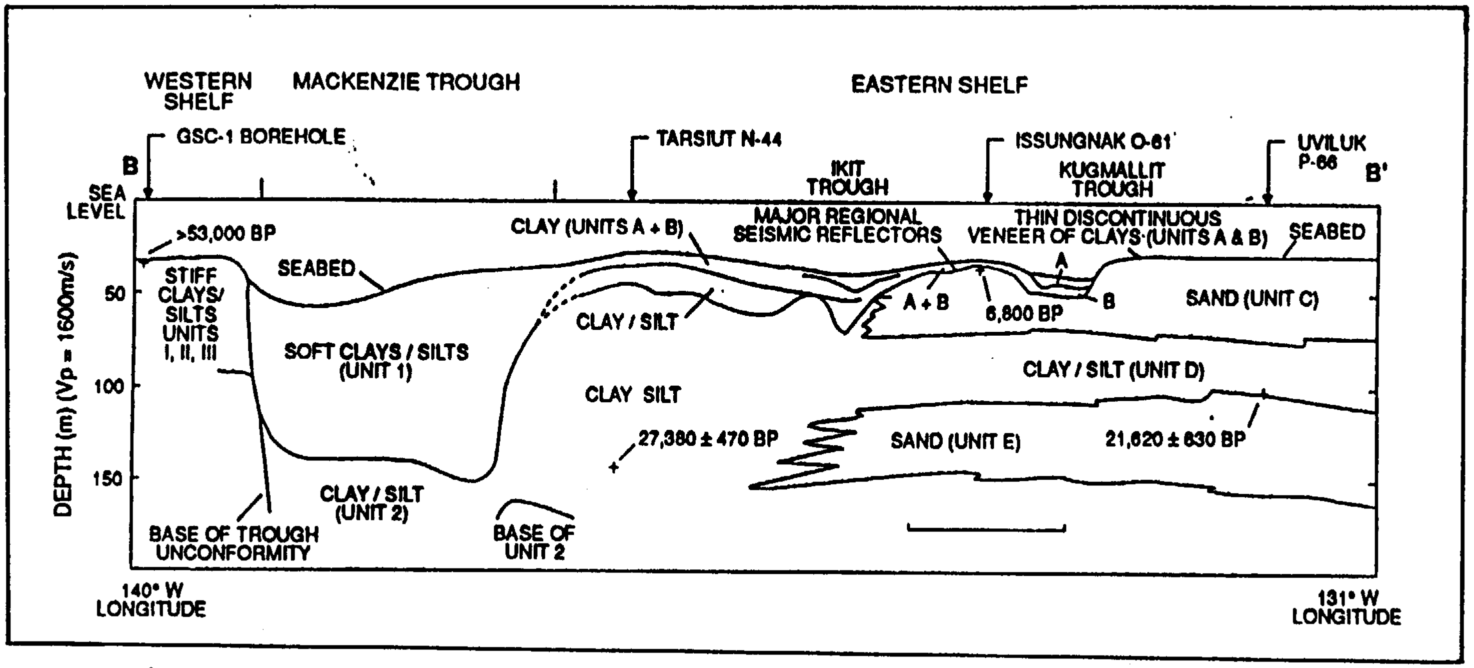
O'Connor, M.J. and King, R.D., M.J. O'Connor and Associates Ltd., 1985. Surficial Geology and Granular Resources Southeast of Herschel Island, Volumes I and II. Indian and Northern Affairs Canada internal report, pp. 146, Appendices A - E (unpaged).

Rampton, V.N., 1988. Quaternary Geology of the Tuktoyaktuk Coast Lands, Northwest Territories. Geological Survey of Canada Memoir 423, pp. 98.



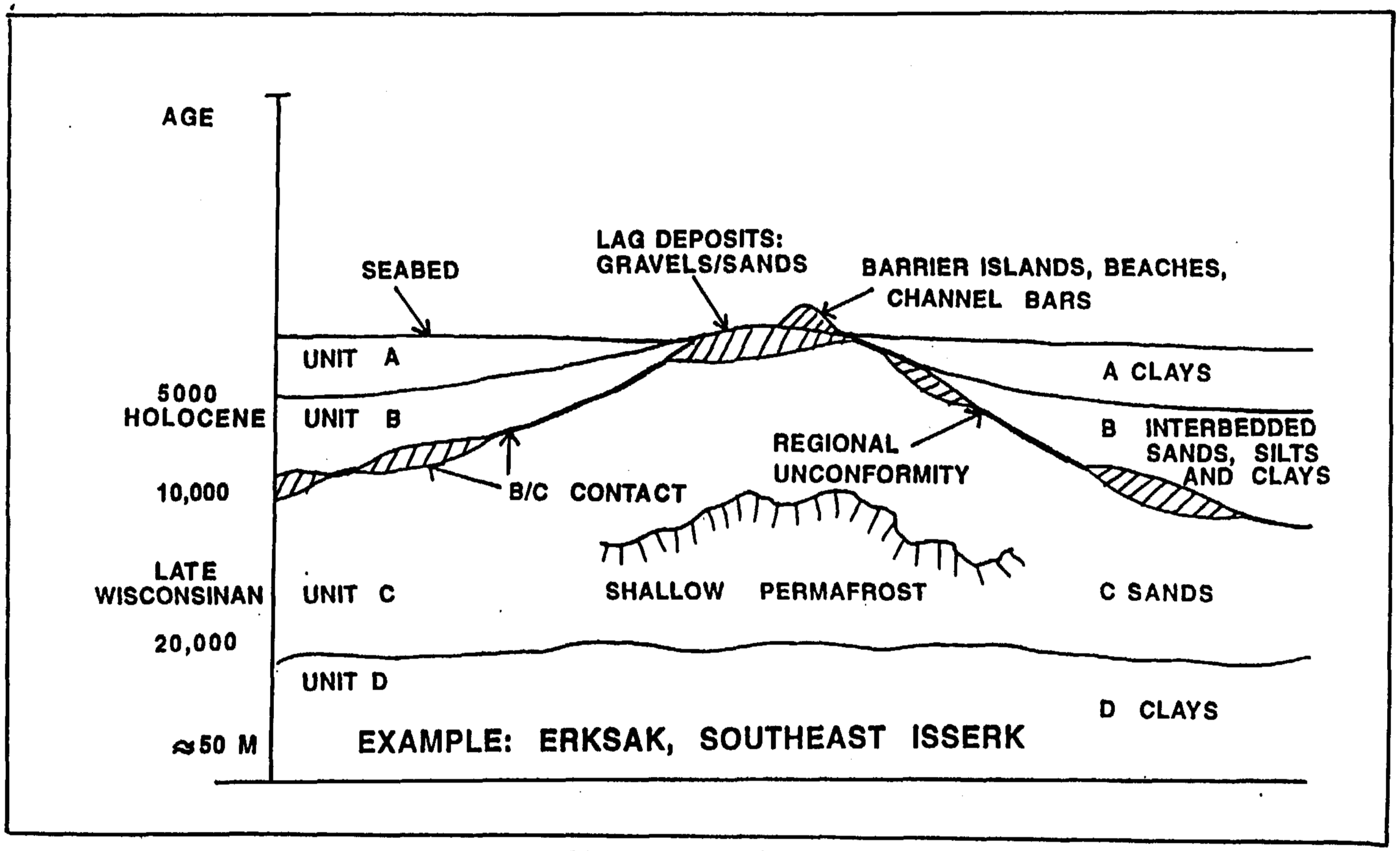
AREAS WITH POTENTIAL SAND AND GRAVEL RESERVES

FIGURE 1



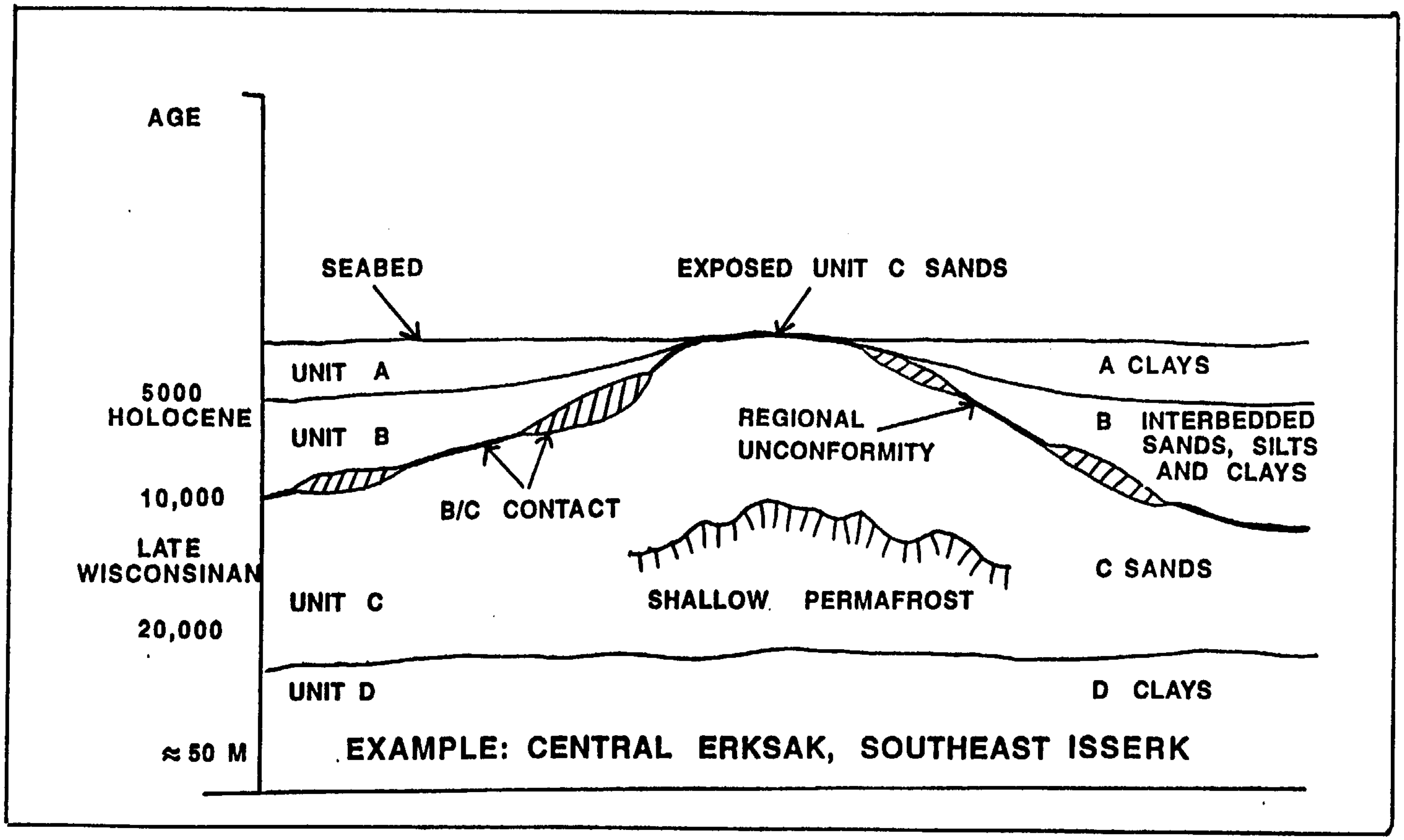
NEAR SURFACE CLAY AND SAND DEPOSITS **FIGURE 2**

024/246/92/1/1



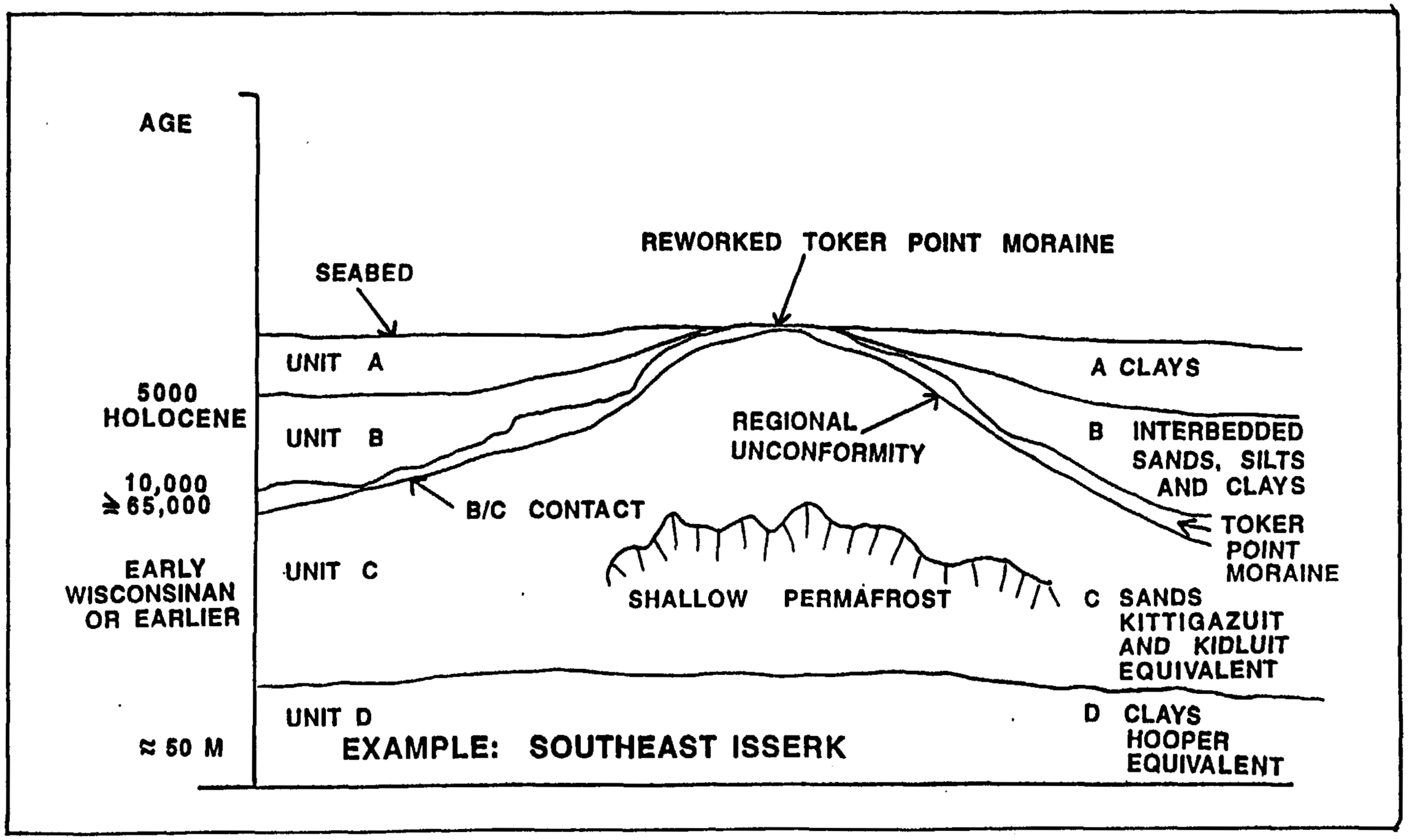
MODEL 1 a: RECENT REWORKED DEPOSITS

FIGURE 3



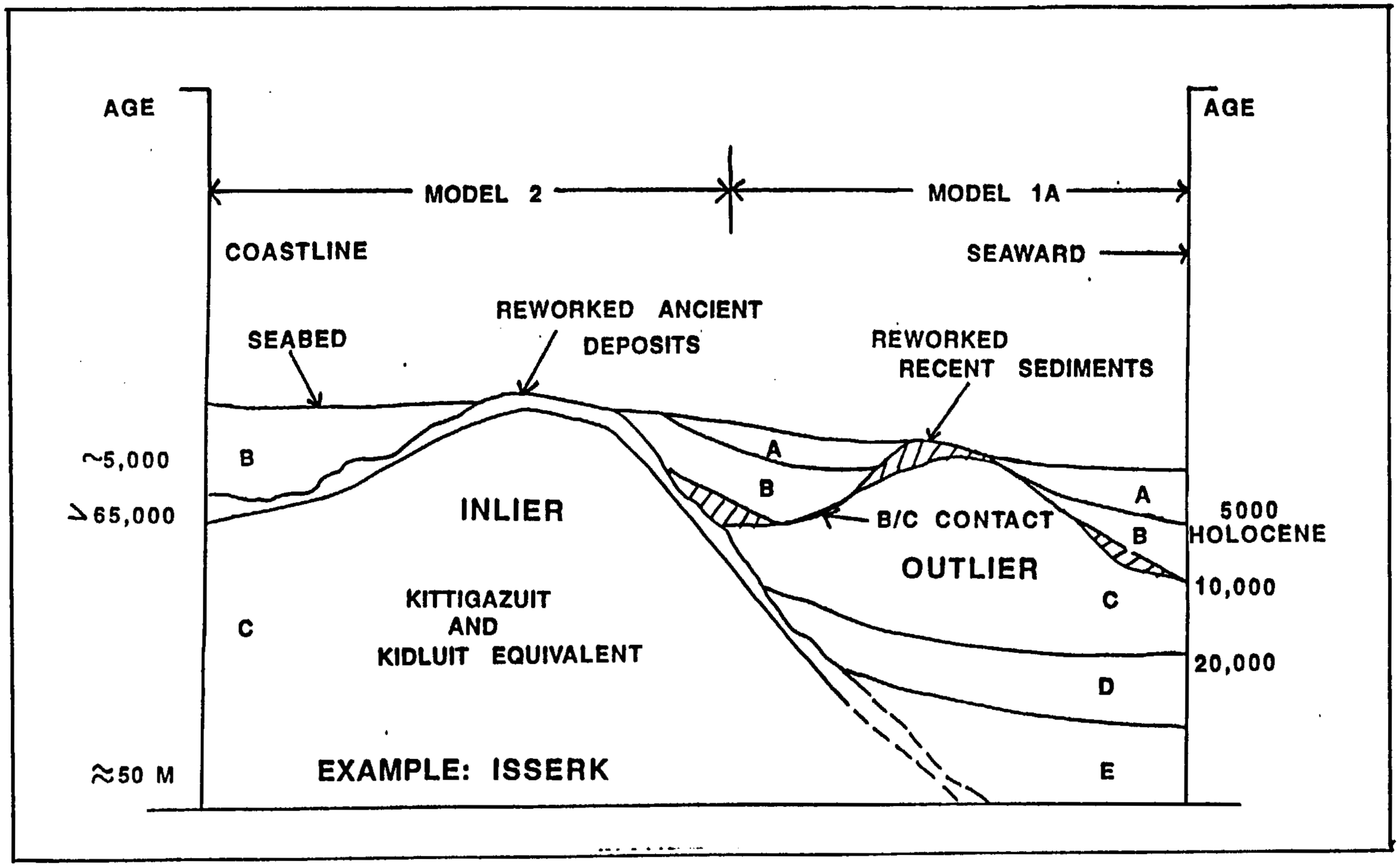
MODEL 1 b: RECENT IN - SITU DEPOSITS

FIGURE 4



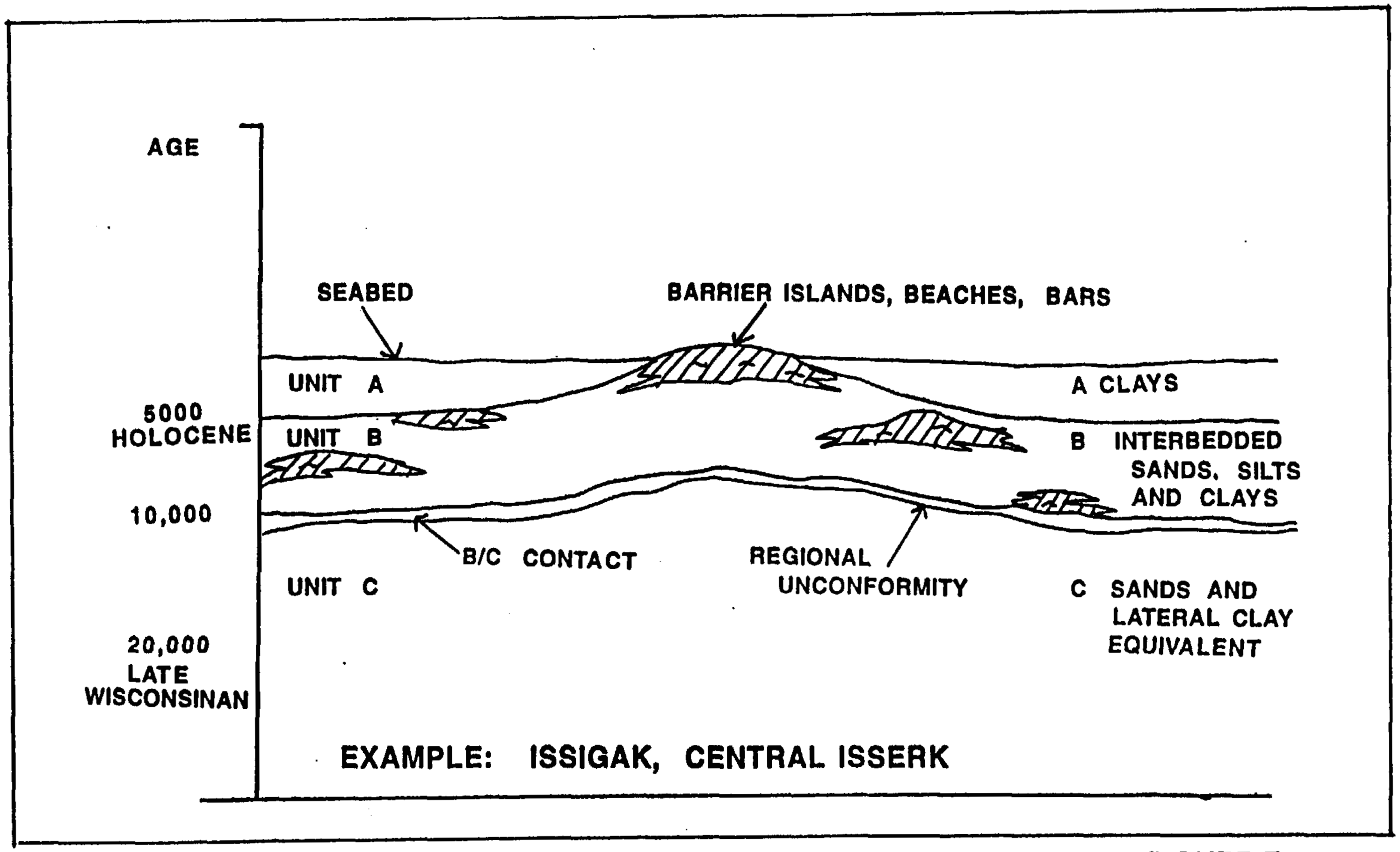
MODLE 2: ANCIENT REWORKED DEPOSITS

FIGURE 5



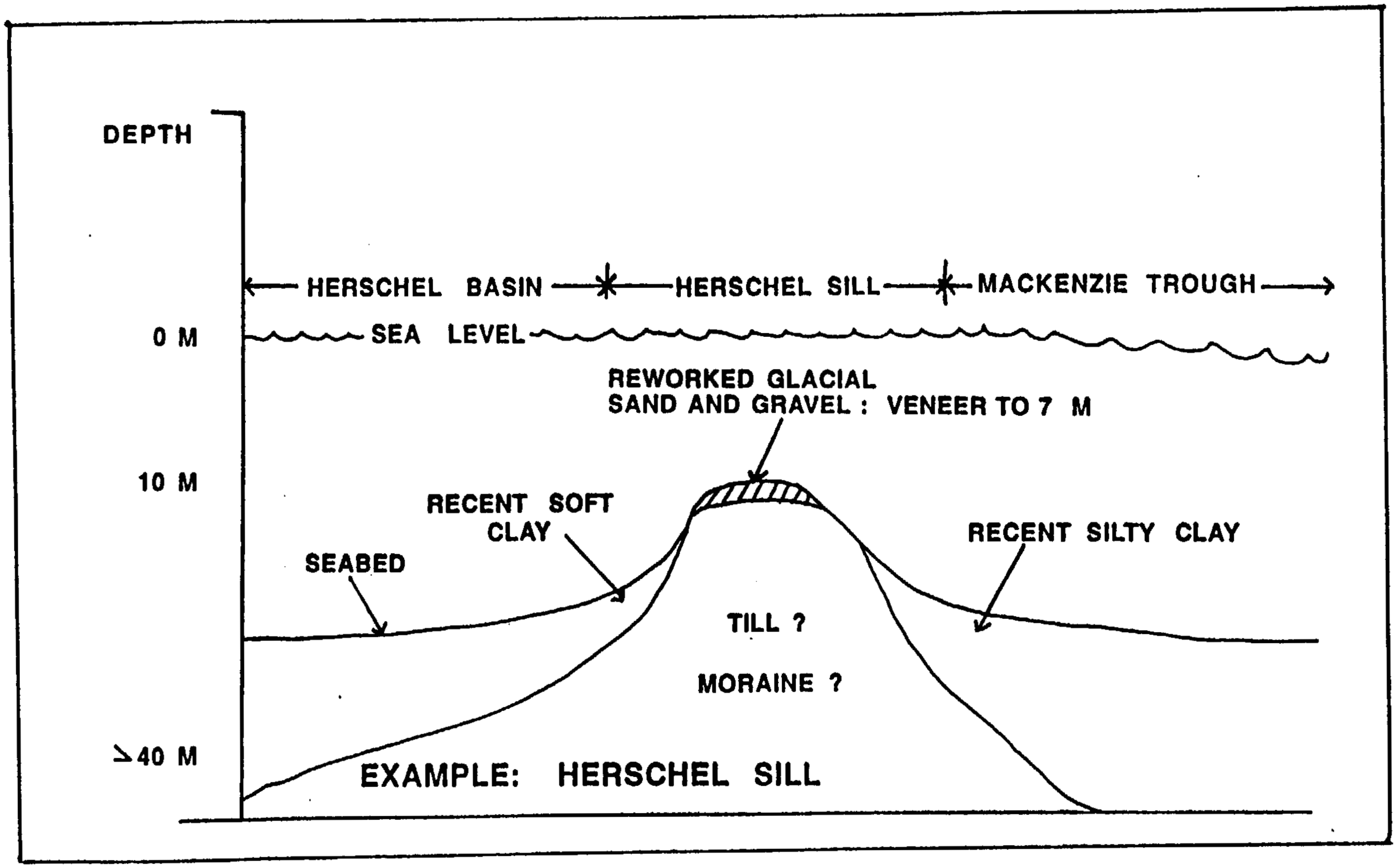
MODEL 3: INLIER / OUTLIER DEPOSITS

FIGURE 6



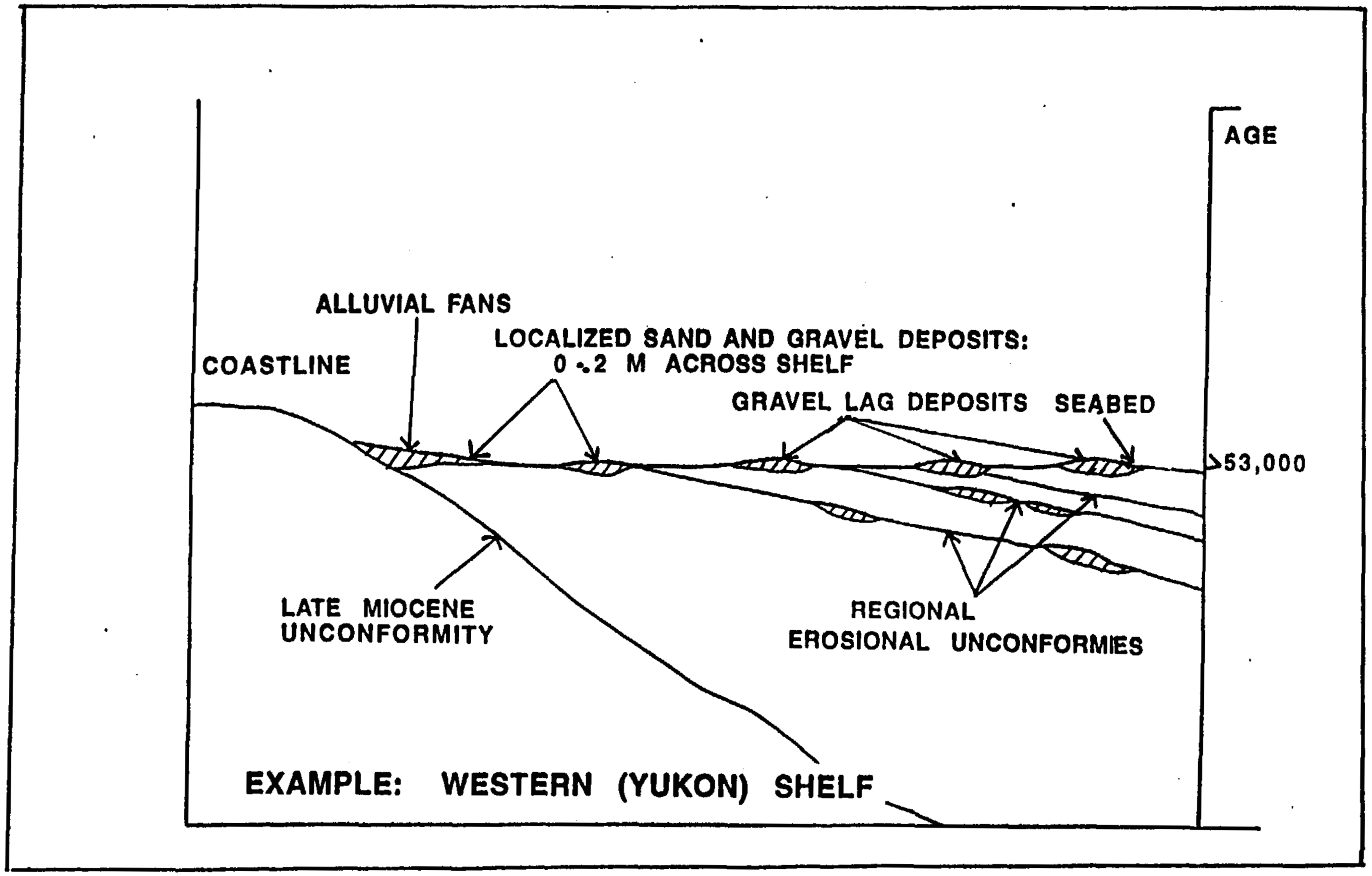
MODEL 4: TRANSGRESSIVE DEPOSITS

FIGURE 7



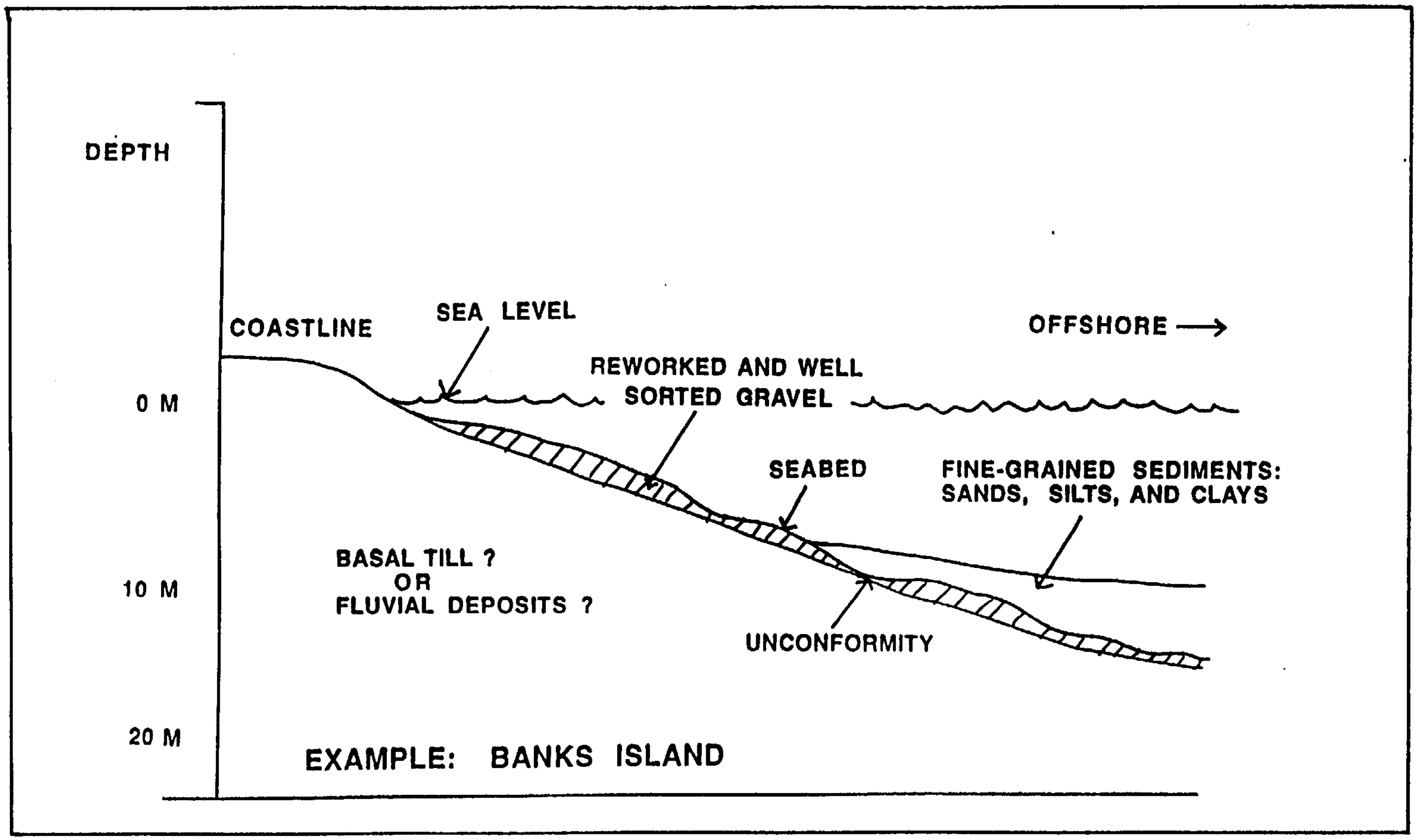
MODEL 5: REWORKED GLACIAL DEPOSITS

FIGURE 8



MODEL 6: UNDIFFERENTIATED MULTIPLE REWORKED DEPOSITS

FIGURE 9



MODEL 7: ALLUVIAL / COLLUVIAL COASTAL DEPOSITS FIGURE 10