PROCEEDINGS OF THE BEAUFORT SEA GRANULAR RESOURCES WORKSHOP

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PART 1

REPORTS ON NOGAP REGIONAL STUDIES

The Erksak Borrow Block
(NOGAP Project A4-21)

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1.0 Introduction

The Erksak Borrow Site study program was one component of a set of three concurrent studies that were initially conducted by Earth & Ocean Research Ltd. through 1987/1988. These studies consisted of a two volume borrow study conducted for DIAND of which Volume 1 is the Isserk borrow site area and Volume 2 is the Erksak borrow site area. The third study was a regional surficial geology program for the south central Beaufort Sea region which was completed for Steve Blasco of AGC. Steve will be discussing these regional geology results in a paper presented at this meeting.

Figure 1 is a map of the Beaufort Sea showing the south central Beaufort geological study area and the two concurrent borrow block study areas. These borrow study reports were completed by EOR under DSS contract AO632-7-5011/ C1ST for Mr. Bob Gowan of DIAND as a part of NOGAP project A4-20.

This paper is specifically in reference to the eastern Erksak study region (Figure 1) which is defined by:

- Northwest: Zone 8; 550,000; 7,800,000 - (70°18'10" 133°40'15").
- Northeast: Zone 8; 609,000; 7,800,000 - (70°17'04" 132°06'15").
- Southeast: Zone 8; 609,000; 7,750,000 - (69°50'12" 132°09'57").
- Southwest: Zone 8; 565,000; 7,750,000 - (69°51'04" 133°18'33").

These co-ordinates describe a quadrilateral that widens to the north. At its closest approach to land, the southern edge of the block lies approximately 9 km to the north of the Tuktoyaktuk Peninsula. The defined area encompasses approximately 2,574 km^2 of the Beaufort Shelf.

The specific purpose of this study has been to evaluate all (or as much as possible) of the geophysical and geotechnical data available within these regions with the primary mandate of attempting to quantize the locations and volumes of proven, probable and prospective granular resources that are present.

All three of the above-referenced studies used a common data base set which was compiled and collated with the intent of using it over the three study programs mentioned above.

2.0 Data Bases

The mandate of these studies was to evaluate all high resolution geophysical and geotechnical data that had been collected in this study area. This consisted of a massive amount of data, though not all of this data could be found and accessed within a reasonable search effort for this study and a resulting more limited, though still significant, data set was actually used.

DIAND had initiated an earlier data compilation contract with McElhanney Services Ltd., which was a library search of the industry geophysical reports to identify the industry geophysical data sets that were originally collected (McElhanney Services Ltd., 1988). A second program with EOR was conducted to compile and digitize the geophysical track data (Peters, 1988) and a third with EBA to identify and compile the geotechnical data bases within the regions (EBA, Isserk 1988a, Erksak 1988b and Central Beaufort 1988c).

The initial tasks of this present study was to locate and copy as much as possible of the geophysical data sets for use within these evaluations. This was carried out over a month long period in Calgary with considerable appreciated help of the respective Beaufort Sea industry operators. A number of the geophysical records couldn't be located and after a reasonable effort, it was decided to go with the data that had been collected.

2.1 Navigation/Geophysical Data Base

The track navigation and geophysical data compilations included the entire area of the south central Beaufort Sea geological study area. Figures 2 and 3 of the section on the Isserk site outlined the entire navigation and geotechnical data bases available for the south central Beaufort study area and will not be repeated hear.

Figure 2 in this paper shows the more limited area of the Erksak borrow site and the geophysical track lines and the location of the geotechnical boreholes available for just this area.

In general, the overall geophysical data set is of good but variable quality. The quality is dependent on weather conditions at the time of collection. Difficult interpretation arises most commonly from real geologic conditions rather than poor collection technique. This is especially evident over the areas of main interest, the borrow sites. Records that display good resolution and are readily interpretable where they cross the channel areas to the east and west of the sites, become congested and the character difficult to determine over the coarser grained materials of the borrow sites.

Of the two main data sources, the boomer and the micro-profiler, the micro-profiler is the more suitable for the resolution of the nature of the surficial cover. The higher frequency envelope of this system makes the signal more susceptible to reflection and attenuation on coarser substrates and is therefore somewhat calibrated to discern sandy material from silty material. In the present application where the determination of coarse material at or very near the seafloor is critical, the profiler's lack of penetration ability in coarser sediments is of less importance than its ability to discriminate between sand and silt/clay. In comparing micro-profiler data to borehole data, it is observed that a strong correlation exists between signal attenuation and reflection character and sediment texture.

The boomer data is more valuable in establishing the seismo-stratigraphy of the study site. The reduced sensitivity to textural changes that limits the usefulness of the tool for discriminating coarse from fine material permits more consistent imaging to greater depths through coarse material. It is also noted that where boomer and borehole correlation is possible, a diagnostic seafloor return is also generated from this source over coarse substrates, though it is less obvious than that of the micro-profiler data.

Appendices 1 and 2 of the text reports (Meagher and Lewis, 1988a and b) describe the McElhanney data base which consisted of a compilation showing the surveys completed and line data originally collected and the results of the data search respectively which describes the listed/found and copied data used for this study. Appendix 2 data base gives the locations of the original data as of April, 1988 and the copied data is currently resident at AGC in their data archives.

2.2 Geotechnical Data Base

The geotechnical data bases were compiled and inserted into ESEBase record form by EBA Engineering Consultants Ltd. for the entire south central Beaufort area. This data base project will be described more fully in a latter paper presented by Rita Olthof of EBA.

Initially, 94 boreholes were identified within the Erksak Borrow Block (EBA, 1988b). While reviewing these data sets, it was discovered that an additional 28 boreholes had been drilled within and just beyond the boundaries of the Erksak Borrow Block which proved useful in this study. These additional boreholes were reported within EBA's final (1988c) report.

The borehole coverage within the entire Erksak Borrow Block is sparse in relation to the overall size of the region. The boreholes tend to be clustered into 4 or 5 main groups which were drilled for exploration island sites and detailed dredging evaluations at specific locations. The coverage in these detailed regions is probably adequate for the detailed local assessment of borrow quality and quantity; however, the detailed re-evaluation of these very limited areas has not been feasible within the context of this regional study.

Mr. Neil MacLeod of EBA, via a sub-contract to this study, assisted in developing a coding system for the sediments encountered within the boreholes which takes into account the sand and gravel quality and current dredging requirements and equipment restrictions of the Beaufort Sea operators. The coding system has been used in the figures describing the borrow prospects and has been used for evaluation of the borrow potential of the respective sites when boreholes are available. This coding system is reproduced on the maps of the detailed borrow prospects discussed later. For detailed discussions, refer to Meagher and Lewis (1988a and b).

3.0 Site Descriptions

Throughout this section, discussion and interpretation is restricted to the region of the Erksak Borrow Block. It is aimed primarily at the surficial physiography and shallow sedimentary section for the sole purpose of granular resource borrow evaluation. These restrictions encompass Units A, B and the top section of Unit C which were initially defined in M.J. O'Connor's 1980 report. In order to facilitate the detailed discussion of this region, the physiography of the area has been examined in detail and additional physiographic names beyond those presented by O'Connor (1982a) have been used to describe the bathymetric and shallow sub-surface features within the area. These names are presented as informal names and are used primarily to aid the reader in following the detailed discussions within the original text report. Sedimentary Unit names referred to within this talk follow the O'Connor (1980) terminology conventions.

The interpretations have been directed specifically at the location and identification of coarser grained borrow materials and therefore does not follow the standard convention of most regional geologic descriptions. Thus sub-surface maps generated are based on seismo-lithologic interpretations directed at delineating coarse materials and use ground-truth borehole evidence where possible. These maps are specifically <u>not</u> time stratigraphic interpretations which would be the norm for geological interpretation procedures.

3.1 Bathymetry

Figure 3 is a contour map of the bathymetric contours over the Erksak site at a 1 m contour interval within regions where the CHS data was adequate and at a 2 m interval where the data was sparse. The high definition information (highly crenulated 1 m contours) has been developed by a careful re-contouring of Canadian Hydrographic Service (CHS) field sheet WA-10176 (water depth postings) which was resurveyed by CHS in 1986. The more smoothed contour area portions of the map have been constructed from the Natural Resource Series bathymetric map for the area. This latter bathymetric map was used to extend portions of the east and north zones of the site where the detailed newer field sheets were not available at the time of writing. The significant decrease in the crenulation of the contours, apparent on the produced map in these areas, is an artifact of this procedure and is not due to real changes in the seafloor micro-topography.

The topography of the site is developed on a regional north-northwestward sloping plane. A minimum depth of 6 m is recorded at the extreme southeast corner of the site and a maximum depth of 54 m is noted at the extreme northwest corner. Superimposed on this plane are a number of distinct topographic features of varying scale that impart an irregularity to this surface. The larger topographic features are the physiographic regions; Tingmiark Plain, Kugmallit Channel and Niglik Channels, outlined and described by O'Connor (1982a). Local variations in the bathymetry and the underlying paleo-surface that influence and control the bathymetry permits the subdivision of the Tingmiark Plain into smaller component regions. These divisions and subdivisions are outlined on Figure 3. For ease of reference, the subdivisions are given informal names intended for use within the context of this report only.

The Tingmiark Plain has been subdivided into the West Erksak High, Erksak Channel, Uviluk High and Uviluk Channel. The West Erksak High is further divisible into the Erksak Crest, Kogyuk Terrace and Ukalerk Slope. The southwest corner of the map area is occupied by the James Shoal Extension. The Kugmallit Channel and Niglik Channels are not subdivided.

3.2 Surficial Cover

The distribution of the surficial sediment type exposed on the seabed within the Erksak Borrow Block is presented in Figure 4. The mapping of the surficial cover is based primarily on an examination of the seismic data, particularly the micro-profiler records, validated wherever possible with visual descriptions of seabed samples. Where the seismically defined textural class boundary differs from that derived from the sample control, it is shown with a dashed line. Seismic data is used exclusively in the northwest and north where there are no boreholes and bathymetric field sheet coverage is not available.

Textural information from the tops of the 122 boreholes has been augmented by 164 seabed samples collected by the Canadian Hydrographic Service during the 1986 field season. CHS collected these seabed samples using a small grab sampler on a 5 km grid over the area covered by Field Sheet WA 10176. Where shoal examinations were carried out, the seabed texture was determined using a smaller armed lead line sampling device. Size analysis are not routinely performed on grab samples by the CHS and the samples are routinely discarded at sea after examination. The textures derived from the borehole logs are primarily based on visual description; though in some cases, they are supported by lab testing. The surficial cover map is, therefore, restricted to broad textural classification.

The distribution of surficial sediments is topographically controlled. Sand and sand-dominant material is restricted to shoals, although not all shoals are sandy. The Kugmallit Channel and Erksak Channel are uniformly fine grained, with exceptions at the Amerk O-09 artificial island site and a sand sample taken from a small shoal located 4 km to the northeast of the Amerk site. This shoal is anomalous in that it rises 6 m to a water depth of 22 m from an otherwise low relief plain and consists of sand where the surrounding area consists of soft clay. The feature has the appearance of an artificial island though the CHS field sheet records the location of artificial islands and this shoal is not noted as such.

Over the West Erksak High the sediment distribution is more varied, but still related to the local relief with sand or muddy sand recorded over the ridges of the Erksak Crest and sandy mud or mud noted within the depressions. The outline of the distribution of sand at the seafloor as determined from the seismic data is displayed on the map with a dotted line. A comparison of this outline with the distribution mapped from the CHS samples shows that the fine cover is more extensive than the seismics alone would suggest. This is most likely the result of a veneer of fine material resting on the sand substrate. The thickness of this veneer would not exceed about 30 cm or it would be visible on the micro-profiler records.

Seismic and borehole data over the Uviluk High indicate that sand covers most of the surface with mud occupying two northwest-southeast trending depressions.

The southern shoreward portion of the area over the James Shoal Extension is generally covered by soft clay or mud. A sand sample is noted next to the Alerk P-23 artificial island and a second sand sample is recorded 3 km to the east on the flank of the main shoal of the James Shoal Extension. The CHS sample grid did not sample the top of the main shoal, but it is surmised that the sand sample is representative of the surficial cover of this feature.

The fine material surrounding the coarse deposits consist uniformly of inorganic clays with very occasional black organic streaks. They are generally low to medium plastic with a water content that varies from about 20% to 45% (Unit B type clays). The clays also vary from soft to very stiff. Trace amounts of sand in fine laminations are noted in several samples as well as trace amounts of silt and shells.

3.3 Subsurface Geology

The sub-surface geology within the site can be described within the framework of O'Connor's stratigraphic model for the Beaufort shelf (Units A, B and C). However, the design of this program has been aimed specifically at "Borrow Materials" and as was noted at the Isserk Site, a very complex relationship can exist with regards to Units B and C as far as coarser grained sands materials distribution is concerned. As there is no reason to assume a different geological scenario for the Erksak site and since this much larger region does not have the density of borehole control that was available at Isserk, a tact of defining the distribution of the top of potential borrow material (sands) was taken as opposed to attempting to map the most recent regional unconformity (top of Unit C). This concept worked well with the micro-profiler and boomer data sets as in many instances, the actual top of the unconformity surface could not be acoustically mapped beneath sandbars and shoals composed of the re-worked Unit B materials. No attempt to differentiate upper and lower sand prospects on the maps of this study has been made as the added complexity would not have been viable on such a large and complex area. This distinction has to be left to more detailed site specific borrow target studies.

With this mandate in mind, the seismic and borehole data sets were combined to produce a depth structure map of the Top of Prospective Sands within the site area (Figure 5). This surface is not a time stratigraphic horizon, but is a composite of, in many cases, overlapping reflecting horizons of laterally discontinuous higher amplitude reflections interpreted to be the top of shallow sands or prospective borrow materials within the area. While these horizons are not time synchronous, when taken together, they form a morphological pattern that suggests a depositional system acting over a short period of time which is likely associated with a high energy shallow water near shore active erosion and redistribution environment. This environment has migrated shoreward with time associated with the most recent marine transgression of the area.

Figure 6 is an isopach contour representation of the soft surficial sediments overlying these prospective sands. This information is necessary for defining regions of prospective resource because of the limiting constraint of having a maximum of 3 m of overlying material that might have to be stripped away to get at the resource. Note from the structure map that the definitions of the supplementary physiographic regions are much more distinct where they were quite muted though still evident on the bathymetric map presented earlier.

These maps indicate that the physiographic highs typically have a thin or absent soft sediment accumulation and irregular patterns of distribution. Within the physiographic lows, the accumulations of soft materials are controlled by the well developed topography of the underlying surface. The Kugmallit Channel shows thick accumulations (up to 24 m) of soft materials in the south and thinning toward the north (between 1 and 11 m). A similar pattern is noted in the Erksak Channel. In the east, in the Uviluk Channel, accumulations are not as well defined due to the general lack of data though range from 4 to 7 m in thickness.

3.4 Depositional Summary

Based on the geophysical and sampling data, a tentative depositional summary of the upper 20 m of the sedimentary column has been developed. The Beaufort sea shallow geological sequence consists of a number of repeated cycles of marine incursion separated by periods of sub-aerial exposure related to glacially induced low stands of sea level. This sequence has been built on top of a continued regional basin subsidence in the region and there are believed to be approximately six or more cycles preserved within the Quaternary section which constitutes the upper 400 to 600 m of sedimentary section in the central Beaufort area. This study concentrates on the upper 20 m of this section which represents the sub-aerially exposed surface developed prior to the most recent marine incursion of the area and the post-transgression deposited sediments. These sediments represent the accumulated deposition over approximately the last 12,000 to 14,000 years. During this period, average sedimentation rates of up to 3 to 4 m per 1,000 years during the early part of the cycle have occurred assuming age dating within the sections have been accurate.

The developmental history of this site essentially consisted of the very fast deposition of Unit C sands as a glacial outwash and braided stream system which existed during the last glaciation from about 14 - 18 ka until inundation by the re-advancing seas. These periglacial coarser grained materials were sub-aerially exposed and subject to significant permafrost aggradation prior to inundation. The 11 boreholes in the area, which fully penetrate this unit, indicate that Unit C is from 35 - 50 m thick.

The region was inundated by the advancing seas during approximately 8,000 (off-shore) to about 3,000 (near shore) years before present based on the current water depths and the presently understood Relative Sea Level curves for the area (Hill et.al., 1985).

The physiographic regions, as defined in this study, are believed to outline the last sub-aerially exposed topographic conditions prior to inundation. The Erksak High, James Shoal Extension and Uviluk High represented topographic promontories that were bounded by the Uviluk, Erksak and Kugmallit Channels. The channels were likely existent some time prior to inundation though because of the excessive down-cutting in the Kugmallit Channel, it is speculated that the Erksak and possibly the Uviluk Channels were abandoned some time prior to inundation. Thus, the sand bar/channel island features noted in the Erksak channel are interpreted to be riverine and not transgressive in origin.

The deeper Kugmallit Channel was the first region to be inundated and as sea levels rose, the Erksak Channel would have been inundated approximately coincident with the Ukalerk Slope. Since the remnant channel and knoll topography is still preserved on the Ukalerk Slope, it is presumed this region was inundated rapidly. The broader contours of the Kogyuk Terrace imply that sea level rise slowed and the region was cut back further by shoreline retreat associated with the breaker zone. This factor suggests the region might be richer in concentrated gravels than other areas though this is not confirmed at this time. The last areas to be inundated would have been the upland Erksak Crest, James Shoal Extension and the Uviluk High.

Both prior to and during inundation of the higher areas, sub-aerial erosion would have concentrated the coarser fraction materials along the edges of these highs. This is evident on the seismic records over the edges of both the Kugmallit and Erksak Channels. Just after inundation in any particular region, the local areas would have undergone a high energy environment which transported the fine materials off-shore while the coarser materials would remain virtually in place. These remnant materials formed the local bars and foreset bedded coarser materials of the surficial Unit B sediments which are quite variable throughout the area. As transgression continued and the regions passed below wave base, a transition to finer sediment deposition occurred with eventual deposition of the finer facies Unit B clays and finally the Unit A clays. Areas where sands are still exposed at the seabed are presumably still under the influence of wave base erosion and winnowing of the finer sediments, though at present, most of the Erksak block would only be significantly affected during major storm events.

4.0 Granular Resource Model and Evaluations - Distribution

Figure 7 is a map of the granular resource prospects determined within the Erksak Borrow Block area. The tight horizontal hatching represents areas defined as proven resource zones based on the borehole sampling and the seismic information and the broader vertical hatching represent areas of prospective resource based on seismic evidence and some limited surface and borehole samples.

The outer boundaries of these prospective zones have been defined by the 3 m contours of the soft surficial sediment isopach map presented in Figure 6, as this is the present day economic limitation of conventional dredging equipment when overburden stripping is required. Areas with a zero-cover isopach might be considered higher priority from a site development point of view.

Because of the large extent of the region, the potential borrow sites have been numbered from 1 to 33. In the large areas of virtually continuous accessible resource on the West Erksak High and the Uviluk High, a subdivision has been made based on the localized areas of the zero-cover isopaches. Where possible, the boundaries between individual sites follow the maximum thickness of soft sediment cover. Within the Erksak Channel and the Kugmallit Channel, most of the resources have at least 1 m of soft cover and therefore, the boundaries of the prospective resource is defined by the 3 m isopach contours. In addition to these prospects, two prospects on the James Shoal Extension have been defined by borehole and sample information only.

Table 1 indicates the surface areas of each of the prospects and is broken down into the area between each set of overburden isopach contours out to the 3 m maximum. It should be noted that some of the identified prospects, or at least portions of them, have been concluded to be marginal in quality as far as their suitability of construction materials are concerned. Given the limited ground truthing available at this time, they are included within the prospective volume estimates pending further direct sampling evaluations.

Prospects 1 to 12 are located on the West Erksak High, 13 to 20 within the Erksak Channel, 21 and 22 on the Uviluk High, 23 to 27 on James Shoal Extension and 31 to 33 within the Kugmallit Channel. Prospects 28 to 30 are on the James Shoal Extension, but have been defined by borehole and grab sampling only.

From the table summary, 364 km^2 show no or virtually no surficial cover (30 cm or less from the acoustics), 146.8 km^2 lie between the 0 and 1 m contours, 294.1 km^2 lie between the 1 and 2 m contours and 192.2 km^2 lie between the 2 and 3 m contours. In total, 997 km^2 of the total 2,574 km^2 Erksak Borrow Block area are considered to be prospective granular resource areas.

Within this thousand square kilometres, a smaller sub-set of area has been designated as proven reserves based on the borehole and sample control which has allowed us to put a quality factor on the sediment resources. These tightly hatched areas on Figure 7 have been based on an arbitrary assumption that the borehole data represents a region within a one-half kilometre radius of the boreholes. Thus, a sub-prospect is defined either by a 1 km diameter circle or a perimeter defined by a grouping of these circles and also limited by the 3 m overburden contour when appropriate. These sub-prospects have been given designations such as "p4b" where the "p" indicate a proven resource, the "4" indicates that it is within prospective area #4 and the "b" is an alpha designator identifier for that particular sub-prospect.

No attempt has been made on the plot of Figure 7 to spatially define the probable resources within the area as limitations on the seismic coverage would not allow a clear definition that could be mapped. Within the following volume of resource discussion, a summary attempt has been made to delineate the probable reserves available within the prospective zones.

5.0 Resource Prospect Granular Volume Estimates

5.1 Proven

Of the 33 prospects outlined above, only 8 have been sampled by borehole testing with sufficient detailed analysis to allow designation of the sediments as a proven reserve. Table 2 summarizes the proven sub-prospects, identifies the borehole control and assigns a short summary quality evaluation to each. In reviewing the boreholes, an estimate of the volume of useable borrow material has been made either on the basis of sampling depths of the boreholes (limit of sample depth) or on layering within the sediments which would indicate that fines are below and it would not be worth deeper dredging. Their dredgeability in terms of dredge type has also been indicated. This is based primarily on the overburden cover and the granular materials.

In total, there are 60.3 km^2 of proven resource areas defined and these areas provide a relatively firm potential for 720 million cubic metres of recoverable resource materials within the Erksak Borrow Block.

Within the original report, there are detailed discussions on each of these sub-prospects which cannot be discussed here.

5.2 Prospective

Table 3 combines Table 1 with an estimated volume calculation of granular resource that is dredgeable by various dredging techniques that are currently in use. This prospective resource estimate does not take into account a quality factor since only a few of the sites have been tested by borehole sampling.

The breakdown of this table assumes Hopper Trailer dredges that can mine the surface sands to a depth of 2 m below the seabed and are limited to 1 m or less of soft surficial sediment cover for stripping purposes. In this instance, the potential resource recoverable is calculated in the eighth and ninth columns with the total resource recoverable by this method in column ten. Assuming a stationary suction dredge which can strip off up to 3 m of overburden and potentially mine to a depth of 20 m below the seabed, total prospective reserves for depths of 5 and 20 m sub-seabed are computed. These areas and volumes include the proven reserve areas of the previous section.

With these processes, a volume of 948 million cubic metres is potentially recoverable by Hopper Trailer Dredge and if Stationary Suction Dredges are used, a total region potential of 18.9 billion cubic metres of prospective resource are possible.

5.3 Probable

The above two sections have provided estimates of the proven and prospective resources within the Erksak Borrow Block. An estimation of the probable proportion of useable reserve from the prospective total above is attempted here. Probable reserve is defined a sands and gravels whose existence and quality has been inferred on the basis of limited ground truthing information and/or several types of indirect evidence including side scan sonar, shallow high resolution seismic, echo sounding and/or bathymetric and/or geologic considerations. These estimates are based on an understanding of the proven reserves determined by boreholes and a comparison with the seismically mapped prospective zones to provide a "best estimate" of probable resource for planning purposes.

Within the Erksak borrow block there are basically three types of prospective granular resource deposits which have been outlined by the seismic mapping program. The upland regions of the West Erksak High, the Uviluk High and the James Shoal Extension contain two basic reserve types. The bar and island features within the Kugmallit and Erksak Channels are the third type. On the upland regions, the reserve consists of exposed remnants of Unit C sand materials as the basal material and of the re-worked coarse materials which are noted as migrational ridges and progradational wedges that have extended the upland regions into the lower lying channels. The re-worked materials may represent Unit C materials if they had been deposited prior to transgression within a sub-aerial or riverine environment or lower facies of Unit B materials if deposited in the near shore breaker zone or current controlled deposition associated with the last transgression of the sea across the region.

The available data have been reviewed on the basis of probability of occurrence of unacceptable sediment layers or limiting zones within each deposit. Although it has not been possible to map, in detail, specific features which indicate a significant probability of containing higher quality materials, volumes have therefore been estimated by applying an interpretive reduction factor to the estimates of prospective resources. Table 4 summarizes these estimates of probable resources in the Erksak Block.

Utilizing these quality factors, the probable granular resource estimate for the Erksak Borrow block reduces to 7.4 billion cubic metres from the almost 19 billion cubic metre prospective reserve. In particular, the area of the James Shoal Extension has been significantly restricted in these evaluations because of the paucity of data over the feature. Therefore, the larger area of the entire feature has been excluded from the tables presented here. If it were to be included, an additional 4 to 6 billion cubic metres might be added within the prospective category of borrow reserve of which 2 to 3 billion might be considered probable.

6.0 Conclusions

The 2,574 km^2 area of the Erksak Borrow Block located in the south central Beaufort Sea continental shelf contains significant quantities of proven, prospective and probable fine to medium grained sandy granular resource materials. The analysis of this region did not indicate any significant concentrations of coarser grained sand or gravel materials, though numerous trace indications were noted from the borehole records.

The region consists of a drowned upland region composed primarily of medium to fine grained sands (Unit C) which had been dissected by a series of channels prior to inundation by the sea within the last 3,000 to 10,000 years. During this time range, the low lying areas of the Kugmallit Channel were inundated toward the southern block area at approximately the same time as the northern upland areas of the prospect were just commencing the transgression process. During this period, the shallower regions of the possibly more ancient Erksak channel system were partially inundated and at some point, left the Uviluk High and the West Erksak High as near shore island features while the James Shoal

Extension area was a promontory point, either attached to the mainland or itself cut off from the mainland by the Uviluk/Niglik Channel system further to the east. All through this process, the upland regions were being eroded both sub-aerially and by the near shore breaker zone and wave base effects of the advancing seas. As sea level rose further, the upland regions were eventually inundated by the sea and were modified by the transgressive erosion activities as the sea progressed through the high energy breaker and wave base erosion zones toward the present day deeper water conditions.

Throughout the transgression process, the surficial sediments of the upland areas were re-worked to form a transgression unconformity with the finer components winnowed out and transported to quiescent regions for re-deposition as Unit B or Unit A materials. The coarser grained sands tended to be transported shorter distances, if at all and in some cases, formed progradational wedges along the edges of the highs or were localized into sand ridges or sand bar features when conditions were correct. These materials form a portion of the granular resource in the region while the main body of the resource is composed of the deeper Unit C materials.

Similar processes were at play prior to marine inundation within the sub-aerial channels of the study area. These process were river and/or wind dominated and contributed to the progradational wedges seen adjacent to the higher regions and formed the river bar features noted within the Erksak Channel and the sub-channels noted within the eastern portion of the Kugmallit Channel. These sedimentary features are technically attached to Unit C; however, in many cases, the distinction between this unit and the higher energy transgressive facies of Unit B are not distinguishable from the seismic or borehole data.

As regions of the borrow site passed through these active zones, accumulations of finer grained sediments began to predominate. These accumulations first began in the deeper water zones and topographic lows and progressed higher on the upland areas as the transgression continued to its present condition.

The original pre-transgression topography and the effects of the transgression process have resulted in the present day conditions within the Erksak Borrow Block. The distribution of the potential borrow materials are concentrated on the upland areas, though significant recoverable materials are available within the Erksak Channel. Much of the eastern portion of the site has not been adequately evaluated within this study as little seismic or borehole data was available. However, bathymetric studies suggest that this area is likely to be relatively silt or clay covered which reduces its attraction.

The geophysical and geotechnical data utilized through this survey did indicate the presence of shallow sub-seabed permafrost in the area. It is, however, of the Hummocky type APF and relatively randomly distributed. In most cases, it is greater than 10 m below the seabed. As a result this hazard to dredging will locally be significant to the utilization of deep stationary dredging methods. On the regional basis, however, it is felt that permafrost does not seriously degrade the assessment of the viable resource in the area.

Analysis of the geophysical and geotechnical data base has shown that almost 720 million cubic metres of relatively fine grained granular resource have been proven. Within the entire Borrow Block, the geophysical data have outlined a maximum potential of some 19 billion cubic metres of prospective borrow material of which about 950 million cubic metres could potentially be recovered by Hopper Trailer dredge (5%). Of this prospective recoverable material, it is estimated that something in the order of 7.4 billion cubic metres would be in the category of probable recoverable resource when quality factors and an estimation of the variability of sub-surface conditions are taken into account. It is noted here that the entire James Shoal Extension physiographic region may be considered as a prospective area, but was not included in these volume estimates because of the paucity of available data in this area.

These estimations are based primarily on the relatively large, but variously distributed geophysical and geotechnical data sets that are presently available for the area. It is noted here that these data sets are not sufficient to define an actual borrow utilization development program and further detailed site survey and borehole quality assessment programs are required within any local area prior to commencing any actual dredging activities.

Table 1
Areas of Granular Resource Prospects - Erksak

Site No.	Water Depth Range (m)	AREA (km^2)				
		Overburden Cover Thickness				
		0 m	0-1 m	1-2 m	2-3 m	Total
West Erksak						
1	15-26	217.0	42.1	47.8	21.8	328.7
2	26-28	16.8	10.2	16.4	8.4	51.8
3	23-25	10.2	5.8	10.9	5.6	32.5
4	26-34	32.1	13.4	19.6	11.7	76.8
5	36-48	2.1	2.0	7.2	1.7	13.0
6	34-36	2.9	7.2	5.7	2.0	17.8
7	36-38	1.8	3.9	7.8	10.6	24.1

Table 1
Areas of Granular Resource Prospects - Erksak

Site No.	Water Depth Range (m)	AREA (km^2)				
		Overburden Cover Thickness				
		0 m	0-1 m	1-2 m	2-3 m	Total
West Erksak Channel (Continued)						
8	37-38	1.2	1.6	7.7	2.7	13.2
9	32-35	5.7	8.7	18.0	6.7	39.1
10	32-34	0.7	2.4	4.6	2.0	9.7
11	28-33	1.6	8.6	14.7	6.9	31.8
12	24-29	8.9	21.0	14.3	15.5	59.7
Erksak Channel						
13	30-35	-	1.1	13.5	7.8	22.4
14	30-33	-	-	7.3	7.2	14.5
15	28-31	-	-	7.0	5.4	12.4
16	14-19	-	3.3	8.4	15.6	27.3
17	20-33	2.2	4.4	30.9	22.5	60.0
18	16-23	-	-	20.4	6.2	26.6
19	15-19	-	-	-	6.5	6.5
20	14-20	-	-	9.5	10.9	20.4
Uviluk High						
21	26-30	23.0	2.8	4.8	4.8	35.4
22	30-32	16.6	5.5	5.5	4.5	32.1
James Shoal Extension						
23	26-28	-	1.1	1.4	0.7	3.2
24	27-30	-	1.1	8.4	1.6	11.1
25	28-30	-	-	0.2	0.3	0.5
26	28-30	-	-	0.1	0.3	0.4
27	28-30	-	-	0.3	0.6	0.9
JSE (boreholes only)						
28	20-22	0.8	-	-	-	0.8
29	8-11	5.3	-	-	-	5.3
30	8-11	15.0	-	-	-	15.0
Kugmallit Channel						
31	46-51	-	0.6	1.7	0.7	3.0
32	50	-	-	-	0.3	0.3
33	50-55	-	-	-	0.8	0.8
TOTAL AREAS		363.9	146.8	294.1	192.2	997.0

Table 2
Proven Granular Resource Estimates

Prospect I.D.	Water Depth (m)	Area $X10^6m^2$	Boreholes I.D. Reference Nos.	Quality Comments	Dredgeability	Volume $X10^6m^3$
p1a	14-17	8.57	EK84S01-EK84S07, EK84S1A-EK84S7A, UB80-40, UB80-41	SP-SM trace silt & clay	Variable	85
p1b	20-23	7.06	UB82S04, S21, S22, S23, S24, S25, S3A, UB82V05, V06, V20, V21, SUB8301	SM to SP, some silt layers	Hop & Sta	141
p1c	23-25	12.67	BTN1-1, -4, -5, -6, -7, -8, -9, UB80-38, UB82S26, UB82V18, V19	SM, some silt clay layers	Hop & Sta & Possible Sta	123
p1d	23-24	0.79	UB80-39	SM to SP	Hop & Sta	16
p1e	25-26	0.44	KBVC03	SP, SP-SM loose S & org to 2.8 m	Hop & ?Sta	8
p1f	26	1.52	KBBH1-KBBH5	SM to SP, clean trace gravel	Sta	30
p1g	24	0.79	SUB83S01	SM to SP	Sta & Hop	16
p1h	25-26	0.79	NT82S01	SP, clay @ 5.5 m peat @ 6.5	Hop	4.3
p1i	22-23	0.79	UB82S01, S02	SP to 10 m trace silt	Hop & Sta	8
p1j	26-27	0.44	UB80-45	SP, SP-SM 2.5 m clay, sand to 10.5 m	n/a	0
p2a	26-28	3.36	UB82V09-B82V14	SP occ SM trace silt	Hop to Sta	27
p4a	28-30	2.77	BTN1-2, -13, -14	SP - SC some silt & clay sampled to 5 m	Hop ?Sta	14
p4b	29	0.79	UB82V07, V08	Excessive fines marginal	n/a	0
p4c	26	1.17	K682S02, S03	SP, SP-SM trace silt & gravel	Sta	22
p14a	32	0.91	NU82S01, S03	SM to ML too much fines	n/a	0
p18a	21-22	0.085	UB80-42	SM only sampled to 7 m	Sta	0.4
p21a	26-28	0.79	UV80-54	SM with some silts sampled to 9 m	Hop & Sta	7
p22a	29-32	10.54	FUVI1, 1A, UV80-46 TO -52, UV80-55 TO -58	SP-SM trace silt, clay & gravel	Hop & Sta Localized	105
p28a	22	0.79	UB80-44	SP-SM some thin silt/clay layers	Sta (to 14 m)	10
p29a	8-12	5.27	AL80-1 to -18	SP, SP-SM some thin silt	Hop & Sta Localized	100
Totals		**60.335 km^2**		**Total Proven Volume**		**720.7**

Table 3
Prospective Granular Resource Volume Estimates

Borrow Site	WD m Range	Area: 0 m cont km^2	Area: 0-1 m cont km^2	Area: 1-2 m cont km^2	Area: 2-3 m cont km^2	Volume Estimates Times $10^6\ m^3$: Under 0 m	Hopper Dredge to 2 m Depth: Under 0-1 m	Total Hopper	Stationary Suction to 3 m of Cover: 5 m Depth	Stationary Suction to 3 m of Cover: 20 m Depth
West Erksak High										
*1	15-26	217.0	42.1	47.8	21.8	434.0	63.2	497.2	1,496.3	6,426.8
*2	26-28	16.8	10.2	16.4	8.4	33.6	15.3	48.9	208.3	985.3
3	23-25	10.2	5.8	10.9	5.6	20.4	8.7	29.1	129.3	616.8
*4	26-34	32.1	13.4	19.6	11.7	64.2	20.1	84.3	318.7	1,470.7
5	36-48	2.1	2.0	7.2	1.7	4.2	3.0	7.2	49.0	244.0
6	34-36	2.9	7.2	5.7	2.0	4.8	10.8	16.6	71.9	338.9
7	36-38	1.8	3.9	7.8	10.6	3.6	5.9	9.5	80.4	441.9
8	37-38	1.2	1.6	7.7	2.7	2.4	2.4	4.8	46.9	244.9
9	32-35	5.7	8.7	18.0	6.7	11.4	13.1	24.5	147.4	733.9
10	32-34	0.7	2.4	4.6	2.0	1.4	3.6	5.0	35.4	180.9
11	28-33	1.6	8.6	14.7	6.9	3.2	12.9	16.1	115.4	592.4
12	24-29	8.9	21.0	14.3	15.5	17.8	31.5	49.3	227.8	1,123.3
Erksak Channel										
13	30-35	-	1.1	13.5	7.8	-	1.7	1.7	71.7	407.7
*14	30-33	-	-	7.3	7.2	-	-	-	43.6	261.1
15	28-31	-	-	7.0	5.4	-	-	-	38.0	224.0
16	14-19	-	3.3	8.4	15.6	-	5.0	5.0	83.3	492.8
17	20-33	2.2	4.4	30.9	22.5	4.4	6.6	11.0	195.2	1,095.2
*18	16-23	-	-	20.4	6.2	-	-	-	86.9	485.9
19	15-19	-	-	-	6.5	-	-	-	16.3	113.8
20	14-20	-	-	9.5	10.9	-	-	-	60.5	366.5
Uviluk High										
21	26-30	23.0	2.8	4.8	4.8	46.0	4.2	50.2	156.4	687.4
22	30-32	16.6	5.5	5.5	4.5	33.2	8.3	41.5	138.3	619.8
27	28-30	-	-	0.3	0.6	-	-	-	2.6	16.1
James Shoal Extension										
23	26-28	-	1.1	1.4	0.7	-	1.7	1.7	11.6	59.6
24	27-30	-	1.1	8.4	1.6	-	1.7	1.7	38.4	204.9
25	28-30	-	-	0.2	0.3	-	-	-	1.5	9.0
26	28-30	-	-	0.1	0.3	-	-	-	1.1	7.1

Table 3
Prospective Granular Resource Volume Estimates
(Continued)

Borrow Site	WD m Range	Area: 0 m cont km²	Area: 0-1 m cont km²	Area: 1-2 m cont km²	Area: 2-3 m cont km²	Volume Estimates Times 10^6 m³: Under 0 m	Hopper Dredge to 2 m Depth: Under 0-1 m	Total Hopper	Stationary Suction to 3 m of Cover: 5 m Depth	Stationary Suction to 3 m of Cover: 20 m Depth
JSE (boreholes only)										
*28	20-22	0.8	-	-	-	1.6	-	1.6	4.0	16.0
*29	8-11	5.3	-	-	-	10.6	-	10.6	26.5	106.0
30	8-11	15.0	-	-	-	30.0	-	30.0	75.0	300.0
Kugmallit Channel										
31	46-51	-	0.6	1.7	0.7	-	0.9	0.9	10.4	55.4
32	50	-	-	-	0.3	-	-	-	0.6	4.4
33	50-55	-	-	-	0.8	-	-	-	1.9	13.1
TOTALS		**363.9**	**146.8**	**294.1**	**192.2**	**727.8**	**220.2**	**948.0**	**3,990.0**	**18,945.0**

Note: "*" indicates borehole control within the prospect area.

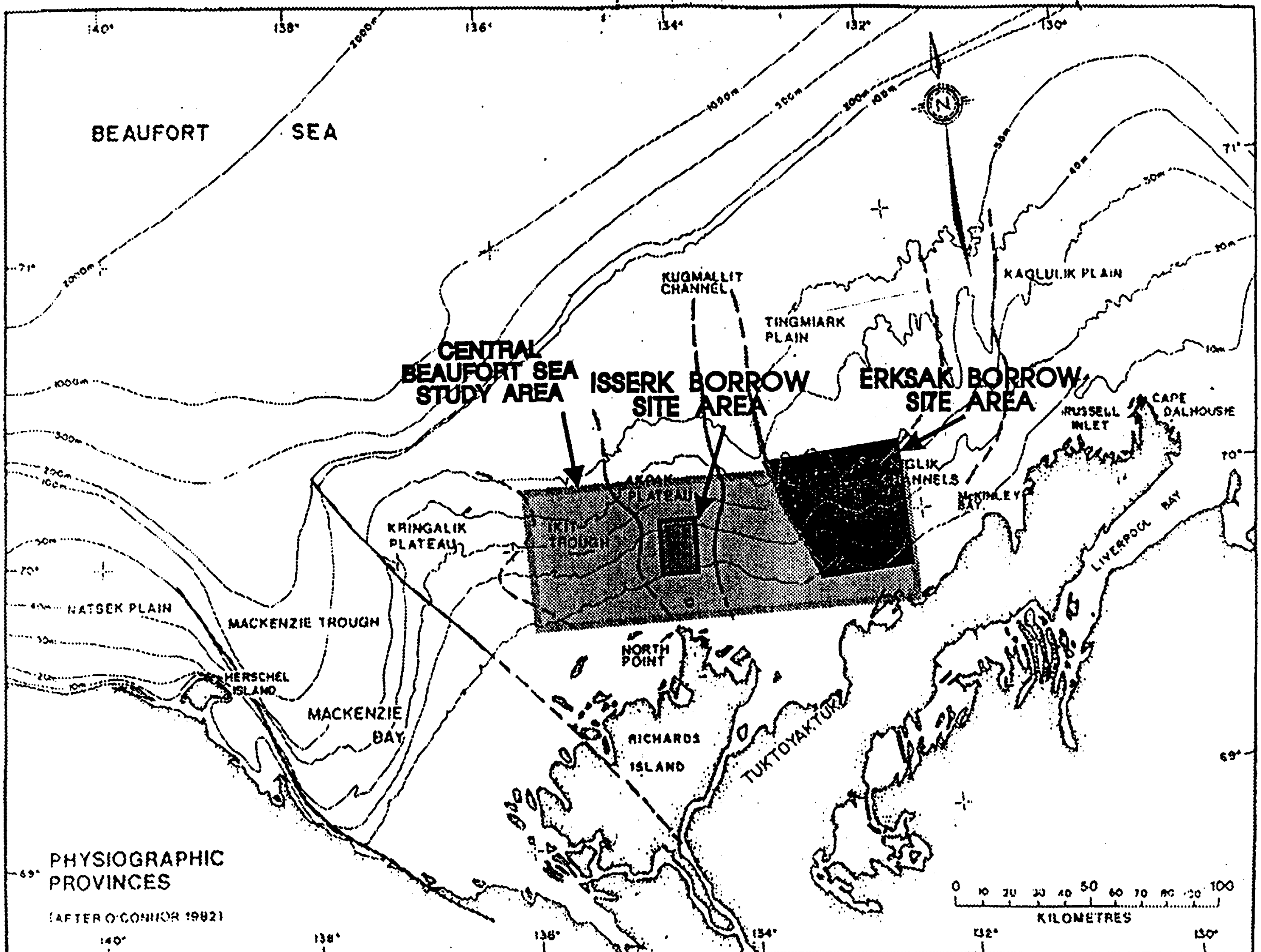
Table 4
Probable Granular Resource Estimates

Site ID	Proven $10^6 m^3$	Prospective $10^6 m^3$	Probable $10^6 m^3$	Comments
West Erksak High				
1	431.3	6,426.9	3,000	Trend toward increasing fines in a northerly direction with considerable fine bedding noted on the seismic records suggesting an increase in the silt and clay component of the sediments. Resource quality is noted to vary significantly with small positional change in borehole tests; thus, estimate 50% to 60% of the prospective resource will be unacceptable though on a localized basis.
2	27	985.3	400	
3	na	616.8	300	
4	36	1,470.7	500	
5	na	244.0	100	
6	na	338.9	100	
7	na	441.9	150	
8	na	244.9	100	
9	na	733.9	200	
10	na	180.9	75	
11	na	592.4	200	
12	na	1,123.3	400	
Erksak Channel				
13	na	407.7	40	Northern reworked-assume low quality factor.
14	0	261.1	25	Northern reworked-assume low quality factor.
15	na	224.0	20	Northern reworked-assume low quality factor.
16	na	492.8	120	Increasing quality southward.
17	na	1,095.2	210	Increasing quality southward.
18	0.4	485.9	240	Good quality proven borehole.
19	na	113.8	70	J.S. Extension.
20	na	366.5	220	J.S. Extension.
Uvliuk High				
21	7	687.4	350	Good proven component; therefore, estimate 50% utility with some localized fine lenses and ignore prospect 27.
22	105	619.8	310	
27	na	16.1	-	
James Shoal Extension				
23	na	59.6	10	Small targets with probable fair to good quality, but sediment cover reduces probability of utilization.
24	na	204.9	40	
25	na	9.0	2	
26	na	7.1	1	

Table 4
Probable Granular Resource Estimates
(Continued)

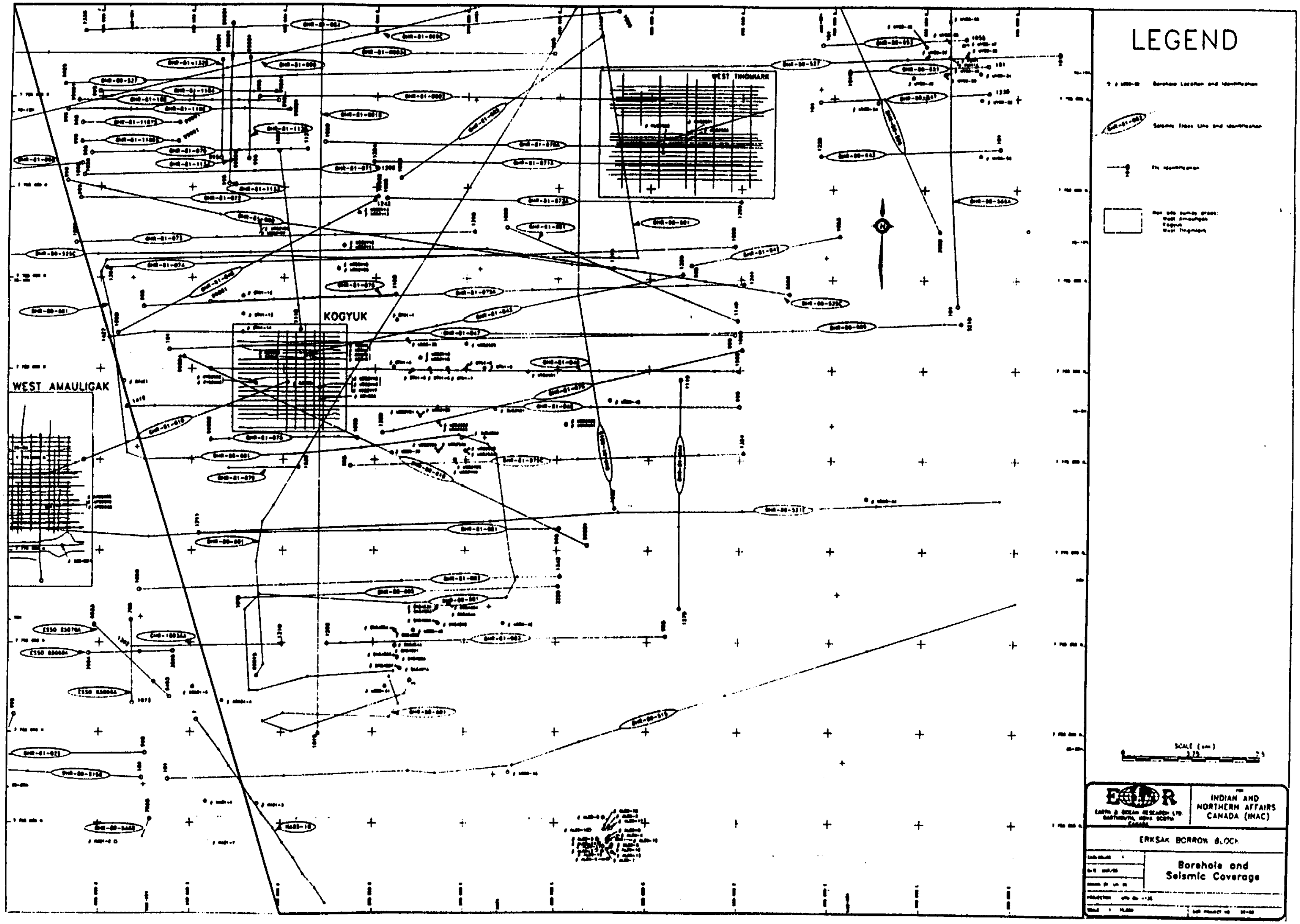
Site ID	Proven 10^6 m^3	Prospective 10^6 m^3	Probable 10^6 m^3	Comments
JSE (boreholes only)				
28	10	16.0	6	Good potential with some fines component and moderately well proven, though significant surficial cover stripping required.
29	100	106.0	75	
30	30	300.0	150	
Kugmallit Channel				
31	na	55.4	0	Small targets of reworked sediment likely containing significant fines and significant surficial cover to strip off.
32	na	4.4	0	
33	na	13.1	0	
TOTAL	**747.7**	**18,945.0**	**7,414.0**	

<u>Note</u>: "na" = no samples available to prove reserve.



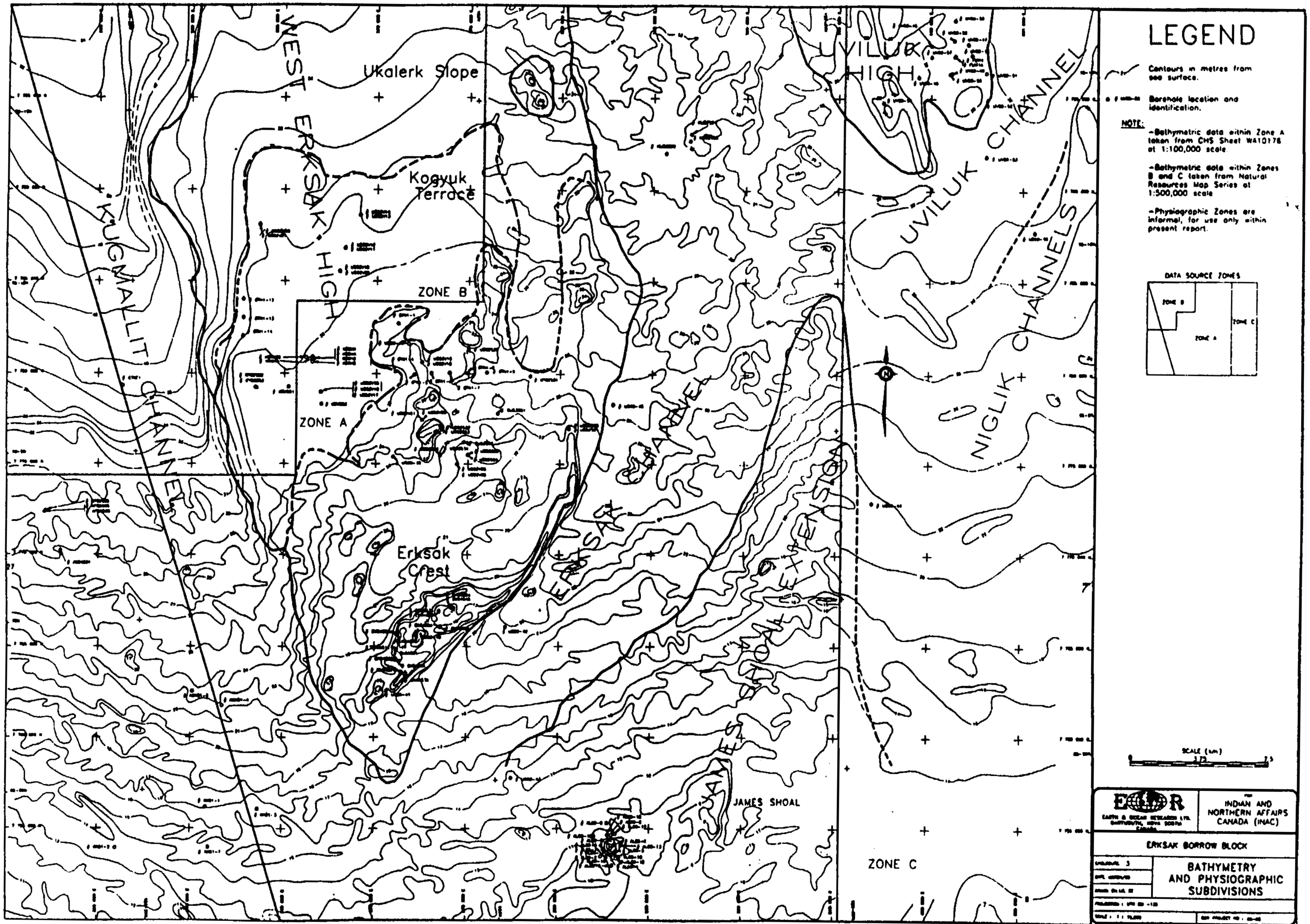
LOCATION DIAGRAM

FIGURE 1



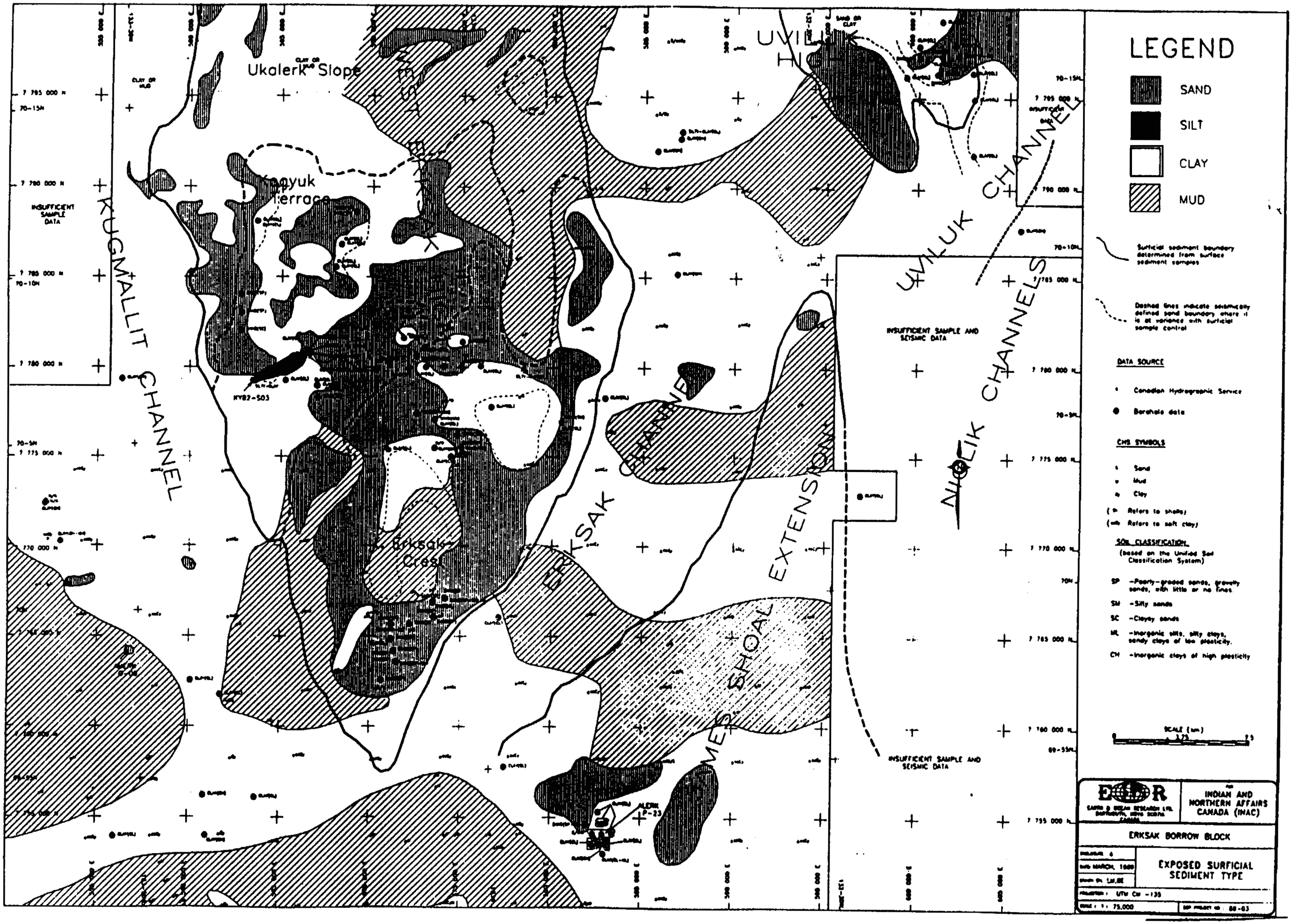
BOREHOLE AND SEISMIC COVERAGE

FIGURE 2



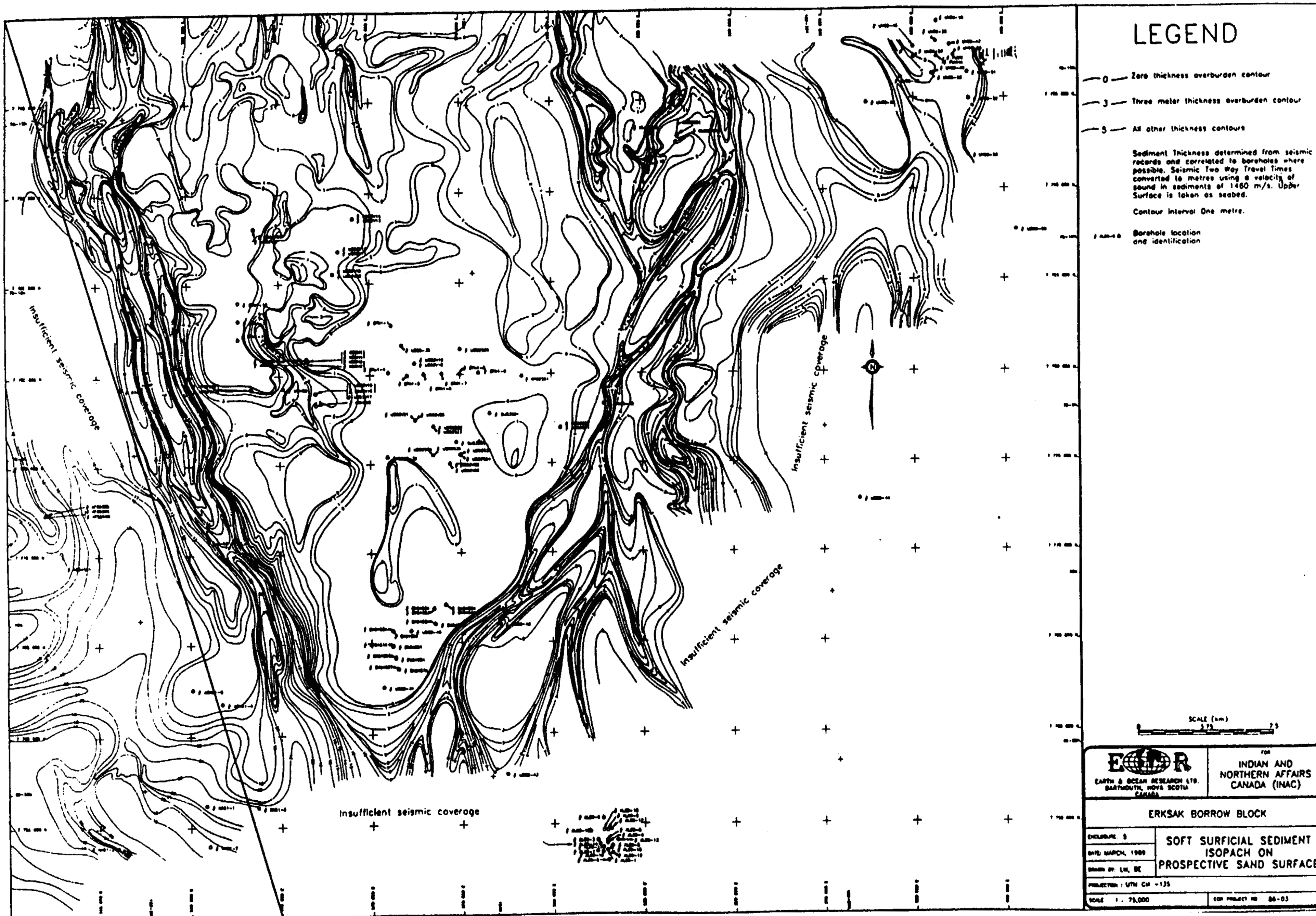
BATHYMETRY AND PHYSIOGRAPHIC SUBDIVISIONS

FIGURE 3



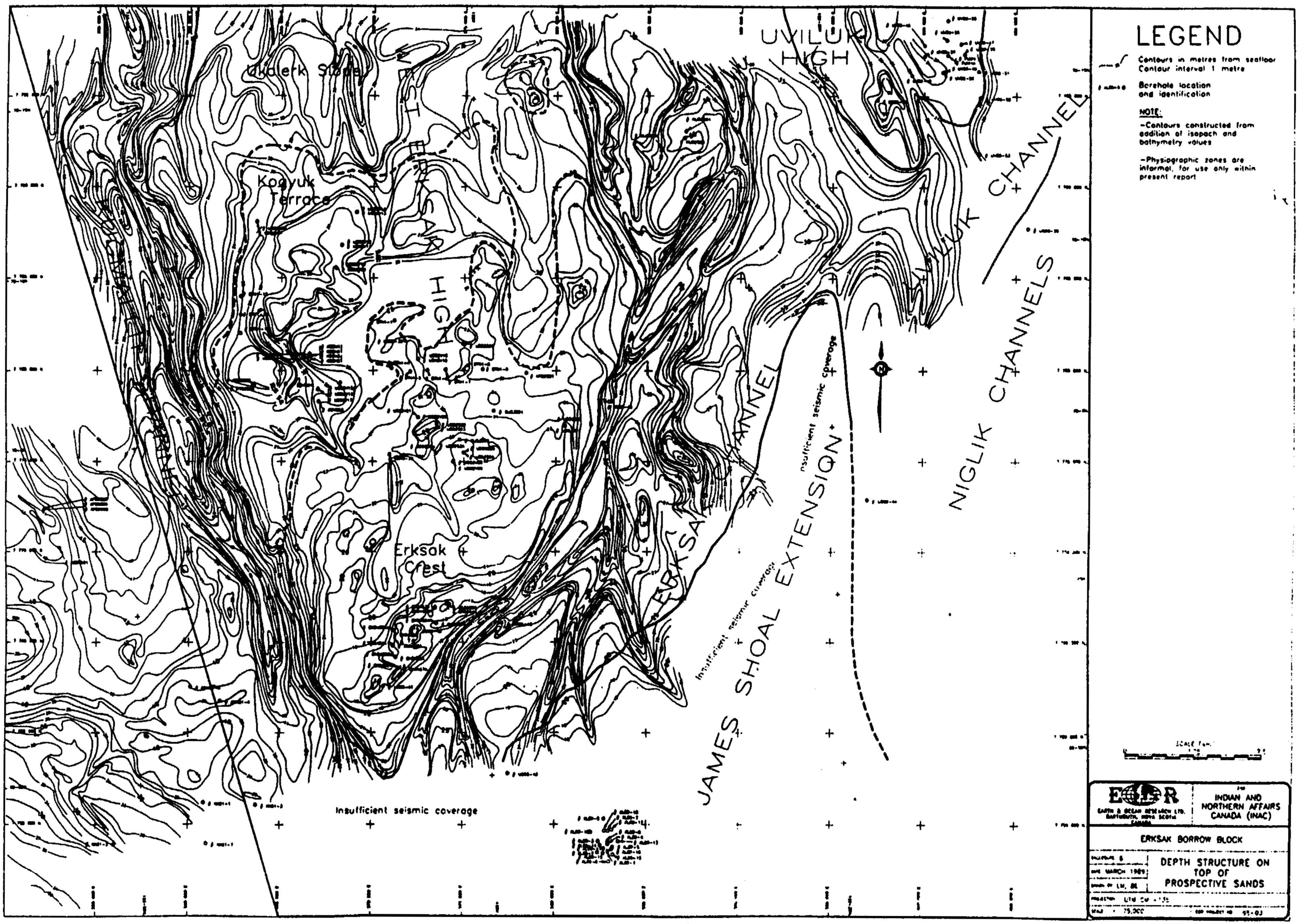
EXPOSED SURFICIAL SEDIMENT TYPE

FIGURE 4



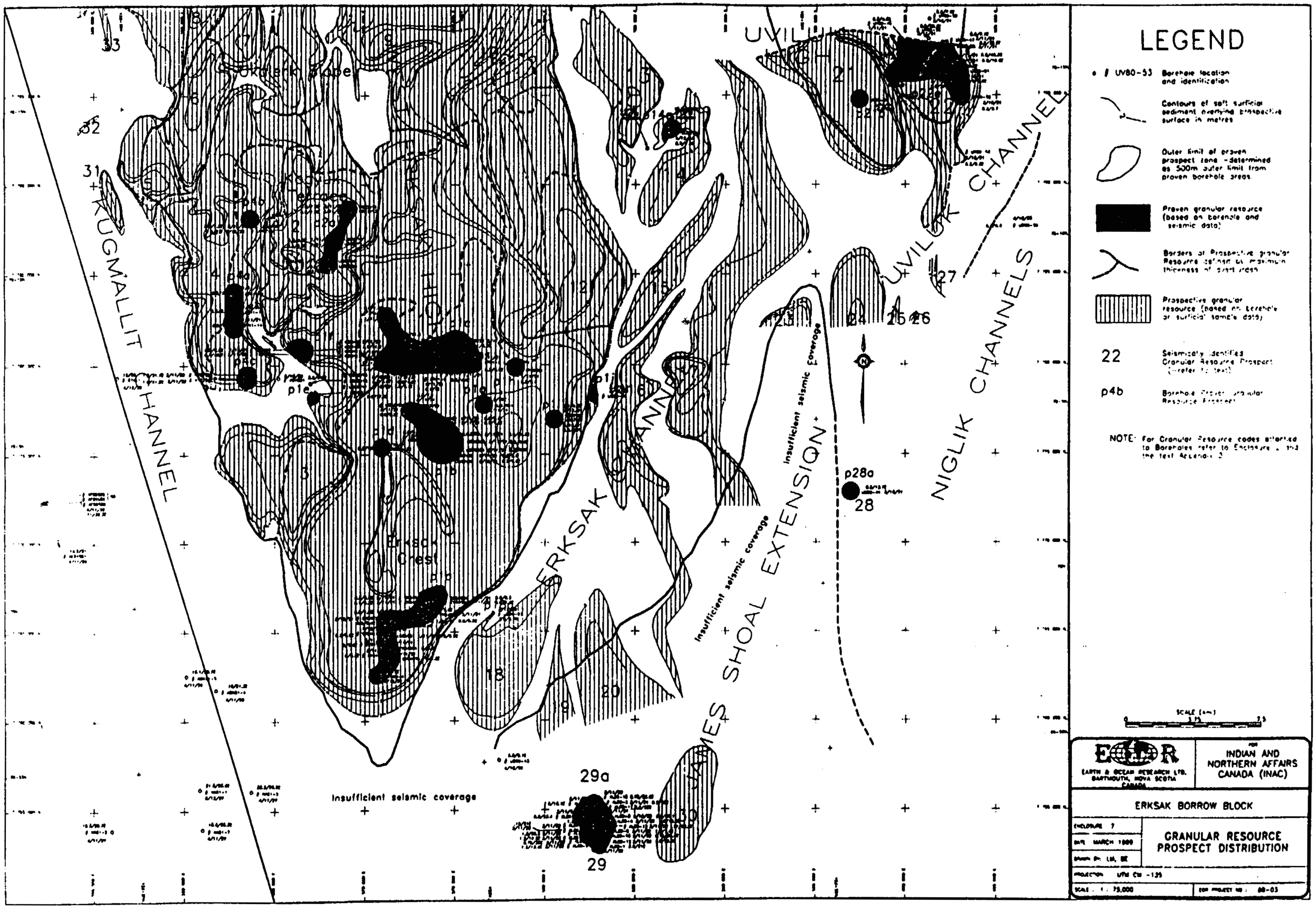
SOFT SURFICIAL SEDIMENT ISOPACH ON PROSPECTIVE SAND SURFACE

FIGURE 5



DEPTH STRUCTURE ON TOP OF PROSPECTIVE SANDS

FIGURE 6



GRANULAR RESOURCE PROSPECT DISTRIBUTION

FIGURE 7