PROCEEDINGS OF THE BEAUFORT SEA GRANULAR RESOURCES WORKSHOP

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PART 1

REPORTS ON NOGAP REGIONAL STUDIES

The Isserk Borrow Block
(NOGAP Project A4-20)

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1.0 Introduction

The Isserk Borrow Site study program was one component of a set of 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 site area and Volume 2 is the Erksak borrow site area which was discussed in Part A. The other 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 western Isserk study region (Figure 1) which is a 20 km x 20 km area of 400 km^2 lying approximately 9 km north or Pullen island. The study region defined as to be within the following boundaries:

- Northwest: Zone 8; 520,000E; 7,770,000N (70°02'16"N; 134°28'30"W).
- Northeast: Zone 8; 535,000E; 7,770,000N (70°02'10"N; 134°04'53"N).
- Southwest: Zone 8; 520,000E; 7,750,000N (69°51'31"N; 134°28'47"W).
- Southeast: Zone 8; 535,000E; 7,750,000N (69°51'25"N; 134°05'22"W).

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 initially 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 industry Beaufort 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.

Figure 2 shows the navigation track plots for only the industry operator survey lines that matched geophysical records that could be located and accessed for these study programs. Figure 3 shows the compiled navigation track plots of the government survey lines that were available to the study and were selectively accessed as required. Figure 4 shows the more limited area of the Isserk borrow site and the geophysical records available for just this area.

In general, the overall geophysical data set is of good, but variable quality. The quality is, however, dependent on weather conditions at the time of collection. Unfortunately, the

Isserk geophysical data set is an exception to this statement and is of limited use in determining stratigraphy equivalency of textural units between boreholes. There are a number of reasons for this.

- Significant data sets collected in 1983, 1984 and 1985 could not be located during the data search.

- Within the remaining data set, the line density is too low over much or the region to accommodate the high variability in texture and elevation of units within and between boreholes. The seismic data commonly shows many small local depressions or channel like features in the top of Unit C (basal sands) that are 100 to 500 m in width over relatively short distances along any line. To confidently map these details, a line spacing of 500 m or less is required which is not achieved in this data set. As a result, considerable interpretive licence has been required in the construction of contours of this surface and the detail of the borrow structures which will be discussed here.

- The data quality of the remaining lines is again variable and 30 to 40% of these lines are of relatively poor quality which further restricts their usefulness

These limitations largely restrict the litho-stratigraphic correlation of the Isserk Borrow Block to a study of the borehole stratigraphy and to the extent the seismic data can contribute, it has been incorporated into the geological model.

Appendices 1 and 2 of the text reports (Meagher and Lewis, 1988) 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

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.

For illustration, Figures 2 and 3 show the locations of all of the almost 400 boreholes within the south central Beaufort area. Figure 4 showed the combined survey lines and the 99 borehole locations within the Isserk study area only.

The boreholes within the Isserk borrow block area tend to be clustered into four main groups within the region which were drilled for exploration island sites and a more regional area associated with previous work on the core area of the borrow prospect itself. 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

3.1 Physiography

The Isserk Borrow Block area lies on the Akpak Plateau (O'Connor, 1982) in 8 to 24 m of water (Figure 1). This region is a submerged upland physiographic region located in the south central Beaufort Sea. The Akpak Plateau is a trapezoidal shaped region of slightly convex seaward bathymetric contours trending almost northerly from the area of North Point on Richards Island virtually out to the shelf edge. It is bounded to the east by the Kugmallit Channel and to the west by the Ikit Trough. The area is characterized by an elevated regional unconformity surface defining the top of Unit C relative to the adjoining depression areas.

3.2 Bathymetry

Figure 5 is a contour map of the bathymetric contours over the Isserk site at a 1 m contour interval. These contours are considerably smoothed as the contours were developed by a re-contouring of the CHS worksheet which were surveyed in 1969 and 1971. These worksheets were displayed at a 1:100,000 scale and line spacings were 800 to 1,500 m. The region has been resurveyed in 1985/1986, though the newer data was not available at the time of this study and it is anticipated that the this newer data, which is more accurately positioned and of a higher line density, will modify the shape and detail of the contours to some degree.

Overall, the contours show a gently dipping plain dipping northward over the southern half and to the north-northeast over the northern half of the site. The seafloor is slightly raised along a north-south axis through the west-centre of the site and again along a northwest-southeast axis near the southeast corner. The ridges are separated from each other and are possible expressions of different geologic features.

Water depths over the site vary from a minimum of 8 m in the southeast corner to a maximum of 24 m in the northeast corner.

4.0 Surficial Cover

The surficial cover over the Unit C sand material is displayed in Figure 6. The construction of this surficial cover map has been defined directly from borehole information and by inference from the seismic data. The map indicates two surficial clay units and a coarser zone of potential borrow materials.

The coarse material occupies roughly the central and west-central part of the block and extends toward the southeast to the southern border of the site. Sample data from the boreholes is available for the coarse material located in the central portion of the deposit. The coarse material is predominantly composed of poorly graded fine sands to silty sands. The sands are non-cohesive, olive brown to dark brown. Occasional gravel clasts from 15 to 25 mm in diameter occur throughout the deposit. The gravel clasts, where described, are polished and sub-rounded. The gravel content increases in pockets located along the southwest edge of the coarse deposit where it is equally dominant with the sand. These deposits are noted as being "gap graded" with the gravels being fine textured and the sands being poorly sorted fine to medium textured.

There are no boreholes within the portion of the coarse zone that extends from the central deposit to the southeast and beyond the southern boundary to the south. Seismic evidence suggests that this zone is composed of a combination of two geologic units. The younger unit is an extension of the central deposit and it is inferred that the texture of this extension will be similar to that of the central zone, i.e., generally poorly sorted silty sands with some gravel. The unit is defined by the transition of the surface character on the micro-profiler and boomer records from an irregular micro-relief to a featureless micro-relief. A slight doming of the seafloor is associated with this change in seismic signature.

The older unit extends from the south and is in contact with the younger in the south-central area. No borehole textural information is available for the deposit within the site, although recent testing of the unit immediately to the south of the block reveals coarse sand and gravel at the seafloor (S. Blasco, personal communication). The boundary of the deposit as outlined on the map, is defined as that area where Unit C rises to within two metres of the seafloor. The seismic data available are not of a sufficient resolution to measure the depth of the unit within this zone and there may be areas within this boundary that are very close to the seafloor. The micro-profiler data do not show the smooth seafloor trace characteristic of sand size sediments at the seafloor across this zone and the deposit may be covered by a thin soft veneer.

The fine material surrounding the coarse deposit consists 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%. 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.

While clay samples from throughout the area share this general variability, those of the Issungnak O-61 group of boreholes (IS78-series) at the northern boundary of the block are more consistently of high plasticity. Those of the Itoyuk I-27 (IT81-series) to the east, Isserk B-15 (B-15-series) to the south and Issungnak South (S81-series) to the west are virtually all low plastic clays. This suggests that the Issungnak O-61 surficial clays are a different body than the clays to the south, a suggestion that is tentatively supported by the seismic data. A somewhat arbitrary boundary has been drawn across the northern end of the survey site to note this change in stratigraphic units.

5.0 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 are identified and facies within these units discerned. The near surface litho-stratigraphy and structure are complex and distinct changes in seismic character are observed vertically and horizontally along individual seismic profiles. Continuity in the seismic data is generally poor and the ability to confidently follow seismic horizons from line to line is low. While varying in detail, the boreholes present a more consistent picture of the general stratigraphy.

Three borehole transects have been constructed; a north-south transect, an east-west transect and a southwest-northeast transect. These are presented as Figures 7, 8 and 9. The orientations are approximate and the transects do not form straight lines as they are determined by the distribution of the boreholes. The geographic positions correlating to these transects has been shown on the seismic track plot and borehole map of Figure 4.

6.0 Top of Unit C

The lowest regionally persistent horizon is a composite of a younger and an older erosion surface, the equivalents of U/C1 and U/CL. The character of each in the borrow block area is distinctive and they are distinguishable one from the other where data quality permits.

The older unconformity forms a highly incised, irregular surface. The surface has been removed by the subsequent erosion episode (U/C1) over the crest of the site and to the east as the Kugmallit Channel is approached. The seismic profiles indicate the irregular lower surface to descend to the east and west from a central high. The extreme irregularity of the horizon suggests an old sub-aerial erosion surface that has not been affected by the transgression.

The structure map presented in Figure 10 describes the shape of the upper surface of Unit C (U/CL unconformity). Where the younger erosion surface has excavated to the top of Unit C, it forms a smooth, featureless plain. The remnant areas that were not affected by this erosion episode display a highly dissected pattern. The surface descends to the north, east and west from an irregular crest that extends from the southeast edge of the site through approximately the site centre and beyond the site boundary to the northwest. The surface descends from a high of 10 m near the southern border, where it lies at or near the seafloor, to 34 m at the northwest edge of the survey coverage. As the surface descends, there is progressively less planation by the later erosion episode, with the result that the map displays an increasingly more complex topography to the north.

7.0 Depositional Summary

Predominantly fine to medium sand was deposited as Unit C through channel cut and fill processes in a locally variable, but generally moderate to high energy fluvial or glacio-fluvial environment. Potentially coarser and more resistant material was deposited as a linear body that extended from the southeast corner of the site through the site centre. Subsequent to this deposition, the surface of the unit was down-cut under sub-aerial conditions to form a highly irregular topography of small channels and mounds (Figure 11a). The more resistant body was down-cut to a lesser extent and formed the positive core for the plateau in this area. During this period, material was moved downslope via the gullies and also on the interfluves via dune formation. On the eastern flank of the plateau, leading down into the Kugmallit Channel, coarse material was aggraded into dune-like bed forms that indicate sediment movement to the east into the channel.

The sculpting of the highly incised topography was followed by a marine transgression that initiated the deposition of Unit B (Figure 11b). Preservation of much of the sub-aerially constructed topography on Unit C suggests that the initial transgression across this area was rapid. Predominantly fine material was deposited in the depressions on Unit C. As the sea level rose, planation of the raised part of Unit C occurred and produced local lag gravel deposits that remained in contact with the source material. A distal sand facies spread out over the clays deposited on Unit C in the basinal areas. This was followed by a period of shallow marine deposition of fine material. A short second regression was followed by a slower transgressive rise in relative sea level, during which time the raised portions of Unit C and the previously deposited Unit B strata were reduced by wave base planation to a smooth surface (Figures 11c and d). The elevated section of Unit C to the south and the previously re-worked Unit B sands and gravels provided the source material for a thin coarse grained deposit centred over the crest of the site. Fine grained clays were deposited coevally away from the crest of Unit C.

With continued transgression, the wave base moved away to the south and the construction of the sand body ceased. The upper sand body was buried by marine clays in the deeper water area to the north. With continued shoreline retreat, this process may be on-going. At present, however, most of the Isserk Block area is floored by old sediments laid down during the most recent transgression.

8.0 Granular Resource Model and Evaluations

The granular resources of the Isserk Borrow Block are located in two geologic deposits of different age, distribution and depositional mode. The upper deposit represents a re-worked deposit associated with Unit B, while the lower deposit consists the Unit C basal material. The distribution of the surficial prospect material is displayed as Figure 12 and the distribution of the lower prospect is shown in Figure 13. These maps incorporate divisions of the reserve into proven, probable and prospective zones. Proven granular resources are defined as those resources whose occurrences, distributions, thickness and quality are supported by considerable ground truthing information such as dredging and/or geotechnical drilling data. Probable reserves are defined as sands and gravels whose existence, extent 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 geological considerations. These estimates are based on an understanding of the proven reserves as determined from boreholes and a comparison with the seismically mapped prospective regions to provide an estimate of probable resource that may represent a viable planning figure for future utilization. Prospective resources are defined as granular resource deposits whose existence and extent are speculated on the basis of limited indirect evidence, such as ripple marks on side scan sonar records or general geological considerations.

Within the Isserk Borrow Block area measurements of overburden and resource thicknesses were made for each borehole. These analyses have revealed that there are two distinct bodies of sand flooring the Isserk block, with the lower sand being ubiquitous and the upper sand being of local extent.

Because of the applicability of this two resource model, the boreholes have been coded and are described in terms of a first encountered coarse unit and a second encountered coarse unit. This allowed spatial display of these data on the map sheets and subsequent contouring and definition of the two prospect areas. From observation, it is apparent that where there is only one sand unit present and the borehole longer than about 10 m, the sand unit present is the older of the two. The only instance where this may not apply is Borehole IB80-84 near the centre of the Isserk block where the upper and lower sands may be in contact with each other.

8.1 Upper Surficial Prospect

The main body of the deposit is roughly triangular in shape and located in the west-central part of the block (Figure 12). A narrow, linear "tail" extends from the southeast edge of the main deposit to near the southeast corner of the block area.

The spatial distribution of this deposit is defined on the basis of borehole control and the seafloor character of the boomer and profiler records. Coarse material on the seafloor, as identified in the boreholes, is associated with a distinct change in character on the seismic records.

While the map in Figure 12 displays the areal distribution of the deposit for the proven, probable and prospective zones, contours indicating the thickness of the deposit are only provided for the proven zone. The thicknesses are derived solely from the borehole logs as the base of the deposit was not observed on the geophysical data.

Twenty-five boreholes have been drilled within the boundaries of this zone. Borehole penetration varies from 4.5 m to 21.4 m with 17 boreholes less than 10 m long. The majority of the boreholes encounter sand at the seafloor and silty or clayey deposits at from 1.25 to 3 m below seafloor. Two boreholes, IB80-84 and IB80-96, record sand from the seafloor to their depth of penetration. Borehole IB80-84 was drilled to a depth of 21.4 m and borehole IB80-96 to a depth of 9.1 m. Three boreholes record a veneer of clay atop the surficial sands. The veneer varies from 0.2 m to 0.6 m. The boreholes IB80-95, IB80-93 and IB78-5 are located in proximity to each other and the clay deposit may form a continuous veneer along the western side and northern tip of the zone.

The proven resource is primarily based on the borehole information and occupies the central part of the deposit with the displayed boundaries defined by both borehole and seismic data. Within this zone, there is a very high confidence that useable granular material occurs. Based on the borehole data, this zone has been further subdivided into zones dredgeable by hopper dredge only and by both hopper and stationary dredge methods. These subdivisions are shown by the heavy dash-dotted line subdivisions within the proven area. The position of these lines has been made using the dredgeability assessments and the development concerns assessment of each of the boreholes and using a simple rule of equidistance between the boreholes within the proven reserve area. Based on these subdivisions, two small regions associated with boreholes IB80-96 and IB80-84 are defined which are categorized as dredgeable with either hopper or stationary dredge. It is assumed that below the approximate 4 m level in each of these regions, one would be mining the lower sand resource as opposed to the upper re-worked Unit B materials.

The probable resource boundaries are based on seismic and limited borehole information. This area is seen to rim the proven region with a tail defined which extends approximately 8 km off toward the southeast from the main body of the deposit. This tail region is defined exclusively with the seismic data.

The prospective region is defined entirely on the seismic data set and is based on bottom character return along with faintly defined internal reflections seen within the data. It may represent an extension of re-worked Unit B materials; however, borehole information would be required to confirm this.

8.2 Lower Basal Prospect

The Lower Basal Prospect represents a region where the unconformity surface representing the top of Unit C comes to within 3 m of the seabed. The 3 m limit has been taken as the practical limit of overburden stripping when a Stationary Suction dredge is utilized. This region is located in the southeastern corner of the prospect area and is highly irregular in shape (Figure 13).

This region is defined almost entirely from mapping of the seismic data and is only confirmed by boreholes in the extreme northwestern tip of the area. Because of this lack of borehole confirmation, the entire prospect is considered to be prospective only at this time. Although some limited quality information is available, the boreholes indicate this lower unit to be highly variable in nature and considerable confirmation drilling will be necessary to confirm this region as a viable resource.

9.0 Resource Prospect Granular Volume Estimates

Table 1 summarizes the estimates of proven, probable and prospective volume of granular resource for the two prospect areas defined in this report. The methods of volume calculation vary slightly for the two prospects in that the upper sand is assumed to represent a body which is exposed at the seafloor and no stripping is required, thus mining is limited to the thickness of the resource. In this case a minimum thickness of one metre is required and volumes are calculated based on the area between the contours times the average thickness assuming a linear proportion distribution between the contour lines (ie. area = 10 m^2, between the 2 and 3 m contours; therefore, volume = 10 m^2 x 2.5 m = 25 m^3). For this upper material, the total volume is taken as the sum of the volumes between all thickness contour lines. The total probable and total prospective resources incorporate the volumes of the higher probability materials.

Within the lower sand body, volumes are calculated based on an assumed thickness of the resource material which reflects the assumed maximum depth of dredging capabilities. Since detailed evaluations of the depth of the resource are not possible at this time, these values are taken as estimations only.

10.0 Conclusions

The Isserk Borrow Block of the south central Beaufort Sea covers an area of 400 km^2 and contains significant amounts of proven, probable and prospective granular resource materials. Through the integration of geophysical, geotechnical and geological data collected over the past 15 years from both industry and government operators, two main deposits were identified. These deposits occur as fine to medium grained sand bodies that lie within a complex sequence of glacio-fluvial, fluvial and transgressive marine type sediments that form a northwest-southeast trending ridge across the Akpak Plateau.

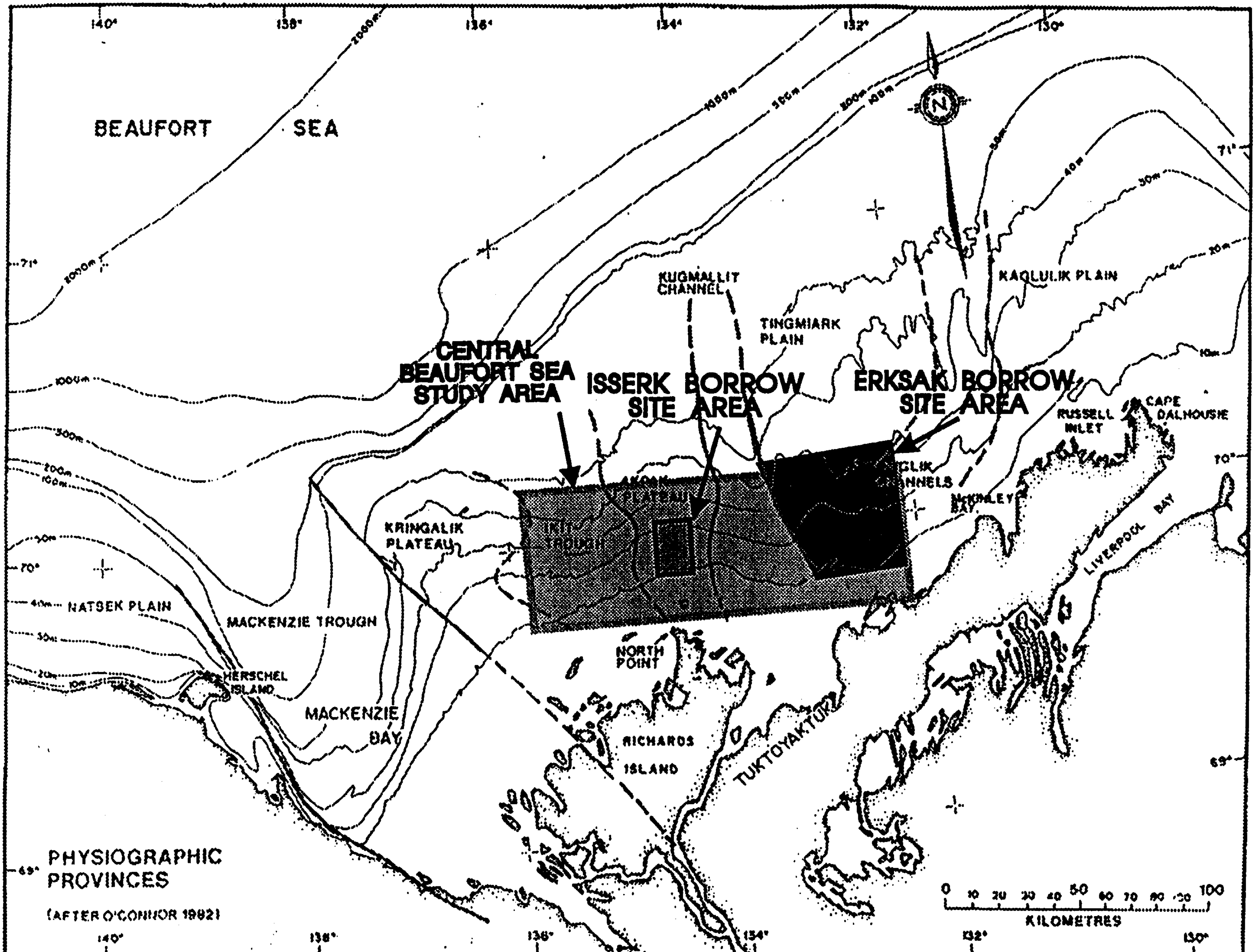
The first deposit (Upper Sand Unit) is a localized shallow sand body which lies in the central portion of the Isserk Borrow Block. Its triangular shape covers an area of approximately 53 million square metres. Borehole and seismic data indicate an estimated 19 million cubic metres of proven, 63 million cubic metres of probable and up to 80 million cubic metres of prospective granular resource materials. The proven resource estimate is based primarily on borehole information and subdivided according to dredging and development concerns.

Table 1
Granular Resource Volume Estimates
Isserk Borrow Block

Unit Thickness (m)	Area ($m^2 \cdot 10^6$)	Volume ($m^3 \cdot 10^6$)
Upper Sand Unit Exposed at the Sea Floor:		
PROVEN RESOURCE		
>1<2	4.483	6.73
>2<3	4.964	12.41
>3<4	5.534	19.37
>4<5	2.896	13.03
>5<6	1.185	6.52
Total Proven Resources	19.062	45.03
PROBABLE RESOURCE		
Assume 1 m minimum	18.006	18.01
Total Resource	37.068	63.04
PROSPECTIVE RESOURCE		
Assume 1 m minimum	16.711	16.71
Total Resource	53.779	79.75
Lower Sand Unit:		
PROSPECTIVE ONLY Portion of Unit C covered by 3 m of overburden or less.		
Assume 1 m	40.840	40.84
Assume 5 m	40.840	204.20
Assume 10 m	40.840	408.00
Assume 20 m	40.840	816.00

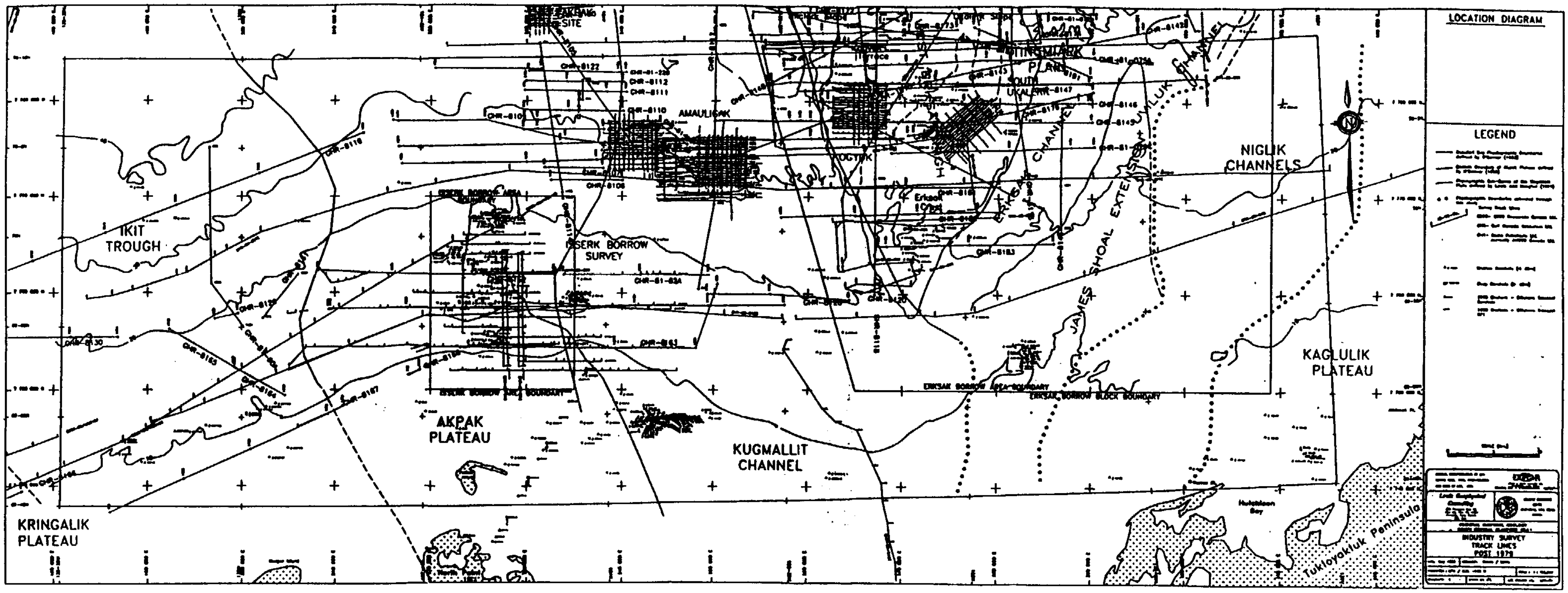
The second deposit (Lower Sand Unit) is a near surface exposure of Unit C which lies in the southeast quadrant of the study area. It is estimated 800 million cubic metres of prospective granular resources is based on limited seismic information only and requires considerable future ground truthing. Of this 800 million, it is likely that only 100 to 300 million might actually be recoverable when permafrost bonding and resource quality are fully considered and delineated.

It is conceivable that the Lower Sand Unit extends beneath the Upper Sand Unit to the northwest, separated, however, by a clay layer of variable thickness. The actual extent and quality of this deposit can only be determined through further investigation.

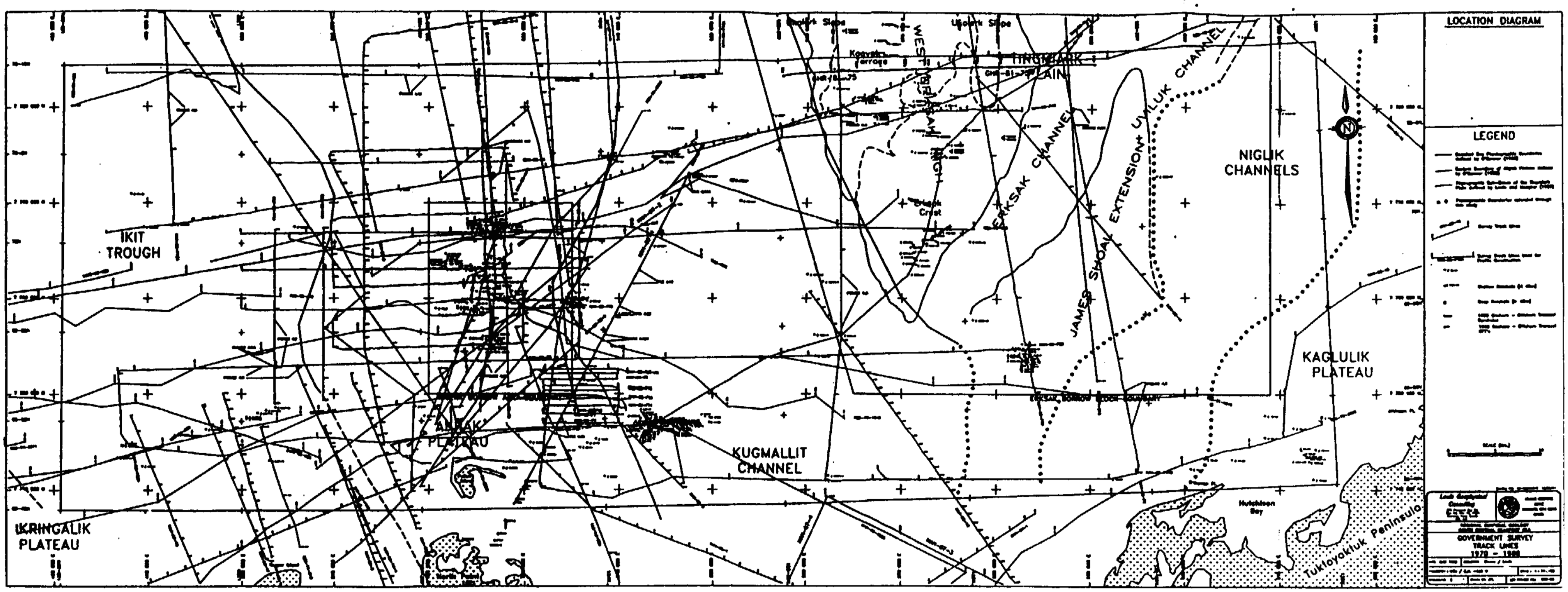


LOCATION DIAGRAM

FIGURE 1

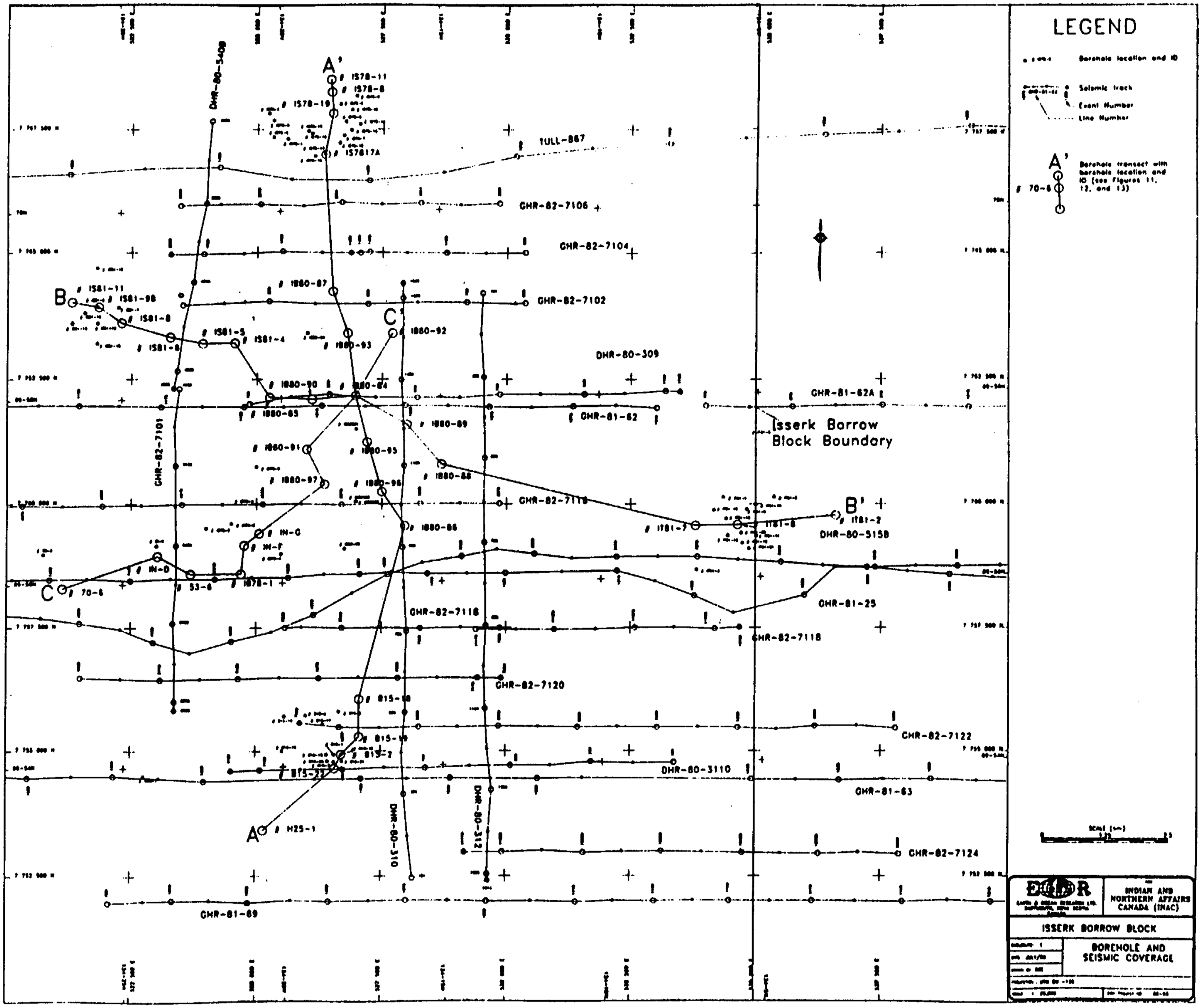


INDUSTRY SURVEY TRACK LINES POST 1979 **FIGURE 2**



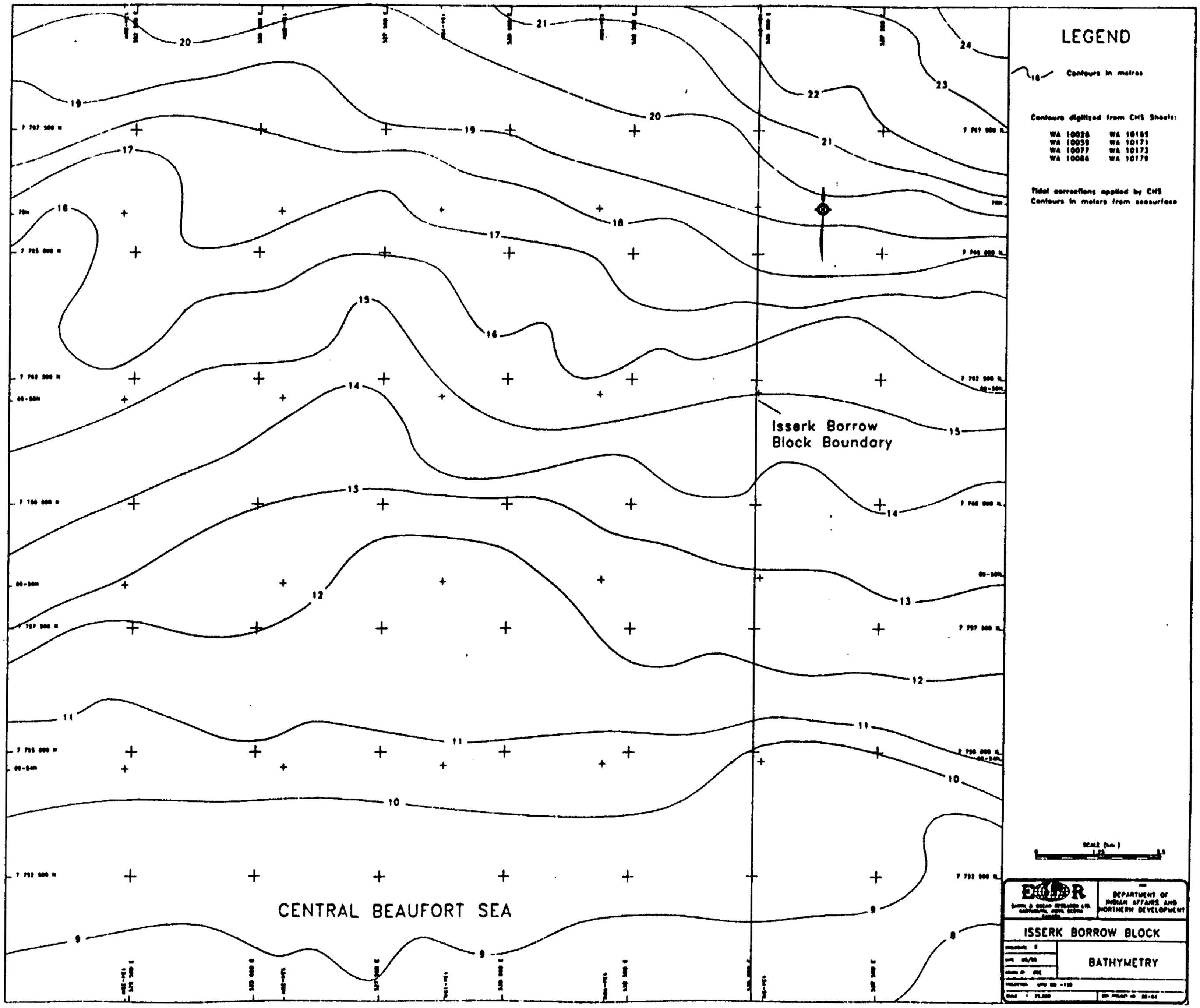
GOVERMENT SURVEY TRACK LINES 1970 - 1988

FIGURE 3



BOREHOLE AND SEIMIC COVERAGE

FIGURE 4



BATHYMETRY

FIGURE 5

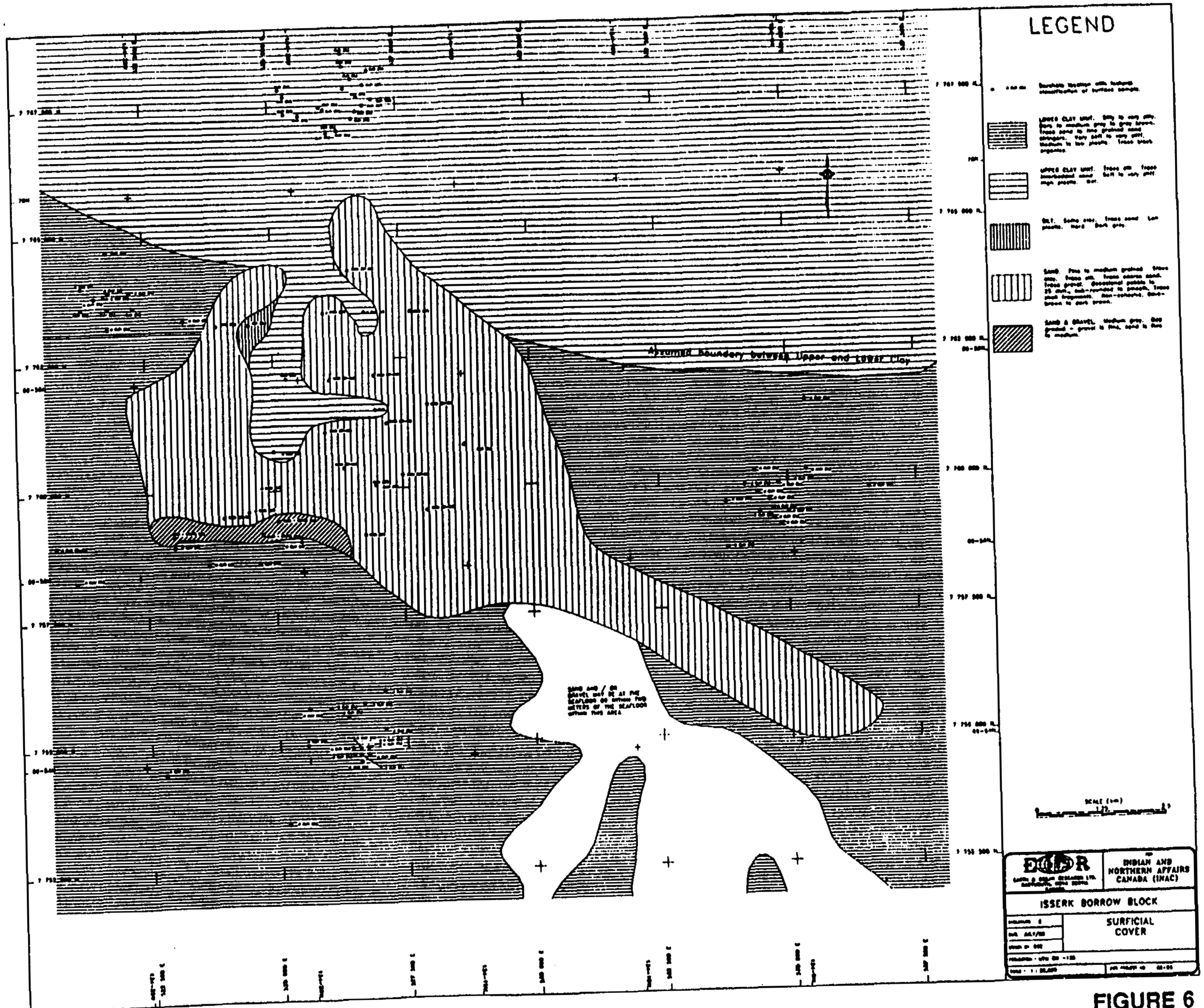
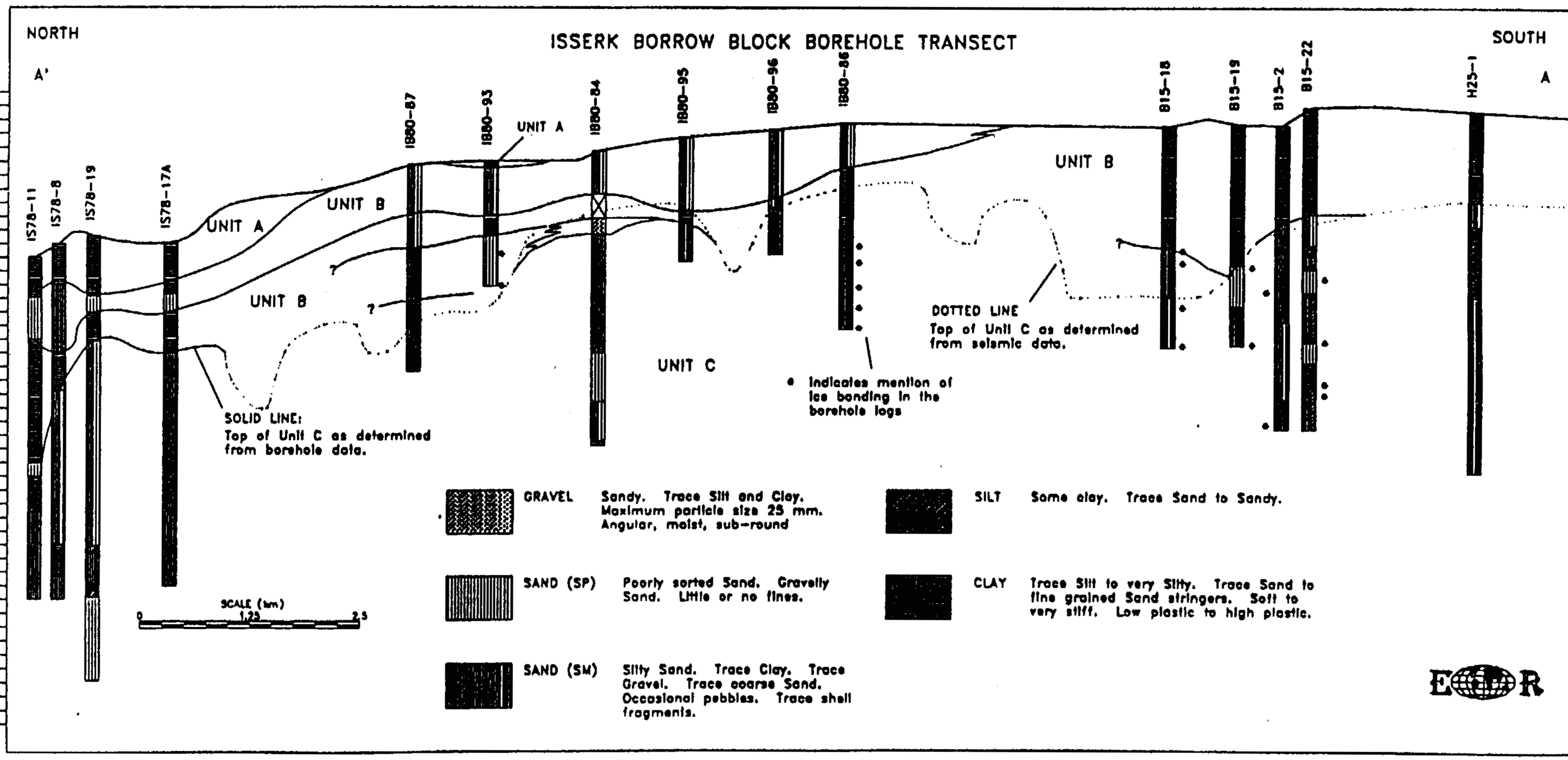


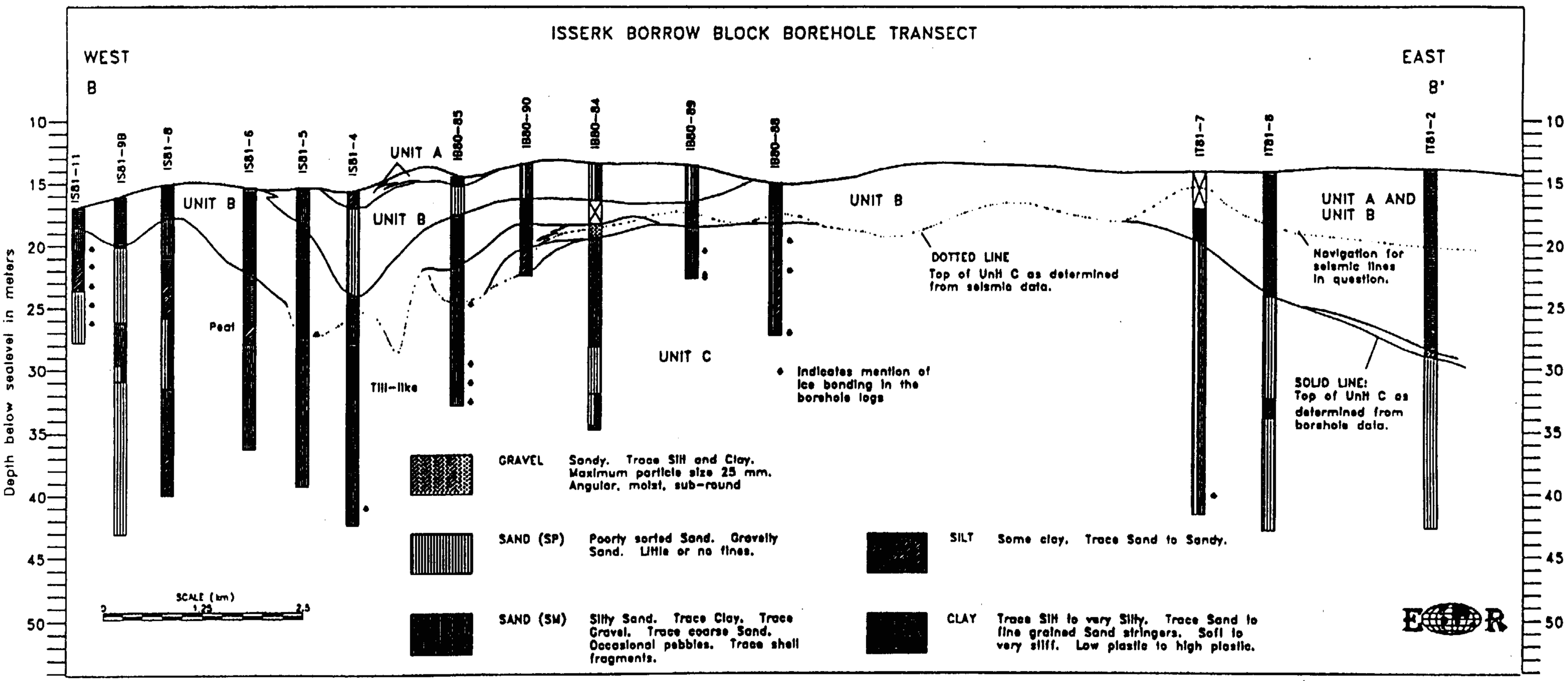
FIGURE 6

SURFICIAL COVER



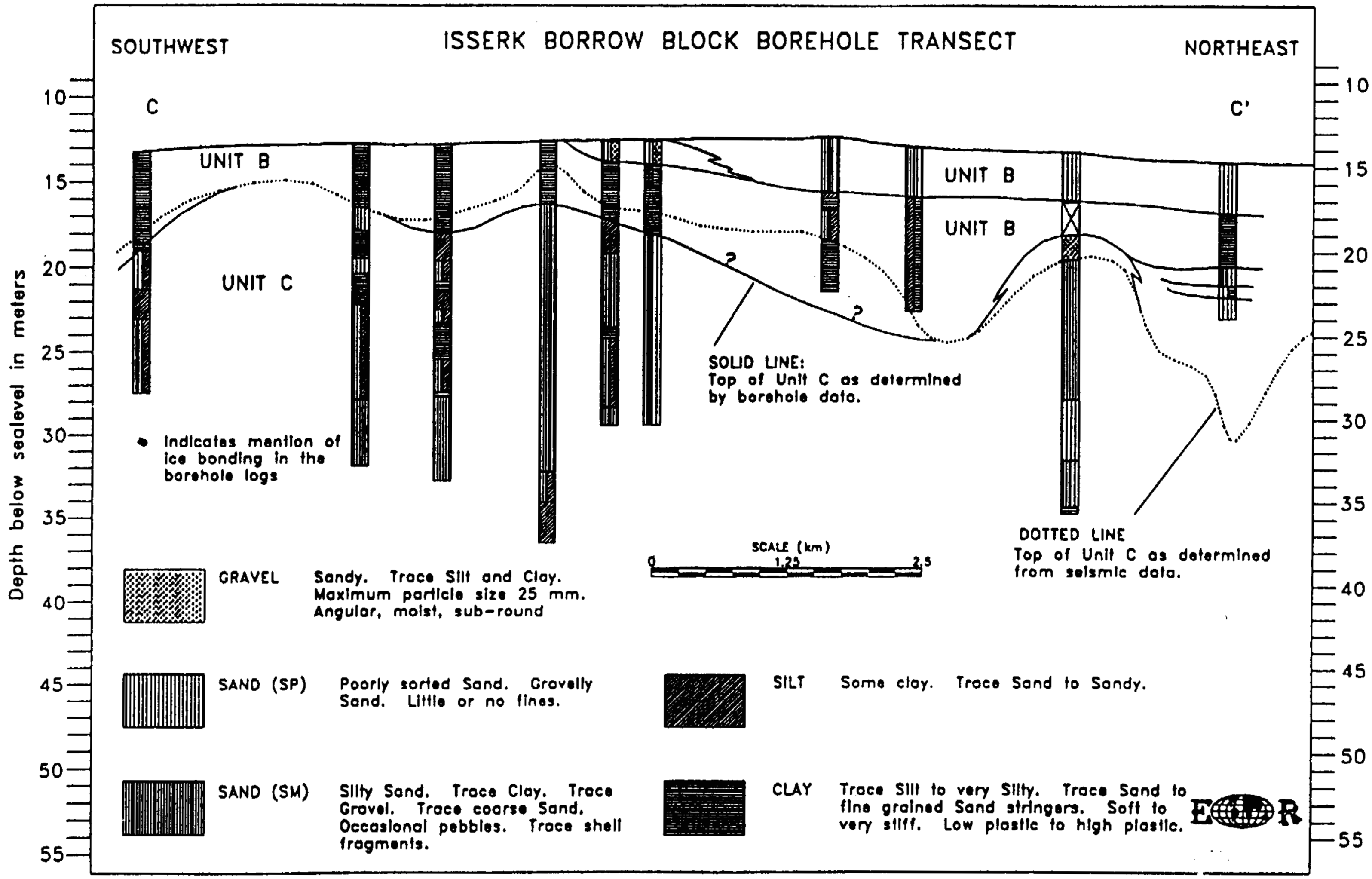
ISSERK BORROW BLOCK BOREHOLE TRANSECT - LINE A

FIGURE 7

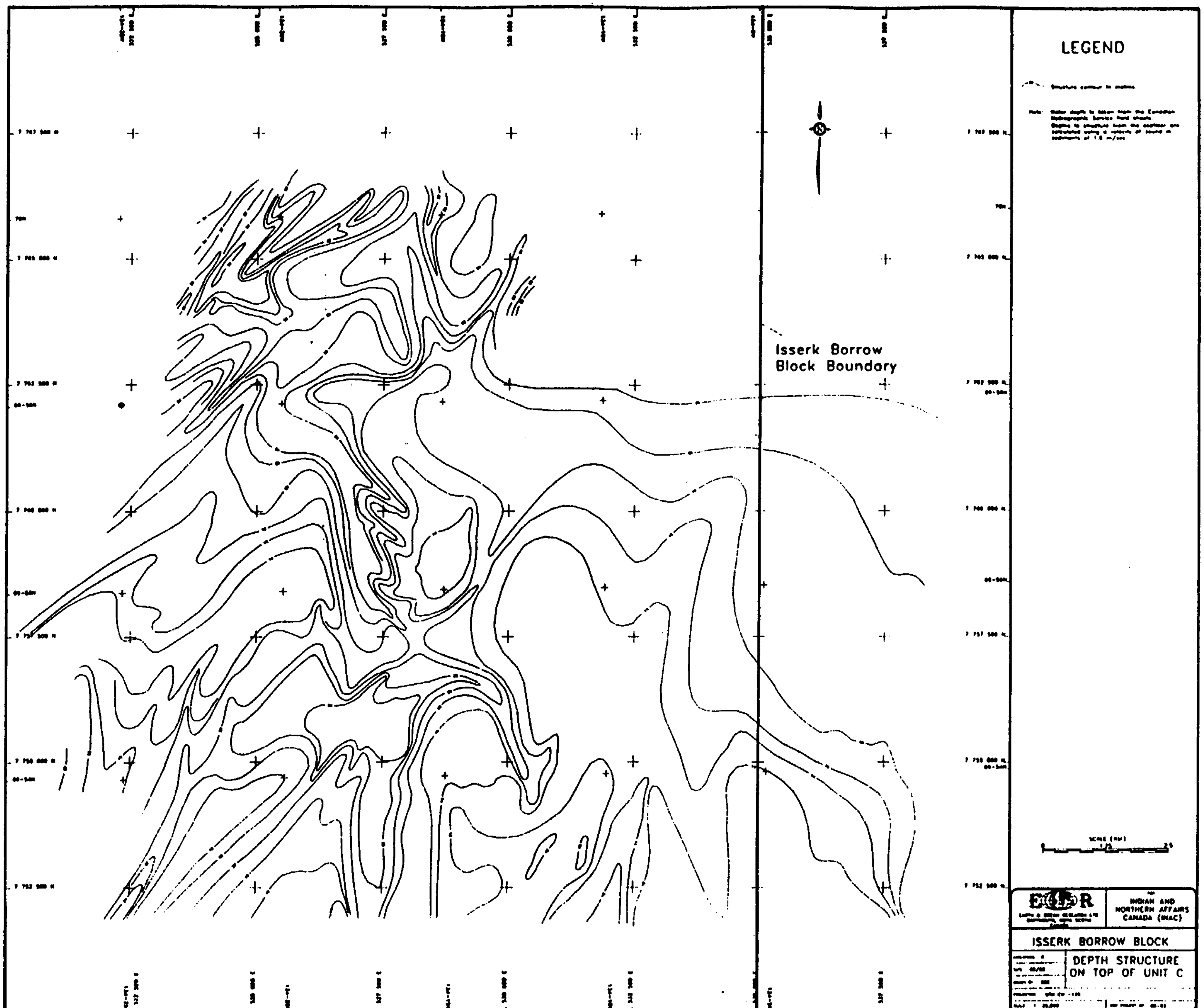


ISSERK BORROW BOLCK BOREHOLE TRANSECT - LINE B

FIGURE 8

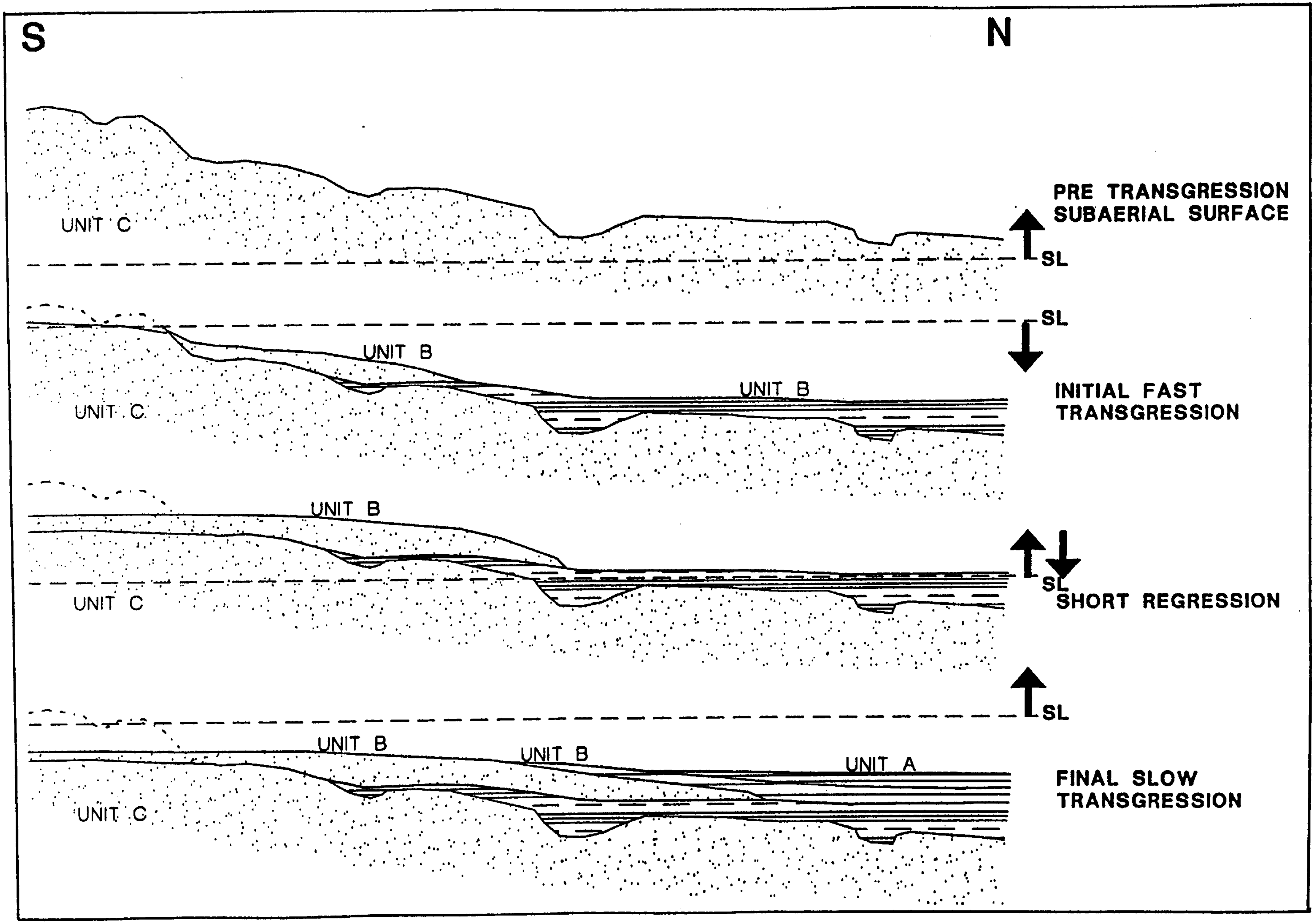


ISSERK BORROW BLOCK BOREHOLE TRANSECT - LINE C **FIGURE 9**



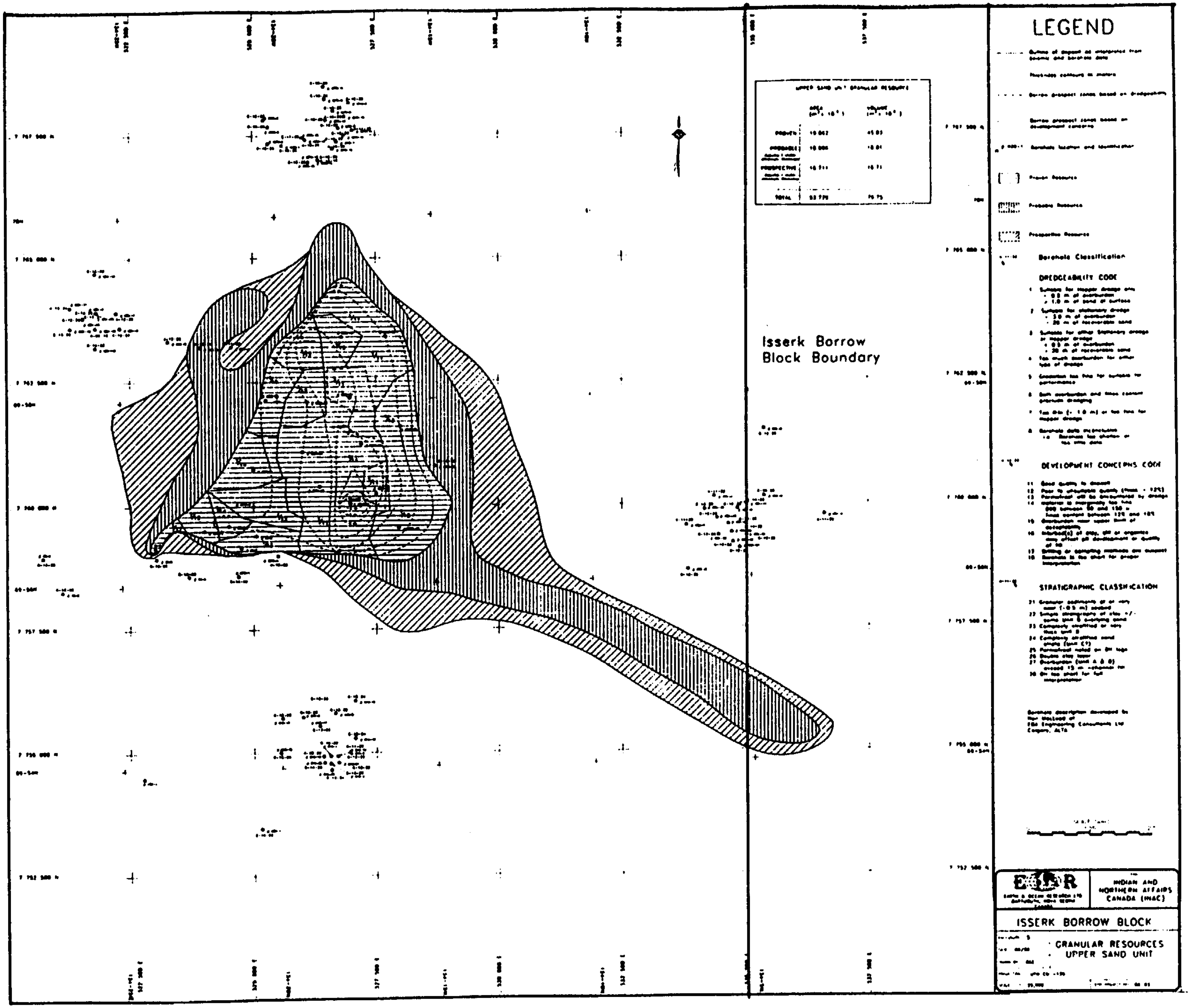
DEPTH STRUCTURE ON TOP OF UNIT C

FIGURE 10

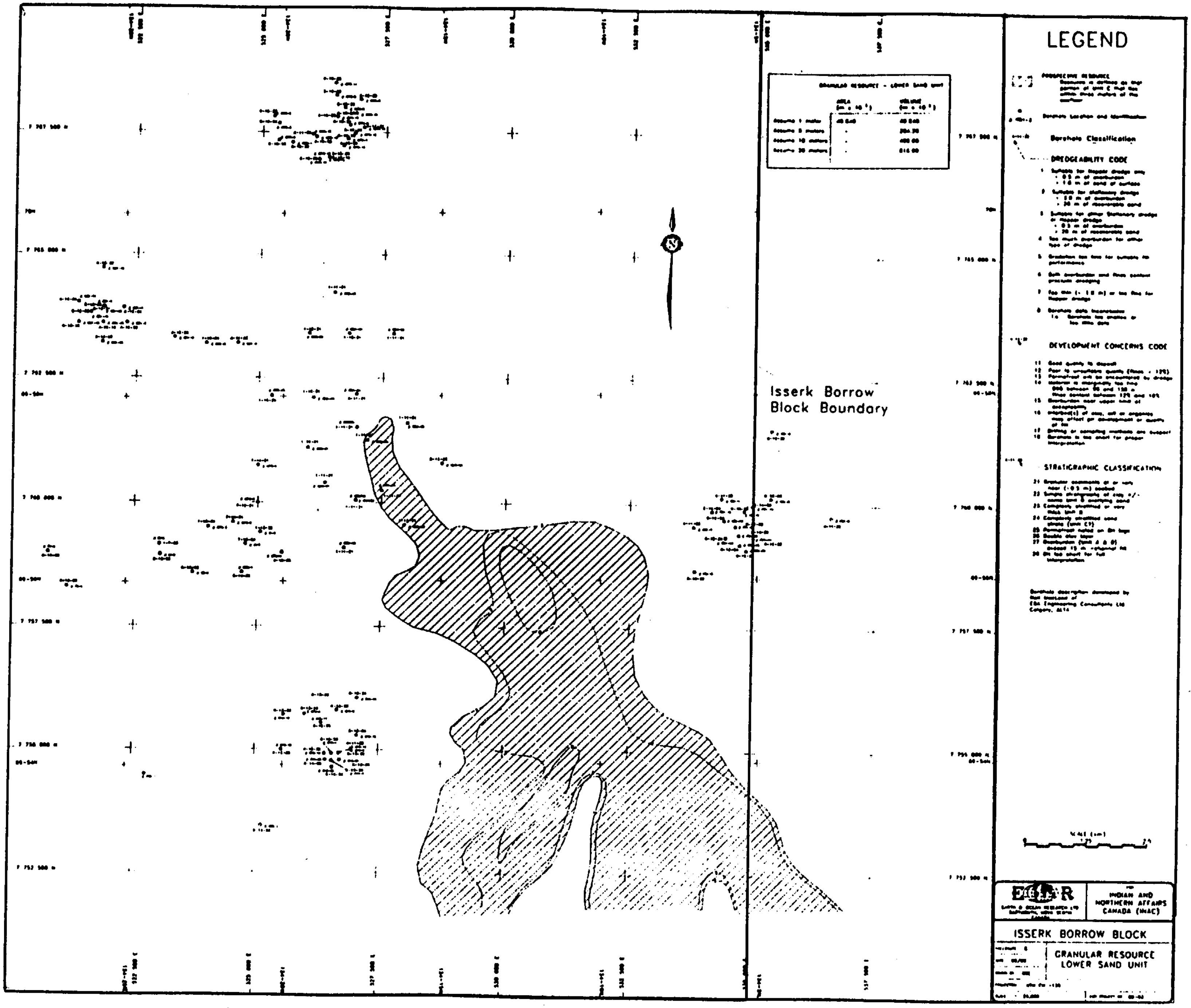


ISSERK DEPOSITIONAL MODEL

FIGURE 11



GRANULAR RESOURCES UPPER SAND UNIT **FIGURE 12**



GRANULAR RESOURCES LOWER SAND UNIT

FIGURE 13