PROCEEDINGS OF THE BEAUFORT SEA GRANULAR RESOURCES WORKSHOP

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PART 1

REPORTS ON NOGAP REGIONAL STUDIES

Granular Resources of the Issigak Deposit
(NOGAP Project A4-06)

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1.0 Introduction

The Issigak site is unique in many ways. It is one of the few deposits with any significant portion of gravel in the Beaufort-Mackenzie region and is the only source of granular materials located between Herschel Island and the Akpak Plateau. For reference, Figure 1 shows the location of the deposit and the major physiographic zones nearby.

In late 1986 through March 1987, EBA Engineering Consultants Ltd. compiled and interpreted available data for the Issigak deposit (EBA, 1987). This work was conducted under funding provided by NOGAP Sub-Project A4-6, through Indian and Northern Affairs Canada. The primary purposes of the study were to interpret the geology of the deposit, and to quantify the remaining reserves. Those tasks were relatively easy. The hard work was in finding the data, much of which was missing, and resolving inconsistencies between overlapping data sets.

2.0 History of Site Evaluation

The first site work on shallow sediments in this area was done in late winter 1974. More work was done in winter 1975. Both programs were conducted through the ice at about the limit of conventional land based equipment. Although we encountered minor gravel and other geologically unique sediments during those programs, we didn't "discover" the Issigak borrow deposit. The credit for the discovery should go to Dome Petroleum which began gravel exploration in the area in the summer of 1980. They were searching for construction materials for work at the Tarsuit N-44 site.

Between 1974 and summer 1986, there were 26 various programs or operations at Issigak. Included in that were nine geotechnical sampling programs, six seismic mapping programs, eight dredging operations, and three bathymetric mapping exercises. Prior to 1986, almost 3.5 million cu.m. of granular material were reported to have been removed from Issigak during four of the dredging operations. In addition, there were four other dredging programs for which the quantity of material removed could not be determined.

3.0 Data Reliability

The problem with too much data is that it has to be compared to look for inconsistencies. At Issigak, there were 199 boreholes, several bathymetric surveys and bathymetric data collected during seismic programs. The correlation between various data sets was found to be very poor. This has serious implications for many other sites because of the scale of inaccuracies implied. For example:

- The difference between water depth interpreted from borehole soundings and bathymetric surveys was greater than 1.0 m for 25% of boreholes. That is a big error for a site in only about 9.0 m of water.

- The difference between various sets of bathymetric mapping was not much better. Datum differences of 0.5 to 1.0 m are common between data sets.

- Where two boreholes were located nearby, the differences in sub-surface interpretation was frequently enough to imply that one of them must be wrong. For nine pairs of holes with an average distance apart of 27 m (maximum 40 m), the average difference in granular material thickness was greater than 0.4 m (max. 0.8 m) and the average difference in water depth was 0.4 m (max. 0.8 m). These are significant differences for a deposit with an average thickness of less than 1.5 m.

4.0 Physical Description

Figure 2 shows the size of the deposit in comparison to northwest of Calgary. It is presented this way because it is easy to underestimate the aerial extent of Issigak on a map without reference to nearby land features. The deposit is almost 11 km long and up to 1500 m wide.

In section, the deposit is a thin veneer which averages less than 1.5 m thick. Issigak appears as a low ridge or series of small knobs on most bathymetric maps because of the overall flatness of the coastal sediments. Figure 3 shows the maximum section through the ridge. Drawings with high vertical exaggeration serve to create the impression of a ridge. Figure 4 shows the ridge at a vertical exaggeration of only 10x. This is a much better section to picture when considering the morphology of the deposit.

Detailed bathymetry, compiled in Figure 5, shows four or five pods of higher relief. The relative importance of initial deposition and subsequent erosion in producing this relief is difficult to establish. These areas of high relief, however, are generally related to the thickness of granular resources. They are also related to the distribution of boreholes, because most were located on areas of higher relief. Figure 6 shows the distribution of boreholes.

Our understanding of the thickness of the deposit is somewhat skewed because the boreholes have been concentrated in areas of highest relief. Based on 162 boreholes which were mostly in the thicker parts of the deposit, the average thickness of the Issigak granular resources is 1.44 m. Overall the average thickness is less.

5.0 Stratigraphic Characteristics

There are enough boreholes in the deposit to develop a reasonably complex facies model of it. Table 1 shows the strata sequence that has been interpreted. It was not practical to try and indicate the thickness of these 12 units and sub-units for such a relatively thin deposit. In fact, the total strata sequence never appears in any borehole, but each unit appears in more than one borehole. Figure 7 shows what might be a typical section, if there is one.

Cobbles and boulders are easily missed by boreholes unless they are in a relatively high concentration. From dredging quality control work, there are reports that some dredge hopper loads contained up to 10% cobbles and boulders. Cobbles up to 130 mm were common and boulders up to 500 mm were observed. Figure 6 indicates the frequency of boreholes encountering cobbles in the deposit and Figure 8 indicates the distribution of coarse material on the seabed.

The relative distribution of sand and gravel within the deposit also was investigated. Based on gradation data provided by the borehole logs an interpretation of the sand to gravel ratio was made for each borehole. By averaging the ratios so derived for eight subdivision of the deposit shown on Figure 9, a trend to a decrease in the gravel fraction (ie. to finer material) from southwest to northeast was identified. The frequency for cobbles, indicated on Figure 6, seems to be greatest in the southwest but relatively uniform along the north arm of the deposit.

6.0 Quantity Determination

It is not possible to determine the quantity of granular material that was originally in the Issigak deposit. As indicated previously, in excess of 3.5 million cubic metres of material had been removed prior to 1986. For at least four other dredging programs, the quantity of material removed was unknown.

Bathymetric data collected for Esso in 1984 and 176 boreholes obtained for Esso in 1983 (EBA, 1983) provide the basis for understanding the quantity of granular material on site, although 1.5 million m^3 of granular resources were removed between those two times.

It was concluded that at the end of 1986, reserves of granular material on site were as follows.

- Proven Reserves 3.3 million cubic metres
- Probable Reserves 5.1 million cubic metres
- Prospective Reserves 5.8 million cubic metres

7.0 Geologic Age

The Issigak deposit was interpreted in this NOGAP study to be of early Holocene age. That means the deposits are non-glacial and likely non-marine. The basis of this interpretation is the correlation of regional unconformities on several regional seismic lines by Guy Fortin (1986) and some biostratigraphic work done by Elliot Burden (1986).

Burden's work on samples from the Tarsiut N-44 site identified three unconformities. The earliest lies below non-marine sediments that Hill (1985) dated at 27,000 years. The second occurs above non-marine sediments which have an age of about 14,600 and overlie prograding late-Wisconsinian deltaic sediments. Above the second unconformity are early Holocene shallow deltaic sediments which were dated between 9,500 and 6,800 years. The third unconformity lies between those and pro-deltaic (marine) late-Holocene sediments that are less than 6,800 years old. This unconformity (U/C3) is the trace of the last marine transgression.

The process by which the three unconformities at Tarsiut N-44 can be traced to Issigak is a little complex. The first correlation was one of stratigraphic similarity between Tarsiut A-25 and N-44. These two site are a little less than 6 km apart. Table 2 shows this correlation. At Tarsiut A-25, Unconformity U/C2 is about 16 m below seabed (bsb).

The next step in the correlation was Fortin's interpretation of a seismic line extending southward from Tarsiut A-25 and passing about 12 km west of Issigak. Figure 10 shows that section. The relatively unvarying depth of Unconformities U/C1 and U/C2 suggest that Wisconsinian sediments are deeply buried at Issigak. Unconformity U/C2 was interpreted to be 10 to 15 m bsb near Issigak.

The third correlation, shown on Figure 11, traces Unconformities U/C2 and U/C3 from Esso's Omat and Kaubvik sites past Issigak at a distance of about 2300 m to the north and further west to a point about 11 km west of Issigak. Unconformity U/C2 is about 10 m below seabed and U/C3 is about 4 m bsb where they pass Issigak.

The fourth tie-in to this correlation is based on stratigraphic correlation of a series of boreholes between Esso's Kadluk 0-07 site and Issigak. This profile, which location is shown on Figure 12, crosses the Omat seismic line and ties the regional seismic data to Issigak.

The stratigraphic features that have been correlated along this section are interesting. There is a zone which begins at the depth of Unconformity U/C2 on the Omat line and can be seen in five of the boreholes between Issigak and the Omat line. It has the features of partially desiccated terrain such as blocky texture and salt encrusted fissures. Overlying that is a silty clay strata containing occasional fine pebbles (drop stones?). This horizon appears to correlate with evidence of unconformable strata changes at 8 to 9 m bsb under the Issigak deposit and at about 8 m bsb inshore of Issigak. Figure 13, shows the interpreted section.

Late Holocene (recent marine) sediments appear to pinch out between the Kadluk site and Issigak. In some boreholes the dropstone clay strata is exposed on the seabed and in others it underlies a thin strata of recent sediments. This interpretation, based mostly on borehole data, could be confirmed with seismic records which could not be found for the study.

In conclusion, it appears that the Issigak deposits pre-date the last marine transgression, which Hill (1985) suggests would be about 2500 years ago. Furthermore they are situated on top of approximately 6 m of early Holocene deltaic sediments which correlate to those Burden dated at between 9500 and 6800 years.

8.0 Sediment Geology

The surface on which the early Holocene deltaic sediments were deposited may have been well above seabed. It is likely that shell fragments, finely laminated clays, and interbedded sands with organic rich strata must be fluvial or lacustrine in origin. Furthermore, it would take a relatively large fluvial channel to move over 9 million m^3 of sand and gravel with cobbles and boulders up to 500 mm. Therefore it is puzzling that such a channel has not been identified on any seismic section or in any borehole.

It also is difficult to conceive of a source for the granular material that is far upslope of the present deposit. The fluvial erosion of a barrier island, like Pelly Island, has been suggested as a possible source for coarse material; however, there is no evidence, as yet, of a rise to the seabed of Unconformity U/C1 and the older, coarser sediments. The question of source area and details of the transport system have not been resolved, as yet.

9.0 References

Burden, Elliot (1986). 'Mid- and Late-Wisconsin Through Holocene Biostratigraphic Zonation of Beaufort Sea Shelf Sediments from Herschel Island to the MacKenzie Shelf'. A draft report submitted to GSC.

EBA Engineering Consultants Ltd. (1983a). '1983 Off-Shore Geotechnical Site Investigation, Issigak Borrow Site.' Report to ESSO, (EBA Job Number 101-3868).

EBA Engineering Consultants Ltd. (1987). 'Synthesis and Interpretation of Bathymetric, Geophysical and Geotechnical Data from Issigak Borrow Block.' Report to Indian and Northern Affairs Canada (EBA Job. No. 0301-34241).

Fortin, G. (1986). 'A Preliminary report on the Issigak Deposit'. An interim project report submitted to EBA Engineering Consultants Ltd.

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 Earth Sciences Vol. 22, No. 10, pp. 1383-1393.

Table 1
Stratigraphy of the Issigak Deposit

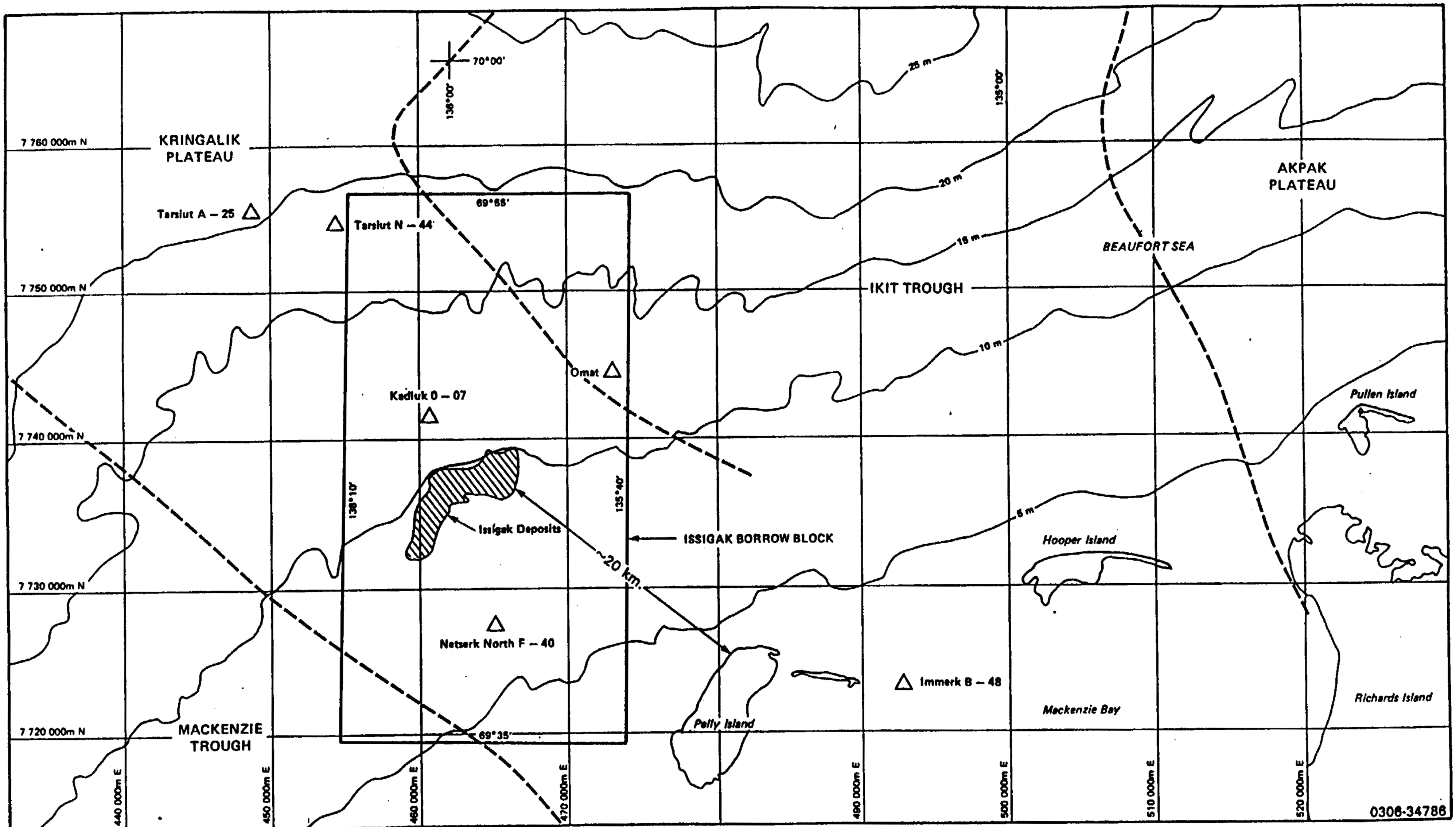
Unit Name	General Description
1A - Overburden Clay	• Soft silty clay of Holocene age. • Thin, irregular veneer, generally absent over main prospect.
1B - Interbedded Clay & Gravel	• Stratified sediments of Holocene? • Clay and gravel washed landward of main prospect.
2A - Upper Sand	• Clean to silty sand, thin but widespread on flanks of main prospect.
2B - Main Gravel	• Ranges from gravel-sand ($2B_1$) to gravelly sand ($2B_2$), coarser on top and may contain cobbles.
2C - Underlying Sand	• Stratified clean, uniformly graded sand ($2C_1$) over silty fine sand ($2C_2$), may contain shell fragments and organic-rich zones.
2D - Clay Interbed	• Silty clay up to 1.2 m thick occurring in at least three areas of main prospect.
2E - Lower Gravel & Sand	• Found below Unit 2D, commonly a gravel strata ($2E_1$) overlying a Sand strata ($2E_2$): $2E_1$ - very similar to 2B. $2E_2$ - very similar to $2C_2$.
3 - Underlying Clay	• Below all granular sediments are: 3A - Interbedded laminae of clay or sand. 3B - Organic-rich silt or clay. 3C - Silty clay.

Table 2
Regional Stratigraphic Comparison

Tarsiut A-25 (from McClellard, 1978)		Tarsiut N-44 (by P. Hill in Burden 1986)		Burden's (1986) N-44 Interpretation			Kadluk H-08 (from Hardy, 1983)		Kadluk O-07 (from Hardy, 1983)	
7 756 500 m N 448 200 m E		7 755 000 m N 454 000 m E		UTM CO-ORDINATES			7 742 360 m N 461 300 m E		7 741 500 m N 400 600 m E	
DEPTH (m) (bsb)	DESCRIPTION	DEPTH (m) (bsb)	DESCRIPTION	UNIT	DEPOSITIONAL ENVIRONMENTAL	INTERPRETED AGE	DEPTH (m) (bsb)	DESCRIPTION	DEPTH (m) (bsb)	DESCRIPTION
0-3	Olive grey soft to firm clay with shell fragments	0-6	Grey bioturbated clay with shell fragments	A	Prodelta Becoming Marine Unconformity (U/C_3)	Present $\leq$ 6 800 7 500	0-3	Soft silty clay	0-2.5	Soft silty clay, trace of gravel
3-16	Dark grey silty clay with silt partings to lenses stiff to very stiff	6-15	Dark grey bioturbated silty clay with silt lenses and dessicated horizons	B	Delta Unconformity (U/C_3)	 9 500 14 600	3-13	Stiff silty clay	2.5-13	Stiff silty clay, laminated, some sand layers near top, trace of gravel
16-22	Dark grey silty fine sand with some gravel	15-21	Laminated/ lenticular graded silty clay (top) to graded sand and clay (bottom)	C	Becoming Non-Marine	17 000	13-26	Compact silt	13-17	Silt sandy to trace of sand
22-34	Olive grey silty clay with silt partings grading down to clayey silt with clay partings	21-36	Laminated dark grey silty clay (gradational transition)	D	Prograding Delta				17-34	Interbedded silty clay and clayey to sandy silt

Table 2 (Continued)

Tarsuit A-25 (from McClelland, 1978)	Tarsuit N-44 by P. Hill Burden 1986)	Burden (1986) Tarsiut N-44 Interpretation	Kadluk H-08 (from Hardy, 1983)	Kadluk 0-07 (from Hardy, 1983)
34-60 Olive grey clay with silty partings and silty layers	(gradational transition) 36-56 Laminated silty clay	E Prograding Delta	26-70 Very stiff silty clay	34-61 Very stiff laminated silty clay with occasional silt pockets
	56-66 Homogeneous bioturbated silty clay with forams	F 18 000		
60-86 Olive grey clay with organic and sandy pockets and some shell fragments 86-94 Olive grey clayey silt with some wood fragments 94-121 Grey clay with silt lenses and partings some wood fragments 121-122 Silty fine sand End of borehole	66-129 Thick bedded, laminated clay with some sand beds and organic debris	Prodelta to Marine G Marine Transgression	70-76 Dense fine sand 76-100 Stiff clay 100-113 Stiff silty clay 113-131 Stiff silty clay. End of Borehole	61-93 Dense fine sand, occasional shell fragments and thin silt and clay layers. End of Borehole
	129 Dated Peat Horizon 130-166 Laminated silt and clay. End of Borehole	H Non-Marine Rapidly Prograding Delta 27 000		



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PHYSIOGRAPHIC REGIONS

FIGURE 1

(after O'Conner, 1982)

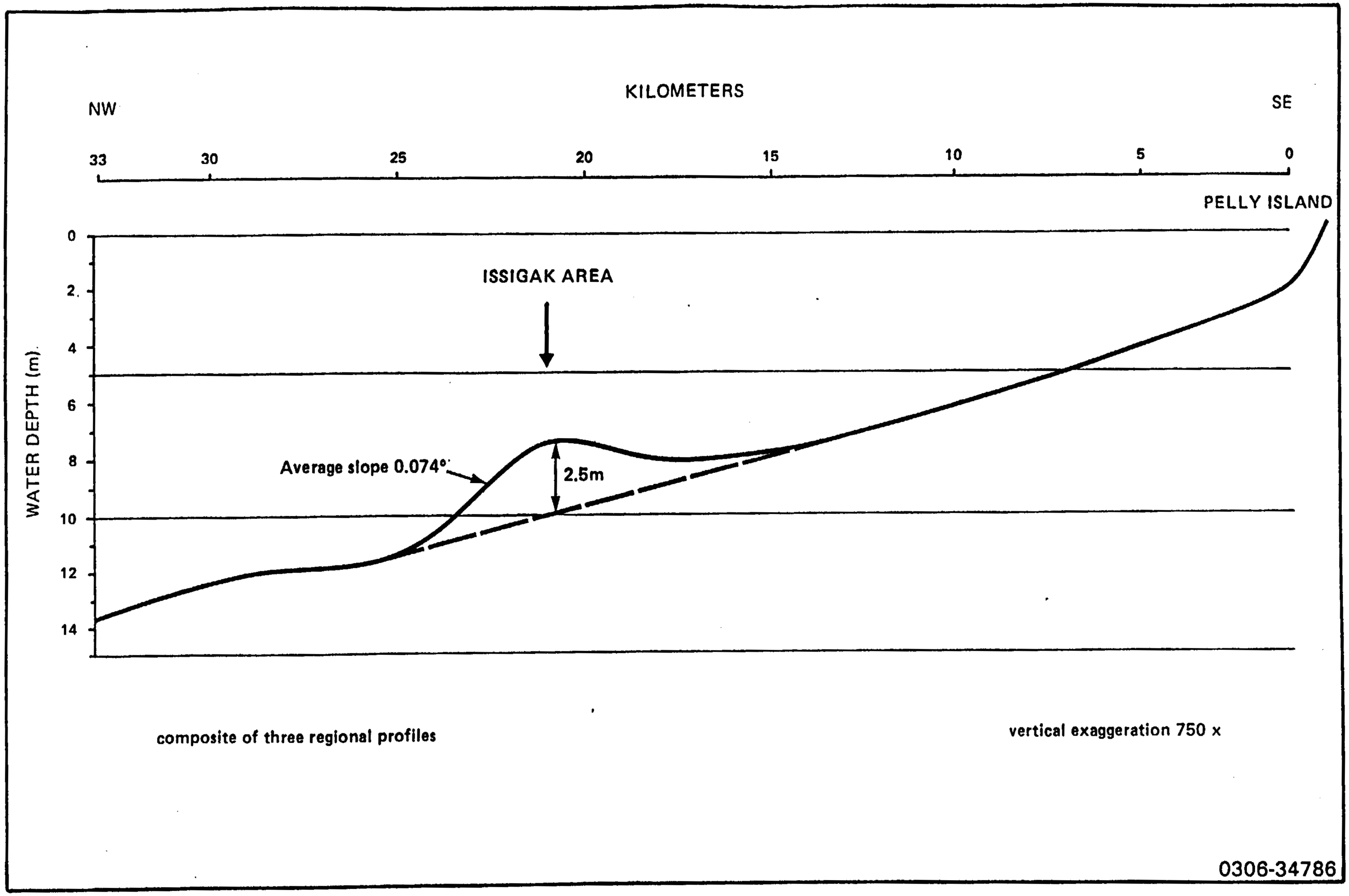


FIGURE 2 COMPOSITE REGIONAL BATHYMETRIC PROFILE FROM PELLY ISLAND THROUGH THE ISSIGAK AREA

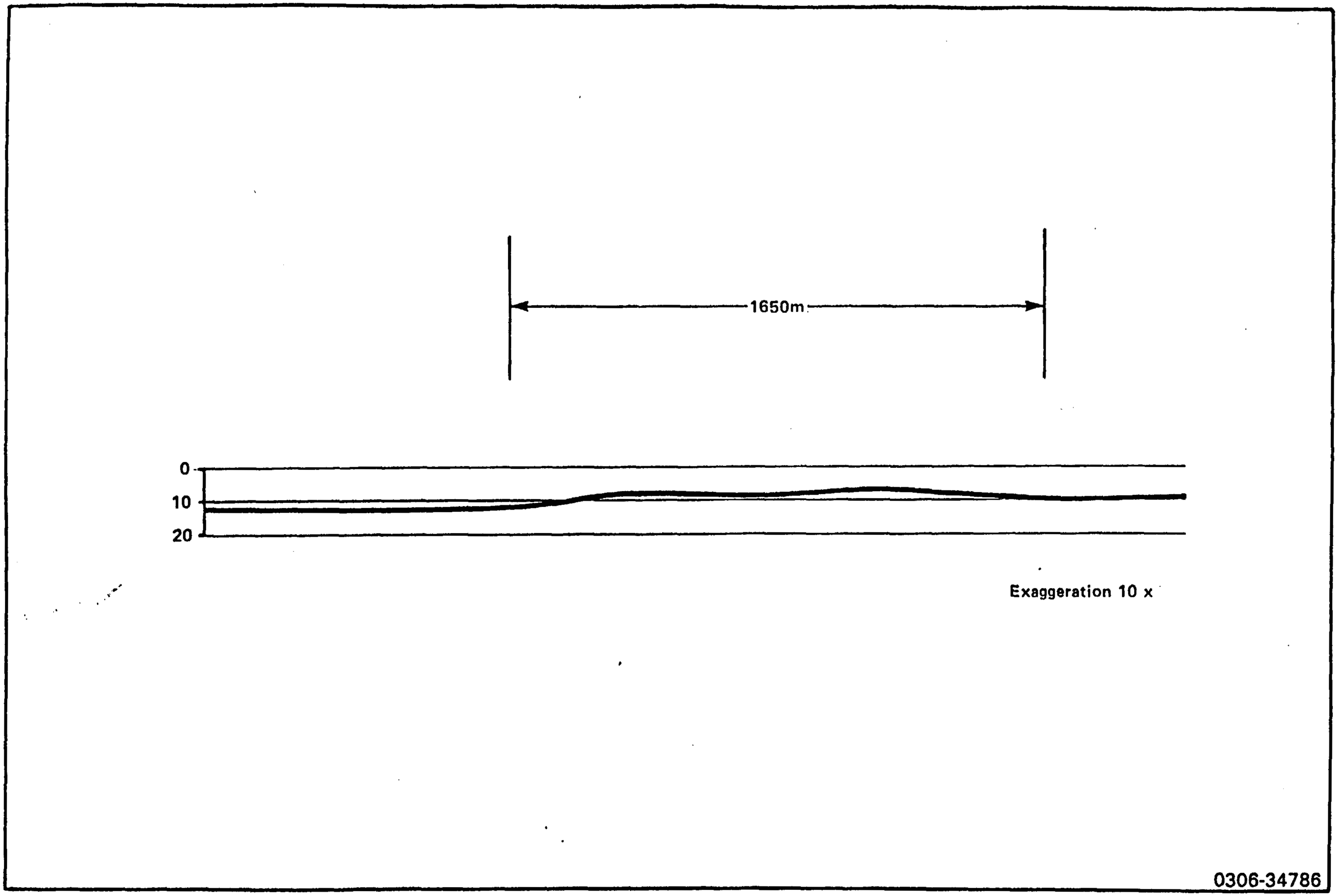
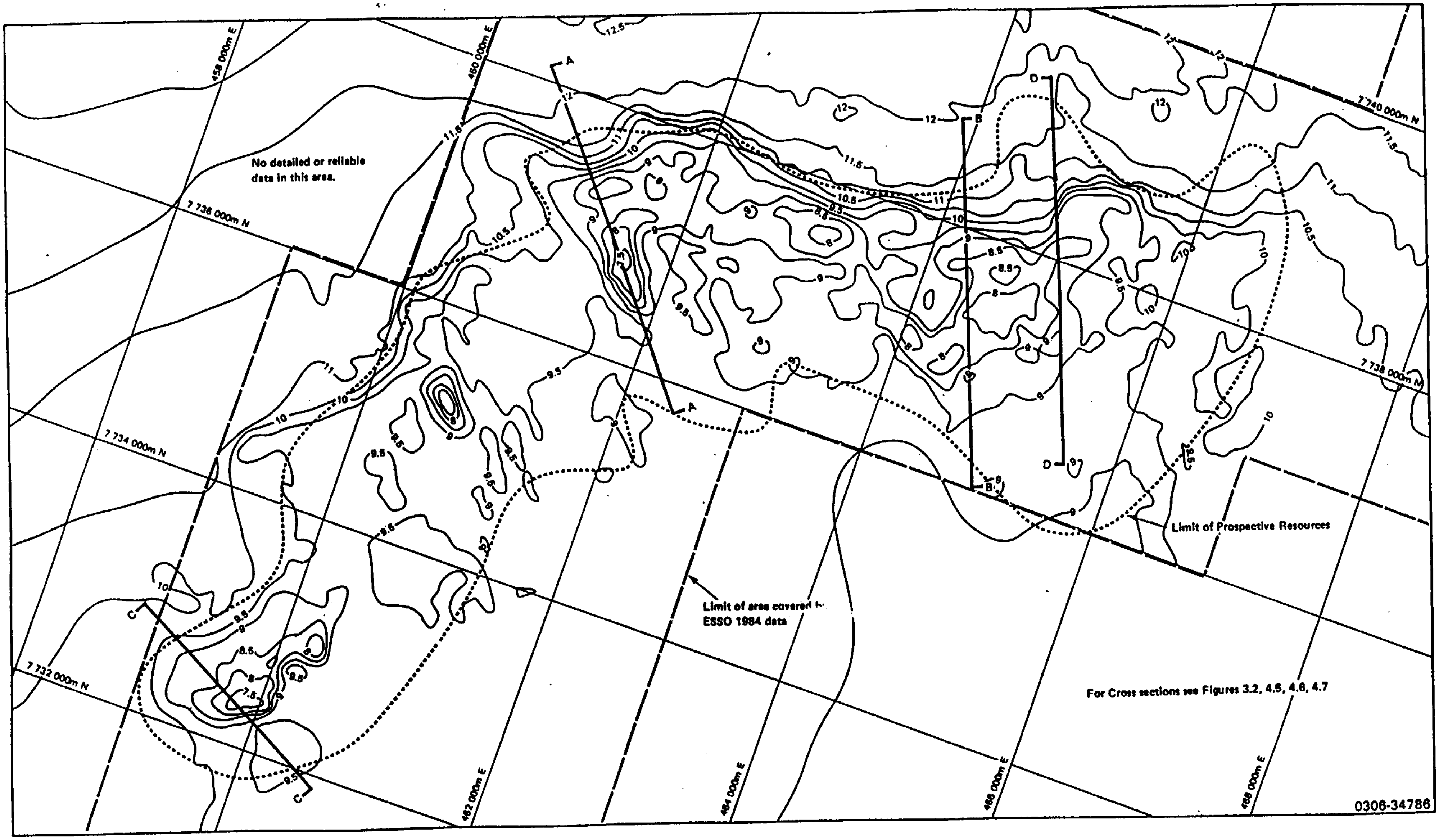


FIGURE 3 SECTION A–A THROUGH ISSIGAK DEPOSIT



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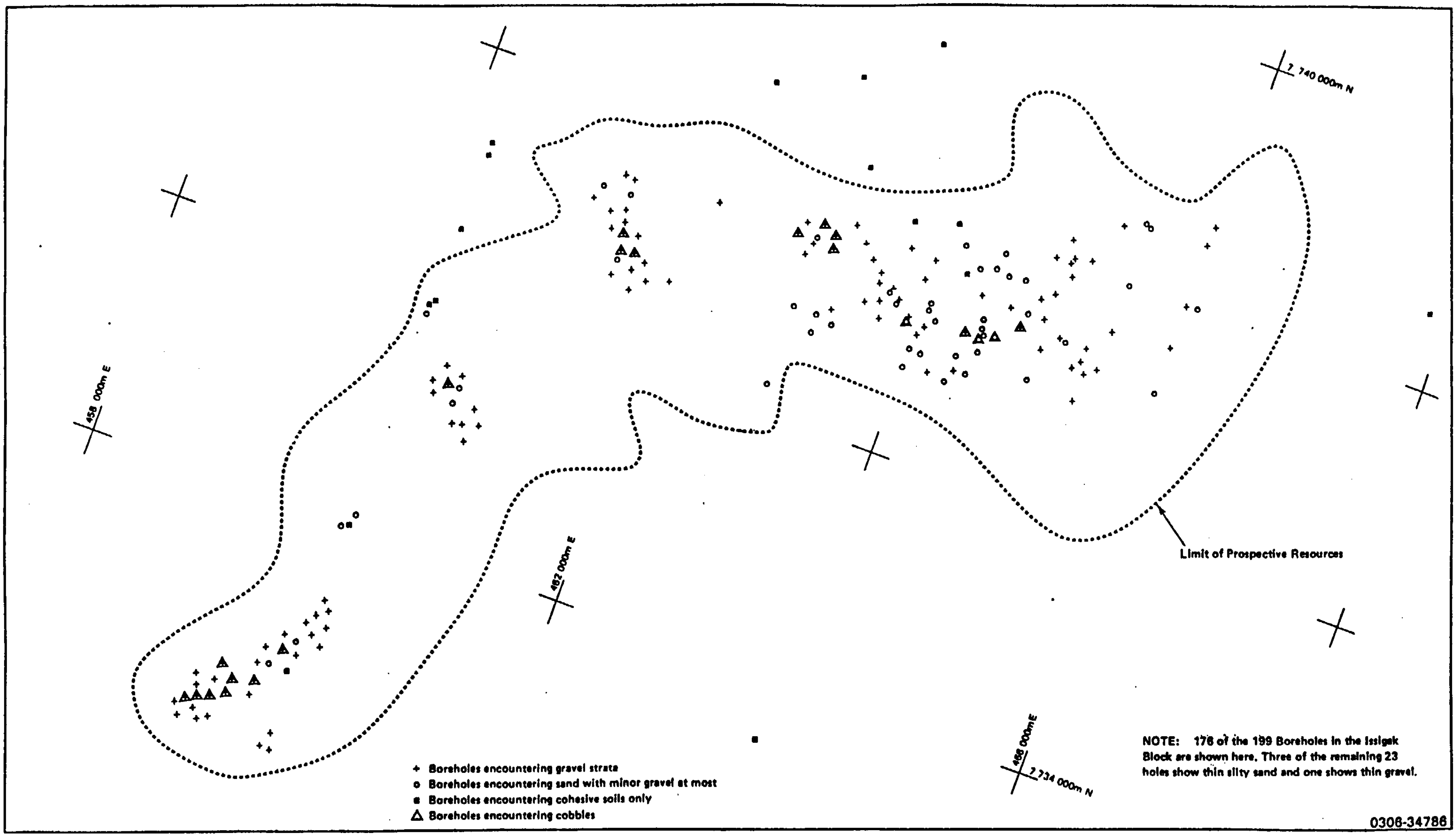
DETAILED BATHYMETRIC CONTOURS FOR THE ISSIGAK DEPOSIT

FIGURE 4



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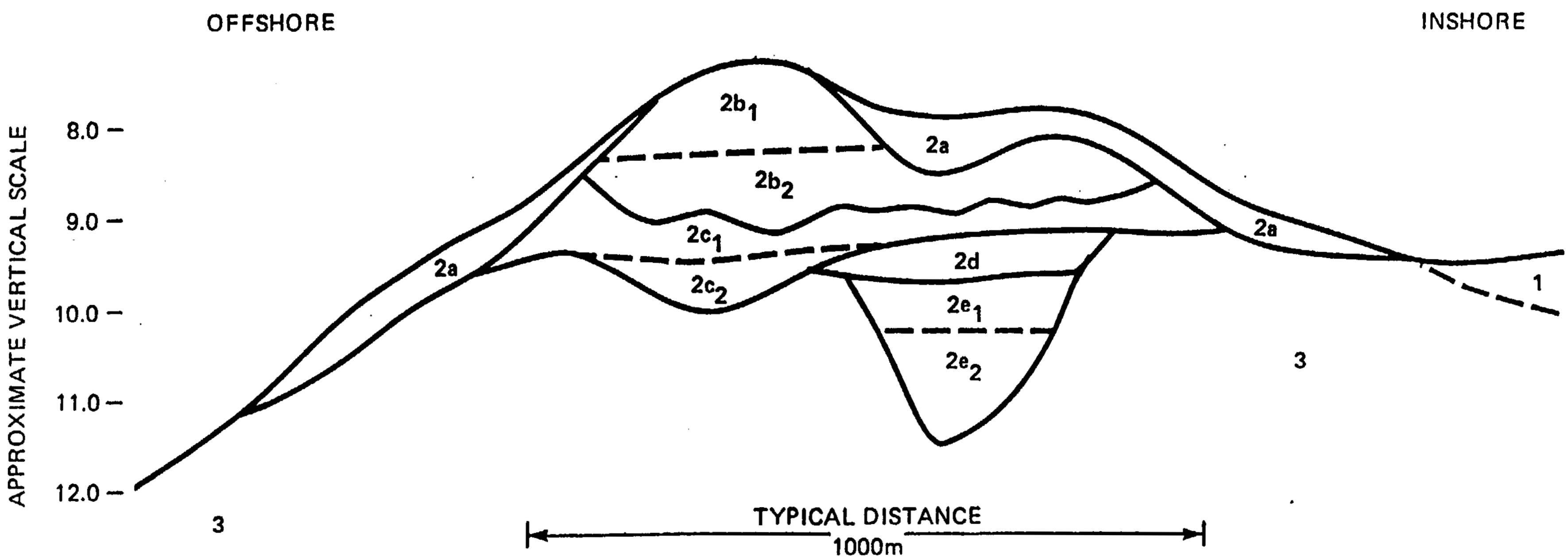
LOCATION OF BOREHOLES IN THE BORROW PIT AREA

FIGURE 5



UNIT	DESCRIPTION	UNIT	DESCRIPTION
1	Silty Clay	$2c_2$	Silty Sand
2a	Clean Sand	2d	Silty Clay
$2b_1$	Sandy Gravel to Sand & Gravel	$2e_1$	Sandy Gravel
$2b_2$	Gravelly Sand	$2e_2$	Silty Sand
$2c_1$	Clean Sand	3	Silty Clay

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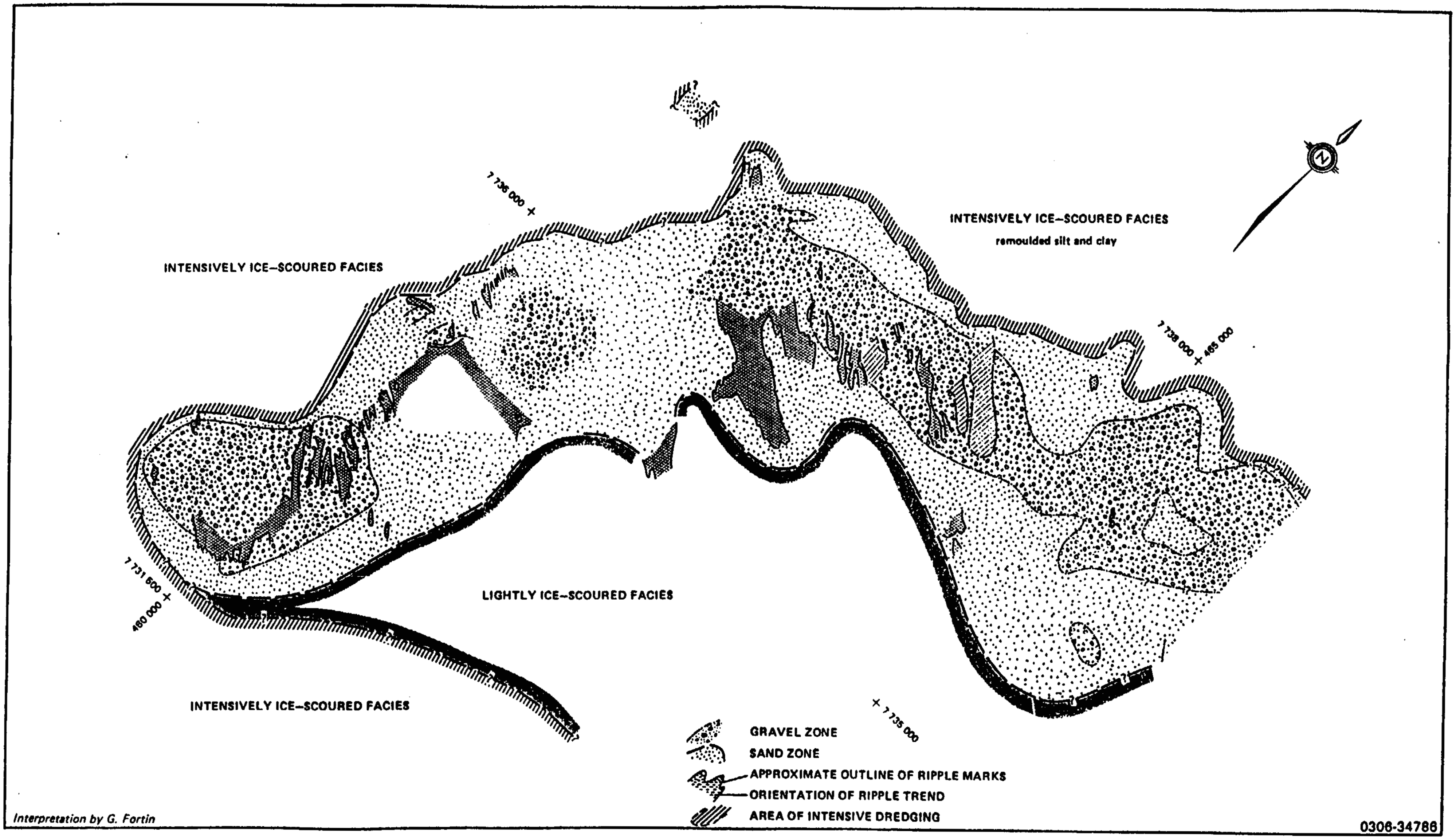
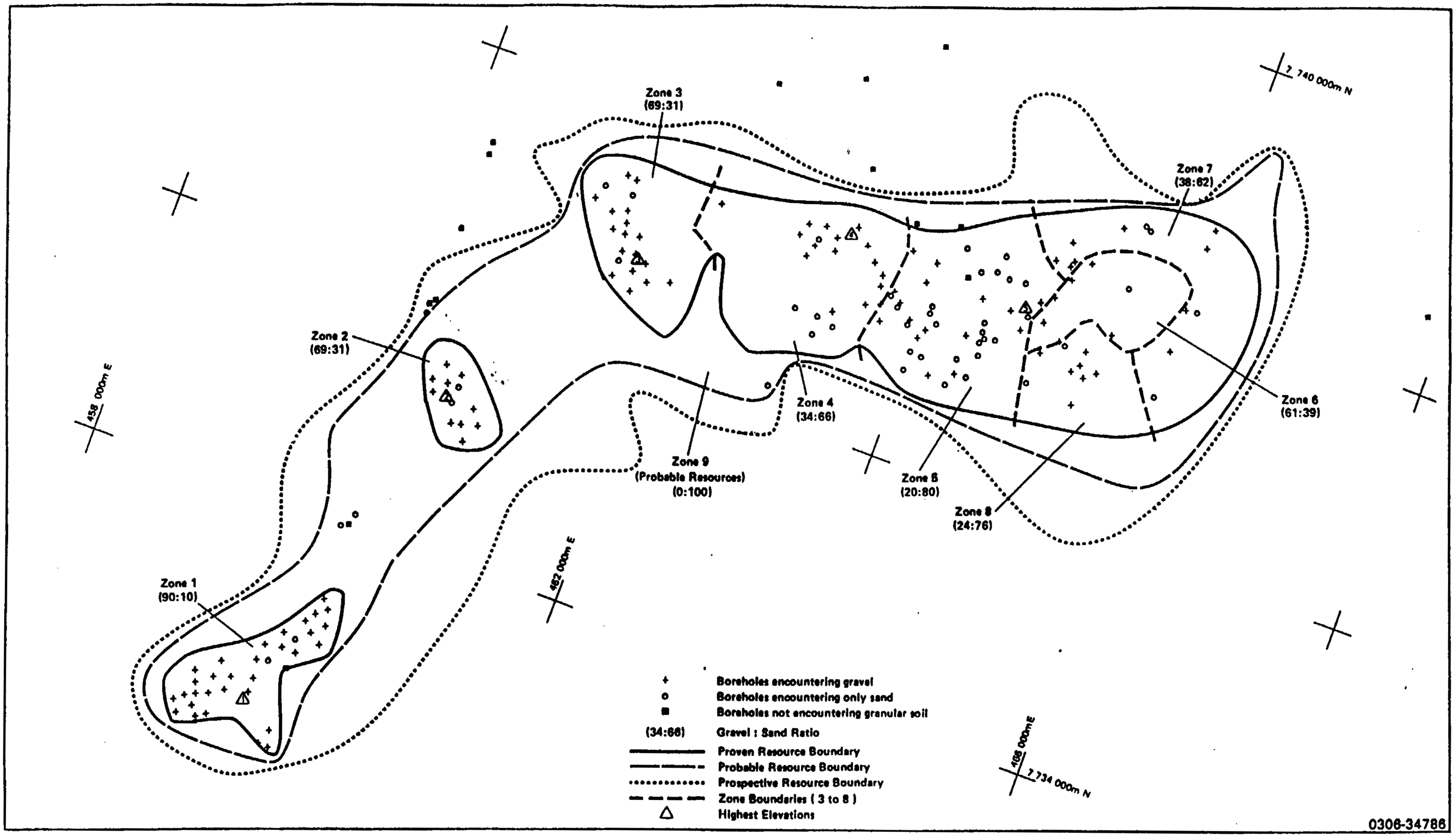
FIGURE 6 GENERALIZED STRATIGRAPHY OF THE ISSIGAK DEPOSIT



SIDESCAN INTERPRETATION OF SEABED CONDITIONS

FIGURE 7



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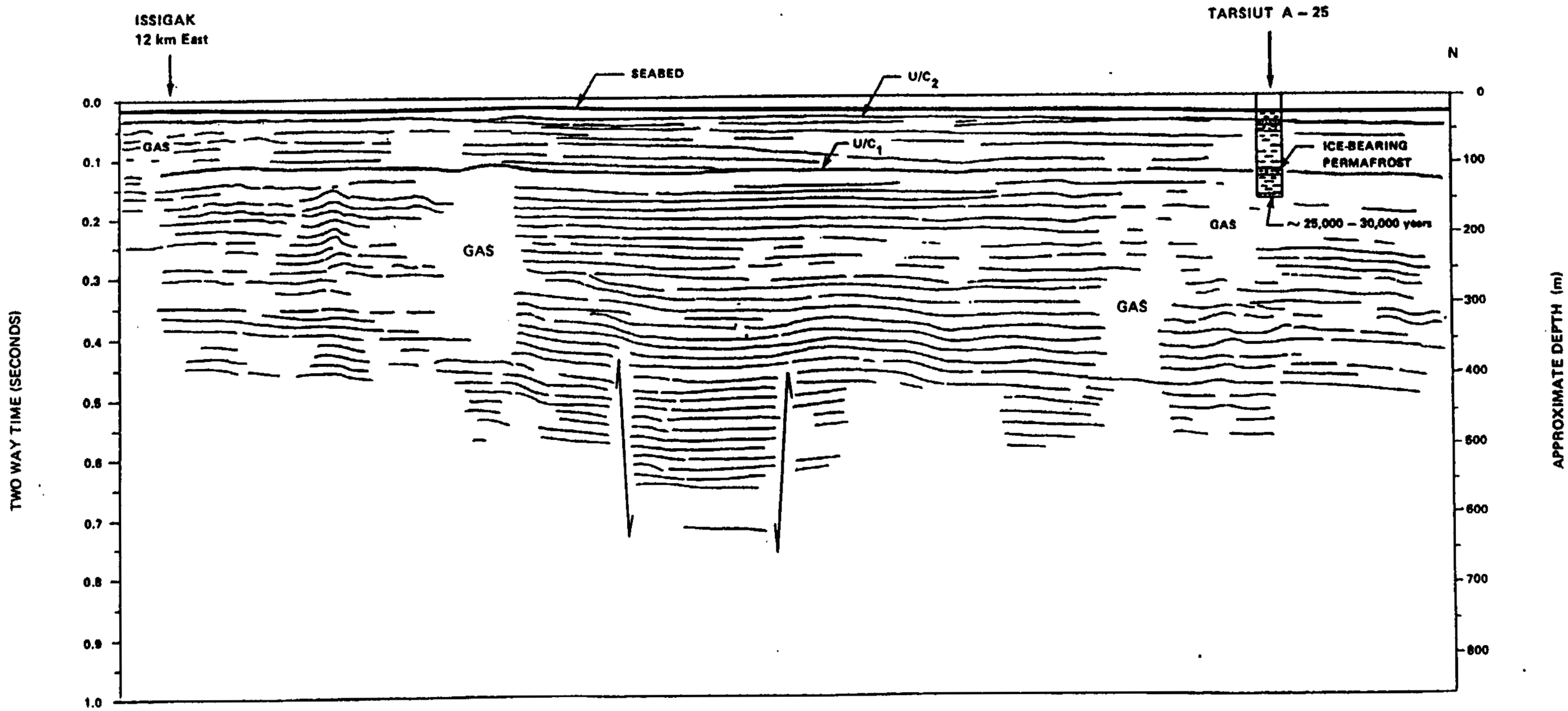
RESOURCE & ZONE BOUNDARIES **FIGURE 8**



DATA SOURCE : MULTICHANNEL HI. RES. LINE DHR 80 – 530

Interpretation by G. Fortin.

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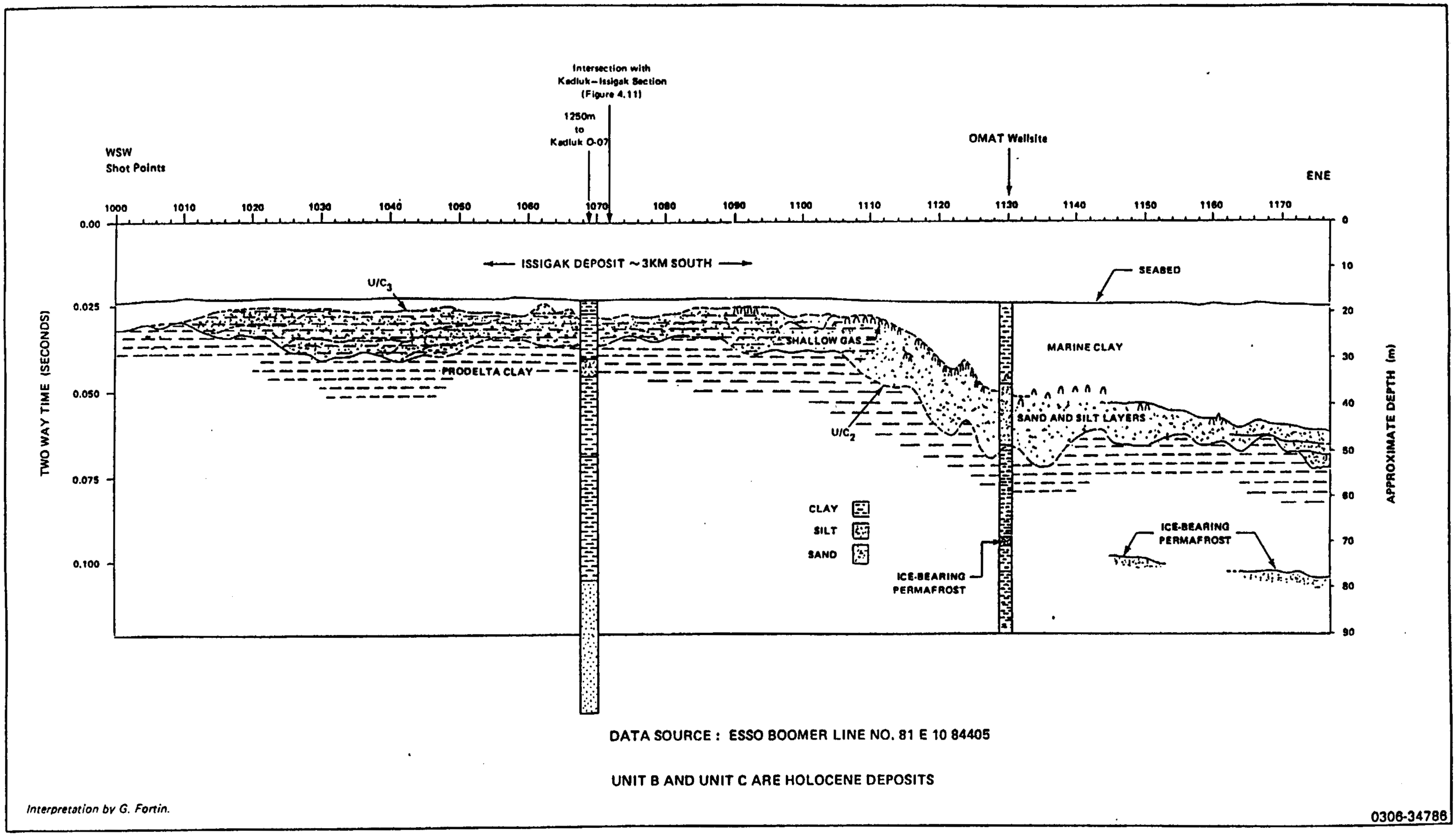
SHALLOW STRATIGRAPHY FROM TARSIUT A - 25 TO ISSIGAK AREA

FIGURE 9



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SURFICIAL GEOLOGY FROM OMAT WELLSITE TO AN AREA NEAR THE ISSIGAK DEPOSIT

FIGURE 10

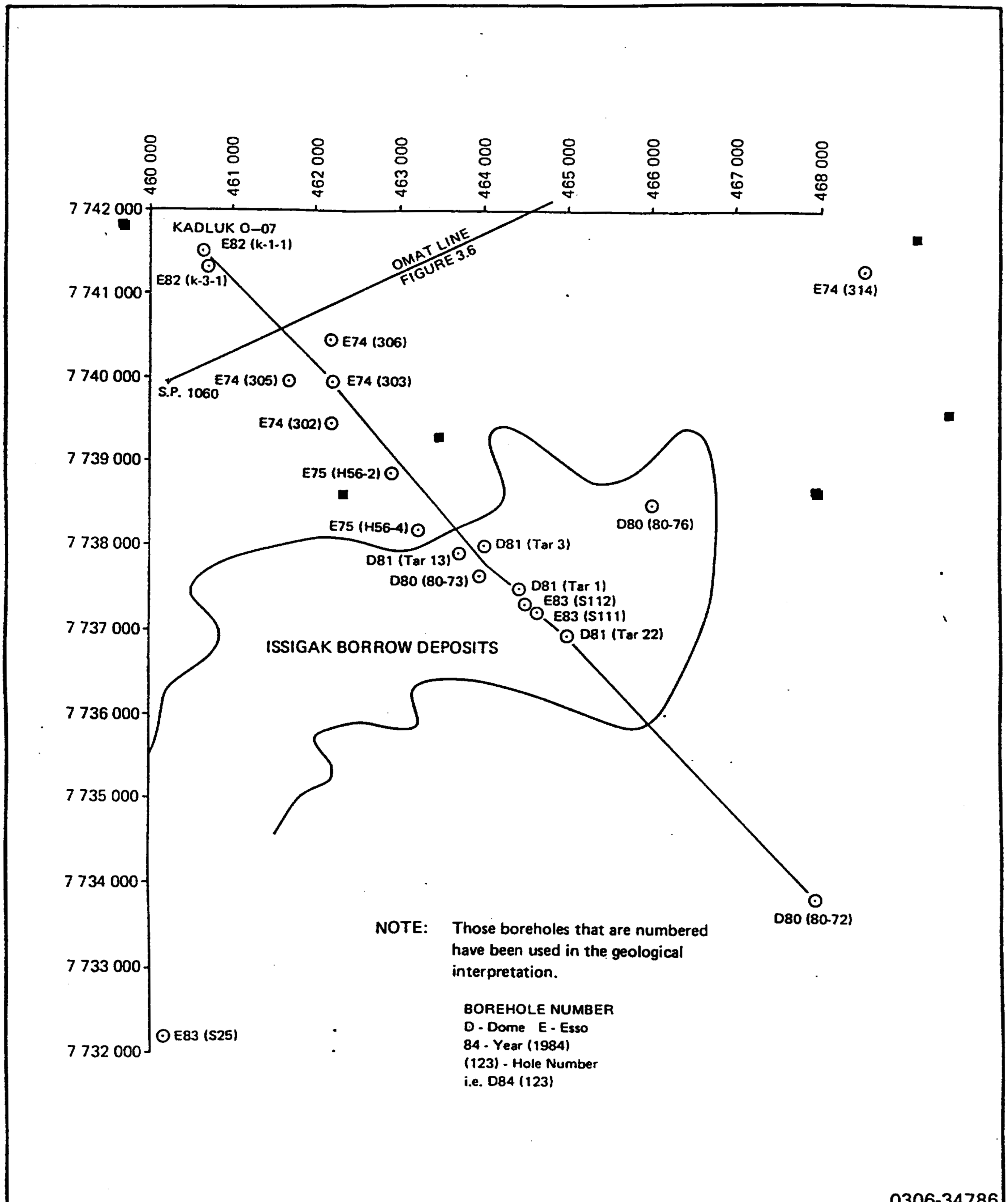

FIGURE 11 INTERPRETATION OF THE KADLUK–ISSIGAK REGIONAL STRATIGRAPHY

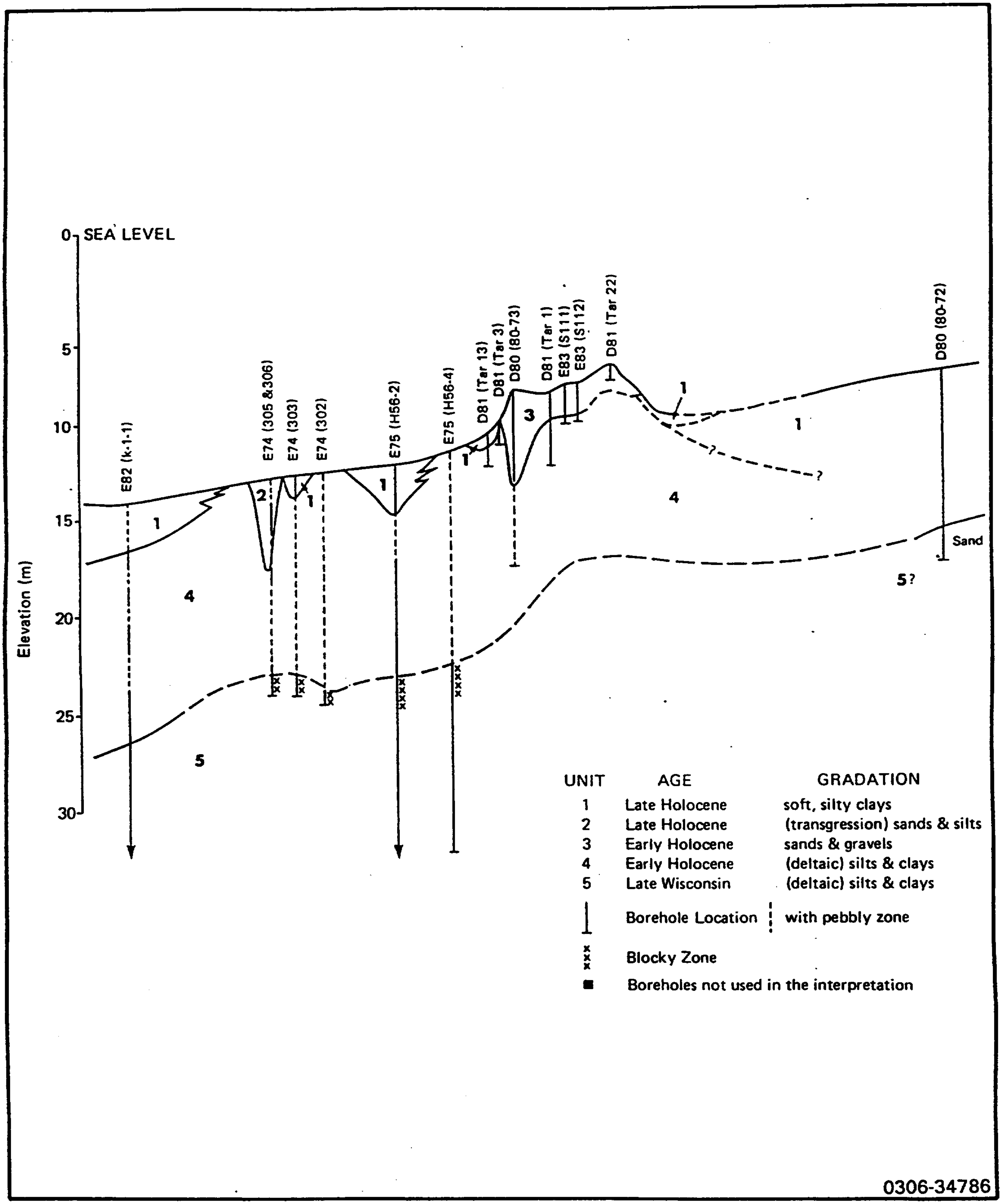

FIGURE 12 INTERPRETATION OF THE KADLUK–ISSIGAK REGIONAL STRATIGRAPHY