GRANULAR RESOURCE POTENTIAL

ANALYSIS BASED ON HIGH–RESOLUTION REFRACTION AND REFLECTION DATA

SOUTHERN AKPAK PLATEAU
Beaufort Sea

Submitted to

INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

October 1989

H.R.SEISMIC INTERPRETATION SERVICES INC.

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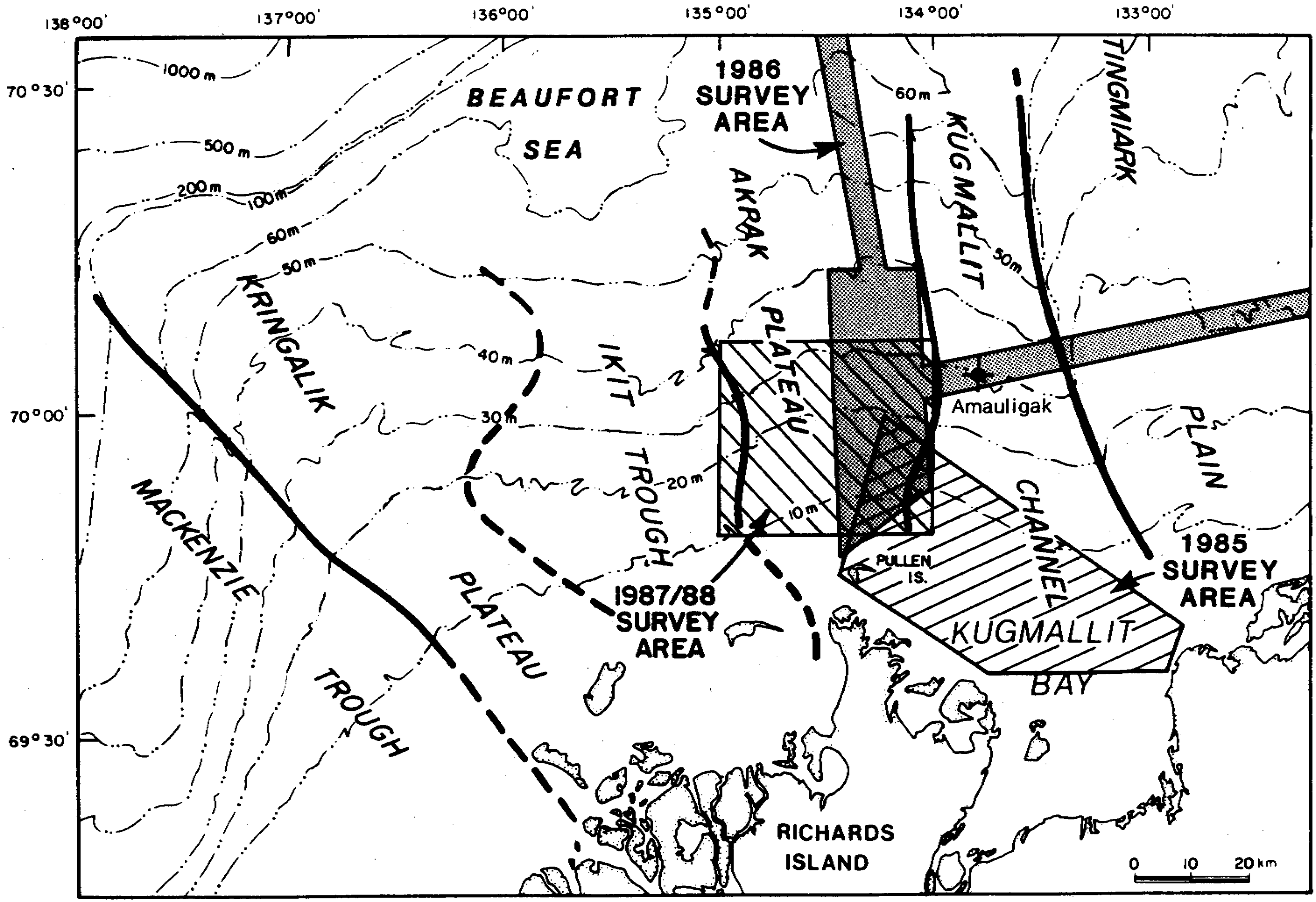

NOTE: SEE GRAPHS 2.1 & 2.2 FOR THE RELATIVE IMPORTANCE OF EACH SURVEY AREA

FIG. 1 LOCATION OF THE SURVEY AREAS.

SECTION 1 - INTRODUCTION

1.1 INTRODUCTION

A unique set of combined high resolution refraction/reflection seismic data has been obtained by the Geological Survey of Canada (GSC) during the open water seasons of 1985 through 1988 (Fortin 1986, 1987, 1988 and 1989). The seismic lines traversed during the course of these surveys are chiefly concentrated over the southern Akpak Plateau in the Canadian Beaufort sea (Figure 1). These reconnaissance-level surveys aimed to test two prototypes (12 and 24 channels) of deep-towed refraction arrays which are currently under development by the Terrain Sciences Division of the GSC. The primary objective of these sea trials was the detection of abnormally high compressional waves velocities indicative of shallow ice-bearing permafrost. In addition, the technique proved to be effective in obtaining information on the acoustic velocities, the seismo-stratigraphy and the lithofacies of seabed and near seabed sediments to a depth of about 10-15m subbottom penetration.

The meticulous analysis of the high resolution refraction data, supplemented by reflection profiles, has demonstrated that interpretation of the surficial geology is significantly more detailed than it would be if, as it was the case in the past, only reflection data were available. As a matter of fact, the recording of compressional wave velocities allows the seismic interpreter to better understand the geological significance of the observed seismic facies on the reflection records, and hence to reduce substantially the interpretation uncertainties. For instance, it is now possible to judge whether diffraction patterns and acoustic blanking visible on the reflection records are caused by boulder beds or shallow gas pockets.

As noted above, the GSC experimentation was focussed primarily on the detection of shallow ice-bearing permafrost and the prediction of the engineering properties of surficial sediments for the evaluation of pipeline routes and well sites. However, the potential application of the deep-tow refraction technique to subseabed granular resources evaluation was recognized (Fortin et al., 1987), and H.R. Seismic Interpretation Services Inc. (S.I.S.) was requested subsequently by the Department of Indian Affairs and Northern Development (DIAND) to review this unique data set in a perspective oriented towards the DIAND offshore granular resources inventory program.

1.2 OBJECTIVES

Based on the existing high resolution reflection profiles, deep-tow refraction data, and other existing geoscience information, the study aims to identify specific target areas and provide future site investigation requirements for confirming the existence and extent of potential granular resources in the southern Akpak Plateau area.

1.3 AUTHORIZATION AND DISCLAIMERS

Authorization to undertake the work was granted to S.I.S. of Hull, Qc, by Supply and Services Canada (SSC) under SCC File No. 38ST.A7134-8-0054. Mr. R.J. Gowan of DIAND in Hull was the Scientific Authority for the study.

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1.4 ACKNOWLEDGEMENTS

S.I.S. appreciates and acknowledges the Panel on Energy Research and Development (PERD), through the following programs: Program 6.1; Permafrost, and Program 6.3; Offshore Geotechnics, for permission to use their geophysical data. Discussions with J.-S. Vincent, J.A.M. Hunter and S.M. Blasco of the Geological Survey of Canada were of great benefit to understanding the main elements of the Quaternary geology.

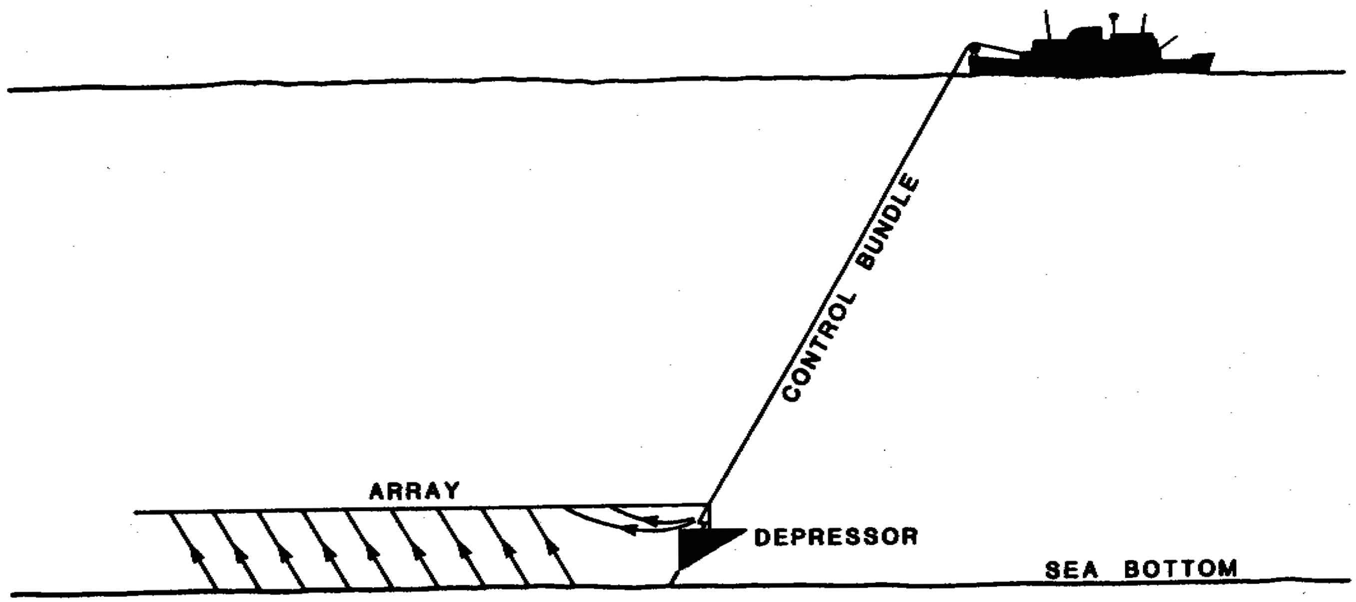


FIG. 2 DEEP-TOW REFRACTION ARRAY.

SECTION 2 - DATA SOURCE

The geophysical data utilized for the preparation of this report have been gathered during four distinct field operations (Fortin 1986, 1987, 1988 and 1989), which were carried out in 1985, 1986, 1987 and 1988 by the GSC (Figure 1). During the course of these combined high resolution refraction/reflection surveys, approximately 9,300 refraction seismograms were collected along with about 1,410 km of reflection seismic profiles.

2.1 GEOPHYSICAL SURVEY TECHNIQUES

The field investigations were conducted by means of deep-towed refraction arrays (12 and 24 channels) and various acoustic profiling systems such as: 3.5 and 7 kHz subbottom profilers, a Uniboom, a Bubble Pulser, and a small airgun array. However, not all the seismic reflection devices were operating simultaneously along the course of the survey lines. Details of the seismic techniques employed in each survey are provided in the earlier reports to the GSC (Fortin 1986, 1987, 1988 and 1989).

2.1.1 High Resolution Refraction Data

The high resolution refraction seismograms were obtained by means of the GSC prototypes of deep-towed refraction eels (Figure 2) that include 12 channels (1985 and 1986 seismograms)

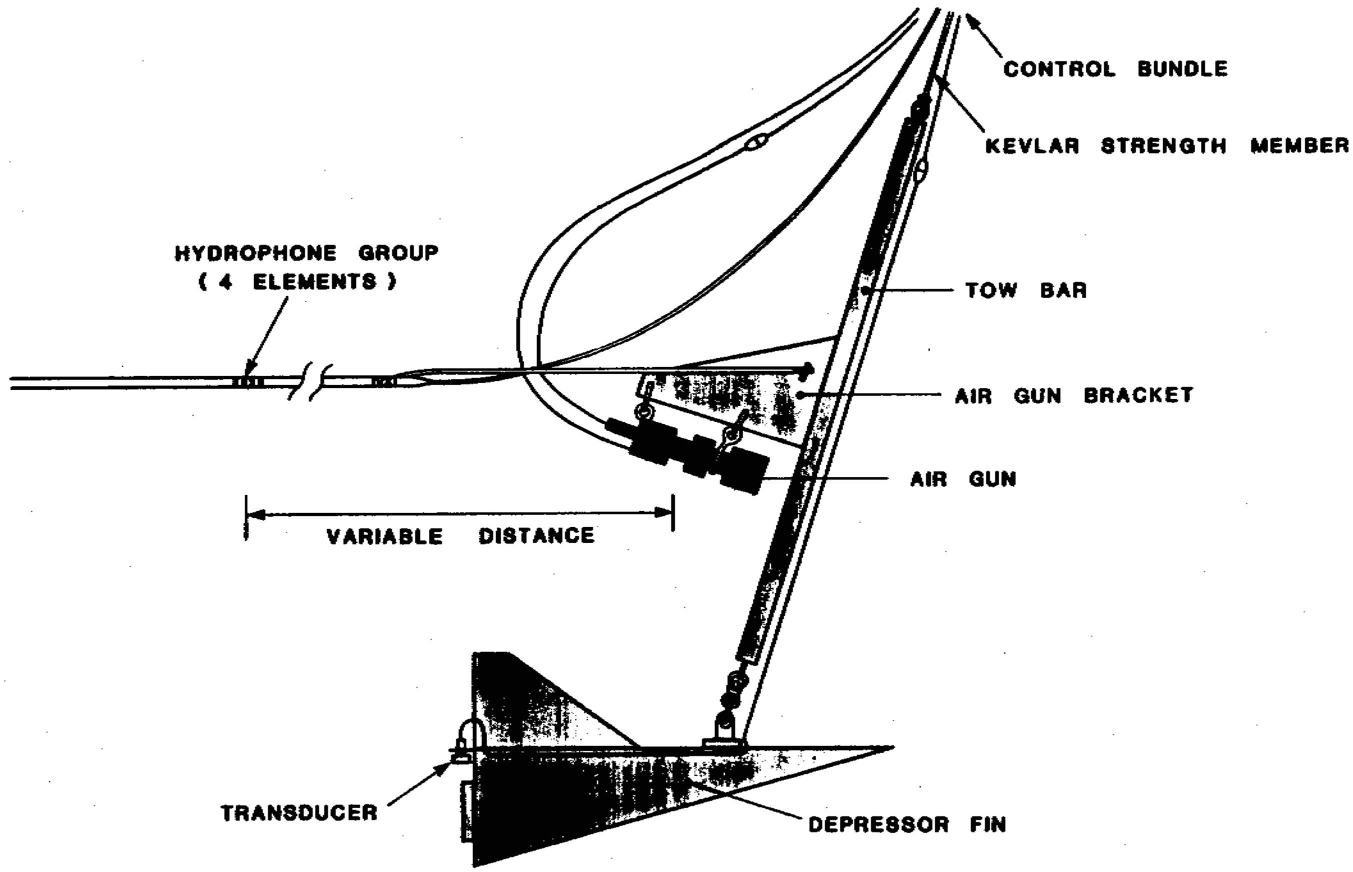


FIG. 3 FORWARD UNIT OF THE EEL.

or 24 channels (1987 and 1988 seismograms). In both cases, the technique remains essentially the same. The array is towed within 5m of the seabottom and an airgun acts as the seismic energy source. Although the prototype systems have the capability of acquiring data at a maximum rate of one seismogram every 15 seconds (30m intervals at a cruising speed of 4 knots), velocity observations were made at intervals ranging between 100 and 200m during these reconnaissance-level surveys.

As illustrated in Figure 3, the forward unit of the eel consists of a tow bar, an airgun mounting bracket, and a depressor fin. The depressor fin includes a high frequency transducer to monitor the position of the leading end of the eel with respect to seabottom. The refraction data from the hydrophone array are captured by a digital acquisition system (Nimbus 1210F or Scintrex engineering seismograph) for analog to digital signal conversion. The refraction data, in a digital format, are transferred directly to a microcomputer (Apple II or Data General) for on-line processing and floppy disc storage for subsequent display on paper print out.

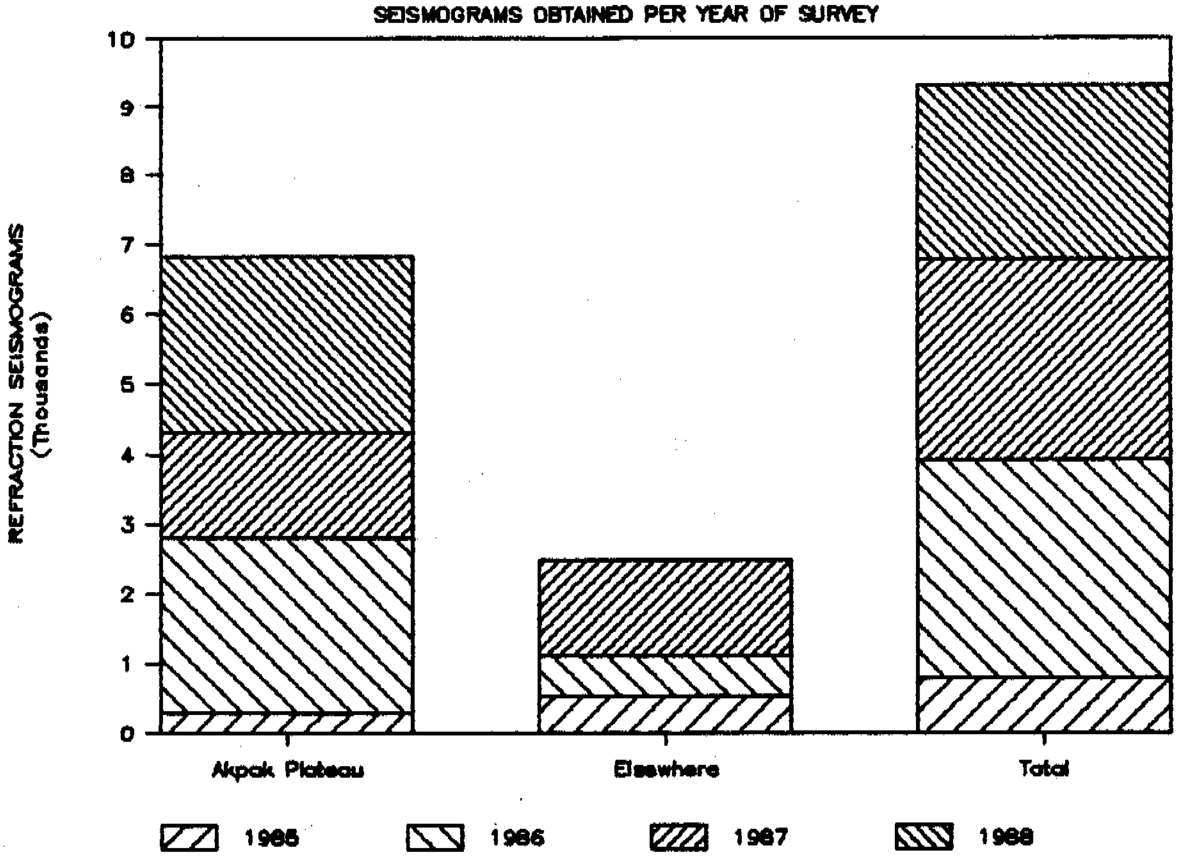
2.1.2 High Resolution Reflection Data

During the 1985 field operations, a Raytheon RTT 1000 profiler operating at a frequency of 7 kHz was utilized as the acoustic profiling system, while a frequency of 3.5 kHz was selected during the 1986 survey. For both years, the subbottom profiler was pipe-mounted at a fixed position aside the survey vessel. In 1987, the reflection equipment consisted of: a Raytheon 3.5 kHz subbottom profiler (pipe-mounted), a surface-tow EGG Uniboom, and a new Data Sonics Bubble Pulser system. During the 1987 survey, the Uniboom system was used quite extensively and boomer records are available for all the survey lines, while the 3.5 kHz subbottom profiler and the Bubble Pulser were in operation along a limited number of lines. The profiling systems utilized during the 1988 field operations consisted of: a Raytheon RTT 1000 operating at a frequency of 3.5 kHz, an EGG surface-tow Uniboom system, and a small array airgun profiler. The reflection systems were operating simultaneously along most of the survey lines.

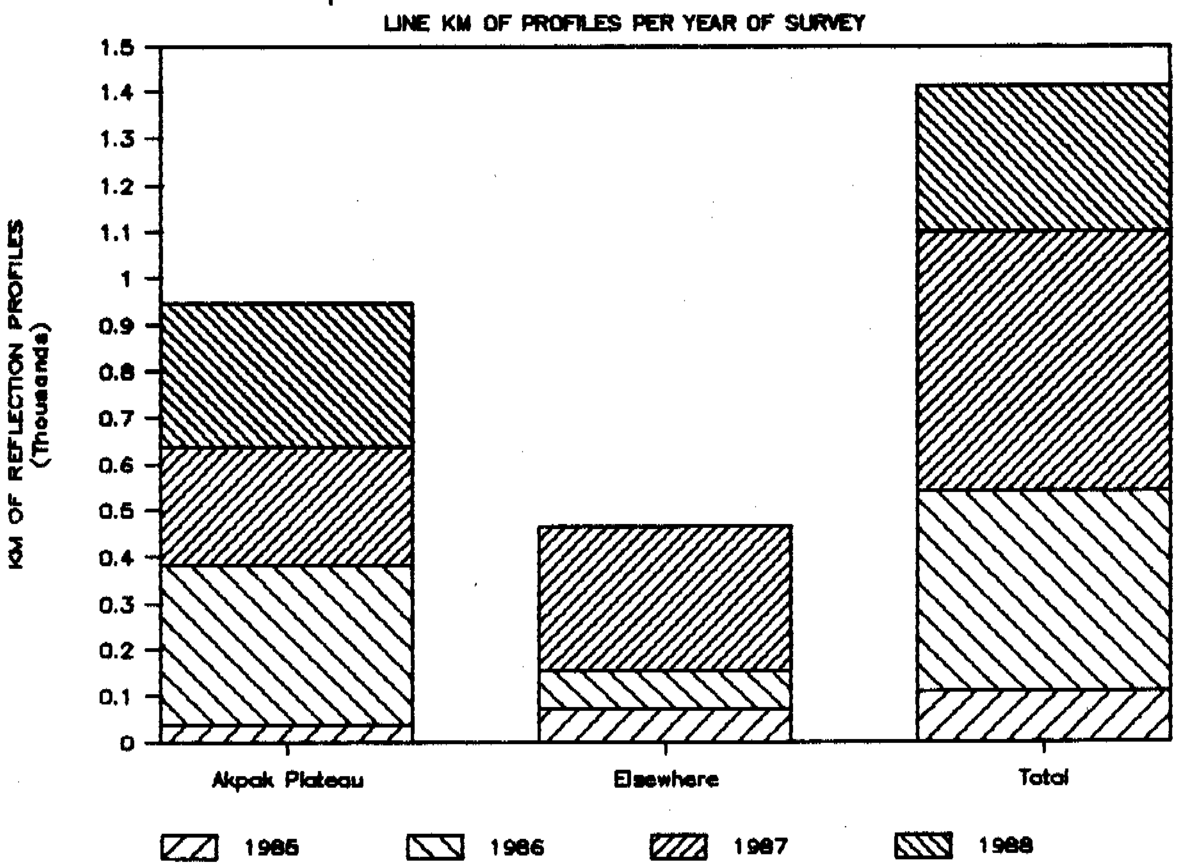
2.2 SEISMIC DATA BASE

A total of 9,300 refraction seismograms and 1,412 km of seismic profiles were collected during the four reconnaissance programs and two site specific studies (see Plate I). As illustrated in Graphs 2.1 and 2.2, a large portion of these seismic records were obtained across the Akpak Plateau providing a reasonably good coverage of reconnaissance survey lines across the southern sector of the Plateau (Cf. Figure 1). The average spacing of the east-west survey lines is about 1.5-2 km, while the tie-lines were traversed at an average spacing of about 4-5 km. From the existing data base, approximately 6,825 seismograms and about 950 km of seismic profiles have served to

Graph 2.1: REFRACTION DATA BASE



Graph 2.2: REFLECTION DATA BASE



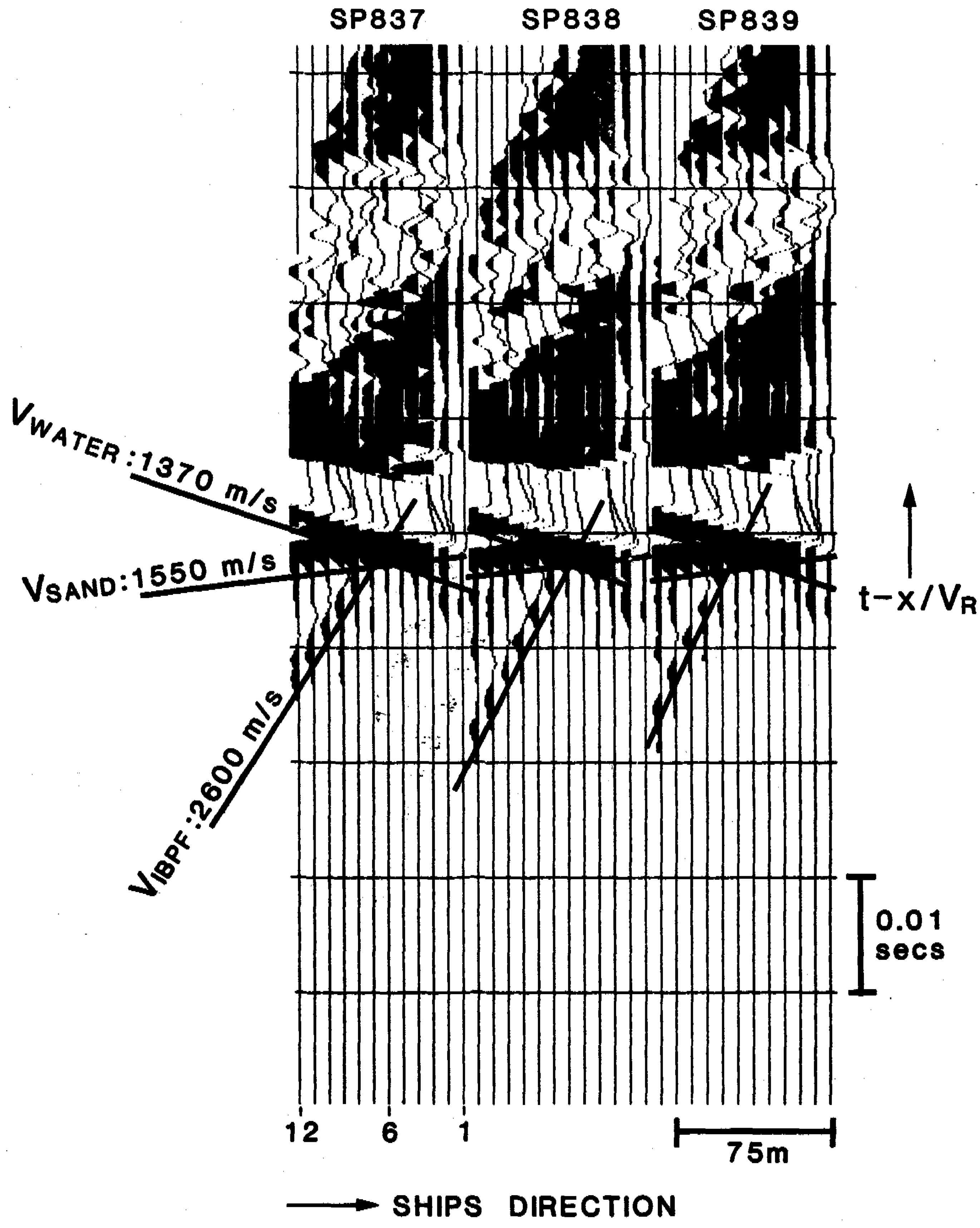


FIG. 4 12-CHANNEL SEISMOGRAMS; "REDUCED TRAVEL TIME".

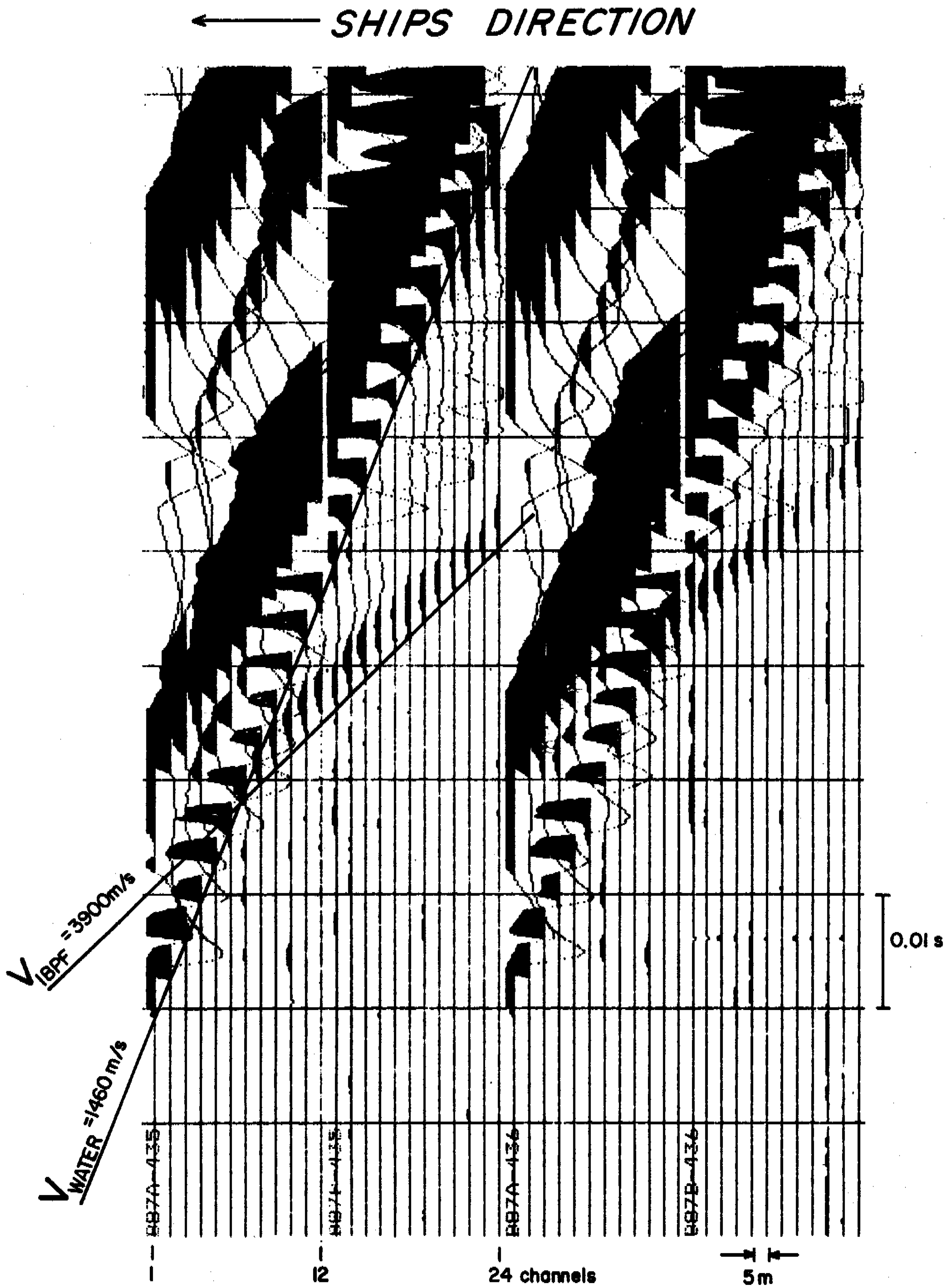


FIG. 5 SEISMOGRAMS SHOWING REFRACTED EVENTS ASSOCIATED WITH ICE-BEARING PERMAFROST (IBPF).

develop a regional model for the surficial geology of the southern Akpak Plateau. In the present report, the proposed geologic model will be used quite extensively in the evaluation of the granular resource potential of this sector of the Plateau.

2.3 DATA HANDLING

2.3.1 High Resolution Refraction Data

The 1985 and 1986, 12-channel refraction data were displayed in the "reduced-travel time" format (Fortin et al.,1987). This technique has the effect of enhancing the slopes of first arrival events having relatively slow velocities (Figure 4), which are in the range of seabed and near seabed velocities (1,400-1,750 m/s) commonly associated with typical Beaufort surficial sediments. Reduced-travel time display software was not available in 1987 and 1988 for the 24-channel refraction data and consequently, the time-distance plots were displayed in the standard format (Figure 5).

In both cases, the analysis of the headwave arrivals is undertaken manually on the annotated paper print out of the seismograms (Figures 4 and 5). A straight line is fitted through at least three points of the observed headwave arrival times on the time-distance plot. The resulting slope (distance over time) gives the compressional wave velocity propagating along a seismic discontinuity or a refracting surface (e.g. seabed, lithological boundary, unconformity, ice-bearing sediments, etc.).

The depth of the refractor is computed using the critical distance method , where:

$$H = \frac{Xc}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

H = depth to the V_2 layer
Xc= critical distance
V_1= velocity of the direct wave
V_2= velocity of the refracted headwave

2.3.2 High Resolution Reflection Data

A constant velocity of 1,500 m/s was utilized for time-depth conversions of the shallow subbottom reflectors. The interpretation procedure used to predict the lithology of the surficial deposits is widely based on qualitative interpretation criteria such as:

1) The depth of penetration through the subbottom achieved by the various profiling systems having different frequencies.

2) The strength of the water bottom multiple which is indicative of the relative seabed hardness.

3) The various acoustic signatures (reflection configuration, continuity and amplitude) and facies (reworked, remoulded, stratified, partially stratified and chaotic) which may be related to depositional processes, gross depositional environment, sediment source, geologic setting, etc.

4) Seafloor anomalies, usually subdued high and low reliefs, which may indicate the presence of submerged features such as: sand ridges, highlands, paleochannels, etc.

Many of the factors or parameters used in this type of seismic interpretation are of qualitative nature and their relative importance may vary considerably among seismic interpreters. The interpretations or inferences proposed in this report are calibrated with the results obtained from both geophysical and geotechnical site investigations using similar high resolution reflection devices. These investigations were conducted in the various environments found in the Beaufort Sea; in particular, in the Isserk and Issigak borrow pit areas, and in the Banks Island area. In the present granular resource evaluation of the southern Akpak Plateau, where borehole information is limited primarily to the Isserk borrow pit area, the lithological nature of the shallow stratigraphic units can only be interpreted from the acoustic character of the signal reflected by the different geologic horizons, and their associated compressional wave velocities. The author acknowledges that some inferences may not be exact at specific sites, but it is his opinion that many of the regional interpretations, and their probable geologic significance, are still valuable in the overall interpretation of both the general surficial geology and depositional environments.

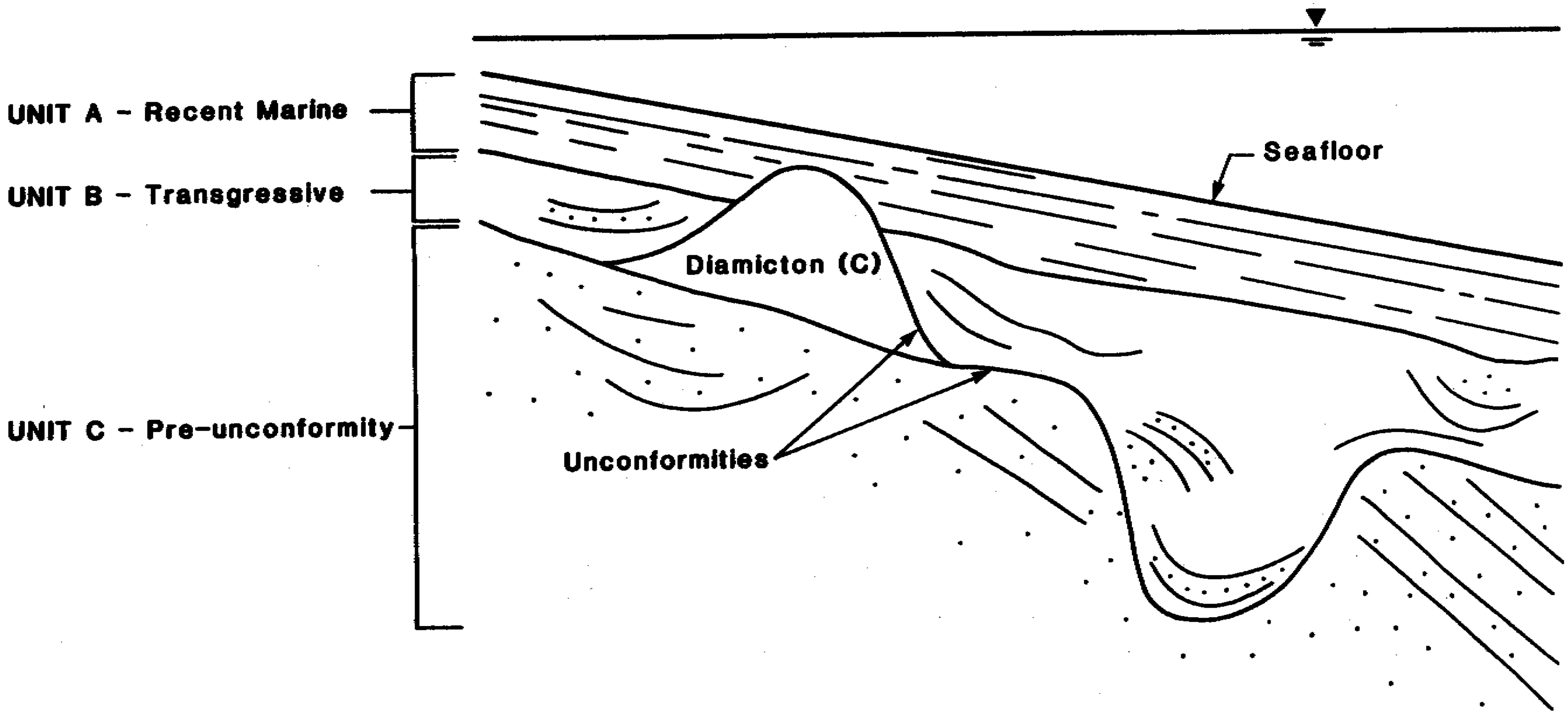


FIG. 6 O'CONNOR's GEOLOGIC MODEL.

SECTION 3 - GEOLOGICAL BACKGROUND

Although the geological model proposed in this report (Cf. Sect. 5) is at variance with the model adopted by the GSC for the surficial geology of the Canadian Beaufort Sea (Figure 6), the nomenclature used for the shallow stratigraphic units along the refraction/reflection survey lines is generally based on the GSC model. Basically, the GSC model is a generalized surficial geologic model of the continental shelf and consists of three basic stratigraphic units (O'Connor, 1980):

"**Unit A**" - a horizontal sequence of recent marine sediment deposited on the shelf following the last sea level rise, which grades into;

"**Unit B**" - a transgressive sequence which includes deltaic, lagoonal and littoral sediments deposited in a complex transitional environment which existed during the last sea level rise.

"**Unit C unconformity**" - Units A and B overlie a regional unconformity that marks the top of an older unit. The unit C unconformity represents a previous land surface which was subaerially exposed to arctic conditions and permafrost aggradation during Late Wisconsin Glaciation.

"**Unit C**" - an underlying, much older sequence whose original depositional environment is poorly known, and probably contains sediments derived from former continental (glacial, fluvial and eolian) and transitional (deltaic, littoral) environments.

3.1 SURFICIAL GEOLOGY OF THE SOUTHERN AKPAK PLATEAU

O'Connor (1982) described the Akpak Plateau as a sandy

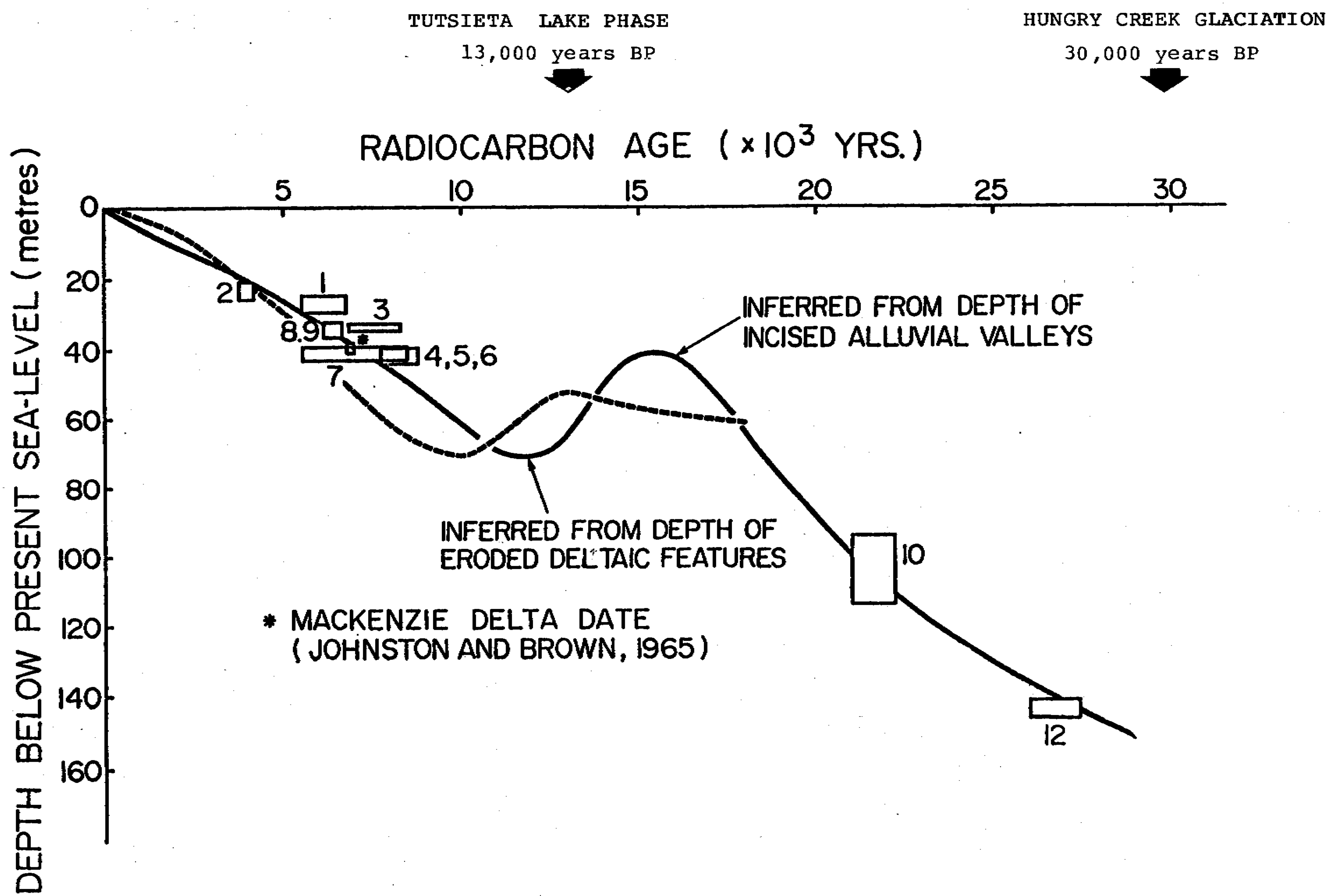


FIG. 7 RELATIVE SEA-LEVEL CURVE FOR THE CANADIAN BEAUFORT SHELF (After Hill et al.1985)

upland area which may have been the northward extension of Richards Island. The seafloor slopes gently and rather uniformly from the existing coastline to water depths of 58 to 60m with the isobaths convex seaward.

According to Hill et al. (1985) the relative sea-level (RSL) rose of 140m since 27,000 years BP (Figure 7). During this period of sea level depression, the continental shelf was exposed to permafrost aggradation, subaerial erosion and eolian deposition. As the sea level rose during the following deglaciation, reworking of surface materials by progressive coastlines took place, redepositing the reworked materials in sequences that reflect the uneven advance of the coastline over the land surface.

O'Connor (1982) reported that, in some nearshore areas of the Akpak Plateau, the silty clay observed near the seafloor is clearly not recent marine in origin. This worker suggested that, since the clay has stiff consistency, its velocity may be slightly higher than the normal recent marine sequence and may have a glacial origin. In the past, identification of glacial sediments on seismic reflection profiles has not generally been possible in the absence of compressional wave velocities. A singular exception to this statement may be provided by O'Connor (1980; Figure 47). On the basis of a seismic profile located about 15 km north of Pullen Island, this author suggested that glacial sediments, perhaps similar to those encountered on Pullen Island (till and associated gravel and sand), have been advanced to this location and then drowned during the last sea level rise.

O'Connor (1982) reported that north of the 15m isobath, the pre-unconformity sediments (Unit C) consist of fine- to medium-grained sand having a trace to some silt. Local channels at and below the unconformity U/C1 may be filled with finer-grained sediments and occasional organic-rich layers. Most of this sand is compact to very dense, but where it outcrops at the seafloor (e.g. Isserk borrow pit) it may be in a slightly looser condition. This sand has been extensively used as borrow material for artificial island construction (e.g. Isserk E-27 and Issungnak O-61 islands).

3.2 QUATERNARY GEOLOGY OF THE ADJACENT MAINLAND

A significant contribution to the study of the Quaternary geology of the Tuktoyaktuk Coastlands has been provided by Rampton (1988). The following discussion on the Quaternary geology of the adjacent mainland (Richards Island) summarizes the results of this worker.

In the immediate vicinity of the southern Akpak Plateau, the surficial geology of Pullen Island and North Point is dominated by two deposits: a thin veneer, generally less than one metre, of morainal deposits of Early Wisconsinan Age, that blankets the Kittigazuit Formation of Middle Pleistocene Age.

The morainal deposits (Unit M T/V of Rampton, 1987), primarily the till and till-related facies, have been assigned to the Toker Point Member of the Tuktoyaktuk Formation. Morainal deposits of the Toker Point Member consist primarily of a stony clayey diamicton. Typically the material contains 3 to 25% clasts greater than 2 mm in size and the remainder contains 10 to 30% sand, 25 to 45% silt, and 30 to 50% clay. Rampton and Bouchard (1975 in Rampton 1988, p.49) noted that "beds and lenses of sandy, stony, diamicton occasionally occur within this unit where it abuts against or is underlain by gravel" in the Tuktoyaktuk area.

The Kittigazuit Formation is typically a light brown, thinly bedded sand; individual beds are commonly 0.5-8 cm thick, and rarely up to 20 cm thick. Individual beds may grade from silty fine sand to a clean fine sand or from a clean fine sand to a medium-fine sand. The most conspicuous characteristic of the Kittigazuit Formation is the presence of thick foreset beds with a common strike and dip; they are up to 12m thick on northern Richards Island and dip in northerly directions on Richards Island. In this area, the Kittigazuit Formation may have a minimum thickness of 18-20m. Rampton (1988) indicated that the Kittigazuit Formation with its large foresets represents deltaic deposition. A rapid influx of terrestrial material into the sea

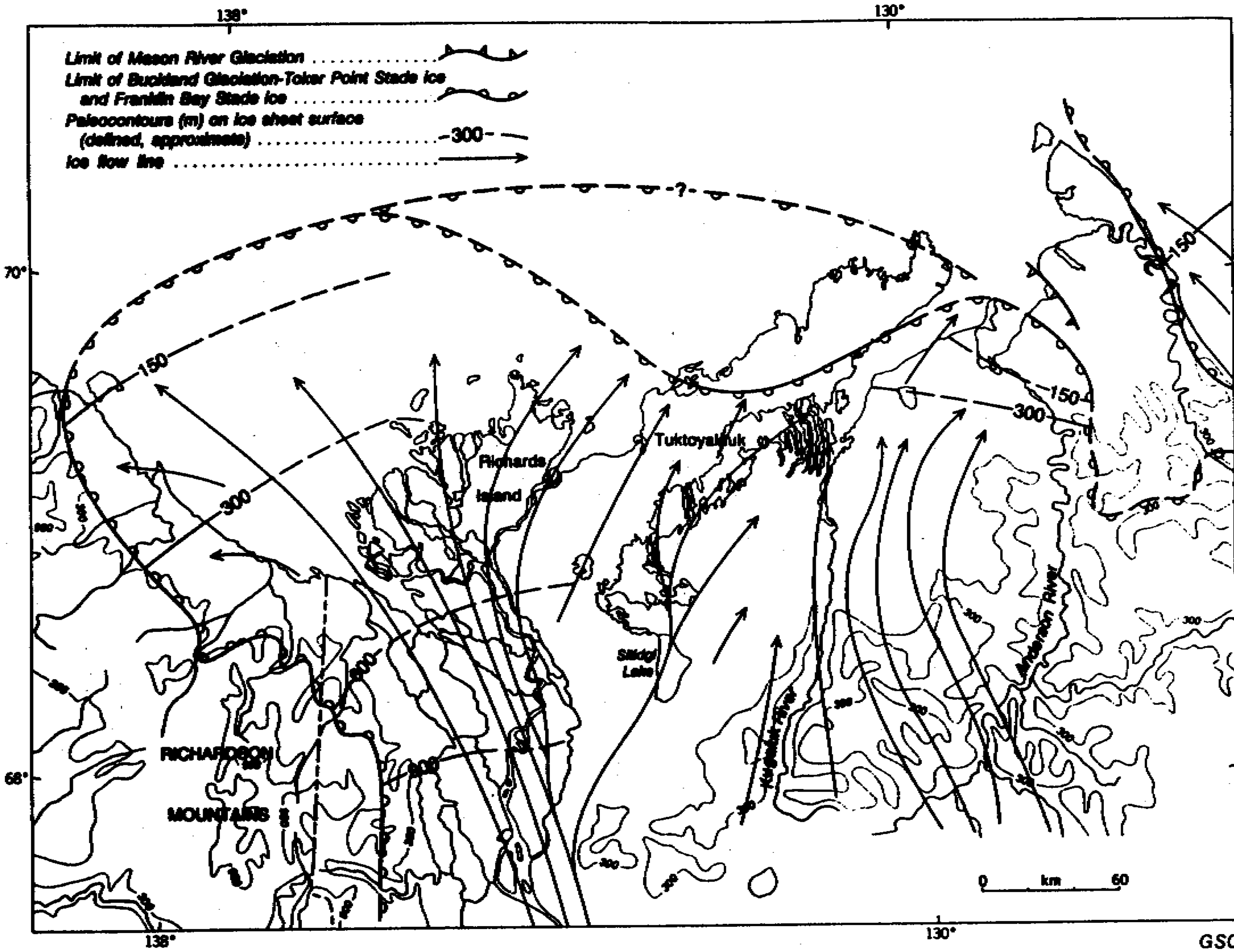


Figure 8. Ice flow and glacial limits during the Middle Pleistocene Mason River Glaciation, and the Early Wisconsinan Toker Point (Buckland Glaciation) and Franklin Bay stades. (After Rampton, 1988) is suggested by the sparseness of marine fossils within the formation. Most fossils identified within the Kittigazuit Formation suggest a cold dry climate during its deposition. Alternatively, J.-S. Vincent (GSC, pers. comm. 1988) suggested that the Kittigazuit Formation may be large sand dunes which would be oriented in a northeast direction.

Figure 8 illustrates the glacial limits during the Middle Pleistocene Mason River Glaciation, and the Early Wisconsinan Toker Point and Franklin stades. This figure shows that glacial maximum during the Toker Point Stade reached a NW-SE oriented limit some 30 km northeast of Pullen Island. On the Tuktoyaktuk Peninsula , this glacial limit delineates the northern boundary of ice-contact deposits and local areas of morainal deposits (Rampton, 1987; Unit G T/X, Map 1647A), generally 5 to 20m thick. North of this limit, thick outwash plains and valley trains (Unit G T/P, Map 1647A), generally 3 to 30m thick, have been mapped in the northern edge of the Tuktoyaktuk Peninsula (assigned to the Cape Dalhousie Sands). Rampton (1988) indicated that when Early Wisconsinan ice stood at its maximum extent, meltwater undoubtedly flowed northward into the Beaufort Sea and deposited large volumes of outwash.

Rampton (1988) has indicated a tentative Early Wisconsinan age for the Toker Point Stade glacial limit on the Tuk Peninsula, although Hughes (1987) suggested that this limit is that of a glaciation younger than the Hungry Creek Glaciation in Bonnet Plume Basin and the correlative Buckland Glaciation in northern Yukon. According to Hughes (op. cit.), the advance of the Laurentide ice sheet to its all-time limit culminated as late as 30,000 years BP during the Hungry Creek Glaciation. This author reported that the Hungry Creek Glaciation was followed by two significant readvances on the mainland: the Tutsieta Lake Phase culminating at or before 13,000 years ago, and the Kelly Lake Phase before 10,600 years ago.

SECTION 4 - ALLIED STUDIES

Much of the information presented in this report is based on the sea trial results of deep-towed refraction array prototypes developed under the leadership of J.A.M. Hunter of the Terrain Sciences Division of the GSC (PERD Program 6.1; Permafrost), as well as the independent interpretation work of S.I.S. (Fortin 1986, 1987, 1988 and 1989; Fortin et al., 1987) under contract to the GSC. An important amount of reflection seismic profiles has been provided by S.M. Blasco of the Atlantic Geoscience Centre (PERD Program 6.3; Offshore Geotechnics).

During the last decade , the GSC has tested various refraction arrays in order to measure the compressional wave velocities associated with ice-bearing sediments, seabed materials, and subbottom layering. The first generation of refraction arrays was designed for deployment on the seafloor from the ice surface (Hunter et al., 1979) or from a ship (Hunter et al., 1982). Although the seabottom-laid refraction arrays are capable of providing velocity measurements and information on the sediment types, this technique is time-consuming being currently limited either to available leads in sea-ice, or by frequent stopping and anchoring during the shipborne operations. This problem was largely overcome during the 1985 through 1988 field seasons by using multichannel, deep-towed hydrophone arrays. The main advantage of the deep-tow arrays over similar bottom-laid arrays is the capability of the towed arrays of acquiring

GEO - ACOUSTIC MODEL
'AKPAK PLATEAU'

(AFTER FORTIN, 1987)

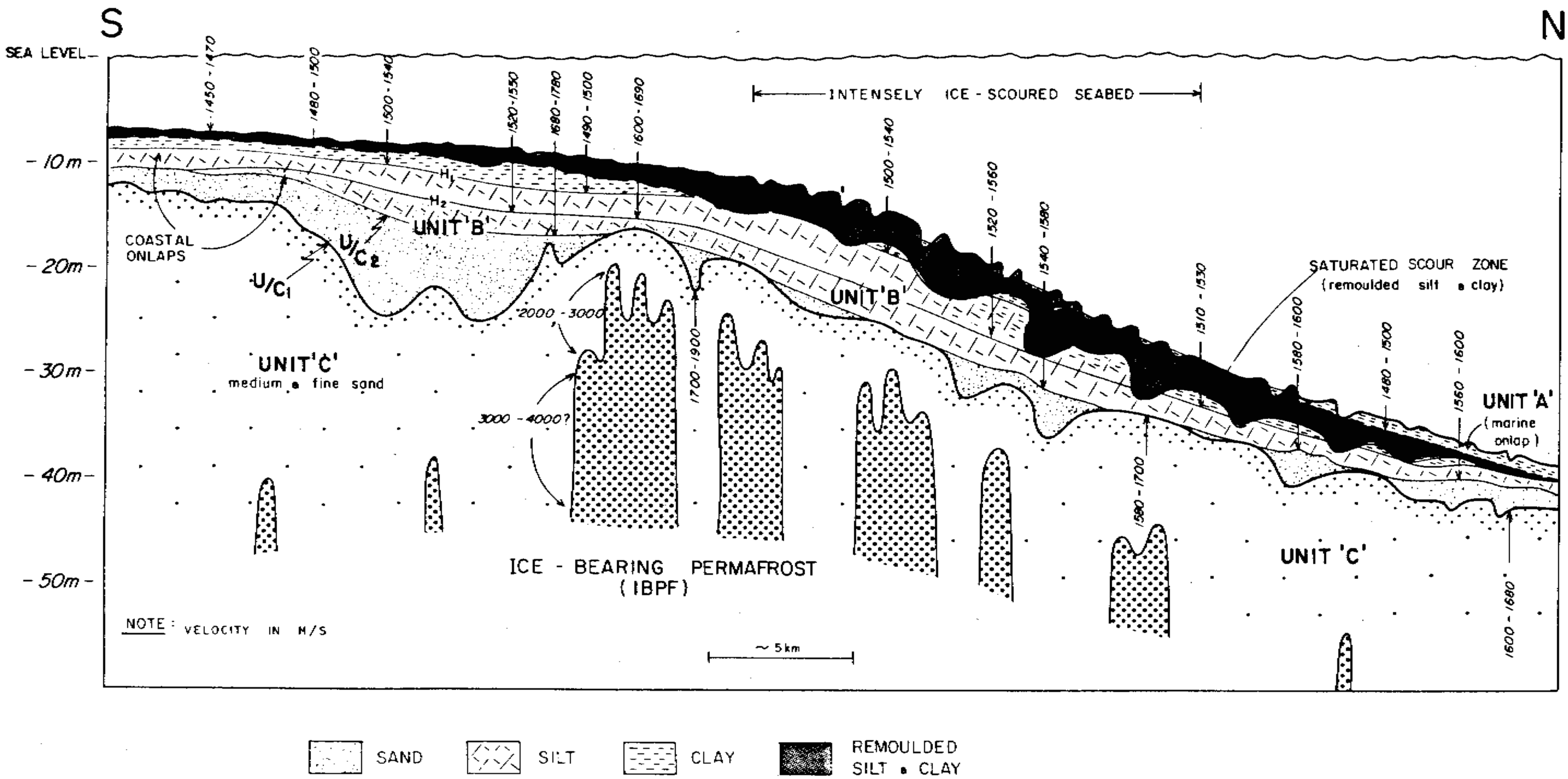


FIGURE 9

velocity data in a near-continuous mode while the ship is cruising at a normal speed of 3 to 5 knots.

Fortin (1986) compiled the 1985 high resolution seismic data which were collected across the Akpak Plateau and the Kugmallit Channel . Fortin (1986) and Fortin et al. (1987) concluded that the 12-channel refraction eel can be used in the hostile environment of the Southern Beaufort Sea. This technique is capable of detecting permafrost velocities (2,000-4,000 m/s) to a depth of about 20-25m, as well as obtaining compressional wave velocities (1,400-2,100 m/s) from seabed sediments and shallow subbottom horizons to a depth of 7-8m.

In 1986, as part of the testing program of the 12-channel eel, a second and more extensive refraction/reflection seismic survey was carried out in the coastal waters of the Southern Beaufort Sea, including: the Akpak Plateau, the Kugmallit Channel and the Tingmiark Plain. Fortin (1987) utilized the 1986 velocity observations associated with the shallow seismic discontinuities to establish the first outline of a geo-acoustic model for the surficial geology of the southern sector of the Akpak Plateau. Fortin (op. cit.) observed a significant increase in the velocity of the surficial sediment in the vicinity of topographic highs (Figure 9), suggesting that a sediment coarsening occurs in the deposits overlying heights of the unconformity surface (U/C1). Fortin (op. cit.) reported that

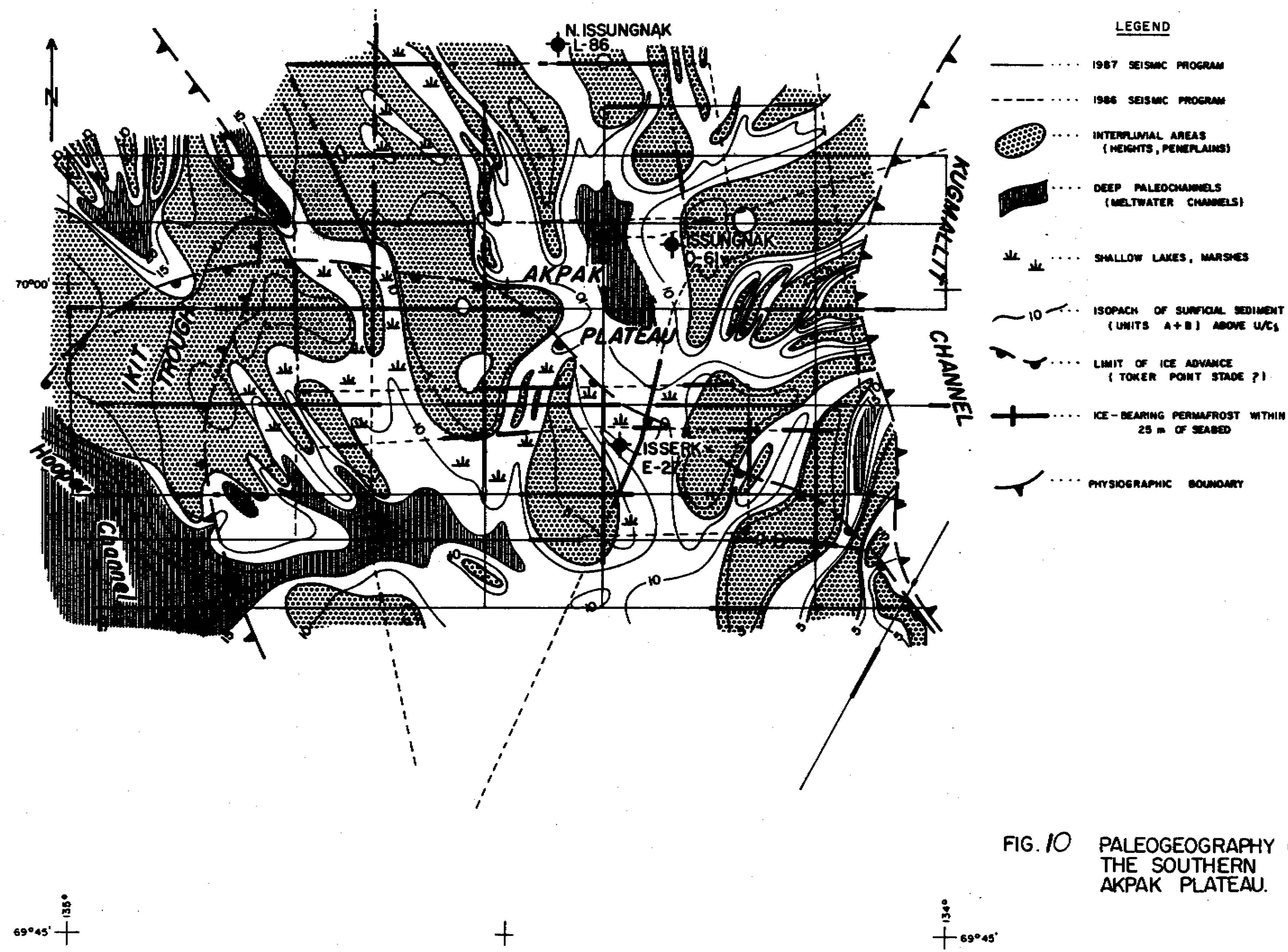


FIG. 10 PALEOGEOGRAPHY OF THE SOUTHERN AKPAK PLATEAU.

abnormally high seismic velocities (2,000-4,000 m/s), typical of ice-bearing sediments, were measured solely within the pre-transgressive Unit C sediments (Figure 9).

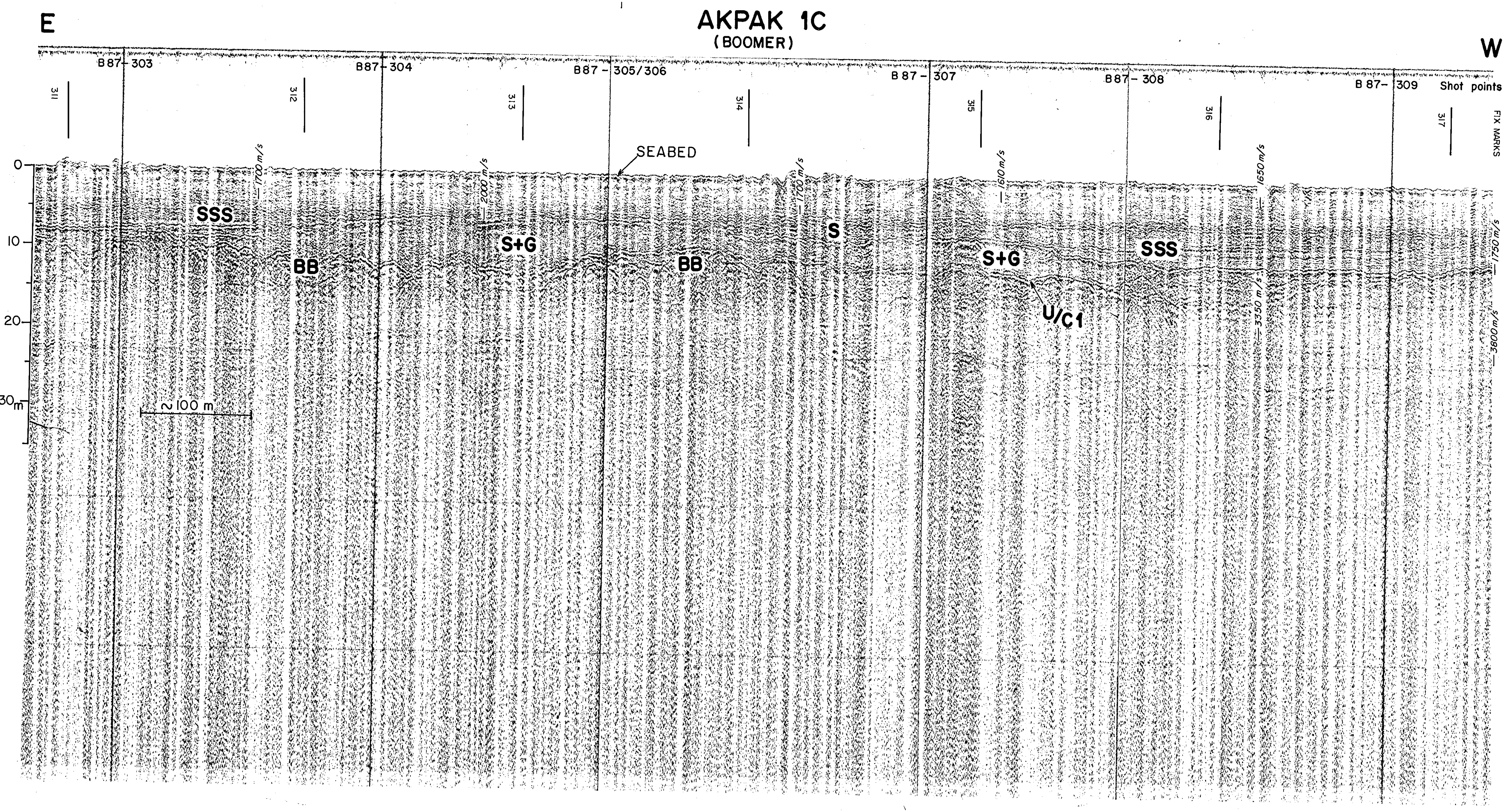
In order to better understand the surficial geology of the southern Akpak Plateau, Fortin (1988) attempted to reconstruct the paleogeography that existed in this sector of the Plateau prior to the last marine submergence. Towards this end, Fortin (op. cit.) undertook a synthesis of the subject high resolution refraction and reflection data in order to picture the residual topography of the land surface, or the last Pleistocene subaerial exposure, that resulted from the shoreface erosion of transgressive coastlines. The resulting map illustrated in Figure 10 is believed to be a powerful tool for both granular resource evaluation and borrow search over this region of the Plateau.

Examination of the seismograms has shown that high velocity (1,800-2,100 m/s) materials are present near the unconformity U/C1 surface. Although these velocities may also result from the presence of frozen sediments having a marginal ice-content, they are thought to be indicative of very coarse-grained sediments (ice contact and morainal deposits ?). This interpretation is supported by the various acoustic signatures visible on the profiling records. The boomer record in Figure 11 exhibits a chaotic seismic facies typical of very coarse deposits that may include sand and gravel, as well as diffraction point sources that are characteristic of boulder beds. In addition, high compressional wave velocities on the order of 1,700-2,000 m/s are associated with the upper (reworked) zone of the deposit. The fact that both pieces of evidence, diagnostic seismic facies and high acoustic velocities, occur above the unconformity U/C1 reinforces the interpretation of granular deposits because the presence of frozen ground above U/C1, i.e. within the surficial sediment, has not been satisfactorily reported elsewhere to date.

In the light of the recent observations made on the adjacent mainland by Rampton (1988), Fortin (1988) speculated that the northernmost occurrences of the interpreted very coarse deposits delineate a limit of ice advance on the Akpak Plateau. This possible limit of ice advance (Figure 10) shows a good agreement with the offshore extension of the limit of the Toker Point Stade ice (Cf. Figure 8) such as mapped onshore by Rampton (1987). On the Tuktoyaktuk Peninsula, this glacial limit marks the northern boundary of ice-contact deposits and local areas of morainal deposits, generally 5 to 20m thick (Rampton, 1987). North of this limit, thick outwash plains and valley trains, generally 3 to 30m thick, have been mapped in the northern edge of the Tuk Peninsula. Although no geological evidence has been provided yet, Rampton (1988) proposed an alternative limit for the Toker Point Stade ice (Cf. Figure 8), which introduces the possibility that ice contact and morainal deposits might be present in the northern sector of the Akpak Plateau. Except for some possible lag deposits (thin patches of gravel near U/C1), there is little evidence for this alternative glacial limit in the present seismic data base.

Fortin (1988), based on the hypothesis that the Toker Point Stade ice stopped near the glacial limit shown on the paleogeographic map in Figure 10, opined that the deep paleochannels outlined north of this boundary may have been meltwater channels that flowed into the Ikit Trough to the west and the Kugmallit Channel to the east. Early deglaciation was likely accompanied by ice retreat that occurred southward into Richards Island leaving a relatively thin (presumably ?) layer of ice contact and morainal deposits (J.-S. Vincent, GSC, pers. comm., 1988), which were deposited south of the mapped maximum ice extent (Figure 10). These granular materials, which are not easily eroded by glacial meltwater, may have formed a resistive barrier paralleling the limit of ice advance (Figure 10). As a result of this resistive hilly belt, large volumes of meltwater and outwash were deflected westward and funnelled through a major meltwater channel debouching into the Hooper Channel to the west (Figure 10).

The above paleoenvironment reconstruction brings out glacial advance and retreat as important mechanisms to explain the presence of glacial sediments over the southern Akpak



SSS : Stratified Sand & Silt
S : Sand
S+G : Sand & Gravel
BB : Boulder Beds

FIG. 11 REWORKED TILL ? AND RELATED FACIES.

Plateau. This proposed model, and other seismic inferences, will serve in the next section of this report to delineate the preferred areas where granular materials may be exposed at or near the seafloor.

SECTION 5 - POTENTIAL SITES FOR GRANULAR RESOURCES

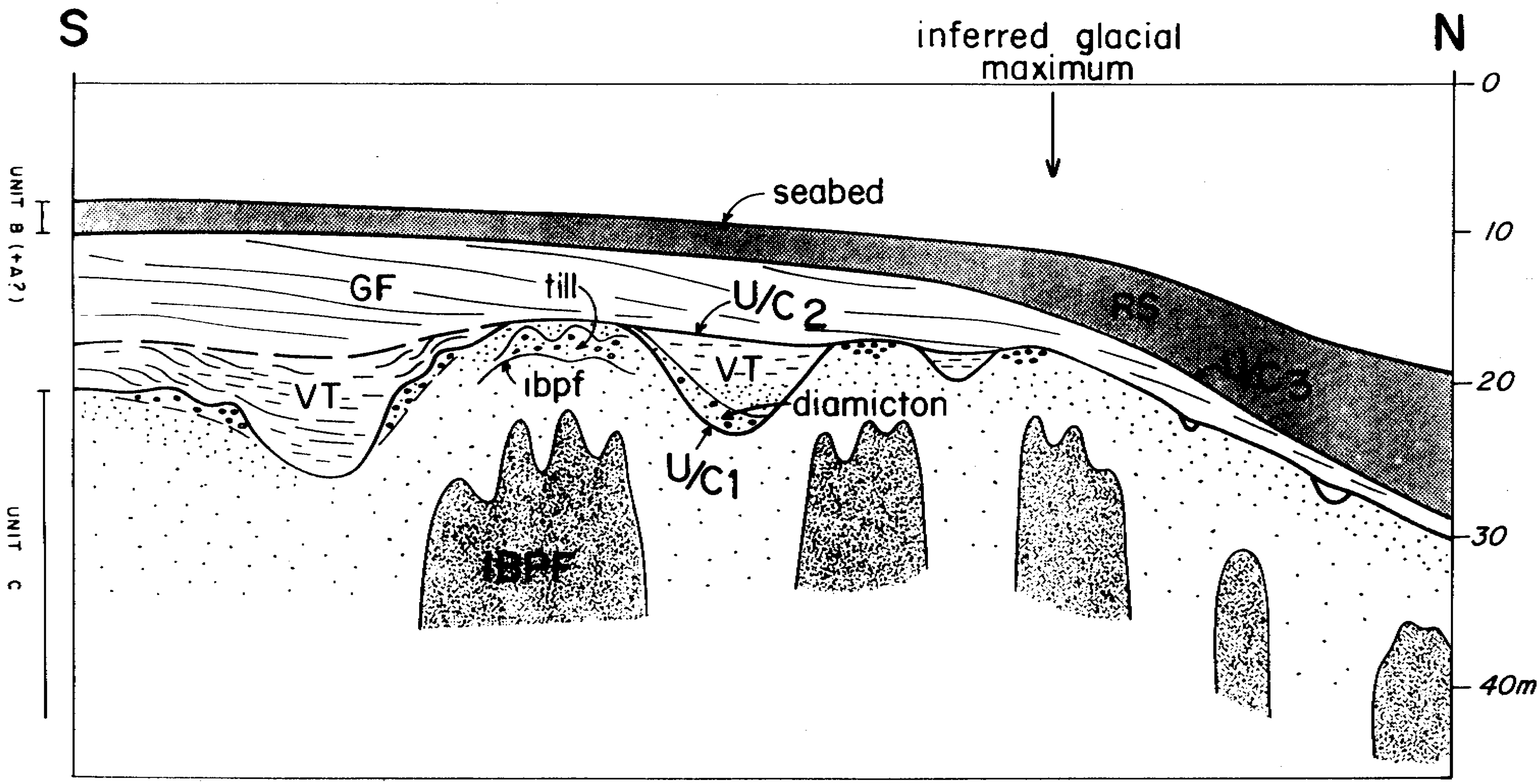
This section involves an evaluation of the granular resource potential of a number of specific target areas in terms of **Prospective Resources.** This term refers to granular resource deposits whose existence is speculated on the basis of indirect evidence (e.g. acoustic signature, compressional wave velocity, etc.), and/or general geological considerations.

One should note that since only geophysical data has been used, no attempt has been made to assess the thickness, quantity or quality of the granular resources that might be present in any of the target areas delineated in this report.

The study does not deal specifically with the Isserk Borrow Pit, but some possible extensions to the present borrow site are outlined in this report.

5.1 GEOLOGICAL MODEL

In this sector of the Akpak Plateau, the O'Connor Unit B is not recognized as a purely transgressive deposit, but it is believed that this unit includes rather a number of sequences which would have deposited following the inferred glacial maximum (Cf. Figure 10). In our model, Unit B would have accumulated during the course of at least three major depositional



VT: Valley Train deposits GF: GlacioFluvial deposits RS: Reworked Sediments

Fig. 12 SEISMO-STRATIGRAPHY AND INFERRED LITHOFACIES, SOUTHERN AKPAK PLATEAU.

environments that existed during the deglaciation and the subsequent marine transgression over the area.

Firstly, a **proglacial environment** that was prevailing between the glacial maximum (Hungry Creek Glaciation - 30,000 years ago), which event was accompanied by an important sea-level lowering to about -140m and the resulting subaerial exposure (**U/C1** in Figure 12) of this sector of the Plateau, and a relative sea-level lowering and minimum to about -70m (Cf. Figure 7). Early in the deglaciation, subglacial and periglacial meltwater channels were incised into the glacial (morainal) and pre-glacial (Unit C) deposit. These channels carried out meltwater and fine outwash directly to the sea while coarser-grained outwash (**VT** in Figure 12) deposited on the channel bottoms. During the deglaciation, a standstill and/or a sea-level lowering from -40m to -70m on the sea-level curve (Cf. Figure 7) resulted in a temporary quiescence in the glacial outwash influx during a probable glacial readvance (Tutsieta Lake Phase - 13,000 years ago). This non-depositional environment corresponds to an hiatal unconformity (**U/C2** in Figure 12) that can be traced within the major meltwater channels.

Secondly, glacier ice retreat may have occurred again to the south of the area depositing large volumes of fine glaciofluvial deposits (**GF** in Figure 12) over U/C2 in a **outwash fan environment.** This environment was interrupted by the approach of a transgressive shoreline in this sector of the Plateau.

Thirdly, a **transitional environment** resulted in shoreface erosion and reworking of the underlying fine glacial outwash. The fine reworked materials (**RS** in Figure 12, or Unit B of O'Connor), with locally concentrations of sand in areas where most underlying outwash deposits are sandy, redeposited over a regional erosional unconformity (**U/C3** in Figure 12). In the deep water areas, a variable fraction of recent marine sediment (Unit A of O'Connor) may have been incorporated into the reworked (transgressive) Unit B sediment as a result of ice-scouring processes. This explains the use of the term "Units B+A" in this report.

5.2 GEOLOGICAL SIGNIFICANCE OF THE GLACIAL MAXIMUM

In order to further investigate the geological significance of the glacial maximum (Hungry Creek Glaciation or Toker Point Stade?) as a controlling factor in the occurrence of coarse glacial sediments over the southern Akpak Plateau, the distributions of the compressional wave velocities obtained to the south and north of this glacial limit were examined. The 24-channel, 1987 and 1988 seismograms were combined and studied as one sample, while the 12-channel 1986 data set was treated separately because the velocity values associated with seabed and shallow subbottom layering are consistently lower than those obtained in 1987 and 1988. In fact, it is suspected that the 1986 raw refraction data were possibly altered by using the reduced travel time display . This data handling procedure may have resulted in a general velocity lowering of about 100 m/s (see Section 7.2, in Fortin, 1988). The 1985 data set was not taken into account in this analysis because the limited number of velocity observations cannot yield statistically reliable results.

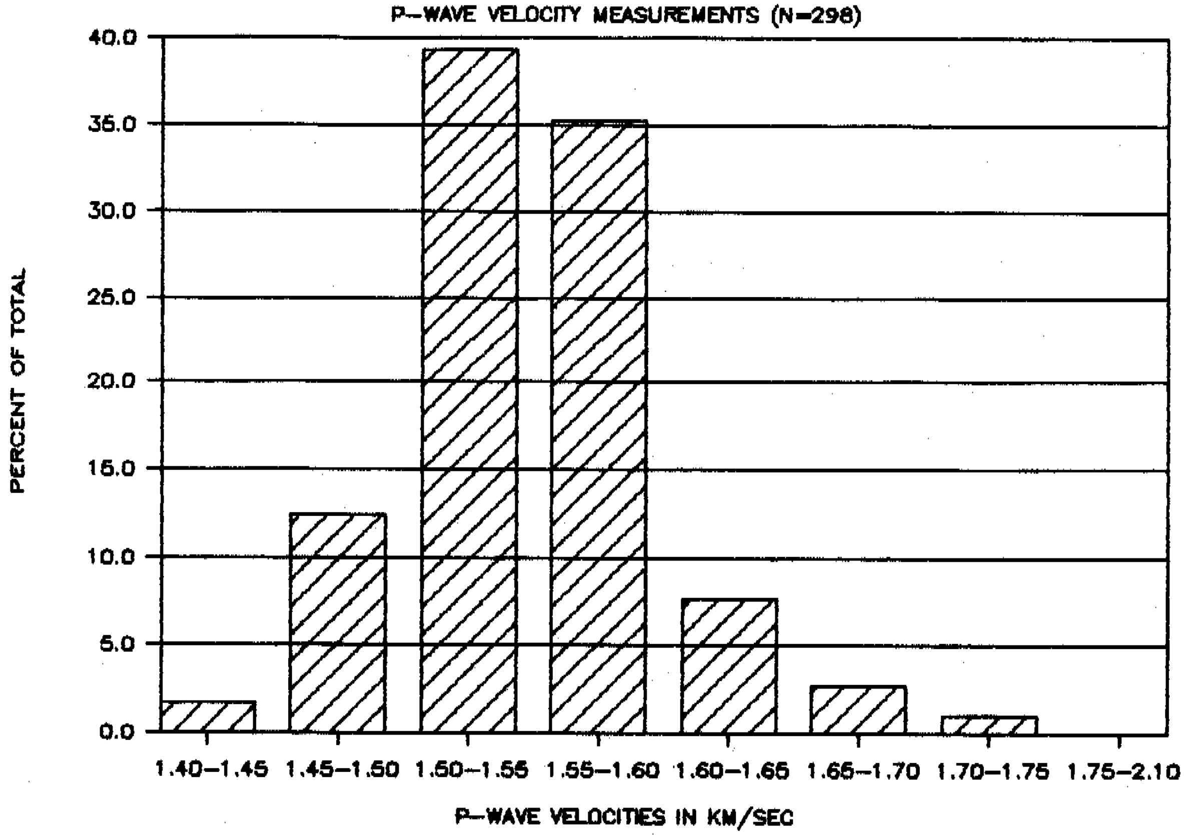
Nevertheless, not considering the potential problem with the 1986 velocity measurements, the histograms presented on Graphs 5.1 through 5.4 display some interesting features. However, the reader should note that: firstly, the histograms include only the compressional wave velocities obtained in the top 10m of seabed penetration and do not include abnormally high velocities (2,100-4,000 m/s) generally associated with ice-bearing sediments; and secondly, the velocity values comprised in a given class interval are equal or greater than the lower class boundary but smaller than the upper boundary.

The histograms for the velocities obtained north of the inferred glacial maximum and for the two samples (Graphs 5.1 and 5.3), display an almost normal distribution. The histograms grouping the velocities obtained south of the glacial maximum (Graphs 5.2 and 5.4) are significantly more complex than the distributions of the velocity measurements made north of this glacial limit. Graphs 5.2 and 5.4 display a substantial increase in percent of total count (N) for the class intervals 1.45-1.50 km/s and 1.55-1.60 km/s respectively. In addition, Graphs 5.2 and 5.4 exhibit higher percentages of total count for the class intervals greater than 1.75 km/s than those in Graphs 5.1 and 5.3. These two anomalies cause a significative distortion of the velocity distributions. The high proportion of velocity measurements in class intervals 1.45-1.50 km/s on Graph 5.2 and 1.55-1.60 km/s on Graph 5.4 may be explained by the presence of the braided paleochannel system debouching into the Kugmallit Channel and the Hooper Channel (Cf. Figure 10). Long segments of the seismic lines running south of the glacial limit were traversed over these channels which were, in most areas, infilled by a fine-grained, low velocity, surficial sediment that may exceed 15m in thickness in several locations. As a result, the large portion of velocity observations that were obtained along these line segments biases the velocity distributions towards the low velocity intervals.

Of particular interest for the present study is the notable increase in the number of measurements associated with materials having velocities greater than 1.75 km/s in the sector south of the glacial maximum (Graphs 5.2 and 5.4). Since most of the compressional wave velocities propagating along unconformity U/C1 (top of Unit C sand) in this area are slower than 1.70-1.75 km/s, it is believed that the velocity observations in the range

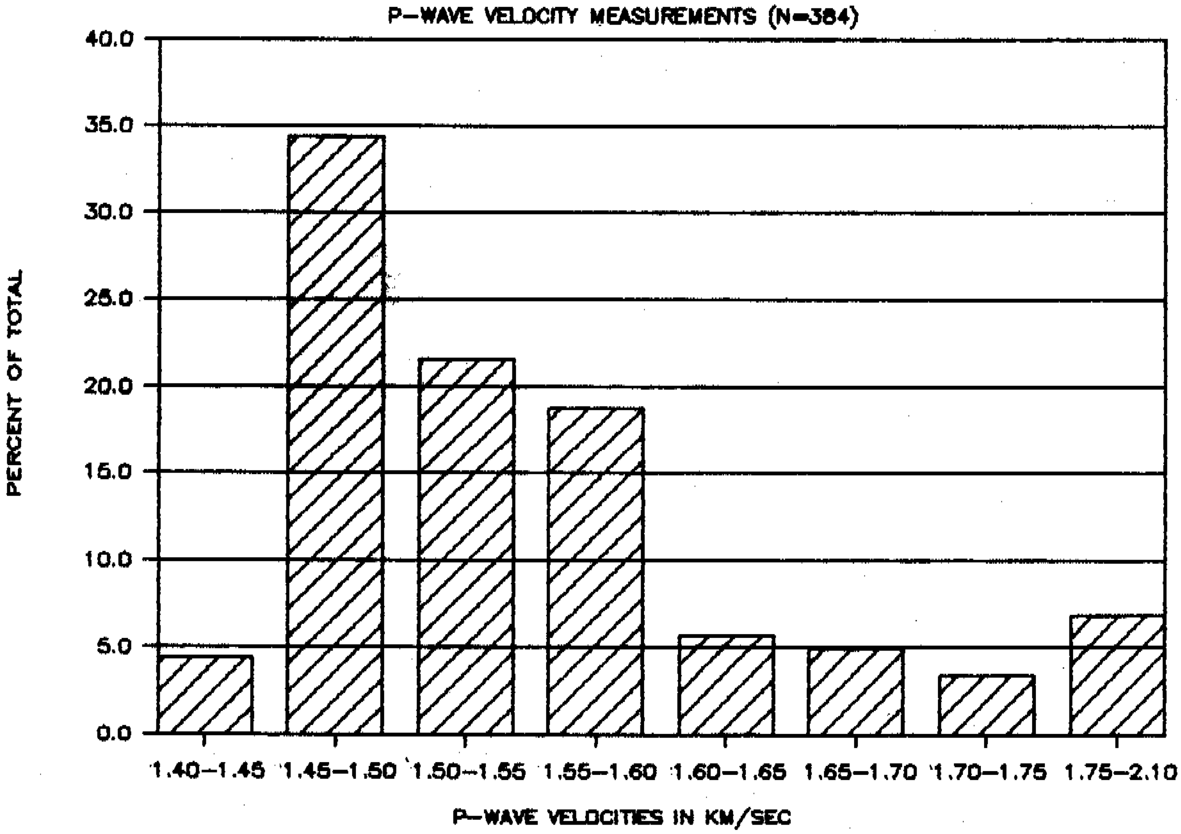
Graph 5.1:NORTH OF GLACIAL MAXIMUM,1986

P-WAVE VELOCITY MEASUREMENTS (N=298)



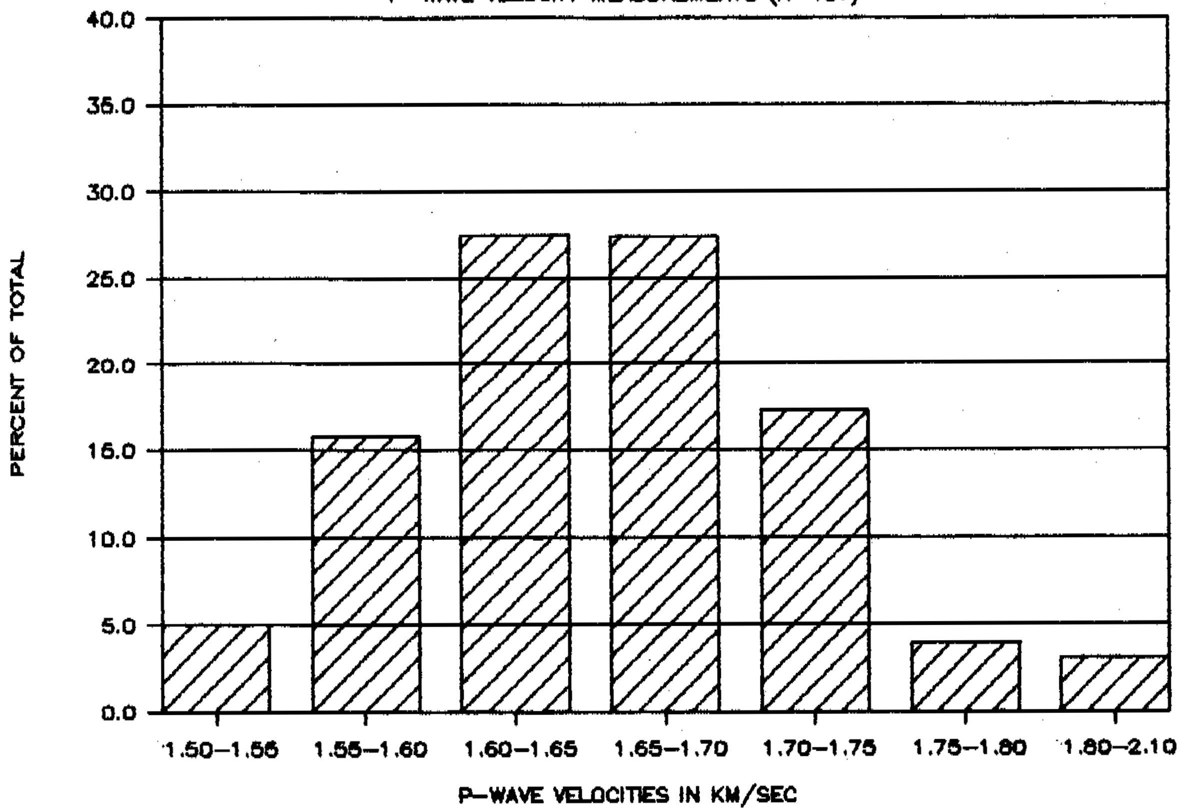
Graph 5.2:SOUTH OF GLACIAL MAXIMUM,1986

P-WAVE VELOCITY MEASUREMENTS (N=384)



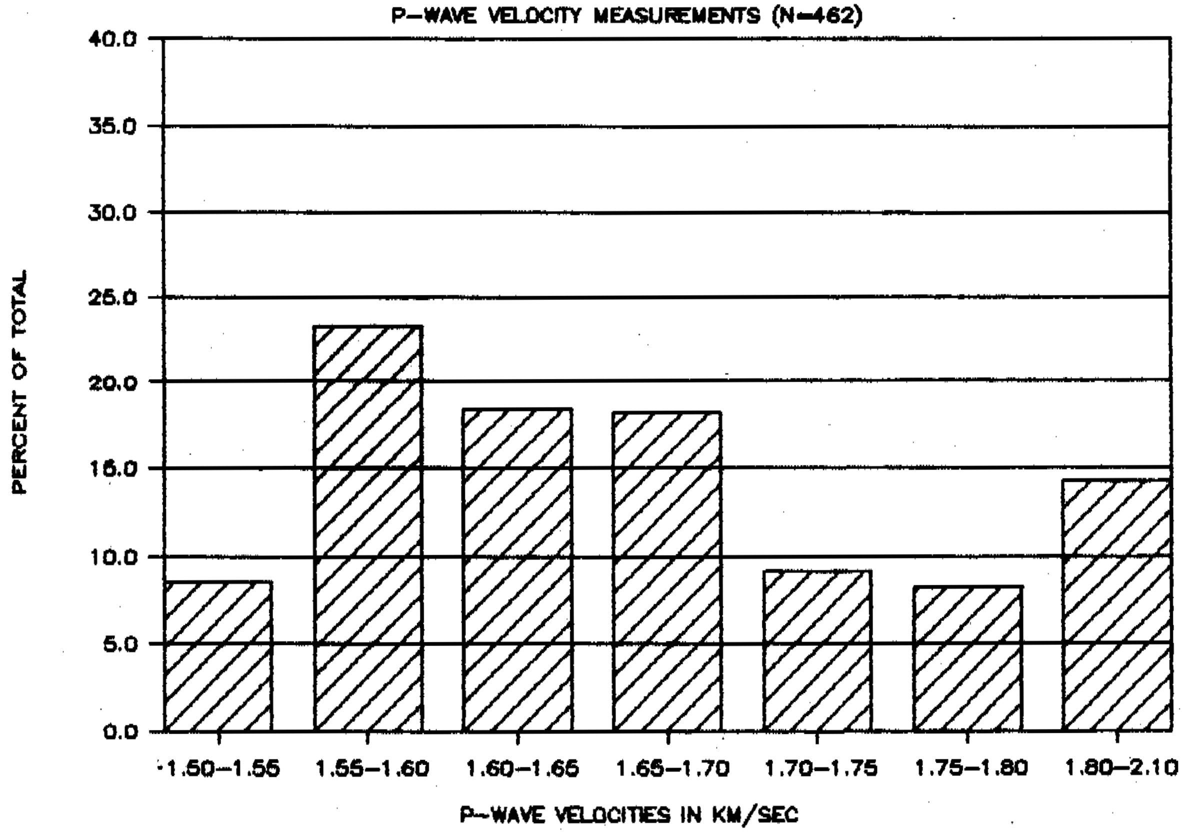
Graph 5.3:NORTH OF GLACIAL MAXIMUM,87-88

P-WAVE VELOCITY MEASUREMENTS (N=457)



Graph 5.4:SOUTH OF GLACIAL MAXIMUM,87-88

P-WAVE VELOCITY MEASUREMENTS (N=462)



of 1.75-2.10 km/s are indicative of the occurrence of very coarse-grained materials within 10m seabed penetration. These postulated granular materials, and their related reworked facies, may be the remnants of eroded morainal and ice contact deposits, which rest at various subbottom depths and may be exposed at the seafloor in some favourable areas.

5.3 TARGET AREAS FOR FUTURE SITE STUDIES

Five potential target areas, designated Sites A to E in this section, have been identified and are delineated on Plate I. In the following subsections, each target area is described in terms of:

(1) present site conditions;
(2) most probable geologic origin; and
(3) recommendations for future investigations.

Table 1, which follows at the end of the section, summarizes the interpretation results and the recommended future studies.

5.3.1 Site "A"

(1) Present site conditions

Site A is situated in the central area of the Akpak Plateau and delineates a broad highland in the former land surface (U/C1) to the south of the inferred glacial maximum (Plate I). In the site area, the water depth ranges between 14

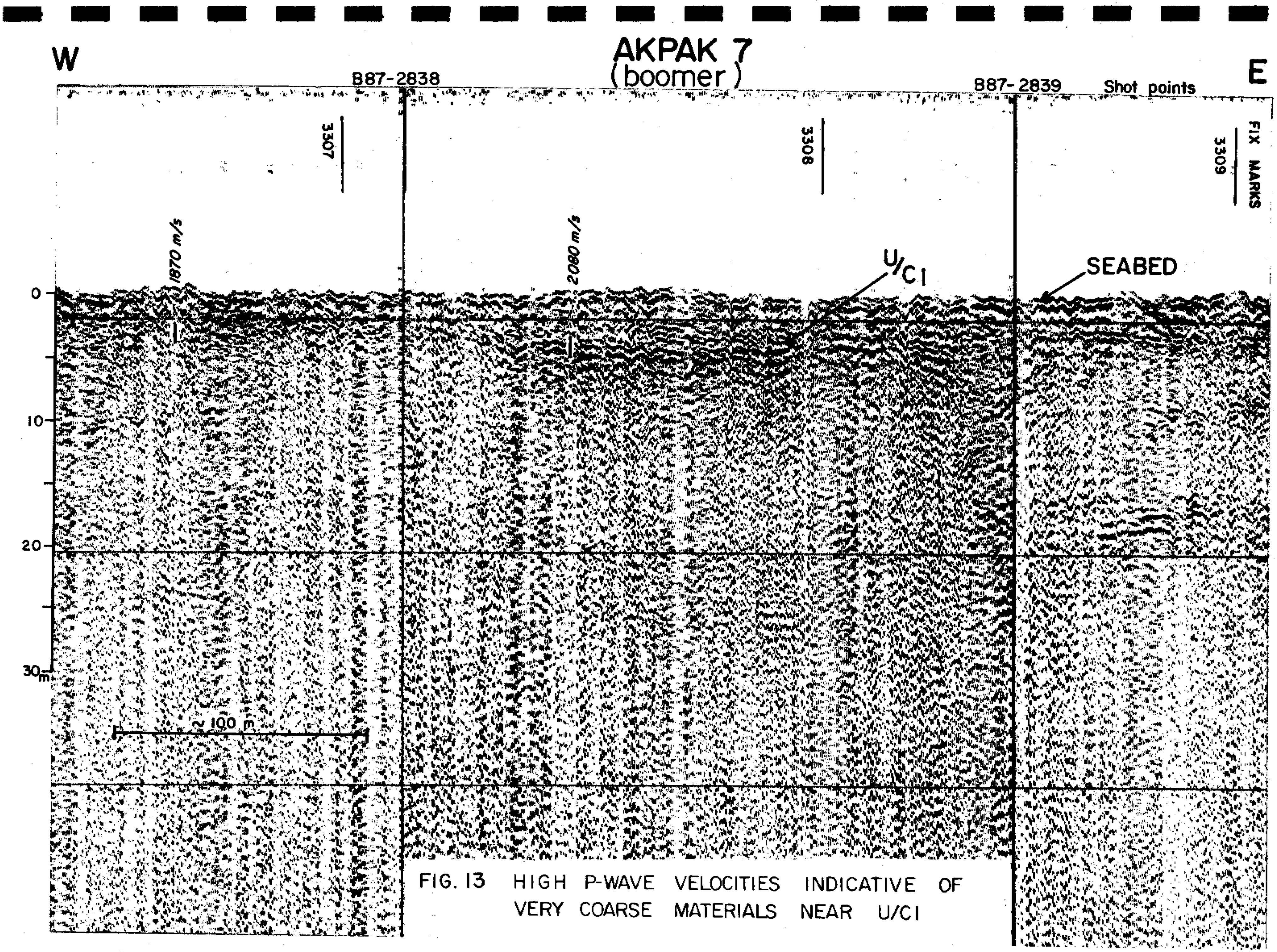


FIG. 13 HIGH P-WAVE VELOCITIES INDICATIVE OF VERY COARSE MATERIALS NEAR U/C1

and 20m with a gentle seabed slope (1:3,000) to the north-northeast.

Section AA' (1987 Line Akpak 7) illustrates the general site stratigraphy in a north-south direction (Plate I). On the basis of the available seismic data, unconformity U/C1 does not appear to outcrop at the seabottom. In some places, as shown by the isopachs of the postglacial sediments on Plate I, U/C1 may rest at less than 2m below seabed. Of particular interest is the presence of relatively high compressional wave velocities (1,870-2,180 m/s) near U/C1 (Figure 13); P-wave velocities of this magnitude are believed to be indicative of very coarse-grained deposits. These materials may have played an important role in a possible coarsening facies change in the reworked sediments (Units B+A) that deposited over the area following shoreface erosion (U/C3). Although it is likely that granular materials (mainly reworked sand) are present atop U/C1, an upward fining facies change occurs probably within the reworked zone giving to most areas of the site a **low potential** as borrow site. One should remember that, in normal conditions, the current subbottom profiling techniques are not very effective in detecting subdued facies change in both lateral and vertical direction.

In the two zones of minimal thickness of reworked sediments (<2m), that generally correspond to U/C1 highs, the hydrodynamic regime may have been slightly different (local current increases) than the surrounding areas. Considering an optimistic scenario, it is possible that the upward fining facies change may have been less important in these two locations allowing local concentrations of fine sand to be present near the seafloor.

(2) Most probable geologic origin

Patches of morainal deposits may have been advanced at this location by the Laurentide ice sheet (Toker Point Stade of Rampton 1988 or Hungry Creek Glaciation of Hughes 1987). These coarse-grained deposits, and possibly thin glaciofluvial outwash present to the south of the site (see Unit B on Section AA'; Plate I), were eroded and reworked during the post-glacial submergence. The sand-size sediment was redeposited over elevated land features while the finer-grained sediment was carried out downslope where it accumulated in a quieter environment.

(3) Recommendations for future investigations (Table 1)

It is recommended to run three additional reconnaissance lines (solid lines on Plate I) that will transect, in a east-west and north-south direction, the zones where the thickness of the post-glacial sediment is less than 2m. Following evaluation of the geophysical records obtained in a reconnaissance level, two shallow boreholes (approx. 5m in depth) should be positioned at the two line intersections in order to tie the seismic interpretation to geologic control. If the results are promising, a more detailed seismic program should be undertaken along east-west lines having a maximal spacing of 1 km with tie lines spaced at about 2-3 km (Plate I). The site survey combined with a few extra (4) boreholes at critical locations should provide a basis for preliminary resource evaluation and future site specific surveys.

5.3.2 Sites "B1" and "B2"

(1) Present site conditions

Sites B1 and B2 are outlined on the basis of both regional geology and its proximity to the Isserk Borrow Pit (Plate I). The Isserk pit lies just to the south of the inferred glacial maximum and overlies two elevated land features oriented in a northeast-southwest direction. The fact that the two main zones of the Isserk pit coincide with two distinct topographic highs, with a narrowing of the deposit above a northeast trending channel, suggests that the paleotopography is a dominant factor controlling the distribution of the granular materials. **Sites B1 and B2 delimit the offshore extension of the** two highlands which may be responsible for localized coarsening facies changes in the overlying reworked zone. However, the locally concentrations of sand-sized sediment in the Isserk Borrow Pit area are believed to grade seaward into finer materials; these conditions would warrant a **low potential** rating for Sites B1 and B2. Nevertheless, if additional investigations are contemplated offshore of the Isserk pit, Sites B1 and B2 represent preferred areas where a sediment coarsening in the reworked zone is most likely to occur seaward of the present Isserk pit.

(2) Most probable geologic origin

The Isserk deposit and its possible offshore extensions may originate from a shoreline eroding localized areas (generally to the south of the Isserk pit) of more sandy beds within the source deposits (underlying glaciofluvial outwash), redepositing the sand-sized sediment over elevated land surfaces, and washing out the finer fractions seaward and within bordering meltwater channels.

(3) Recommendations for future investigations (Table 1)

In the Isserk area, the lateral transition from granular materials to a cohesive overburden is believed to be very gradational. In certain conditions (e.g. calm weather), this gradation in the surficial sediment might be detected by high resolution seismic methods, specifically the 3.5 kHz subbottom profiler and possibly the deep-towed refraction array, as well as by the side scanning technique. If weather conditions are very good, it is recommended to run seismic lines which should cross both the present Isserk pit and the proposed Sites B1 and B2 (see Plate I). This should allow calibration of the geophysical records in an area where granular materials are known to exist right at the seafloor. Otherwise, in marginal sea conditions, seabed sampling by means of a piston corer or grab sampler according to a close sampling grid (approx. 500m sample spacing) might represent an acceptable alternative to seismic surveying. Two reconnaissance boreholes (approx. 10m in depth), which should be drilled through the crest of the two elevated land features will provide useful stratigraphic information in the zones where the geological conditions are the most favourable for a coarsening in the reworked sediment.

5.3.3 Site "C"

(1) Present site conditions

Site C delineates the inshore extension of the northeast-southwest trending ridge-like feature that underlies the southeastern zone of the Isserk Borrow Pit (Plate I). The water depth varies from 9m to 12m across the site giving to the seabed a gentle seaward slope (1:2,500). Section CC' on Plate I illustrates the site seismo-stratigraphy and the inferred lithofacies along a east-west profile (1987 Line Akpak 3). The U/C1 high is bordered to the west by a deep meltwater channel that has been infilled by stratified to partially stratified sequences (Unit B; fine-grained valley trains and glaciofluvial deposits), and to the east by a narrow meltwater channel that includes primarily non-cohesive materials. The fine channel infillings abut against a constructive morphology (kame?, levee?)

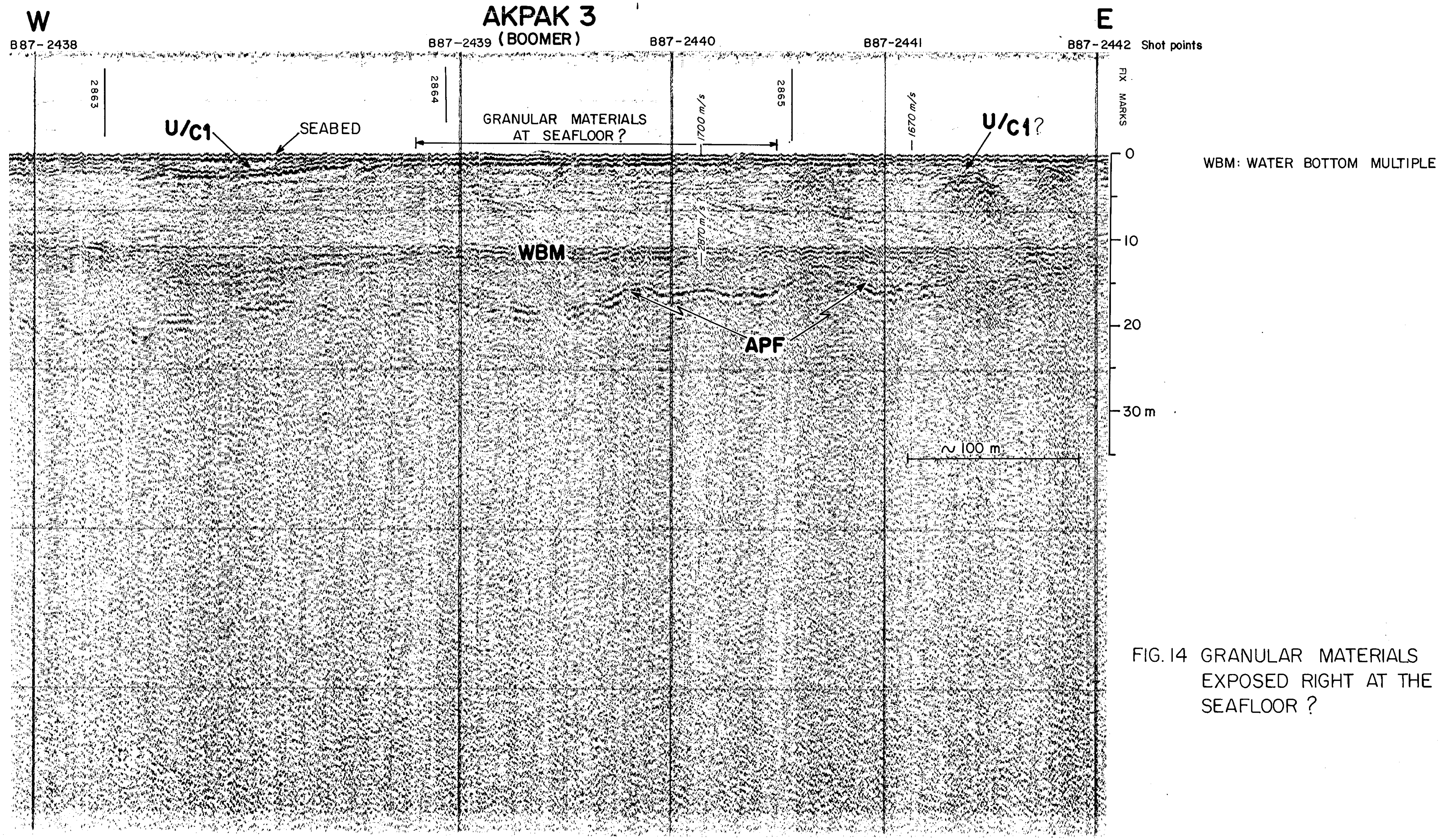


FIG. 14 GRANULAR MATERIALS EXPOSED RIGHT AT THE SEAFLOOR ?

that rests on the western flank of the elevated land.

High compressional wave velocities on the order of 1,750 to 1,810 m/s measured near U/C1 attest to the occurrence of very coarse marerials (sand and gravel) at close proximity of the seabed. It is likely that the reworking of these deposits by a transgressive shoreline has resulted in a thin veneer of reworked sediments that deposited in the immediate area giving to the site a **fair potential.** Although the shoreface erosional surface (U/C3) can be traced within the meltwater channel to the west, this seismic discontinuity approaches the seafloor over the ridge-like feature, where U/C3 lies beyond the observed resolution (about 1m) of the boomer system. Unfortunately, the higher resolution 3.5 kHz subbottom profiler was not deployed along this 1987 line. Figure 14 exhibits a reasonably good quality boomer record that profiles a short section of the elevated land feature (see Sectionn CC' for location). In the western part of this line segment, the boomer delineates a lens of reworked materials that reach about 2m in thickness. For the remainding of the line segment, this layer is not easily resolved by the Uniboom system. Although in most areas it is difficult to judge whether or not a thin layer of reworked sediment deposited over the site, the magnitude of the P-wave velocities (1,590 to 1,700 m/s) associated with seabed and/or near seabed materials (accuracy of about 1m on the refractor depths), and the strong water bottom multiple on the boomer record (**WBM** in Figure 14) indicate an acoustically hard seabottom (granular materials?).

(2) Most probable geologic origin

The northeast trending ridge is believed to be the remnants of a former hilly belt that was deposited at the front of a glacier ice during an extreme glacial advance. These hills would consist primarily of morainal and ice-contact (small eskers?) deposits. The source deposits, and possibly a thin layer of coarse outwash, would have been reworked during the post-glacial submergence. Granular materials (sand and gravel) were likely redeposited in patches, or clusters of patches, atop the morainal and glaciofluvial deposits that form the crest of the ridge.

(3) Recommendations for future investigations (Table 1)

As a first step, it is recommended to run at least one seismic line along the crest of the northeast-southeast trending ridge (Plate I). This seismic profile should extend across both the southeastern portion of the Isserk pit (for seismic facies calibration) and Site B2 (for efficiency). Additional acoustic profiles could be traversed at a spacing of 1 km and subparallel to the ridge with tie lines run at a spacing of about 2 km. In addition to the boomer and refraction systems, deployment of a combined side scan sonar and 3.5 kHz subbottom profiler system is strongly recommended. As a second step, three boreholes

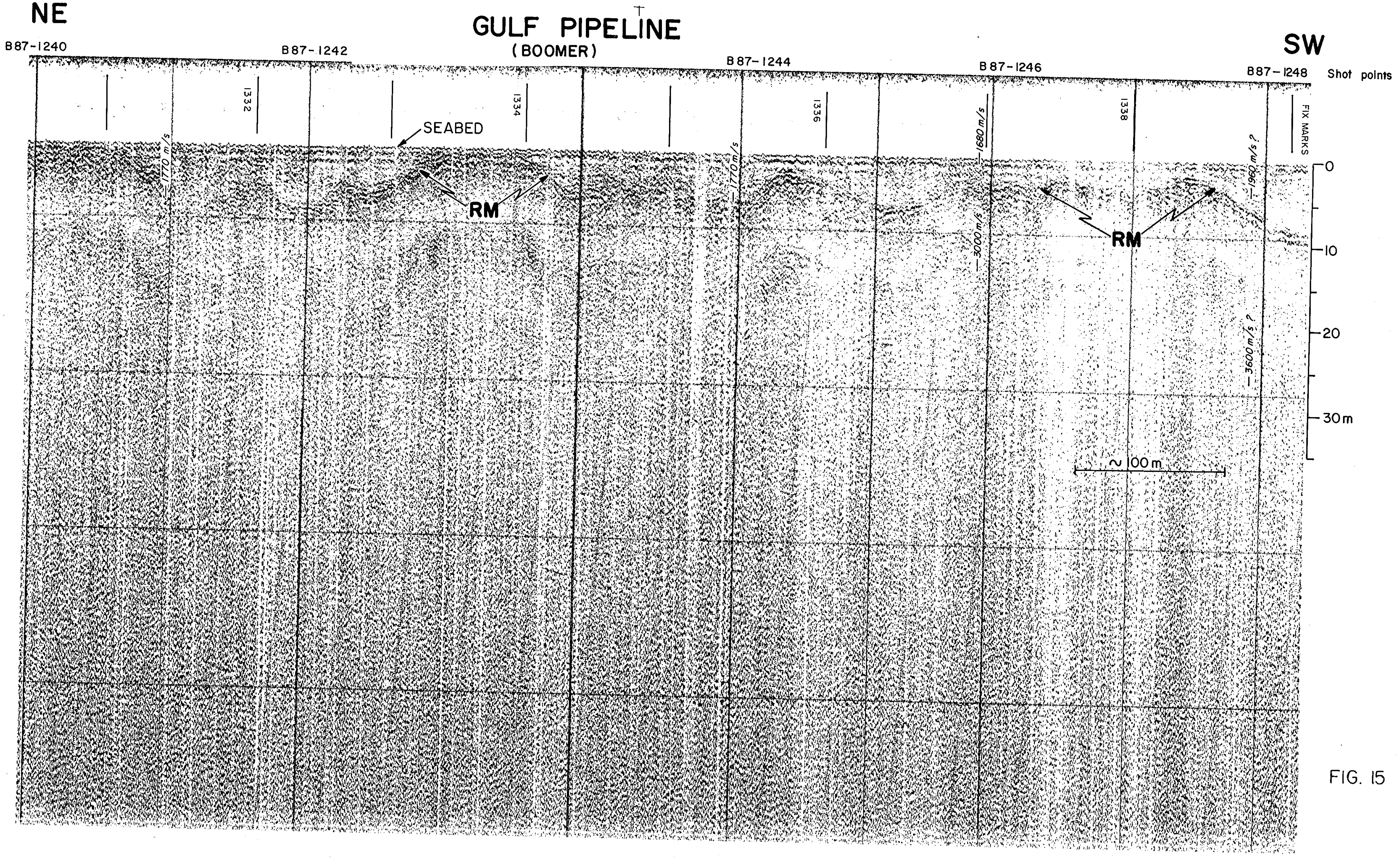


FIG. 15 HUMMOCKY OR ROLLING MORAINAL DEPOSITS (RM) NEAR THE SEABED.

(approx. 5m in depth) should be positioned at seismic line intersections to tie the site seismo-stratigraphy to geologic control. If both geophysical and geotechnical evidence are conclusive, a full picture of the seabottom by side scan imagery with 3.5 kHz subbottom profiling, and a extensive seabed sampling program (approx. 500m sample spacing) by means of a piston corer or grab sampler, should allow the seismic interpreter to delineate the borrow site or the clusters of granular deposits.

5.3.4 Site "D"

(1) Present site conditions

Site D is situated to the southeast of the Isserk pit in water depth ranging between 6m and 10m (seabed slope of about 1:2,500). The site delimits a cluster of topographic highs at the margin of the Akpak Plateau and to the south of the inferred glacial maximum (Plate I). Sites C and D are separated by a narrow meltwater channel that may be infilled by finer-grained materials. Section DD′ on Plate I depicts the general site stratigraphy traced from a northeast-southwest oriented seismic profile (1987 Gulf pipeline transect). Section DD′ extends further to the southwest and terminates some 5-6 km northeast of Pullen Island providing a general stratigraphic framework for the inshore zone.

As shown in Section DD′, the shallow site seismo-stratigraphy is very complex in this area due to the presence of several hummocky reflectors. In the inshore zone, the seismic sequences appear to be structurally simple, however the frequent occurrences of shallow gas and the resulting acoustic blanking hamper the interpretation of long segments of the seismic profile. The sequences (Unit B on Section DD'; Plate I) that accumulate within the flat-bottomed topographic low delineated landward of the hummocky features (till and APF), are believed to consist primarily of glacial outwash. Note that the presence of a basal layer having velocities ranging between 1,800 and 2,100 m/s (Fix Mark Nos. 1346 to 1360; Section DD') suggests that a till-like unit was deposited near the depression bottom. Alternatively, this basal layer may originate from morainal deposits which have become incorporated into the depression fills by retrogressive-thaw flow sides.

The P-wave velocities are very useful in determining the possible origin of the hummocky features. On this basis, the hummocky reflectors may be differentiated between rolling or hummocky moraines (velocities of 1,750 to 2,000 m/s) and hummocky APF features (velocities of 2,000 to 4,000 m/s). Figure 15 provides an example of the acoustic signature of an hummocky or rolling moraine-like feature near the seabed (**RM** in Figure 15; see DD' on Plate 1 for location). The magnitude of the P-wave velocities (1,770-1,960 m/s) associated with the rolling deposit allows the seismic interpreter to distinguish this feature from an APF horizon or a shallow gas front. In Figure 15, permafrost velocities of 3,000 and 3,600 m/s occur at greater depths than the moraine-like feature and therefore they cannot be correlated with the shallow hummocky reflector. Gas-charged sediments do not propagate refracted waves and the resulting refraction seismograms are devoid of headwave arrivals. The incoherent seismic facies visible within the unit that covers the rolling moraine (Figure 15) suggests that this deposit has been reworked.

A site specific study (eleven E-W profiles at a spacing of 400m) has been conducted in 1987 over the easternmost, northwest-southeast trending topographic high of Site D (see Plate I). Although the reflection records collected during this detailed survey were of little practical use due to poor data quality (resulting from bad weather), an isopach map of the post-glacial sediments was prepared in order to picture the general paleotopography of unconformity U/C1 surface. The resulting plan of view map (Plate IV in Fortin, 1988) showed that over the elevated land feature, the thickness of the surficial sediment (Units B and A?) is often beyond the resolution of the reflection systems. Although 3.5 kHz subbottom profiler records are available for this detailed survey grid, the vertical seismic resolution is only slightly better than 1m due to the marginal sea conditions that prevailed during the survey. Nevertheless, the results of this survey indicate that the hummocky (morainal?) deposits are blanketed by a relatively thin (about 1-2m) reworked layer with a probable coarsening facies change (Units B+A(?) above U/C3 on Section DD';Fix Marks Nos.1300-1315 on Plate I).

A second site specific survey (ten E-W profiles at a spacing of 400m to 1 km) was carried out in 1988 in the same area in order to re-survey this topographic high as well as a broader elevated land feature trending in the same direction (see Plate I). The quality of the 1988 seismic data is good to reasonably good which allowed the seismic interpreter to trace the base of the reworked zone (U\C3 in Figure 16). The isopach presentation of the reworked sediments in Plate II provides a picture of the spatial distribution of this unit across site D. The isopachs indicate clearly that shoreface erosion was a very active process in the seaward zone where more than 8m of reworked materials have accumulated. Although present in the backbarrier zone, this environment was less dominant than in the offshore zone, as evidenced by the relatively thin layer (1-3m) of reworked sediments covering the inshore region. The reworked zone is very thin (<1m) over the elevated land features, and it is likely that a coarsening facies change occurs over these uplands giving to Site D a **high potential** for borrow deposits.

(2) Most probable geologic origin

It is hypothesized that the hummocky deposits present

RS: Reworked Sediments
GF: GlacioFluvial deposits
RM: Rolling Moraine

Fig. 16 REWORKED SEDIMENTS (RS) ABOVE U/C3 IN SITE 'D'
(SEE PLATE II FOR LOCATION)

near the inferred glacial maximum are formed of hummocky or rolling moraines whose relief would originate primarily from ice thrusting. The flat-bottomed depression in the inshore zone (Section DD′) would have been carved into Unit C sediment by the Toker Point Stade or Hungry Creek ice during its northward advance. As discussed in Section 3.2 of this report, the morainal deposits of the Toker Point member consist primarily of a stony clayey diamicton containing typically 3 to 25% clasts greater than 2mm in size and 10 to 30% sand. The coarse fractions (sand and gravel) of these source deposits may have been concentrated and redeposited atop the hummocky or rolling moraines as a result of shoreface erosion and reworking that were prevailing during the submergence of the site.

(3) Recommendations for future investigations (Table 1)

In order to clarify the complex seismo-stratigraphy of the area and evaluate the potential of the elevated land features as source deposits, it is recommended to proceed first with ten reconnaissance boreholes (approx. 5m in depth) that will be positioned near the crest of these landforms (Plate II). Secondly, seismic profiles of good quality, including side scan sonar, 3.5 kHz profiler, boomer and deep-tow refraction array, should be run through the boreholes and between the 1988 traverses (for an average line spacing of about 300m) in order to obtain preliminary information regarding the lateral extent of potential borrow deposits. Thirdly, if the reconnaissance program indicates good potential, a extensive seabed sampling program (approx. 500m sample spacing) should be initiated to determine the lateral extent of the borrow deposits and the probable volumes of granular materials.

5.3.5 Site "E"

(1) Present site conditions

Site E is outlined on the basis of both bathymetric data and regional geology. The site delineates a NNW-SSE trending ridge that culminates at less than 2m below the sea surface. The location of this shoal relative to the perceived glacier margin suggests that it could reasonably be part of the hilly belt bordering the inferred glacial maximum. Although the shallow water represents a serious constraint to dredging by means of trailing suction hopper dredges which are commonly used in the Beaufort Sea, Site E presents a **high potential** for borrow deposits.

(2) Most probable geologic origin

This ridge may be the remnants of till-capped deposits that have been less severely eroded than the finer-grained outwash (unit C?) during the last marine submergence. The seafloor expression of this feature, which is visible on the bathymetric charts (see Plate I), suggests that the glaciofluvial deposit cover is relatively thin or absent over the ridge. This situation may lead to morainal deposits being reworked by the transgressive shoreline leaving sandy and gravelly beds concentrated on the ridge.

(3) Recommendations for future investigations (Table 1)

Three reconnaissance boreholes (approx. 5m in depth) could be positioned along the crest of the ridge and drilled from the ice surface. If these boreholes indicate good potential, additional shallow boreholes could be drilled to delineate the lateral extent and thickness of the borrow deposit. Unless seismic surveying could be organized from a very shallow draft platform (e.g. river boat, pontoon), it will be hazardous for the current survey vessels to transect this shoal. If such a shallow water seismic survey is contemplated, the platform could serve to sample the seafloor (approx. 500m sample spacing) by means of a lightweight sampler (Shipek grab).

TABLE 1. SUMMARY OF BORROW PROSPECTS.

SITE	POTENTIAL	PROGNOSTIC	RECOMMENDED PRIORITY AND EXTENT OF FUTURE STUDIES[1]					
			GEOPHYSICS(R)	GEOPHYSICS(S)	DRILL(R)	DRILL(S)	SAMPLE	MOSAIC
"A"	LOW	-reworked sand near unconformity U/C1 grading upward to silt and clay with possible localized concentrations of sand. -presence of overburden likely.	(1) 3 lines 17 km	(3) 8 lines 32 km	(2) 2 BHs 5m deep	(4) 4 BHs 5m deep	—	—
"B1 & B2"	LOW	-possible seaward extension of the Isserk Borrow pit. -seaward fining facies change likely.	—	(1)[2] 8 lines 42 km	(3) 2 BHs 10m deep	—	(2)[2] 90 samples 500m grid	(4)
"C"	FAIR	-patches, or cluster of patches, of reworked materials (sand & gravel) deposited atop an elevated land feature.	(1) 1 line 11 km	(2) 5 lines 21 km	(3) 3 BHs 5m deep	(6)?	(5) 90 samples 500m grid	(4)
"D"	HIGH	-thin patches, or cluster of thin patches, of reworked materials (sand & gravel) deposited atop hummocky or rolling moraines.	—	(2) 19 lines 90 km	(1) 10 BHs 5m deep	—	(3) 100 samples 500m grid	(4)
"E"	HIGH	-largely gravel and coarse sand beds derived from the reworking of an underlying till-like unit.	(2)[3] 7 lines 26 km	—	(1) 3 BHs 5m deep	—	(3)[3] 85 samples 500m grid	—

NOTES:

[1] The recommended future investigations at each site should be conducted in the order indicated by the numbers in parentheses. One should proceed with the next step only if the results of the previous step(s) dictate additional works.

[2] The extent and order of work will be dependent on sea conditions (See Section 5.3.2 (3)).

[3] Shallow water depth may prevent shipborne seismic surveying and seabed sampling (See Section 5.3.5(3)).

GEOPHYSICS(R): Reconnaissance seismic lines including: side scan sonar, subbottom profiler, Uniboom and deep-tow refraction systems.

GEOPHYSICS(S): Detailed geophysical program including: precision echo sounder, side scan sonar (fully corrected records), subbottom profiler and Uniboom systems.

DRILL(R) : Reconnaissance geotechnical boreholes (BHs).

DRILL(S) : Delineation geotechnical boreholes (BHs).

SAMPLE : Seabed sampling (Shipek grab, piston corer).

MOSAIC : Construction of a seafloor mosaic from side scan imagery.

SECTION 6 - SUMMARY AND CONCLUSIONS

On the basis of interpretation of compressional wave velocities measured along high resolution acoustic profiles, a glacial limit was recognized and delineated across the southern Akpak Plateau. The writer refers to this glacial limit as the offshore extension of the Early Wisconsinan Toker Point Stade mapped onshore by Rampton (1988), but he offers no evidence as to it age. Notwithstanding the chronological problems, the examination of the GSC 1985 through 1988 seismic data suggests that the limit marks the all-time maximum extent of the Laurentide ice sheet over the Akpak Plateau, since no conclusive evidence of morainal deposits has been found north of this limit yet. The presence of morainal and other ice-marginal features within this limit warrants to the area a good potential for borrow deposits.

The glacial deposits recognized south of the inferred glacial maximum and delineated between the seabed and the former land surface (O'Connor's Unit C unconformity) are not solely transgressive in origin, and hence they cannot be classified as Unit B sediment. In this sector of the Akpak Plateau, the O'Connor model may not be adequate for describing the various sequences that deposited during the glacial advance and the subsequent deglaciation. In most places, glaciofluvial deposits (valley trains, outwash plains) cover the former land surface.

During the last marine submergence, shoreface erosion, reworking, and redistribution of these deposits have resulted in a transgressive sequence (essentially Unit B sediment) having a variable thickness.

In the study area, the present granular deposits (Isserk Borrow Pit) and target borrow sites are believed to originate from two different geological settings, or a combination of both. Firstly, locally sand concentrations in the transgressive deposits that would result from the reworking and re-mobilization of coarser-grained glaciofluvial deposits atop elevated land features. The Isserk pit and its possible offshore extensions, Sites B1 and B2, as well as Site A, may be of this type. Secondly, the till and till-related facies forming the hilly belt, which is delineated in the southeastern sector of the Plateau, would have been reworked during submergence leaving a layer of very coarse materials (sand and gravel) near the seabed. Seismic contouring carried out throughout two detailed survey grids indicates that the layer of reworked sediments, that redeposited over the till, is often beyond the seismic resolution, i.e. thinner than about 1m. This may result from the fine nature of the till matrix (25-45% silt and 30-50% clay) and the relatively small proportions of sand (10-30%) and gravel (3-25% of clasts greater than 2 mm) typical of the morainal deposits of the Toker Point member. A cluster of borrow deposits of this type may be present within Site C and Site D, while more laterally continuous granular deposits may be present in Site E.

SECTION 7 – RECOMMENDATIONS

The evaluation of the borrow potential for the southern Akpak Plateau proposed in this report implies that this region was the scene of an extreme ice advance that deposited morainal and glaciofluvial deposits. As a result, these glacial deposits cannot be easily linked to the O'Connor model posing a major correlation problem with other regions of the Beaufort Sea (e.g. northern Akpak Plateau and Tingmiark Plain). Therefore, there is a need for a geological model to account for the whole glacial and post-glacial stratigraphy of the southern Akpak Plateau.

In order to reflect the different site characteristics, recommendations for future geophysical and geotechnical investigations are provided in this report on a site basis (see Sect. 5.3 and Table 1).

Respectfully submitted;

H.R. SEISMIC INTERPRETATION SERVICES INC.

G. Fortin, M.Sc.

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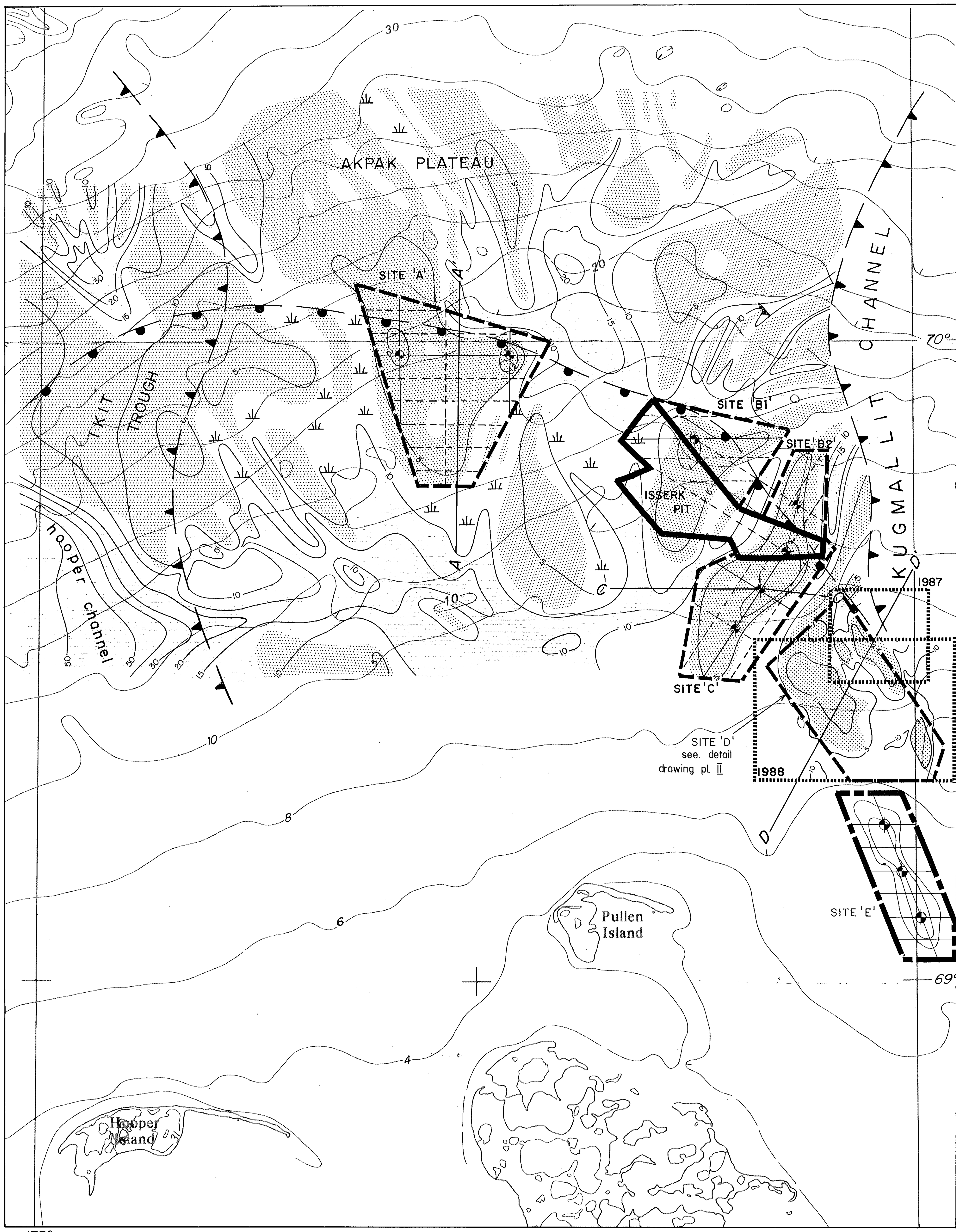
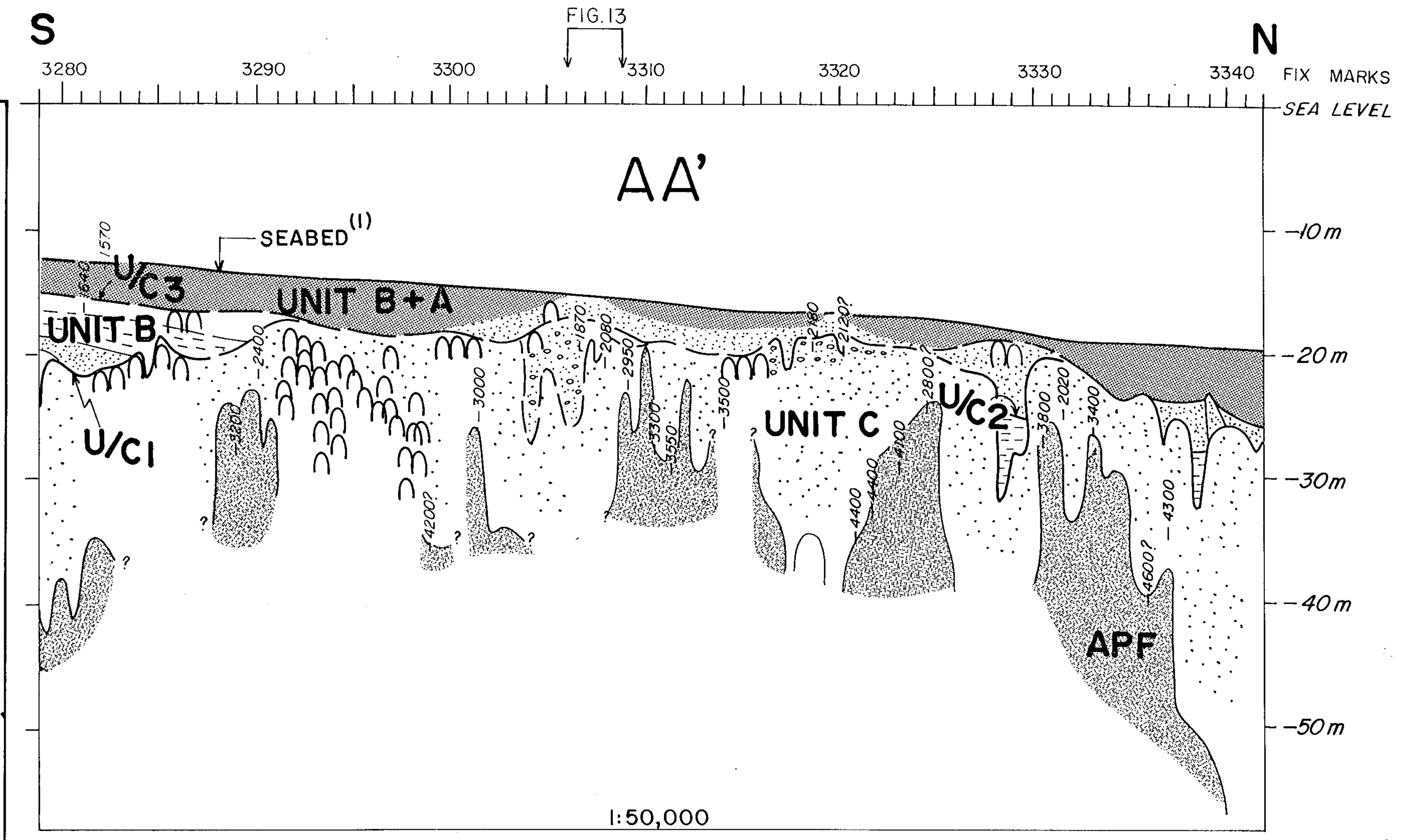
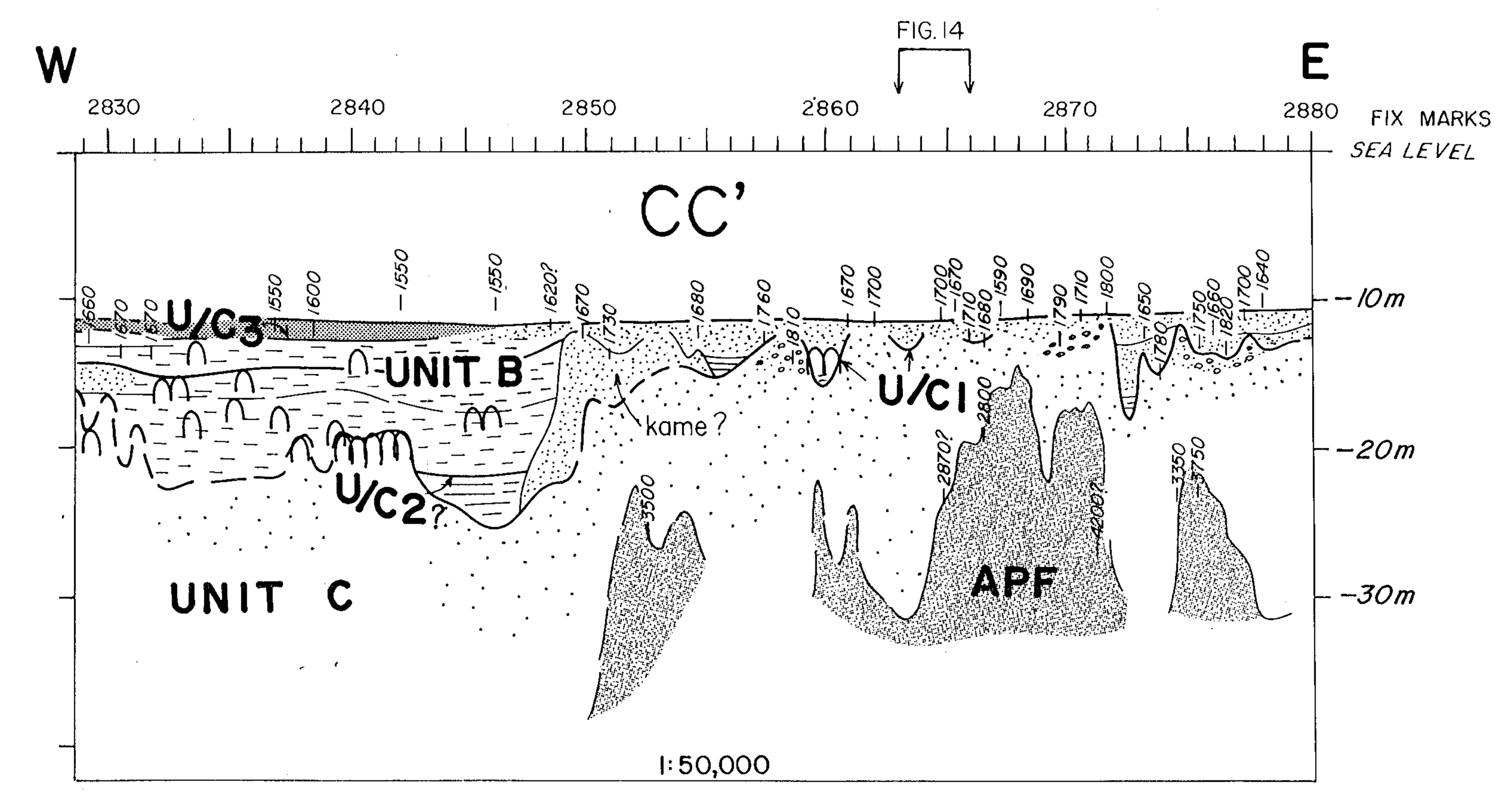
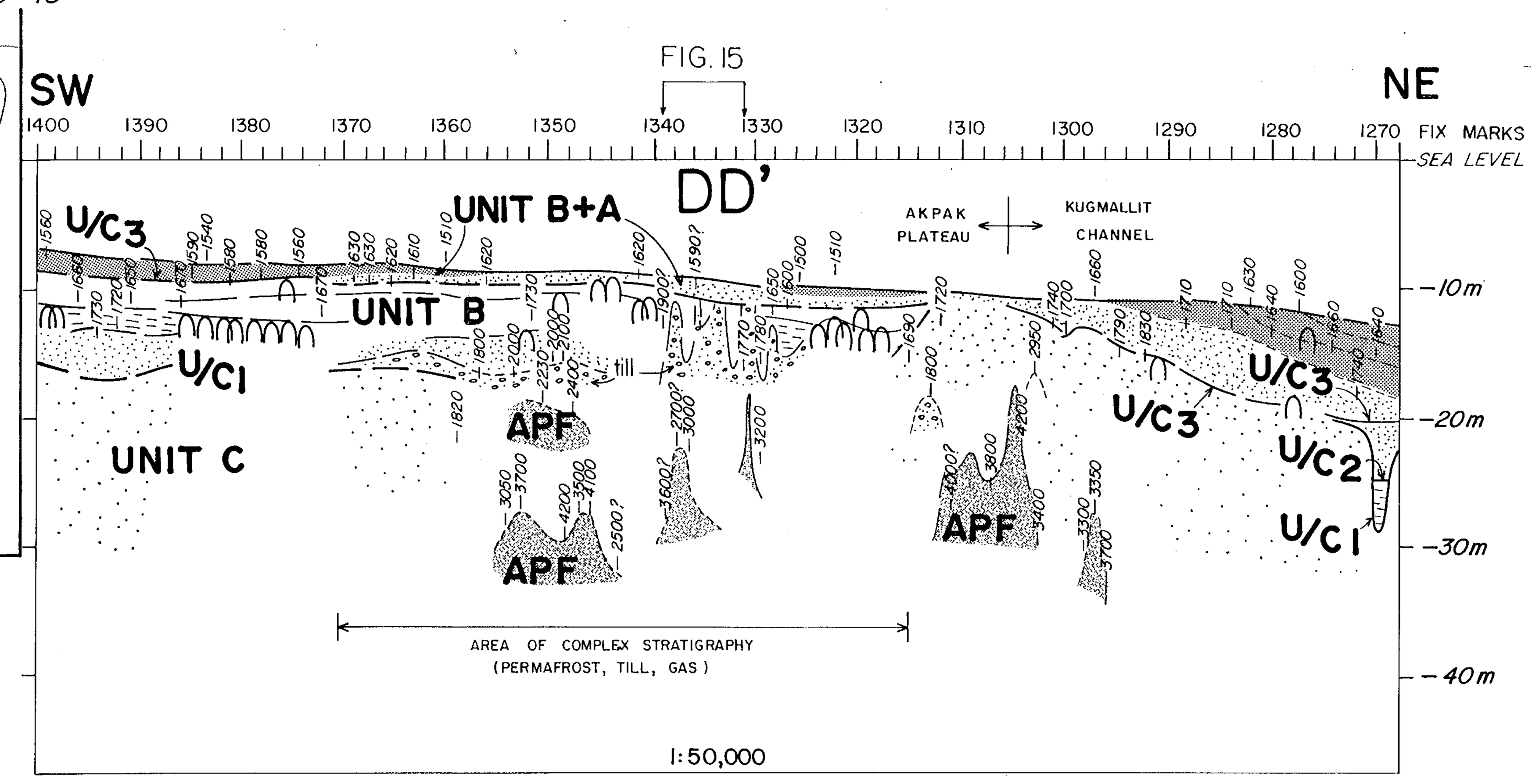






EXPLANATIONS:

- ...... REFLECTOR (defined ; approximate)
- ...... REFRACTOR
- ...... SHALLOW GAS
- ...... ACOUSTIC VELOCITY IN M/SEC.
- REWORKED, REMOULDED FACIES (clay & silt)
- STRATIFIED FACIES (clay, organics)
- PARTIALLY STRATIFIED FACIES (interbedded clay, silt, sand)
- SAND
- GRAVEL, TILL



LEGEND

PALEOGEOGRAPHY:

- ...... INTERFLUVIAL AREAS (ELEVATED LAND FEATURES, AND PENEPLAINS)
- ...... MELTWATER CHANNELS (STREAMLINED FLUTING)
- ...... MARSHES, DORMANT CHANNELS
- ...... ISOPACH OF POST-GLACIAL SEDIMENTS (UNITS B+A)
- ...... INFERRED GLACIAL MAXIMUM (TOKER POINT STADE ?)
- ...... PHYSIOGRAPHIC BOUNDARY

SURVEY PLAN

- A A' ...... LINE OF SECTION
- ...... RECONNAISSANCE — LEVEL SEISMIC LINE
- ...... PROPOSED ADDITIONAL SEISMIC LINE
- ...... RECONNAISSANCE BOREHOLE
- ...... OUTLINE OF SITE SPECIFIC SURVEY
- ...... OUTLINE OF ISSERK BORROW PIT
- ...... OUTLINE OF TARGET AREAS

NOTE:

DEPTH CONTOURS IN BACKGROUND FROM THE NATURAL RESOURCES MAP SERIES.

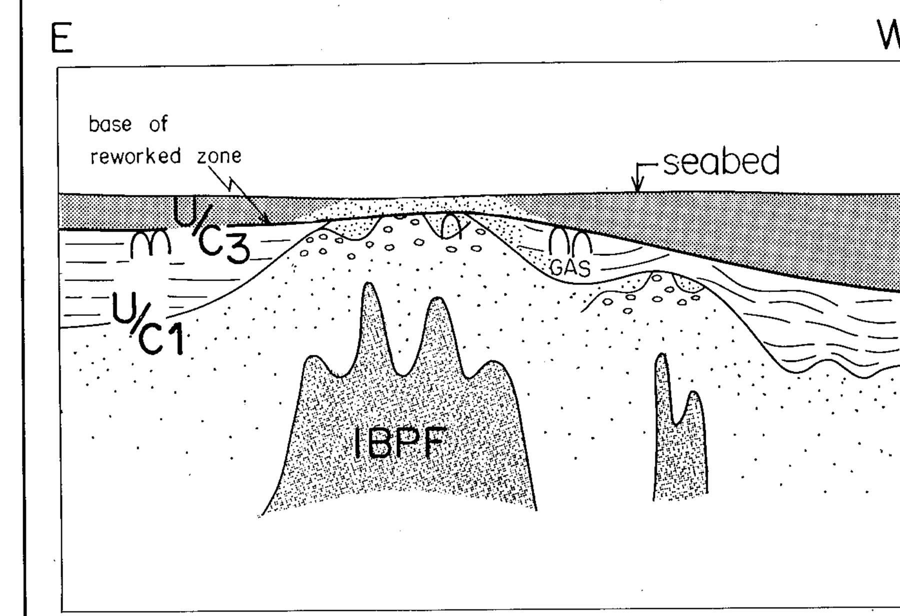
PL. I

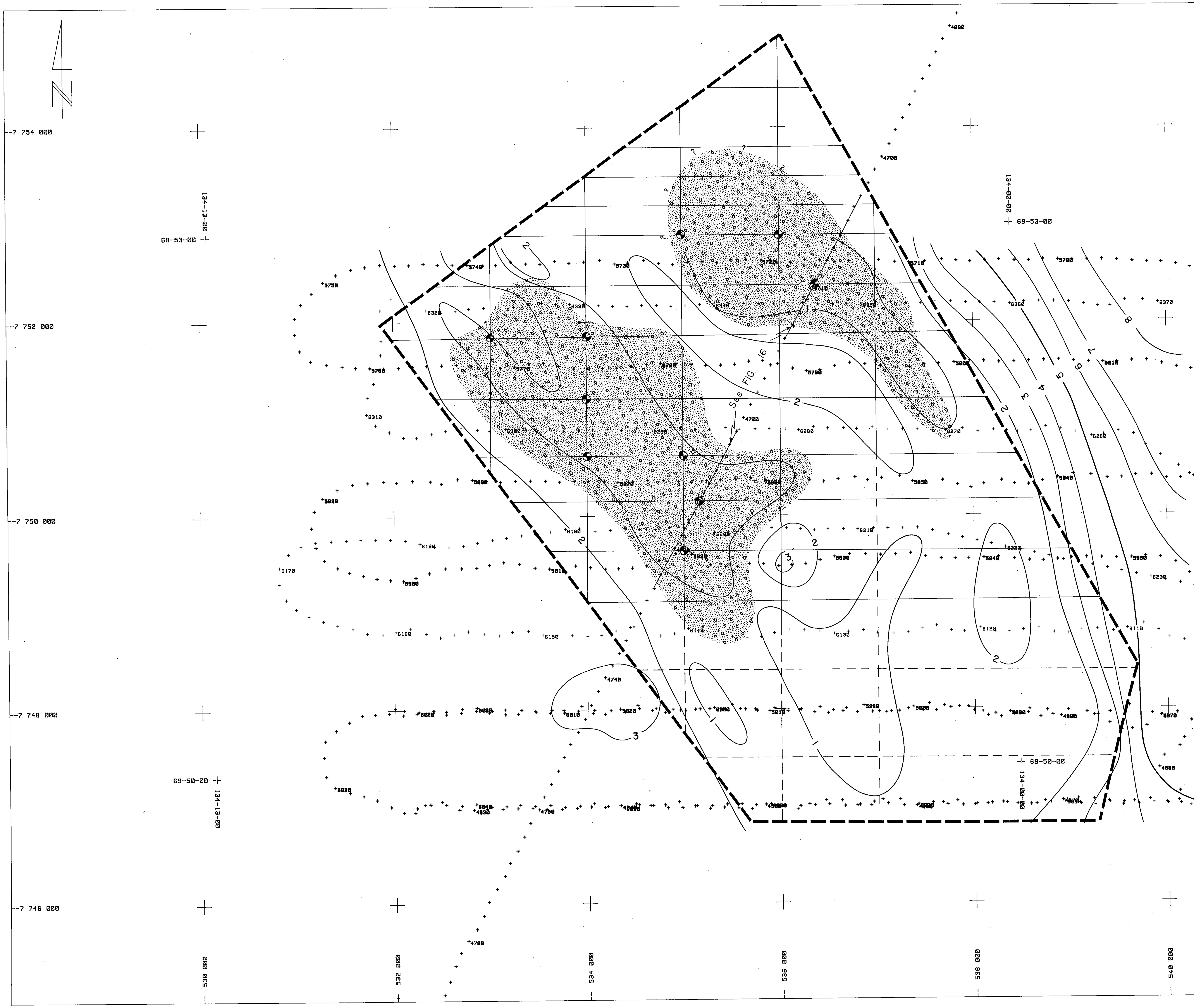
H.R. SEISMIC INTERPRETATION SERVICES INC.	for DIAND
MARINE BOTTOM & SUBBOTTOM SURVEY BY HIGH RESOLUTION SEISMIC METHODS	
AKPAK PLATEAU	PALEOGEOGRAPHY AND SURVEY PLAN
SCALE: Horizontal 1:100,000 — INTERPRETED BY: G. FORTIN	PROJECT No. 012 — MARCH 1989

NOTES:

1. HORIZONTAL POSITIONING : SERCEL SYLEDIS IN PASSIVE MODE. POSITIONING EXCELLENT DRMS 01, LPME 02/03 ENROUTE

KEY CROSS SECTION





LEGEND

3, 2 ....sediment thickness(m) to U/C_3

........AREA OF PROSPECTIVE RESOURCES

........OUTLINE OF SITE 'D'

........PROPOSED SEISMIC LINES

........PROPOSED ADDITIONAL SEISMIC LINES

........LOCATION OF PROPOSED BOREHOLES

610 ....SEISMIC LINES AND FIX MARKS (1988)

PL. II SITE 'D' & SURVEY PLAN

DIAND

NAHIDIK
SEISMIC SHOTPOINT LOCATIONS

BEAUFORT SEA
1988

H.R. SEISMIC INTERPRETATION SERVICES INC.				S.I.S.
SCALE: 1:20000	DATE: AOUT 1989	JOB NO.: 012	DWG. NO.: PL. II	