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'INTERPRETATION AND SYNTHESIS
OF HIGH RESOLUTION REFLECTION
SEISMIC DATA FROM BANKS ISLAND
BORROW AREA'

A report prepared for:

DEPT. OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

(DIAND)

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(DIAND)

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SECTION 1: INTRODUCTION

1.1 INTRODUCTION

As part of the development of a granular resources management plan for the Beaufort Sea region, the Department of Indian Affairs and Northern Development (DIAND) is systematically undertaking an inventory of sand and gravel deposits. The gravel resources are very scarce in the Canadian Beaufort, hence, DIAND's offshore granular resources inventory program has concentrated on areas exhibiting the greatest potential for gravel deposits.

The offshore area along the southwestern coast of Banks Island has been identified as prospective. Despite long sailing distances from present hydrocarbon exploration sites (e.g. Amauligak, Amerk, etc.) in the central Beaufort Sea, the petroleum industry has shown considerable interest in the granular resource potential of this area since 1980. The future development of such areas is likely to be cost-effective as the presently-developed sources (e.g. Issigak deposit) are depleted, or if exploration extends to the eastern Beaufort region (e.g. Esso Angasak site off Cape Dalhousie).

Based on test and production dredging, and on a limited amount of seismic information, O'Connor (1983) indicated that more than 50 000 000 m^3 of gravel may exist at suitable depths for dredging along the coast of Banks Island between Cape Lambton and

Sachs Harbour (Figure 1). However, the granular resource potential of the southwestern coast of Banks Island remains largely unexplored.

1.2 BACKGROUND

Since 1981, three separate geophysical programs have been carried out off the southwestern coast of Banks Island in order to investigate the surficial geology for granular resource deposits. The first geophysical investigation was conducted by Geomarine Associates Ltd on behalf of Dome Petroleum Ltd (DOME). The surveyed area comprises a grid that is situated at the mouth of the Rufus River (Figure 1); the results of this original survey have been presented to DOME by Geoterrex Ltd (Fortin, 1982).

In 1983, a second shallow geophysical program was carried out in the area on behalf of DOME and Gulf Canada Resources Inc. (GULF), by McElhanney Surveying and Engineering Ltd onboard the M.V. Robert Lemeur, a Canmar ice breaker. Unfortunately, the acoustic records collected during this program are of no practical use owing to positioning instrumentation difficulties, severe ice conditions, and possibly ship-generated noise. The same year, but onboard a different survey vessel, namely the M.V. Canmar Teal, Geoterrex Ltd successfully carried out a third geophysical program on behalf of DOME and GULF. The seismic lines cover the portion of the coast of Banks Island between the Rufus River to the south and Blue Fox Harbour to the north (Figure 1). Geoterrex Ltd

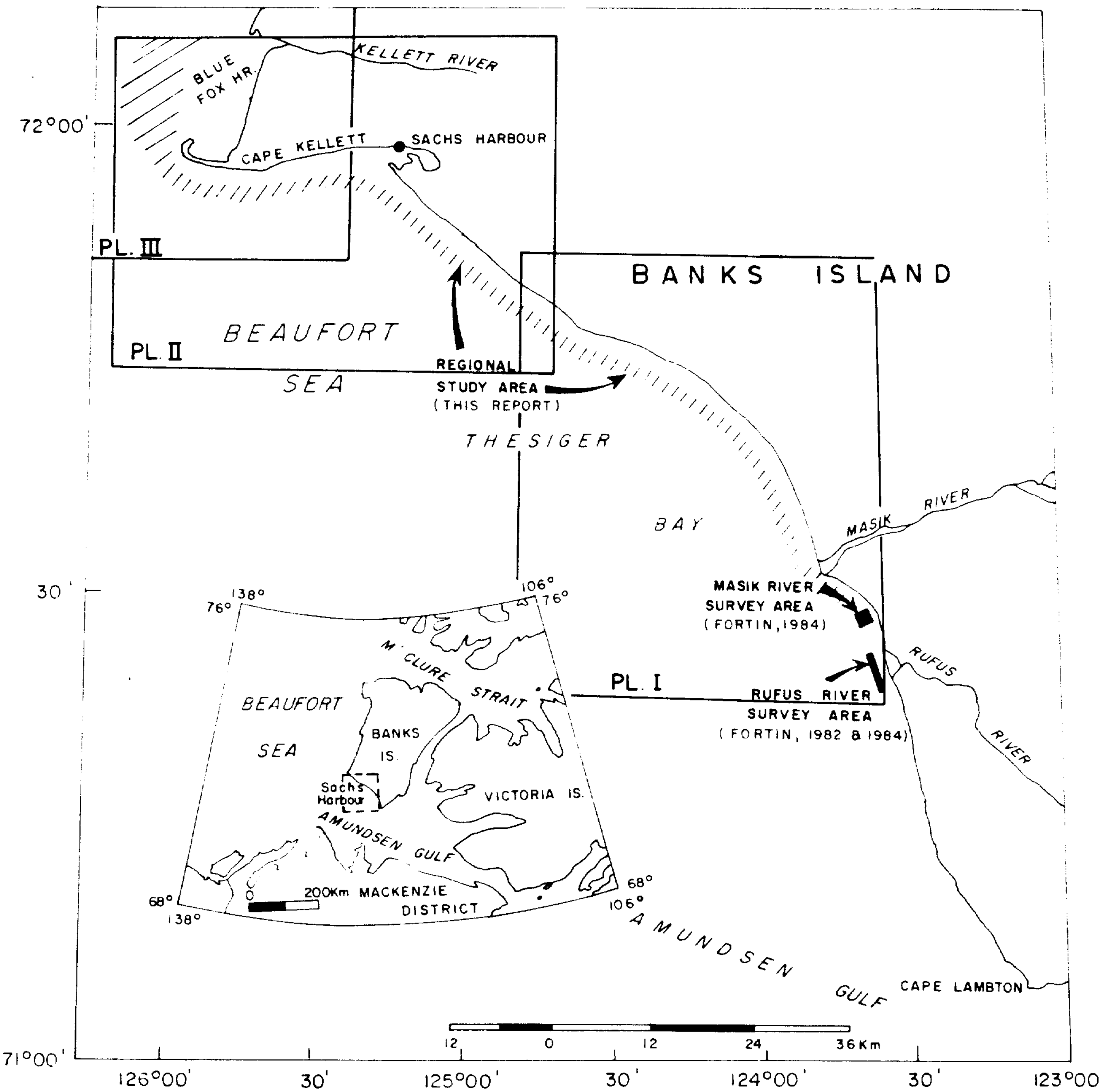

FIG. 1 LOCATION MAP

prepared an interpretation report (Fortin, 1984) which deals with two potential sites for granular resource deposits, one at the mouth of the Rufus River and the other near the mouth of the Masik River (Figure 1). In this borrow site report (Fortin, op. cit.), a number of other potential gravel deposits were ignored due to the practical limitations (draft, seabed slope and roughness, hopper capacity) of trailing suction hopper dredges which are commonly used in the Beaufort Sea. Despite the limitations to dredging by means of the current trailer-hopper suction dredges, it was felt that these potential deposits should be taken into account in the DIAND's inventory of sand and gravel deposits for the Beaufort Sea region. As a result, the present study was initiated in order to identify and delineate target sites for future regional and/or site specific granular resource evaluation studies.

1.3 AUTHORIZATION

Authorization to proceed with this study was granted to Mr. G. Fortin, private consultant operating in Hull, P.Q., by the Department of Supply and Services Canada under DSS File No. 38ST.A7134-6-028. Mr. R.J. Gowan of DIAND in Ottawa was Scientific Authority for the study, conducted under the terms and conditions of the A4 NOGAP project; subproject A4-16.

1.4 ACKNOWLEDGMENTS

The author appreciates and acknowledges the following Beaufort Sea petroleum operators for permission to use their geophysical data: Dome Petroleum Ltd and Gulf Canada Corporation.

SECTION 2: SURVEY SYSTEMS AND DATA BASE

2.1 GEOPHYSICAL SYSTEMS

The purpose of the 1983 Teal geophysical program was to investigate the seafloor morphology and subbottom geology to a depth of about 10-20 metres beneath the seafloor in order to provide information on the occurrence of subsea granular resources. To meet these survey requirements, a comprehensive suite of geophysical equipment was selected by the geophysical contractor (Geoterrex Ltd). This equipment had overlapping capabilities for investigation of the subbottom in terms of output frequencies, output power, and resolution.

A general review of the various geophysical equipment used during the Banks Island survey is presented in this section along with the equipment layout (Figure 2). A detailed description of the survey systems and survey vessel can be found in Fortin (1984).

2.1.1 Precision Echo Sounder

a) Equipment:

*Type:	Raytheon, Model DE-719C
*Operating frequency:	208 kHz
*Sounding rate:	534 soundings per minute

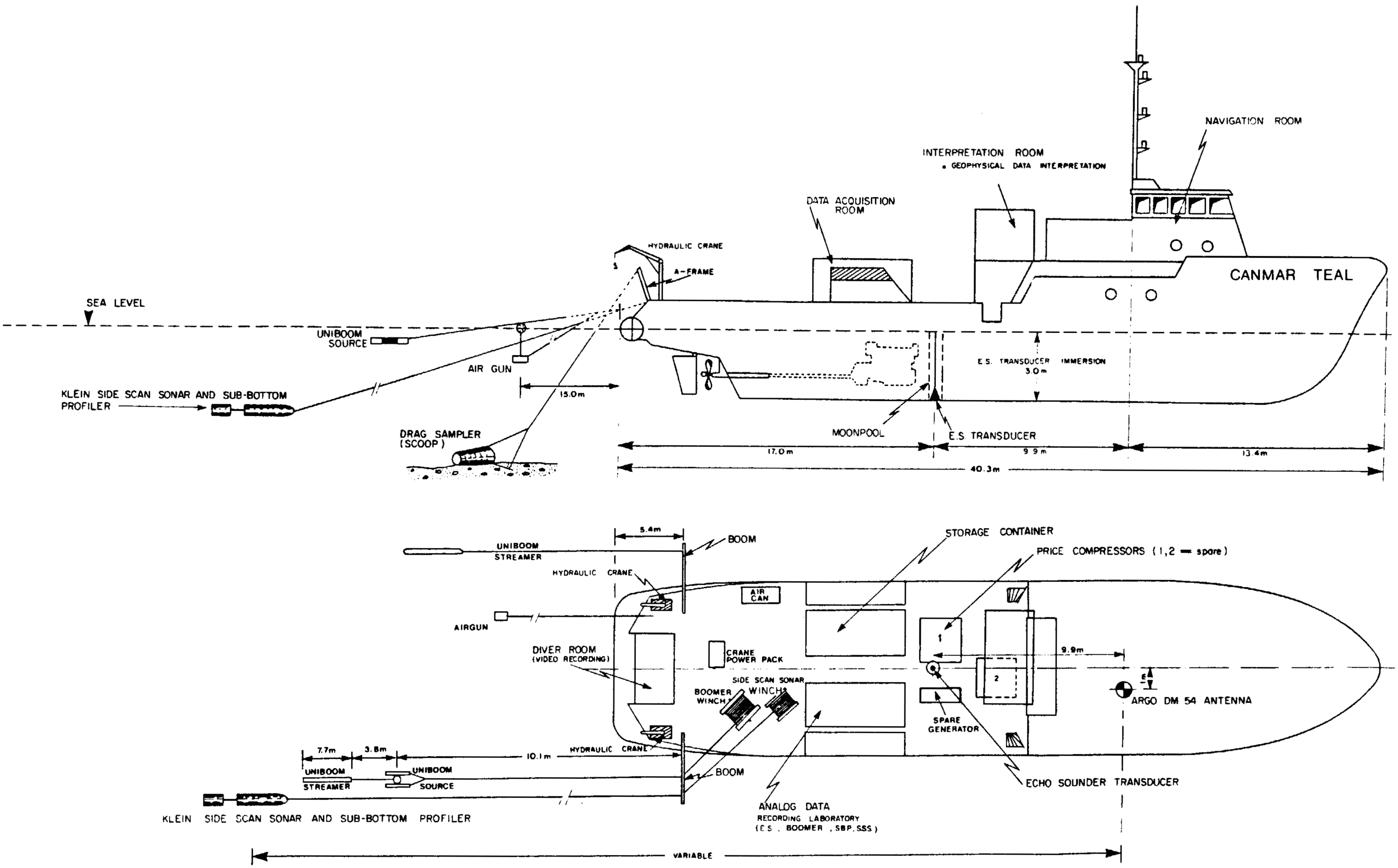

Figure 2
GEOPHYSICAL EQUIPMENT LAYOUT (-CANMAR TEAL - BEAUFORT SEA SURVEYS 1983-)

b) Survey Parameters:

*Speed of sound in water: 1460 m/s

*Transducer draft: 3.0 m

<u>Note</u>: Before the survey operation, the echo sounder was calibrated by positioning a plate beneath the moonpool-mounted transducer and lowering the plate from a pre-measured wire to maximum depth in steps of 5 m. The sounder reading was corrected using the speed of sound adjustment to provide agreement between measured and observed water depths.

2.1.2 <u>Side Scan Sonar</u>

a) Equipment:

*Tow fish: Klein, Model 422S-001F

*Recorder: Klein, Model 531T

*Slant range correction device: Klein, Model 606

*Digital Processor: Klein, Model 611

b) Survey Parameters:

*Horizontal beamwidth: 0.75 degree

*Vertical beamwidth: 40 degrees tilted down

10 degrees from horizontal

*Output frequency: 100 kHz

*Pulse length: 0.1 msec

2.1.3 <u>Subbottom Profiler</u>

a) Equipment:

*Tow fish: Klein, Model 532S-001

*Recorder: Klein, Model 531T

b) Survey Parameters:

*Output frequency:	3.5 kHz
*Acoustic output:	105 db (peak), reference one microbar at one metre
*Pulse length:	0.4 msec
*Resolution:	approximately 60 cm in water
*Beam angle:	50 degrees

Note: The subbottom profiler data was displayed on channel No. 3 of the side scan sonar recorder as well on channel A of a separate EPC 3200 recorder. Channel B of the EPC 3200 displayed the boomer record so that both records could be viewed simultaneously. This feature was a useful aid to the interpretation of the shallow geology.

2.1.4 Boomer System

a) Equipment:

*Sound source:	EG&G Uniboom catamaran
*Energy source:	EG&G Power supply
*Streamer:	Single trace, 22 hydrophones, 8 m long active section, manufactured by Nova Scotia Research Foundation
*Recorders:	EPC 4600 and EPC 3200

Note: The boomer data was recorded on both EPC 4600 and EPC 3200 dry paper recorders. The EPC 4600 recorded the boomer data at 1/4 second sweep while the EPC 3200 combined both the 3.5 kHz subbottom profiler and boomer records on channels A and B respectively. The subbottom data on channel A was recorded at 1/4 second sweep and channel B at 1/8 second sweep.

b) Survey Parameters:

*Energy level: 200 joules

*Firing rate: 4 pps (pops per second)

2.1.5 Air Gun System

A complete air gun system was installed aboard the survey vessel but it was not extensively utilized due to severe interference with the higher resolution boomer system.

2.2 NAVIGATION SYSTEM

A description of the individual components and their function is as follows:

*ARGO DM-54. The Argo navigation and positioning system was the primary horizontal control system. Argo uses an active mobile interrogator (DM-54) and four active responder stations at known fixed locations. Lane width was approximately 91 m.

*MX 1107 R/S Satellite Navigator. A SatNav was used to assist in monitoring Argo lane count.

*DEC VT-125 CRT and monitors. This terminal provided a graphic display of positioning information and transferred it to remote displays on the bridge and in the seismic lab.

*HP 9876A Printer. This printer provided a hardcopy of collected positioning information.

*HP 9872B Plotter. This printer was used to produce navigation track plots. Also it served as a back-up to CRT for display to helmsman, if required.

*JMR SIA 2134 Event Marker. This device provided the link between the navigation system and all of the data gathering systems on board the vessel; it had the ability to provide six different event mark closures.

2.3 SEABED SAMPLING

During the geophysical program, bottom samples were obtained by means of a drag sampler device, or scoop (Figure 2). As illustrated in Figure 2, the scoop was deployed astern of the survey vessel and dragged on the seabed, while the ship was drifting over a distance of several tens of metres. Table 1 summarizes the results of the seabed sampling program.

2.4 SEISMIC DATA BASE

The data base used in this report includes six regional lines (Lines 1, C-1, C-2, C-3, C-4 and C-5), totalling 130 km of seismic data. These profiles parallel the southwestern coast of Banks Island (Plates I and II). Water depths along the course of these lines oscillate generally between 10 and 25 m. In addition, a

TABLE 1: SEABED SAMPLING PROGRAM

Sample No.	Visual Description*	Location		
GR-1	Well sorted sand	proposed:	8001565N	388080E
		actual**:	8001586N	388094E
GR-3	Clayey silt, trace of sand	proposed:	7996240N	391033E
		actual**:	7996259N	391055E
GR-4	Fine sand with some clay	proposed:	7989284N	394492
		actual**:	7989305N	394506E
GR-9	Coarse sand and gravel up to 3 cm	proposed:	7971470N	435510E
		actual**:	7971495N	435506E
GR-9A	Stiff clay with some gravel up to 4 cm	proposed:	7971493N	435436E
		actual**:	7971488N	435460E
GR-11	Very stiff clay	proposed:	7964631N	446706E
		actual**:	7964607N	446709E

* Visual description carried out onboard the survey vessel by G. Fortin.

** Location where the drag sampler is presumed to have collided with the seafloor.

TABLE 2: SEISMIC DATA BASE

DATE	LINE #	FIX SOL / EOL	TIME (GMT) SOL / EOL	LENGTH (KM)	BATH	SSS	SBP	BOOMER	REMARKS
Aug. 22/83	1	1 778	0510 0721	19.5	X	X	X	X	-marginal weather for Hi.Res. seismic
	C1	1 842	1502 1725	21.1	X	X	X	X	-strong easterly winds, force 7
	C2	843 1315	1741 1908	11.9	X	X	X	X	
	C3	1319 1751	1910 2021	10.8	X	X	X	X	
Aug. 23/83	C4	1752 3211	2029 0036	36.5	X	X	X	X	
	C5	3212 4441	0042 0410	30.7	X	X	X	X	
	KK1	1 658	0520 0710	17.3	X	X	X	X	-SE wind, force 3
	KK4	659 1367	0841 1041	13.6	X	X	X	X	
	KK2	1368 2153	1110 1322	14.2	X	X	X	X	-SE wind, force 4 1-1.5 m seas
	KK3	2154 2953	1424 1638	17.5	X	X	X	X	-weather marginal for Hi.Res. seismic

BATH: echo sounder SSS: side scan sonar SBP: subbottom profiler (3.5 kHz) survey grid that comprises four profiles (Lines KK1, KK2, KK3 and KK4) was traversed off Cape Kellett (Plate III). This grid consists of 74 km of seismic profiles for a total data base of 204 km. Echograms, sonograms, subbottom profiler and boomer records were collected along all the above seismic lines (Table 2) and were all available for the present study. Data for the southern part of 1983 survey area, including the Masik River Borrow Area and the Rufus River Borrow Area (Figure 1), which were described in the original survey interpretation report (Fortin, 1984), has not been included in the present study.

SECTION 3: PREVIOUS WORKS

The offshore geology of the southwestern coast of Banks Island is poorly documented and to the author's knowledge no works have been published yet regarding the surficial geology of the offshore area. Much of the geological interpretations presented in the present report are based on extrapolations of the onshore geology to the nearshore region. A significant contribution to our understanding of the Quaternary geology of Banks Island has been provided by Vincent (1983). The following discussion on the Quaternary geology and geomorphology of the southwestern coast of Banks Island summarizes the results of this worker.

In the immediate vicinity of the survey area, the onshore surficial geology is dominated by morainal deposits and three distinct glacial till sheets have been mapped: the Bernard Till, the Sachs Till, and the Carpenter Till. The Bernard Till (Unit 2; Plate II) covers extensive areas of the western region of Banks Island and is present north of Sachs Harbour. The Bernard Till was deposited during the Banks Glaciation (Table 3), which was the oldest and most powerful of the recorded continental ice advances on Banks Island. The Banks Glaciation covered most of Banks Island and extended well into the Beaufort Sea (Vincent, 1985). A marine submergence (Post-Banks Sea) following this glaciation covered the glacio-isostatically depressed coastal areas to more than 50 m on the west coast (Table 3). Remote observations (air-

TABLE 3. TABLE OF FORMATIONS; west coast of Banks Island (adapted from Vincent *et al.*, 1983 and Vincent, 1985).

GEOLOGICAL EVENTS	FORMATIONS & LITHOLOGY	ONSHORE UNITS(1)	OFFSHORE EQUIVALENTS(1)	SEA LEVEL (M)
QUATERNARY				
POSTGLACIAL	Organic, eolian, alluvial, marine and colluvial sediments	23, 24 & 25		<0(2)
ADMUNDSEN GL. -Russell Stade	PRINCE OF WALES FM.			
-M'Clure Stade	Carpenter Till (Sand Hills Advance)	15	facies e	
	Meek Point Sea Sediments	20	facies b, Line C4, Pl.II	+20(3)
	Sachs Till (Thesiger Lobe)	12	SITES B,C,D,E,F?, H?,J? & K; facies d	
CAPE COLLINSON INTERGL.				
THOMSEN GL.	NELSON RIVER FM. Big Sea Sediments Kellett Till			
MORGAN BLUFFS INTERGL.				+30(2)
BANKS GL.	DUCK HAWK BLUFFS FM. Post-Banks Sea Sediments Bernard Till (and Durham Heights Till) Pre-Banks Sea Sediments	2	SITES D?, E?,F?, H?, J? & K?	>-51(3)
INTERGL. OR PREGLACIAL	WORTH POINT FM.			
UNDIFFERENTIATED QUATERNARY	Glaciofluvial deposits	1	LINE 1, Pl. I	
PRE-QUATERNARY MIOCENE	BEAUFORT FM.	R3		
LOWER CRETACEOUS TO EOCENE	KANGUK FM.	R2		

(1) THIS REPORT, PLATES I, II & III
(2) TRANSGRESSION
(3) REGRESSION

craft, aerial photographs) indicate that the Bernard Till is relatively thin and comprises a fine-grained matrix. The blackish colour and the fine matrix are two diagnostic properties that visually characterize the Bernard Till (Table 4). In the Duck Hawk Bluffs sector (Plate II), the Bernard Till, which may reach one to 10 m in thickness, overlies the Pre-Banks Sea sediments and underlies the Post-Banks Sea sediments. The glacial and marine sediments are grouped in the Duck Hawk Bluffs Formation (Table 3) that were deposited during or in association with the Banks Glaciation (Vincent et al., 1983).

During the long Morgan Bluffs Interglaciation, marine waters transgressed to more than 30 m above present sea level (Table 3). Following this nonglacial period, continental ice advanced again toward the Beaufort Sea as the Thomsen Glaciation. The glacial sediments (Kellett Till) associated with the Thomsen Glaciation deposited in the south-centre of Banks Island, but were not recognized along the southwest coast of the island. During deglaciation, the glacio-isostatic Big Sea flooded much of the depressed western Banks Island to 60 m (Vincent, 1985).

Following the Cape Collinson Interglaciation, the Thesiger lobe impinged on the southwest coast of Banks Island during the M'Clure Stade of the Amundsen Glaciation. The island was isostatically depressed and marine waters flooded the west coast to 20 m (Meek Point Sea). The Thesiger lobe and the Sand Hills Advance

TABLE 4 TILL PROPERTIES

TILLS	GRAIN SIZE				VISUAL CHARACTERISTICS
	>2 mm	sand	silt	clay	
BERNARD TILL (UNIT 2)	28.7	45.0	33.0	22.0 (1)	-blackish colour -fine matrix -fraction >2 mm: high proportion of sedimentary rocks (carbonates, sandstones and chert); small proportion of igneous rocks (diabases, gabbros).
SACHS TILL (UNIT 12)	50.7	61.4	21.8	16.8 (2)	-light colour -sandy matrix -high fraction >2 mm -fraction >2 mm: mainly sedimentary rocks (carbonates, sandstones), higher proportion of gabbros than other tills.
CARPENTER TILL (UNIT 15)	38.6	46.5	32.2	21.3 (3)	-sandy and rocky matrix -high proportion of gravel and diabase rock fragments -granitic rocks within the till.

Grain size analyses carried out on:

(1) 34 samples

(2) 3 samples

(3) 1 sample

built a morainic system on the southwest coast, the Sachs Till and the Carpenter Till respectively in Table 3.

The distribution of the Sachs Till (Unit 12; Plates I and II) has been particularly well established in the Sachs Harbour and Masik River areas. In these areas, the Sachs Till marks the maximum advance of an ice sheet from the south, as indicated by the presence of frontal moraines and meltwater streams. The Sachs Till is generally thin (1-2 m), although it may be thicker over escarpments that developed in the Kanguk Formation (Unit R2; Plate II) near Sachs Harbour. This till consists of a sandy matrix (61% sand, 22% silt, 17% clay) that includes a high fraction (51% per weight), of sediments coarser than 2mm, as compared to other tills in the area (Table 4). The coarse fraction (coarser than 2 mm) of the Sachs Till includes for the most part sedimentary rocks (carbonates, sandstones) and a greater proportion of gabbros than the other till units (e.g. Bernard Till and Carpenter Till).

The Carpenter Till (Unit 15; Plate I) extends along the coast between Masik River to the south and Middle Lake to the north. Field observations indicate that the Carpenter Till rests either on an older till or over sands and gravels of unknown origin. The Carpenter Till is characterized by a sandy and rocky matrix, as well as by a significant proportion of gravel and diabase rock fragments. Field observations have also indicated the presence of granitic rocks within the till. The distribution of the Carpenter

Till indicates that this glacial feature was carried and deposited by a glacier situated in the Thesiger Bay. The diabase rock fragments (Glenelg Formation) suggest that the ice sheet, emanating from the south, advanced towards the north. Of particular interest is the morphology of the Carpenter Till which consists of a morainic complex that is very "young" in appearance (Figure 3). Crests of till and (or) ice contact deposits (terminal moraines) are oriented parallel to the coast and are separated by kettles.

Marine deposits (Unit 20; Plates I, II and III), probably related to the Meek Point Sea (Amundsen deglaciation), predominate along the coast between Sachs Harbour and Middle Lake. In this area, glaciofluvial sands and gravels are believed to have been deposited by glacial meltwater in a shallow embayment which existed to the southeast of Sachs Harbour.

Post glacial marine deposits (Unit 23; Plates I, II and III) are restricted mainly to beaches and spits; they consist of gravels and sands deposited along the modern coastline. Postglacial fluvial deposits (Unit 25; Plate I) are found as stratified gravels, sands and silts deposited on modern floodplains or on low stream terraces. Eolian deposits (Unit 24; Plate II) are present locally in the area southeast of Sachs Harbour as a cover on older glaciofluvial deposits.

Undifferentiated Quaternary deposits (Unit 1; Plates I, II and III) have been mapped at several locations on Banks Island and in particular at the mouth of the Masik River. They are particularly relevant to this study because they consist of stratified sand and gravel deposited by glacial meltwater during the various glaciations; they include sediments reworked from older sand and gravel deposits (several cycles of reworking). Although 11 grain size analyses have been carried out on the glaciofluvial deposits mapped on Banks Island (appendix B in Vincent, 1983), none of the samples has been obtained for the sediments (Unit 1, Plate I) near the mouth of the Masik River. However, at a sample site for radiocarbon dating, which is situated in a gully near the Thesiger Bay at 14.5 km north of the Masik River (71° 40'N and 123°50'W), J.G. Fyles noted in his field book that the peat and colluvium deposits cover a fluvioglacial or marine terrace that includes 20 feet (6.1 m) of stratified pea-size gravel and sand. J.-S. Vincent (GSC, pers. comm., 1987) indicated that the coarsest fraction of the glaciofluvial deposits (Unit 1) in the Masik River area consists of pea-size gravel, which may originate from erosion and reworking of the Beaufort Formation (Unit R-3).

In the study area, pre-Quaternary deposits have been recognized mainly in the Duck Hawk Bluffs area (Vincent et al., 1983, Vincent, 1984). The whole series of bluffs extending from the Kellett Spit in the west to Mary Sachs Creek in the east are designated collectively 'Duck Hawk Bluffs' (Vincent et al., 1983).

FIGURE 3. Photograph of Carpenter Till.
(GSC photo 167652)

The pre-Quaternary deposits consist of the fluvial coastal plain unconsolidated sands and gravels of the Beaufort Formation (Unit R3; Plates II and III) of Miocene age; they unconformably overlie the Kanguk Formation (Unit R3; Plates II and III). In the eastern sector of the Duck Hawk Bluffs, the Kanguk Formation is made of unlithified to poorly lithified open marine deposits (silty shale) of Late Cretaceous age (Vincent et al., 1983).

As stated by O'Connor (1983), DOME conducted in 1980 some test dredging along the southwest coast of Banks Island, concentrating mainly in areas near the mouths of the steeper rivers which empty in the Beaufort Sea. The results of the dredging in 1980 and subsequent production dredging in 1982 indicated that, unlike some of the other borrow prospects in the Beaufort Sea (e.g. Isserk borrow site), the Banks Island deposits contain a substantial amount of coarse gravel. Cobbles and boulders up to 300 mm in diameter were found to be common at some locations. O'Connor (1983) indicated also that recent quality assurance inspections have demonstrated that clayey materials may also exist near the seabed in some of the gravel prospects. This author points out the considerable speculation among the industry regarding the clay. It was speculated that the clay may be part of an underlying glacial till unit. At that time, insufficient information was available to determine the glacial and post-glacial stratigraphy of the nearshore sediments with any certainty.

Based on the results of two detailed geophysical programs conducted at a site near the mouth of the Rufus River in 1981 (Fortin, 1982) and 1983 (Fortin, 1984), i.e. before and after the production dredging at this site, a prospective area of some 2500 ha was delineated. Fortin (1984) concluded that the Rufus River Borrow Area consists mainly of a submarine till sheet which comprises a number of distinct till units. The bathymetric style in this area is characterized by a flat seabed which descends seaward with an average grade of about 1:35. This seafloor morphology could not be easily associated to the "young" appearance of the Carpenter Till delineated onshore, and therefore it is believed that the flat seabed relief in the Rufus River Borrow Area indicates the presence of an older till unit (Sachs Till ?).

In the Masik River Borrow Area, a surficial layer of fine-grained materials has been interpreted atop the gravel deposits. As a result, this site presents a low potential for future gravel development.

This review of the surficial geology of the southwestern coast of Banks Island demonstrates that coarse-grained deposits are widespread along the coast; as a result, source areas for nearshore granular materials are as numerous as various. Among these units, the offshore extension of the undifferentiated Quaternary deposits (Unit 1), the Sachs Till (Unit 12), and the Beaufort Formation (Unit R3) constitute the most promising sources of aggregate for the immediate nearshore area. Some other units are considered to be marginal sources of good quality granular materials. For instance, the relatively young Carpenter Till (Unit 15) is characterized by a high relief onshore, hence it is likely that this deposit has not been intensively eroded and reworked following its deposition during the Sand Hills readvance (last glacierization of this area).

SECTION 4: DISCUSSION OF RESULTS

A discussion of the seabed and subbottom features detected in the available geophysical records, and pertinent to the potential aggregate deposits off the southwest coast of Banks Island is presented in this section of the report.

4.1 INTERPRETATION PROCEDURE

The interpretation procedure used to predict the occurrence of aggregate deposits near the seabed is mainly based on qualitative interpretation criteria such as:

1) The depth of penetration through the subbottom achieved by various acoustic signals (3.5 kHz profiler and Uniboom) having different frequencies and power (see Section 2.1).

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 (stratified, partially stratified and chaotic) which may be related to depositional processes, gross depositional environment, sediment source, geologic setting, etc.

4) The shape (ice contact deposits such as: moraine and till; sand dunes, ice shoved ridges, ice scours, etc.) and texture (strength of the echoes versus mud, sand or gravel) observed on the sonographs.

5) Bathymetric anomalies, usually of high relief, which may indicate the presence of submerged features such as: moraine ridges, tills, spits, remnants of eroded terraces, etc.

Many of the factors or parameters used in this type of seismic interpretation are of a 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 similar high resolution analogue seismic surveys. These investigations were conducted in the various environments found in the Beaufort Sea; in particular, at Issigak, Herschel Island and, most significatly, the proven Banks Island borrow deposits. 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, illustrate well the surficial geology of the southwest coast of Banks Island. Although a better seismic coverage will undoubtedly provide a more comprehensive perspective of the granular resource potential of the area, only a detailed seabed sampling program can confirm the occurrence of borrow deposits.

4.2 PRESENTATION OF RESULTS

The positions of the navigation fix marks, the location of the seabed samples and the seismic coverage obtained along this portion of the island coast and off Cape Kellett are presented on Plates I, II and III. The interpretation results of the geophysical field work are also displayed on these plates as a series of cross sections (Plates I, II and III) and a plan view map (Plate III); they are constructed from the bathymetric, side scan sonar, and shallow analogue seismic data. Figures 4 through 13 provide acoustic evidence for the geophysical interpretation.

The Uniboom records were of relatively poor data quality due to the wide source signature. The poor resolution on the Uniboom records meant that only larger scale features and structures could be mapped while smaller detail was obliterated. One should note that, although high resolution 3.5 kHz subbottom profiler records were available, the subbottom penetration achieved by this high frequency device is usually very limited (a few metres) and near zero through coarse-grained and highly cohesive materials.

The top portion of the cross sections displays the interpretation of the shape and texture of the surface of the seafloor obtained by means of side scan sonar imagery out to a maximum range of 100 m from the ship. These corridors provide a basis for tying together the morphology and nature of the seabed on the sonographs, information obtained by sampler at isolated points and by echo sounder, subbottom profiler and boomer along seismic lines.

The maps enclosed with this report (Plates I, II and III) are at a horizontal scale of 1:50 000, as are the cross sections which are displayed at a vertical scale of 19.8 cm per 0.1 sec or approximately 1:380. The equivalent vertical exaggeration is approximately 130 times.

4.3 LINES 1 AND C-1 (Plate I)

Lines 1 and C-1 traverse the submerged portion of the Masik River delta over a distance of about 20 km. Lines 1 and C-1 were intended to parallel the 15 m and 25 m isobaths respectively; however, departures from the chosen isobath are quite frequent as illustrated on Plate I. The quality of both side scan sonar and shallow seismic data is generally good, but the presence of shallow gas in the southeast portions of these profiles has made interpretation of the real acoustic returns very difficult.

4.3.1 Surficial Geology

In the southeastern portion of Lines 1 and C-1 (southeast of fix marks (251 and 321 respectively), an acoustically transparent layer was delineated by the 3.5 kHz subbottom profiler (Plate I).

This layer exhibits a notable thickening offshore, and a probable slight decrease in sediment grain size, in the same direction. The acoustic penetration of several metres by the low energy 3.5 kHz profiler and the intensively ice-scoured facies on the sonographs suggest that this surficial layer is unconsolidated and consists of fine-grained sediments. On the same basis, it can be assumed that the surficial layer, between fix marks 401 and 501, and 461 and 551, on lines 1 and C-1 respectively, is also comprised of fine-grained materials, probably silt and clay. In the western sector of Lines 1 and C-1, the 3.5 kHz profiler records exhibits less subbottom penetration and the seafloor is only slightly ice-scoured which would indicate that the immediate seabed material is comprised of coarser grained sediments, probably fine sand and silt.

In the central portion of Line 1, coarse-grained sediments, possibly sand and gravel, may be associated with an apparent bathymetric high situated between fix marks 311 and 381; in addition, this zone displays a different and more uniform shade (tone) on the sonograph. This feature may extend offshore until Line C-1, between fix marks 431 and 461; at this location however the deposit appears to be fine-grained (fine sand and silt). It is likely that this feature also extends shoreward of Line 1 with a possible increase in grain size in this direction.

On the boomer record, the surficial layer is underlain by a stratified or a partially stratified sequence which is possibly equivalent to the glaciofluvial stratified sand and gravel of Unit 1 (Plate I). The surficial layer, in which no internal structure is visible, is thought to mark the transition between the sub-aerial exposure and the ensuing postglacial submergence when reworking and transportation of sediments of Unit 1 by wave action was a dominant process.

Shallow gas is generally trapped within Unit 1, however migrating gas is also visible in some places within the surficial layer. The exact origin of the shallow gas is unknown, although it is common to observe biogenic gas in a deltaic environment. In the present survey area, evidence of shallow gas has been noted frequently at the mouth of the Masik River and only sporadically between the Masik River and Cape Kellett.

4.3.2 Potential for Granular Resources

The surficial layer in this area (seaward of the 15 m isobath) is interpreted as consisting of medium- to fine-grained sediments with a possible fining seaward. These conditions may improve locally, where the coarsest remnants of the former glaciofluvial deposits (Unit 1) may have been less extensively eroded and remobilized than the surrounding areas. The apparent bathymetric high, designated Site 'A' on Plate I, constitutes a good target for a future site specific study. Although the relief of this feature may be accentuated or even created by a change in the ship course, the boomer record (Figure 4) shows clearly a chaotic stratigraphic unit with diffraction patterns (boulders ?). This deposit (Unit 1? in Figure 4) may exist right at the seafloor without any overburden. In addition, the absence of subbottom penetration on the 3.5 kHz profiler record attests to the acoustically hard nature of the seabed at this location.

The most probable geologic origin for the deposit is the coarse-grained remnants of a submerged glaciofluvial terrace (Unit 1), or alternatively an elevated interfluvial area of a paleodrainage system. This deposit, which is about 1-2 km wide along Line 1, merits further investigation. A combined geophysical/bottom sampling program should be conducted seaward and shoreward of Line 1 to confirm the exact lateral extent and nature of the deposit.

4.4 LINE C-2 (Plate I)

Line C-2 begins at about 2.3 km from the northwest termination point of Line 1 and roughly parallels the 15 m isobath for approximately 12 km. The distance from the seismic line to the coast varies between 0.3 and 1 km; note that seismic data is missing over a distance of 2.3 km between Lines 1 and C-2.

The quality of both the side scan sonar and shallow acoustic records is good along Line C-2, especially the sonograph which was very useful for delineating seafloor morphologies and outcrops of stratigraphic units.

4.4.1 Surficial Geology

The southeast portion of Line C-2 exhibits a surficial geology that is very similar to the western sectors of Lines 1 and C-1 (Plate I). In this zone, the surficial layer is interpreted to be the result of reworking and re-distribution of the upper section of a stratified sequence (Unit 1), which was recognized on the boomer record (Figure 5). Except for the southeast end of Line C-2 where the 3.5 kHz signal of the subbottom profiler penetrates through about 1 m of reworked sediments, this low power device usually achieved no subbottom penetration in this sector. The absence of penetration on the 3.5 kHz profiler record is attributed to the presence of sand (and gravel?) waves which cover large portions of the seafloor between fix marks 933 and 1043.

A shallow and irregular reflector delineated on the boomer record outlines a few depressions; they may be the remnants of the deepest portions of channel rivers or lakes forming parts of a paleodrainage system. The boomer system was also very effective in delineating a number of irregular and high amplitude horizons occurring at greater depths (6 to 30 m subbottom). This acoustic signature visible in Figure 5 is typical of hummocky shallow Acoustically defined PermaFrost (APF) which is encountered frequently beneath the continental shelf area of the Southern Beaufort Sea (O'Connor, 1980 and 1982). The presence of ice-bearing permafrost would reinforce the interpretation of the stratified facies as equivalent to the glaciofluvial deposits of Unit 1 which were likely exposed to arctic conditions during deposition. It is believed that these hummocky acoustic returns (Figure 5) are too irregular to be related to an older till surface.

A dramatic change in the acoustic facies occurs in the central portion of Line C-2 (fix mark 1043); this change is thought to indicate the boundary between the stratified glaciofluvial deposits (Unit 1) and the Sachs Till (Unit 12). As is the case onshore, the seabed profile displays an apparent escarpment at this location (fix mark 1043); providing it is not a change in the ship's course. In addition, the sonograph (Figure 6) reveals that large and flat portions of the Sachs Till, or Unit 12, outcrop on the seafloor. Figure 6 also displays patches of a thin veneer of probably reworked materials (sand and gravel?) which deposited atop the till surface. Except for the line segment between fix marks 1093 and 1123, where a large east-west trending patch has been delineated on the sonograph, the thin layer of reworked sediments is generally not resolved by the 3.5 kHz profiler (Figure 6). Of particular interest is the texture of the seabed; the sonograph in Figure 6 suggests the occurrence of several erratics.

These large blocks (boulders) are scattered over the till surface and occasionally pierce through the thin veneer of reworked sediments.

Northwest of fix mark 1153, an abrupt change in the seabed relief is interpreted as the boundary between the older Sachs Till (Unit 12) and the younger Carpenter Till (Unit 15). One should note that till ridges culminate at very shallow depths (less than 10 m); these sudden variations in water depths over very short distances may constitute hazards for a safe navigation in this area. The submarine relief of the Carpenter Till closely resembles the morphology of this till (Figure 3), such as described onshore by Vincent (1983). In the offshore area, morainic ridges made up of Carpenter Till deposits appear to be separated by depressions (kettles), which may have been subsequently infilled with materials reworked during the postglacial submergence. It is speculated that the materials infilling the kettles consist of proximal deposits including the coarsest grain sizes (sand, gravel, boulders) derived from the reworking of the Carpenter Till (Unit 15).

In the western sector of Line C-2, the high relief of the Carpenter Till and the relatively small quantities of reworked materials suggest that this young till was not extensively eroded during the postglacial (rapid ?) submergence, or alternatively the Carpenter Till may be very resistive to erosion. The presence of ice within the Carpenter Till may have prevented a more severe erosion. A very strong water bottom multiple (unusual) on the echogram, between fix marks 1163 and 1183, could be acoustic evidence for ice lenses near the seabed.

4.4.2 Potential for Granular Resources

The potential for aggregate deposits in the southeast portion of Line C-2 (east of fix mark 1003) is considered to be generally low. Although the surficial layer may be locally coarse-grained (sand), the acoustic data indicates that in this area the reworking of the glaciofluvial deposits (Unit 1) has resulted chiefly in medium to fine grain sizes (fine sand and silt).

The most promising sector for granular materials is located in the central portion of Line C-2 (between fix marks 1003 and 1153), where the Sachs Till (Unit 12) lies at or immediately below the seabed (Figure 6). The erosional surface of this till is apparently flat lying along this profile which suggests that these old deposits have been extensively eroded during the following glaciation(s) and marine submergence(s). Hence important quantities of coarse-grained materials (sand and gravel) may be available in the immediate area. The sonograph and the shallow seismic records (Figure 6) indicate that only thin patches of reworked sediments have been deposited atop the till surface, on which also rests numerous erratics; therefore most of the reworked materials have likely accumulated in some other areas. The apparent escarpment that seems to occur (fix mark 1043) between the relatively more elevated Sachs Till (Unit 12) and the low lying glaciofluvial deposits (Unit 1) may be covered by substantial quantities of granular materials which deposited downslope.

On the basis of quantity and quality of the granular resources available, the central portion of Line C-2 has been subdivided for future studies into two sites, each of which has a different potential. The first site, or Site 'B', is thought to have a better potential than the second site, or Site 'C'. Site 'B' delimits the possible offshore extension of an escarpment (present onshore between Units 12 and 1), along which good quality and significant volumes of granular materials may have accumulated.

Future investigations of Site 'C' should include mapping the submarine distribution of the Sachs Till and the patches of reworked sediments which cover parts of the till surface. The thickest pockets of reworked deposits constitute the best targets, although the Sachs Till itself may be considered as prospective granular resources if its physical properties (sorting, compaction, erratics, etc.) do not constrain dredging.

4.5 LINE C-3 (Plate 1)

Line C-3 begins at approximately 1 km from Line C-2 (data gap of 1 km) and, over a distance of about 11 km, closely parallels the coast that extends some 400-500 m to the northeast. The line was originally intended to follow the 15 m isobath but drastic variations in water depths were frequently encountered along the course of this seismic profile.

The quality of the sonograph and seismic records is good along the entire line.

4.5.1 Surficial Geology

The seafloor morphology and the surficial geology along Line C-3 are very similar to the northwest portion of Line C-2. Here again, the shallow geology is characterized by morainic ridges, 5-10 m high, which are likely made up of Carpenter Till and separated by kettles that are infilled to various degrees by reworked materials (Figure 7).

4.5.2 Potential for Granular Resources

The offshore extension of the Carpenter Till has a great potential as source deposits from which good granular materials can be derived by erosional processes. Unfortunately, as discussed in Section 4.4, the "young" appearance of the Carpenter Till and the relatively small quantities of reworked materials strongly suggest that the erosion of this feature was not severe. Nevertheless, these deposits may be considered as prospective granular resources.

If the future development of such granular resources is contemplated, serious constraints to dredging must be envisaged. Among these limitations, the most important are: 1) the high seabed relief; 2) the probable strong seaward gradient of the narrow shelf; 3) the proximity of the coast; 4) the small dimension and scattering of the pockets of good borrow materials (reworked sediments) and, 5) the frequent occurrence of morainic ridges made up of various grain sizes, erratics, and possibly ice lenses.

4.6 LINE C-4 (Plates I and II)

Line C-4 begins at approximately 1.1 km from Line C-3 (data gap of 1.1 km) and follows fairly well the 15 m isobath for about 36.5 km to terminate near the entrance of Sachs Harbour. The southeast portion of the seismic line runs very close (300-500 m) to the coast, but the shoreline slowly gets farther away (2-3 km) presumably as a result of the widening of the shelf in the northwest part of Line C-4.

The quality of the sonograph and shallow acoustic records is reasonably good along the entire line. In most areas, the 3.5 kHz subbottom profiler delineates fairly well the shallow surficial sediments. Deeper stratigraphic features can be identified from the boomer record gathered in the southeast half of Line C-4. However, due to a notable decrease in subbottom penetration along the northeast half of this profile, shallow geologic features are less evident on the boomer record thus increasing interpretation difficulties.

4.6.1 Surficial Geology

The seabed profile in the southeast termination of Line C-4 (east of fix mark 1922) exhibits the characteristic signature of the Carpenter Till. The shallow seismic data (Figure 8) confirms the presence of "young" morainic ridges so typical of these deposits. These ridge features were sampled at location GR-11 near fix mark 1852 (Plate I) where a large outcrop of Carpenter Till has been delineated on the sonograph. A visual inspection of the sample indicated that the drag sampler, or scoop, had gouged into a very stiff clay. This is conflicting with the description of the Carpenter Till (Unit 12) from Vincent (1983) who indicates that characteristically the Carpenter Till includes a sandy and rocky matrix (Table 4). Vincent (GSC, pers. comm., 1986) mentioned also that fine-grained units are occasionally encountered within the till deposits.

Between fix marks 1922 and 1932, a notable change in the seabed relief (Plate I) along with a deepening of the chaotic facies (Figure 8) may indicate a geological boundary. At this location, the relatively "young" Carpenter Till (Unit 15) may be bordered and possibly underlain by an older till unit (Sachs or Bernard Till) that is in turn, overlain by a relatively thick layer of surficial (reworked Unit 20?) sediments. This geological boundary is interpreted offshore as the northwestern end of the Carpenter Till or Unit 15. Considering that ice sheets emanating from south, advanced generally towards the north and impinged on the southwest coast of Banks Island during at least two glacial events (Thesiger Lobe and Sand Hills Readvance in Table 3), or perhaps three (Banks Glaciation), it is likely that old till deposits (Sachs and/or Bernard Till) underlie the marine deposits (Unit 20) in the nearshore areas.

As we progress away from the Carpenter Till, the surficial layer increases in thickness to a maximum in excess of 8 m, towards the axis of large depressions. These basin features may have been the remnants of ancient lakes similar to the Middle and Fish Lakes, which have been infilled as the strandline climbed the low lying littoral zone. This region was probably subjected to erosion and reworking resulting primarily from wave and current actions. As a result of this high energy shoreline environment, the relatively thin marine deposits of Unit 20, and possibly parts of the underlying till deposits, may have been eroded and the reworked sediments deposited within the paleodepressions delineated between fix marks 1942 and 2373.

The old till(?) and the reworked deposits were sampled at two closely spaced locations, GR-9 and GR-9A near fix mark 2373 on Plate II and in Figure 9. The first sample (GR-9) is positioned over a patch of reworked materials and the sediments collected were visually described as a coarse sand with gravels up to 3 cm in diameter. The second sample (GR-9A) was taken at the margin of a till outcrop and described as a stiff clay with some gravels up to 4 cm in diameter. The results of these two samples give support to the acoustic analyses of the sonograph and shallow seismic records, but also they demonstrate the high variability of the bottom materials over a very short distance (a few tens of metres). That may have a serious impact on the future development of this type of deposits.

Due to the limited penetration of the analogue boomer system between fix marks 2583 and 3053, acoustic returns are basically undetectable thus preventing a more thorough stratigraphic interpretation of the shallow geology in this area. In this zone, a faint reflector visible on the 3.5 kHz profiler record has been tentatively mapped by following the "grain" of the seismic reflection. In certain places, no distinct reflection is evident and the inferred position of the horizon has been shown on the cross section as very questionable (question marks on Plate II). This weak reflector may mark the base of the reworked sediments which, in some places, may be too thin to be resolvable on the seismic records. The surficial layer exhibits a variable thickness and may overlie the acoustically hard surface of a dense coarse-grained layer.

4.6.2 Potential for Granular Resources

Five targets for future site specific evaluation studies have been identified along the course of Line C-4; these targets are labelled Sites 'D', 'E', 'F', 'G' and 'H' on Plates I and II. The five sites are considered to be potential borrow sources because they display similar stratigraphic conditions; in addition, one bottom sample (GR-9) has confirmed the presence of granular materials (sand and gravel) at one of these locations (Site 'F'). The surficial geology of these sites is characterized by outcrops of stratigraphic units (Figure 9) which exhibit a chaotic facies on the boomer record (Figure 8). This acoustic facies is interpreted as indicative of old till deposits (Sachs or Bernard Till, or both?). In these five site areas, the surficial layer may include sand and gravel that originate from the erosion, reworking, and re-distribution of old till deposits, and possibly from the coarsest facies of marine deposits (Unit 20), through a combination of wave and current action that prevailed during postglacial submergence(s). The reworked sediments were likely deposited over a paleorelief surface which is incised by a great number of river channels and lakes. The variations in seafloor shade on the sonograph suggest that the grain size of the seabed material decreases as the reworked sediments get farther away from the till outcrops from which they evolved. This facies change can be easily explained. The coarse fraction (sand and gravel) of the reworked materials would have been redistributed on the paleo-surface near its source. The finer fractions (fine sand, silt and clay) were either carried away and deposited on the bottom of depressions (e.g. shallow lakes) as a result of a deeper water column, or accumulated offshore where a quieter hydrodynamic regime prevailed.

Although five relatively large areas were delineated along Line C-4 for site specific evaluation studies to prove the occurrence and distribution of potential granular resources, the portion of Line C-4 from fix mark 2152 to 3023 (Plate II), between the 10 m and 25 m isobaths, can be identified as an area for a more detailed regional study. In fact, the generally smooth seafloor, the observed nearshore surficial geology, and the occurrence (not confirmed by ground-truth information) of old till deposits underlying the marine deposits (Unit 20) are favorable conditions for the presence and development of subsea granular resources in this area.

4.7 LINE C-5 (Plate II)

Line C-5 begins near the entrance of Sachs Harbour at about 750 m from the termination point of Line C-4 (data gap of 750 m) and initially runs in a northwesterly direction towards Duck Hawk Bluffs. The line then follows a westerly path, roughly parallelling the coast to Cape Kellett Spit where it turns north to its termination point some 3-4 km off Cape Kellett Spit. The total length of the line is approximately 31 km and the water depth oscillates slightly from the 15 m isobath.

The boomer data is fairly poor throughout the entire line due to the swell that developed along the course of Line C-5. In addition, the boomer record suffers considerably from interference patterns. This interference was due to the operation of the airgun system from the start of the line until fix mark 3822. At that point the poor quality of the boomer record prevented further use of the air gun. The quality of the 3.5 kHz subbottom profiler record, mounted in the deep-tow fish of the side scan sonar, is marginally better but again its limited subbottom penetration has made interpretation difficult in most areas. The quality of the sonograph is reasonably good.

4.7.1 Surficial Geology

At the eastern end of Line C-5, located near the entrance of

Sachs Harbour (mouth of Sachs River), a reflector visible on the omer record dips away to the east and may represent the western flank of a depression-like feature. This reflector, along with another similar horizon delineated in the western sector of Line C-4, may mark the bottom of a paleochannel. It would have been incised into older deposits by the ancestral Sachs River during a period of lower sea level. This paleochannel is interpreted to have been infilled first by fine-grained stratified estuarine sedimentation, and after by sandy silt originating from the reworking by wave action of the interfluvial deposits (Unit 20?).

The paleochannel is bordered to the west by an irregular surface that is similar to the acoustic signature of the till deposits delineated in the southeastern sector of Line C-4. This irregular surface occurs between fix marks 3342 and 3512 (Figure 10) and may well be the offshore extension of the Sachs Till which onshore forms an arcuate and narrow deposits (Unit 12) mapped north of Sachs Harbour. West of this location, a relatively more elevated area lying between fix marks 3532 and 3602 (Figure 11) may be covered by very coarse materials (sand and gravel). These deposits are possibly derived from the reworking of a frontal moraine and would be equivalent to the frontal morainic system associated with the Sachs Till; onshore, these deposits are used as a borrow pit by the community of Sachs Harbour (J.-S. Vincent, GSC, pers. comm., 1986).

For the remainder of the line, the surficial geology is characterized by stratified or partially stratified acoustic facies visible on the boomer record. These facies differ notably from the chaotic facies associated with the various till deposits recognized southeastward. The stratified and partially stratified facies suggest that the shallow stratigraphic units consist mainly of relatively thick sequences (10-15 m) of fine-grained sediments. In several places, the absence or limited subbottom penetration achieved by the 3.5 kHz signal may indicate that these fine-grained sediments have a high consistency and hence would represent old deposits. Evidence supporting this hypothesis is gained from Vincent et al., 1983; Figure 6 (a photograph) from this paper illustrates a section in the eastern sector of the Duck Hawk Bluffs showing Kanguk Formation sediments unconformably overlain by Beaufort Formation sands and gravels. This photograph also shows that the Silty Shale Member of the Kanguk Formation forms the lowermost beds exposed on the sea cliffs. This would seem to introduce the possibility of a complete erosion of the Beaufort Formation in the immediate nearshore area leaving the fine-grained Kanguk beds near the seabed. This then leads to the question of where the gravels and sands, derived from the Beaufort Formation, were deposited after erosion.

In some places, the 3.5 kHz subbottom profiler shows an acoustically transparent layer, between one and four metres thick (Figure 12), that covers the Kanguk (?) strata. This surficial layer appears to include mostly medium and fine grain sizes along long segments of Line C-5; this is supported by a bottom sample (fine sand with some clay) that was obtained at location GR-4 on Plate II. The surface deposit may be slightly coarser between fix marks 3682 and 3812, where the 3.5 kHz signal did not penetrate through the seabed. From the present data base, it is difficult to determine whether the surficial layer is made of the coarse fraction of the reworked material from the Kanguk Formation, or is the result of the fining seaward facies change of the sediments derived from the erosion of the Beaufort Formation sands and gravels. To answer this question adequately is beyond the limits of the present data base.

Special geological features have been noted along the course of Line C-5. The origin of these events is not clear but it could be related to certain glacial processes. These features are termed on Plate II: 'ice-shoved ridges' and 'deformations from overriding glaciers'. Similar ice-related features have been observed on the adjacent coastal areas (J.-S. Vincent, GSC, pers. comm. 1986). The ice-shoved ridges (Figure 12) are more recent in origin and are attributed to the gouging effect of the polar ice pack when impinging on the littoral zone, while the deformations by overriding glaciers would be the result of an older process that was active during the past glaciations(s) of Banks Island. Onshore, the Kanguk beds as well as the overlying Beaufort beds are commonly deformed and it was speculated that these deformations were created by lateral pressure due to overriding glaciers (Vincent et al., 1983). The ice-shoved ridges are particularly well defined in the southern sector of Cape Kellett Spit, where a large section of the surface deposit is thought to have been almost entirely bulldozed by grounded ice and piled up on the seafloor forming ridges that display heights of 2-3 m and widths of 200-300 m. At the western end of Line C-5, diagnostic horizons delineated on the boomer record picture quite well a probable thrust zone, which is interpreted as deformations caused by overriding glaciers.

4.7.2 Potential for Granular Resources

Three sites for follow-up studies are delineated in the eastern sector of Line C-5 and they are identified Sites 'I', 'J' and 'K' on Plate II. Site 'I' delimits a probable bathymetric high that gives rise to a strong water bottom multiple on the boomer record. This deposit is bounded at its base by a distinct reflector which pinches out near the seabed in a easterly direction and fades out in the opposite direction. The acoustic data also reveals a possible fining westward facies change. The seismic interpretation of this site is questionable and hence the geologic origin of Site 'I' is very speculative. Site 'I' could not be associated easily with a till sheet and it is speculated that this feature relates to some form of lag deposits.

Site 'J' covers a large portion of the seafloor between fix marks 3352 and 3482 (Figure 10). At this location, a surficial layer of reworked materials (sand and gravel?) of variable thickness rests atop an old till surface which outcrops on large portions of the seafloor. On the echogram the seabed relief, which is generally flat in this area, is disturbed by ridge-like features, 1-3 m high; these anomalies may be caused by the presence of either moraine crests or ice-shoved ridges. Except for a deep depression centered a fix mark 3455, in which about 10 m of reworked materials may have accumulated, the surface deposit is usually less than one metre thick. This suggests that a large fraction of the reworked sediments was washed away, thus introducing the possibility that the source deposit is a mostly fine-grained till (Bernard Till?).

Site 'K' constitutes the best prospect for borrow materials along Line C-5. The site delimits a bathymetric high that is believed to be real particularly as the ship track is almost a straight line in this sector. The deposit exhibits a thickness of 1-2 m over a distance of about 2 km, and is interpreted as a reworked frontal moraine associated with the offshore extension of the Sachs Till (Unit 12). Acoustic evidence suggests that the deposit includes mostly coarse materials (Figure 11), probably sand with gravel between fix marks 3532 and 3602, with a fining facies change that occurs west of fix mark 3622.

4.8 CAPE KELLETT AREA (Plate III)

The offshore area between Cape Kellett Spit and Blue Fox Harbour was surveyed along four seismic lines (KK1, KK2, KK3 and KK4) which run in different directions in water depths ranging between 13 and 31 m. Regional line C-5 terminates in this area and hence provides a basis for the geological correlations between the Cape Kellett area and the coastal zone to the south.

The quality of the sonographs and 3.5 kHz subbottom profiler records varies from good (Line KK1) to fair (Lines KK2, KK3 and KK4). The field log book indicates that weather conditions were degrading along the course of Lines KK2, KK3 and KK4. The relatively high seas (1-1.5 m) resulted in a notable deterioration in data quality, especially on the boomer records which were collected by means of a catamaran and a hydrophone streamer, both towed near the sea surface. These devices are more sensitive to the sea state than the sub-tow fish of the side scan sonar that also includes the 3.5 kHz pinger. As a result, the boomer records are of poor quality but do provide some useful information regarding the shallow geology and features.

4.8.1 Surficial Geology

A bathymetric map of the Cape Kellett area is shown on Plate III; this map roughly portrays the seabottom relief at a contour interval of one metre. One should note the variable line spacing that has resulted in large zones where the position of the isobaths is approximate. The residual seafloor morphology (smoothed for ice-scouring effect) appears to be controlled by shallow subdued sedimentary features. Of interest among these morphologies is an arcuate ridge-like feature that extends in a roughly northwest direction between Lines KK1, KK2 and KK3. Some other ridge-like features are also apparent in the eastern sector of Line KK4. The paucity of good data and the inadequate seismic coverage do not permit a definite conclusion in regard to the probable geologic origin of these ridges. However, it is thought that these morphologies may result from some submerged coastal features (spits, ice-shoved ridges).

Although the base of a surficial deposit was only sporadically delineated by the 3.5 kHz subbottom profiler (Figure 13) over the length of Lines KK1, KK2, KK3 and KK4 (see cross sections; Plate III), it is believed that this surficial layer blankets most, if not all, of the surveyed area. In some places, the similarity in grain size between the reworked surficial materials and the underlying deposits (Unit 1?), coupled with the reduced penetration of the 3.5 kHz acoustic signal, may prevent detection of a distinct reflector along this boundary. Note that the wide signal of the boomer system and the poor quality of the boomer data have prevented in most areas the resolution of this thin layer. The variable subbottom penetration achieved by the 3.5

kHz signal, if not the result of a changing sea state, may indicate that the surficial layer consists of a variety of lithologies. In addition, the observed subbottom penetration suggests also that the surface deposit is comprised of medium to fine grain sizes (fine sand and silt) in most places (Figure 13). The thickness of the surface deposit is usually between 1 and 4 m but may thicken significantly seaward of the 30 m isobath on Line KK3. The surficial layer is thought to mark the transition between a very shallow water environment and the ensuing post-glacial submergence. These sediments may result from the erosion of the coastal areas by the wave action and transportation by near shore currents.

On the boomer records, the underlying unit displays a chaotic to weakly stratified facies and may exceed 20 m in thickness. This unit may be bounded at its base by an unconformity, however the presence of the water bottom multiple and the poor data quality at this level on the boomer records has made the interpretation of the real acoustic returns very difficult. A number of internal structures visible within this unit (Unit 1?) are characteristic of upward migrating gas fronts. The poorly stratified acoustic facies and the occurrences of migrating gas may be evidence for the non-cohesive nature (fine sand?) of this unit.

Evidence of shallow acoustic permafrost horizons may be present on the boomer records, specially throughout the length of Line KK4 (Plate III). Along this line, a weakly developed, hummocky reflector was tentatively delineated at a subbottom depth ranging between 2 and 20 m. The presence of ice-bearing sediments within Unit 1 (?) would reinforce a possible glaciofluvial origin for these deposits.

4.8.2 Potential for Granular Resources

Based on the available acoustic evidence, the potential for gravel in the surveyed area off Cape Kellett Spit is probably very low because of the presence of a fine- to medium- grained surficial layer that covers the area, and the absence of source deposits (till units) for very coarse materials. If surveying for sand is contemplated in this area, the field investigation should be first undertaken in the zones of coarsest facies which have been delineated on Plate III.

SECTION 5: SUMMARY OF THE BORROW PROSPECTS

This section involves an evaluation of the granular resource potential of Sites "A" to "K" in terms of Prospective Resources (Table 5). This term refers to granular (sand and gravel) resource deposits whose existence is speculated on the basis of indirect evidence (e.g. acoustic data), and/or general geological considerations. The quality of the granular resources is also inferred from seismic evidence, geological considerations, and occasionally from limited ground-truth information. The identification of possible constraints to future development of the prospective granular deposits is based on the limitations dictated by the dredging equipment which is currently used in the Beaufort Sea.

5.1 SITE 'A'

LOCATION: Line 1; fix marks 311 to 381 (Plate I)
Line C-1; fix marks 431 to 461 (Plate I)

MOST PROBABLE GEOLOGIC ORIGIN: Coarse-grained remnants of a submerged terrace (Unit 1).

PROSPECTIVE RESOURCES: Volume estimate: 3 200 000 m^3 (1)

Quality: Reworked sand with some gravel.

CONSTRAINT TO FUTURE DEVELOPMENT: Shallow gas might cause difficulties during geotechnical drilling.

NOTE: (1) Based on the prospective area delineated on Plate I and an average thickness of 2 m.

5.2 SITE 'B'

LOCATION: Line C-2; fix marks 1005 to 1060 (Plate I)

MOST PROBABLE GEOLOGIC ORIGIN: Down-slope deposits along an escarpment(?) between Sachs Till (Unit 12) and low-lying glaciofluvial deposits (Unit 1).

PROSPECTIVE RESOURCES: Minimum volume: 125 000 m^3 (1)

Quality: reworked sand and gravel, frequent erratics.

CONSTRAINTS TO FUTURE DEVELOPMENT: Number of erratics (cobbles and boulders) may increase near seabed toward the Sachs Till outcrop (Unit 12).

NOTE: (1) Based on a 200 m wide sonograph and an average deposit thickness of 0.5 m.

5.3 SITE 'C'

LOCATION: Line C-1; fix marks 1060 to 1153 (Plate I)

MOST PROBABLE GEOLOGIC ORIGIN: Patches of reworked materials covering an old till surface (Sachs Till; Unit 12).

PROSPECTIVE RESOURCES: Volume estimate: undeterminated

Quality: Patches of reworked sand and gravels, and erratics atop a sandy till.

CONSTRAINTS TO FUTURE DEVELOPMENT: Good materials form thin patches of variable sizes and thicknesses. Frequent outcrops of a old till surface (poor sorting, high compaction, possibly ice-bearing). Numerous erratics visible on sonograph. Proximity of the coast.

5.4 SITE 'D'

LOCATION: Line C-4; fix marks 1882 to 1952 (Plate 1)

MOST PROBABLE GEOLOGIC ORIGIN: Reworked materials originating from an old till sheet (Sachs or Bernard Till ?).

PROSPECTIVE RESOURCES: Minimum volume: 500 000 m^3 (1)

Quality: reworked sand and gravel with a fining facies change away of the till outcrop.

CONSTRAINTS TO FUTURE DEVELOPMENT: Erratics (cobbles and boulders) may be common. Outcrop of a till surface (poor sorting, high compaction, possibly ice-bearing). Proximity to the coast.

NOTE: (1) Based on a 200 m wide sonograph and an average thickness of 2 m for the two patches of reworked materials lying on both sides of the till outcrop. The till itself is not taken into account as a prospective resource.

5.5 SITE 'E'

LOCATION: Line C-4; fix marks 2152 to 2265 (Plate II)

MOST PROBABLE GEOLOGIC ORIGIN: Patches of reworked materials (sand and gravel) lying atop a old till sheet (Sachs or Bernard Till ?).

PROSPECTIVE RESOURCES: Volume estimate: undetermined

Quality: reworked sand and gravel that form patches of variable sizes and thicknesses.

CONTRAINTS TO FUTURE DEVELOPMENT: Frequent outcrops of a till surface (poor sorting, high compaction, possibly ice-bearing). Patchy nature of the good granular materials. Possible presence of erratics. Proximity to the coast.

5.6 SITE 'F'

LOCATION: Line C-4; fix marks 2310 to 2460 (Plate II)

MOST PROBABLE GEOLOGIC ORIGIN: Reworked materials that originate from the erosion, reworking and re-distribution of old till deposits (Sachs or Bernard Till?).

PROSPECTIVE RESOURCES: Minimum Volume: 900 000 m^3 (1)

Quality: Reworked sand and gravel with a fining facies change away from the till outcrops.

CONSTRAINTS TO FUTURE DEVELOPMENT: Clayey units (bottom sample GR-9A) that may be included in the till deposits. Outcrops of a till surface (poor sorting, high compaction, possibly ice bearing).

NOTE: (1) Based on a 200 m wide sonograph and an average thickness of 2 m for the patches of reworked materials lying in the site area. The till outcrops are not taken into account as a prospective resource.

5.7 SITE 'G'

LOCATION: Line C-4; fix marks 2660 to 2770 (Plate II)

MOST PROBABLE GEOLOGIC ORIGIN: Reworked materials that originate from the erosion, reworking and re-distribution of old till deposits (Sachs or Bernard Till?).

PROSPECTIVE RESOURCES: Volume estimate: undetermined

Quality: sand and gravel with a fining facies change away from the till outcrops.

CONSTRAINTS TO FUTURE DEVELOPMENT: Occurrence of till outcrops that may include fine-grained units, highly compacted soils and ice-bearing sediments.

5.8 SITE 'H'

LOCATION: Line C-4; fix marks 2960 to 3025 (Plate II)

MOST PROBABLE GEOLOGIC ORIGIN: Reworked materials that originate from the erosion, reworking and re-distribution of old till deposits (Sachs or Bernard Tills?).

PROSPECTIVE RESOURCES: Volume estimate: undetermined (probably marginal).

Quality: sand with some gravel, probable fining facies away from the till outcrop(s).

CONSTRAINTS TO FUTURE DEVELOPMENT: Occurrence of till outcrops that may include fine-grained units, highly compacted soils and ice-bearing sediments. Marginal volume of granular (sand and gravel) resources.

5.9 SITE 'I'

LOCATION: Line C-5; fix marks 3212 to 3242 (Plate II)

MOST PROBABLE GEOLOGIC ORIGIN: Lag deposits (?)

PROSPECTIVE RESOURCES: Volume estimate: undetermined

Quality: reworked sand with some gravel, fining westward facies change.

CONSTRAINTS TO FUTURE DEVELOPMENT: Geologic origin very speculative; stratigraphy of the site not well established. Marginal potential (?).

5.10 SITE 'J'

LOCATION: Line C-5; fix marks 3352 to 3482 (Plate II)

MOST PROBABLE GEOLOGIC ORIGIN: Reworked materials that originate from the reworking of an old till surface (Sachs or Bernard Till?).

PROSPECTIVE RESOURCES: Volume estimate: undetermined

Quality: Probably thin surficial layer of reworked sand with some gravel.

CONSTRAINTS TO FUTURE DEVELOPMENT: Thickness of reworked materials appears to be thin. Source deposit might be a fine-grained till (Bernard Till ?). Original stratigraphy of the site may be disturbed by ice-shoved ridges that produce micro-relief (1-3 m high) on the seafloor. Occurrence of till (fine-grained) outcrops that may include a variety of lithologies, highly compacted soils, and ice-bearing sediments.

5.11 SITE 'K'

LOCATION: Line C-5; fix marks 3532 to 3600 (Plate II)

MOST PROBABLE GEOLOGIC ORIGIN: Reworked frontal moraine associated with the Sachs Till.

PROSPECTIVE RESOURCES: Minimum volume: 525 000 m^3 (1)

Quality: Reworked sand and gravel, gravel fraction probably high.

CONSTRAINTS TO FUTURE DEVELOPMENT: No serious constraints

NOTE: (1) Based on a 200 m wide sonograph and a average deposit thickness of 1.5 m.

SECTION 6: CONCLUSION

This study has produced a series of cross sections and one plan view map which serve to illustrate a description of the surficial geology and stratigraphic conditions present in the nearshore area of the southwestern coast of Banks Island. At present, there exists a paucity of ground-truth information and the seismic data coverage is very sparse in this remote area. To fill these data gaps, there is an obvious need for both additional high-resolution geophysical and geotechnical investigations. Nevertheless, the present analysis of the subsurface stratigraphy and features along this portion of the island coast is a new contribution that permits some preliminary conclusions concerning the granular resource potential of the Banks Island borrow area.

Based on the available acoustic data and a very limited amount of bottom samples, one may conclude that the potential for granular resource deposits is very important in this area. However, the very uneven seafloor relief and/or the complexity of stratigraphic conditions encountered in several places present challenging environmental obstacles to the safe and efficient dredging of these granular resources. With regard to the complex geology, great diversity of source deposits and the poor seismic coverage, an evaluation of the quantities of borrow materials even in terms of prospective resources, is meaningless at this point for this area of Banks Island; however, some preliminary estimates have been provided on a site specific basis.

Given the limitations inherent to the dredging techniques used at the present time and in the foreseeable future, eleven target areas have been identified for more detailed specific studies (Table 5), which may result in the future development of these prospective granular deposits. The most promising sites (Sites 'B', 'C', and 'K') appear to be offshore extensions of the Sachs Till and the associated morainic system. These relatively old deposits may have been reworked at several times in the past, which would have resulted in good sorting and flat relief. Similarly, Site 'A' is believed to be of a good potential because this deposit may have been subject to several cycles of reworking during Quaternary Time.

The portion of the coast between Middle Lake and Mary Sachs Creek is designated for future regional projects. The potential for gravel resources in the vicinity of the Duck Hawk Bluffs (east of Mary Sachs Creek) and in the Cape Kellett Spit area appears to be marginal due to the absence of submerged source deposits, despite the presence of pre-glacial Beaufort Formation sand and gravel in the adjacent Bluffs.

Although gravel resources are likely associated with the off-shore extension of the Carpenter Till, this deposit has a low potential as a result of its high seabed relief, its "young" appearance (little reworking), and the occurrence of numerous erratics on top of the till sheet.

TABLE 5. SUMMARY TABLE OF BORROW PROSPECTS

SITE	PRIORITY	PROGNOSTIC	RECOMMENDED FUTURE STUDIES ① SAMPLE	GEOPHYSICS	MOSAIC	PHOTO	DRILL
"A"	HIGH	-Large volume of well sorted materials. -Reworked sand with some (pea-size) gravel.	(1)	(2)	--	--	(3)
"B"	HIGH	-Fair volume of patchy materials (sand & gravel). -Till (Sachs ?) outcrops. Erratics.	(1)	(2)	(3)	(4)	(5)
"C"	FAIR	-Small volume of thin patches of reworked materials (sand & gravel) atop a till (Sachs ?) surface. -Frequent erratics.	(1)	(2)	(3)	(4)	(5)
"D"	LOW	-Irregular seafloor. -Westward fining facies change.	(1)	(2)	(3)	(4)	(5)
"E"	FAIR	-Patches of reworked sand with some fine gravel. -Frequent outcrops of a fine-grained till (Sachs or Bernard ?)	(1)	(2)	(3)	--	(4)
"F"	FAIR	-Patches of reworked sand with some fine gravel. -Frequent outcrops of a clayey till (Bernard ?).	(1)	(2)	(3)	--	(4)
"G"	LOW	-Thin veneer of reworked sand with some fine gravel. -Fining facies change away from the source deposit (fine-grained till ?).	(1)	(2)	(3)	--	(4)
"H"	LOW	-Thin veneer of reworked sand with some gravel. -Marginal volume of borrow materials.	(1)	(2)	(3)	--	(4)
"I"	LOW	-Marginal volume of reworked sand with some gravel. -Origin of the deposit very speculative (lag deposit ?, submerged coastal feature ?).	(1)	(2)	--	--	(3)
"J"	FAIR	-Thin veneer of reworked sand with some gravel. -Frequent outcrops of a fine-grained till (Sachs or Bernard ?).	(1)	(2)	(3)	--	(4)
"K"	HIGH	-Reworked sand and gravel. -Large volume of borrow materials.	(1)	(2)	--	--	(3)

NOTE: ①The recommended future studies should not be conducted simultaneously, but in the order shown. One should proceed with the next step only if the results of the previous step(s) dictates additional works.

SAMPLE: Seabed sampling (grab and drag samplers, gravity corers).
GEOPHYSICS: Detailed geophysical program including: precision bathymetry, side scan sonar, subbottom profiler, Uniboom, deep-tow refraction data.
MOSAIC: Construction of a seafloor mosaic from side scanning imagery.
PHOTO: Seabed photographs and/or video, diving.
DRILL: Shallow geotechnical drilling.

SECTION 7: RECOMMENDATIONS

One of the most severe constraints to future development of the granular deposits in this area is the very irregular seafloor relief, which constitutes a serious hazard for the safe navigation of the dredges. A typical hydrographic survey using a shipborne echo sounder would require very closely-spaced survey lines in order to map all the seafloor highs (till crests), which sometimes culminate at depths shallower than 10 m. Hence, the airborne LARSEN 500 laser system, recently developed by Terra Surveys Ltd of Ottawa, may represent a cost-effective alternative to the conventional hydrographic surveys in areas where the bathymetry is very irregular.

If a site specific study is contemplated for any of the target areas identified in this report, it is recommended that the first phase of the follow-up includes a bottom sampling program by means of low-cost devices (grab and drag samplers, piston corers), in order to first confirm the presence of granular materials in these sites.

As a second step, it is recommended that a detailed geophysical program, including echo sounder, side scan sonar, subbottom profiler and boomer systems, be undertaken to more accurately delimit the borrow prospects. In most places, the resource evaluation and the production dredging would benefit greatly from a full seabottom coverage by side scan sonar imagery and the subsequent construction of a seafloor mosaic. In addition, valuable velocity and stratigraphic information can be gained by using the 12-channel, deep-tow refraction eel (Good et al., 1984; and Fortin et al., 1987) in conjunction with the high-resolution reflection methods. This innovative high-resolution refraction eel performed very well in obtaining compressional wave velocities associated with seabed materials and shallow subbottom horizons in the Isserk borrow area (Fortin 1986).

Following the geophysical program, it is recommended that geotechnical boreholes be positioned at critical locations in order to determine the quality and exact thickness of the granular deposits.

Respectfully submitted;

H.R. SEISMIC INTERPRETATION SERVICES INC.

G. Fortin, M.Sc.

GF/ml

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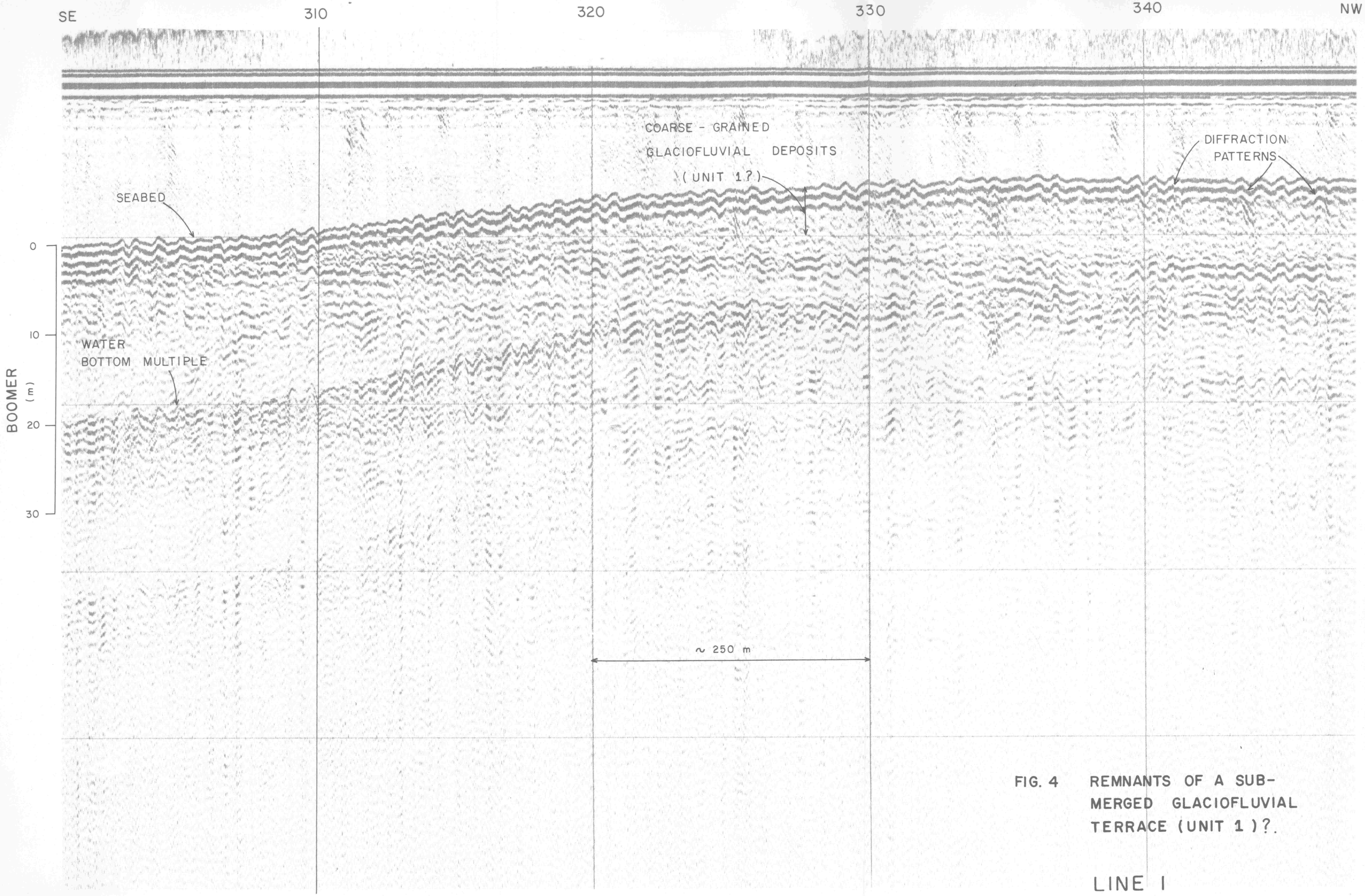


FIG. 4 REMNANTS OF A SUBMERGED GLACIOFLUVIAL TERRACE (UNIT 1)?.

LINE I

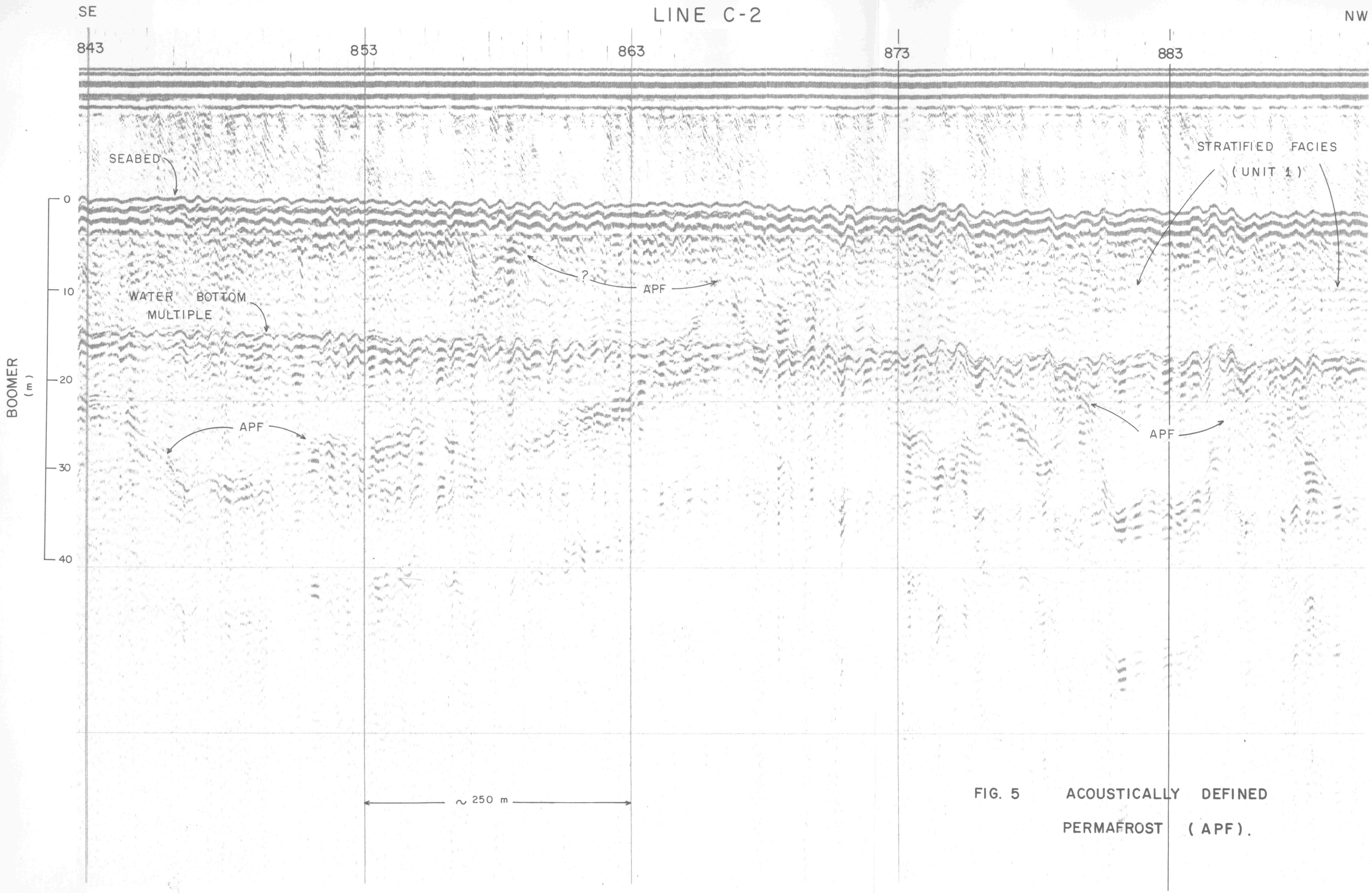


FIG. 5 ACOUSTICALLY DEFINED PERMAFROST (APF).

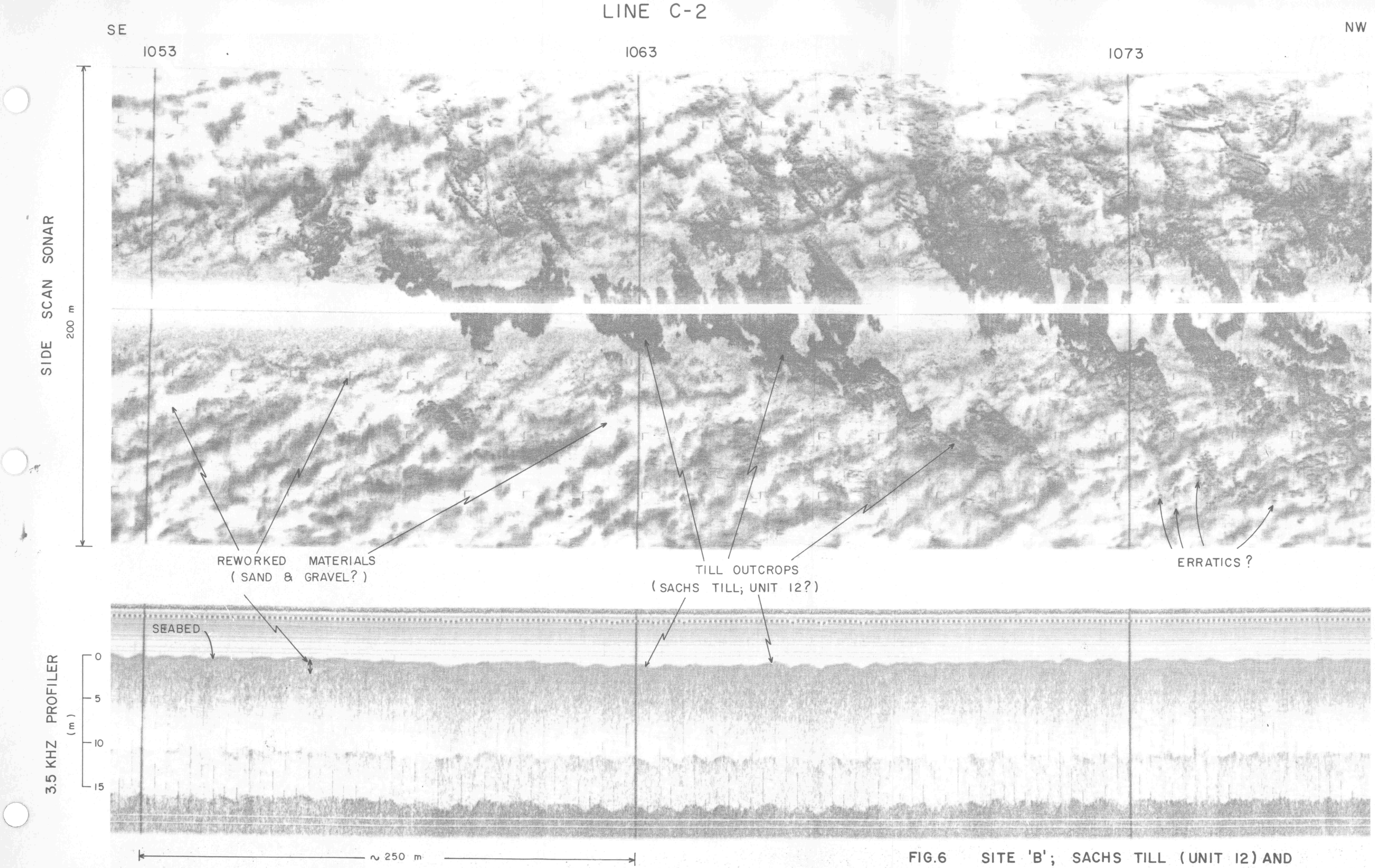


FIG.6 SITE 'B'; SACHS TILL (UNIT 12) AND REWORKED MATERIALS.

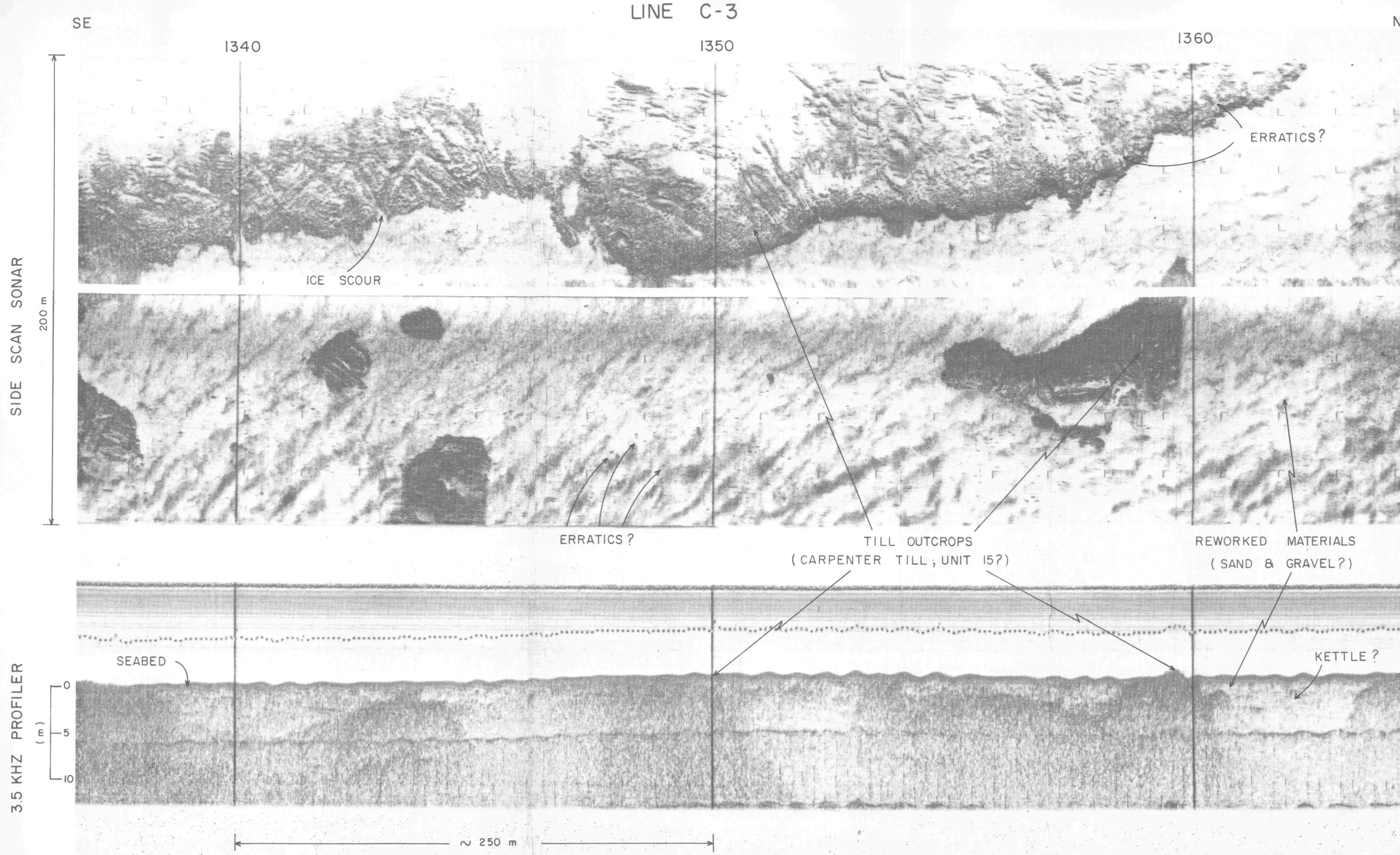


FIG.7 CARPENTER TILL (UNIT 15) AND REWORKED MATERIALS.

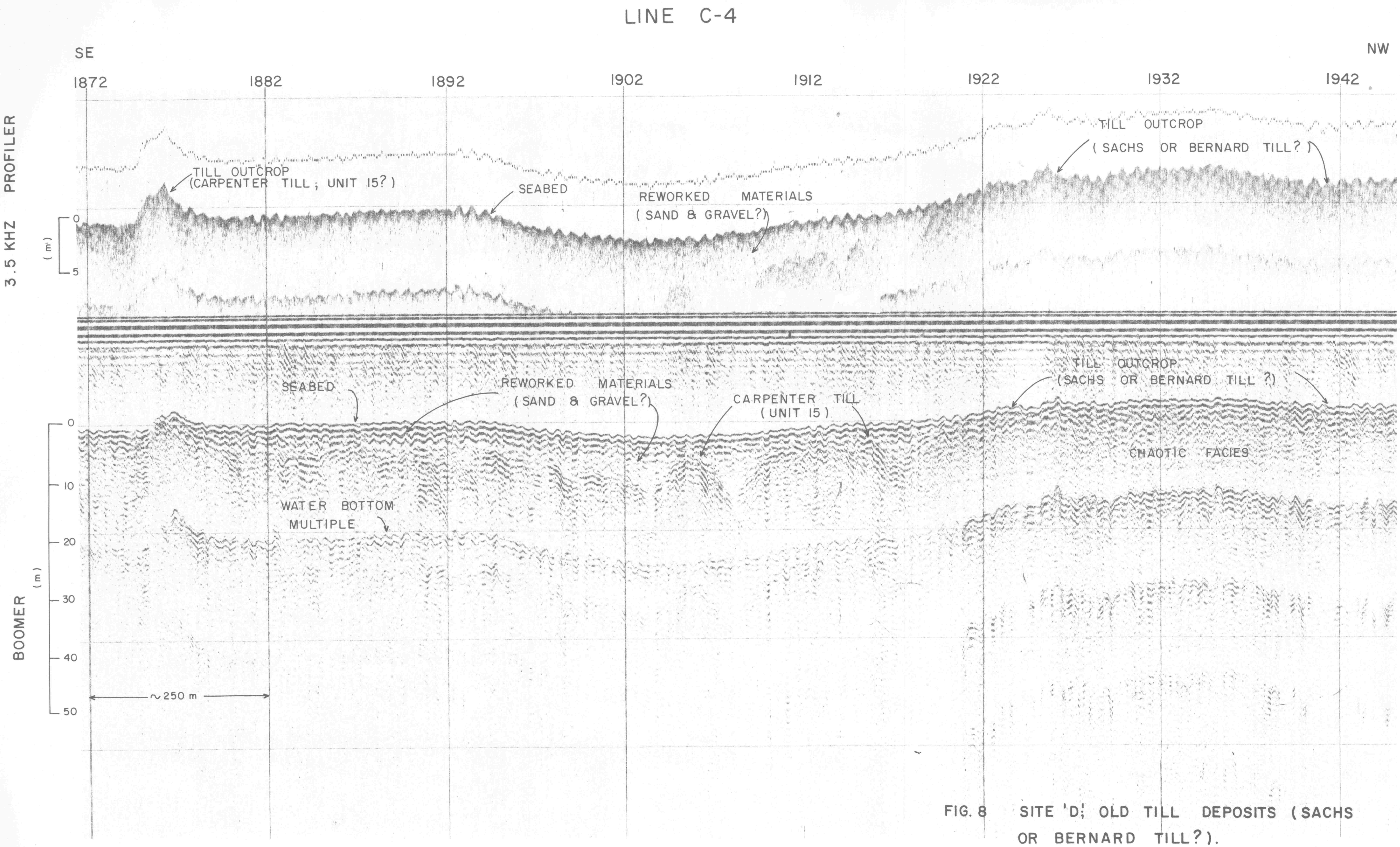


FIG. 8 SITE 'D'; OLD TILL DEPOSITS (SACHS OR BERNARD TILL?).

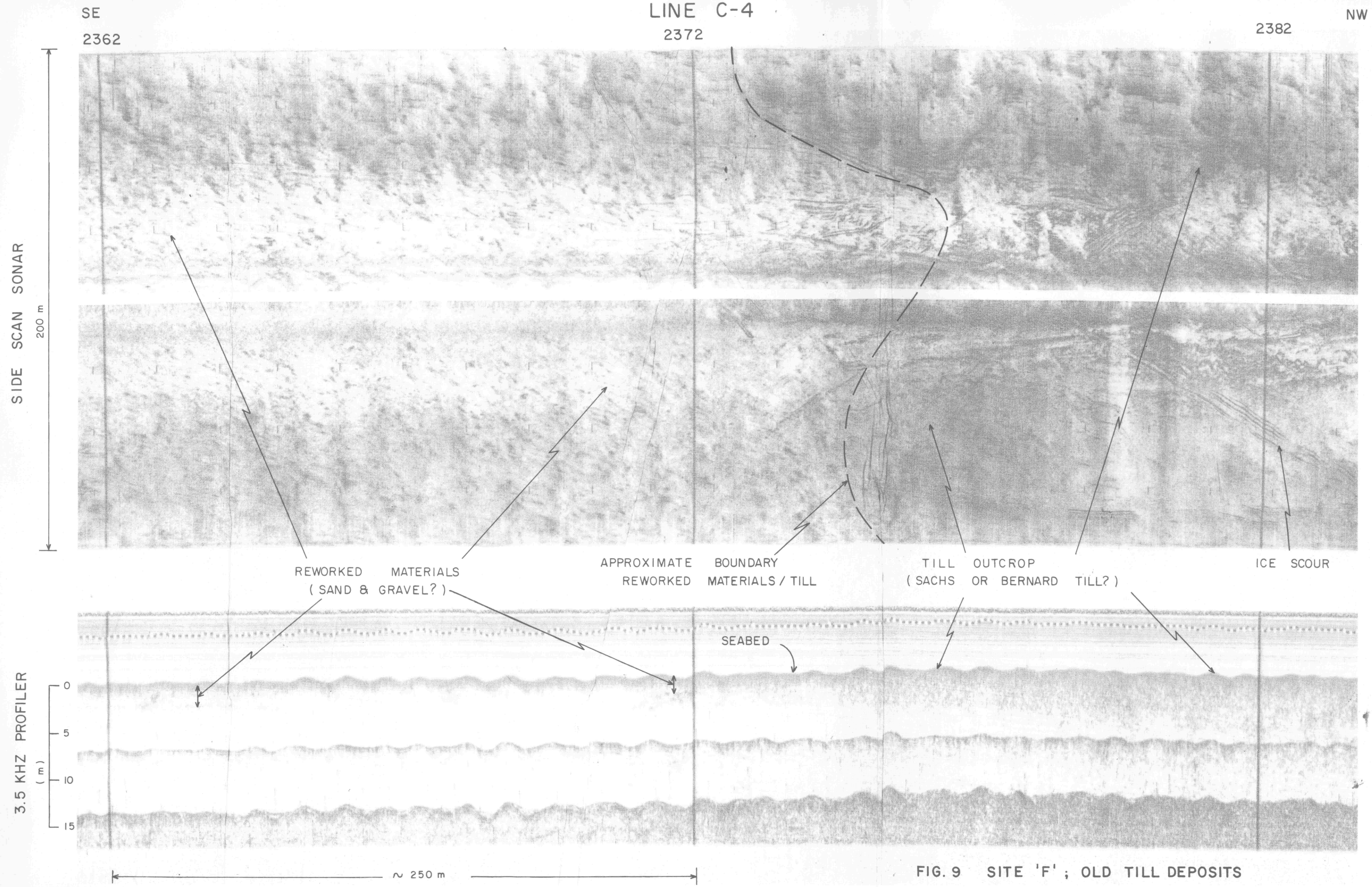


FIG. 9 SITE 'F' ; OLD TILL DEPOSITS
(SACHS OR BERNARD TILL ?)

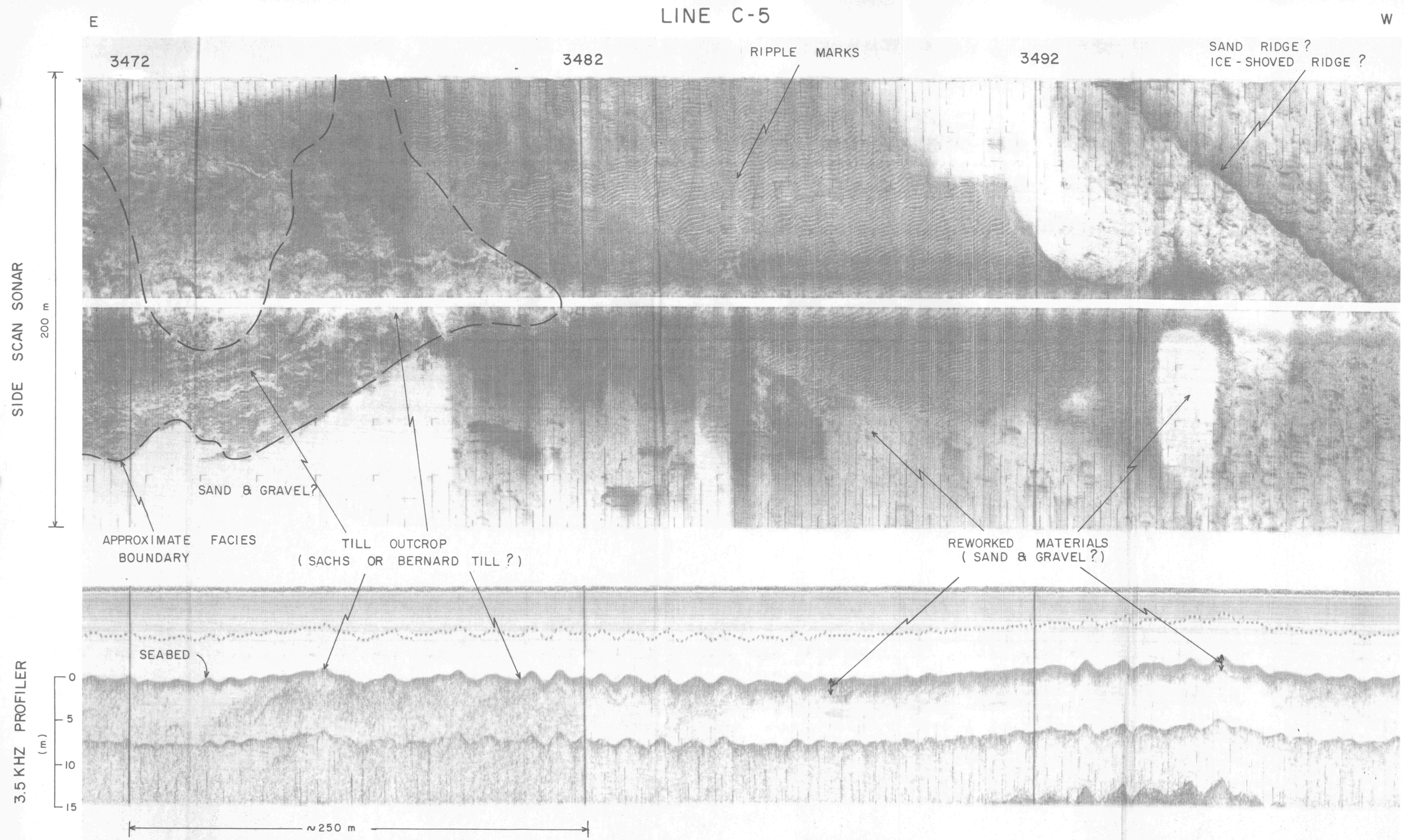


FIG. 10 SITE 'J'; OLD TILL DEPOSITS (SACHS OR BERNARD TILL?).

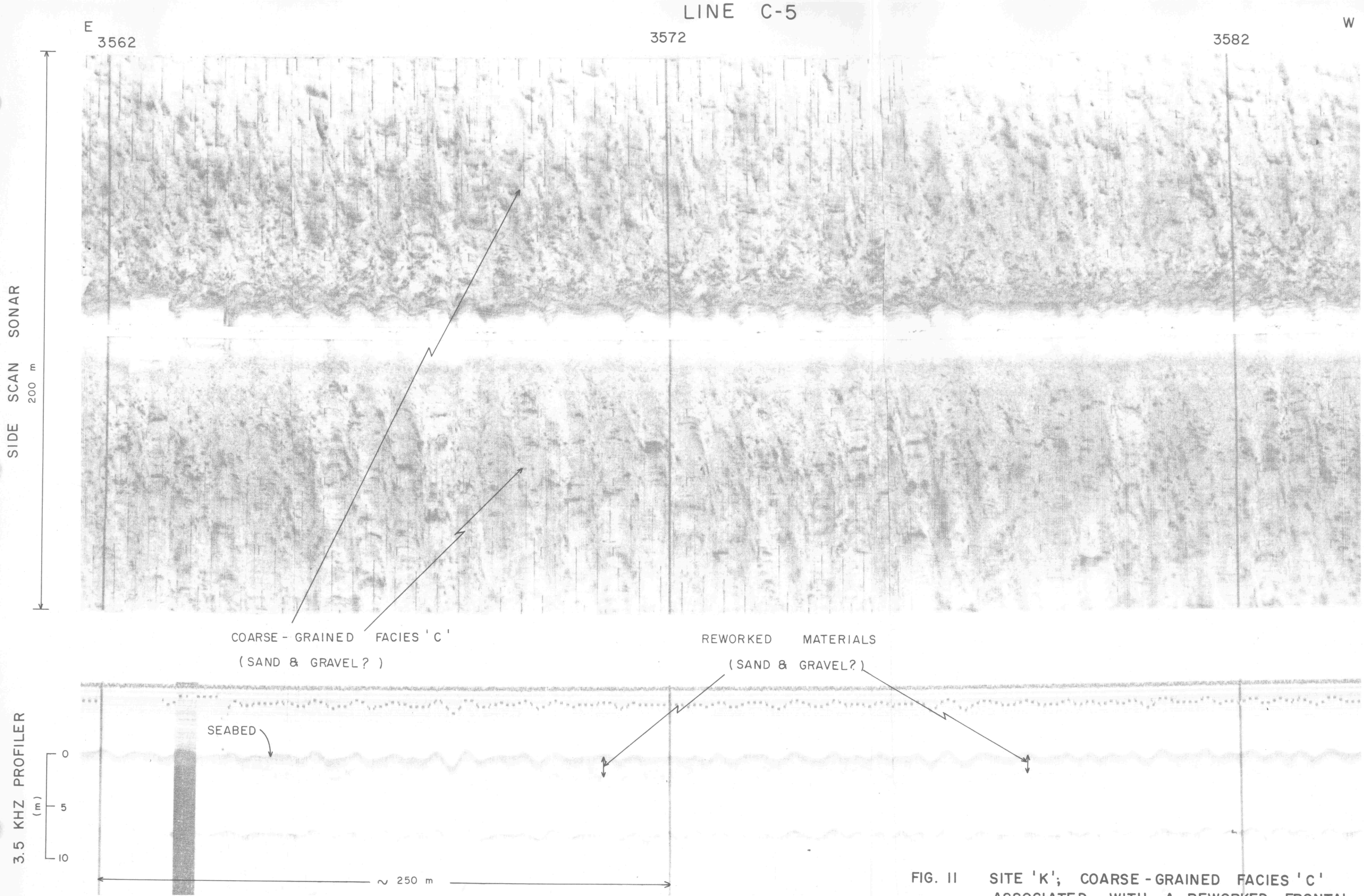


FIG. 11 SITE 'K'; COARSE-GRAINED FACIES 'C' ASSOCIATED WITH A REWORKED FRONTAL MORAINE.

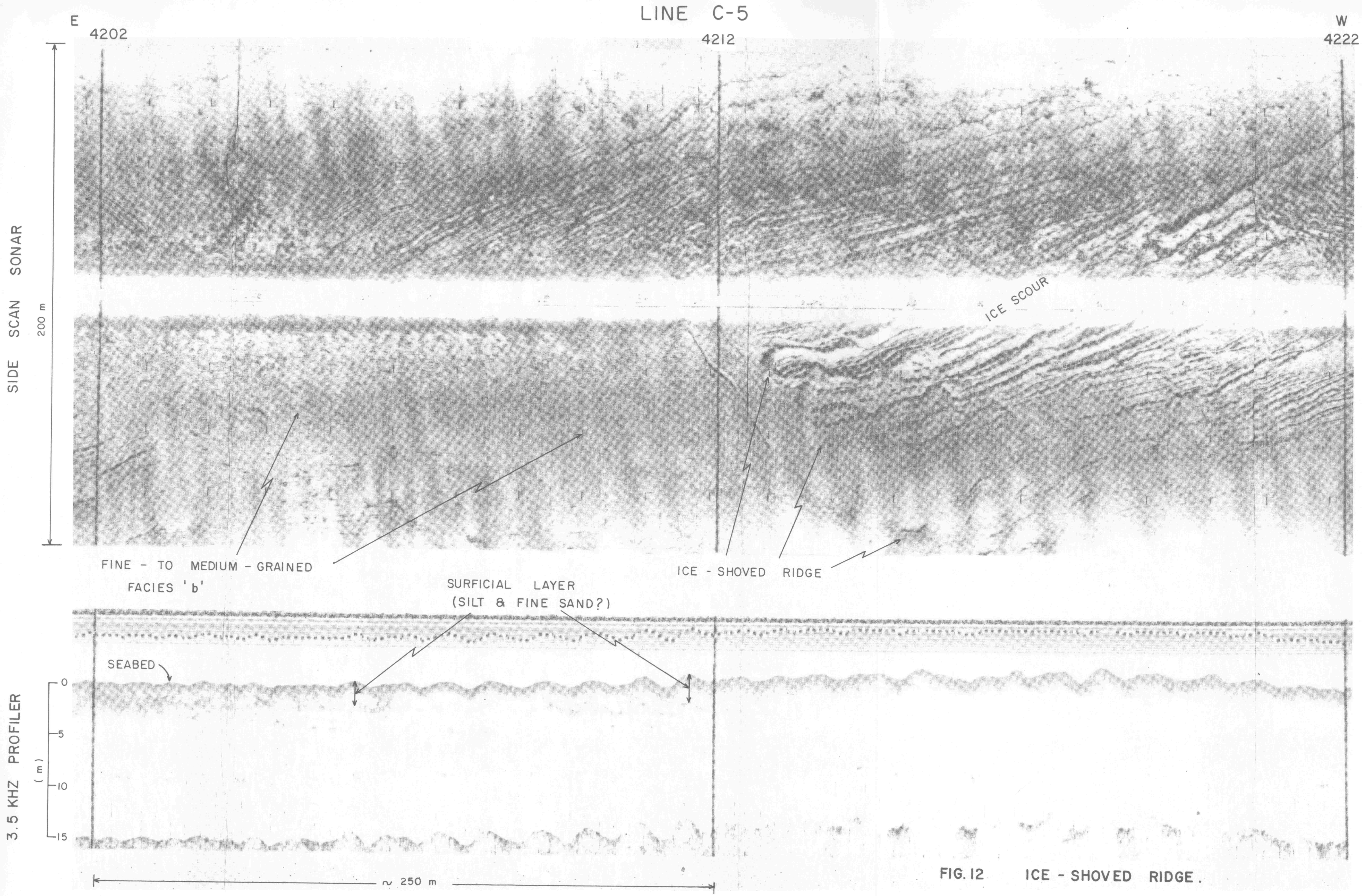


FIG. 12 ICE - SHOVED RIDGE.

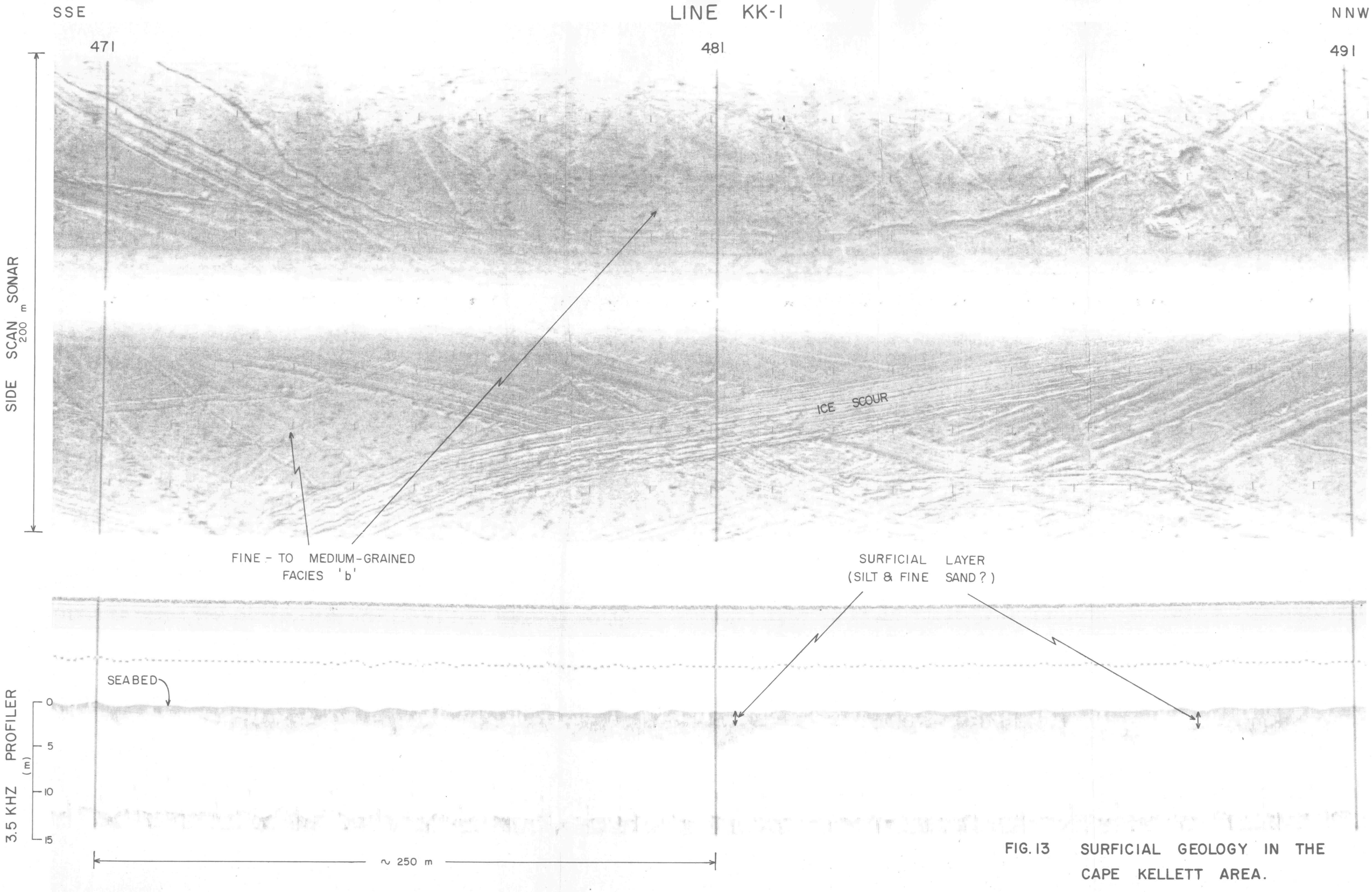
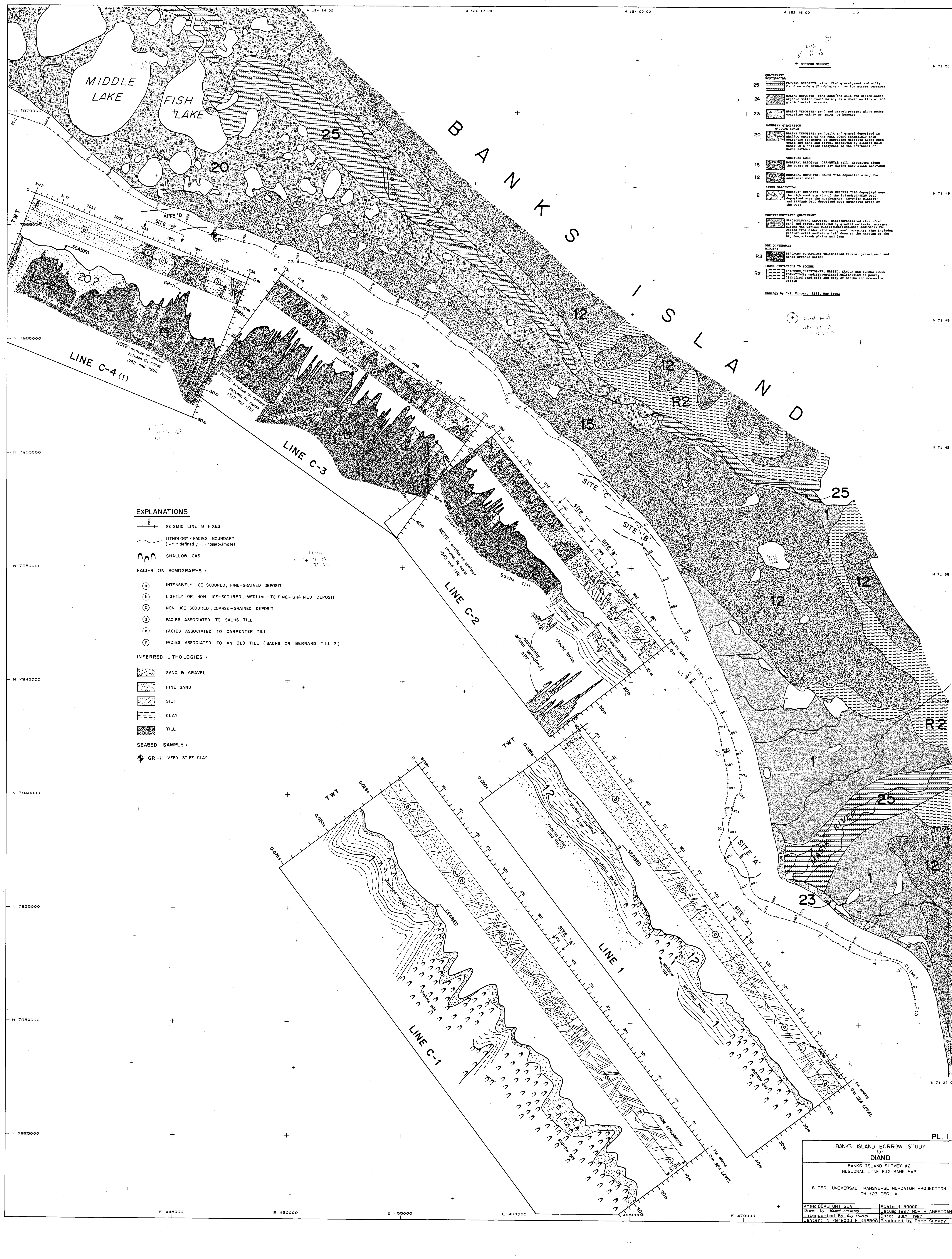
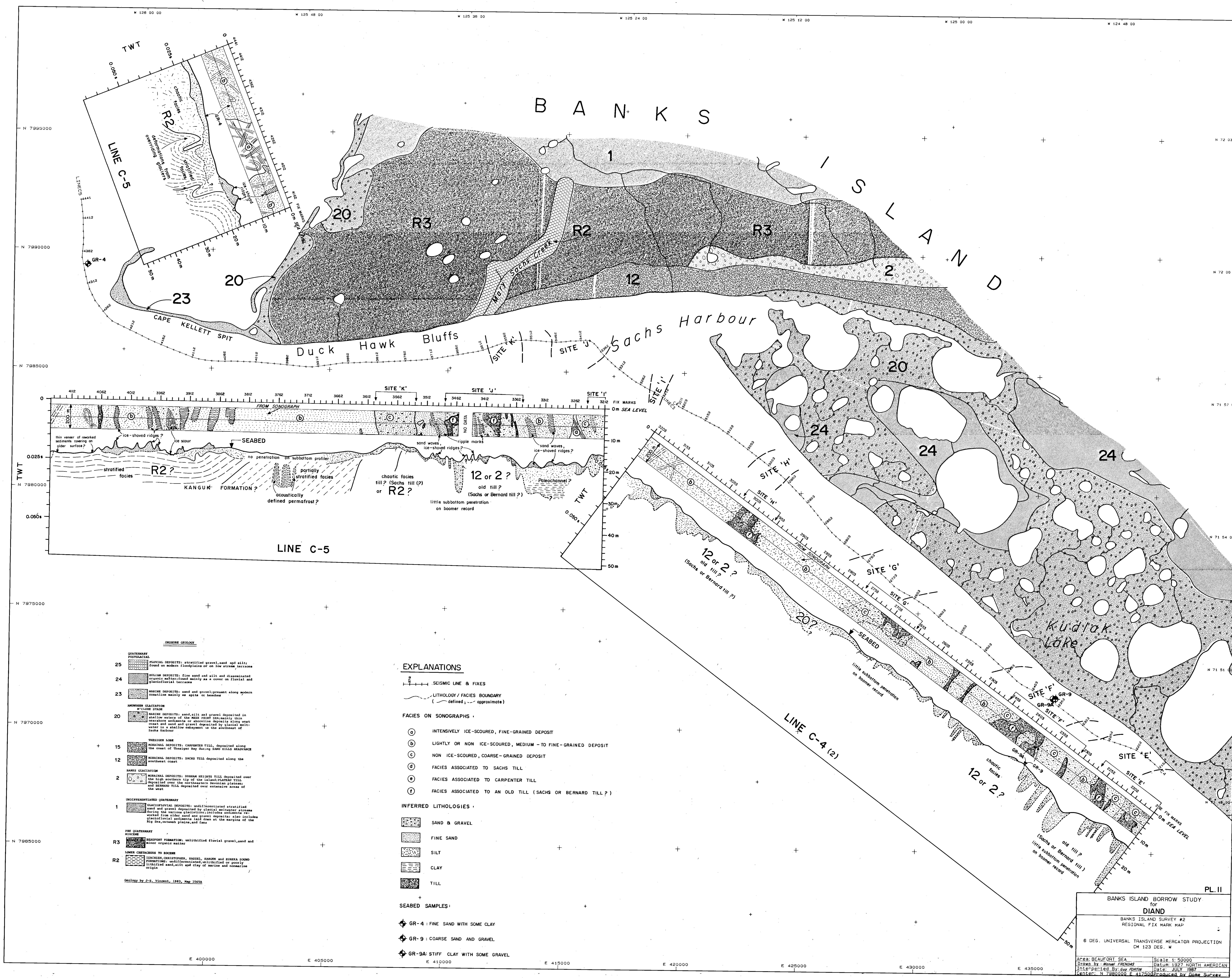


FIG. 13 SURFICIAL GEOLOGY IN THE CAPE KELLETT AREA.



BANKS ISLAND
MIDDLE LAKE
FISH LAKE
Sachs River
MASIK RIVER
ONSHORE GEOLOGY
QUATERNARY
POSTGLACIAL
25 FLUVIAL DEPOSITS: stratified gravel, sand and silt; found on modern floodplains or on low stream terraces
24 EOLIAN DEPOSITS: fine sand and silt and disseminated organic matter; found mainly as a cover on fluvial and glaciofluvial terraces
23 MARINE DEPOSITS: sand and gravel; present along modern coastline mainly as spits or beaches
AMUNDSEN GLACIATION
M'CLURE STADE
20 MARINE DEPOSITS: sand, silt and gravel deposited in shallow waters of the MEEK POINT SEA; mainly thin nearshore sediments or shoreline deposits along west coast and sand and gravel deposited by glacial meltwater in a shallow embayment to the southeast of Sachs Harbour
THESIGER LOBE
15 MORAINAL DEPOSITS: CARPENTER TILL, deposited along the coast of Thesiger Bay during SAND HILLS READVANCE
12 MORAINAL DEPOSITS: SACHS TILL deposited along the southwest coast
BANKS GLACIATION
2 MORAINAL DEPOSITS: DURHAM HEIGHTS TILL deposited over the high southern tip of the island; PLATEAU TILL deposited over the northeastern Devonian plateau; and BERNARD TILL deposited over extensive areas of the west
UNDIFFERENTIATED QUATERNARY
1 GLACIOFLUVIAL DEPOSITS: undifferentiated stratified sand and gravel deposited by glacial meltwater streams during the various glaciations; includes sediments reworked from older sand and gravel deposits; also includes glaciofluvial sediments laid down at the margins of the Big Sea, outwash plains, and fans
PRE QUATERNARY
MIOCENE
R3 BEAUFORT FORMATION: unlithified fluvial gravel, sand and minor organic matter
LOWER CRETACEOUS TO EOCENE
R2 ISACHSEN, CHRISTOPHER, HASSEL, KANGUK and EUREKA SOUND FORMATIONS: undifferentiated, unlithified or poorly lithified sand, silt and clay of marine and nonmarine origin
Geology by J-S. Vincent, 1983, Map 1565A
EXPLANATIONS
SEISMIC LINE & FIXES
LITHOLOGY / FACIES BOUNDARY (defined ; approximate)
SHALLOW GAS
FACIES ON SONOGRAPHS :
a INTENSIVELY ICE-SCOURED, FINE-GRAINED DEPOSIT
b LIGHTLY OR NON ICE-SCOURED, MEDIUM - TO FINE-GRAINED DEPOSIT
c NON ICE-SCOURED, COARSE-GRAINED DEPOSIT
d FACIES ASSOCIATED TO SACHS TILL
e FACIES ASSOCIATED TO CARPENTER TILL
f FACIES ASSOCIATED TO AN OLD TILL (SACHS OR BERNARD TILL ?)
INFERRED LITHOLOGIES :
SAND & GRAVEL
FINE SAND
SILT
CLAY
TILL
SEABED SAMPLE :
GR-11 : VERY STIFF CLAY
LINE C-4 (1)
LINE C-3
LINE C-2
LINE C-1
LINE 1
SITE 'A'
SITE 'B'
SITE 'C'
SITE 'D'
SEABED
TWT
FROM SONOGRAPH
0m SEA LEVEL
PL. I
BANKS ISLAND BORROW STUDY
for
DIAND
BANKS ISLAND SURVEY #2
REGIONAL LINE FIX MARK MAP
6 DEG. UNIVERSAL TRANSVERSE MERCATOR PROJECTION
CM 123 DEG. W
Area: BEAUFORT SEA
Scale 1: 50000
Drawn by: Manuel FRENDAS
Datum: 1927 NORTH AMERICAN
Interperted By: Guy FORTIN
Date: JULY 1987
Center: N 7948000 E 458500
Produced by Dome Survey

2


BANKS ISLAND
Sachs Harbour
Duck Hawk Bluffs
CAPE KELLETT SPIT
Mary Sachs Creek
Kudlak Lake
LINE C-5
LINE C-4 (2)
SITE 'K'
SITE 'J'
SITE 'I'
SITE 'H'
SITE 'G'
SITE 'F'
SITE 'E'
FROM SONOGRAPH
SEABED
0m SEA LEVEL
FIX MARKS
TWT
chaotic facies
stratified facies
KANGUK FORMATION ?
acoustically defined permafrost ?
partially stratified facies
no penetration on subbottom profiler
12 or 2 ?
old till ?
(Sachs or Bernard till ?)
little subbottom penetration on boomer record
Paleochannel ?
thin veneer of reworked sediments covering an older surface ?
ice-shoved ridges ?
ice scour
sand waves, ice-shoved ridges ?
ripple marks
NO DATA
deformation from overriding glaciers
ONSHORE GEOLOGY
QUATERNARY
POSTGLACIAL
25 FLUVIAL DEPOSITS: stratified gravel, sand and silt; found on modern floodplains or on low stream terraces
24 EOLIAN DEPOSITS: fine sand and silt and disseminated organic matter; found mainly as a cover on fluvial and glaciofluvial terraces
23 MARINE DEPOSITS: sand and gravel; present along modern coastline mainly as spits or beaches
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M'CLURE STADE
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MIOCENE
R3 BEAUFORT FORMATION: unlithified fluvial gravel, sand and minor organic matter
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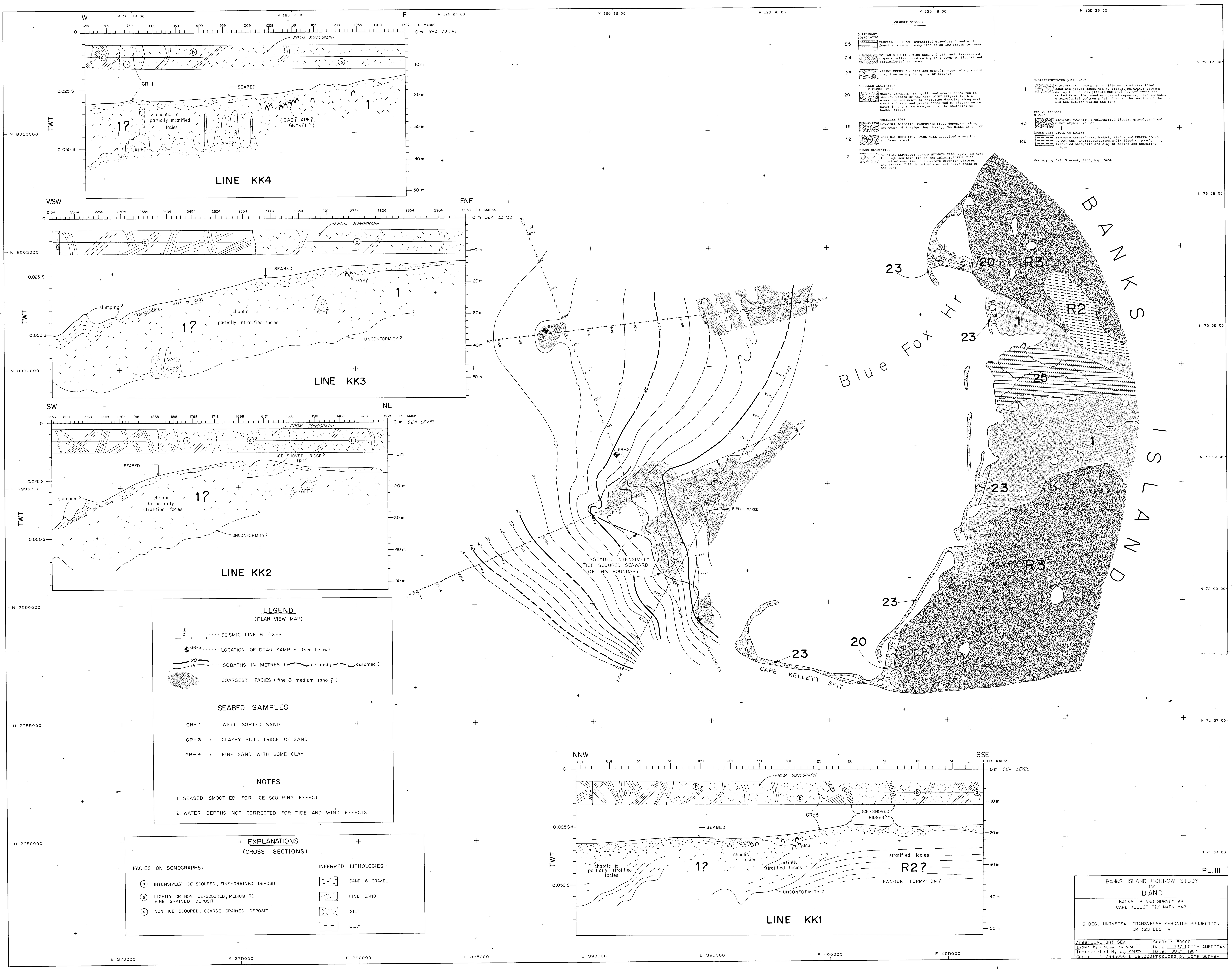
R2 ISACHSEN, CHRISTOPHER, HASSEL, KANGUK and EUREKA SOUND FORMATIONS: undifferentiated, unlithified or poorly lithified sand, silt and clay of marine and nonmarine origin
Geology by J-S. Vincent, 1983, Map 1565A
EXPLANATIONS
SEISMIC LINE & FIXES
LITHOLOGY / FACIES BOUNDARY (defined; approximate)
FACIES ON SONOGRAPHS :
(a) INTENSIVELY ICE-SCOURED, FINE-GRAINED DEPOSIT
(b) LIGHTLY OR NON ICE-SCOURED, MEDIUM - TO FINE-GRAINED DEPOSIT
(c) NON ICE-SCOURED, COARSE-GRAINED DEPOSIT
(d) FACIES ASSOCIATED TO SACHS TILL
(e) FACIES ASSOCIATED TO CARPENTER TILL
(f) FACIES ASSOCIATED TO AN OLD TILL (SACHS OR BERNARD TILL ?)
INFERRED LITHOLOGIES :
SAND & GRAVEL
FINE SAND
SILT
CLAY
TILL
SEABED SAMPLES :
GR-4 : FINE SAND WITH SOME CLAY
GR-9 : COARSE SAND AND GRAVEL
GR-9A: STIFF CLAY WITH SOME GRAVEL
PL. II
BANKS ISLAND BORROW STUDY
for
DIAND
BANKS ISLAND SURVEY #2
REGIONAL FIX MARK MAP
6 DEG. UNIVERSAL TRANSVERSE MERCATOR PROJECTION
CM 123 DEG. W
Area: BEAUFORT SEA
Scale 1: 50000
Drawn by : Manuel FRENDAS
Datum: 1927 NORTH AMERICAN
Interperted By: Guy FORTIN
Date: JULY 1987
Center: N 7980000 E 417500
Produced by Dome Survey



ONSHORE GEOLOGY
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AMUNDSEN GLACIATION
M'CLURE STADE
20 MARINE DEPOSITS: sand, silt and gravel deposited in shallow waters of the MEEK POINT SEA; mainly thin nearshore sediments or shoreline deposits along west coast and sand and gravel deposited by glacial meltwater in a shallow embayment to the southeast of Sachs Harbour
THESIGER LOBE
15 MORAINAL DEPOSITS: CARPENTER TILL, deposited along the coast of Thesiger Bay during SAND HILLS READVANCE
12 MORAINAL DEPOSITS: SACHS TILL deposited along the southwest coast
BANKS GLACIATION
2 MORAINAL DEPOSITS: DURHAM HEIGHTS TILL deposited over the high southern tip of the island; PLATEAU TILL deposited over the northeastern Devonian plateau; and BERNARD TILL deposited over extensive areas of the west
UNDIFFERENTIATED QUATERNARY
1 GLACIOFLUVIAL DEPOSITS: undifferentiated stratified sand and gravel deposited by glacial meltwater streams during the various glaciations; includes sediments reworked from older sand and gravel deposits; also includes glaciofluvial sediments laid down at the margins of the Big Sea, outwash plains, and fans
PRE QUATERNARY
MIOCENE
R3 BEAUFORT FORMATION: unlithified fluvial gravel, sand and minor organic matter
LOWER CRETACEOUS TO EOCENE
R2 ISACHSEN, CHRISTOPHER, HASSEL, KANGUK and EUREKA SOUND FORMATIONS: undifferentiated, unlithified or poorly lithified sand, silt and clay of marine and nonmarine origin
Geology by J-S. Vincent, 1983, Map 1565A
BANKS ISLAND
Blue Fox Hr
CAPE KELLETT
CAPE KELLETT SPIT
SEABED INTENSIVELY ICE-SCOURED SEAWARD OF THIS BOUNDARY
RIPPLE MARKS
LINE KK4
LINE KK3
LINE KK2
LINE KK1
FROM SONOGRAPH
SEABED
GAS?, APF?, GRAVEL?
chaotic to partially stratified facies
slumping?
remoulded silt & clay
UNCONFORMITY?
ICE-SHOVED RIDGE? spit?
ICE-SHOVED RIDGES?
KANGUK FORMATION?
LEGEND
(PLAN VIEW MAP)
SEISMIC LINE & FIXES
LOCATION OF DRAG SAMPLE (see below)
ISOBATHS IN METRES (defined; assumed)
COARSEST FACIES (fine & medium sand ?)
SEABED SAMPLES
GR-1 · WELL SORTED SAND
GR-3 · CLAYEY SILT, TRACE OF SAND
GR-4 · FINE SAND WITH SOME CLAY
NOTES
1. SEABED SMOOTHED FOR ICE SCOURING EFFECT
2. WATER DEPTHS NOT CORRECTED FOR TIDE AND WIND EFFECTS
EXPLANATIONS
(CROSS SECTIONS)
FACIES ON SONOGRAPHS:
a INTENSIVELY ICE-SCOURED, FINE-GRAINED DEPOSIT
b LIGHTLY OR NON ICE-SCOURED, MEDIUM-TO FINE GRAINED DEPOSIT
c NON ICE-SCOURED, COARSE-GRAINED DEPOSIT
INFERRED LITHOLOGIES:
SAND & GRAVEL
FINE SAND
SILT
CLAY
PL.III
BANKS ISLAND BORROW STUDY
for
DIAND
BANKS ISLAND SURVEY #2
CAPE KELLET FIX MARK MAP
6 DEG. UNIVERSAL TRANSVERSE MERCATOR PROJECTION
CM 123 DEG. W
Area: BEAUFORT SEA
Scale 1: 50000
Drawn by: Manuel FRENDAS
Datum: 1927 NORTH AMERICAN
Interperted By: Guy FORTIN
Date: JULY 1987
Center: N 7995000 E 391000
Produced by Dome Survey