The Analysis of High Resolution Shallow Seismic Reflection Data From Sable Island Bank

by

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ABSTRACT

This project involves the analysis of high resolution shallow seismic reflection profiles collected on the south flank of Sable Island Bank. The objective of this study is to gain an understanding of the genesis and sediment distribution of Sable Island Bank during late Quaternary times.

Six units were identified using the three seismic records. The units are labelled A to F where A is the lowermost unit and F is the uppermost unit. The two lowermost units are present over the whole survey area and are probably glacial in origin however more data are required to verify this. Unit B doesn't contain any internal reflectors but lens-shaped internal reflectors are present in unit A near the shelf edge. These features are interpreted as shelf edge deltas associated with the influx of sediment during the Wisconsinan glaciation.

Unit C is composed of sand and gravel and is present from the northern portion of the survey to the shelf edge. It has horizontal, wavy, inclined and crescentic internal reflectors and it's contact with unit B below is unconformable. Unit C is interpreted as an outwash plain deposit which formed when the Wisconsinan ice sheet retreated approximately 16,000 y B.P.

Unit D is present south of the shelf edge and has horizontal and x or v-shaped internal reflectors. Unit D is interpreted as having been deposited in a marine environment which was sheltered by the remnant

Wisconsinan ice. Although the lithology of Unit D can not be determined from the borehole data, interpretation of this acoustic unit suggests that it is fine-grained and derived from the glacial outwash plain. This marine environment transgressed the outwash plain environment as sea level was rising during this time.

Unit E is present only in the northern portion of the survey and is composed of fine sand with the occasional occurrence of silty layers and medium and coarse sand layers. The lower contact of unit E is planar and conformable whereas it's upper contact is unconformable. Unit E is interpreted as an extensive dune system which was later submerged by the rising sea level. Unit E is composed of the reworked sediments of units C and D.

Unit F is exposed on the seafloor and is present from the northern portion of the survey to the shelf edge. It has inclined internal reflectors and it's lower contact is unconformable. The isopach map for this unit indicates that unit F is associated with the shoreface - connected ridges found in the northwestern section of the survey. Unit F is probably derived from ridge migration and represents a transgressional event which reworked the sediments of units C, D and E.

CHAPTER I

Introduction

1.1 General Morphology of the Scotian Shelf

The Scotian Shelf is made up of three distinct zones which run almost parallel to the coastline of Nova Scotia. The first zone which is adjacent to the coastline has a rough topography and is mainly Paleozoic bedrock overlain by a thin layer of Quaternary deposits. The middle zone is characterized by its irregular relief where it alternates between basins and shallow banks. This zone contains several large basins such as the Emerald Basin and the LeHave Basin. The outer zone is broad and flat and contains a series of banks, two of which are Sable Island Bank and Banquereau. The outer portion of the shelf is dissected by a large submarine canyon called The Gully, which separates Sable Island Bank from Banquereau (Terasmae and Mott, 1969). Using Figure 1, the three zones can be distinguished by noting the bathymetry off the coast of Nova Scotia.

1.2 Sable Island and Sable Island Bank

Sable Island Bank trends in an easterly direction and covers an area of 17,000 square kilometers. Sable Island Bank contains Sable Island, which represents the only emergent point on the outer banks of the Scotian Shelf. The outer banks of the Scotian Shelf are built on a basement of seaward - dipping Mesozoic and Cenozoic coastal plain deposits. Therefore most of the basic framework for the Scotian Shelf was formed before the Quaternary while the present surface distribution is a result of depositional and erosional events occurring during the Quaternary Geophysical investigations determined the basic geologic column for material below Sable Island. It was found that the uppermost section contains 300 to 400 metres of unconsolidated Quaternary sediments (Berger et al., 1965).

Sable Island is a narrow, arcuate sand body which is located approximately 290 km southeast of Halifax at a latitude of 44°N and a longitude of 60°W. It varies between 34 and 39 km in length and its width is less than 1.5 km. Presently, the island is made up of parallel dune ridges extending 28 km along the length of the island. These features are stabilized by the vegetation and humus layers. The humus layers average 25 cm in thickness and underlie the ridges. At the east and west sides of the island there are unstable bars which continually change shape and exposed length (Cameron, 1965).

1.3 Wisconsinan Glaciation

Preliminary investigations had found evidence to support glacial activity on the Scotian Shelf. Southeasterly oriented ice flow features such as glacial striations, drumlins, eskers and terminal moraines are present across Maine, Southern Nova Scotia, New Brunswick and the Scotian Shelf (Prest & Grant, 1969). It has also been determined that the sediments found on Sable Island and Sable Island Bank are derived from various areas on the Nova Scotia mainland (James and Stanley, 1968). These features developed during Wisconsinan Glaciation (Grant, 1981).

Wisconsinan Glaciation involved the advance and the later retreat of the Laurentide ice sheet and the local ice cap of the Appalachian region. Dreimanis (1975) was able to divide this period of glaciation into three major stages. The Early Wisconsinan time was calculated to be between 120,000 and 65,000 years before present. However there is evidence that a warm interglacial environment referred to as the Sangamon existed between 125,000 and 75,000 y BP. If so, this would compress the Early Wisconsinan substage (Grant, 1981). The Mid-Wisconsinan time were found to occur between 65,000 y BP and 23,000 y BP and Late Wisconsinan times between 23,000 y BP and 10,000 y BP.

The southeasterly flow patterns attributed to Wisconsinan glaciation are absent in Cape Breton, Prince Edward Island, northern Nova Scotia and eastern New Brunswick. This is due to erasure by later ice which was influenced by the drawdown of the Gulf of St. Lawrence (Goldthwait, 1924). This created northeasterly flow patterns in Cape Breton and easterly patterns in Prince Edward Island (Prest and Grant, 1969).

1.4 Glacial History of the Scotian Shelf

This section is based on the recent work of King and Fader (1985) who divided the glacial history of the Scotian Shelf into five stages. Figure 2, which illustrates this model, represents a cross-section oriented in a north-south direction across Country Harbour Moraine, Emerald Basin and to the edge of the Scotian Shelf.

Stage 1 is believed to have begun before 50,000 y BP and ended approximately 46,000 y BP. During this period the shelf was covered by a dry-base continental ice sheet which extended to the edge of the shelf. This is mainly an erosional event. However a thin layer of basal till was deposited at the base of the section overlying bedrock. The theory for the dry-base continental ice sheet was prompted when no glacial deposits older than Mid-Wisconsinan could be found by seismostratigraphic interpretation.

Stage 2 was from approximately 50,000 y BP to 45,000 y BP and signals the beginning of glacial recession. The thick ice sheet associated with stage 1 caused an extensive isostatic depression. This resulted in an increase in water depth and a trend towards thinning of the ice sheet. In turn, this led to wet-based glaciation and lift-off in deeper areas of the shelf. However the ice remained grounded in the area of the banks.

Within the deeper areas of the shelf, blanket till was deposited, followed by the development of lift-off moraines on top of the till. Glaciomarine sediment was then deposited between the moraine ridges. All during this stage, glaciomarine sediment continued to be deposited at the shelf edge.

Stage 3 was from 45,000 y BP to 32,000 y BP during which Emerald Silt, facies A was deposited. The Emerald Silt, seismic facies A pertains only to the basin areas of the Scotian Shelf and is recognized by high-amplitude, continuous, coherent reflections. During the early part of this stage, glacial recession reached a maximum resulting in the development of the Scotian Shelf moraine complex. Also fluctuations in the buoyancy line caused by minor glacial surges and retreats resulted in wedge-shaped till deposits along the main moraine and on the edge of the outer banks. It is apparent that the wet-base ice sheet remained grounded over the banks and at least for part of this stage, it was depositing till over the banks.

Stage 4 represented the retreat of the ice shelf from the central shelf and occurred between 32,000 y BP and 16,000 y BP. With the retreat of the ice, open water conditions were responsible for the development of bottom currents. These currents created a widespread unconformity which is dated at 30,000 y BP. In several areas this unconformity is overlain by glacial till which is evidence of a return of a grounded ice sheet in parts of inner and central shelf. This material is in turn overlain by Emerald silt, seismic facies B, which is recognized by medium to low amplitude, continuously coherent reflections.

Stage 5 was between 16,000 y BP and 10,000 y BP. It signals a low sea level stand and the beginning of the Late Wisconsinan -

Holocene trangression which would result in the deposition of clean, well sorted sands and gravels across the outer banks. The evidence for this is found in the trace of a terrace which contains a boundary between poorly sorted Sambro Sand and clean, well sorted sand and well rounded gravels of the Sable Island Sands and Gravels. The fines associated with this transgression were deposited in basins as LaHave Clays. This transgressive sequence was undercut and eroded by advancing seas.

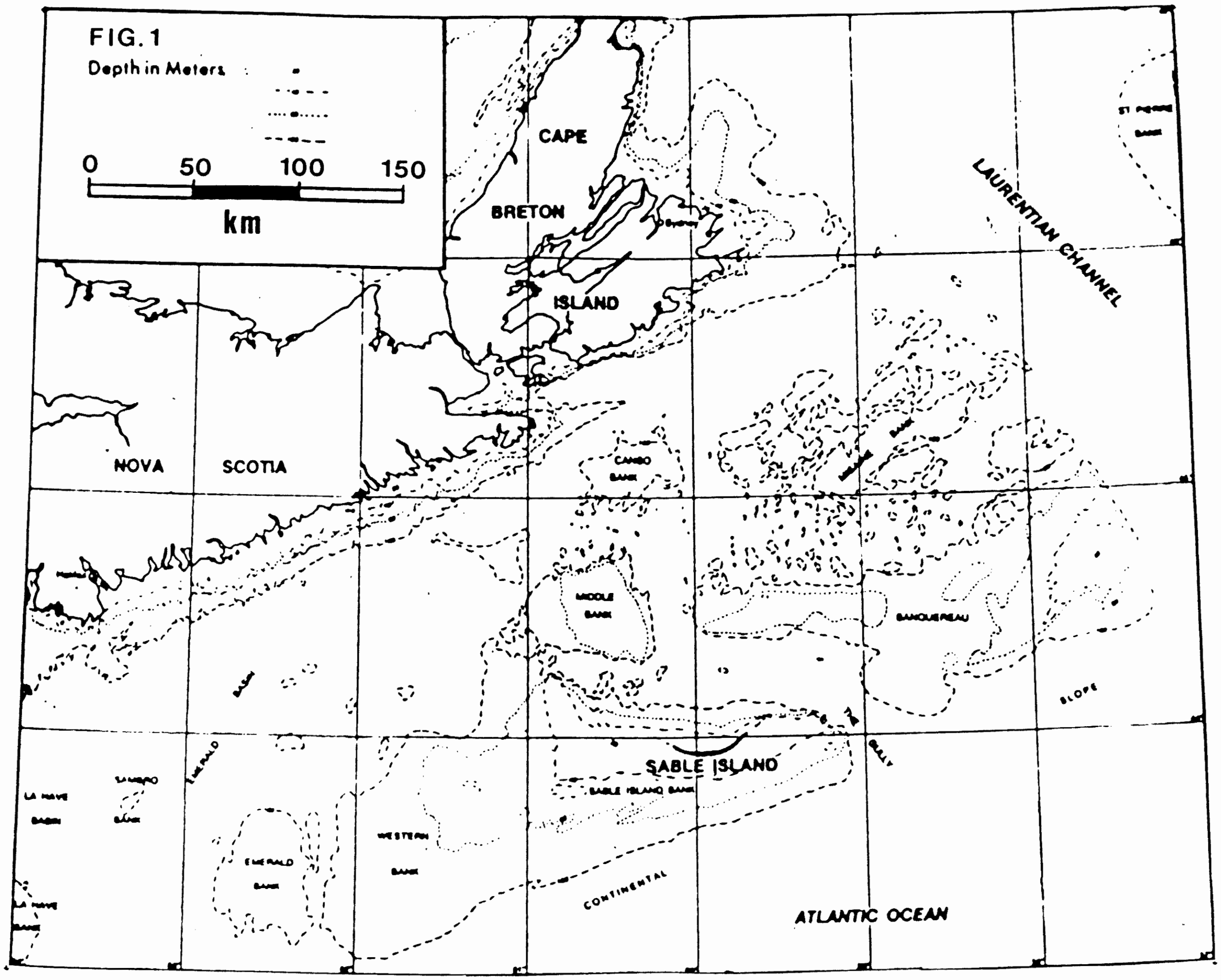
Why Sable Island exists is under debate but currently it is proposed that the island is a result of counter-moving action of the Inner Labrador current flowing south and the Gulf Stream which is flowing north (Cameron, 1965) (Fig. 3).

1.5 Objectives

Although this model of glacial history for the Scotian Shelf is widely accepted, it still lacks crucial data for the area of the outer banks. For this reason is it important to continue research in areas such as Banquereau and Sable Island Bank.

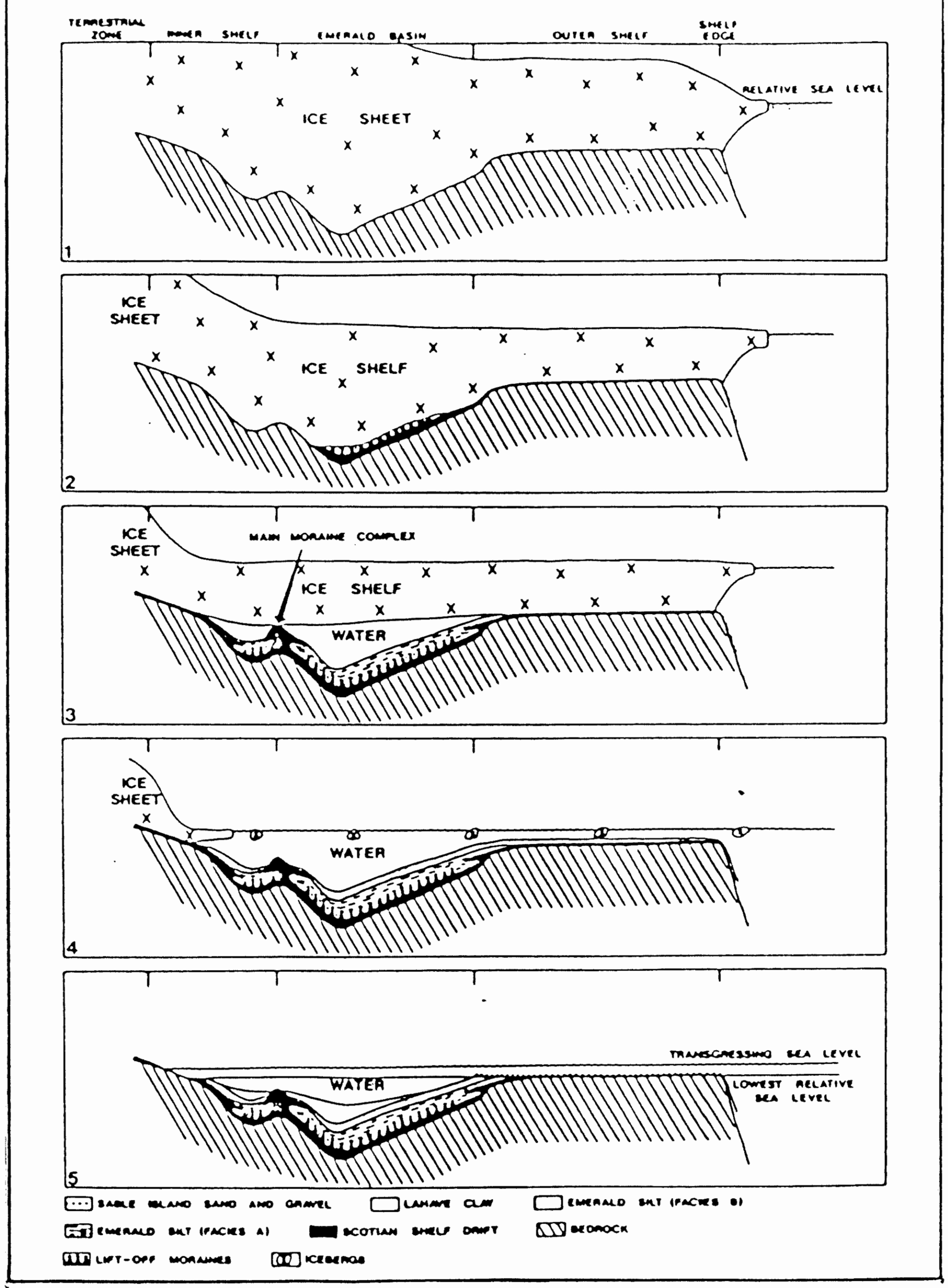
The objective of this project is to gain an understanding of the genesis and sediment distribution of Sable Island Bank during late Quaternary times and to determine if these distributions are related to the barrier systems on present day Sable Island. An understanding of the geologic history and stratigraphy for Sable Island Bank will allow for a better comprehension of the late Quaternary history of the Scotian Shelf or, more specifically, other sand bodies in the area like

Banquereau and Northern Spur. It is possible that since this survey was conducted on the south flank of the bank that the relationship between the continental slope and shelf will also be further resolved.



Bathymetry of the Scotian Shelf (Terasmae and Mott, 1967)

FIG. 2



Model of Wisconsin Glaciation (King and Fader, 1985)

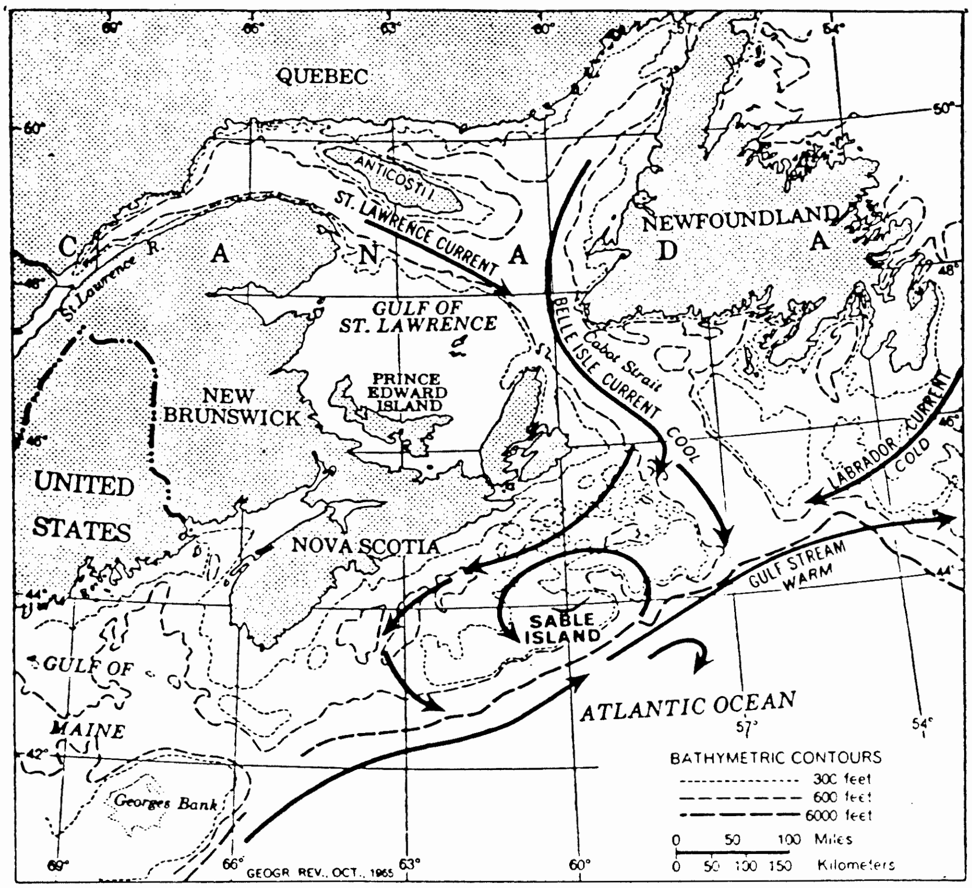


FIG. 3—Location of Sable Island on the continental shelf off Nova Scotia and its relation to the principal currents.

(Cameron, 1965)

CHAPTER II

Collection of Data

High resolution shallow seismic data were collected during the CSS Dawson Cruise 84-005 from March 8th, 1984 to March 16th, 1984. Data were collected for two major projects, one of which was headed by Dr. Ron Boyd. His project involved a study of the Quaternary stratigraphy of Sable Island Bank. The other major project was headed by Dr. C. Amos and involved a similar study of Banquereau. It was anticipated that the information collected during these two projects could provide a better understanding of the geologic history for the outer portion of the Shelf during Quaternary times.

The collection of data consisted of running a 255 line kilometre shallow seismic reflection survey using an Argo network as the primary navigation system. This system consisted of four slave stations located at Three Fathom Harbour, Port Bickerton, Fourchu, and East Sable. Fixes were taken every 100 metres and marked on the graphic recorders every 500 metres (Fig. 4). This system is accurate to 10 metres. Navigational systems such as the Magnavox 1107 Satnav receiver, the Internav LC404 (Loran-C) and the Motorola Miniranger were also used to back-up the Argo network.

Three seismic systems were used to obtain a precise record of the upper 50 to 60 metres of sediment:

1) The Huntec Internal Hydrophone Deep Tow System (DTS)

2) The Huntec External Hydrophone DTS

3) The Airgun System

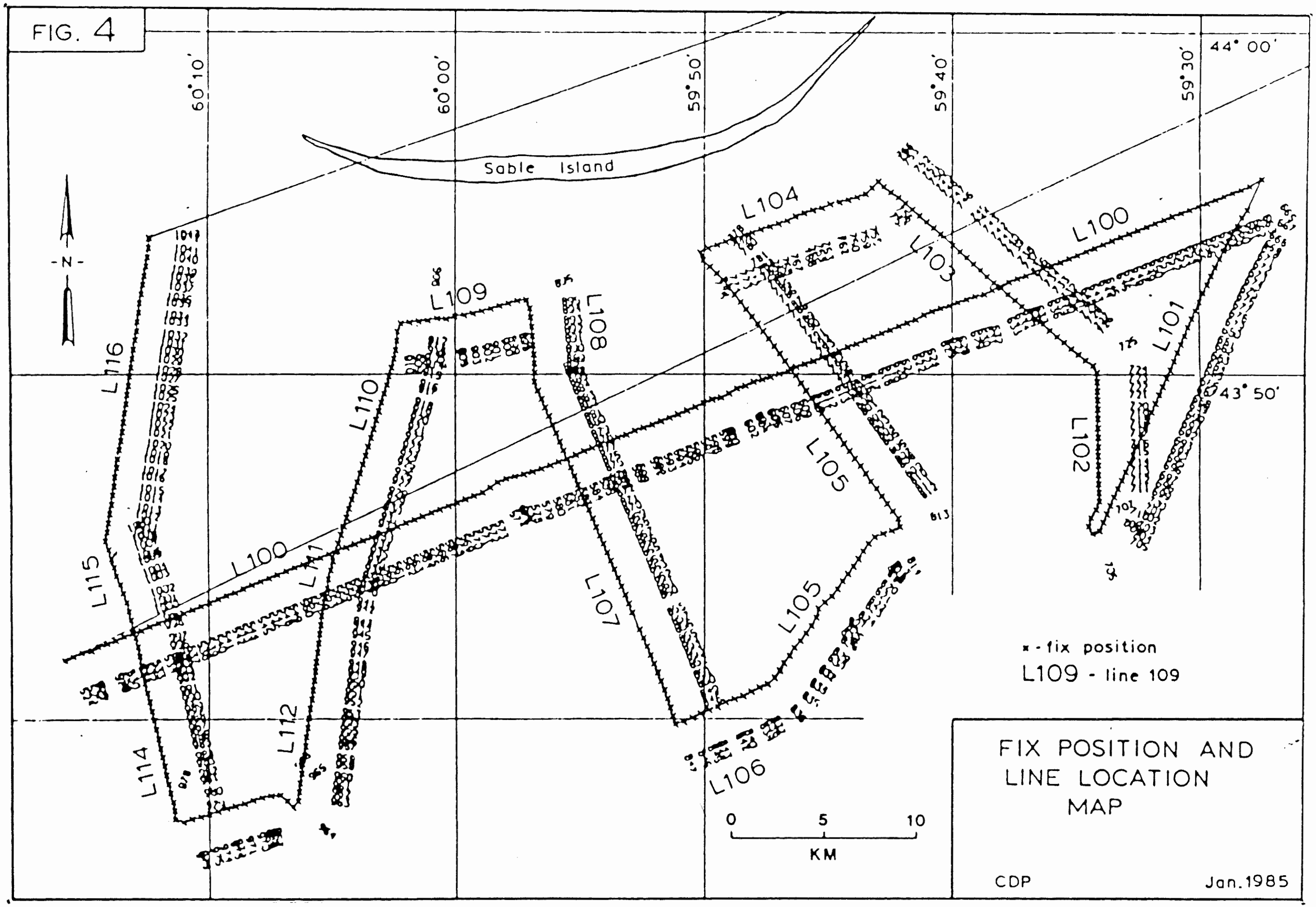
The Huntec equipment was towed 10 metres behind the ship at an average depth of 9 metres. It consisted of a boomer (seismic source) which fired every 0.75 seconds and two sets of hydrophones, a single internal hydrophone and an array of external hydrophones (streamer). The internal hydrophone was filtered between 700 and 12,000 Hz by an Adaptive Signal Processor (ASP) and the signal was printed on a EPC model 4100 graphic recorder. The external hydrophones were filtered between 750 and 4,000 Hz using the Kronhite filter and printed on a EPC model 4603 graphic recorder. The filters were used to eliminate the effects of the line voltage of the ship and of the fish and, in addition, to create contrasting penetration depths for the internal and external hydrophones. This means that the external hydrophones which were filtered between 750 and 4,000 Hz (lower frequency) could accomplish deeper penetration (lower resolution) in comparison to the internal hydrohone which was filtered between 700 and 12,000 Hz (higher frequency). Another important factor which resulted in contrasting penetration depths was the configuration of the hydrophones. The array of external hydrophones made it possible to detect acoustic signals which were too weak to be detected by the internal hydrophone. This meant the external hydrophones could observe acoustic reflectors at greater depths. These contrasting penetration depths resulted in two sets of shallow seismic data from the Huntec equipment. The Huntec internal hydrophone DTS had a maximum penetation of 8 metres and a resolution of 0.5 metres in comparison to the Huntec external hydrophone DTS whose maximum penetration and resolution were 25 metres and 3 metres, respectively.

The Airgun system was operated at the same time as the two Huntec DTS systems. It's purpose was to achieve greater penetration than could be accomplished with the other two systems. It consisted of a 40 cubic inch Bolt airgun which was lowered over the side of the ship and a streamer which was towed behind the ship. The airgun was equipped with a pulse shaper and was fired every 3 to 4 seconds at a pressure of 900 to 1,600 psi. The acoustic signals were received by an NSRF tapered streamer which was towed approximately 20 metres behind the ship. This system obtained up to 50 metres of penetration and resolution of approximately 10 metres (Amos, 1984).

It was hoped that the NORDCO drill could be used along the survey lines, however storm conditions did not allow this. For this reason ground-truthing the seismic information must be done using the Mobil Oil Canada and Shell Resources Canada well and borehole data which they have made available. Unfortunately, two major problems have evolved from using these data. The first is that the well data don't include the upper 40 to 60 metres of the record because it is unconsolidated sediment which is not of major concern to the oil companies. The only exception to this is well C-67 which was the first well drilled in the area. Unfortunately, it is not located in the survey area but rather on Sable Island. The second problem is that the boreholes that are available are geotechnical boreholes done for jack-up rig siting. This means the borehole material was probably analyzed by engineers who were concerned with things such as shear strengths and water content rather than describing the lithologies and sedimentary structures in detail or attempting to date the material. For this reason, Onondaga and Thebaud, the only two boreholes in the survey area (Fig. 5), have been described solely on general lithologies such as gravel, sand, silty-sand, or clay.

In an attempt to alleviate this problem correlations between the Sable Island Bank study and Banquereau study will be attempted. The Banquereau project has more borehole data which are of better quality.

FIG. 4



FIX POSITION AND LINE LOCATION MAP

CDP Jan. 1985

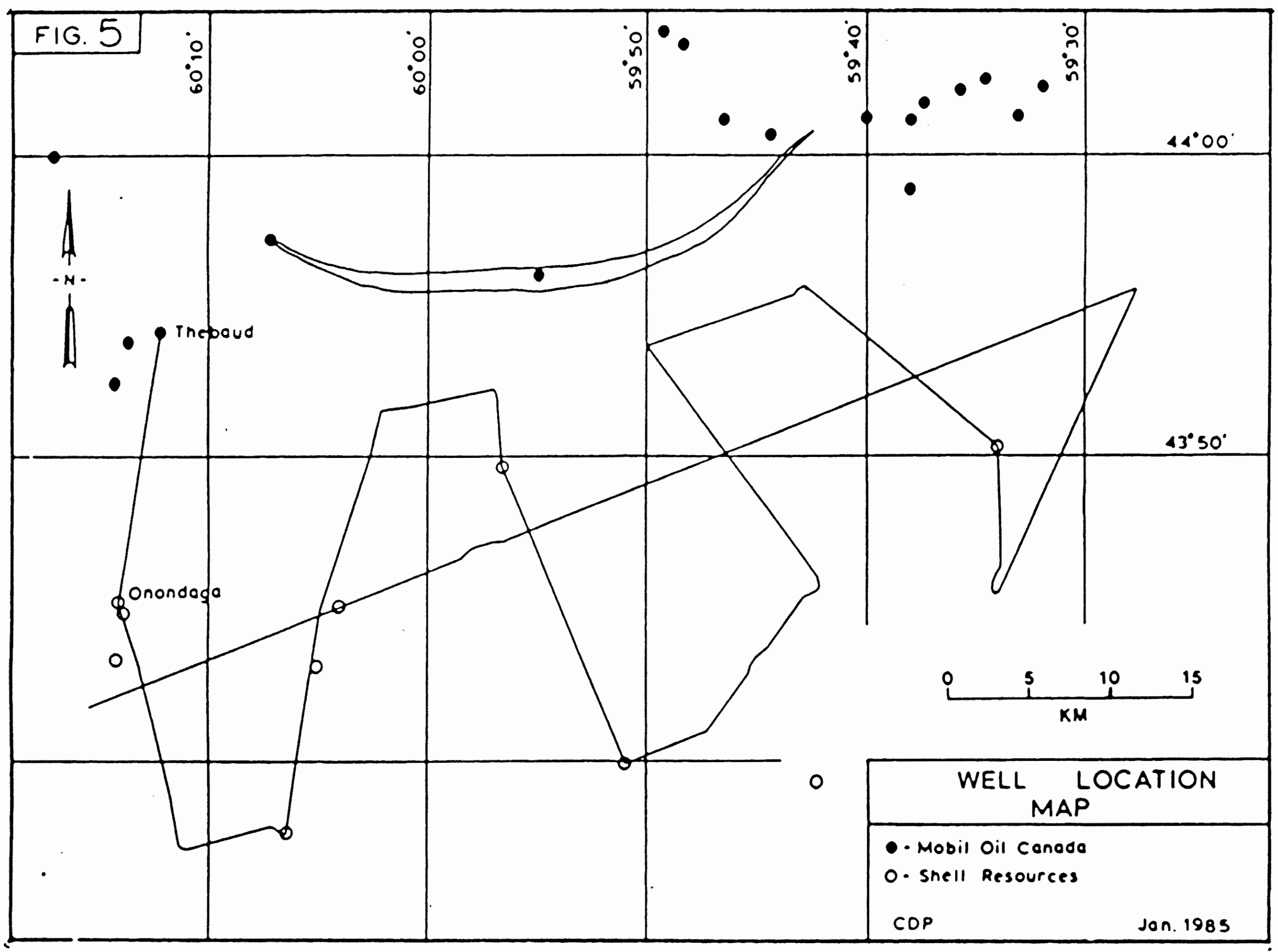


FIG. 5
60°10'
60°00'
59°50'
59°40'
59°30'
44°00'
43°50'
Thebaud
Onondaga
0 5 10 15
KM
WELL LOCATION MAP
● - Mobil Oil Canada
O - Shell Resources
CDP
Jan. 1985

CHAPTER III

Methods and Procedures

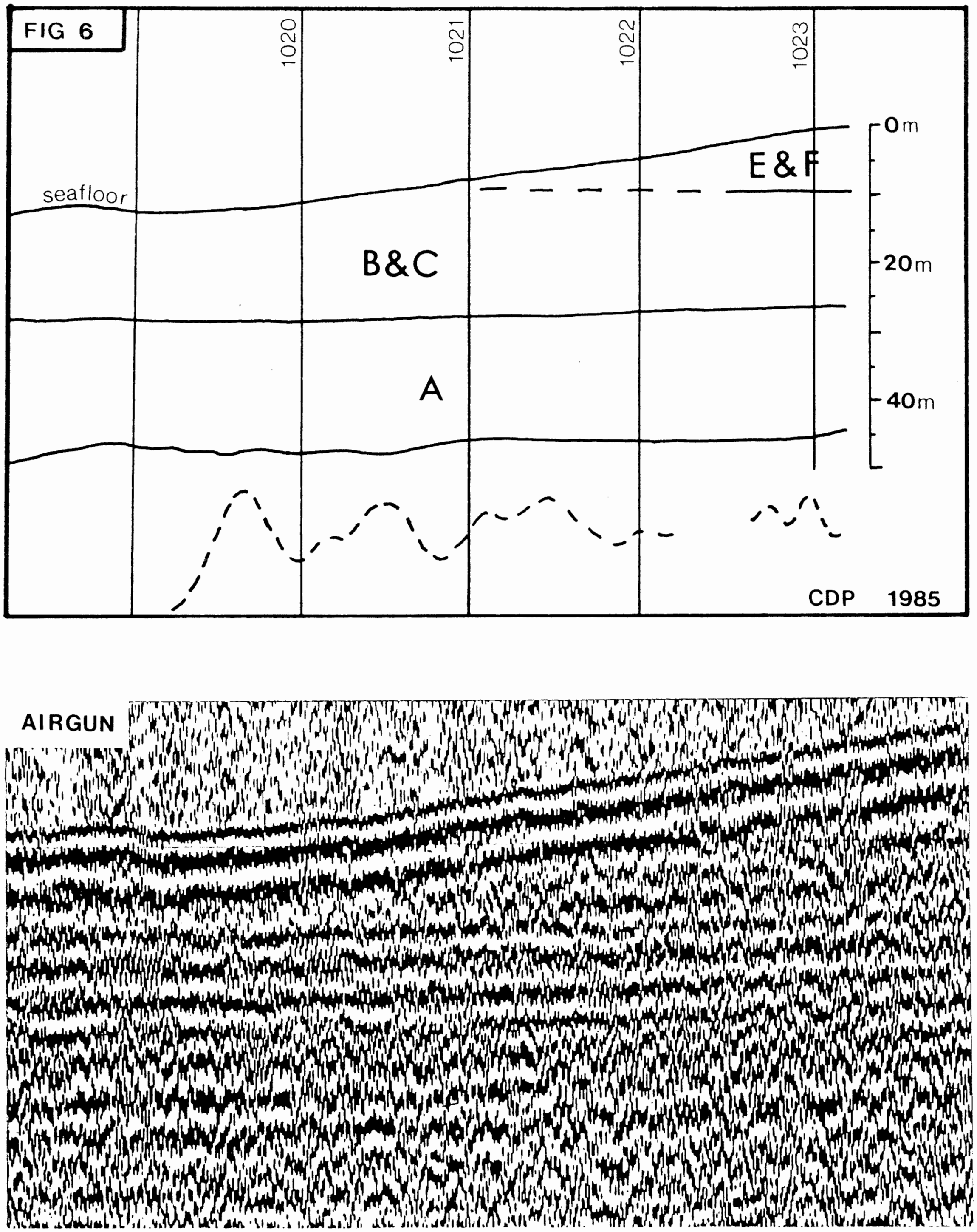
Initially a literature search was made to obtain some general information concerning Sable Island, Sable Island Bank and continental shelf processes. Information was also collected in the area of the processing and analysis of shallow high resolution seismic data.

The airgun record was the first to be analysed. Taking into account the effects of the bubble pulse, noise and the multiples, the acoustic reflectors were traced out. Then it was determined whether these acoustic reflectors represented a contact between two different acoustic units or represented an internal reflector within a unit. An example of this airgun analysis can be seen in Figure 6.

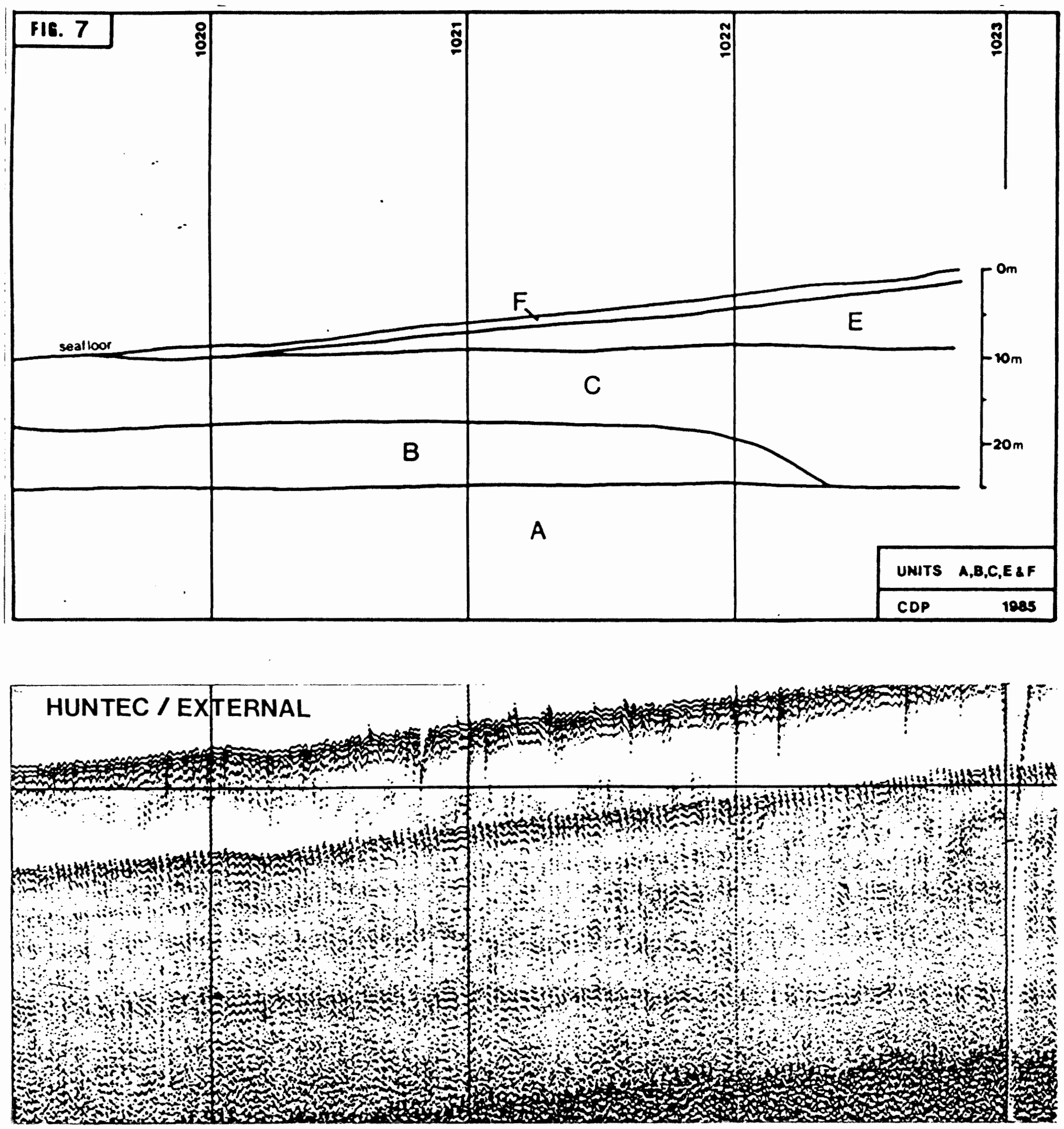
The Huntec external hydrophone record and Huntec internal hydrophone record were analysed at the same time. The same procedure was followed for tracing out the acoustic reflectors. Again it was determined whether these reflectors represented contact or internal features. This was slightly easier because the acoustic reflectivities, r_1 and r_2, (Parrot et al., 1980) located on the Huntec internal hydrophone record could provide supporting evidence for a contact only suggested on the seismic section. Once the acoustic units had been determined for the two records, they were compared to the airgun analysis. If there was a conflict, both tracings of the three records were re-evaluated. In general the higher resolution of the Huntec systems made it possible to observe reflectors which were only inferred on the airgun record. This can be seen by comparing Figures 6 and 7. Once the two tracings had been compared and verified, the acoustic units were defined and described.

These acoustic units were then correlated to the borehole data. Unfortunately, the borehole lithologies are predominantly sands and correlation was difficult. Therefore the thicknesses of these units were measured using a scale based on the velocity of sound through unconsolidated sand of 1800 m/s. The thickness of each unit over every fix position was then measured and recorded. Using these data, isopach maps were constructed for each unit.

At this point, a general interpretation was made for each unit based on its distribution and features. Then a more extensive literature search was conducted in order to find information which would more clearly explain the presence of these units. Following this, the final interpretations and conclusions were drawn for the project.



Analysis of Airgun Record



Analyses of Huntec External Hydrophone Record

CHAPTER IV

Observations

4.1 Introduction

By analysing the three high resolution shallow seismic records, it was determined that six units could be identified in the survey area. A seventh unit is visible on the airgun record however it is extremely difficult to trace it out over a large area. These six units have been called A to F where A is the lowermost unit and F is the uppermost unit. It was originally hoped that acoustic reflectivities could be calculated for each unit. However, it was found that the differences in reflectivities were minimal. They were only useful in cases where supporting evidence was needed to indicate the presence of a contact which was only suggested on the seismic record.

The following descriptions of the units include a color code for each unit. This is useful if one wishes to refer to the tracings of the original seismic record. The observations made along the survey lines and the measurements of the unit thicknesses are also available and can be found in the appendix.

In order to understand how these units are related spatially, it is useful to refer to figures 7 and 8.

4.2 The Unit below Unit A

The unit below unit A (the brown unit) is only partially exposed on the airgun record. It is difficult to identify its upper contact with unit A because it is often masked by the multiples. However the acoustic signature of this contact appears strong in the areas where it is visible. Along line 116 where this unit is most visible, it is hard to determine whether the contact is conformable or unconformable due to the poor resolution of the airgun system. The lower contact of this unit is not visible on the records therefore an isopach map can not be constructed. Ths means that it is impossible to determine the distribution and geometry of this unit.

Internal reflectors are present within the unit below unit A. Continuous to discontinuous coherent wavy internal reflectors can be seen along line 116. These reflectors have an average waveheight of 7 metres and an average wavelength of 200 metres. The other type of internal reflector for this unit can be observed along lines 114 and 107 at the shelf edge. These coherent reflectors are lens-shaped and resemble features which are associated with progradation.

4.3 Unit A

It has already been mentioned that the contact between unit A (the red unit) and the unit below A is very difficult to locate. Therefore not enough reliable data could be obtained to construct an isopach map, however, the data that were collected indicated that the thickness for unit A ranges between 12 and 40 metres. The upper contact of unit A is well defined on the airgun and Huntec external hydrophone records. This contact is planar and conformable with the units B and C. It appears as a horizontal continuous coherent reflector. Since the upper contact of unit A is so visible, it was possible to construct a structural contour map on the upper surface of unit A (Figure 9). This map shows that unit A has a gentle slope to the south for most of the northern portion of the survey area. However, this slope becomes much steeper when unit A approaches and passes the shelf edge. Unit A can be found approximately 80 metres below sea level in the northern section of the survey whereas in the most southerly section, it is found 130 metres below sea level. This coutour map also shows that unit A is present over the whole survey area.

Unit A is featureless but when it approaches the shelf edge, lens-shaped internal reflectors can be seen. These coherent reflectors are very similar to the ones observed in the unit below unit A. Examples of these lens-shaped features can be observed along the southern sections of lines 114, 112 and 107.

4.4 Unit B

Unit B (the orange unit) is overlain by unit C in the northern and central portion of the survey area but it is overlain by unit D south of the shelf edge. The contact between unit B and C is unconformable but the contact between unit B and D is conformable. It is very difficult to determine the contact between unit B and C because unit C is comprised of various internal reflectors. For this reason the isopach map of unit B is limited to the western portion of the survey area (Fig. 10). The map illustrates that unit B tends to thicken as it moves to the southern section of the survey area.

The thickness of unit B ranges between 0 and 32 m. The data suggest that unit B is present over the whole survey even though the upper contact of unit B is difficult to identify. This deduction is made because a featureless zone is present below the internal reflectors of unit C. Occasionally, the erosional event which created the unconformable contact between unit B and C, scoured away all of B so that unit C is in contact with unit A. However unit B usually is present again less than 1 km further down the survey line.

4.5 Unit C

Unit C (the green unit) is present from the northern section of the survey area to the shelf edge. As it approaches the shelf edge, it thins and terminates approximately 85 m below sea level (Fig. 11). The thickness of this unit varies between 0 and 18 m. The disappearence of unit C at the shelf edge coincides with the termination of unit F and the beginning of unit D (Fig. 8). As mentioned in the last section the base of unit C is difficult to identify therefore the isopach map of unit C is limited to the western portion of the survey area. In an attempt to alleviate this problem a map of the combined thicknesses of unit B and C was constructed (Fig. 12). The map illustrates that unit B and C are thick to the east and thin towards the west.

The contact between unit C and E is planar and conformable. This contact appears as a coherent continuous reflector on the airgun and Huntec external hydrophone records. However, unit E thins and terminates in the northern portion of the survey causing unit C to be in contact with unit F. This contact is unconformable and appears as a coherent continuous reflector on the seismic records. When unit C terminates at the shelf edge, unit D begins in such a manner that unit D overlies unit C for this short interval (1 km).

The most interesting features of unit C are the internal reflectors it possesses. These reflectors are coherent and discontinuous, and fall into four categories:

1) horizontal
(ex. fix position 731 to 740)

2) inclined
(ex. fix position 863)

3) wavy
(ex. fix position 1003)

4) crescentic (convex downwards)
(ex. fix position 888)

The horizontal and wavy internal reflectors can usually be traced for 3 km along the records. The inclined and crescentic reflectors conversely were seldom greater than 600 metres in length.

4.6 Unit D

Unit D (the blue unit) is present in the southern section of the survey and like unit C, it contains internal reflectors. The discontinuous, coherent reflectors fall into two different categories:

1) planar horizontal internal reflectors
2) x or v-shaped internal reflectors

As mentioned before, the beginning of unit D coincides with the termination of units C and F at the shelf edge. At this point of transition, unit F overlies unit D and in turn unit D overlies unit C. This information indicates that south of the shelf edge, unit D is exposed on the seafloor and that unit D is in contact with unit B below. This lower contact of unit D is conformable and appears as a coherent, continuous reflector on the airgun and Huntec external hydrophone records.

The thickness of unit D ranges between 0 and 19 m. Figure 13 is an isopach map which illustrates how unit D begins and tends to thicken away from the shelf edge.

4.7 Unit E

Unit E (the pink unit) which contains no internal reflectors, is present in the northern portion of the survey area. This unit doesn't extend to the shelf's edge as do units C and F. The isopach map illustrates that unit E is thickest in the northern section, thins and finally terminates as it trends south Fig. 14). The thickness of unit E varies between 0 and 28 m.

The contact between unit E and F is unconformable. This upper contact of unit E appears as a coherent, continuous reflector on both of the Huntec records. The contact between unit E and unit C below, is planar and conformable. This lower contact of unit E appears as a coherent, continuous reflector on the airgun and Huntec external hydrophone records.

4.8 Unit F

Unit F (the yellow unit) which is exposed at the seafloor is present from the northern section of the survey to the shelf edge. As previously mentioned the termination of unit F at the shelf edge is in proximity to the termination of unit C and the beginning of unit D. Unit F overlies units C and D at the shelf edge. Unit F also overlies unit E in the northern portion of the survey area. In all these cases, the lower contact of unit F is unconformable and appears as a coherent, continuous reflector on both of the Huntec records.

Figure 15 is an isopach map for unit F. It shows that unit F terminates at the shelf edge and tends to be thickest in the central portion of the survey area extending in an southwest-northeast direction. These thicknesses range between 0 and 5 metres. The thicknesses for the northwestern section of the survey are far more irregular and range between 0 and 10 metres. These irregular thicknesses coincide with the presence of ridges in the area (Fig. 16).

Inclined internal reflectors which are approximately 350 metres in length are present in unit F. These reflectors are coherent and discontinuous. It is possible these internal reflectors are related to the ridges found in the northwestern portion of the survey.

4.9 Correlations to Borehole Data

Ground-truthing of the seismic data was accomplished by constructing borehole cross-sections and comparing them to the tracings of the acoustic reflectors. The borehole cross-sections were constructed in such a manner that the different acoustic velocities of the various lithologies could be taken into account. The different velocities of sound which were used were:

1) 1490 m/s for water
2) 1600 m/s for clay
3) 1800 m/s for sand

This was done so that the cross-sections and the tracings would be at the same scale. Figure 17 shows how the Onondaga and Thebaud boreholes were correlated to the tracings of the acoustic reflectors.

The unit below unit A appears to be predominantly fine sand except for the upper 4 to 6 metres which are clay. Unit A itself has an upper 3 to 6 metres of fine sand and gravel. Then unit A fines downwards to a fine and medium grained sand then to a fine sand. Determining the lithology of unit B is difficult because it is not present at one borehole location and is not traceable on the seismic records at the other borehole site. However, the correlation suggests that unit B is probably silty sand. The upper 4 to 6 metres of unit C is gravel. The remaining material below this in unit C is fine-grained sand.

Unit D which is only present in the southern portion of the survey area, can not be correlated to the borehole data. Therefore the lithology of unit D is unknown. Unit E appears to be predominantly fine sand with occasional occurrence of silty layers and fine, medium and coarse sand layers. Unit F is composed of fine sand and a little medium-grained sand.

It is important to remember that these correlations are made using the acoustic velocities listed above. If different velocities were used it is possible that the correlations above could not be obtained.

A summary of the observations discussed in this chapter can be found in Table 1.

FIG. 8

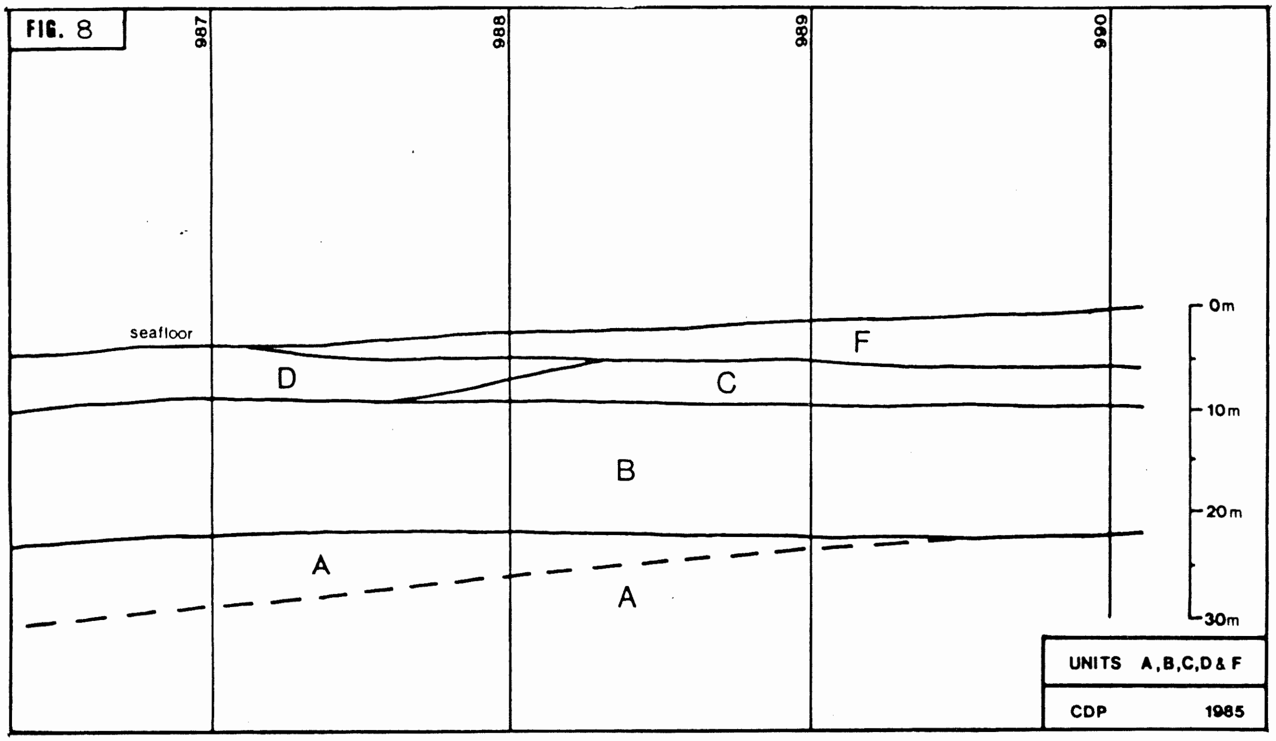
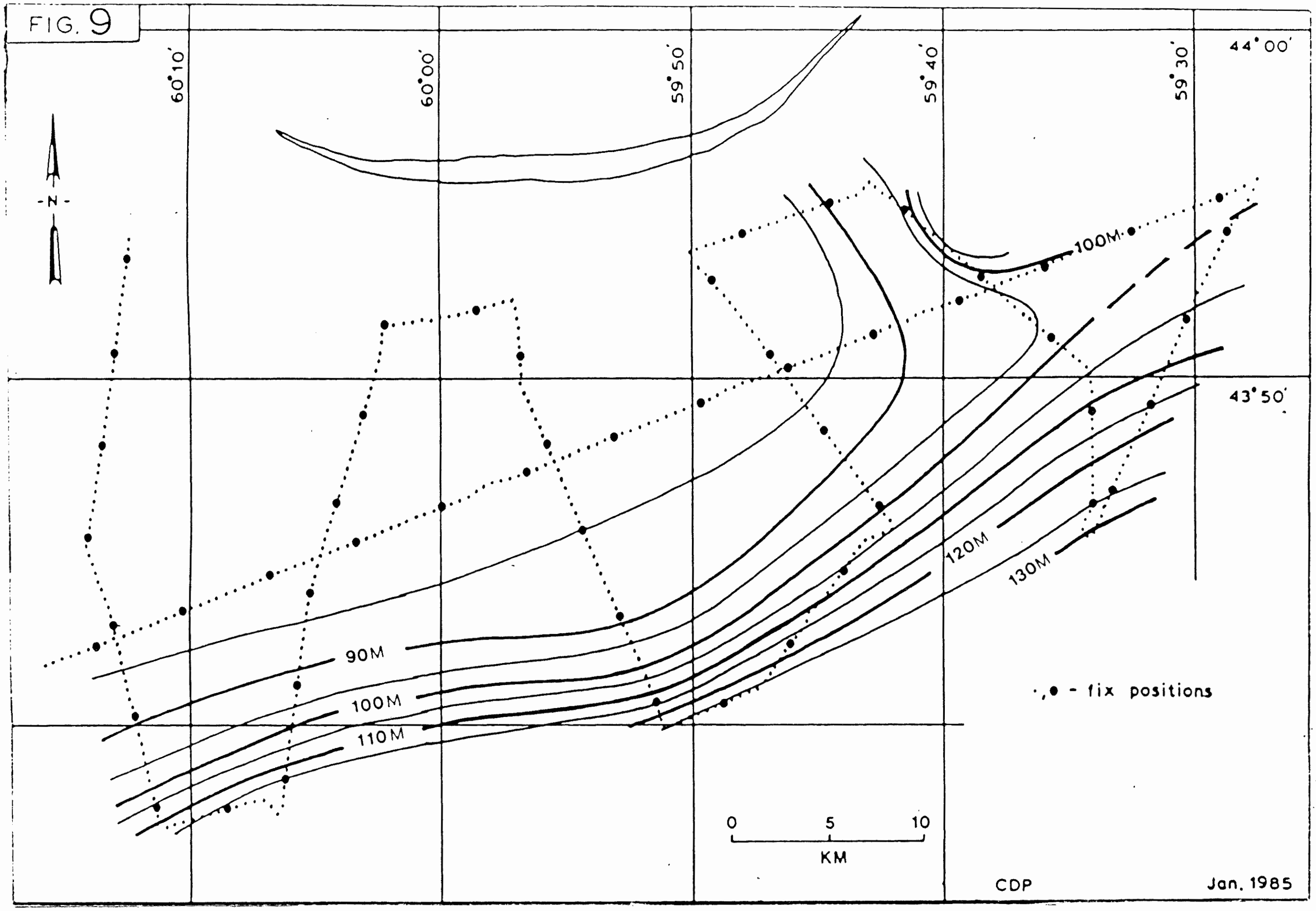
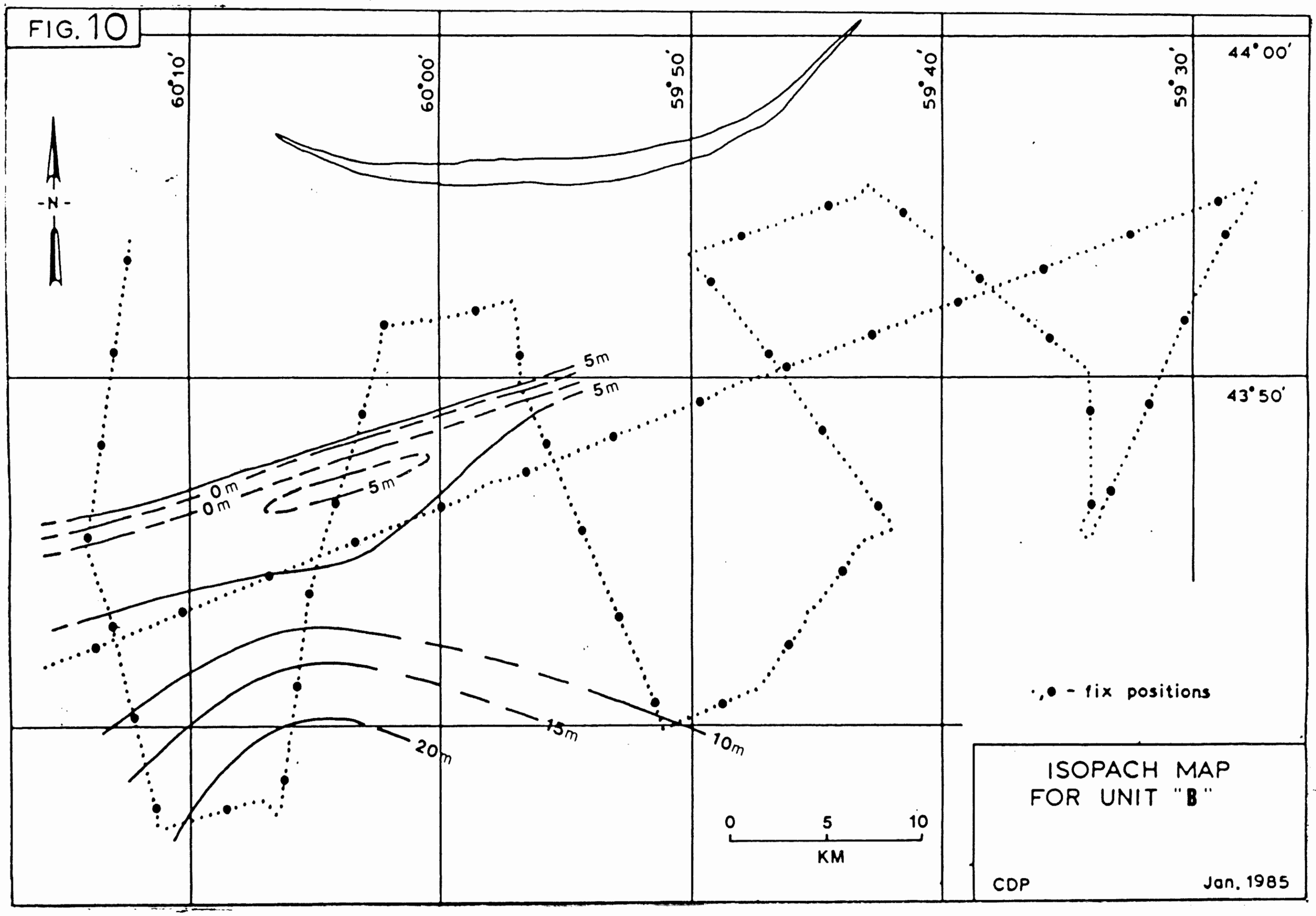

987
988
989
990
seafloor
F
D
C
B
A
A
0m
10m
20m
30m
UNITS A,B,C,D & F
CDP 1985

FIG. 9

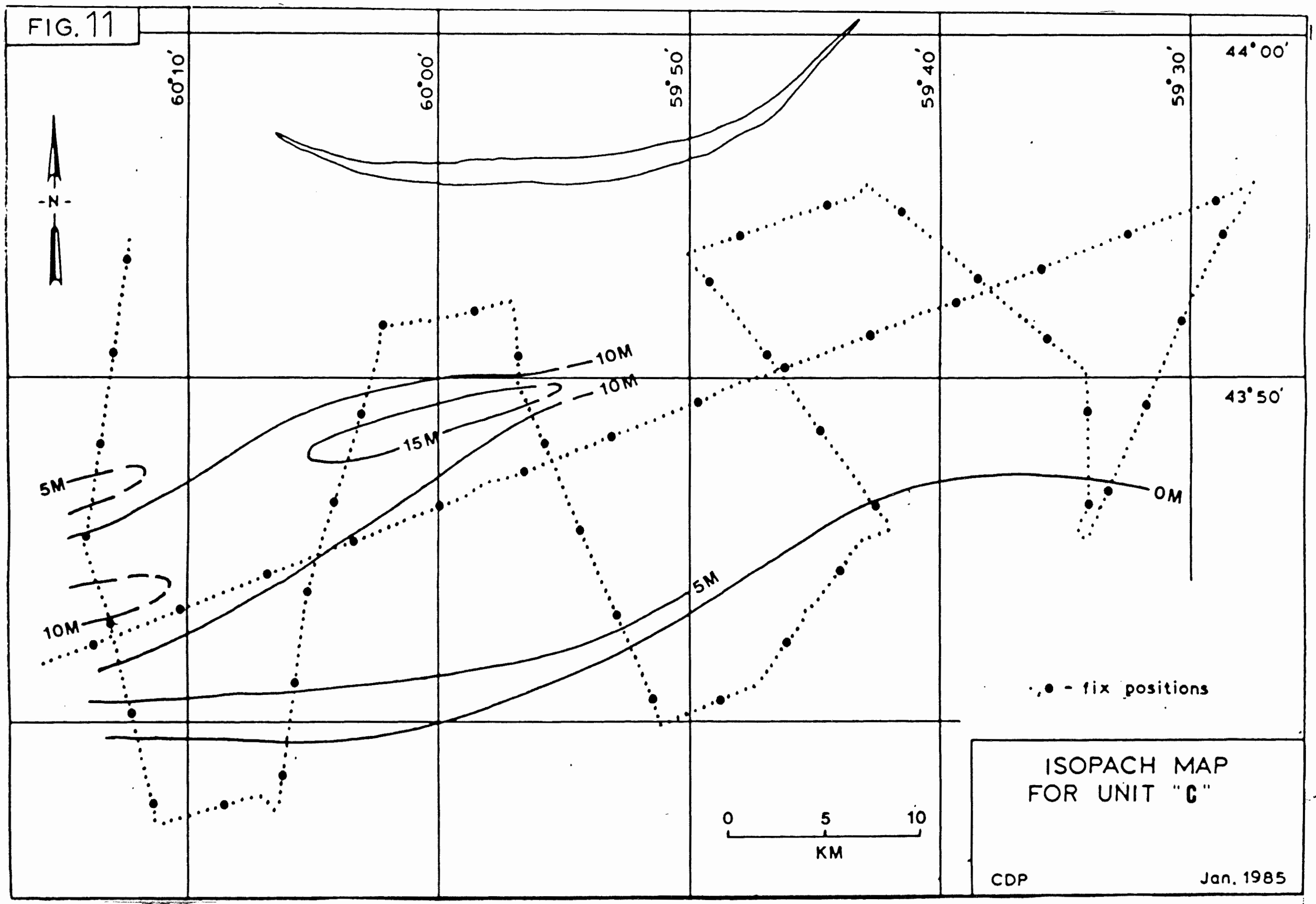


Stuctural Contour Map for the Upper Contact of Unit A - The contour lines represent the number of metres unit A is below sea level.

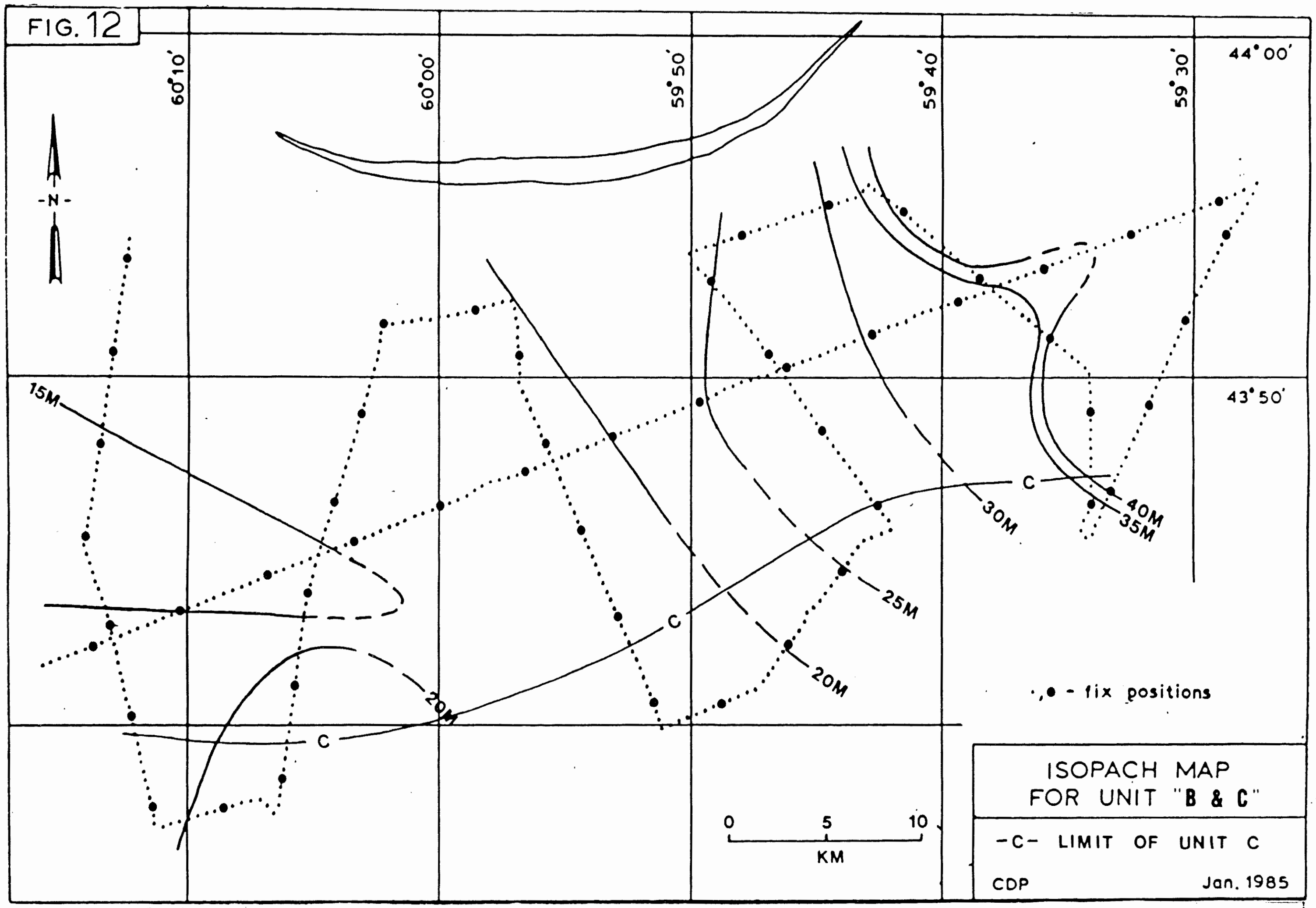
FIG. 10



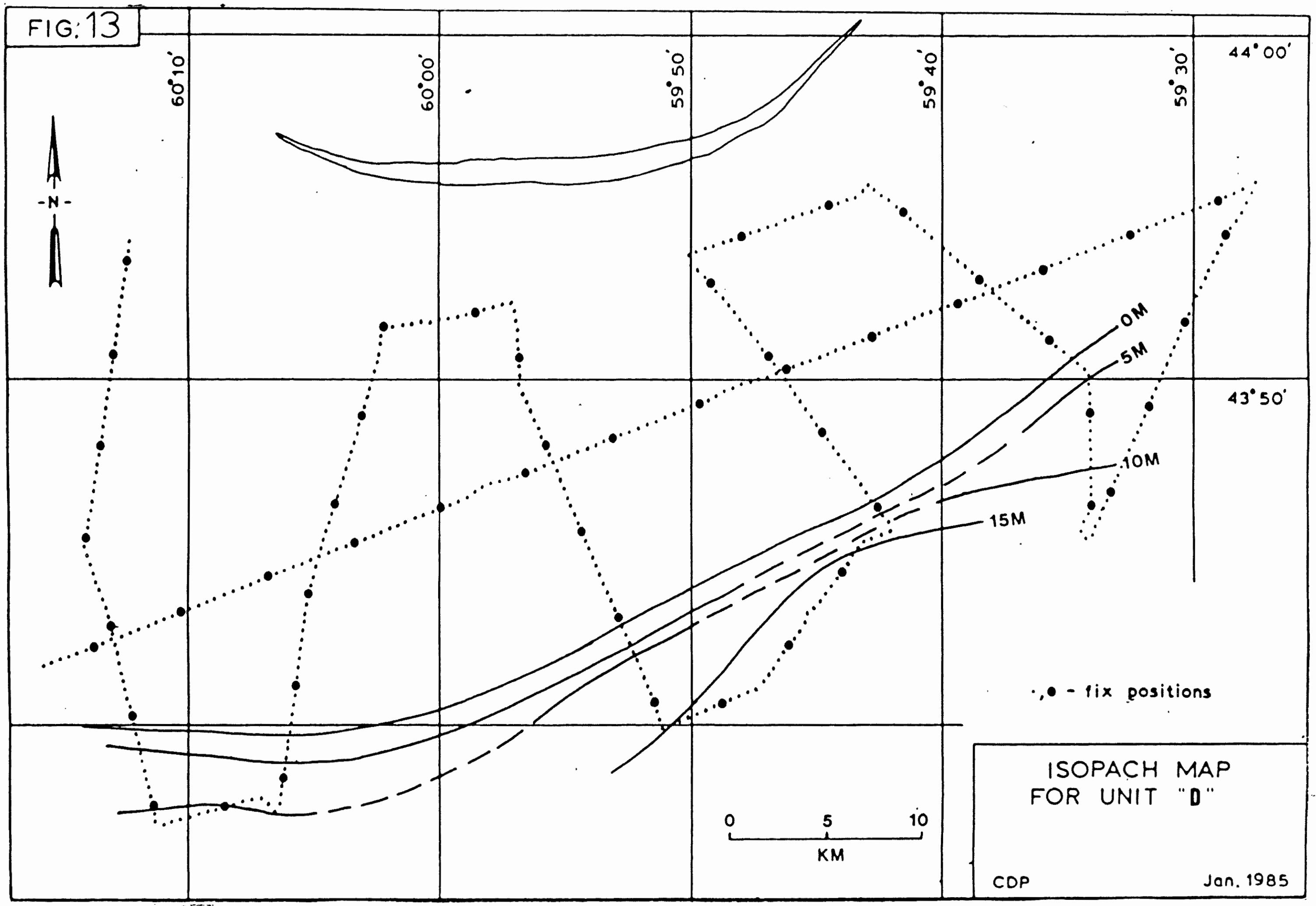
Dashed lines are isopach lines which are drawn with a level of uncertainty.



Dashed lines are isopach lines which are drawn with a level of uncertainty.

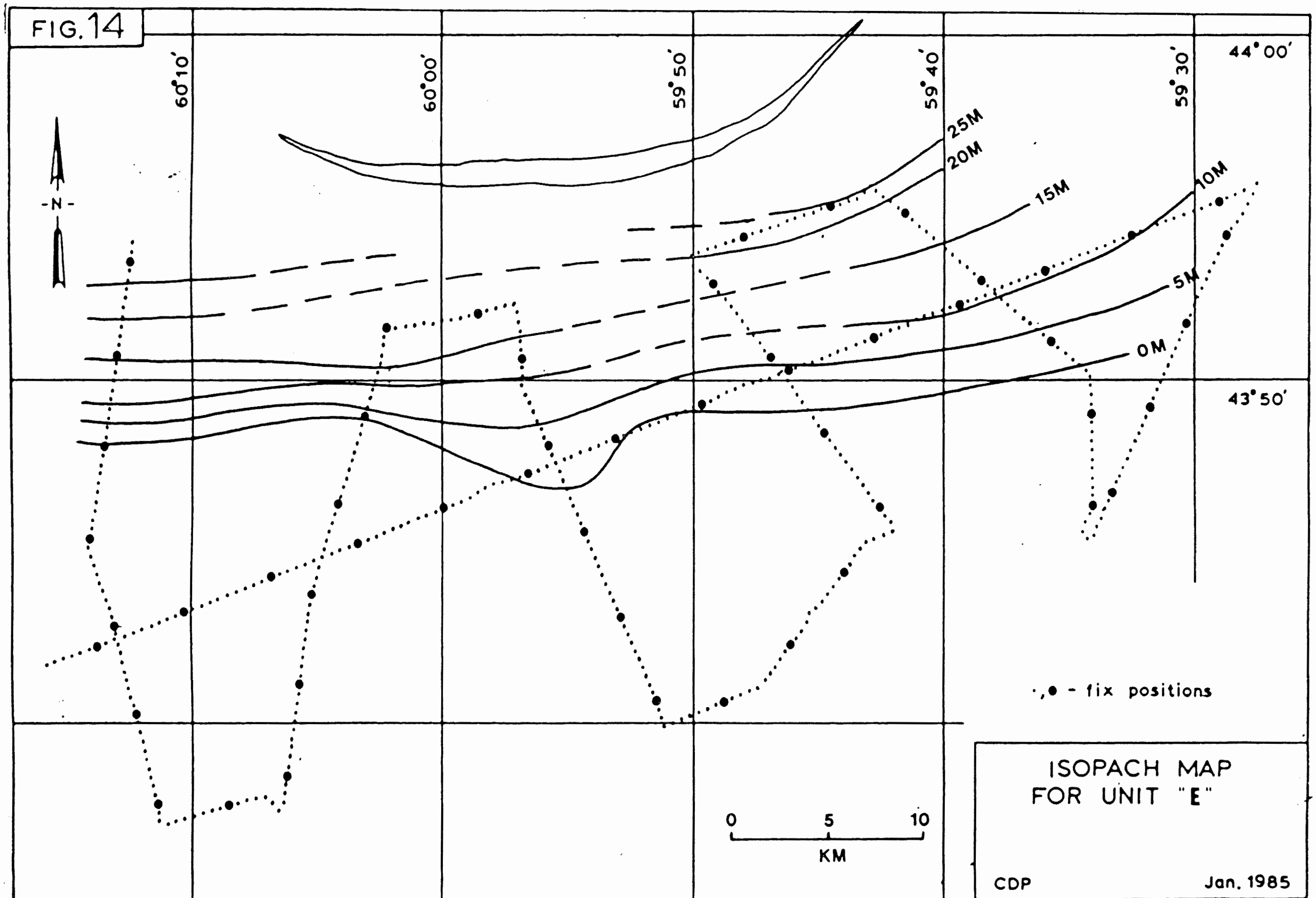


Dashed lines are isopach lines which are drawn with a level of uncertainty.



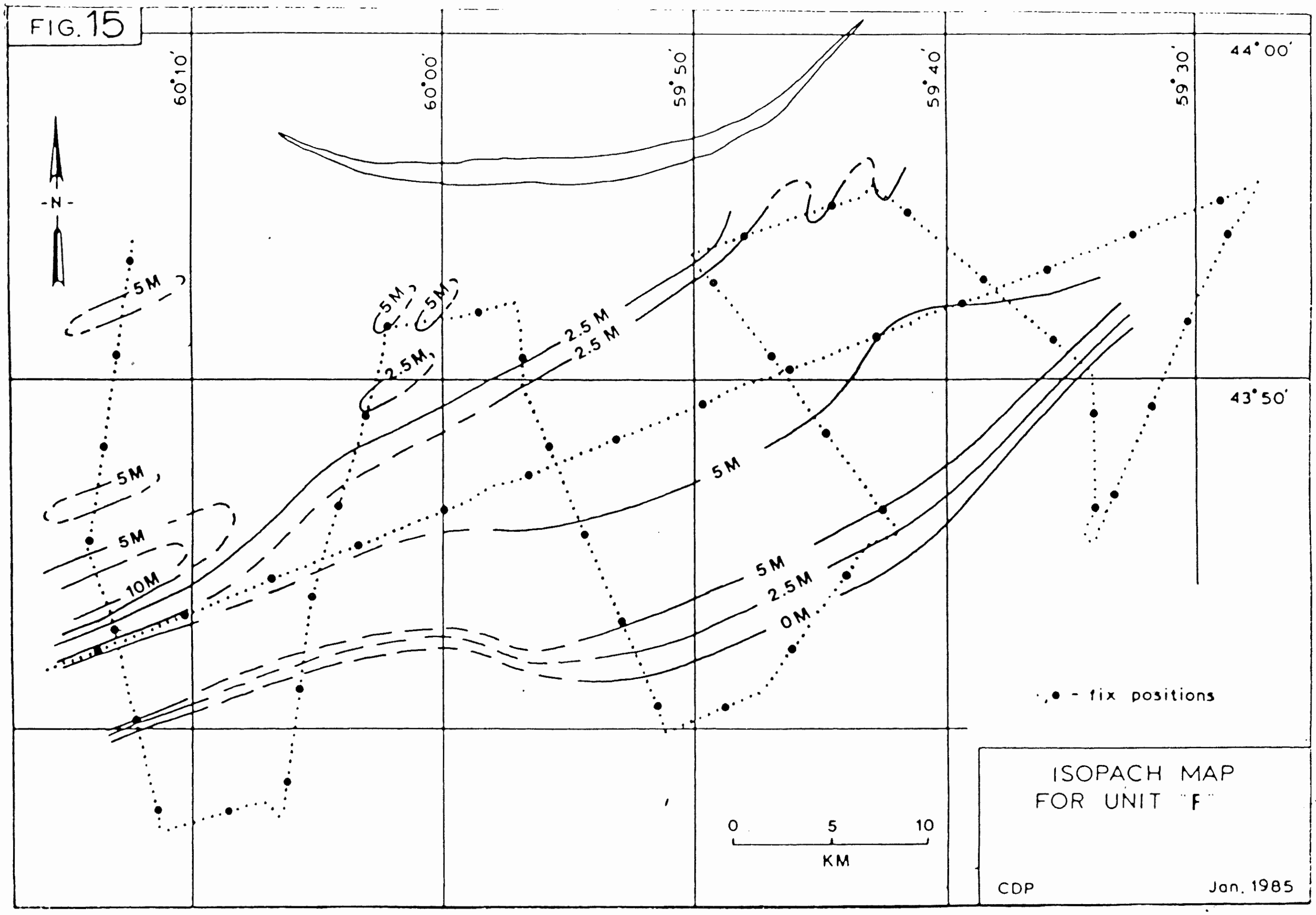
Dashed lines are isopach lines which are drawn with a level of uncertainty.

FIG. 14



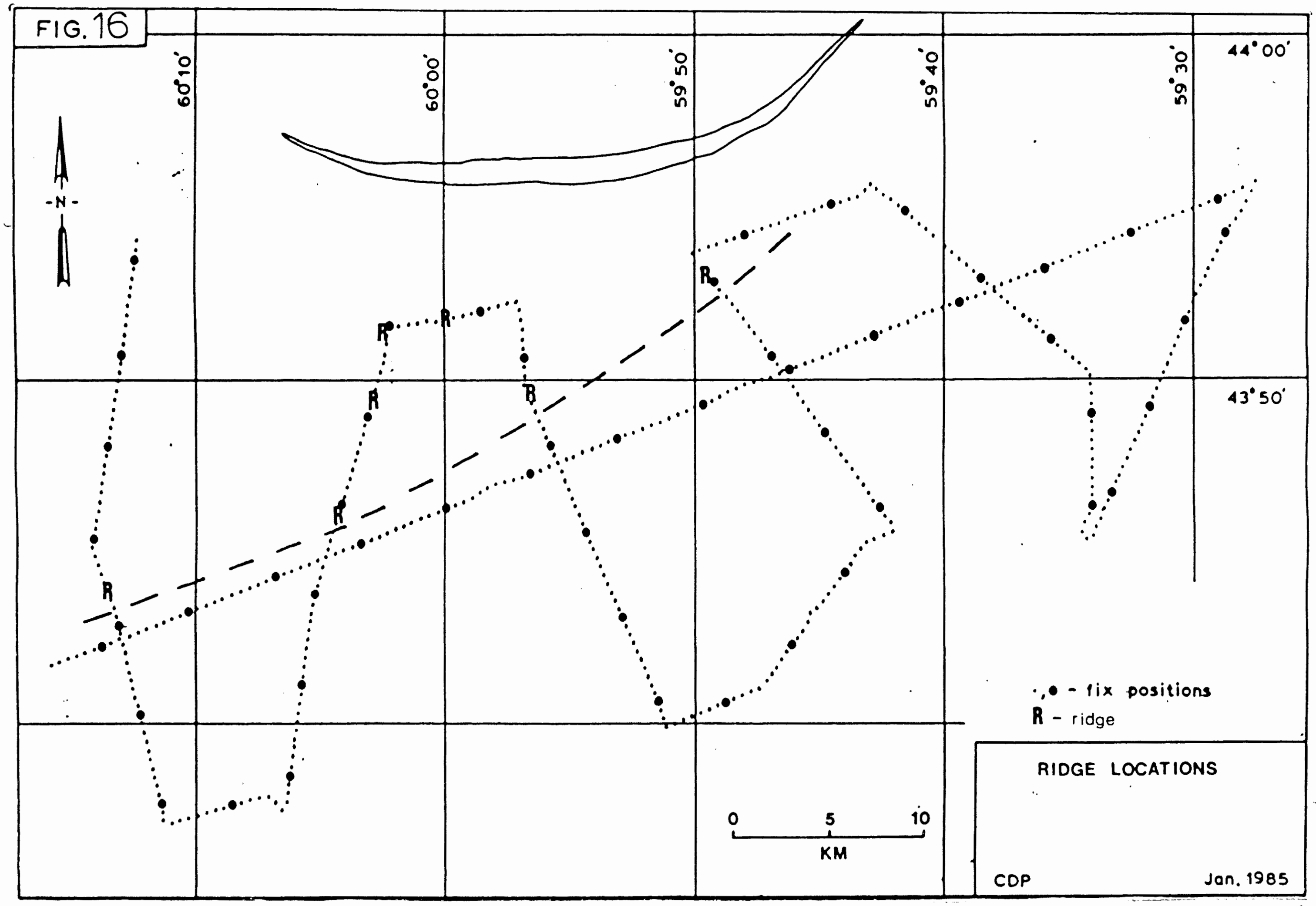
Dashed lines are isopach lines which are drawn with a level of uncertainty.

FIG. 15



Dashed lines are isopach lines which are drawn with a level of uncertainty.

FIG. 16



60°10'
60°00'
59°50'
59°40'
59°30'
44°00'
43°50'
N
R
•,● - fix positions
R - ridge
0
5
10
KM
RIDGE LOCATIONS
CDP
Jan. 1985

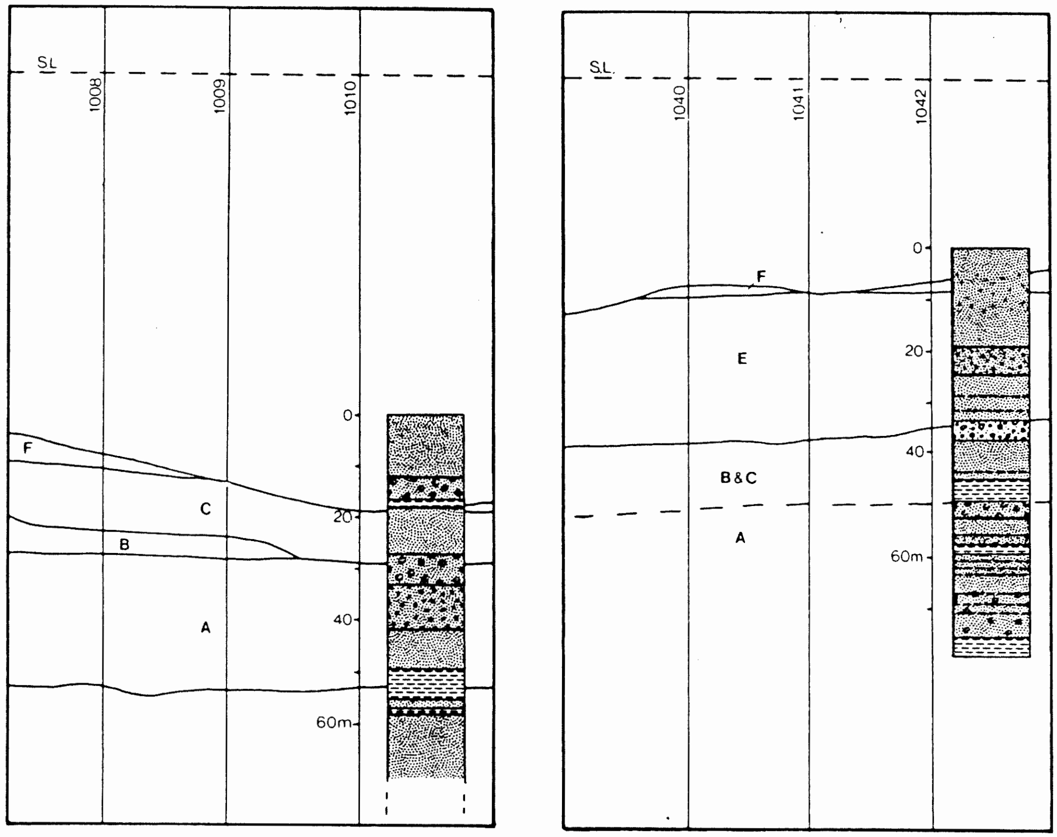


Figure 17 Borehole Correlations

clay

fine sand

medium sand

coarse sand

gravel

The Thebaud borehole is shown on the right and the Onondaga borehole is shown on the left.

Table 1 – A Summary of the Observations

UNIT	THICKNESS	OVERLAIN BY WHICH UNIT	CONTACT WITH UNIT ABOVE	INTERNAL REFLECTORS	LITHOLOGY (Borehole)	DISTRIBUTION
F	0 - 10 m	none	--	inclined (discontinuous, coherent)	fine sand with a little medium sand	From the northern portion of the survey area to the shelf edge.
E	0 - 28 m	unit F	unconformable (continuous, coherent)	none	fine sand with occasional silty, medium and coarse sand layer	Only present in the northern portion of the survey area.
D	0 - 19 m	none except near the shelf edge where it overlain by unit F	unconformable with unit F (continuous, coherent)	x or v-shaped and horizontal (discontinuous, coherent)	unknown	Only present south of the shelf edge.
C	0 - 18 m	unit E in northern section of survey unit F in central portion of survey	planar, conformable with unit E unconformable with unit F (both are continuous and coherent)	horizontal, wavy inclined, and crescentic (discontinuous, coherent)	the top 4 to 6 metres are gravel. Below this, it is fine sand.	From the northern portion of the survey area to the shelf edge.
B	0 - 32 m	unit C in the northern portion of the survey and unit D in the southern portion of the survey	unconformable with unit C and conformable with unit D (both are continuous and coherent)	none	(silty sand?)	Over the whole survey area.
A	12 - 40 m	unit B	planar, conformable (continuous, coherent)	lens-shaped reflectors near the shelf edge	the top 3 to 6 metres is fine sand and gravel. Below this, it fines downwards to a silty sand.	Over the whole survey area.
unit below unit A.	unknown	unit A	unknown	discontinuous to continuous coherent wavy internal reflectors and lens-shaped reflectors near the shelf edge	the top 4 to 6 metres is clay. Below this, it's fine sand.	Unknown

CHAPTER V

Discussion

The most critical problem of this study is that the material within the boreholes has not been dated. Fortunately Dr. C. Amos who is conducting the study of Banquereau has several good boreholes. Using his information it is anticipated that dates can be obtained.

Data concerning unit C are of good quality and are more abundant than the data available for the other units. For this reason, the discussion will begin with unit C. This unit has horizontal, wavy, inclined and crescentic internal reflectors and has an unconformable contact with unit B below.

Dr. Amos has a similar unit present in his study. Using carbon dating he places the top of unit C at 8,000 yrs B.P. and the base of the unit at 16,000 y B.P. This means that this unit was forming during the minimum stand of sea level at 15,100 y B.P. Dr. Amos (pers. comm. 1985) also identifies units A and B on his records therefore it appears that the seismic stratigraphy on Sable Island Bank can be correlated with that on Banquereau.

The shape of the internal reflectors within unit C appear to represent channel-like features. The unconformable contact with unit B below is probably a result of this channelization. The gravel correlated to this unit most likely represents gravel lag which would be deposited at the bottom of a channel and since this unit lacks fine-grained material (silt and clay) it is possible that the channels closely resembled braided streams. Braided streams have high influxes of water at irregular times which causes fine-grained sediments to be removed, leaving the coarser grained material behind. Therefore the crescentic internal reflectors do not represent one braided stream but rather a group of braided streams which migrated within that area. The overall interpretation of unit C is that it represents a subaerially exposed outwash plain which formed during the glacial retreat. Modern examples of such outwash plains can be seen on Baffin Island. Church (1972) found that these outwash plains lacked fine-grained sediment and that the channels on the plains exhibited braided patterns.

At the shelf edge, the termination of unit C coincides with the beginning of unit D in such a manner that unit D overlies unit C. If units D and C were deposited at the same time, they would represent a transgressive sequence. The termination of unit F also occurs at the shelf edge in such a manner that unit F overlies D. If units F and D were deposited at the same time, they would represent a regressive sequence. The first hypothesis is probably true for two reasons. The first reason is that the minimum stand of sea level occurred when unit C was being formed and unit D overlies unit C at the shelf edge. Therefore sea level was probably rising when unit D was being deposited which would support the idea of a transgressive contact between units D and C. The second reason is that the discontinuous horizontal reflectors within unit D probably represent planar bedding features. These features are very similar to the horizontal reflectors which are seen in the Emerald Silt found on the inner and central portions of the Shelf (King and Fader, 1985). The dates for the deposition of the Emerald Silt correspond with the dates obtained by Dr. Amos for unit C. Therefore, it is likely that unit D is an Emerald Silt equivalent and is genetically related to unit C. This would explain where the fine-grained sediments not present in unit C were deposited. This Emerald Silt equivalent was probably deposited in a marine to shallow marine environment. The main source of the sediment was the sub-aerially exposed glacial outwash plain (unit C). The V or X-shaped reflectors within unit D have been interpreted as iceberg furrows. This means that remnant ice from the Wisconsinan Glaciation was present in this marine environment. This ice protected the fine sediment in unit D from being reworked by wave and current action during this stage. This remnant ice would also contribute minor amounts of sediment to unit D.

The dates obtained by Dr. Amos also show that the contacts between units E and C and between units F and C represent the division between Pleistocene and Holocene times.

It is probable that the rising sea level, caused the sub-aerially exposed outwash plain (unit C) to be drowned. These deposits would then be subjected to wave and current action. The reworking of these sediments would result in a higher degree of sorting and the deposition of this new clean sediment further north. This theory would explain the presence of unit E which is well sorted in respect to unit C. Unit E is composed of predominantly fine sands with the occasional silty layer or fine, medium and coarse sand layer. Unit C is composed of gravels and fine sands.

If unit E represents reworked sediment from unit C, then an unconformable contact between unit E and C would be expected. However if unit E is derived from eolian processes, the conformable contact between unit E and C could be explained. Therefore, it is interpreted that wave action deposited reworked sediments from unit C in a beach environment. These newly acquired beach sediments would be exposed to wind action and result in the formation of dune systems. In general, dune sands are finer, better sorted and more rounded than the source sediments on the adjacent beaches (Davis, 1978). This high degree of sorting would explain why no internal reflectors are observed in unit E. The widespread distribution of unit E infers that these dune systems must have been very extensive. Such a system could only form in areas with sufficient sand supply and wind regime (Van Straatan, 1961). Both of these conditions could have been satisfied during this time.

The relationship between units E and F doesn't appear to be as speculative. Unit F has an unconformable contact with unit E and is made up of inclined internal reflectors. It is also known that unit F makes up either all or part of the ridges found in the northern portion of the survey. Using this information it can be deduced that unit F represents an erosional event which scoured and reworked the sediments of unit E. It also scoured and reworked the sediment of unit C in the central section of the survey area and reworked the sediment of unit D near the shelf edge. The erosion was probably caused by ridge migration which was a result of wave and current action. The inclined internal reflectors are probably remnants of these migrating ridges. Since only the remnants are present in the sourthern portion of unit F, it is probable that the deeper water in this area doesn't allow for the formation of ridges by wave and current action. However, in the northern portion, the water is shallow enough to allow the wave and current action to change the seafloor topography. This means that sea level would have had to be lower in order to form ridges in the southern portion of unit F. This coincides with the information that sea level has been rising since the beginning of Holocene times.

Another interesting observation is that the sediment in unit F (fine sand) is well sorted in comparison to unit C. Therefore using this information and the information concerning ridge migration, the unconformable contacts and the rise in sea level, it is quite likely that unit F represents a transgressive sequence. This means unit F was derived from the reworking of sediment from units C, D and E. Therefore unit E probably extended further south but was reworked as the ridges migrated north.

A study being conducted by Dalrymple (1985) has found that ridges on Sable Island Bank are migrating in an easterly direction. It is also known that large bars are present at the east and west ends of Sable Island. This evidence suggests that longshore transport is occurring off Sable Island. The ridge field is quite extensive, covering approximately one third of the survey area. The extension of the two bars underwater results in a total length of 80 km for the Sable Island structure (Medioli et al., 1967). Therefore, it can be assumed that longshore transport has been occurring for a long period of time, possibly as far back 8,000 y B.P.

Thus far, the paper has dealt with upper four units and how they relate to the final stage of Wisconsin glaciation and the rise in sea level which occurred during Holocene times. Unfortunately the data are insufficient for the units found below units C and D. For this reason it is very difficult to determine the origin of each unit.

Unit B represents a depositional event since it has a conformable, planar contact with unit A. It has no internal reflectors and is overlain by unit C which has channel-like features. It is overlain by unit D south of the shelf edge. Unit B is probably composed of silty sand. This information tells one that unit B was not sub-aerially exposed like unit C. The sediment is more likely derived from the retreating wet-based glaciers. This would explain why no internal reflectors are observed and why the dominant lithology is silty sand. Since unit B is present over the whole survey area, it can be concluded that the Wisconsinan ice shelf must have extended to the shelf edge.

Unit A has lens-shaped internal reflectors at this shelf edge. These reflectors have been interpreted as progradational features. When sediment reaches the canyons at the shelf edge it is deposited in lobes forming a shelf edge delta. This also occurs in the unit below A. The sediment within unit A varies from gravel to fine sand (poorly sorted) and no internal reflectors except for the ones observed at the shelf edge are present in the unit. The sediment could have been derived from wet-based glaciers. Unfortunately, more data are required to verify this theory.

The unit below unit A has continuous to discontinuous wavy internal reflectors which are interpreted as scoured channels. These channel features average 500 m in width and 10 m in depth. They probably formed by fluvial processes or by ice erosion during a low sea level stand. However, more age dating data are required to determine which of these two theories is correct.

An outline of the interpretations made in this chapter is available in Table 2.

Table 2 - An Outline of the Interpretations

UNIT	INTERNAL FEATURES	INTERPRETATION
F	remnants of migrating ridges	represents a transgression which reworked the sediment of units E and C (Holocene)
E	none	represents a transgression which reworked the sediment of unit C to form an extensive dune system (Holocene)
C	channel-like features	represents a sub-aerially exposed outwash plain which formed during the glacial retreat
D	iceberg furrows and planar stratification	an Emerald Silt equivalent which was derived from Unit C and deposited in a marine to shallow marine environment
B	none	derived from a wet-based ice sheet
A	progradational features at the shelf edge	probably derived from a wet-based ice sheet (uncertain)
unit below A	progradational features at the shelf edge and channel-like features	derived from a grounded ice sheet (uncertain)

CHAPTER VI

Proposed Model

By interpreting the seismic and borehole data, a model was constructed for sedimentation on Sable Island Bank during Late Pleistocene and Holocene times. This model incorporates units C, D, E and F but doesn't explain the presence of units found below unit C. The three underlying units are probably glacial in origin where units B and A formed from a wet-based glacier and the unit below A formed from a grounded ice sheet. However more data are required to verify this.

Figure 18 is a series of sketches which represent the proposed history for the outer Scotian Shelf. The sketches are oriented in a north-south direction running from the most northerly portion to the most southerly portion of the survey area. This model has been divided into three stages.

Stage 1 represents the retreat of the Wisconsin ice sheet occurring between 16,000 and 8,000 y B.P. As the ice retreats, glacial run-off results in the accumulation of a sub-aerially exposed outwash plain (unit C). The crescentic reflectors within unit C have been interpreted as channels which are associated with such outwash plain environments. These channels are probably very similar to braided streams because very little fine-grained material is deposited. This fine-grained outwash sediment is transported seaward to a marine environment (unit D). The x and v-shaped reflectors within unit D have been interpreted as iceberg furrows. This indicates that remnant ice from the retreating ice sheet shelters this marine environment. Therefore, the sediment is not reworked by wave and current action. This sheltered marine environment results in the deposition of a well stratified sequence. King and Fader (1985) have calculated that the low sea level stand for the Wisconsin glaciation occurred 15,100 y B.P. After this period, sea level would begin to rise causing the marine environment to encroach the outwash plain environment. This results in a typical transgressive sequence where the marine sediments (unit D) overlie the outwash plain sediments.

The disappearance of the remnant ice in the shallow marine environment signals the beginning of Stage 2 and the end of sediment deposition from the retreating ice sheet. Sea level is continuing to rise during this stage. When the remnant ice is gone, the wave and current action rework the sediment in unit D and portions of unit C which are not sub-aerially exposed. This reworked sediment formed the shoreface detached ridges (unit F) and some of it is transported landward to be deposited in beach-like environments. This reworking by wave and current action results in a well sorted sand. When this newly acquired beach sediment and the sediment of the former outwash plain is exposed to wind action, it is reworked and accumulates in extensive dune systems on land. This explains the presence of unit E which is well sorted and contains no internal reflectors.

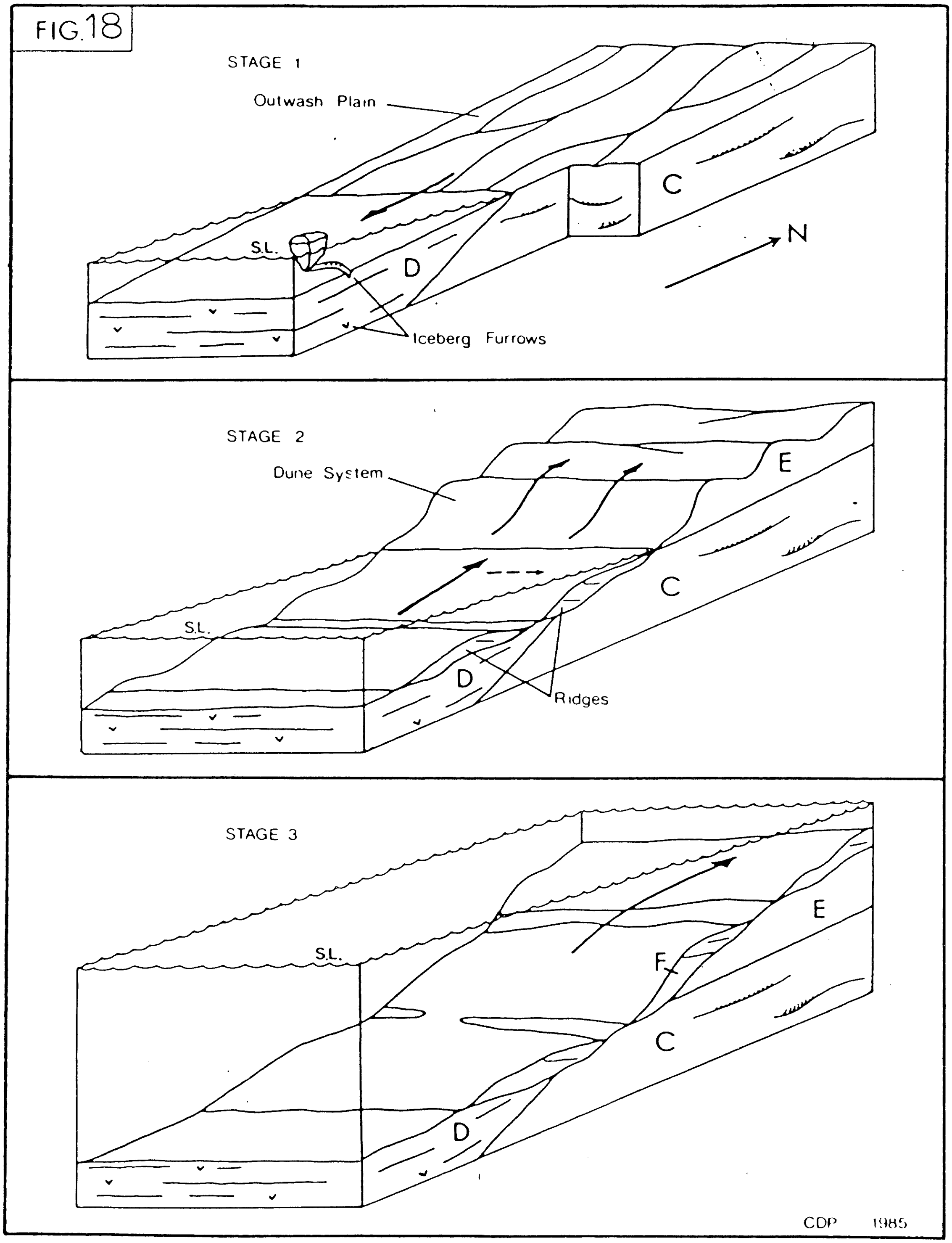
The morphology of Sable Island Bank and the easterly migration of ridges suggest that longshore transport is occurring off present-day Sable Island. It is believed that this longshore transport was also taking place during this stage and stage 3.

Stage 3 represents a continual rise in sea level which drowns the dune system. Wave and current action scour into the dune sediments which have been submerged. This reworked sediment from ridges which migrate landward. This explains the presence of unit F which contains inclined internal reflectors and which makes up all or part of the present day ridges found in the survey area. Therefore it is apparent that unit F is composed of transgressed sands. This erosional event results in an unconformable contact between units F ad E.

The end of stage 3 represents the present day sediment distribution for the outer portion of the shelf where the survey was conducted.

Unfortunately this model doesn't explain the origin of Sable Island. It is inferred that the island is the last emergent point of extensive dune system present in stage 2. However not enough data is available to confirm this.

FIG.18



This is the proposed model for the origin of units C, D, E and F on Sable Island Bank.

CHAPTER VII

Conclusions

7.1 Summary and Conclusions

1) The Wisconsinan ice shelf extended to the shelf edge.

2) Large amounts of sediment were deposited during the Wisconsin glaciation. This high influx of sediment coupled with the gradient of the continental slope resulted in the formation of shelf edge deltas.

3) An outwash plain formed when the Wisconsin ice sheet retreated approximately 16,000 y B.P. The fine-grained sediment from this outwash plain was transported south. It was deposited in a marine environment which was sheltered by remnant Wisconsinan ice. Sea level was rising during this time causing the marine environment to transgress the outwash plain environment.

4) When the remnant Wisconsin ice in the marine environment disappeared, the marine sediments and the submerged outwash plain sediments were no longer sheltered from wave and current action. This wave and current action reworked the sediment and transported it landward where it was deposited in coastal barrier systems. This sediment was then reworked by wind action which resulted in the formation of an extensive dune system.

5) This dune system was eventually submerged by the rising sea

level. Wave and current action reworked this sediment and resulted in the formation of shoreface - connected ridges.

7.2 Suggestions for Future Work

1) Obtain more borehole data and age date the various units to confirm or further resolve the conclusions made in this report.

2) Obtain seismic records which have deeper penetrations. The lower limit of the Wisconsinan glaciation and the processes which occurred during this period of glaciation could be determined using this data.

3) More borehole and shallow seismic data should be collected in the vicinity of Sable Island. With this information, correlations could be made between Sable Island and Sable Island Bank. Therefore the origin of Sable Island could be incorporated into the proposed model in the previous chapter.

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APPENDIX

Observations Along Survey Lines

Line 100 (fix position 524 to 665)

524 to 582 - Huntec data is not available.

524 to 560 - Only the base of unit B is visible on the airgun data.

560 to 590 - Airgun data is not available.

582 - The top of unit A and units B, C and F are visible.

582 to 588 - Unit B is visible but it is difficult to trace unit further due to the poor quality of the record.

587 to 618 - Unit C has a horizontal internal reflector and a few minor inclined internal reflectors.

601 - Unit E begins. The base of the unit is conformable with unit C below. However, the top of unit E is unconformable with unit F above. The base of unit E is difficult to determine but it is inferred using the Huntec external hydrophone data.

608 to 613 - Unit A has an internal reflector which terminates when it intersects the top of unit A. (Progradational Feature?)

609 to 615 - There are two large crescentic (convex downwards) reflectors within unit C.

645 to 665 - Airgun data is not available.

662 to 665 - Huntec data is not available.

Line 101 (fix position 665 to 705)

665 to 705 - Huntec data is not available but the base of unit B and the base of unit A are visible on the airgun record.

Line 102 (fix position 706 to 725)

706 to 713 - Huntec data is not available.

714 - Unit C which was probably not present for a portion of line 101, begins again between units B and D.

714 to 725 - Unit D which was much thicker then unit C before fix position 714 is now approximately 5 to 6 metres thick and overlying unit C.

714 to 725 - Unit C has a large horizontal internal reflector which could be the base of unit C but it is uncertain.

Line 103 (fix position 725 to 754)

726 - Unit D terminates and unit E begins.

729 to 730 - Unit F has inclined internal reflectors and overlies unit C. Unit E terminates at 729 and begins again at 731.

731 to 742 - Inclined, crescentic and horizontal internal reflectors are present within unit C. These are visible on the Huntec external hydrophone record and on the airgun record.

747 to 754 - Generally unit F overlies unit E however unit E is exposed at the sea floor in areas.

Line 104 (fix position 754-778)

754 to 778 - The Huntec external hydrophone record is of poor quality but units E and F are visible.

Line 105 (fix position 778 to 837)

778 to 799 - It is difficult to determine whether one of the reflectors actually represents the base of unit F (top of unit C) or if its just an internal reflector of unit C. A similar problem exists with a reflector below. Does this reflector represent the base of unit C or is it another internal reflector of unit C? Inclined reflectors are also present in the area which is thought to be unit C.

778 to 781 - A small ridge is visible on the seafloor.

800 to 804 - Unit A has an internal reflector which terminates when it intersects the top of unit A at fix positions 800 and 804 (Lens-shaped).

804 to 808 - Three inclined internal reflectors are present within unit F.

810 - Conjectural interpretation suggests the termination of unit C and initiation of unit D at this fix position.

810 to 837 - Small horizontal discontinuous reflectors are present within unit D. In deeper water, small V or X-shaped internal reflectors are visible in unit D.

824 - Unit F terminates.

826 to 837 - There is a difficulty determining the base of unit B on all the records.

830 to 837 - The Huntec external hydrophone data is of poor quality.

830 to 837 - Wavy internal reflectors are present within unit below unit A.

Line 106 (fix position 837 to 848)

837 to 844 - The Huntec external hydrophone data is of poor quality.

Line 107 (fix position 848 to 888)

848 to 857 - Unit A has an inclined internal reflector which terminates when it intersects the lower and upper boundary of unit A. A similar feature is observed in the unit below unit A. Wavy internal reflectors are also present in the unit below unit A.

848 - The lower and upper boundaries of unit B are visible.

855 - Unit F initiates and overlies unit D.

857 to 860 - Unit D thins and terminates at 860. Unit C begins at 857 in such a manner that unit D overlies unit C.

860 to 870 - A horizontal internal reflector within unit A is visible.

861 to 888 - Wavy, inclined and crescentic internal reflectors are present in unit C.

868 to 879 - The base of unit A is visible on the Huntec external hydrophone record.

875 - Unit E begins.

884 to 886 - Unit B terminates at 884 and initiates again at 886. Within this interval, the base of unit C is in contact with the top of unit A. A small ridge is visible on the seafloor at 886.

Line 108 (fix position 888 to 898)

889 - The top of unit A and units B, C, E and F are still visible on the Huntec record.

894 to 898 - The Huntec external hydrophone data is of poor quality.

Line 109 (fix position 912 to 933)

914 to 917 - A ridge is visible on the sea floor.

917 - The top of unit A and units B, C, E and F are visible again. There is also a crescentic internal reflector within unit C.

921 - Unit E terminates.

928 to 933 - Huntec record is of poor quality resulting in a difficulty of determining whether the uppermost unit is unit E or unit F.

931 - A small ridge is present on the seafloor.

Line 111 (fix position 933 to 943)

933 to 938 - A wavy internal reflector is present in unit C.

931 to 941 - A horizontal reflector is present within unit A.

Line 112 (fix position 943 to 964)

944 - The uppermost unit which is either unit E or unit F, terminates.

946 to 956 - A lens-shaped internal reflector is present within unit A.

955 - Unit C terminates and unit D begins in such a manner that unit D overlies unit C.

955 to 964 - Unit D has small discontinuous horizontal internal reflectors and occasionally a V or X-shaped internal reflectors.

<u>Line 113</u> (fix position 964 to 979)

964 to 979 - Internal reflectors within unit A and below unit A are present and continue until 990. These are similar to the ones seen between 848 and 857.

<u>Line 114</u> (fix position 979 to 999)

983 to 989 - An internal reflector within unit A terminates when it intersects the top of unit A at fix positions 983 to 989. This lens-shaped feature is similar to the one observed in Line 112.

987 - Unit F begins.

988 - From the internal hydrophone data it appears that unit D terminates and unit C begins in such a manner that unit D overlies unit C.

988 to 999 - The contact between units B and C and between units C and F are unconformable. The contact between units A and B is planar and conformable.

995 to 997 - Horizontal and crescentic internal reflectors are present in unit C.

Line 115 (fix position 999 to 1011)

1001 to 1003 - Unit C has wavy internal reflectors.

1002 to 1009 - A ridge is visible on the seafloor.

Line 116 (fix position 1011-1042)

1017 to 1032 - Unit F thins and averages about 1 metre thick.

1020 - Unit E begins. Also wavy internal reflectors are present in the unit below unit A.

1032 to 1042 - The Huntec external hydrophone record is of poor quality.

fix pos.	thicknesses in metres A (red)	B (or.)	C (gr.)	D (blue)	E (pink)	F (yell.)	B + C
0524							
0525							
0526							
0527							
0528							
0529							
0530							
0531							
0532							
0533							
0534							
0535							
0536							
0537							
0538							
0539							
0540							
0541							
0542							
0543							
0544							
0545							
0546							
0547							
0548							
0549							
0550							
0551							
0552							
0553							

fix pos.	thicknesses in metres A (red)	B (or.)	C (green)	D (blue)	E (pink)	F (yell.)	B + C
0554							
0555							
0556							
0557							
0558	14.0						
0559	14.3						
0560	15.7						
0561	16.1						
0562							
0563							
0564							
0565							
0566							
0567							
0568							
0569							
0570							
0571							
0572							
0573							
0574							
0575							
0576							
0577							
0578							
0579							
0580							
0581							
0582		12.5	4.4	0	0	5.7	16.9
0583		12.0	5.0	0	0	5.8	17.0

	thicknesses in metres								thicknesses in metres						
fix pos.	A (red)	B (or.)	C (gr.)	D (blue)	E (pink)	F (yell.)	B + C	fix pos.	A (red)	B (or.)	C (green)	D (blue)	E (pink)	F (yell.)	B + C
0584		12.4	5.0	0	0	5.2	17.4	0614				0	6.5	1.8	28.8
0585		12.5	4.8	0	0	5.3	17.3	0615				0	6.2	2.6	28.3
0586		12.3	5.7	0	0	5.0	18.0	0616				0	6.0	3.2	28.5
0587		10.7	7.1	0	0	5.0	17.8	0617				0	5.4	3.8	29.5
0588		7.0	11.4	0	0	4.8	18.4	0618				0	6.1	4.7	29.0
0589				0	0	3.8	19.8	0619				0	6.5	4.5	30.0
0590	33.5			0	0	5.0	19.0	0620				0	5.0	6.0	30.5
0541	32.5			0	0	3.9	20.5	0621				0	6.0	5.5	30.5
0592	32.5			0	0	4.1	20.0	0622				0	7.0	5.3	31.5
0593	32.5			0	0	4.0	20.7	0623				0	7.2	5.0	32.5
0594	32.0			0	0	4.7	20.4	0624				0	8.0	5.0	32.0
0595	31.5			0	0	5.0	20.6	0625				0	10.2	3.0	32.5
0596	33.0			0	0	4.6	21.7	0626				0	10.5	4.0	32.0
0597	31.5			0	0	3.6	23.4	0627				0	9.0	5.0	31.8
0598	31.0			0	0	4.1	23.1	0628				0	10.5	3.9	33.0
0599	31.0			0	0	4.0	24.0	0629				0	12.7	2.5	32.0
0600	32.0			0	0	4.3	24.0	0630				0	11.0	2.8	33.5
0601				0	1.3	2.0	25.5	0631				0	9.5	3.0	34.5
0602				0	2.1	1.5	25.5	0632				0	10.3	2.5	35.1
0603				0	2.2	2.2	26.0	0633				0	10.2	3.0	35.2
0604				0	2.2	2.8	26.0	0634				0	10.8	2.5	36.0
0605				0	2.5	3.0	25.0	0635				0	11.0	2.4	36.8
0606				0	4.5	1.4	25.3	0636				0	10.5	3.7	37.0
0607				0	5.0	1.2	25.3	0637				0	10.5	2.6	37.5
0608				0	5.2	1.2	24.7	0638				0	12.0	3.5	37.5
0609				0	4.7	1.5	25.5	0639				0	10.5	5.5	37.5
0610				0	4.8	2.0	25.0	0640				0	12.0	4.0	37.0
0611				0	5.0	2.6	24.8	0641				0	13.6	1.8	38.0
0612				0	4.0	3.8	24.5	0642				0	13.8	2.0	37.0
0613				0	5.0	3.8	26.5	0643				0	13.5	2.9	37.0

	thicknesses in metres								thicknesses in metres						
fix pos.	A (red)	B (or.)	C (gr.)	D (blue)	E (pink)	F (yell.)	B + C	fix pos.	A (red)	B (or.)	C (green)	D (blue)	E (pink)	F (yell.)	B + C
0644				0	13.5	2.5	37.0	0674							
0645				0	14.8	2.0	36.0	0675							
0646				0	13.9	2.0		0676							
0647				0	12.3	2.7		0677							
0648				0	11.8	3.0		0678							
0649				0	12.0	3.2		0679							
0650				0	11.5	3.0		0680							
0651				0	11.8	1.5		0681							
0652				0	8.8	3.0		0682							
0653				0	8.9	3.3		0683							
0654				0	10.0	2.3		0684	17.0						
0655				0	8.5	2.5		0685	16.2						
0656				0	6.8	3.8		0686	16.0						
0657				0	7.5	3.0		0687	16.0						
0658					7.0	4.4		0688	15.0						
0659					7.1	5.0		0689	14.8						
0660					7.7	3.0		0690	15.0						
0661					8.9	2.0		0691	15.5						
0662						1.8		0692	15.0						
0663								0693	15.5						
0664								0694	16.0						
0665								0695	15.5						
0666								0696	16.0						
0667								0697	16.5						
0668	18.5							0698	16.0						
0669								0699	16.0						
0670								0700	16.5						
0671								0701	14.5						
0672								0702	14.5						
0673								0703	13.5						

	thicknesses in metres								thicknesses in metres						
fix pos.	A (red)	B (or.)	C (gr.)	D (blue)	E (pink)	F (yell.)	B + C	fix pos.	A (red)	B (or.)	C (green)	D (blue)	E (pink)	F (yell.)	B + C
0704	13.5							0734				0	7.0	3.0	34.3
0705	12.5							0735				0	5.3	5.0	34.3
0706	12.8							0736				0	5.1	5.8	33.7
0707	13.5							0737				0	6.4	4.6	33.5
0708	15.0							0738				0	8.0	4.0	34.0
0709	17.0							0739				0	8.5	3.0	36.2
0710	16.0							0740				0	10.2	2.2	36.5
0711	16.0							0741				0	10.3	2.0	38.3
0712	16.0							0742				0	10.3	3.3	40.2
0713	18.0		0	12.0	0	0	35.0	0743				0	7.0	6.2	42.6
0714	19.0			7.0	0	0	44.0	0744				0	8.7	6.2	45.5
0715	20.0							0745				0	15.6		42.8
0716	18.8							0746				0	15.5	0	42.8
0717	19.5			5.2	0	0	45.2	0747				0	15.2	0	43.0
0718				5.3	0	0	44.0	0748				0	15.0	2.4	44.0
0719				4.7	0	0	44.2	0749				0	17.0	.7	44.5
0720				5.8	0	0	43.2	0750				0	17.5	2.0	45.0
0721				6.2	0	0	42.5	0751				0	19.0	2.3	43.6
0722				5.8	0	0	41.0	0752				0			42.8
0723				5.6	0	0	41.5	0753				0	22.5	0	39.5
0724				5.5	0	0	43.0	0754				0	24.3	0	37.2
0725				5.3	0	0	43.2	0755				0	25.5	0	36.7
0726				4.8	0	0	41.7	0756				0	24.5	1.2	35.5
0727				0	2.2	3.8	39.8	0757				0	25.0	1.2	34.0
0728				0	2.5	4.3	40.3	0758				0		2.0	
0729				0	0	7.5	40.7	0759				0	25.5	2.5	32.4
0730				0	0	8.0	40.0	0760				0	25.0	1.5	30.5
0731				0	4.0	5.0	36.0	0761				0	24.0	0	28.5
0732				0	5.0	4.7	34.3	0762				0	20.5	0	26.7
0733				0	6.0	4.0	34.6	0763				0	22.0	1.5	25.8

	thicknesses in metres								thicknesses in metres						
fix pos.	A (red)	B (or.)	C (gr.)	D (blue)	E (pink)	F (yell.)	B + C	fix pos.	A (red)	B (or.)	C (green)	D (blue)	E (pink)	F (yell.)	B + C
0764				0	23.2	2.2	25.0	0794				0		2.5	
0765				0	25.0	2.5	23.7	0795				0		1.8	
0766				0	24.5	3.0	24.5	0796				0		4.0	
0767				0		4.5		0797				0		4.7	
0768				0		4.7		0798				0		4.2	
0769				0		2.5		0799				0		5.0	
0770				0	26.0	0	27.5	0800				0	0	8.0	23.0
0771				0	24.3	0	28.0	0801				0	0	8.0	21.0
0772				0	21.5	0	26.0	0802				0	0	8.3	20.5
0773				0	19.5	1.2	21.7	0803				0	0	5.0	25.0
0774				0	19.8	3.0	19.7	0804				0	0	4.0	30.3
0775				0	21.5	1.0	18.7	0805				0	0	5.7	27.9
0776				0	21.5	1.9	19.5	0806				0	0	7.8	26.3
0777	21.5			0	17.3	0	19.5	0807				0	0	8.0	25.8
0778	22.5			0		0		0808				0	0	6.8	25.7
0779	25.0			0		4.7		0809				0	0	5.3	28.0
0780	24.5			0		5.2		0810			0	10.3	0	3.0	
0781	25.0			0		2.0		0811			0	11.3	0	4.2	
0782	26.5			0		4.0		0812	35.5		0	14.0	0	3.3	
0783	28.0			0		3.8		0813	33.5		0	15.0	0	2.5	
0784	28.5			0		2.0		0814	33.5		0	13.4	0	2.8	
0785	29.0			0		3.3		0815	35.0		0	12.4	0	3.3	
0786	29.5			0		2.8		0816	33.5		0	14.7	0	2.0	
0787	29.5			0		2.5		0817	35.5		0	15.0	0	1.5	
0788				0		2.0		0818			0	15.0	0	1.8	
0789				0		5.0		0819			0	14.9	0	1.5	
0790				0		2.0		0820			0	13.8	0	1.3	
0791				0		3.0		0821			0	14.0	0	1.6	
0792				0		1.5		0822			0	14.5	0	1.0	
0793				0		2.8		0823			0	15.0	0	1.2	

fix pos.	A (red)	B (or.)	C (gr.)	D (blue)	E (pink)	F (yell.)	B + C
	thicknesses in metres						
0824	30.0		0	17.2	0	0	
0825	31.0		0	17.9	0	0	
0826	30.5		0	19.0	0	0	
0827	29.0		0	18.0	0	0	
0828	27.7		0	18.8	0	0	
0829	25.5		0	17.0	0	0	
0830	23.7		0	16.0	0	0	
0831	22.5		0	16.0	0	0	
0832	23.0		0	18.0	0	0	
0833	21.0		0	18.3	0	0	
0834	18.0		0	17.7	0	0	
0835	17.5		0	18.8	0	0	
0836	17.0		0	18.8	0	0	
0837	18.0		0	19.5	0	0	
0838	18.5		0	19.0	0	0	
0839	20.0		0	19.5	0	0	
0840	22.0		0	18.7	0	0	
0841	23.0		0	18.5	0	0	
0842	23.5		0	18.5	0	0	
0843	24.5		0	17.2	0	0	
0844	26.0		0	17.0	0	0	
0845	27.0		0	16.0	0	0	
0846	26.7	14.0	0	15.5	0	0	
0847	28.7	12.5	0	14.7	0	0	
0848	31.5	10.7	0	14.2	0	0	
0849	36.0	9.6	0	14.0	0	0	
0850	40.0	7.8	0	14.0	0	0	
0851	38.5	6.5	0	13.5	0	0	
0852	37.0	5.8	0	14.2	0	0	
0853	36.0		0		0	0	

fix pos.	A (red)	B (or.)	C (green)	D (blue)	E (pink)	F (yell.)	B + C
	thicknesses in metres						
0854	34.5	5.5	0	10.8	0	1.1	
0855	33.5	5.4	0	10.2	0	1.0	
0856	33.0	5.8	0	10.0	0	2.0	
0857	32.0	5.2	4.8	4.5	0	3.0	10.0
0858	32.0	6.1	5.0	4.0	0	3.1	11.1
0859	33.0	7.2	5.1	2.7	0	3.6	12.3
0860	33.0	8.7	7.2	0	0	5.0	15.9
0861		9.5	8.5	0	0	6.7	18.0
0862		6.8	8.7	0	0	7.7	15.5
0863		7.2	7.0	0	0	9.3	14.2
0864		7.3	7.0	0	0	10.0	14.3
0865		7.3	8.0	0	0	8.9	15.3
0866		7.7	8.8	0	0	6.5	16.0
0867		9.0	7.4	0	0	4.0	16.4
0868	29.5	5.6	12.2	0	0	0	17.8
0869	28.8	8.8	9.0	0	0	1.4	17.8
0870	29.0	10.5	7.1	0	0	4.5	17.6
0871	29.9	10.0	6.8	0	0	5.2	16.8
0872	30.0	8.8	8.0	0	0	4.2	16.8
0873	30.6	8.8	7.5	0	0	3.8	16.3
0874	31.4	8.9	8.2	0	0	3.9	17.1
0875	31.4	9.5	6.6	0	3.0	1.8	16.1
0876	30.6	10.6	5.4	0	5.0	0	16.0
0877	31.0	11.3	4.9	0	4.6	0.3	16.2
0878	30.9	10.9	5.3	0	0.5	5.4	16.2
0879	31.0	9.1	7.9	0	3.7	3.0	17.0
0880	32.5	8.8	8.9	0	4.2	2.8	17.7
0881	32.5	7.8	8.5	0	3.8	4.5	16.3
0882	32.5	6.1	9.7	0	4.6	4.6	15.8
0883	32.0	6.0	9.2	0	7.5	3.0	15.2

	thicknesses in metres								thicknesses in metres						
fix pos.	A (red)	B (or.)	C (gr.)	D (blue)	E (pink)	F (yell.)	B + C	fix pos.	A (red)	B (or.)	C (green)	D (blue)	E (pink)	F (yell.)	B + C
0884	32.0	4.3	11.8	0	9.2	3.0	16.1	0914	8.0			0	16.0	0	17.5
0885	31.5	0	16.8	0	9.0	4.3	16.8	0915				0	15.0	3.0	15.5
0886	31.5	0	18.8	0	9.6	5.4	18.8	0916	20.0			0	11.8	5.3	15.5
0887	28.0	7.2	11.0	0	10.0	1.0	18.2	0917	11.0	9.0	7.0	0	10.1	2.2	16.0
0888		11.9	6.3	0	11.6	0	18.2	0918	15.0	4.5	11.0	0	9.0	0	15.5
0889		13.2	5.4	0	11.0	1.0	18.6	0919	17.0	4.7	10.5	0	8.2	0	15.2
0890		11.5	6.0	0	10.8	2.1	17.5	0920	16.0	6.2	10.8	0	3.4	2.0	17.0
0891		9.8	7.6	0	13.0	3.0	17.4	0921	16.0	6.8	11.0	0	0	3.0	17.8
0892		10.8	8.0	0	13.1	4.3	18.8	0922	15.5	2.0	15.4	0	0	4.3	17.4
0893					16.4	2.4	18.7	0923	15.0	0	17.3	0	0	2.2	17.3
0894					17.5	2.8	18.5	0924	15.0	0	17.6	0	0	1.4	17.6
0895						2.3	19.0	0925	14.8	0	17.7	0	0	1.3	17.7
0896						.5	20.0	0926	14.0	4.3	14.0	0	0	1.7	18.3
0897							19.5	0927	15.0	8.0	11.1	0	0	2.3	19.1
0898							19.5	0928	15.5	8.0	10.0	0	0	3.0	18.0
0899							19.5	0929	15.5						
0900							19.0	0930	16.0						
0901							19.0	0931	17.5						18.0
0902							19.0	0932	16.5						18.0
0903							18.8	0933							16.5
0904							19.6	0934							16.2
0905					16.5	2.3	17.5	0935		0	14.4	0			14.4
0906					18.0	5.0	17.0	0936		0	13.2	0			13.2
0907							17.0	0937		3.7	9.0	0			12.7
0908					16.0	0	18.0	0938		8.4	4.8	0			13.2
0909					18.3	1.5	17.2	0939		10.4	2.5	0			12.9
0910					18.7	4.8	17.0	0940		6.0	6.0	0			12.0
0911					18.5	2.5	16.5	0941		9.4	4.6	0			14.0
0912					16.2	1.0	17.0	0942		8.5	4.5	0			13.0
0913	13.0				15.2	0	18.0	0943		6.4	5.4	0			11.8

	thicknesses in metres								thicknesses in metres						
fix pos.	A (red)	B (or.)	C (gr.)	D (blue)	E (pink)	F (yell.)	B + C	fix pos.	A (red)	B (or.)	C (green)	D (blue)	E (pink)	F (yell.)	B + C
0944		10.6	5.0	0			15.6	0974		21.0	0	11.5	0	0	
0945		9.0	9.0	0	0	0	18.0	0975		17.8	0	12.2	0	0	
0946		12.2	7.0	0	0	0	19.2	0976		16.5	0	12.5	0	0	
0947		14.5	6.5	0	0	0	21.0	0977		15.0	0	12.8	0	0	
0948		16.3	5.3	0	0	0	21.6	0978		15.0	0	12.0	0	0	
0949		15.8	6.0	0	0	0	21.8	0979		17.5	0	10.0	0	0	
0950		13.5	8.2	0	0	0	21.7	0980		19.5	0	7.3	0	0	
0951		17.5	4.0	0	0	0	21.5	0981		21.7	0	5.2	0	0	
0952		17.0	4.3	0	0	0	21.3	0982		22.0	0	5.7	0	0	
0953		17.0	4.5	0	0	0	21.5	0983		22.0	0	5.6	0	0	
0954		18.3	5.0	0	0	0	23.3	0984		17.0	0	7.0	0	0	
0955		21.0	5.3	0	0	0	26.3	0985		11.8	0	8.0	0	0	
0956		26.0	3.0	1.5	0	0	29.0	0986		12.3	0	6.0	0	0	
0957		27.8	0	3.0	0	0		0987		12.8	0	5.0	0	0	
0958		28.8	0	4.8	0	0		0988		12.5	1.8	2.0	0	2.3	14.3
0959		30.5	0	7.3	0	0		0989		12.0	4.4	0	0	3.9	16.4
0960		31.5	0	9.7	0	0		0990		12.5	3.0	0	0	5.7	15.5
0961			0	10.5	0	0		0991		9.6	4.5	0	0	7.3	14.1
0962			0	9.3	0	0		0992		9.5	5.0	0	0	6.8	14.5
0963			0	8.3	0	0		0993		8.3	6.8	0	0	6.3	15.1
0964			0	9.5	0	0		0994		9.5	4.8	0	0	7.0	14.3
0965								0995		8.0	7.8	0	0	5.8	15.8
0966								0996		4.7	11.2	0	0	6.5	15.9
0967								0997		5.0	12.0	0	0	7.0	17.0
0968								0998		6.2	8.7	0	0	7.0	14.9
0969			0	10.8	0	0		0999		6.0	10.8	0	0	2.0	16.8
0970			0	10.3	0	0		1000		4.0	11.8	0	0	2.3	15.8
0971			0	10.8	0	0		1001	28.5	5.7	8.0	0	0	4.8	13.7
0972			0	10.4	0	0		1002	29.0	5.0	6.5	0	0	8.0	11.5
0973		23.0	0	11.0	0	0		1003	28.5	4.7	7.0	0	0	10.3	11.7

fix pos.	thicknesses in metres A (red)	B (or.)	C (gr.)	D (blue)	E (pink)	F (yell.)	B + C
1004	27.0	4.2	9.2	0	0	14.3	13.4
1005	26.0	4.8	10.5	0	0	13.0	15.3
1006	26.5	5.4	11.5	0	0	10.0	16.9
1007	25.0	8.7	9.5	0	0	6.0	18.2
1008	25.5	4.5	11.8	0	0	5.0	16.3
1009	25.5	4.3	10.0	0	0	0	14.3
1010	25.0	0	8.4	0	0	0.7	8.4
1011	24.5	0	7.8	0	0	3.2	7.8
1012	23.0	0.8	9.0	0	0	3.4	9.8
1013	24.0	5.5	5.0	0	0	4.0	10.5
1014	23.5	8.2	2.9	0	0	6.0	11.1
1015	21.0	8.4	3.2	0	0	5.0	11.6
1016	21.0	8.1	3.4	0	0	4.0	11.5
1017	22.0	8.0	5.0	0	0	0	13.0
1018	21.5	8.0	4.8	0	0	1.0	12.8
1019	17.5	8.0	5.7	0	0	0.7	13.7
1020	19.0	6.8	7.4	0	0	1.0	14.2
1021	17.0	7.0	7.8	0	2.2	0.7	14.8
1022	18.5	5.0	10.5	0	4.0	1.2	15.5
1023	19.0	0	15.5	0	8.5	1.0	15.5
1024	16.0			0	10.4	1.0	16.0
1025	15.8			0	11.2	0.5	15.5
1026	15.0				12.2	0.5	16.0
1027	16.5				13.0	0.7	15.0
1028	17.0				14.0	1.0	15.0
1029	20.0				14.8	3.7	14.5
1030	21.8				16.0	4.0	14.8
1031	23.5				16.8	0.7	14.0
1032	22.5				17.6	0.7	15.0
1034					17.3	2.7	15.3

fix pos.	thicknesses in metres A (red)	B (or.)	C (green)	D (blue)	E (pink)	F (yell.)	B + C
1034					20.0	3.0	15.0
1035					21.0	5.0	14.3
1036					21.1	5.2	14.3
1037					24.0	1.5	14.5
1038					26.0	0	13.5
1039					26.0	0	15.5
1040					28.2	2.3	
1041					28.3	0	
1042					26.7	1.8	