

OFFSHORE LABRADOR

BOTTOM SURVEY REPORT

August 1972

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## I. INTRODUCTION

The difficulties encountered in the 1971 drilling campaign in Labrador due to the presence of boulders causing considerable delay in the setting of the first casing has put the accent on this very problem and the East-can Group decided to proceed with a bottom survey aiming:

- (1) to experiment with "sparker type" devices giving a good resolution of the overburden on the Labrador Shelf
- (2) to map boulders on specific drilling locations if this device was giving good and reliable results.

## PREVIOUS WORK

The overburden of the Labrador Shelf has already been studied from 1965 to 1969 by the Bedford Institute in collaboration with Tenneco Oil and Minerals and most of the results have been gathered in Dr. A. C. Grant's thesis: "The Continental Margin off Labrador and Eastern Newfoundland - Morphology and Geology" (Ref. 1).

Most of the geophysical data were collected using repetitive source single channel seismic profiling systems:

Sparker 200 J in 1965  
Sparker 9000 J in 1966  
1 inch<sup>3</sup> airgun in 1967  
10 inch<sup>3</sup> airgun in 1968  
10 inch<sup>3</sup> airgun in 1969.

The location of this shallow seismic coverage (as well as the 1971 and 1972 surveys) is shown in Enclosure 1.

Since 1969, Tenneco conducted limited sparker and analog sources surveys around specific locations.

In 1970, Dr. McMillan of Tenneco and Dr. Bidgood of Nova Scotia Research Foundation used a Huntac Hydrosonde System and a Simrad Echo Sounder to detail three locations named Area 1 (Leif), Thorvald, Area 4. The results of this survey are contained in a report by Dr. McMillan and Dr. Bidgood "Report on the Sparker Survey off North East Newfoundland September 1970" (see Ref. 2).

Good information was obtained in regard to the bathymetry, and the Huntac sounding device provided a strong bottom reflection suggesting a rather compact and covering the bedrock surface. However, nothing could be seen below the bottom reflection (as far as bedrock outcrop).

In 1971, Dr. McMillan, assisted by Dr. Bidgood, Dr. Murray, Associate Professor of Oceanography UBC, and Mr. David Franz, President of ORE, conducted another bottom survey around Leif, Bjarni and Thorvald locations.

The following equipment was used:

1. ORE Model 1036 Echo Sounder
2. EGG Boomer (1000 joules single plate)
3. EG & G Sparker (3000 to 5000 joules) 1 electrode pulsing every two seconds.

The areas surveyed were:

1. Leif (around the P-84 well site)
2. Thorvald
3. Bjarni
4. finally, a test line was recorded from Bjarni, traversing south along the Labrador Coast, east to the Bulldog Islands, to the north of the Hamilton Inlet and terminating twelve miles west of L-38 well site.

The purpose of the survey was to provide as much detail as possible on the upper 200 feet of strata in the vicinity of the Leif P-48 drilling location after the unsuccessful attempt by the drilling ship Typhoon to set casing due to the presence of "boulders" within 50 feet of the sea bottom. This survey was also to investigate the relationship of the Leif E-38 surface stratigraphy with that of the P-38 location.

The results of the campaign are contained in a report written by Dr. Murray and Mr. V. Lovoi, District Geophysicist of Tenneco (see Ref. 3).

The EGG Boomer gave insufficient acoustic output and most of the data were obtained with the ORE and EG & G Sparker Instruments. The results were inconclusive in terms of defining the presence or absence of boulders. The aspect of the records was quite similar in each individual area suggesting a uniform cover of glacial till containing numerous boulders.

In the same year, the Bedford Institute carried out an extensive survey using a 40 inch<sup>3</sup> airgun on the Labrador Coast and the Baffin Bay area. Location of the lines are shown on Enclosure 1.

### 1972

Following the experience of the previous surveys and the recommendations of the geophysicists involved in them, Eastcan took the opportunity of the Leif well head detection survey to run at Leif and Thorvald locations a bottom survey with the task of locating boulder areas.

The idea was:

- (1) to try a high resolution source towed at a depth close to the sea bottom
- (2) to use a side-scan sonar for a picture of the bottom topography in connection with the detection of the E-38 well head
- (3) to try a small airgun as recommended by Dr. Murray
- (4) to go on the other side of the scale and use a high energy sparker (up to 24,000 joules).

The survey was done in collaboration with the Bedford Institute and the Nova Scotia Research Foundation, using the "Newfoundland Hawk" a 1000 ton trawler chartered from Bonavista Cold Storage Company in St. John's, Newfoundland.

On board were

- (1) Dr. A. C. Grant AGC - Bedford Institute
- (2) Mr. V. Coady AGC - Bedford Institute
- (3) Mr. Michel C.G.G. (Toran Operator)
- (4) Mr. Martiner, C.G.G. (Side scan sonar and sparker operator)
- (5) Dr. D. E. T. Bidgood - Nova Scotia Research Foundation
- (6) Mr. D. Prentice - Nova Scotia Research Foundation
- (7) Mr. G. de Lombares - Eastcan Exploration Ltd.

The total survey including Leif well head detection was conducted between August 9th and August 29th. Work was done on both Leif and Thorvald sites with more extensive testing done on Leif. One traverse was extended about 60 nautical miles NW from Leif. Appendix "A" describes the time sequence of the operations, and Enclosure 1 shows the location of the survey among the preceding ones.

II. COMMENTS ON THE OPERATIONS (See Appendix "A" for details)(1) Newfoundland Hawk

This ship was a very suitable boat for this kind of operation and, except for some troubles in the main engine, (which nevertheless cost us two days) has provided adequate support for all the electronics and the winching involved in this kind of survey. (This ship was also used to bring Toran and Tellurometer equipment respectively to Cartwright and Saglek). It took three days to install all the necessary connections for the different recording equipment and a day to demobilize the ship.

(2) Toran Positioning System

The success of the well head detection was mainly due to the accuracy and the repeatability of the Toran System

The Toran coordinates of the well-head observed in 1971 were:

A = 5380.85  
B = 5192.26

The Toran coordinates of the well-head found this year were:

A = 5380.91  
B = 5192.32

which gives, if the propagation velocities were the same this year, an accuracy of:

13.2 meters in A network  
13.2 meters in B network.

The localization of the well in 1971 was made aboard a supply ship with the proper correction to the drilling ship and we could not exactly locate in 1972 the position of the echo sounder transmitter, with which the well head was finally found, with regards to the position of Toran antenna. We nevertheless consider the repeatability to be excellent.

Note: The one and only problem with the Toran system is the lane identification. Once one plans to work in a specific area, one should moor a buoy which is going to be used for lane identification as soon as the signal is lost because of atmospheric interferences, breakdown of the land station, etc.

Two days were lost due to lane identification problems.

Another way to solve this problem of lane identification is to fly with a plane or a helicopter to "bring" the lane to the ship, but this is much more expensive and subject to weather conditions etc..

Sparker 24,000 Joules

This instrument could not be operated due to deficiencies in the high voltage circuitry, etc..

Side Scan Sonar

Although it took several days to have the proper recording parameters set up, most of the information of the campaign was recorded with this instrument.

It was nevertheless very important:

- (1) to have the fish at a critical distance from the bottom
- (2) in order to keep the fish at this critical depth, to sail at low ship speed, the maximum length of cable available with this instrument being 2000'
- (3) to balance continuously the gain of the receivers.

A report about the theory of the side scan sonar and its interpretation has been put in Appendix "B".

### Airgun 1 inch<sup>3</sup>

#### Equipment and Operational Procedures

Apart from test apparatus and spare components the basic profiler system comprised the following:

Ingersoll-Rand Air Compressor, Model 15T4XD  
Bolt Associates PAR airgun, Model 600B (2)  
Bolt firing circuit, Model FC-1  
Alpine Hydrophone (9 elements x 20')  
Alpine Pre-Amplifier, Model 505A  
Hewlett-Packard Tape Recorder, Model 3960  
Krohn-Hite Band Pass Filter, Model 330NR  
E.P.C. Graphic Recorder, Model 4100.

The above units compose a standard profiling system as used by the Bedford Institute over the past several years. As the aim of the present survey was to achieve optimum resolution rather than necessarily deep penetration, the receiving components of the seismic system were selected to yield good response to high frequencies and the energy source was operated at rapid firing rates (0.5, 0.75, 1.0 sec.) with small firing chambers (1 - 5 cu. in.). Air pressure to the firing chamber was maintained at approximately 1800 psi. Tow distances (astern) to air-gun and hydrophone averaged 50' and 200' respectively, the latter streamed from a short boom off the starboard quarter. Seismic returns were recorded on magnetic tape, unfiltered, and on dry paper record in a frequency interval about 100-600 cps. Exact firing and recording parameters are noted on the paper recordings.

With occasional minor difficulties the seismic profiler system functioned properly throughout the survey period. Concurrent operation with the side scan sonar proved difficult from this particular survey vessel due to the excessive noise level at slow towing speed (2-3 knots). This condition has been observed in the past as a characteristic of vessels with variable-pitch propellers; as speed increases to 4 knots or so the propeller noise diminishes rapidly to "normal" levels. Concurrent operation with the N.S.R.F. "V-Fin" system proved entirely feasible, and yielded interesting results.

A series of closely spaced, parallel survey lines were run over both the Leif and Thorvald proposed drilling sites. A broader, radial survey pattern was also run from the Leif site, a N-S tie-line was run between Leif and Thorvald, and a seismic traverse was extended approximately 60 nautical miles NW from Leif (Encl. 2).

#### Nova Scotia Research Foundation "V-Fin"

The equipment and its characteristics are fully described in Appendix "C".

We must mention that we were using a prototype and the only usable records that we have acquired were gathered with the sparker source firing at .5 second intervals and a single crystal hydrophone.

Nevertheless, it is possible to see clearly the definition obtained by the device and although the lack of power of the sparker (165 joules) did not permit penetration more than several feet, we think that as mentioned in Appendix "C" the entire device could be improved to achieve at the same time proper resolution with a penetration of some 50 feet.

Another limitation of this prototype system is its relative instability. The V-Fin varies in height by  $\pm$  50 feet depending on the ship's speed and heading, giving a corresponding change in the position of the record over a period of minutes. It should be possible to use the output from the V-fin depth sensor to remove electronically this apparent depth variation from the record to allow maximum use of the available resolution and penetration.

#### POSITIONING

The Toran readings of the line fixes are in Appendix "D".

### III. RESULTS

#### AIRGUN

##### Seismic Profiles: Enclosures A<sub>1</sub> to A<sub>7</sub>

The quality of the seismic profiler results from the present survey is generally comparable to results obtained from previous seismic traverses in this region. The seismic character of the surficial deposits in the Leif-Thorvald area appears to be consistent with the premise that the Labrador Banks are blanketed by glacial drift. Reflectors within the surficial layer are weak, discontinuous, and irregular. Although it is difficult to identify the base of these deposits, presumably because of lack of substantial velocity contrast with the underlying bedrock, no apparent relationship exists between the configuration of the bedrock surface and irregularities of the sea floor. While the impression prevails that bottom irregularities reflect depositional vagaries, it has not been possible thus far to establish reliable criteria for identifying individual or concentrated boulder occurrences within the surficial layer.

#### LEIF AREA

The seismic profiler interpretation of the Leif area has been derived chiefly from traverse No. 2 (Enclosure A<sub>2</sub>) which comprises a series of lines radial to the Leif E-38 well site (Encl. 4). A bathymetric diagram drawn from these profiles (Encl. 5) shows regional slope to the N.E., however, the configuration of contour closures on specific highs and lows is highly speculative. Presumed bedrock reflectors can be traced with reasonable continuity from below depths of 60-100' (apparent) sub-bottom, which is accordingly taken as the approximate thickness of overburden. As determined from points of line intersection and course alteration the reflective layers in bedrock strike about NW-SE and dip (apparent) NE approximately 25' per nautical mile (0.25 degrees).

The E-W seismic traverses in the Leif area (Enclosures A<sub>1</sub> and A<sub>4</sub>, Enclosure 3) have been examined in conjunction with enclosure A<sub>2</sub> in deriving the tentative interpretation outlined above. Enclosure A<sub>7</sub>, which extends 60 nautical miles NW from the Leif area, is a valuable addition toward compiling a regional interpretation of the surficial geology of the Hamilton Bank, but it does not contribute greatly to the present detailed survey. It proves, however, that the character of surficial deposits is variable on a regional scale, and that major areas of the Hamilton Bank may be devoid of other than ice-rafted boulders.

In conclusion, as more or less anticipated, the one cubic inch airgun system did not provide adequate resolution of individual or concentrated occurrence of boulders. Nevertheless the records (whose reproduction is poor, we admit) seem to indicate a 60-100' thickness of unconsolidated deposits.

#### Bathymetric Map (Enclosure 6)

The airgun records were used, with proper offset adjustment and integrated with previous surveys in the tentative drawing of a bathymetric map on the Leif Site. The contours have been drawn on a 10' interval, taking into account discrepancies at the intersections of the lines.

This map shows a regional slope to the north east with a possible lower area on the NE side of the well head.

THORVALD AREA (Enclosure 7)

The seismic records from the Thorvald area (Enclosure A6) appear to be among the best obtained during the survey. A smooth reflector - presumably a bedrock layer - was observed on all traverses at an apparent depth in the order of 150' sub-bottom. The strike and dip of this layer are similar to the bedrock attitude determined for the Leif area. A shallower, relatively flat reflector occurs fairly consistently at a depth of 50' - 60' sub-bottom. This event is tentatively picked as the bedrock surface. Bottom relief with respect to this event accordingly reflects variations in thickness of overburden. As in the Leif area, very few coherent reflectors are apparent within the surficial deposits.

The bedrock event identified throughout the Thorvald area can be carried northward on line No. A5 (Enclosure A5) to its termination approximately two miles east of seismic lines in the Leif area. Character correlation of this event with a bedrock reflector in the Leif area appears credible. Possibly the overburden layer thickness to the north on line No. A5, which agrees at least qualitatively with the estimated thickness of 50-60' in the Thorvald area vs. 60-100' in the Leif area.

Bathymetric Map (Enclosure 8)

The records were used in a similar way to tie with 1970 data to produce a tentative water depth map in this area. As opposed to regional slope to the NE in the Leif area the bathymetric diagram compiled from Thorvald traverses shows regional slope to the SE. Also, physiographic anomalies appear to be identifiable from traverse to traverse, and depth values contour quite logically with strong NE-SW trends.

GEOLOGICAL SAMPLING

Samples of bottom sediment were collected in the Leif area by a VanVeen grab sampler at the ten locations marked on Enclosure 3. Core samples were also taken from the M. V. Hudson Handler with the Hyco "slack line coring device".

Inspection of grab samples when collected indicated little variation from grey-brown sandy mud or muddy sand, containing granules and occasional pebbles. Core samples were finer grained - clayey, with pebbles some large enough to jam in the drill barrel. The behaviour of the drill as monitored from the control panel suggested that several feet of surface material may have been jetted aside before core began to lodge in the barrel. The tilt recorder indicated an irregular bottom surface.

CONCLUSIONS

Results from seismic profiling and geologic sampling can be summarized as indicating 50-100' (apparent) of glacial drift in the Leif Thorvald area, with a thin cover of fine sand. Unless local depressions occur in the bedrock surface which are not apparent from seismic profiling, the extreme depth of boulder occurrence

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logged at Leif E-38 should perhaps be viewed in terms of caving. It is stressed, however, that the overburden/bedrock interface is difficult to define by conventional seismic profiling, and no criteria have yet been established for estimating boulder content of the surficial deposits.

Conventional seismic profiling nonetheless establishes a useful framework for evaluating side scan sonar and deep tow "sparker" data.

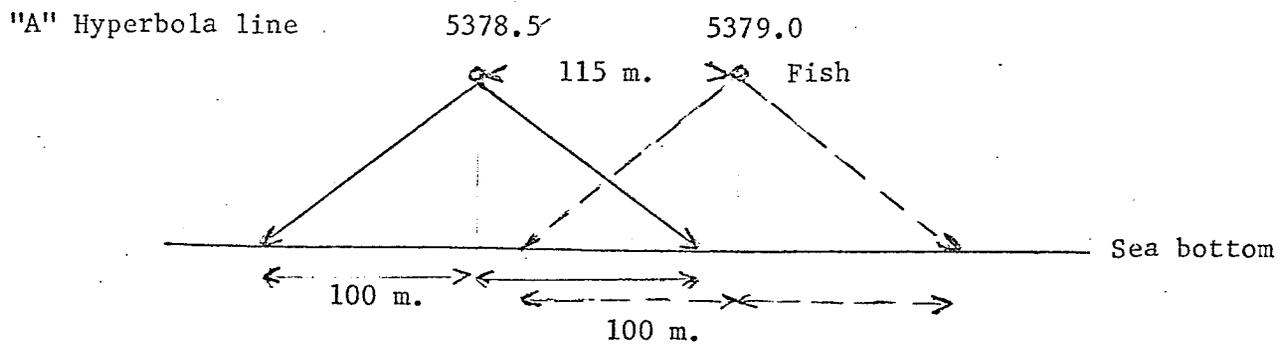
The water depth maps are an attempt to integrate all the data available. All the data lack accuracy (especially data from sparker and airgun) and consistency. If one wants good water depth maps in the drilling areas, one has to plan carefully a hydrographic survey with appropriate equipment, eg., good narrow beam fathometer and Toran positioning.

SIDE SCAN SONAR

Enclosures S <sub>1</sub> to S <sub>21</sub>	Side scan sonar records, Leif
Enclosures S <sub>22</sub> to S <sub>29</sub>	Side scan sonar records, Thorvald
Enclosures S <sub>30</sub> to S <sub>48</sub>	Statistical analysis of the scours, Leif
Enclosures S <sub>49</sub> to S <sub>64</sub>	Statistical analysis of the scours, Thorvald

The side scan sonar lines have been run every half 'A' hyperbola in the Leif area, that is every 115 meters and every hyperbola in Thorvald, i.e. every 230 meters.

In the Leif area, the scale chosen for the side scan sonar (with the exception of a few lines) was 300' (around 100 meters).



According to the above figure the area has been almost covered twice. We must note an overlap of 50% on the records and this helped a great deal to distinguish between real and symmetrical echos, produced by side arrivals or by electric mixing involved in the circuitry of the EG & G side scan sonar.

In the Thorvald area, only single coverage has been recorded with less side arrival effects.

The offset of the fish with respect to the TORAN antenna has been computed as approximately 1900' by using the same echo recorded on two paths with opposite directions. For convenience it has been assumed constant throughout the entire survey.

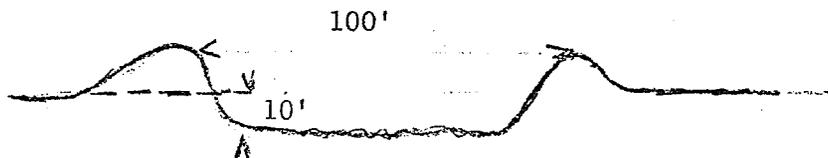
Only major features have been picked as shown on the records attached to this report (Enclosures S<sub>1</sub> to S<sub>29</sub>). They have later been corrected and plotted on a map (Enclosure 9 for Leif and Enclosure 10 for Thorvald). We experienced some difficulties in mapping these features due to the uncertainty about the position and the orientation of the fish which was towed some 1900' behind the boat. The position of the Toran aerial on the boat is known with an accuracy of a few meters while the position of the fish is known to approximately 50 meters on both sides of the towing line. We emphasize that only the major features have been picked. A lot of them have been voluntarily discarded to simplify the interpretation, especially those in saturated (very heavily marked) areas or circular or shapeless marks. We have concentrated our picking on parallel straight marks which resemble very closely those discovered in the Beaufort Sea by the Bedford Institute in 1970 (Ref. 4). We will anticipate the conclusion assuming that the marks correspond probably to scours made by large icebergs. Unlike the Beaufort Sea we do not think that they have been made by pressure ridges. Some marks have been identified as being anchoring cables and others as scours made by ripping anchors and cables during the 1971 drilling campaign. Some wellhead locations have been identified in particular E-38. We do not believe that some scours have been made by military or fishing devices, but this possibility must not be excluded for the time being.

As said above, Enclosures 9 and 10 show the marks picked on the records after having made proper corrections. We have used three different colours, mainly for quick identification purposes; the widest tracks being red, then green and the narrowest ones being blue.

As already mentioned we have not plotted the circular or shapeless marks which might correspond to a "kiss" of an iceberg. Most often the scours are linear or curvilinear, some keeping the same width while others change width in a very short distance (grounding effect?).

The length of the scours varies and can be as long as several kilometers.

We have tried to reconcile the "V" fin records with the side scan with the purpose of getting an indication on their depth. The circled numbers on the maps of Enclosures 9 and 10 refer to probable scours identified on the "V" fin records. The depth of the scours does not seem to exceed 10-12' in Leif and 15' in Thorvald.



Typical cross section of a common iceberg scour.

#### STATISTICAL ANALYSIS OF THE SCOURS

We have tried to study in a little more detail the width and the orientation of the scours (see Enclosures S30 to S64). To this purpose we divided each individual scour into elements 50 meters long whose width and orientation have been measured. The width increment was 5 meters and the orientation increment  $22^{\circ}30'$  to fit with a 16 point of direction compass card.

For each of the two areas studied we drew two series of diagrams:

##### 1. Ice scour width distribution

Enclosures S30 and S49 show the distribution of all the picked scours with regard to their width plotted on the horizontal axis. The scale used on the vertical axis was the total length of scours expressed in kms.

Enclosures S31 to S42 and S50 to S57 show the width distribution as a function of the orientation N-S for instance for Enclosures S31 and S50, NNE-SSW for Enclosures S32 and S51 etc...

The total length (on the vertical axis) is expressed in meters.

##### 2. Ice Scour Orientation Distribution

This set of diagrams, Enclosures S39 to S48 for Leif and S58 to S64 for Thorvald correspond to another representation of these width/orientation relationships: we used polar coordinates to build a 16 point windrose.

## RESULTS

From these statistics we realize that most of the scours in Leif area are within the 15-30 meters width range with two nearly perpendicular orientations: NNW-SSE and NE-SW.

In Leif area we have the impression that for 10 and 15 meters width the orientation is N-S, for 20 meters there is no perpendicular orientation and then beyond 20 meters width the orientation is NE-SW.

It is interesting to note that a width of 30 meters corresponds to the scour made by the grounding of a spherical iceberg in a soft bottom in 185 meters of water, the depth of the scour being approximately 1 meter. (See Appendix E.) These conditions are the ones encountered at Leif and Thorvald locations.

For Thorvald area the width of the scours are within the 15-40 meter range with 2 orientations, N-S and NE-SW but our statistics are less reliable there than for Leif (too little information).

## INTERPRETATION

Instead of drawing conclusions, we will limit our ambition to asking questions that arise when one looks at the maps.

### (a) Nature of the tracks

It is fascinating to see how straight and regular some of the tracks can be. One may just wonder how an iceberg, whose path is influenced by so many factors such as wind, current, etc.. can make such a straight scour.

If not by icebergs, could scours be caused by pressure ridges such as mentioned by Dr. Pelletier and Dr. Shearer in their findings in the Beaufort Sea (Ref. 4)? Pressure ridges seem to be present in water up to 50 meters deep. In our case, one would have to admit that the sea level was at least 130-150 meters lower at the time these tracks were made.

Sheppard and Curray (Ref. 5) mention worldwide sea level as being around 100 meters lower at the peak of the Wisconsin glaciation times (Ref. 6 also).

It is important to note too that these physiographic features do not seem to be very deep (10-12' in Leif, 15' in Thorvald as mentioned earlier), and that they seem to fit with the ploughing that a spherical iceberg would make. It can also be possible that these scours could be old and partially filled up.

### (b) Age of the Scours

The sedimentation rate may be a clue to the age of the scours. We have no data for the time being and we can just rely on guesses. If we assume that the sedimentation rate in our area is not negligible: 1 to 3 meters/1,000 years for instance. Let us assume that some scours still visible were originally 1 meter deep. We know that theoretically with such a hole with 1 meter of original relief it might take more than 3 meters of sediment to completely bury it. With a fast sedimentation rate of 3 meters/1,000 years we arrive at an age of 1,000 years and thence we can assume that all the scours visible today would have been made in the last 1,000 years.

(c) Frequency of the Scours

The area surveyed at Leif represents roughly 10 square kilometers while the total area of the scours mapped covers 1.5 square km. Let us assume that we have mapped only one third of all the scours. In other words let us suppose that the scours have ploughed roughly half of the surveyed area in the last 1,000 years. That means that a small structure located at random on our map has roughly a 50% chance to be hit in 1000 years.

In other words the probability of a structure not to be hit is 50% in 1,000 years and  $\frac{1000}{50} \sqrt{0.5} = \frac{20}{\sqrt{0.5}} = 2.5\%$  in 50 years.

This assumption is valid for an area taken at random but if we look into the detail we notice that some areas have been practically untouched during that period of time (NE portion of the Leif map for instance). If we compare this map with the water-depth map we may observe that this virgin area corresponds to a deeper place protected by some small undulations where icebergs ground because of their draft. The few scours entering this virgin area have in fact a westerly direction where there is no seaward protection. The comparison of the Thorvald side scan sonar interpretative map with the water-depth map of the same area confirms this observation.

The possibility of an old glacial landscape with scours made by glaciers and/or icebergs connected to the Labrador ice cap is remote but not impossible. We must remember that the ice flow in Cartwright during the last glaciation had probably a north-eastern or eastern direction. If one of these NE or E scours have such origin, our frequency estimates have to be revised towards the safe side; the probability of an impact with an iceberg being for instance once every 10,000 years or more.

In conclusion, without knowing too much about the age even the nature of these physiographic features, it is fair to say that they are not very deep, certainly less deep than the ones observed in the Beaufort Sea. The frequency of their occurrence seems to be related in some way to minor topographic changes of the sea bottom as shown on the Leif area. It should not be difficult to protect a structure at the bottom of the sea by digging a hole of let us say 20' and the chances of the structure being hit by an iceberg would be extremely slim.

Nova Scotia Research Foundation "V" Fin Enclosures V<sub>1</sub> to V<sub>7</sub>

As mentioned previously, the "V" Fin results have been gathered on two recorders giving different appearances to the records: the EPC Model 4100 providing the longer time scale where it is possible to see both arrivals from the sea floor and from the air-water contact; the Huntec M2A where it is possible to see only the arrivals from the sea-floor.

In looking at the records we must not take the "A" curve as the sea floor profile. The records depict the travel time of sound waves between the "V" Fin and the sea floor and obviously reflect any depth variation of the "V" fin. At the present stage they permit only a qualitative analysis of the nature of the sea floor.

It is possible to see that in the Leif area the penetration did not exceed a few feet, but some changes in character could reflect some change in the nature of the bottom, namely in the boulder content.

We think that proper improvement can be made on the "V" fin system in order to increase the penetration and this is going to be one of the recommendations of this report.

On the other hand, the "V" Fin records have been very helpful in giving a third vertical discussion to the ice scourings detected by the side scan sonar.

Although it is difficult to evaluate the respective location of the "V" Fin and of the side scan sonar fish (they were run at different times with different speed etc..) we think we have recognized some of the scouring and have put numbers on the records which correspond to numbers on the scouring maps, both in Thorvald and in Leif. In the majority of the time, the scouring on the "V" Fin records correspond to something seen on the side scan sonar records but it is not always the case. This could be explained by the difference in location mentioned above or by variation in depth by the two fishes.

Nevertheless, it has provided us with some measurements on the depth of this scouring which do not seem to exceed 10-12' in Leif area and 15 feet in Thorvald area (see anomaly 8 on line 4400 in the Thorvald area).

#### IV. CONCLUSION

The principal task of this bottom survey was to experiment with a tool able to give a good resolution of the overburden on the Labrador Shelf.

Although we must admit that we did not completely achieve it, we have succeeded in getting enough encouragement to pursue studies in a deep tow Sparker type arrangement.

In order to get resolution and penetration in areas of thick boulders the Sparker system should send a signal of high frequency (of the order of a few KHz) and must be very contracted. At the same time the firing rate must be fast, of the order of 250 ms.

We feel confident a stabilized and improved "V" Fin system after having reached these characteristics could provide a satisfactory solution to our problem.

There will always be one problem, inherent to any system towed at a great distance behind a ship, that is, the exact localisation of the fish with respect to the ship.

The Bedford Institute's 1 cubic inch air gun system did not give the adequate resolution we were asking for, but enough penetration to more or less delineate the base of the unconsolidated sediments, believed to be around 100' in the Leif area, compared to 60' in the Thorvald area.

It showed on a regional basis the changes in thickness of the glacial material, but was unable to delineate the very local variations for which we were looking.

The outstanding result of the combined survey was the detection by side-scan sonar of iceberg scours on the sea floor. It is equally important that the deep-tow "sparker" detects these scours in profile, and reveals their depth and degree of infilling. Comparison of these results with surface-tow profiles of the sea bottom is a sharp reminder of the "smoothing" inherent in the latter. The character of iceberg scours seems to bear some relationship to bathymetric trends.

In the Thorvald area the resolution of iceberg scours is much sharper in the western portion of the survey where water depth seems shallowest; to the east, the side scan records have "a mottled" or "blotchy" aspect, which gives some impression that ice scours may be present but subdued in expression due to burial by younger sediments. In the Leif area, the apparent trough shown by the bathymetry in the NE part of the area seems to show less scours than the other part of the area. This may be explained in terms of scouring by moving to water depths exceeding its draft.

The relative age of intersecting scours is usually apparent from the cutting relationship at their point of intersection. The absolute age of ice scours is a much more difficult and critical question, as it bears upon whether icebergs pose a threat to sea-bottom installations such as wellhead, pipelines, etc.. Reports that grounded icebergs have been observed on the outer banks off Labrador should be carefully examined, as this would suggest that ice-scouring is a contemporary process rather than an artifact of lower sea-level in the past. The direct approach to establishing the minimum age of iceberg scours would appear to require age determinations on samples of the sediments infilling the scour depressions. Apart from limitations inherent in dating techniques the reliability of this approach would depend largely on the precision of sampling.

Assuming that an average sedimentation rate could be established by sampling the age of scours might be estimated from acoustic measurement of the sediment thickness covering the scour feature. Presumably the occurrence of scours vs depth could then be evaluated to determine whether scours in deeper water may date from periods of lower sea level.

The effectiveness of applying sedimentation rates as outlined above will depend upon the degree of understanding regarding the present and past sedimentary regime of the bank areas of the Labrador Shelf. The dominant trend of ice-scours in the Thorvald area coincides with the trend of physiographic axes as presently contoured. Possibly this coincidence reflects a prevailing current direction affecting both berg and sediment transport.

Assuming that bottom scouring by icebergs is a contemporary process on the Labrador Shelf, the survey of these features for the practical considerations referred to above should probably concentrate on assessing their physical dimensions and occurrence with respect to local and regional physiography and the nature of surficial deposits. It seems that the maximum depth for iceberg scouring seems not to exceed 15' and this will likely dictate the minimum depth of burial necessary to achieve a protected situation for long term bottom installations.

#### V. RECOMMENDATIONS

1. Future surveys to assess the character of surficial deposits and the extent of bottom scouring by icebergs should include systematic regional coverage, at least on the scale of the individual banks comprising the outer Labrador Shelf. Such coverage is vital to furnish detailed bathymetry and establish glacial and post glacial sedimentary regimes as settings for detailed surveys. The instrument used could be an improved, stabilized "V" fin system.
2. It would be certainly very useful to combine in the same instrument side scan sonar with one or more seismic systems.
3. A conventional echo-sounder should be operated throughout all surveys as a convenient base for compiling all sounding data.
4. Intensive sampling program should follow definitions of regional frame-work.

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- Reference 6: Milliman, J. D., and Emery, R. O. 1968. Sea Levels during the Past 35,000 years. Science 162 pp 1121-1123.

LIST OF ENCLOSURES

- (1) Shallow Seismic Coverage.
- (2) Airgun General location map - August 1972.
- (3) Airgun location map - Leif Area.
- (4) Airgun location of Traverse 2 - Leif Area.
- (5) Bathymetry - Leif Area (from Traverse 2 lines)
- (6) Bathymetry around Leif location.
- (7) Airgun location map - Thorvald Area.
- (8) Bathymetry around Thorvald location.
- (9) Side Scan Sonar Interpretation Map - Leif Area.
- (10) Side Scan Sonar Interpretation Map - Thorvald Area.

APPENDIX A

TIME SEQUENCE OF 1972

BOTTOM SURVEY OPERATIONS

August 9: Sailing out of St. John's Newfoundland.

August 10: Sailing to Cartwright.

August 11: 11H30 Arrival Cartwright for Toran calibration.  
Toran coordinates of calibrating point  
A = 5708.47  
B = 4571.80  
Installation of a battery and charger for  
the Toran systems.  
Recordings on board: A = 5708.72  
B = 4564.75.

August 12: 4H45 Sailing towards Leif.  
Verification of Toran when crossing the base  
line A.  
Theoretical A 5760.26. Observed A 5760.25.

10H40 Marine Engine valve broken. Return to  
Cartwright.

14H-15H Setting up of side scan sonar on the way.  
Difficulty encountered in lowering the fish  
at 4 knots. The speed would have to be  
reduced.

15H15 Crossing base line A.  
Observed A: 5760.26 OK:

16H20 Arrival Cartwright. Valve being temporarily  
repaired by Frank Kelly.

August 13: 5H20 Leaving Cartwright sailing to Leif.  
A network perturbed by magnetic storms.

6H15 Channel buoy, Cape 4072.  
A: 5759.99 15 m starboard  
B: 4588.75

6H20 Crossing A base line extension.  
Observed A: 5760.24.

7H00 Values read when crossing the northern tip  
of Long Island: A: 5374.60  
B: 4714.50.

11H30 -  
17H50 Preparation and setting of side scan sonar.  
Side scan lines run:  
5381.00 W-E  
5380.50 E-W  
5380.50 (bis) W-E  
5381.00 E-W  
5381.00 W-E  
5381.00 E-W  
5381.50 E-W

19H30-21H40 Magnetometer survey on the presumed locations of Leif

Line 5380 W-E  
Line 5380.50 W-E  
Line 5381.00 E-W

21H40-22H30 Rough seas. Sailing towards buoy for Toran calibration.

August 14: 4H35 Sailing towards buoy (1 hour east of Cartwright)

6H00 Theoretical A 5759.99 Observed A 5759.99  
B 4588.75 B 4588.75

7H50 Route towards Leif - Rough sea. Main engine not working properly. Decision to sail back to Cartwright.

11H10 Arrival in Cartwright  
Repair of side scan sonar.  
Preparation of a buoy to be moored on Leif site.

19H45 Sailing to Leif.

20H55 Crossing A base line.  
Observed A 5760.25

August 15: 3H00 Exploitation of side scan sonar.  
Side scan sonar lines:  
5381.00 W-E  
5380.50 E-W

8H45 Toran network A not functioning. Sailing to Cartwright for calibration of network A.  
Nova Scotia Research Foundation hydro-sonde at sea. Different tries at sea (depth, speed of towing, etc..) without any precise localization.

18H00 Crossing A base line.  
Observed A 5760.31

18H05 Calibration at buoy.  
Observed A 5760.15 Theoretical A 5759.99  
B 4588.87 B 4588.75

We were approximately 50 meters north of the buoy, this explains the difference in A network.

August 16: 0H15 B network perturbed by atmospheric waves.

0H35 B network not functioning.

1H30 Side scan sonar. Exploitation with A network only. Leif well head echo found. Checking with ship echo sounder.

2H35 Sailing to Cartwright.

8H35 Calibration A base line  
A = 5760.25.

10H00 Arrival in Cartwright  
Meeting with Hudson Handler.

August 17: 4H00 Leaving Cartwright

13H00 Arrival at Leif location

13H30 Mooring of a buoy just on the presumed well head.

14H00 Side Scan sonar lines:

	5380	E-W
	5379.50	W-E
	5379.00	E-W
	5378.50	W-E
Bedford line	5377.50	W-E
5379.00 W-E	5377.00	E-W
	5378.00	E-W (bis)
	5377.00	W-E

16H30 Starting of Air gun  
Bedford Institute Airgun 1 inch<sup>3</sup>.

23H15 Exploitation of Bedford air-gun  
Star pattern around Leif (see Bedford location map)

August 18: 7H15 End of Bedford air-gun survey.

8H00 Exploitation of NSRF Hydrosonde and air-gun.

NSRF lines:

5380.50	Sparker + hydrosonde
5379.50	Sparker + streamer
5377.0	Sparker + depth sounder receiver
5377	Sparker + streamer
5377 (bis)	Sparker + streamer
5379.50	Sparker + depth sounder receiver.

All of the lines recorded on Huntec 2A recorder

18H45 End of survey.

20H15 Calibration over Leif well head  
A = 5380.90  
B = 5190.31

It is important to note that 2 hyperbolae were lost during the trip from Cartwright to Leif and were checked on the way back. The coordinates of Leif should be A = 5380.90, B = 5192.31.

August 19: 5H10 Toran calibration over well head  
A = 5380.89  
B = 5190.33

6H10 Side scan sonar in operation.

## Side scan sonar lines run:

5376.50 E-W  
 5381.25 W-E  
 5381.50 E-W  
 5382.00 W-E  
 5382.50 E-W  
 5383.50 E-W  
 5383.00 W-E

16H30 End of side scan sonar survey.

17H00 Calibration on well head

17H30 -

24H00

Exploitation of Bedford Airgun and NSRF  
 Hydrosonde

Line 5378.00 Sparker + single hydrophone  
 5377.50 Sparker + single hydrophone  
 5377.00 Sparker + single hydrophone

Recorded on Huntec Mark 2A

Line 5380 Sparker + single hydrophone  
 5379 Sparker + single hydrophone  
 5384 " "  
 5380 " "  
 5386 " "  
 5374 " "

Recorded on EPC recorder.

August 20:

9H00

Toran calibration on well head.

13H00

Exploitation of Hydrosonde + airgun

Lines:

5378 E-W Mark 2A recorder  
 5377.50 W-E Mark 2A recorder  
 5377.00 E-W  
 5378.50 W-E Mark 2A recorder  
 5379.00 W-E  
 5379.50 E-W EPC Recorder  
 5380.00 W-E EPC Recorder

21H10

End of airgun and hydrosonde survey.

August 21:

5H25

Toran calibration on well head

5H30

Experiment with sparker  
 The sparker did not work.

15H00

Experiments with Pinger receiver - successful.  
 Reception at about 1.5 miles.

18H15

Sailing toward the Thorvald site.  
 Exploitation of one hydrosonde line 5449.00  
 Rough sea. Returning to Leif to escort  
 Hudson Handler back to Cartwright.

August 22:

11H00

Toran calibration at Long Island.

A = 5734.60

B = 4714.50.

11H30

Sailing towards Leif and Thorvald  
 Marine engine valve of Newfoundland Hawk  
 broke down.

August 25:	3H30	Bad weather waiting on Hudson Handler.
August 26:		Bad weather. Dr. A. C. Grant and G. de Lombares transfer to Hudson Handler. Waiting on weather.
August 27:	18H00	Sailing to Thorvald.
	20H15	Waiting for Hudson Handler on Thorvald site.
	23H00	Sailing to Cartwright.
August 28:	0H15	En route to Cartwright. Exploitation NSRF Hydrosonde.
	8H15	End of survey.
	10H35	Arrival at Cartwright. Toran calibration OK.

16H00 Arrival at Leif. Toran calibration on well head.

18H15 Sailing to Thorvald.

19H00 Exploitation of NSRF Hydrosonde and Bedford Airgun.

Lines:

5444	E-W
5445	W-E
5446	E-W
5447	W-E
5448	E-W
5449	W-E
5450	E-W
5451	W-E

August 23: 2H20 End of NSRF Hydrosonde and Bedford Airgun Survey.  
Sailing toward Leif for Toran calibration.

7H45 Toran calibration on well head  
Waiting for Hudson Handler.

12H15 Sailing to Thorvald.

12H50 Exploitation of side scan sonar.

Lines run:

5451	E-W
5450	W-E
5449	E-W
5448	W-E
5447	E-W
5446	W-E
5445	E-W
5444	W-E

21H40 End of survey.

23H15 Toran calibration on Leif well head.

August 24: 00H00 North of Leif.

7H00 End of survey

8H00 Toran calibration on Leif well head

8H12 Waiting for Hudson Handler re diving.

14H00 The seismic ship "Andromede" is passing by.  
Sampling around the different Leif locations.

G <sub>2</sub> : A = 5380.35	B = 5189.80	(92 fathoms)
G <sub>3</sub> : A = 5380.21	B = 5190.78	"
G <sub>4</sub> : A = 5381.12	B = 5193.21	(93 fathoms)
G <sub>5</sub> : A = 5382.25	B = 5193.75	(92 fathoms)
G <sub>6</sub> : A = 5382.12	B = 5193.20	(93 fathoms)
G <sub>7</sub> : A = 5380.90	B = 5191.25	"
G <sub>8</sub> : A = 5377.49	B = 5188.35	(93 fathoms)
G <sub>9</sub> : A = 5377.48	B = 5187.77	( " )
G <sub>10</sub> : A = 5376.91	B = 5187.90	(92 fathoms)
G <sub>11</sub> : A = 5378.77	B = 5189.28	"

17H45 Exploitation of NSRF and Bedford airgun en route to Bjarni.

## APPENDIX B

### THEORY AND INTERPRETATION OF THE SIDE SCAN SONAR SYSTEM

#### PRINCIPLE

The side scan sonar is an acoustic system used to distinguish topographic features of the sea bottom and objects on or above sea floor.

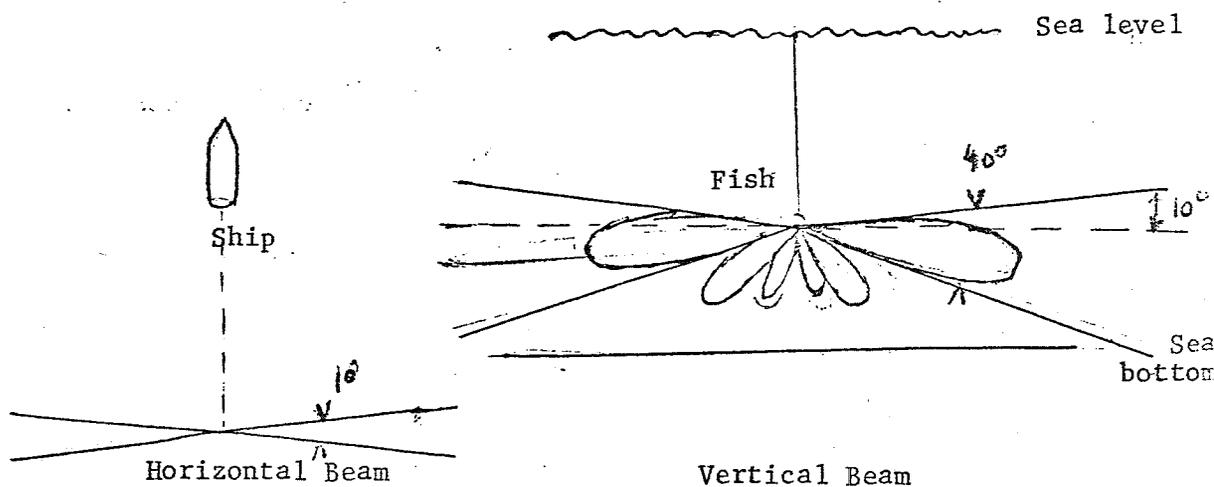
It is mainly made of

- 1) a stable towed transducer, mechanically decoupled from the hull to reduce distortion caused by vessel roll, pitch and yaw. This transducer sends a very high frequency signal (105<sub>-</sub> Khz in our case) of small length (0.1 ms in time).
- 2) an array of piezo-electric crystal receivers which transmit the recorded signal through preamplifiers to a:
- 3) dual channel graphic recorder permitting range scale of 250' 500' and 1000' each side. In some cases the signal can be magnetically recorded.

The beam is contained in a vertical plane perpendicular to the south followed by the ship.

Its horizontal opening is 1° only.

Its vertical beam is 40° tilted down - see figure (amplitude more than 3 db)



At any moment the transducer investigates in a vertical plane the relief and the aspects of the sea bottom.

When the signal encounters such an object like a rock or object on the sea floor, this object diffuses the energy backward in every direction and some of it reaches the fish receiver at a time after the start of signal transmission  $\frac{2D}{V}$ ,  $D$  is a distance transducer-object and  $V$  is propagation velocity in the sea water.

In the case of the instrument used in the 1972 survey the recorder automatically transforms the time scale into a distance scale using a velocity of 1500 m/s.

Analysis of the Records

If one looks at a side scan record, one may see from the centre of the record (Fig. B<sub>1</sub>):

- 1) a dark line representing the impulsion
- 2) a zone without any signal representing the travel in the water
- 3) the first signal is usually the vertical reflection from the bottom of the sea and the grey zone represents the response from the bottom of the sea in the vertical plane perpendicular to the fish.

The echos are represented by a dark zone showing sometimes a white zone corresponding to the shadow of the reflecting object.

- 4) The lines parallel to the course of the boat are the scale lines.

The total scale (10 divisions) can be 250, 500 or 1,000 feet (each side).

In our case we have recorded in 500 and 1,000 foot scales.

N.B. 1: When the fish is immersed at a certain depth it is possible to see at the upper and lower part of the record the air-water reflection. It is then possible to deduct the depths of water from this reflection and the distance fish-bottom.

N.B. 2: In very many cases it is possible to observe a repetition of the starboard side echos on the port side. This is due to electronic mixing of the signals received in the recorder and one should adjust the gain of each channel in order to eliminate this symmetry.

In the case of the 72 survey, symmetry was observed on most of the records but the double coverage of each line helped to sort out real objects from the symmetrical images.

N.B. 3: The diffusion coefficient depends on the nature of the sea bottom and some dark spots could be interpreted as changes in its nature more than in specific echos.

Interpretation

The purpose of the interpretation is to position as exactly as possible the different echos observed on the records.

(a) Along the course of the Boat

In the case of a detailed survey like ours, the boat is positioned by an accurate electro-magnetic device, such as Toran, Loran, Raydist and it is important to know the offset along the course.

- one way to do it is to run the same line (usually a positioning lane) in two directions and identify the same echo in both ways.

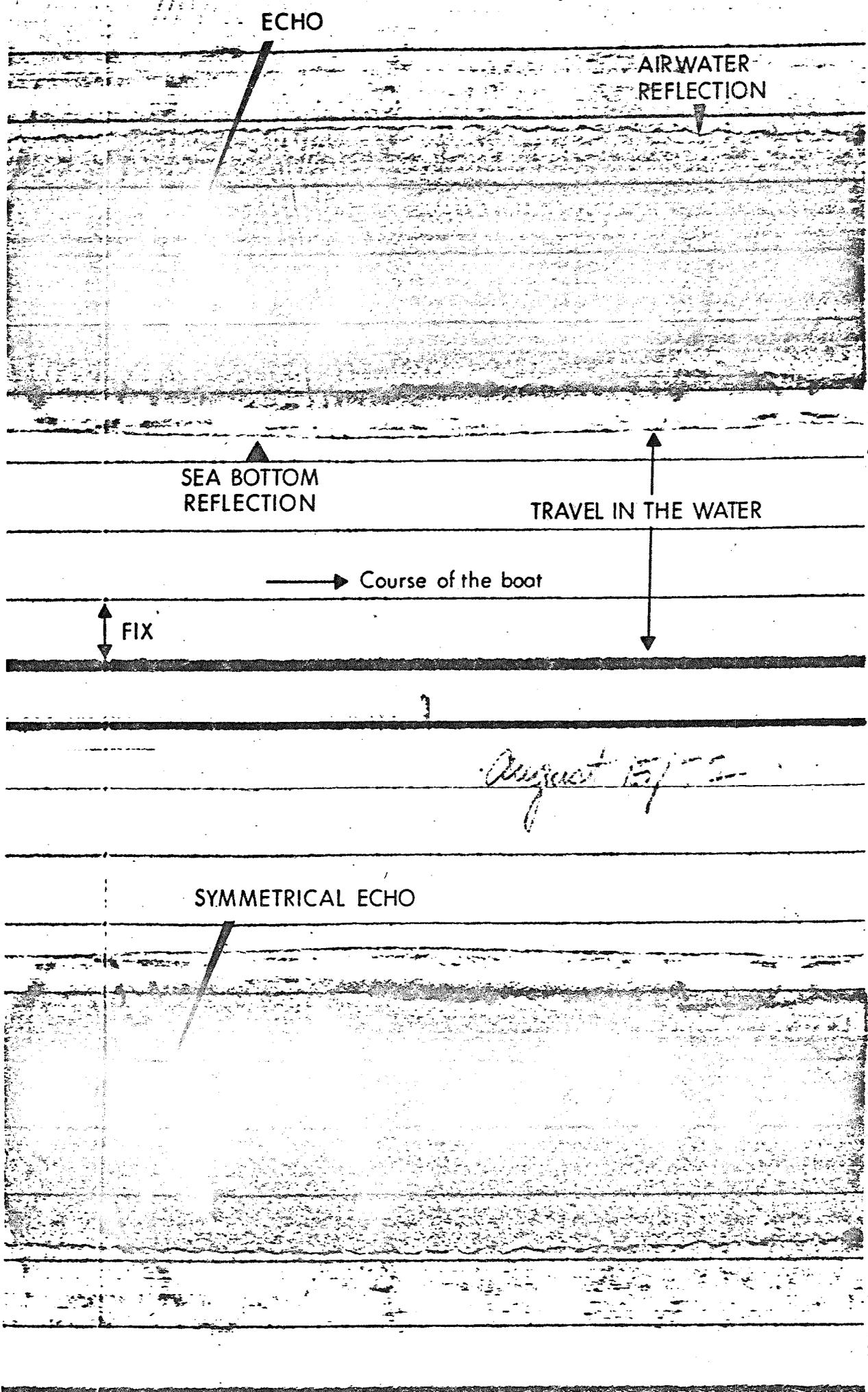
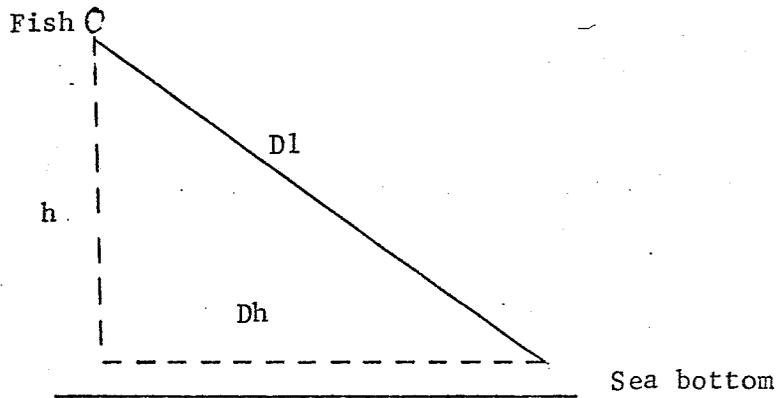


FIG. B<sub>1</sub>

EXAMPLE OF SIDE SCAN SONAR RECORD.  
 LINE 8050 E - W , AUG. 15, 1972.

- another way is to read a chart which computes the offset versus depth at different speeds but this involves a good knowledge of the ship speed, which is not usually the case.

(b) Perpendicular to the course of the Boat



According to the above figure,  $D_1$  is recorded by the instrument,  $h$  is read on the records and it is very easy to compute

$$Dh = \sqrt{D_1^2 - h^2}$$

The interpreter usually works by chart where a set of hyperbolae

$$y = \sqrt{x^2 - h^2}$$

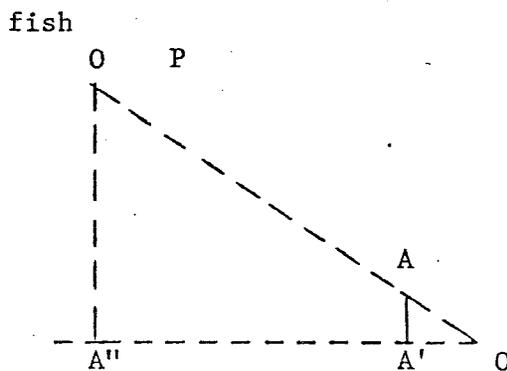
are computed with different values

of  $h$ .

N.B. The fact that the horizontal scale is non-linear is to be noted.

(c) Determination of the height of the echo

It is possible to compute the height of an echo from its "shadow effect".



$$AA' = PA'' \times \frac{AO}{PO}$$

( This worked very well in the case of the well head. )

Photomosaic

It is possible to assemble adjoining records of side scan in order to produce a mosaic similar to the one that one obtains with air photo.

In the first step, one transforms the non-linear scale (perpendicular to the course) of the record into a linear scale. This could be done optically (anamorphosis) or in a computer if the data are tape recorded.

In a second step, one transforms the so obtained linear scale into a scale equal to the longitudinal (along the course of the ship).

This is currently being done at the Institut Français du Pétrole in Paris.

APPENDIX D

TORAN READINGS

Date: Tuesday, August 15

Profile: 5381.00 A (W-E)

Method: Side-scan

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Heading	Time	A	B
77°	06H40	5381.04	5187.02
	41	5381.03	5187.38
	42	5381.01	5187.78
	43	5381.00	5188.22
	44	5381.00	5188.63
	45	5381.00	5189.08
75°	46	5381.01	5189.50
	47	5381.00	5189.92
	48	5381.00	5190.32
	49	5380.99	5190.69
	50	5381.00	5191.15
	51	5381.01	5191.63
	52	5381.05	5192.12
	53	5381.04	5192.57
	54	5381.03	5193.01
	55	5381.03	5193.40
	56	5381.01	5193.79
	57	5381.03	5194.20
	58	5381.01	5194.50
77°	07H00	5381.01	5195.30
	01	5380.98	5195.72
	02	5380.99	5196.15
	03	5381.00	5196.59

Date: Tuesday August 15

Profile: 5380.50 A (E-W)

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Heading	Time	A	B
260°	08H00	5380.50	5196.50
	01	5380.50	5196.10
	02	5380.51	5195.67
	03	5380.51	5195.25
	04	5380.50	5194.82
262°	08H05	5380.49	5194.38
	06	5380.48	5193.89
	07	5380.50	5193.45
	08	5380.49	5192.98
	09	5380.50	5192.56
	10	5380.51	5192.17
	11	5380.50	5191.70
	12	5380.51	5191.30
	13	5380.52	5190.83
	14	5380.49	5190.33
	15	5380.48	5189.83
	16	5380.49	5189.37
	17	5380.50	5188.91
260°	18	5380.49	5188.45
	19	5380.50	5188.03
	20	5380.50	5187.56

Date: Thursday, August 17

Profile: 5380.00A (E-W)

Heading	Time	A	B
	15H22	5379.79	5195.25
	23	5379.81	5194.60
	24	5379.84	5194.01
	25	5379.85	5193.75
	26	5379.89	5193.40
	29	5380.00	5192.60
	30	5379.88	5191.95
	31	5379.93	5191.75
	32	5380.03	5191.46
	33	5380.08	5191.10
	34	5380.07	5190.80
	35	5380.21	5190.43
	36	5380.20	5190.05
	37	5380.17	5189.67
	38	5380.15	5189.60
	39	5380.14	5188.90

Profile: 5379.50 (W-E)

Heading	Time	A	B
80°	16H00	5379.49	5187.60
	01	5379.50	5188.00
	02	5379.52	5188.43
77°	03	5379.53	5188.87
80°	04	5379.52	5189.23
	05	5379.54	5189.63
	06	5379.55	5190.01
	07	5379.55	5190.40
77°	08	5379.56	5190.82
	09	5379.54	5191.18
	10	5379.50	5191.53
	11	5379.52	5191.94
	12	5379.50	5192.33
	13	5379.50	5192.69
80°	14	5379.50	5193.00
	15	5379.48	5193.41
	16	5379.50	5193.80
	17	5379.53	5194.23
	18	5379.51	5194.54
	19	5379.51	5194.93
	20	5379.48	5195.27
	21	5379.49	5195.63
	22	5379.51	5196.08
	23	5379.50	5196.42

Date: Thursday August 17

Profile: 5379.00 A (E-W)

Heading	Time	A	B	
265°	16H43	5378.94	5195.55	
	44	5378.90	5195.22	
	45	5378.89	5194.77	
	46	5378.90	5194.48	
	47	5378.91	5194.15	
	48	5378.91	5193.77	
	49	5378.93	5193.38	
	50	5378.97	5193.04	
	260°	51	5379.01	5192.72
		52	5379.02	5192.40
262°	53	5379.01	5192.05	
	54	5379.01	5191.70	
	55	5379.01	5191.35	
	56	5379.01	5191.02	
264°	57	5379.01	5190.66	
	58	5379.00	5190.31	
	59	5378.99	5189.87	
	17H00	5378.99	5189.52	
	01	5379.01	5189.18	
	02	5379.03	5188.81	
	03	5379.05	5188.47	
262°	04	5379.04	5188.10	
	05	5379.03	5187.75	
	06	5379.01	5187.36	

Profile 5378.50 A (W-E)

Heading	Time	A	B	
83°	17H28	5378.60	5188.69	
	29	5378.60	5189.00	
	30	5378.59	5189.40	
	31	5378.55	5189.75	
	32	5378.54	5190.51	
	75°	33	5378.55	5190.51
		34	5378.60	5190.95
	72°	35	5378.60	5191.37
		36	5378.55	5191.62
		37	5378.51	5191.95
38		5378.49	5192.29	
39		5378.48	5192.65	
40		5378.47	5192.99	
41		5378.45	5193.40	
42		5378.48	5193.79	
43		5378.48	5194.14	
82°		44	5378.50	5194.52
	45	5378.50	5194.89	
80°	46	5378.49	5195.22	
	47	5378.48	5195.61	
	48	5378.49	5195.99	
	49	5378.49	5196.32	

Date: Thursday August 17

Profile: 5378.00 A (E-W)

Heading	Time	A	B
255°	18H18	5377.80	5195.71
260°	19	5377.87	5195.40
257°	20	5377.87	5195.09
	21	5377.92	5194.75
	22	5377.95	5194.46
	23	5377.96	5194.13
	24	5378.00	5193.86
260°	25	5378.00	5193.48
	26	5378.01	5193.10
	27	5377.99	5192.73
257°	28	5377.98	5192.36
	29	5377.99	5192.05
	30	5377.97	5191.68
255°	31	5377.98	5191.36
	32	5377.96	5191.00
	33	5377.98	5190.71
	34	5378.01	5190.38
257°	35	5378.03	5190.05
	36	5378.04	5189.67
	37	5378.04	5189.28
	38	5378.04	5188.87
	39	5378.05	5188.41
	40	5378.07	5187.98

Profile: 5377.50 (W-E)

Method: Magnetometer and side-scan

Heading	Time	A	B
77°	19H00	5377.50	5187.32
	01	5377.48	5187.68
	02	5377.50	5188.10
	03	5377.46	5188.45
80°	04	5377.47	5188.87
	05	5377.47	5189.34
	06	5377.48	5189.70
	07	5377.49	5190.13
	08	5377.49	5190.50
82°	09	5377.48	5190.89
	10	5377.49	5191.30
	11	5377.48	5191.68
	12	5377.50	5192.02
	13	5377.48	5192.41
	14	5377.50	5192.85
80°	15	5377.48	5193.26
	16	5377.49	5193.57
	17	5377.51	5193.94
	18	5377.50	5194.35
	19	5377.51	5194.68
79°	20	5377.50	5195.06
	21	5377.53	5195.45
	22	5377.48	5195.82

Date: Thursday, August 17

Profile: 5377.00 (E-W)

Heading	Time	A	B
	19H41	5376.98	5197.24
	42	5377.00	5197.00
	43	5377.00	5196.63
	44	5377.05	5196.31
265°	45	5377.02	5195.94
262°	46	5377.01	5195.53
260°	47	5377.00	5195.08
	48	5376.97	5194.71
	49	5376.96	5194.26
257°	50	5376.96	5193.86
	51	5376.97	5193.50
255°	52	5376.99	5193.16
	53	5376.99	5192.77
	54	5376.98	5192.37
	55	5376.99	5192.05
	56	5376.97	5191.60
	57	5377.01	5191.31
260°	58	5377.03	5190.91
	59	5377.05	5190.60
	20H00	5377.05	5190.17
	01	5377.04	5189.81
	02	5377.05	5189.42
258°	03	5377.06	5189.08
	04	5377.03	5188.66
	05	5377.02	5188.30
	06	5377.00	5187.87

Profile: 5378.00 Bis (E-W)

Heading	Time	A	B
258°	21H40	5377.97	5194.77
	41	5377.95	5194.40
262°	42	5377.95	5194.04
	43	5377.92	5193.68
	44	5377.93	5193.30
255°	45	5377.89	5192.80
	46	5377.88	5192.43
	47	5377.89	5192.09
257°	48	5377.91	5191.72
	49	5377.96	5191.35
260°	50	5377.97	5190.95
	51	5378.00	5190.63
	52	5378.02	5190.25
	53	5378.00	5189.83
262°	54	5378.02	5189.41
	55	5378.00	5189.02
	56	5378.01	5188.62
260°	57	5378.00	5188.20
	58	5378.03	5187.73
	59	5378.03	5187.28
259°	22H00	5378.03	5186.84
	01	5377.97	5186.44
	02	5377.95	5186.02
	21H03	5377.97	5185.60

Date: Thursday, August 17

Profile: 5377.00 A (W-E)

Heading	Time	A	B
285°	22H17	5376.92	5185.96
	18	5376.99	5186.50
	19	5377.02	5186.90
282°	20	5377.05	5187.38
	21	5377.00	5187.85
	22	5377.05	5188.28
277°	23	5377.00	5188.60
	24	5377.05	5188.87
	25	5376.95	5189.30
	26	5376.90	5189.82
	27	5376.95	5190.25
	28	5376.97	5190.55
	29	5376.95	5190.92
	30	5376.97	5191.28
	31	5377.00	5191.62
	280°	32	5377.05
33		5377.00	5192.35
34		5376.97	5192.65
35		5377.00	5193.05
36		5377.00	5193.40
282°	37	5377.02	5193.83
277°	38	5377.03	5194.25
	39	5377.10	5194.68
	40	5377.07	5195.12
	41	5377.05	5195.45
280°	42	5376.97	5195.80
	43	5376.95	5196.25
	44	5376.95	5196.60
	45	5376.95	5197.05
	46	5376.98	5197.40

Date: Saturday August 19

Profile: 5376.50 (E-W)

Heading	Time	A	B
260°	9H35	5376.42	5194.90
257°	37	5376.45	5194.12
	39	5376.50	5193.50
	41	5376.53	5192.73
	42	5376.52	5191.91
	44	5376.51	5191.50
262°	46	5376.49	5190.60
	48	5376.47	5189.68
260°	50	5376.45	5188.78
	52	5376.45	5187.94
	54	5376.47	5187.10
	56	5376.50	5186.26
	58	5376.48	5185.31
	10H00	5376.47	5184.57

Date: Saturday August 19

Profile: 5381.25 (E-W)

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Heading	Time	A	B
	10H24	5381.18	5188.15
	26	5381.32	5189.15
	28	5381.30	5190.10
	30	5381.27	5191.00
	32	5381.25	5191.87
	34	5381.24	5192.72
	36	5381.24	5193.65
	38	5381.25	5194.53
	40	5381.23	5195.40
	42	5381.24	5196.35
	44	5381.25	5197.23
	46	5381.25	5198.11

Profile: 5381.50 (E-W)

Date: Saturday August 19

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Heading	Time	A	B
	11H05	5381.30	5199.15
	07	5381.38	5198.31
257°	09	5381.41	5197.43
	11	5381.45	5196.51
	13	5381.45	5195.73
	15	5381.47	5194.83
	17	5381.49	5193.90
261°	19	5381.50	5192.99
	21	5381.50	5192.02
	23	5381.48	5191.05
	25	5381.48	5190.08
	27	5381.45	5189.13
	29	5381.47	5188.10
	31	5381.49	5187.16

Profile: 5382A

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Heading	Time	A	B
	11H51	5381.96	5187.22
	53	5381.98	5188.12
	55	5382.08	5189.10
	57	5382.06	5190.10
	59	5382.00	5190.98
	12H01	5381.97	5191.90
	03	5381.95	5192.85
	05	5381.97	5193.68
	07	5381.98	5194.66
	09	5381.99	5195.62
	11	5382.00	5196.53
	13	5382.02	5197.43
	15	5382.00	5198.33
	17	5382.00	5199.25

Date: Saturday August 19

Profile: 5382.50 A

Heading	Time	A	B
260°	12H40	5382.48	5199.18
	43	5382.49	5197.91
	45	5382.50	5197.10
257°	47	5382.48	5196.15
	49	5382.50	5195.25
	51	5382.51	5194.36
	53	5382.50	5193.46
262°	55	5382.51	5192.53
	57	5382.50	5191.56
258°	59	5382.51	5190.58
	13H02	5382.50	5189.24
	05	5382.51	5187.07

Profile: 5383.00 (W-E)

Heading	Time	A	B
282°	15H39	5383.04	5187.43
	41	5383.01	5188.32
	43	5383.00	5189.19
	45	5382.97	5190.08
285°	47	5382.98	5190.98
	49	5383.00	5191.89
	51	5383.02	5192.87
290°	53	5383.00	5193.81
	55	5383.00	5194.78
	57	5382.98	5195.79
287°	59	5382.94	5196.73
	16H01	5382.95	5197.57
	03	5382.95	5198.54
	05	5382.99	5199.51
	07	5383.01	5200.50

Profile: 5383.50 A

Heading	Time	A	B
260°	14H50	5383.60	5200.28
	52	5383.54	5199.25
	54	5383.51	5198.31
258°	56	5383.50	5197.43
	58	5383.50	5196.51
	15H00	5383.54	5195.64
260°	02	5383.50	5194.71
	04	5383.49	5193.78
	06	5383.48	5192.81
	08	5383.45	5191.82
	10	5383.48	5190.90
	12	5383.51	5190.12
	14	5383.52	5189.16
	16	5383.50	5188.14

## AIRGUN + HYDROSONDE PROFILES

Sunday, August 20

Line: 5378.00 A (E-W)

Time	Fix	A	B	
14H05	1	5378.04	5198.37	
07	2	5377.98	5197.21	
09	3	5377.97	5196.02	
11	4	5378.00	5194.91	
13	5	5378.01	5193.79	
15	6	5378.03	5192.64	
17	7	5378.06	5191.46	
19	8	5378.08	5190.30	
21	9	5378.06	5189.05	
23	10	5378.04	5187.73	
25	11	5378.01	5186.40	Typhoon I
27	12	5378.00	5185.04	no fix on recorder
30	13	5372.01	5183.24	
32	14	5372.00	5181.92	W

Line: 5377.50 A (W-E)

Time	Fix	A	B	
15H05	1	5377.46	5181.07	W
07	2	5377.49	5182.25	
09	3	5377.50	5183.42	
11	4	5377.51	5184.50	
13	5	5377.50	5185.55	
15	6	5377.48	5186.57	Typhoon
17	7	5377.45	5187.65	
19	8	5377.50	5188.82	
21	9	5377.50	5189.87	
23	10	5377.51	5190.83	
25	11	5377.48	5191.86	
27	12	5377.50	5192.91	
29	13	5377.50	5193.94	
31	14	5377.52	5194.91	E
33	15			

Line 5377.50

Time	Fix	A	B	
16H05	1	5377.00	5196.83	
07	2	5377.00	5195.87	E
09	3	5377.06	5194.96	
11	4	5377.02	5193.90	
13	5	5377.00	5192.85	
15	6	5377.02	5191.86	
17	7	5377.03	5190.88	
19	8	5377.00	5189.84	
21	9	5376.99	5188.85	
23	10	5376.98	5187.81	
25	11	5377.00	5186.79	
27	12	5376.98	5125.69	
29	13	5376.97	5184.61	
31	14	5377.00	5183.57	
33	15	5377.01	5182.49	

Date: Sunday August 20

Line: 5378.50

Time	Fix	A	B
17H00	1	5378.50	5184.10
03	2	5378.54	5185.80
05	3	5378.52	5186.93
07	4	5378.51	5188.00
09	5	5378.50	5189.05
11	6	5378.50	5190.12
13	7	5378.48	5191.13
15	8	5378.49	5192.17
17	9	5378.51	5193.32
19	10	5378.53	5194.38
21	11	5378.50	5195.39
23	12	5378.47	5196.39

Line: 5379 A

Time	Fix	A	B
19H15	1	5378.97	5185.00
17	2	5379.00	5186.17
19	3	5378.99	5187.27
20H07			
09	4	5378.79	5188.17
11	5	5378.84	5189.33
13	6	5378.93	5190.57
15	7	5379.00	5191.73
17	8	5379.04	5192.97
19	9	5379.01	5194.00
21	10	5379.00	5195.02
23	11	5379.02	5196.16
25	12	5379.06	5197.32
27	13	5379.70	5198.41

Line: 5379.50 A

Time	Fix	A	B
20H55	1	5379.52	5198.12
57	2	5379.50	5197.13
59	3	5379.48	5196.07
21H01	4	5379.48	5194.93
03	5	5379.51	5193.87
05	6	5379.53	5192.72
07	7	5379.48	5191.56
09	8	5379.50	5190.42
11	9	5379.51	5189.31
13	10	5379.50	5188.21
15	11	5379.48	5187.01
17	12	5379.50	5185.90
19	13	5379.53	5184.81

Line: 5380.00 A

Time	Fix	A	B
21H43	1	5379.75	5186.46
45	2	5379.93	5187.84
47	3	5379.87	5188.87
49	4	5379.99	5190.14
51	5	--	5191 ?
53	6	5380.35	5192.75
55	7	5380.17	5193.75
57	8	5380.12	5194.77
59	9	5380.25	5195.95
22H01	10	5380.18	5197.12
03	11	5380.26	5198.24

## LINES LEIF-THORVALD

(HYDROSONDE)

Line:

Date: Monday, August 21

Time	Fix	A	B
16H20	1	5397.15	5230.35
30	2	5404.38	5237.25
40	3	5411.82	5243.31
50	4	5419.00	5248.75
17H00	5	5426.50	5254.70
10	6	5433.20	5260.00
20	7	5439.91	5266.22
30	8	5446.25	5273.30
40	9	5448.85	5280.75

Line: 5444 A

Time	Fix	A	B
20H30	1	5444.01	5291.15
32	2	5444.08	5290.50
34	3	5444.06	5289.75
36	4	5444.05	5288.90
38	5	5444.02	5288.05
40	6	5444.00	5287.15
42	7	5444.01	5286.25
44	8	5444.00	5285.32
46	9	5444.02	5284.46
48	10	5444.03	5283.58
50	11	5444.05	5282.65
52	12	5444.02	5281.69

Line: 5445 A

Time	Fix	A	B
21H35	1	5445.00	5284.63
37	2	5445.01	5285.63
39	3	5445.00	5286.66
41	4	5445.01	5287.67

## Line 5445 A continued

Time	Fix	A	B
21H43	5	5444.99	5288.65
45	6	5444.98	5289.64
47	7	5445.01	5290.63
49	8	5445.00	5291.60
51	9	5445.01	5292.51
53	10	5445.00	5293.49

## Line 5446

Time	Fix	A	B
22H20	1	5445.92	5292.60
22	2	5445.96	5291.75
24	3	5445.97	5290.95
26	4	5446.01	5290.15
28	5	5446.03	5289.28
30	6	5446.02	5288.37
32	7	5446.00	5287.35
34	8	5445.99	5286.41
36	9	5445.98	5285.51
38	10	5446.00	5284.58
23H06	1	5446.81	5287.28
08	2	5446.72	5288.33)
10	3	5446.68	5289.31)
12	4	5446.78	5290.38
14	5	5446.87	5291.51
16	6	5446.99	5292.52
18	7	5446.98	5293.54
20	8	5447.01	5294.55
22	9	5447.00	5295.49

Iceberg detour

## Line 5448

Time	Fix	A	B
23H50	1	5448.01	5295.57
52	2	5447.96	5294.58
54	3	5447.98	5293.68
56	4	5448.00	5292.85
58	5	5448.02	5291.96
24H00	6	5448.05	5291.08
00H02	7	5448.09	5290.21
04	8	5448.05	5289.17
06	9	5448.01	5288.13
08	10	5448.00	5287.10
10	11	5447.98	5286.07

## Line 5449 A

Time	Fix	A	B
0H35	1	5448.91	5287.61
37	2	5448.90	5288.65
39	3	5448.96	5289.66
41	4	5449.00	5290.64
43	5	5449.01	5291.66
45	6	5449.00	5292.64
47	7	5449.02	5293.62
49	8	5449.06	5294.58
51	9	5449.02	5295.51
53	10	5449.00	5296.42

## Line 5450

Time	Fix	A	B
01H15	1	5449.91	5297.47
17	2	5449.99	5296.74
19	3	5450.04	5295.91
21	4	5450.06	5295.10
23	5	5450.08	5294.14
25	6	5450.02	5293.18
27	7	5450.03	5392.20
29	8	5450.00	5391.25
31	9	5450.00	5390.20
33	10	5449.97	5389.22
35	11	5449.99	5388.19

## Line 5451

Time	Fix	A	B
02H00	1	5451.00	5290.00
02	2	5451.03	5290.91
04	3	5450.93	5291.72
06	4	5450.99	5292.68
08	5	5451.02	5293.67
10	6	5451.04	5294.51
12	7	5451.01	5295.37
14	8	5451.00	5296.24
16	9	5451.00	5297.15
18	10	5451.01	5298.02
20	11	5451.03	5298.92

## Line 5451 A Side Scan

Heading	Time	A	B
285°	14H56	5450.95	5301.20
	58	5450.92	5300.51
277°	15H00	5450.97	5299.90
	02	5450.95	5299.24
	04	5450.94	5298.51
	06	5450.95	5297.91
	08	5450.98	5297.33
	10	5451.00	5296.70
	12	5451.08	5296.10
	14	5451.06	5295.45
	16	5451.08	5294.85
	18	5451.06	5294.18
	20	5451.05	5293.48
	22	5451.00	5292.78
275°	24	5451.01	5292.12
	26	5451.02	5291.45
277°	28	5451.00	5290.76
	30	5450.98	5290.02
275°	32	5450.99	5289.28

Line: 5450 A

Heading	Time	A	B
75°	15H55	5450.05	5288.77
87°	57	5450.03	5289.32
82°	15H59	5450.00	5289.90
85°	16H01	5450.01	5290.57
82°	03	5450.02	5291.21
	05	5450.03	5291.88
85°	07	5450.00	5292.36
	09	5449.94	5292.95
90°	11	5449.96	5293.56
87°	13	5449.99	5294.25
	15	5450.01	5294.87
	17	5450.00	5295.46
	19	5450.04	5296.09
	21	5450.00	5296.62
90°	23	5450.01	5297.21
	25	5449.97	5297.75
	27	5449.96	5298.36

Line 5449 A

Heading	Time	A	B
277°	16H45	5448.92	5297.24
	47	5448.83	5296.45
	49	5448.85	5295.84
	51	5448.81	5295.22
	53	5448.93	5294.66
270°	55	5448.99	5294.11
	57	5449.00	5293.38
	59	5449.92	5292.62
267°	17H01	5449.90	5291.93
	03	5449.72	5291.20
	06	5448.74	5290.28
	08	5448.81	5289.65
	10	5448.84	5288.97
	12	5448.89	5288.27
	14	5448.91	5287.62

Line 5448

Heading	Time	A	B
85°	17H38	5447.81	5287.35
	40	5447.87	5288.07
90°	42	5447.86	5288.66
95°	44	5447.94	5289.30
85°	46	5448.01	5290.02
87°	48	5448.00	5290.58
90°	50	5447.98	5291.15
95°	52	5447.93	5291.73
	54	5447.95	5292.37
	56	5447.88	5293.00
	58	5447.83	5293.60
97°	18H00	5447.92	5294.20
	02	5447.95	5294.86
	04	5447.97	5295.49
	06	5447.96	5296.16

Line: 5447

Heading	Time	A	B
260°	18H25	5446.63	5294.76
	27	5446.85	5294.33
265°	29	5446.99	5293.81
	31	5447.00	5293.12
	33	5446.85	5292.36
260°	35	5446.87	5291.66
	37	5446.85	5290.95
255°	39	5446.89	5290.38
250°	41	5446.78	5289.15
	43	5446.79	5289.17
255°	45	5446.88	5288.70
	47	5446.92	5288.08
	49	5446.96	5287.47
	51	5446.99	5286.81

Line 5446 A

Heading	Time	A	B
97°	19H20	5446.01	5285.29
	22	5446.02	5286.00
	24	5446.04	5286.65
	26	5446.02	5287.26
92°	28	5446.04	5287.91
	30	5446.01	5288.48
90°	32	5446.03	5289.17
	34	5446.01	5289.76
92°	36	5446.02	5290.41
90°	38	5446.00	5291.07
	40	5446.00	5291.06
92°	42	5446.01	5292.19
95°	44	5445.93	5292.81
	46	5445.97	5293.39
	48	5446.01	5294.02

Line: 5445 A

Heading	Time	A	B
255°	20H05	5445.05	5292.63
262°	07	5445.00	5291.85
	09	5444.76	5290.95
250	11	5444.55	5290.10
	13	5444.60	5289.25
	15	5444.66	5289.05
247°	17	5444.82	5288.66
255°	19	5444.91	5288.12
	21	5444.98	5287.60
	23	5445.00	5286.92
	25	5445.01	5286.25
	27	5444.98	5285.61
252°	29	5444.99	5284.98
	31	5445.02	5284.48

Line: 5444 A August 24, Wednesday

Heading	Time	A	B
90°	20H47	5443.92	5283.72
95°	49	5443.96	5284.50
	51	5443.98	5285.15
	53	5343.99	5285.67
	55	5344.00	5286.26
	57	5343.96	5286.69
	59	5343.88	5287.35
97°	21H01	5343.96	5287.99
	03	5343.99	5288.66
	05	5344.00	5289.16
	07	5344.01	5289.78
	09	5344.00	5290.37
	11	5344.03	5291.06
	13	5344.03	5291.78
	15	5344.01	5292.26
	12H20	5380.35	5189.80
	35	5380.21	5190.78
	13H10	5381.12	5193.21
	13H30	5382.85	5193.75
	14H30	5382.19	5193.20
	40	5380.90	5191.25
	55	5377.49	5188.35
	15H35	5377.48	5187.77
	15H55	5376.91	5187.90
	16H10	5378.77	5189.28

## HYDROSONDE AND AIRGUN

Thursday August 24

Line: N-W Leif to Bjarni

Fix	Time	A	B
1	17H45	5357.35	5159.00
2	18H15	5335.32	5135.10
3	18H45	5311.55	5110.52
4	19H15	5288.00	5086.65
5	19H45	5264.25	5063.90
6	20H15	5240.05	5042.16
7	20H45	5213.60	5021.01
8	21H15	5185.90	5001.28
9	21H45	5162.05	4984.98
10	22H15	5134.55	4966.90
11	22H30	5118.30	4956.05
12	23H00	5093.60	4939.10
13	23H40	5058.80	4915.80
14	24H00	5043.32	4905.95
15	00H30	5013.60	4887.80
16	01H00	4983.50	4871.60
17	01H30	4944.60	4852.90
18	02H00	4913.70	4840.35
19	02H30	4877.50	4827.30
20	03H00	4845.70	4816.30
21	03H30	4811.55	4805.05

## SIDE SCAN

August 25, Friday

Line: 5376.50

Heading	Time	A	B
95°	17H00	5376.50	5183.95
92°	02	5376.51	5184.92
90°	04	5376.52	5185.75
	06	5376.53	5186.48
88°	08	5376.50	5187.15
	10	5376.50	5187.87
90°	12	5376.48	5188.65
	14	5376.51	5189.45
92°	16	5376.53	5190.24
	18	5376.51	5191.00
	20	5376.50	5191.78
	22	5376.50	5192.56
	24	5376.48	5193.23

Line 5377.00

Heading	Time	A	B
252°	17H45	5376.94	5192.75
255°	47	5376.99	5192.02
252°	49	5376.99	5191.25
	51	5377.00	5190.41
	53	5377.01	5189.60
251°	55	5377.00	5188.73
	57	5377.00	5187.86
254°	59	5377.03	5187.08
	18H01	5377.07	5186.23
	03	5377.05	5185.36
	05	5377.01	5184.42
	07	5376.98	5183.52

Line: 5377.50

Heading	Time	A	B
87°	18H45	5377.50	5184.67
	47	5377.56	5185.53
	49	5377.55	5186.37
82°	51	5377.50	5187.12
	53	5377.47	5187.90
85°	55	5377.49	5188.65
	57	5377.50	5189.39
	59	5377.45	5190.21
	19H01	5377.49	5191.08
84°	03	5377.51	5192.92
	05	5377.55	5192.72
	07	5377.53	5193.33
	09	5377.50	5194.00
	11	5377.43	5194.67

## HYDROSONDE AND AIRGUN

Thorvald Area

August 27, Sunday

A = 5446.90  
B = 5289.1058°08'09" N  
54°52'05" W

Fix	Time	A	B
1	00H15	5455.10	5253.30
2	45	5462.45	5243.70
3	01H15	5471.10	5232.20
4	01H45	5481.65	5218.90
5	02H15	5492.90	5205.05
6	45	5507.80	5187.80
7	03H20	5525.60	5166.35
8	03H45	5537.90	5148.50
9	04H15	5554.40	5122.50
10	55	5577.81	5076.57
11	05H15	5591.15	5045.90
12	50	5616.34	4988.10
13	06H15	5632.60	4953.10
14	07H15	5677.15	4872.20
15	07H45	5696.65	4808.55
16	08H15	5724.50	4750.40

Line: 5385.00

Heading	Time	A	B
260°	19H35	5385.03	5199.50
	37	5385.02	5198.57
	39	5385.00	5197.66
	41	5385.04	5196.78
	43	5385.04	5195.87
	45	5385.03	5194.93
	47	5385.02	5193.95
	49	5385.00	5192.99
	51	5385.01	5192.01
	53	5385.00	5190.98
	55	5384.96	5190.01

Line 5384.50

Heading	Time	A	B
80°	20H15	5384.50	5190.00
	17	5384.50	5190.81
82°	19	5384.50	5191.63
	21	5384.48	5192.43
83°	23	5384.46	5193.28
85°	25	5384.47	5194.18
	27	5384.48	5195.01
87°	29	5384.50	5195.86
	31	5384.49	5196.72
90°	33	5384.49	5197.57
	35	5384.50	5198.10
	37	5384.50	5198.86

Line 5381.25

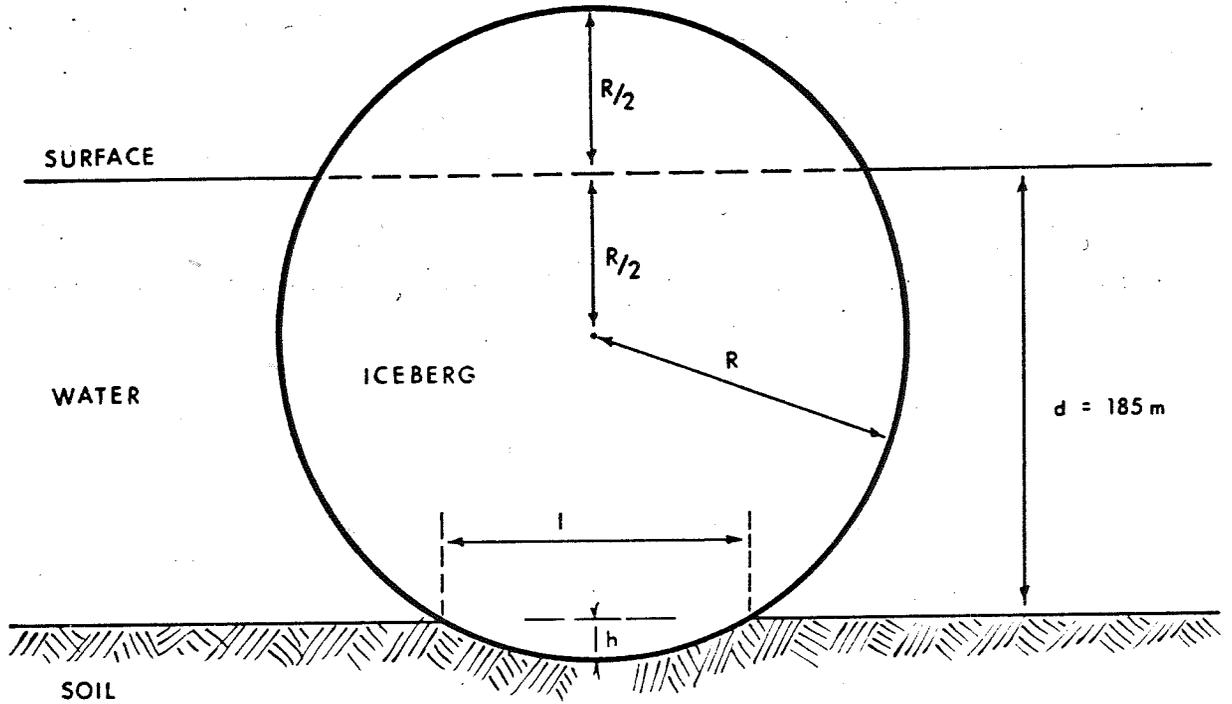
Heading	Time	A	B
75°	09H50	5381.25	5187.71
	54	5381.20	5189.67
	56	5381.12	5190.50
	59	5381.30	5192.20
	10H02	5381.40	5193.92
		5381.37	5195.30

Line 5381.50

Heading	Time	A	B
280°	10H49	5381.62	5199.55
	51	5381.50	5198.77
	53	5381.51	5198.10
	55	5381.44	5197.41
	57	5381.40	5196.70

# APPENDIX "E"

## GROUNDING EFFECTS OF SPHERICAL SHAPE ICEBERGS



$$h = R - \sqrt{R^2 - \frac{l^2}{h}}$$

- $h$  = DEPTH OF SCOURING
- $R$  = RADIUS OF ICEBERG
- $l$  = WIDTH OF SCOURING

