STRAIT OF BELLE ISLE - PISCES IV DIVES - AUGUST 1985

MANNED SUBMERSIBLE OBSERVATIONS OF THE SUBMARINE CABLE TEST TRENCH IN THE STRAIT OF BELLE ISLE

February, 1986

Prepared for:

Atlantic Geoscience Centre
Geological Survey of Canada
GSC Open File #
and
Newfoundland and Labrador Hydro

By:

John Zevenhuizen
Orca Marine Geological Consultants
Halifax, Nova Scotia

Preamble

This report is the result of a cooperative venture between the Atlantic Geoscience Centre and Newfoundland and Labrador Hydro. The program was initiated by Mr. H.W. Josenhans of the Atlantic Geoscience Centre in order to study the nature and degradation of a 60 centimeter deep trench that was plowed across the Strait of Belle Isle in August 1984.

Understanding the nature and degradation of this trench is useful in determining the mechanisms of seabed scouring by such agents as grounded icebergs, trawlboards and pipeline trenchers - areas of ongoing study at the Atlantic Geoscience Centre. For Newfoundland and Labrador Hydro detailed visual inspection of the trench was helpful in determining the feasibility of a buried submarine transmission cable crossing of the Strait of Belle Isle.

In order to compile the results in a timely format beneficial to both parties it was decided to contract the services of Orca Marine Geological Consultants to prepare this report. The same manuscript is presented as a report to Newfoundland and Labrador Hydro and is available as an Open File Report with Energy Mines and Resources.

H.W. Josenhans

Abstract

In August 1984 a towed prototype 5 ton plowing device trenched three potential cable routes across the Strait of Belle Isle. The plow was capable of a 60 cm substrate penetration. The manned submersible PISCES IV surveyed this trench feature a year later. When located the trench was easily identified by its linear character and the lack of biogenic cover on the recently turned up faces of previously buried boulders. Generally the feature did not have any prominant relief due to the backfilling design feature of the plow. However relief was visible in areas where the plow transected boulder ridges. The unconsolidated sediments of the Strait of Belle Isle consist mainly of till overlain by an armour lag of cobbles and gravels. Boulder ridges 1-3 meters in height, mobile shell hash beds and stringers and bedrock outcrops were also observed. The trench was most prominant in the boulder ridges and infilled with shell hash in the armour lag over till. The trench was totally obscured in the areas of shell hash. There were no indications of any tool mark over bedrock outcrop contacts. Engineering problems identified were possible suspension of cable between boulder ridges, problems with cable burial in zones of mobile shell hash, the presence of occasional large boulders and isolated areas where small bedrock outcrops come to the surface.

The relatively slow rate of biogenic recolonization observed on freshly overturned boulders indicates that seabed disturbance such as seabed scouring can be clearly recognized at least one year after their formation. Visual observation by manned submersible of the features observed on the 100 kHz. Klein sidescan sonar data has shown that linear features less than 50 centimeters in height and width can be clearly recognized on the sidescan sonar sonograms.

INDEX PAGE

APPENDICES

Introduction

In 1984, Newfoundland and Labrador Hydro completed an extensive trenching program in the Strait of Belle Isle. This trenching program was the last major program completed in the Strait of Belle Isle by Newfoundland and Labrador Hydro after many years of intensive site specific oceanographic, engineering and geological studies. The trenching was accomplished by a prototype 5 ton plowing device capable of trenching to a total depth of 60 cm. The trenching program was an integral part of a continuing feasibility study for submarine transmission cable crossings of the Strait of Belle Isle. Three potential cable routes between Labrador and Newfoundland were trenched with this plow. Due to this ongoing study; the physical oceanography, surficial and bedrock geology, environmental data and physiography of the Strait of Belle Isle region are well documented.

The mechanical trenching operation carried out in the Strait of Belle Isle is similar to iceberg scouring but under controlled conditions with known parameters. It is therefore of general interest to engineers and geologists for process studies as well as applications such as submarine cable protection and pipeline construction for the oil industry.

The Bedford Institute of Oceanography cruise Pn 85-061 using the MV Pandora II and the manned submersible PISCES IV was planned to observe iceberg scouring processes and seabed dynamics on the Labrador Shelf.

The Strait of Belle Isle trenching program provided the opportunity to augment the program by providing a target similar to iceberg scours for which the physical oceanographic processes and dynamics are well known and the chronology is certain. Geologists from the Atlantic Geoscience Centre at Bedford Institute of Oceanography under the direction of Heiner Josenhans and engineers from Newfoundland and Labrador Hydro under the direction of Harvey Young completed three highly succesful PISCES IV dives. In two dives the trench was located, observed and documented by video, still camera, and audio recordings. Understanding of the audio and visual data was further supported by bottom samples. Dive 2 failed to locate the trench but valuable observations of the seafloor were made.

The identification, degradation or preservation of the trench feature were determined and some engineering problem areas were successfully identified during the PISCES IV dives. This report is a summary of these observations and a catalogue of the acquired data.

Purpose

The Strait of Belle Isle phase of the Pandora II cruise 85-061 was planned to observe the results of the Newfoundland and Labrador Hydro 1984 submarine cable crossing test plowing project. The purpose of the sidescan sonar and PISCES IV manned submersible surveys were to identify and observe the trench produced by a towed prototype five ton plowing device contracted by Newfoundland and Labrador Hydro to assess the feasibility of a buried submarine transmission cable crossing of the Strait of Belle Isle.

The project objectives were;

1. To allow Newfoundland and Labrador Hydro engineers to visually observe the trench feature.

2. To calibrate and determine the resolution of the 100 kHz Klein sidescan sonar system.

3. To determine the degradation rate of the trench with a known chronology and environment for future comparison to features in similar environments of unknown chronology such as iceberg scours.

4. To determine the effect of a known scouring instrument upon various types of surficial geological substrates.

5. To identify potential problem areas for a submarine cable program such as bedrock outcrops, steep slopes, boulder ridges and depth of disturbance by such agents as trawlboards.

Project Funding

The Pandora cruise 85-061 using the PISCES IV submersible from August 15 -August 17 in the Strait of Belle Isle was funded by the Department of Energy Mines and Resources (approximate cost $15,000-20,000 per day). A contribution of $ 10,000 by Newfoundland and Labrador Hydro was used to obtain; cruise planning and logistic support; a video camera/recorder system, travel and the compilation and preparation of this report. Newfoundland and Labrador Hydro personnel were actively involved and participated in both the planning phase and the actual PISCES IV dives in the Strait of Belle Isle.

Participants

Ms. A. Cotie,(navigation) Atlantic Geoscience Centre
Mr. H.W. Josenhans (chief scientist) Atlantic Geoscience Centre
Ms. L. Kiley,(logistic support) contractor
Mr. G. Lundrigan,(observer) Newfoundland and Labrador Hydro
Mr. H. Young,(observer) Newfoundland and Labrador Hydro
Mr. J. Zevenhuizen,(observer) Orca Marine Geological Consultants

Diving Crew

Mr. F. Chambers (chief pilot)
Mr. B. Taylor
Mr. J. Oszust
Mr. B. Holland

Dive Planning

Time allowed on the Strait of Belle Isle survey was sufficient to complete 3-4 PISCES IV dives allowing some time for a sidescan sonar survey at each site. Due to high tidal current velocities in the Strait of Belle Isle it was importand to position and schedule the dives to maximize diving time during low tidal flows.

Five possible dive sites were selected based on Huntec Deep Towed Seismic and sidescan profiles supplied by Newfoundland and Labrador Hydro. These records were collected in previous surveys and with the resulting reports and maps, formed the primary control for the 1985 PISCES IV survey. Previous PISCES IV dives in 1981 were also used in positioning dives to provide some sort of control so that the surficial geology and surficial features of the target areas were known. Dive planning was completed at the Atlantic Geoscience Centre with input from the Newfoundland and Labrador Hydro.

The dive sites selected were;

1. 51.2166 N/ 56.8000 W, Winter Cove. This nearshore dive was planned to locate the trench in shallow water and document it with a zig-zag dive transect starting at 20 meters water depth into deeper water.

2. 51.2917 N / 56.9750 W, Newfoundland Trough. This dive was positioned to locate the trench in an area of well defined boulder ridges and scours formed in glacial till located towards the center of the strait in water depths below but proximal to the Newfoundland escarpment.

3. 51.3500 N / 56.9417 W, Newfoundland Trough. This dive was positioned to observe the trench in an area of well developed scour ridges in an area of appproximately ten meters (?) thickness of glacial till . Strong tidal currents were expected to be encountered in this area.

4. 51.3750 N / 56.9000 W, Newfoundland Trough. This dive site was positioned near the bathymetric low which separates North and South Center Banks. In 1981 striations were observed on limestone bedrock outcrops. If a comparison of the tool marks produced by the plow to the older striations could be observed a relative degradation rate may be determined and the possible origin of the features could be established.

5. 51.3667 N / 56.7667 W, Newfoundland Escarpment. This dive was positioned at the Newfoundland Escarpment which is the physiographic boundary between the Newfoundland Trough and the Newfoundland Coastal Zone. This escarpment displays iceberg impact pits and linear features on side scan records.

Report Preparation

Navigation

Navigation used for this project consisted of LORAN C, Satnav, and radar fixing from known points to determine the position of the survey and submersible tender ship the MV Pandora II. The navigation was recorded on the bridge and is enclosed in this report (Appendix II). The position of the PISCES IV manned submersible was determined by range and bearing in relation to the tender vessel using a Honeywell 902 system. Navigational accuracy of the tender vessel was generally poor and subsequent correction and reconstruction of the navigational track plot was not as accurate as desired.

Newfoundland and Labrador Hydro supplied bathymetric, control and surficial geological maps at a 1:20,000 UTM projection. These maps were compiled during previous reconnaissance and feasibility studies. Specific segments of these maps provided base maps for this study. These maps are enclosed in this report as Appendices III, IV and V. These maps were used in conjunction with the 100 kHz Klein sidescan sonar data and the 12 kHz. echosounder records to construct a best possible PISCES IV transect.

The location of PISCES IV was referenced to the ships position using ranges and bearings from the Honeywell system. A preliminary PISCES IV track along the seafloor was established and then corrected by using visual observations as recorded in the submersible during the dive. Parameters such as orientation of surficial geological features, trench orientation when observed and water depths were considered and used to correct the recorded navigation with respect to the well controlled maps supplied by Newfoundland and Labrador Hydro.

Data Recording

All data collected was referenced to Atlantic Daylight Time (A.D.T.) and the Julian Calender. The data and samples collected are catologued and archived stored at the Atlantic Geoscience Centre, Dartmouth, Nova Scotia.

Video Recording

During all dives continuous externally mounted camera video footage was collected. During dives 1 and 3 additional video was collected in areas of specific interest using an internal hand held camera system. Deployment and recovery of the PISCES IV submersible were documented on the hand held portable camera during dive 2. Three and a half hours of video tape was recorded during the Strait of Belle Isle phase of Pandora II cruise 85-061. The video tapes were then all standardized to a VHS 1/2 inch format and edited. The edited tape is approximately one hour in duration and is included with this report.

Report

The report is a summary of the data collected and observations made during Pandora II cruise 85-061 using the PISCES IV manned submersible together with data collected during the 1981 PISCES IV dives in the Strait of Belle Isle. The unedited audio channel of the preliminary video tape which is part of this report does not necassarily reflect the only possible interpretation or the interpretation accepted by the Department of Energy Mines and Resources.

Previous Data; 1981 Strait of Belle Isle Pisces IV dives

MV Pandora II cruise 81-057 successfully completed four dives in the Strait of Belle Isle region. Observations were obtained in the form of video tape footage and still 35mm camera photos. The previous data collected and the diving experience gained from diving in difficult environmental conditions for the submersible were utilized in planning the Strait of Belle Isle phase of MV Pandora II cruise 85-061. The following information and dive descriptions were obtained from the MV Pandora II 81-057 cruise report (Josenhans, 1981). For the 1981 dive locations see appendix I.

Dive 1 description

This dive was undertaken during ideal weather conditions. The submersible was launched in an area considered to have the lowest bottom current velocities in the survey area. The survey was planned trough the use of sidescan sonar mosaics and surficial geological maps compiled and produced by Geonautics Ltd. for Newfoundland and Labrador Hydro. The sidescan sonar mosaics and surficial geology map indicated a veneer of sediment with sand waves developed on it overlying an area of DeGeer ridges. Direct observations have refined this interpretation in determining that the sediment veneer is predominantly composed of broken shell fragments of coarse sand to gravel size. The interpreted DeGeer moraines are linear boulder ridges but there is some controversy as to their origin. The boulder ridges are similar to those documented on the Labrador Shelf and associated with iceberg scouring (Josenhans and Barrie, 1981) and also to lift-off moraines (DeGeer moraines) as discussed by King and Fader (1985) and others. These boulder ridges have an observed heading of approximately 040 with a spacing of typically 30 meters or less. Shell fragments overlying a pebble lag deposit were found between these ridges. It was observed that in general the morphology and surficial features observed were in close agreement with those indicated on the surficial geology map and sidescan mosaic.

Dive 2 description

This dive was planned a short distance north of dive site 1 to sample areas of boulder ridges and a fresh scour. Most scour features in the area are interpreted to be relic on the basis of completely winnowed rims and a lack of fine matrix. One feature observed near the area marked as a fresh scour on the surficial geology map had noticeably steeper slopes on the rims and significantly more fine matrix. Transects across the relic features typically show well developed boulder rims changing rapidly to a consistant size pebble clasts at the bottom of the trough with some shell fragments at the base. Orientation of the ridges is consistantly 040 to 060. Boulders and pebbles are covered with barnacles and a variety of organic growth. Numerous isolated (ice rafted (?)) boulders were found sitting above the seabed all covered with organic growth suggesting that they were deposited at least a few years ago. No recently deposited boulders were observed in this dive. Current winnowing at the base of the boulders is common, and a small outcrop of well rounded bedrock was observed near the termination of the dive. The bedrock outcrop in this area is significantly more rounded than similar bedrock exposed near or on shore. No conspicuous striations were noted on the bedrock surface this may be in part due to the small outcrop exposure or possibly a more resistant bedrock type.

Dive 3 description

This dive was planned to investigate the areas marked as sand stringers and sand waves on the South Centre Bank area of the map area. The observations have shown that the sand stringers are composed entirely of shell fragments. Fresh accumulations of this shell material on the lee side of the isolated boulders may indicate that this material is moved with every tidal cycle. The areal distribution of the shell stringers or bands is similar to that indicated on the sidescan sonar mosaic, that is a width of approximately 20 to 30 meters and a length of approximately 100 meters. Little bottom relief is observed in this area in contrast to the other areas observed . An area of bedrock outcrop was observed. This outcrop had well developed laterally continuous striations cut into its surface. These striations are typically 3 to 10 centimeters wide and 2 to 5 centimeters in depth . Orientation was measured at 040 to 060 true. Broken shell material infills some of the striations and barnacles cover the surface of the bedrock.

Dive 4 description

This dive was planned to sample an area of boulder ridges; to transect the shell fragment stringers; to identify dynamic bottom conditions at the base of the escarpment on the Labrador side; and to investigate the escarpment cliff face side for glacial or iceberg striations. The surface veneer of shell fragments and pebbles was sampled. Numerous shell stringers were identified in areas shown as sand stringers on the surficial geology map. Also, a six meters vertical cliff was transected in the middle of the shell stringer zone. The seabed on top and at the base of the cliff was relatively flat whereas the face of the cliff was vertical with a talus slope of boulders at its base. Bottom currents appear to be concentrated at the base of the cliff resulting in an accumulation of mobile shell debris and making close inspection of the cliff face difficult.

Present Study; 1985 Strait of Belle Isle Pisces IV dives

MV Pandora II cruise 85-061 successfully completed four dives in the Strait of Belle Isle region. Of these dives three are described in this report (figure 1). Observation were documented by an externally mounted video camera, a hand held internal video camera, 35 mm still camera photos, a cassette deck voice recording and samples acquired with the manipulator arm on PISCES IV.

Dive site 1 description

Survey and dive site 1 represents the second site picked in the planning stage. This dive was planned to observe the trench in glacial till and well defined boulder ridges. Weather conditions were ideal for both the sidescan survey and the PISCES IV dive. The trench was identified on the sidescan as a thin linear feature cross cutting the surficial geological features (Appendix III, figure 1) at the same orientation as indicated on the base maps supplied by Newfoundland and Labrador Hydro (Appendix III, figures 2 and 3). The slant range uncorrected sidescan sonar sonogram (Appendix III, figure 1) also displays boulder ridges, stringers of shell hash, and bedrock outcrop identified on the surficial geology map (Appendix III, figure 3) as Hawke Bay Sandstone. The PISCES IV was deployed slightly south of the target area and north of the Newfoundland Escarpment in the Newfoundland Trough.

PISCES IV upon submerging hit bottom at 90 meters water depth, currents were observed to be 1/2 - 3/4 knots. The material on the seafloor was predominantly sub-rounded to rounded cobbles and gravels with 80 -90 % complete but thin biogenic cover. Occasional 2 - 3 meter high, 10 - 20 meter wide continuous (?) boulder ridges were encountered. The grain size composition of the boulder ridges was variable but predominantly sub-angular to sub-rounded boulders up to 1/2 to 3/4 meters in diameter. The boundary between the boulder ridges and the remaining seafloor is marked by a general decrease in grain size. There were no areas of clastic fine-grained sediments identified but shell hash was selectively present in the lee of large boulders suggesting a fairly high mobility of the shell hash in the Strait of Belle Isle current regime. A plume of fine grained material was disturbed when semi-buried rock samples were recovered. The course along seabottom for PISCES IV was 035, normal to the orientation of the trench. The PISCES IV course was approximately parallel to a boulder ridge. After searching for approximately 15 minutes the trench was clearly identified in this boulder ridge and along the remaining seafloor as a linear feature marked by the exposure of fresh surfaces on disturbed cobbles and boulders. The lack of biogenic cover on the turned faces of the cobbles and boulders was the most prominant aspect of the trench. The plow had also encountered areas of exposed bedrock and over these outcrops the trench stopped and plow tool marks were not observed.

1985 SURVEY SITES

BLOCKS REPRESENT APPENDICES III, IV & V MAP AREAS

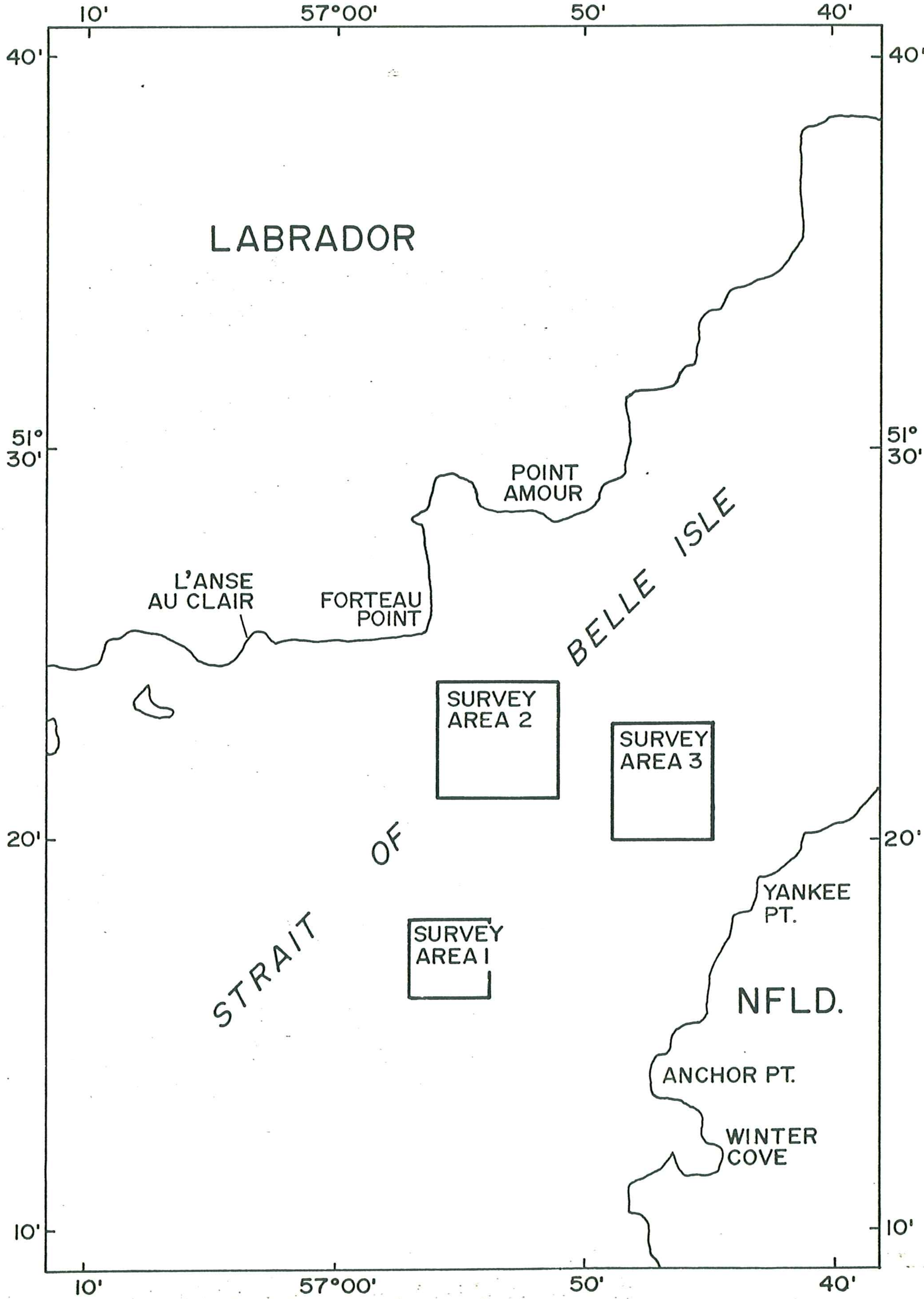


FIGURE I

In areas of boulder ridges the trench could be easily identified by the exposure of freshly disturbed boulders and a 15 - 25 centimeter depression (see front cover). The freshly exposed boulders lacked biogenic cover and the depression was caused by the displacement or removal of the boulders. In some cases little or no expression of the trench could be located for 3 - 4 meters past the crest of the trench. These boulder ridges had relief of 1 - 3 meters with slopes of 15 - 40 degrees.

Over the cobble and gravel seafloor between the boulder ridges the trench was visible as a 20 - 30 centimeter wide linear band of shell hash infill with no indication of relief. The trench feature was at times completely obliterated and unrecognizeable due to the mobile shell hash.

One 2 - 3 meters wide, 4 - 5 meters long bedrock outcrop was observed. The trench stopped abruptly at this outcrop and no straiations or tool marks of any type were observed. The contact between the bedrock and unconsolidated sediments marked the end of the expression of the trench.

Major accomplishments of dive 1 were; the location, identification and observation of the trench, observation of the lack of significant biogenic cover on freshly disturbed boulders, observation of the reaction of the plow to various substrates, the groundtruthing of the sidescan and other geophysical data and the actual visual observation of the substrate environment. Dive 1 was terminated after 55 minutes on the seafloor to allow time for another sidescan survey and dive in the afternoon.

Dive site 2 description

Survey and dive site 2 represents the fourth site picked in the planning stage. The object of this survey was to attempt to observe the tool markings of the plow remaining on the Forteau Limestone. During 1981, dive 3, parallel striations were observed and documented on the limestone outcrops. It was hoped that a comparison of the two features observed in 1981 and 1985 could give some indication of the rate of erosion or obliteration and hence an indication of the age of the striations. Weather and sea state conditions were good for both the survey and dive. Navigation during the survey was poor but a triangular grid of sidescan sonar and echosounder data was obtained. The trench feature was tentatively identified on two legs of the triangle (Appendix IV, figures 1 and 2)along a 10 meter bathymetric high. The sidescan sonar and echosounder profile compilation indicates linear continuous and discontinuous shell hash stringers interspaced and sometimes separated by boulder ridges with some possible bedrock outcrop (Appendix IV, figure 2). Identification of the trench feature was based on the crosscutting orientation of the trench to the surficial geology (Appendix IV, figure 4). PISCES IV was deployed north-east of the target to compensate for the current upon descent.

PISCES IV encountered bottom at 88 meters water depth. The submersible proceeded at a course of 250 degrees to intersect the trench perpendicular to its trend. The seafloor was composed of predominantly cobbles and gravel as observed during dive 1 but with a higher shell hash component. The boulder ridges were similar to those described in dive 1, 1 - 3 meter high ridges composed of a variation of grain sizes predominantly boulders up to 3/4 meters in diameter and with steep slopes. A boulder of 2 - 2 1/2 meters in diameter was observed during this dive but was the only sample of this size located during all three dives. Frequent shell hash deposites were encountered. These varied from small concentrations in the lee of prominant features such as cobbles, to large elongated shell hash beds or stringers (Appendix IV, figures 1 and 2). The shell hash particles have a large surface area but have a low density compared to the accompanying smaller rock fragments. The shell hash provided minimal resistance to the PISCES IV manipulator arm and were easily moved around. The preferential deposition of the shell hash material around prominant feature suggest that the shell hash is highly mobile and may undergo transport as often as every tidal cycle. The average settling velocities of the shell hash material, 0.15 meters/second, was determined by observing the time required for 100 randomly selected particles (both shell and rock fragments) to settle 20 centimeters in 20 degree Celcius fresh water. Maximum current velocities recorded within 5 meters of the seabed (L.C.D.C.,1984A) range from 0.60 to 1.68 meters/second. A simple comparison of settling velocities versus maximum current velocities indicates the possible mobility of the shell hash deposits. This interpretation is limited by such factors as cohesion, particle orientation and shape, surface roughness, cementation and consolidation which all could influence the shell hash mobility. A bedrock outcrop 2 meters wide and 10 meters long was observed. This outcrop was covered by striations approximately of the same size and orientation as those noted during the 1981 dives but no cross-cutting striations were noted as a result of plow tool marks.

Due to strong currents this dive did not cover as much seafloor as dive 1. The trench was not located due to a combination of; inaccurate navigation, bottom feature obliteration by a blanketing of shell hash and possibly due to overshooting of the feature during descent. Many attempts were made to correct the course but the dive had to be aborted due to a current velocity greater than 1 knot encountered at the base of a 5 - 6 meter high scarp. This scarp was difficult to observe but was possibly constructed of bedrock as some almost horizontal bedding planes (?) were noted. Loss of submersible control due to high velocity currents at this locality did not allow detailed inspection of the scarp.

The terrain observed during dive 2 was very similar to the area covered during dive 1 with the notable exceptions of; a very large increase in the shell hash component, the formation of actual shell hash beds or stringers, the presence of a large boulder of a size not located during other dives and the presence of striations on the bedrock outcrops not noted during dive 1 but possibly due to a different rock type. The presence of the scarp at the end of the dive was not noted on the bathymetry map (Appendix IV, figure 3).

Dive site 3 description

Survey and dive site 3 represent the fifth site picked during the planning stage. This dive was planned to observe the Newfoundland Escarpment which represents the physiographic boundary between the trough and the coastal zone. Sidescan sonar mosaics from previous surveys completed by Newfoundland and Labrador Hydro of this escarpment display features interpreted as iceberg impact pits and linear features. The sidescan sonar survey completed prior to the dive indicates boulder ridges, some of them crosscutting each other suggesting that they are iceberg scour marks with different times of formation (Appendix V, figure 1) and some irregular pits (?) or possible bedrock outcrop (?) areas. The sidescan sonar and echosounder profiles show an area with frequent well defined boulder ridges oriented parallel to the bathymetric contours. PISCES IV was deployed slightly south of the trench location just to the north of the Newfoundland Escarpment. The dive was planned to initially locate the trench and proceed along the trench to the east to intersect the bedrock cliff which forms the escarpment.

PISCES IV upon submerging encountered bottom at 93 meters water depth directly on top of the trench. On the sidescan sonar profile the seafloor features such as boulder ridges of dive site 3 are more distinct and fresher (?) looking than at the other dive site surveys. This observation was not confirmed during the dive as the seafloor resembles that of both dives 1 and 2. The course followed the trend of the trench. The trench generally has a slightly negative relief of 5 - 15 centimeters. The major factor in recognizing the trench as in dive 1 is the lack of biogenic cover on the fresh faces of the disturbed boulders. Colonization was noted on some of the fresh faces consisting of a few barnacles and one colourful intricate bright orange biota tentatively identified as "Basket Star" , family Gorgonocephalus (personal communication, Tim Lambert, MEL, Bedford Institute of Oceanography). Relief of a few of the boulder ridges was determined using the submersible's digital echosounder. The two ridges measured had relief of 1.4 and 2.0 meters respectively which is similar to the 1 - 3 meters range as observed during dives 1 and 2. The composition of the boulder ridges consists primarily of boulders set in a fine grained very cohesive clay matrix. This fine grained material was sampled for future analysis. The boulders exposed on top of the ridges remain after the finer sediments have been winnowed away by bottom currents to leave the boulder ridges seen throughout the area.

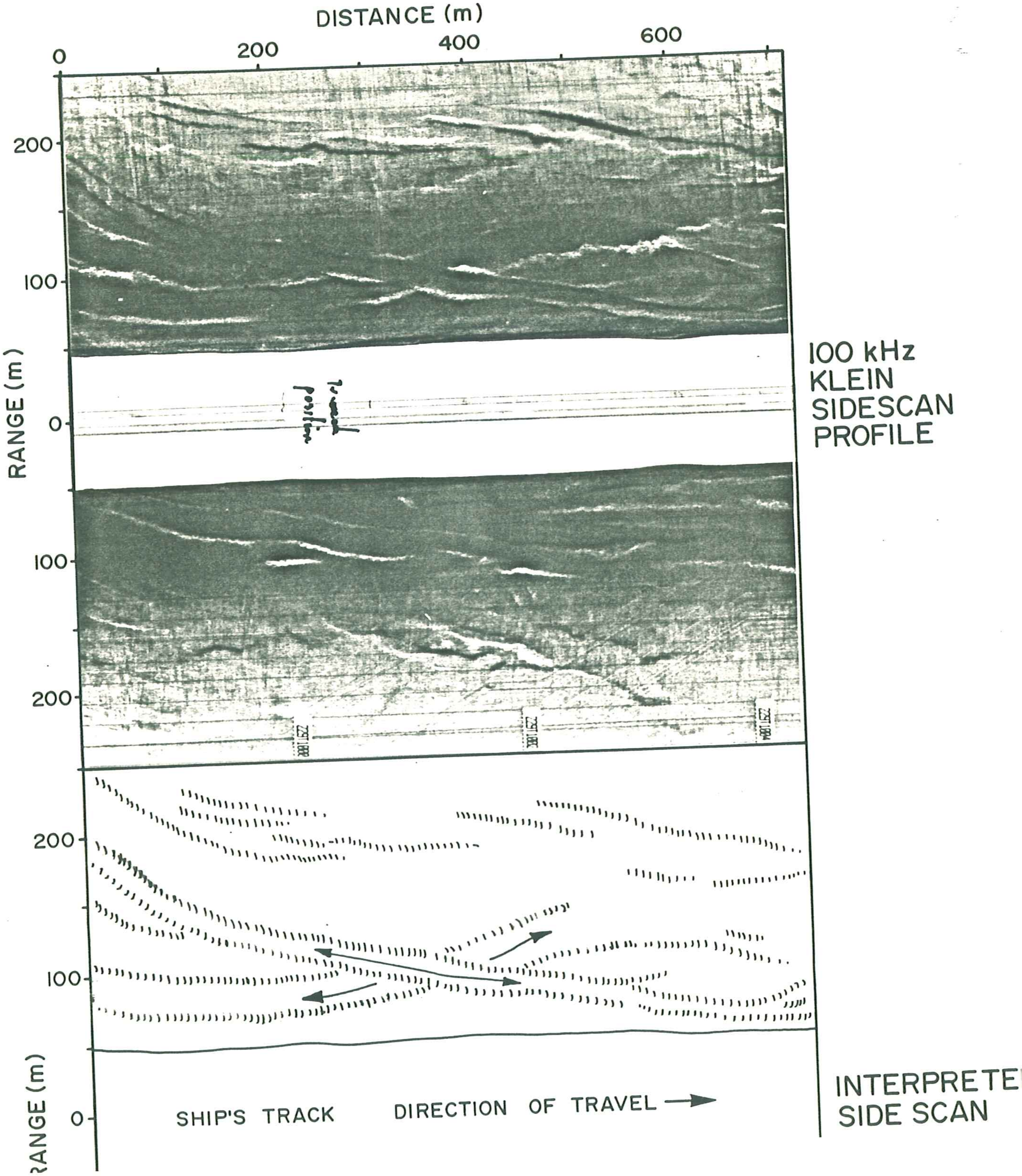
Dive 3 had to be aborted due to the proximity of a large iceberg. Major observation during this dive were; the similarity of this seabottom to that of the other dive sites, the colonization of some of the fresh faces on the disturbed boulders by barnacles and an orange intricate biota Gorgonocephalus and the presence of a clay matrix in the boulder ridges.

1981 - 1985 Observations

Observations made during the 1981 PISCES IV dives confirmed and in some cases allowed refinement of the surficial geological interpretations made from geophysical data collected in the area. Active bedforms and sediment deposits identified initially as sand were observed to be beds of shell hash which displayed bedforms. These beds were interpreted to be highly mobile possibly during each tidal cycle (Josenhans, 1981). The boulder ridges initially identified as DeGeer morainal ridges could also be interpreted as iceberg scour rims however no conclusive evidence for either argument was made during the dives. Degradation rates of surficial features is rapid and colonization rates by organic growth appear to be rapid. A "fresh" scour identified in the dive site 2 survey area could visually only be distinguished from the surrounding seafloor and boulder ridges by its steeper slopes. All seafloor material had been completely colonized by biogenic growth. Striations were observed on Forteau Limestone but it was difficult to determine the age due to the unknown erodability of limestone in the Strait environment. Some dominant bathymetric features encountered during the PISCES IV dives were not identified on the bathymetric maps this suggests inaccurate navigation during the PISCES IV dives.

Observations made in 1981 were resurveyed during the 1985 dives and sidescan sonar surveys. The shell hash deposits were clearly identified on both the sidescan survey and during the dive at site 2. The mobility of the shell hash in the current regime encountered in the Strait was evident. The colonization rate by biogenic cover was determined to be slower than initially thought with little or no colonization occuring within the period of one year therefore the "fresh" scour observed in 1981 could be a substantially older scour. Striations over bedrock were also observed during the 1985 dives but only on the Forteau Limestone and not on the Hawke Bay Sandstone, only two small outcrops were observed. Unfortunately it could not be determined whether the plow had traversed the Forteau Limestone outcrop, the small observed outcrop of Hawke Bay Sandstone was traversed by the plow but no plow tool mark were observed. The presence of unexpected bathymetric features such as the 5 - 6 meter scarp encountered during dive 2 are largely due to the navigational inaccuracies of the tender vessel. The crosscutting relationships (where one feature is seen to transect another) (figure 2) of boulder ridges was observed indicates that some of the boulder ridges are indeed iceberg scours and not DeGeer moraines. This is supported to a lesser degree by the presence of a fine grained cohesive matrix in the cores of the boulder ridges sampled during the dive. These two features were not observed for all the boulder ridges.

CROSSCUTTING BOULDER RIDGES



Highlights

Findings and observations made were:

1. the trench preservation potential varies with subbottom type,
2. the trench displays very little relief where preserved (maximum 20 cm in boulder ridges based predominantly on disturbance of boulders),
3. the colonization rate of biogenic cover provides a good relative indicator of time of disturbance, although detailed evidence on rates is required,
4. shell hash beds comprising of high surface area and low density material are possibly very mobile within the Strait of Belle Isle,
5. loss of trench definition after the crest of boulder ridges could indicate that the plow missed 3-4 meter sections,
6. good definition of the trench was noted on 100 kHz. Klein sidescan sonar system,
7. good visual groundtruthing of trench feature and measure of plow disturbance,
8. the cobble and gravel lag deposit acts as an effective armouring layer which when disturbed allows a plume of fine sediment to be put into suspension as observed during sampling on dives 1 and 3,
9. Hawke Bay Sandstone bedrock outcrop traversed by the plow displayed no indication of scouring by the plow or any other visible tool markings,
10. most boulder ridges are 1-3 meters in height with slopes of approximately 15-40 degrees,
12. scarp feature on dive 2. Dive abandoned at this site due to high velocity current possibly directed around cliff feature cliff carved into bedrock exposed face of sedimentary rock type with visible horizontal widely spaced bedding planes (?), scarp face displayed distinct linear horizontal features but this could not be confirmed or investigated.

Conclusions

The MV Pandora II cruise 85-061 using the PISCES IV manned submersible in the Strait of Belle Isle was very successful with excellent visual observation and video recordings pertinent to engineering, surficial geological and process related studies.

Observations regarding the engineering aspects are; the gradients and composition of the boulder ridges, resistant material of the bedrock outcrops, and cable burial depth in mobile(?) shell hash beds. The gradients of the boulder ridges range from 15-40 degrees it was noted that after the plow passed the crest of some of the boulder ridges the trench was poorly defined or discontinuous (figure 3). Only one instance of plow contact with a Hawke Bay Sandstone bedrock outcrop was observed. The trench was visible on both sides of the outcrop but no plow tool mark were observed on the bedrock outcrop. The shell hash beds and stringers observed during the dives were only tested for consolidation and composition at the immediate surface. This surface layer was predominantly composed of 1-2 centimeter diameter shell hash with occasional gravel, this layer was easily disturbed and mobile. The composition of the entire bed thickness was not determined. The visual ground-truthing capability of the PISCES IV manned submersible provided an insight into some possible problem cable burial areas as well as documenting the plowability of the majority of the unconsolidated substrate of the Strait of Belle Isle.

Surficial geology of the substrate in the Strait of of Belle Isle is influenced to some degree by iceberg scouring, both by relict and by contemporary scouring . The action of the plow on the substrate is analogous to an iceberg scour and the preservation potential of its tool marks is useful in the study of the chronology of the iceberg scour phenomena. During the PISCES IV dives the major observation was the colonization rate of the biogenic activity upon the fresh surfaces on boulders exposed during the plowing operation. Within one year only a few barnacles were encrusted on the exposed fresh faces of the boulders and an occasional orange "coral like" fauna tentatively identified as Gorgonocephalis (pers. comm. T. Lambert). This member of the echinoderm family seems to be prolific in some locations in the Strait of Belle Isle. On the Labrador Shelf rapid colonization of fresh iceberg scour features by closely related species has also been observed.

GENERALIZED OBSERVED SEAFLOOR & TEST TRENCH

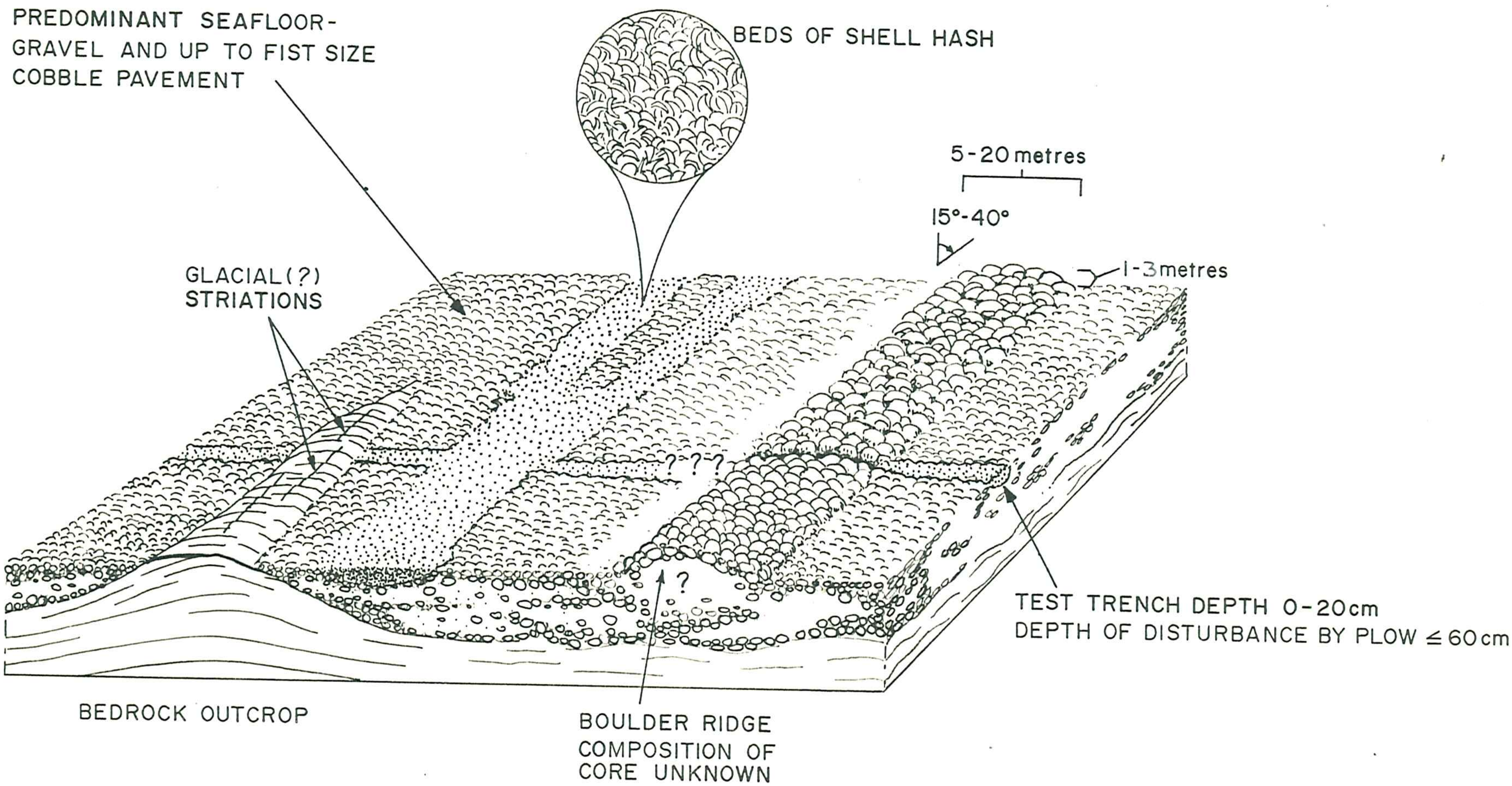


FIGURE 3

Acknowledgements

We wish to thank the captain, officers and crew of the MV Pandora II for their assistance and a very special thank to Mr. Frank Chambers, chief pilot of Pisces IV, and the remaining Pisces IV crew who made this cruise a success. We wish to thank Mr D. Locke and Ms. A. Cotie (AGC) for technical and navigational support and Ms. L.A. Kiely (contractor) for logistic support. We also wish to thank Mr. Russell Parrott and Mr. Gordon Fader of the Atlantic Geoscience Centre, and Mr. Harvey Young and Mr. George Lundrigan of Newfoundland and Labrador Hydro for there useful comments and critical review.

References

Josenhans, H.W., 1981. Cruise Report - Pandora II 81-057 October 13 - 28, 1981. Atlantic Geoscience Centre internal report.

Josenhans H.W. and Barrie, J.V., 1982. Preliminary results of submersible observations on the Labrador Shelf. Geological Survey of Canada, Paper 82-1B, pp. 269-276.

King, L.H. and Fader, G.B., 1985. Wisconsinan Glaciation of the Continental Shelf - Southeast Atlantic Canada. Geological Survey of Canada, GSC Bulletin 363.

Lower Churchill Development Corporation Limited, 1984A. Final Report on Strait of Belle Isle Crossing HVDC Transmission Submarine Cable Scheme 1984 Program, Volume I Engineering Report, L.C.D.C. internal report

Lower Churchill Development Corporation Limited, 1984B. Final Report on Strait of Belle Isle Crossing HVDC Transmission Submarine Cable Scheme 1984 Program, Volume IV Appendix A - Review of Data, L.C.D.C. Internal Report

APPENDIX I: DIVE LOCATIONS MAP

APPENDIX II: NAVIGATION AND DIVE LOCATIONS

APPENDIX II

Pandora II cruise 81-057 Strait of Belle Isle dive sites

PISCES IV dive 1

Begin dive: 51.3650 N / 56.8617 W
End dive: 51.3417 N / 56.8683 W

PISCES IV dive 2

Begin dive: 51.3567 N / 56.8017 W
End dive: 51.3397 N / 56.8103 W

PISCES IV dive 3

Begin dive: 51.4000 N / 56.8667 W
End dive: 51.4083 N / 56.8517 W

PISCES IV dive 4

Begin dive: 51.3750 N / 56.8933 W
End dive: 51.4000 N / 56.9067 W

Navigation MV Pandora II, 1985, Strait of Belle Isle

Ship's Navigation Dive 1 Site Survey

228-1030	51.1666	56.8728	Loran	
228-1040	51.2410	56.8827	Loran	Deployed sidescan
228-1050	51.2475	56.8952	Loran	
228-1100	51.2557	56.9067	Loran	
228-1100	51.2653	56.9203	Radar	
228-1110	51.2727	56.9350	Radar	Survey extended due to sonar malfunction on PISCES IV
228-1110	51.2660	56.9167	Loran	
228-1118	51.2833	56.9417	Radar	
228-1118	51.2730	56.9222	Loran	Start turn
228-1123	51.2753	56.9300	Loran	
228-1123	51.2838	56.9408	Radar	
228-1125	51.2830	56.9302	SatNav	
228-1130	51.2770	56.9492	Loran	In line with dive site 2.25 cables away
228-1130	51.2863	56.9652	Radar	
228-1137				Passed over dive site
228-1140	51.2915	56.9477	SatNav	
228-1140	51.2850	56.9800	Radar	Passed a little to the west of the proposed site proceeding with turn to starboard for a wide turn to recross proposed dive site
228-1151	51.2852	56.9792	Loran	Steering 063
228-1151	51.2942	56.9985	Radar	
228-1200	51.2983	56.9987	Radar	
228-1200	51.2900	56.9662	Loran	
228-1208	51.2922	56.9548	Loran	Proceeding with turn to go back over dive site
228-1208	51.2983	56.9567	Radar	
228-1220	51.2888	56.9378	Loran	
228-1220	51.2942	56.9605	Radar	
228-1230	51.2742	56.9498	Loran	
228-1230	51.2830	56.9668	Radar	Sidescan recovered end survey

Ship's Navigation and PISCES Position Dive 1

228-1300	51.2830	56.9475	Loran	Turning to launch PISCES and ugly boat
228-1306	51.2830	56.9517	Loran	Ugly boat in water
228-1315	51.2748	56.9622	Loran	PISCES launched, water depth 96 meters
228-1318	51.2718	56.9650	Loran	PISCES submerged on port side
228-1325	51.2698	56.9627	Loran	PISCES descending
228-1330	51.2700	56.9587	Loran	PISCES on bottom, water depth 90 meters

PISCES bearing: 309.8 range: 530.4 meters
Vessel heading: 036.4
True bearing : 346.2

```
228-1335  51.2708 56.9575 Loran    PISCES heading 035
             PISCES bearing: 336.0  range: 479.6 meters
             Vessel heading: 357.2
             True bearing  : 333.2
228-1340  51.2718 56.9562 Loran    Bridge indicates that  target
                                   is  located 150 meters  north
                                   of present PISCES position
             PISCES bearing: 346.7  range: 523.9 meters
             Vessel heading: 348.2
             True bearing  : 334.9
228-1350  51.2728 56.9543 Loran    PISCES at trench
             PISCES bearing: 003.8  range: 544.3
             Vessel heading: 341.5
             True bearing  : 345.3
228-1405  51.2752 56.9497 Loran    PISCES will be coming up in
                                   20 minutes
             PISCES bearing: 314.9  range: 541.7
             Vessel heading: 345.3
             True bearing  : 300.2
228-1410  51.2763 56.9482 Loran    PISCES will be coming off
                                   bottom in 20 minutes
             PISCES bearing: 312.3  range: 729.9 meters
             Vessel heading: 334.2
             True bearing  : 286.5
228-1410 to 1423                   PISCES range and bearing not
                                   recorded due to poor fixes
                                   from Honeywell system
228-1715  51.2770 56.9468 Loran
228-1423                           PISCES 50 meters from surface
228-1425                           PISCES 25 meters from surface
228-1426  51.2807 56.9523 Loran    PISCES on surface
228-1432                           PISCES in tow
228-1436  51.2737 56.9582 Loran    PISCES recovered
```

Ship's Navigation Dive 2 Site Survey

```
228-1525  51.3252 56.8983 Loran    Streaming sidescan
228-1531  51.3252 56.8983 Loran    Sidescan out
228-1534  51.3633 56.9008 Radar
228-1540  51.3622 56.8788 Loran    Proceeding over dive site and
                                   starting turn to resurvey site
228-1549  51.3705 56.8782 Loran    Completed turn recrossing site
228-1550  51.3842 56.9063 Radar
228-1558  51.3617 56.8923 Loran
228-1600                           Starting turn
228-1603  51.3717 56.9167 Radar
228-1600  51.3607 56.8745 Loran    Over target
228-1615                           Retrieving sidescan
228-1618  51.3625 56.8575 Loran
228-1621  51.3638 56.8495          Sidescan on board
```

Ship's Navigation and PISCES Position dive 2

228-1636	51.3617 56.8735 Loran	Ugly boat launched and clear
228-1640		PISCES launched and released approximately 0.06 cables from dive target, bearing 160
228-1643	51.3600 56.8832	PISCES submerged
228-1648	51.3585 56.8830 Loran	
	PISCES bearing: 237.6	range: 261.9 meters
	Vessel heading: 150.1	
	True bearing : 027.7	
228-1652	51.3578 56.8817 Loran	PISCES on bottom water depth 88 meters, Pisces heading 270
	PISCES bearing: 263.0	range: 315.5 meters
	Vessel heading: 100.9	
	True bearing : 003.9	
228-1700	51.3575 56.8785 Loran	
	PISCES bearing: 231.8	range: 504.8
	Vessel heading: 074.9	
	True bearing : 306.7	
228-1707	51.3580 56.8770 Loran	
	PISCES bearing: 244.8	range: 712.6
	Vessel heading: 041.1	
	True bearing : 285.9	
228-1715	51.3583 56.8773 Loran	
	PISCES bearing: 266.8	range: 738.2
	Vessel heading: 019.4	
	True bearing : 286.2	
228-1720	51.3605 56.5337 Loran	Steam to initial dive position to provide a good fix for PISCES
	PISCES bearing: 320.0	range: 466.0
	Vessel heading: 304.7	
	True bearing : 264.7	
228-1730	51.3610 56.8853	
228-1740	51.3598 56.8782 Loran	
228-1752	51.3580 56.8797 Loran	
228-1800	51.3570 56.8832 Loran	
228-1808	51.3560 56.8852 Loran	
228-1809	51.3638 56.9115 Satnav	
228-1815	51.3548 56.8873	PISCES 60 meters from surface
228-1830	51.3577 56.8895 Loran	Tow line attached to PISCES

Ship's Navigation Dive 3 Site Survey

229-0928	51.3642 56.8107 Radar	Steaming to start of survey site
229-0931		Sidescan deployed, ship's heading 074
229-0939	51.3642 56.8017 Radar	
229-0946	51.3633 56.7933 Radar	
229-0954	51.3675 56.7903 Radar	
229-1000	51.3750 56.7847	Passing iceberg on port side,

				iceberg over trench
229-1006	51.3618	56.8228	Satnav	
229-1011	51.3783	56.7767	Radar	
229-1023	51.3458	56.7908	Radar	
229-1037	51.3580	56.7900	Radar	
229-1042	51.3675	56.7900	Radar	
229-1046	51.3585	56.7620	Radar	Maintaining a straight course over trench
229-1103	51.3700	56.7738	Radar	
229-1110	51.3600	56.7583	Radar	
229-1115	51.3558	56.7508	Radar	Recovering sidescan

Ship's Navigation and PISCES Position Dive 3

229-1205 51.3590 56.7658 Radar — Launching PISCES 250 meters North of target as determined from 229-1000 position

229-1215 51.3592 56.7685 Loran
PISCES bearing: 250.7 range: 301.9 meters
Vessel Heading: 255.5
True bearing : 146.2

229-1220 51.3573 56.7730 Loran
PISCES bearing: 347.0 range: 38.7 meters
Vessel heading: 240.5
True bearing : 227.5

229-1225 51.3692 56.8008 Radar — PISCES landed on trench orientation of trench 120
PISCES bearing: 253.5 range: 396.6 meters
Vessel heading: 159.6
True bearing : 053.1

229-1237 51.3667 56.7967 Radar
PISCES bearing: 350.5 range: 434.2 meters
Vessel heading: 056.9
True bearing : 046.9

229-1300 — Abort dive due to proximity of iceberg, PISCES off bottom at 95 meters

229-1305 — PISCES on surface

229-1310 51.3700 56.7908 Radar — PISCES in tow

.pa

APPENDIX III: SURVEY AND DIVE SITE 1

APPENDIX IV: SURVEY AND DIVE SITE 2

APPENDIX V: SURVEY AND DIVE SITE 3

APPENDIX VI: TECHNICAL INFORMATION

RESEARCH MANNED SUBMERSIBLE PISCES IV

The submersible PISCES IV is owned by the department of Fisheries and Oceans and operated from the Department's Institute of Ocean Sciences at Sidney B.C. PISCES IV has served the scientific community since 1972. Operated for oceanographic research, she has made some 1600 dives on the Canadian West and East Coasts and in Arctic waters. PISCES IV has worked away from home port (Institute of Ocean Sciences) for periods of up to six months. The submersible is capable of operating from any platform that can supply the necessary power requirements and lifting capability. PISCES IV is also air transportable (i.e. Hercules CC 130) and has been transported from coast to coast and to the Arctic many times in the past.

PISCES IV generally operates from the submersible handling vessel M.V. Pandora II or the self contained barge "Pender" and has a crew of six pilots/maintainers. This crew is highly trained in various trades to enable repairs/maintainance to be carried out in the field. All crew members are trained scuba divers and adept in the use of small boats and launches.

Operating Characteristics

Length:	:	6.1 meters
Beam	:	3.0 meters
Height	:	3.7 meters
Draft	:	2.7 meters
Speed	:	Cruise 0.5 knots Maximum 2.0 knots
Weight (in air)	:	10,630 Kg
Normal dive duration	:	3-8 hours
Depth capacity	:	2000 meters
Complement	:	1 Pilot 2 Observers

Navigation

Gyro compass, magnetic compass, scanning sonar system,
Depth gauges (analog + 1 meter, digital + 0.005 meters),
3 viewports, pinger locating and homing receiver,
echo sounder, Honeywell tracking system, external strobe.

Electrical power

120V D.C., 385 Amp/hr lead acid battery
24V D.C., 385 Amp/hr lead acid battery
inverter for 120V A.C. power
inverter for 12 V.D.C. power

Manouvering control

Two, 5 H.P. each, reversible thrusters mounted P/S amidships. Thrusters are rotatable 90 degrees upwards and 15 degrees downward from the horizontal.

Communication

Underwater telephone, VHF Radio telephone.

Photographic capabilities

Outside colour BETA video camera and 70 mm still camera with strobe, inside/outside colour and b/w video cameras and use of handheld camera from inside using external strobe.

Temperature

External probe

External lightning

Two 1000 watt and three 500 watt Quartz Iodide lights, may be used seperately or any combination and may be moved prior to dive as required.

Water sampling system

External sampling and storage.

Other features

The submersible is fitted with a general purpose 6-function manipulator arm and a heavy duty 3-function claw may be fitted. Through hull electrical connectors (52F electro type series underwater plugable connector) via an external junction box, 5 amp. per conductor are available. A 19" equipment rack with limited space is available in the sphere.

The submersible is designed to be versatile with respect to the weight, space and power requirements of portable scientific equipment in order to meet the differing needs of scientists using the vehicle but sufficient lead time must be given to allow for feasibility studies and to plan the fitting of such equipment.

PISCES IV operating limits

Dives are not conducted when the conditions exceed the following limits:

Depth of water	: 2000 meters
Visibility	: 3000 meters
Sea state	: 1.5 - 2.0 meters
Current	: 2 knots
Wind	: Over 22 knots at commencement of dive

- As a rule the submarine is not to operate in the vicinity of known wrecks woithout careful assessment of the situation.

- Dives are not conducted at or near vicinity of known explosive dumping areas.

Safety features

In the event of accident or malfunction, PISCES IV occupants can be safely returned to the surface. Three lead dropweights can be jettisoned to reduce the vehicle's weight, and the mechanical arm can be released if it should becomes entangled. Breathing apparatus is provided for each occupant in the event of fire. A fire extinguisher system is also fitted.

User responsibility

1. Films for 70 mm camera, Betamax tapes, audio cassettes.
2. Cameras for inside use (lens protection-rubber hood).
3. External connectors and penetrators.
4. Internal space limitations (i.e. 19" tool rack).
5. Voltage and power restrictions.
6. Preparation of special equipment, consultations and fitting time.
7. Protective clothing for deck use.

Contacts

R.W. Parkinson Regional Marine Supt.	Bus. Home.	604-656-8245 604-656-6385
L.A.H. Fitch Assistant Mar. Supt. (deck)	Bus. Home.	604-656-8246 604-656-6871
F. Chambers Chief Pilot PISCES IV	Bus. Home.	604-656-8332 604-386-9677

Special additional equipment

Guillotine

A rope cutting guillotine can be easily fitted and is designed for up to 2.5 centimeter diameter rope. This is used during recovery of sub-surface equipment.

Recovery hook

The manipulator jaws can be fitted with a three ton snap hook which either tied off to Pisces IV, or attached to a surface buoy line makes recovery of large objects safe and easy.

PISCES IV "heavy" lift capability is limited to 227 kilograms in water. In heavy lift conditions PISCES IV must be fitted with drop weights and a line release system.

The surface buoy line recovery method is usually restricted by water depth and line handling.

Carousel collecting Jars

PISCES IV may be fitted with up to 8 - 2.5 litre "clear-view" collecting jars. These are mounted on a rotating carousel assembly on the upper sensor frame, in easy view of the pilot. Each jar can be fitted in turn by a variable speed suction impellor and rotated onward by a simple hydraulic indexing latch. This also seals each jar, minimising specimen contamination or washout during recovery.

Each jar is fitted with a stainless filter screen and these in turn may be overwrapped with additional filters according to the type of specimen collecting. The variable speed impellor motor may be adjusted to suit the flow requirement. Upon recovery each jar and filter body may be removed from the carousel for specimen retention.

Carousel sample tray

A large diameter tray (70 centimeters) is fitted at all times on the lower sensor frame and within easy reach of the 6-function manipulator arm.

The tray hydrualically extends into the pilot's view and automatically indexes to provide a fresh compartment for specimen collecting.

Up to 8 compartments can be provided for smaller specimens but with standard 4 compartments it is further possible to be fit with a number of wide mouth (3 litre) jars to ensure specimens are recovered in their natural environment. When retracted the individual compartments move under a close fitting clear-view cover. This ensures minimum disturbance and washout of specimens during recovery.

Through-hull water collecting

This system enables small multi specimens of water to be collected within the main sphere. Fine metering control is provided to the scientist but at all times a backup hull shut-off valve is under the control of the pilot. An extension tube may be fitted to the manipulator to enable precise levels to be sampled. No internal sampling will be allowed in fine silt or anoxic bottoms or in bodies of water which may induce cabin environmental contamination. Researchers are requested to provide racked or secured and sealed bottles and adequate overflow containers. No salt water contamination will be permitted in the submersible and no corrosive or contaminating chemicals are allowed. Through hull water collecting is limited to 1000 meters and is at the pilot's discretion at all times.

M.V. PANDORA II

General Arrangement

Dimensions

Length o.a.	58.0 meters
b.p.	56.1 meters
Beam	13.7 meters
Draft	4.5 meters
Tonnage	1377.7 GRT

Machinery

Twin screw diesel	2,600 BHP each shaft
Speed	13 knots maximum
	10.5 knots economical
Endurance-Steaming	100 days
-Provisions	100 days
Bow Thruster	

Generator capacity for ship's service plus 250 Kw

Fresh water	8 tons per day

Accomodation

Crew	18
Additional	12 (includes 6 PISCES IV crew)

Navigation

Two (2) marine radar sets maximum range 48 miles
Loran type C
Omega (can be fitted)
2 Gyro compasses
Echo sounders

Communications

Radio telephones

HF - 2 Marconi CH25 6 channel
1 Marconi CH26 12 channel
VHF sets

Alarm generator

TG 502A Distress Tone Alarm Generator

Helicopter deck

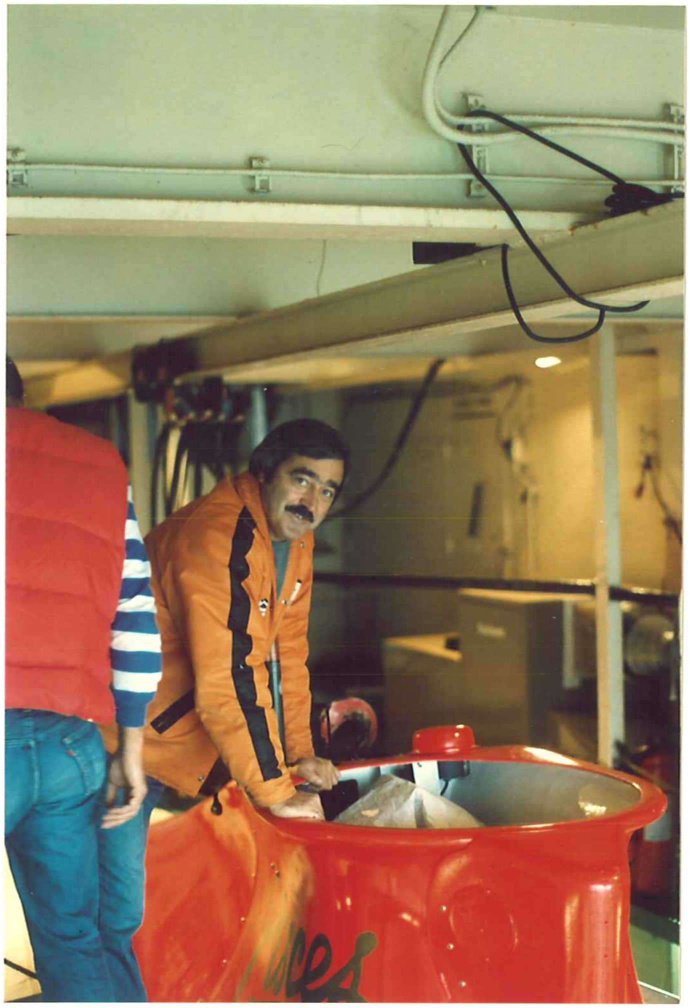
Fitted on after superstructure. Size: 900 sq. ft.
Weight: 4000 Ibs.

Submersible support equipment

- 'A' frame, fitted aft, capable of recovering and deploying PISCES IV.
- Machine shop
- Portable gas welding equipment, arc welding equipment
- Diving facilities (divers washdown, bottle stowage), no recompression
- HP air charging
- 27 ft. workboat
- 12 ft. rubber boat
- 120 V, 24 V chargers
- VHF-FM Channel 15
- ADFS-320 VHF radio direction finder
- 2 wet labs on main deck
- Scientific lab (internal)
- Winches as required
- Gallow A Frame
- Austin Western - Extension Crane 1100 lbs @ 22 ft.

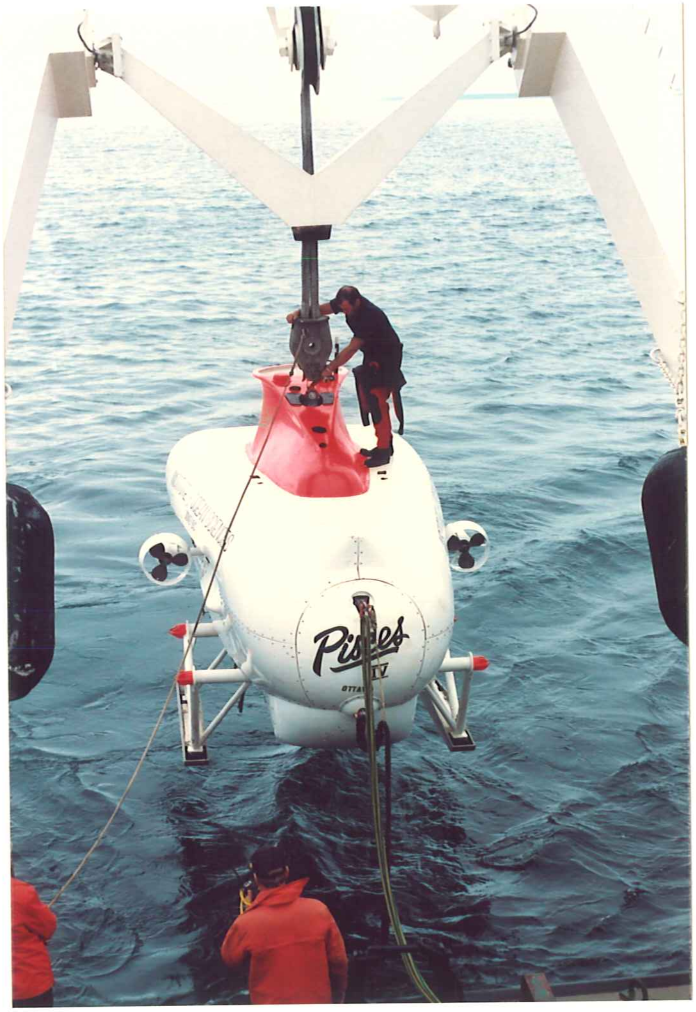
APPENDIX VII: PHOTOGRAPHS

Photographs of deployment and recovery, dive 3



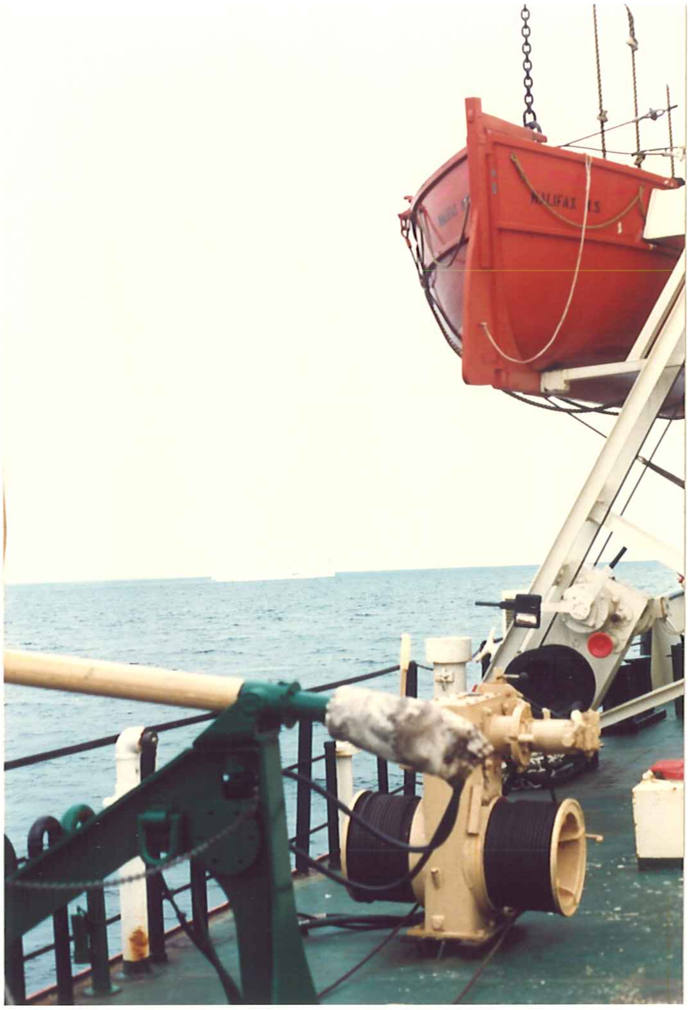
1: Harvey Young preparing to board

2: Preparing to launch PISCES IV



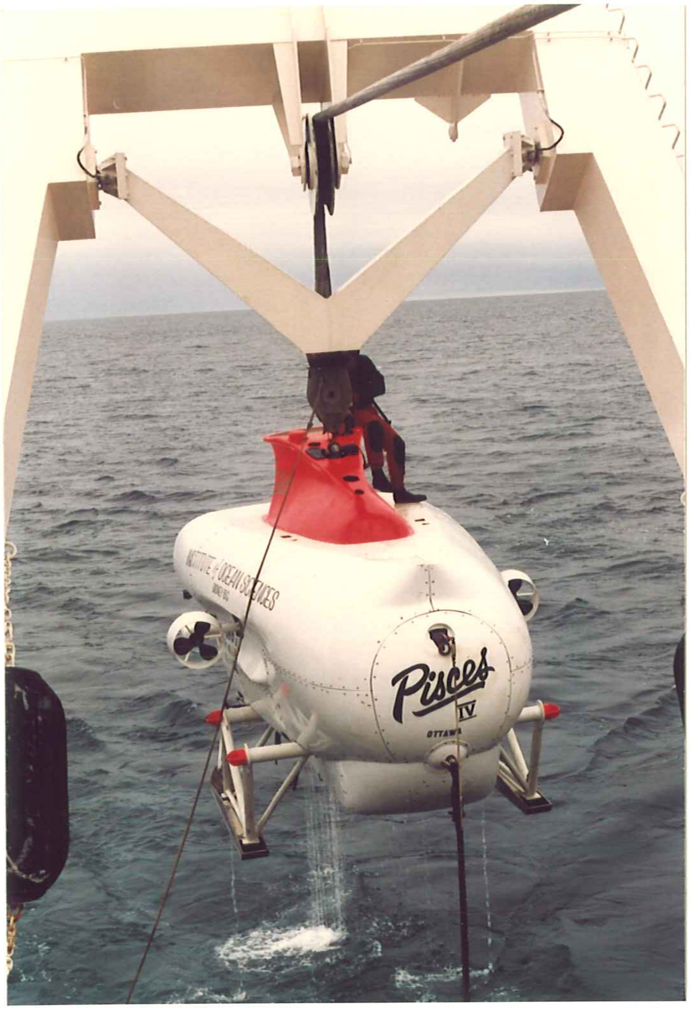
3: Launching PISCES IV

4: Preparing to dive



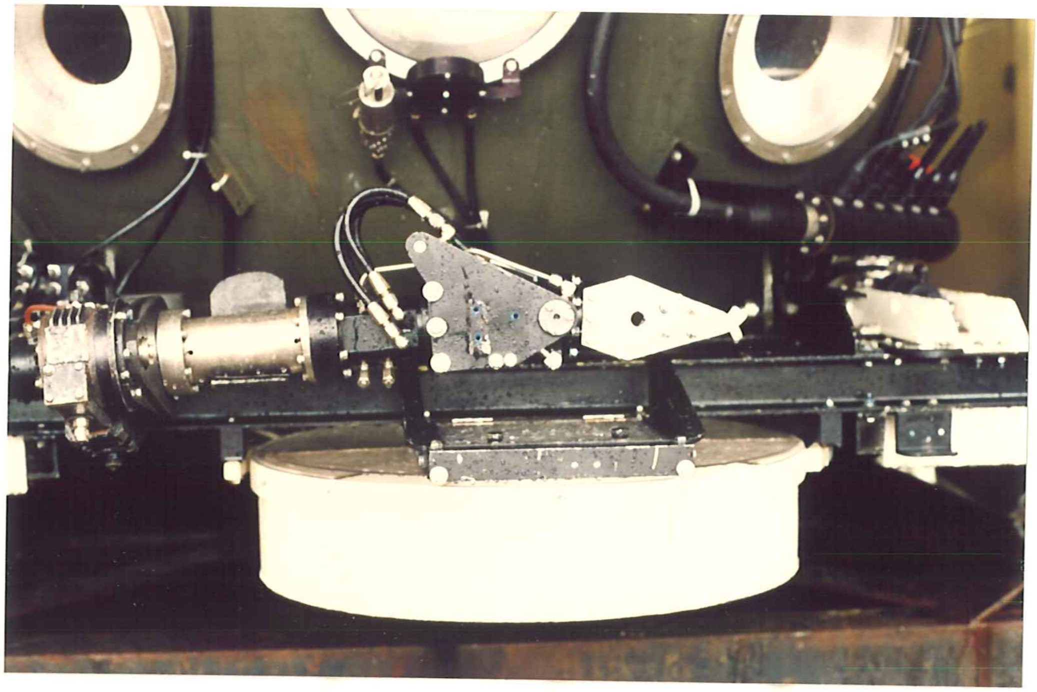
5: Problem iceberg

6: PISCES IV recovery



7: PISCES IV recovery

8: PISCES IV and problem iceberg



9: Manipulator arm and sample tray

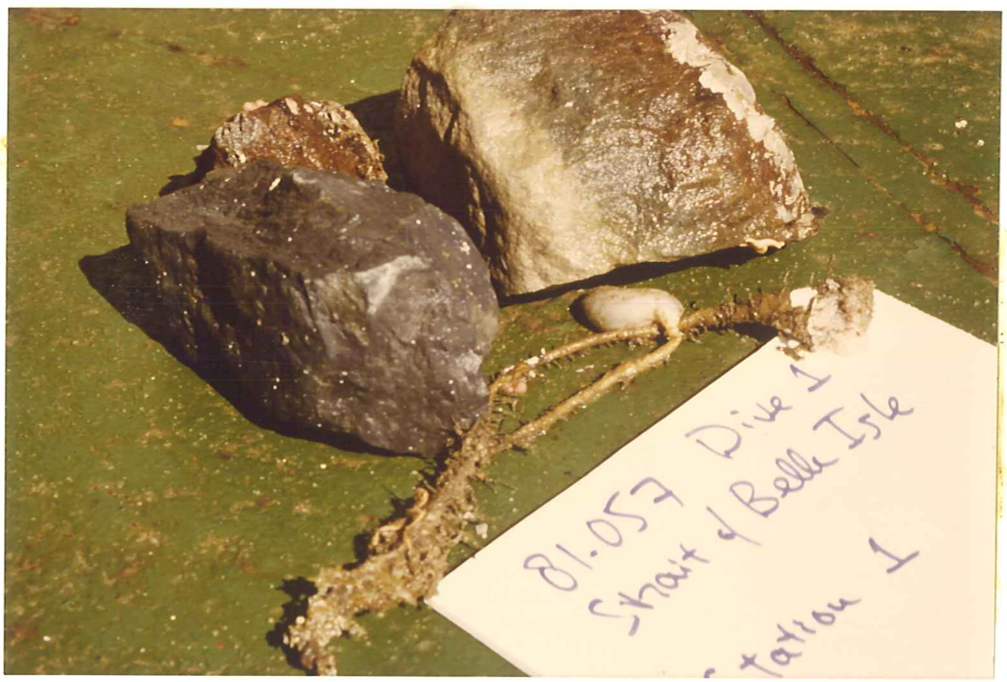
10: External video and sonar

Bottom photographs, Dive 1

1: Trench cut through boulder ridge, note sea anemone bottom centre of photo, approximately 10 centimeters in diameter

2: Trench cut through boulder ridge, note uncolonized fresh rock faces on disturbed rocks

3: Same site as previous photograph, fresh face exposed on light coloured rock approximately 20 centimeters per side



4: Rock samples indicating lack of biogenic cover on previously buried faces

APPENDIX VIII: VIDEO ANNOTATION

Appendix VIII contains the preliminary compilation of dive observations prepared by Ms. Linda Kiley. This report documents all video and audio observation recorded during the PISCES IV dives and references these observations to Atlantic Daylight Time and to the tape counters of the video recordings. The final version of this report will form an integral part of the M.V. Pandora II cruise 85-061 report. This report will be released as a Bedford Institute of Oceanography internal publication.