Natural Resources Canada Ressources naturelles Canada

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 4824

Hudson 2004-030 Cruise Report
July 10–20, 2004

D.C. Mosher

2014

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 4824

Hudson 2004-030 Cruise Report
July 10–20, 2004

D.C. Mosher

2014

doi:10.4095/295081

Recommended citation
Mosher, D.C., 2014. Hudson 2004-030 Cruise Report, July 10–July 20, 2004; Geological Survey of Canada, Open File 4824, 73 p. doi:10.4095/295081

Table of Contents

List of Figures

List of Tables

Hudson 2004-030 Cruise Report
July 10-20, 2004
Days 192-202
David C. Mosher

Depart: St. John's. Newfoundland
Arrive: Dartmouth (BIO Jetty)
Chief Scientist: Dr. D.C. Mosher
Master: Capt. Michael Hemeon

Geographic Location

St. Pierre Slope (Haddock Channel), central Scotian Slope (Mohican Channel) and Scotian Shelf (Western Bank) (Fig. 1).

53° 00.00'	-63° 00.00'	43° 41.00'	-59° 25.00'
42° 20.00'	-61° 30.00'	43° 07.00'	-59° 25.00'

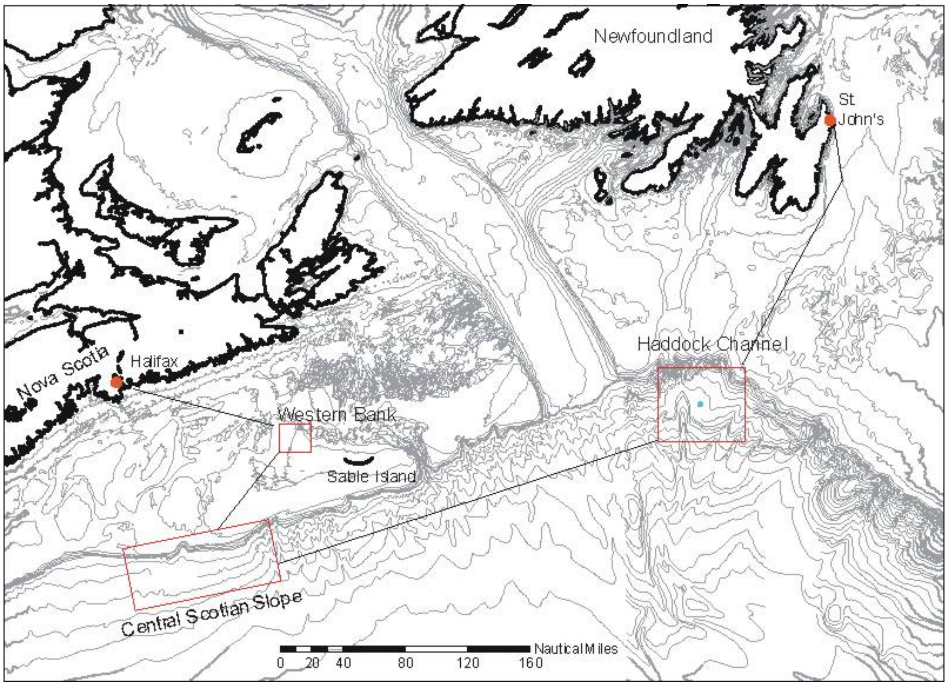


Figure 1: Location map outlines of survey areas for Hudson 2004-030.

Objectives

The objectives of the cruise were principally focused on gas hydrate research on the eastern continental slope of Canada, as part of the Earth Science Sector "Gas Hydrates: Fuel for the Future" program. Areas of known bottom simulating reflectors (BSR's) were mapped and sampled for stratigraphy and velocity structure to characterize the BSR's and possible associated hydrate occurrences through standard seismic reflection techniques and with ocean bottom seismometer experiments. Piston core sampling of gas "chimneys" was conducted to characterize the gas contained within sediments that appears from 3D seismic data to come from deep (1 sec) in the stratigraphic section. Heat flow measurements were also made to establish the baseline thermal regime of the margin and to recognize any anomalous characteristics over BSR regions. Sampling and heat flow measurements were also conducted in non-BSR regions as controls.

Secondary objectives included geohazard research for the Geoscience for Ocean Management (GOM) program. Regional seismic reflection lines were acquired on the Scotian Slope to provide ties with the stratigraphy established in the Verrill Canyon region of the slope. In addition, cores were acquired to contribute to the slope geotechnical program and an "in situ "probe (Free Fall Cone Penetrometer Tool) was tested to provide additional geotechnical data. The tool was developed by industry (ChristianSitu and Brook-Ocean Technologies) and this was the first field test.

The final objective of the cruise was to acquire geophysical data on the Scotian Shelf as part of the Geoclutter study to contribute to the ESSIM project of GOM. Geoclutter is a collaborative program between the GSC(A) and Defence Research Development Canada of the Department of National Defense. The GSC(A) contribution is to provide a regional geological assessment of the Scotian Shelf and detailed studies of two areas on the shelf where "clutter" and "no-clutter" have been identified. Geoclutter are geologic targets that may appear on military sonar records when searching for man-made targets. The objectives during this expedition were to map a 10 x 10 km area on Western Bank that was identified as a possible "no-clutter" site. The site was mapped with sidescan sonar, Huntec DTS boomer and 10 in^3 sleeve gun seismic reflection systems.

Scientific Personnel

Name	Affiliation	Duties
David Mosher	GSC-A	Chief Scientist
Keith Louden	Dalhousie	Second Scientist – OBS and flow
Ken Asprey	GSC-A	marine geophysics/seismic operations technician
Austin Boyce	GSC-A	marine electrical technician
Calvin Campbell	GSC-A	seismic/watchkeeping/GIS support
Borden Chapman	GSC-A	marine geophysics/seismic operations technician
Harold Christian	Christiansitu	FFCPT testing
Lori Cook	Student	General watchkeeping/sampling
Ray Cranston	GSC-A	Geochem sampling
Paul Girouard	GSC-A	Navigation and geophysical record keeping
Bob Iuliucci	Dalhousie	OBS
Kate Jarrett	GSC-A	Sampling/Coring
Terri Lawrence	Student	General watchkeeping/sampling
Bill LeBlanc	GSC-A	Geochem sampling
Chris LeBlanc	Dalhousie	OBS
Adam MacDonald	Student	Coring tech / sampling
Greg Middleton	GSC-A	marine sampling technician
Jody Olson	Student	geotechnical sampling/coring
John Shimeld	GSC-A	Seismic watchkeeping
Marty Uyesugi	Geoforce	Huntec operations technician
Maureen White	Student	General watchkeeping

Summary of Accomplishments

7 Long Core Facility piston cores
1 Stacor fixed reference core
4 FFCPT tests
460 line-km of seismic reflection profiles
3 OBS experiments with deployment and recovery of 26 instruments total.
3 heat flow deployments covering 7 stations

Regional and site specific high quality digital seismic reflection and high resolution Huntec DTS sparker data were acquired in key areas of the St. Pierre and Scotian Slopes. Two locales, Haddock Channel and Mohican Channel, with known occurrences of bottom simulating reflectors (BSRs) were investigated with site specific reflection profiling, OBS experiments, heat flow measurements and core sampling. Cores within seafloor mounds suspected of containing shallow gas proved that gas was present in abundance. Geochemical analysis confirmed high gas contents and that hydrate was likely not present in the shallow subsurface. Heat flow measurements provided confirmation of the thermal gradient required for the formation of hydrate at the position of the observed BSR. Regional lines were run along the Scotian Slope in dip and strike orientations to tie the seismic stratigraphy. Where feasible, these lines were run coincident with industry multichannel seismic tracks to maximize utility of the data. It should now be feasible to tie the stratigraphy in the “Gauley” area with that in the “Mosher” area. Ties further west are likely difficult because the stratigraphic section is highly mass-wasted.

Sidescan sonar, high resolution subbottom and small-airgun seismic reflection data were acquired in the Western Bank “cold” area of the Scotian Shelf to complete seafloor mapping for the geoclutter program. This work included 180 km of in-line track data and should allow completion of a sidescan mosaic for full coverage of the block. It appears as though a thin (5-10 m-thick) sand wedge overlies till/Tertiary sediment everywhere within the block. At the seafloor, therefore, there is little evidence of geologic features that might pose artifact sonar targets, making this an ideal area fitting the “non-clutter” experimental test site.

Daily Log

Day 192 (July 10, 2004)
Departed St. John’s, NL, at 0900 hrs proceeding to Haddock Channel area where a known BSR is present some 350 ms below sea floor. Arrived about 2330 hrs that evening and conducted 3.5 kHz survey (Lines 1-5) of site chosen for a corer-FFCPT test (Station 1; see Table 8). The site had an existing core from 2002-046 (core 77).

Day 193 (July 11, 2004)
A 10 m corer was rigged with the CPT tool on the end. The tool was driven into the seafloor with the winch (i.e. no free fall). The test proved unsuccessful as the optical sensor pre-triggered data recording before entry into the sediment; however, the tool was deployed and recovered successfully in deep water for the first time.

Six OBS instruments were deployed (OBS 1-6, Table 5) – 2 for Sonya Dehler over shallow salt targets in the upslope region of Haddock Channel and 4 Dalhousie University instruments over the BSR region.

One heat flow station (Station 2; Table 8) with three tests was occupied over the BSR.

Seismic lines were shot through the night (Lines 6-12) over the OBS deployed sites to shoot the wide-angle reflection and refraction profiles while concurrently acquiring reflection profiles. 2xGI gun array used as source and shot interval was 16 m, although changed to 30 m on last line due to a leak in the electric generator.

Day 194 (July 12, 2004)
0600 hrs recovered seismic gear and proceeded to recover OBS instruments. All secured by 1330 hrs and proceeded to the Mohican Channel area; approx. 300 nmi transit. Passed by a dead Beaked Whale on transit, with blue sharks circling in the water 44° 20.04’ -56° 03.46’.

Day 195 (July 13, 2004)
Arrived at the Mohican Channel/Torbrook block at 1130 hrs. First piston core site (Station 3; Table 8) chosen on basis of good control site with no evidence of slope failure or shallow gas. Station 4 (Table 8) was at the same site for a Fixed Reference Core, but the barrel was lost, probably on pull-out. Clearly the barrel was not secured sufficiently to the core head as the set screws were barely protruding through the head coupling joint. Station 5 (Table 8) was another corer-FFCPT test with 10 m length and the tool at the cutter end. No free fall was used; the corer was driven in with the winch. Data were successfully recorded this time but preliminary results showed effects of cable rebound.

Conducted signature tests on GI guns during deployment. Ran regional strike lines through the Torbrook block to connect up lines with the eastern Central Scotian slope, in an attempt to trace the stratigraphy across. An air hose blew early on and so ran the night with just 1 GI gun.

Day 196 (July 14, 2004)
Coring mounds observed from 3D seismic data that appeared to have gas flowing from depth to shallow subsurface. The first core (Station 6; Table 8) was in a mound in the southeast portion of the block. No gas was present and on closer inspection it appears as though the mounds in this area are not caused by gas but by a subsurface blocky debris flow that has been draped. Core 7 (Station 7; Table 8) was on a mound over the BSR that also showed shallow gas in Huntec data. Significant gas expansion was observed on recovery of the core. Core 8 (Station 8; Table 8) was in a mound over the BSR that did not show shallow gas in Huntec profile. The core had no gas expansion. Finished coring by 16:30 hrs, then deployed the OBS instruments over the BSR – 10 deployments with 100 m separation (Table 5). Shot seismics with 2xGI gun array. Weather not particularly good – blowing 25 knots. Deployed guns off the ironing board to move them away from the Huntec cable.

Day 197 (July 15, 2004)
Recovered seismics 0700 hrs and recovered OBS instruments. Fog hampered recovery to a degree. All on board by 1400 hrs. Station 9 (Table 8), piston core acquired on gas charged mound over BSR. Significant gas expansion of the core observed. Pore water chemistry suggests two of the barrels were switched in the half height container. 1700 hrs deployed seismic gear to continue tie lines between Verrill Canyon area and Mohican Channel areas. Shooting just 1 GI gun and Huntec.

Day 198 (July 16, 2004)
Seismic gear recovered at 0700 hrs. Conducted heat flow at two stations (10 and 11) and discovered that equipment failed. Redid station 11 and went back to redo 10 (now Station 12; Table 8). Conducted a freefall corer FFCPT site with 16.5 m barrel length (Station 13; Table 8). System worked well and high quality data were recorded. Heat flow data worked well too, showing reduced heat flow over gas-charged zone and "normal" heat flow over BSR site.

Launched 10 OBS instruments over non-BSR region of Torbrook block – 100 m separation between instruments. 2100 hrs seismic gear in the water. Ran Line 28 upslope across OBS' at shot interval of 20 m. Conducted lines 28-31, up and down slope.

Day 199 (July 17, 2004)
Finished line 31, which was run perpendicular to the OBS line, in order to locate the instruments. Pulled seismic gear by 0800 hrs. Proceeded to Core Site 14 (Table 8) – a well stratified control site for geohazard assessment.

Picked up OBS instruments with some difficulty – could not communicate with a number of the instruments and they had to self-time release. Had them all on by 1600 hrs. Took another FFCPT station (15; Table 8), rigged with 50 ft core barrels and 8 ft freefall. Then steamed to the west to conduct survey lines tying in to Shelburne well and BEPCO block. Started with line 32 at the western edge of the Torbrook block and proceeded west. Conducted Huntec sparker signature trials on launching of gear, but turns out experiment failed as they were logged incorrectly

Day 200 (July 18, 2004)
Recovered seismic gear at 0630 hrs. Conducted Huntec sparker signature tests again…with success! Steamed east to do a fixed reference core (FRPC) at the last core/FFCPT site (Station 16; Table 8). Should provide surface control on core. Took a 4 m core and cut sections at 1 m for more detailed geochemistry analysis. Finished Stacor at 1400 hrs.

Ran line from Slope tie lines up on to Western Bank. Ran for about 4 hours and pulled gear to transit to Western Bank "Cold" site for geoclutter survey.

Deployed seismics (**10 in^3 sleeve gun, Huntec Boomer**) and sidescan at 2200 hrs. Firing seismics at 3 secs. Using Teledyne streamer but reduced offset, towing about 7 ft and using only the front section of the streamer. Attempted to run sidescan with 600 m range, but thermocline comes in about 300 m, so had to reduce range to 300 m – which means a higher survey line density than anticipated.

Day 201 (July 19, 2004)
Continue shooting grid in geoclutter area. Reduced grid offset to 400 m. Pulled gear at 22:35 hrs and "heading for Halifax"

Day 202 (July 20, 2004)
Arrived Dartmouth, BIO dock at 08:00 hrs

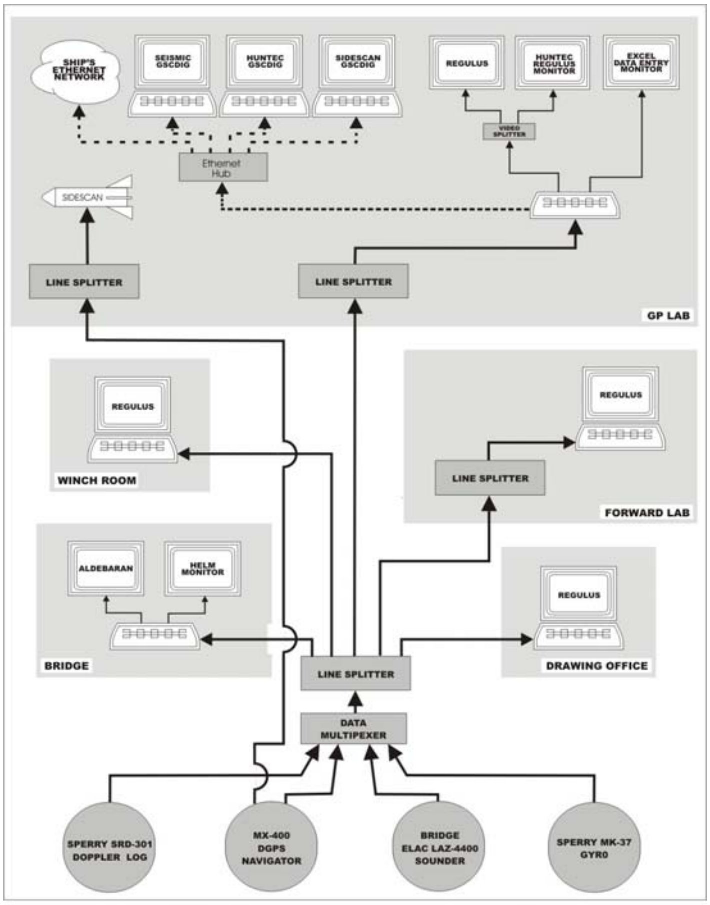
Equipment and procedures

Navigation

Differential GPS navigation was provided by the ship's MX400 series receivers. NMEA sentences from these systems were combined with the NMEA sentences from the ship's log and gyro through a Baytech Multiplexer in the NAV centre. Data from the multiplexer was then forwarded to a Black Box line splitter for distribution throughout the ship at 9600 baud. A second navigation feed, directly from the MX400 GPS receiver, was provided to the Sidescan system through the GP Lab 4800 baud Black Box line splitter. In addition, the GP Lab Regulus system rebroadcast all the received NMEA sentences over the Ethernet network to the three GSCADIGS systems in the GPLAB (Fig. 2).

Four Regulus systems were in use on the ship to view and log the scientific navigation. All systems were running the latest version of Regulus, Build 27001. These systems were set up in the Drawing Office, the Winch Room, the Forward Lab and the GP Lab. The GP Lab Regulus system was used as the primary data logger. The data was copied over the network to the shipboard NT server on a daily basis, enabling access to the files from a variety of networked workstations. The data were cleaned and merged using a text editor and the standard GSCA programs ETOA, INTA and APLOT. Raw E-format, raw A-format and cleaned and edited 10 second A-format files were saved on a daily basis and transferred to CD for GSCA archiving. 60 second A-format files were supplied to the GIS system on a daily basis, for display of the lines on the GIS system. A second monitor was attached to the GP Lab Regulus system through a video splitter. This allowed for the concurrent display of the navigation data for the benefit of the Huntec operator. A monitor was also attached to the second video output on the GP Lab Regulus system for display and editing of the electronic log and 12KHz bathymetric log.

Most problems reported during the last field season appear to be resolved in this latest release. The only apparent problem still persisting is the feature which allows an individual to retrieve a position, based on time, from the Regulus voyage file. A position showing a latitude of approximately half its actual value is occasionally returned when this is attempted. This problem can be sidestepped when it occurs by entering a time one second off from the desired time.



Hudson 2004-030 Navigation Data Distribution

Figure 2: Navigation work flow

Geophysics

Seismic Reflection

GSC(A) provided all mechanical equipment used in the collection of seismic reflection data for the cruise. Two reflection systems were employed: 1) a single channel seismic reflection profiling system, and 2) a high resolution Huntec DTS sparker system received on an internal and external hydrophone array.

Seismic reflection Profiling

The seismic reflection profiling system consists of a pneumatic source, supplied with pressurized air from two onboard compressors, a firing system, a receiving hydrophone array, a digital data recorder, an analogue recorder and a hardcopy recorder.

Seismic Sources

The sound source used for most seismic operations on Huds2004-030 was the Seismic Systems Inc. Generator Injector (GI) Gun (or a 2 GI gun array). When operating two GI guns, the blast phones were used to synchronize the guns. The Long Shot firing unit automatically adjusts fire delays to synchronize the two guns.

The concept behind the GI Gun is that an initial pressure wave is generated by the release of compressed air (the Generator), as in a conventional airgun. This blast of compressed air produces the primary pulse and the resulting volume of air (the bubble) starts to expand. When the bubble approaches its maximum size, it encompasses the injector ports and its internal pressure is far below the outside hydrostatic pressure. In a conventional airgun, the bubble would now collapse and it is this expansion and collapse that gives rise to the bubble pulse. In the GI Gun, the injector is fired at this time, injecting air directly inside the bubble, increasing the internal pressure of the bubble and preventing its violent collapse. The oscillations of the bubble and the resulting secondary pressure pulses are reduced and reshaped, therefore.

There are several modes of operation of the GI Gun. For this expedition, the gun was operated in Harmonic mode (recommended for high resolution surveying). In harmonic mode, the generator and injector volumes are each 105 in^3.

The GI Gun is equipped with a blast phone and through monitoring the blast phone and varying the delay between the generator and injector pulses, the optimum bubble cancellation was achieved. The optimum delay was found to be 35 ms.

The two guns were mounted horizontally below a 3 m long I-beam, hung by chains. The guns were 2 m apart and 0.54 m below the sled. The sled was suspended from two Norwegian floats (Fig. 3). From the top of the sled to the middle of the float (approximately the position of the waterline while stationary), was 1.2 m. The source signature data for the array (**Appendix I: Seismic Source Signatures**) show no frequency notching below 500 Hz, suggesting the underway tow depth was likely about 1.2 m. The array was towed on the port side of the stern and later moved to the port "ironing board".

Figure 3: Two x GI gun array configuration

For most of the single GI gun operations, the same configuration was used but one gun was not fired. After OBS work was complete, a single GI gun was deployed, suspended from the factory-supplied iron mount and a single Norwegian float (Fig. 4). For sleeve gun operations, the gun was towed from the starboard ironing board and the gun was suspended from a single Norwegian float at a depth of 1.2 m.

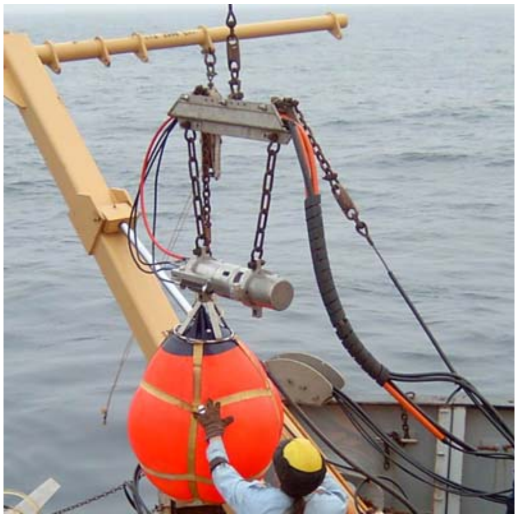


Figure 4: One GI gun configuration

Compressed air, typically between 1550 and 1850 PSI was supplied to the GI guns and sleeve gun from 2 Price Model W2 electric compressors owned and operated by GSC-A. These compressors are driven by a 200 HP electric motor through a variable speed drive producing approximately 80-85 SCFI of compressed air, at pressures up to 2500 PSI. For one of the compressors, power for the electric motor was supplied by a diesel generator. It was located on the flight deck. The other compressor used the ship's main generator. This generator was located on the port quarter deck in a modified shipping container. Cooling water for the compressor intercoolers comes from a pump in the engine room of the vessel. During normal seismic operations, the compressor is left unattended and checked every 15 to 20 minutes by the seismic watch keepers. Because of its low air volume capacity, using this compressor restricts the "fire rate" of the 210 in^3 GI guns to about 8 seconds for a single gun and 16 seconds for the 2 gun array. Significant repairs had to be implemented at sea, including extensive repairs to a leaky coolant system.

Because of the complexity of the Price diesel-electric compressor, an operator was required to be constantly available to monitor the functions of both the diesel engine and the compressor. All machine statistics were recorded at 15 minute intervals and entered into a log by the watch keepers.

Trigger Control

Airgun (GI and sleeve) firing was controlled by the MITS system to fire on time intervals or, to fire on distance, the Frydecky control system which takes a navigation feed and calculates offset since the last shot. In both cases, the trigger signal was supplied to the RTS Long Shot firing box which sent a voltage to the gun solenoid to trigger firing. The time interval between the generator and the injector firing for the GI gun was set by the software of the Long Shot gun controller. It was observed that the optimal interval between "G" and "I" firing was 35 ms for the gun tow depth of approximately one meter. The fire rate was variable, between 6 and 8 seconds throughout the cruise when firing on time and between 16 and 20 m when firing on distance. The system is fired on time to allow synchronization with the Huntec system. During OBS trials, it was preferable to fire on distance. An interval of 20 m was used as it is an even multiple of the OBS spacing (100 m) and should facilitate CMP grouping.

Hydrophone streamers

The Teledyne model 28420 streamer is 61 m (200 ft) in length, which includes an 8 m (27 ft) lead in dead section and a 4.9 m (16 ft) dead section at the tail. The active section is 45.2 m (148.33 ft) long, consisting of 2 interlaced sets of 3 groups, comprising a total of 6 groups of Teledyne B-1 acceleration canceling hydrophone cartridges. There are 16 individual hydrophones within a group, each element separated by 1 m (3.14 ft). The companion, interlaced group is equivalent in dimensions and is offset from the first group by 0.23 m (0.75 ft). For all operations, signals from the active groups in the streamer were summed into a single channel. This capability is provided by a deck-unit switching board into which the signal feeds. This unit also provides some gain control on signal levels. For the shallow water work on Western Bank, only the first channel was employed (i.e. the near-offset channel).

The Teledyne hydrophone streamer was outfitted with a DigiCourse DigiBird Model 9000-5010 for each deployment, mounted at the lead dead section. This “bird” allows for actively setting and maintaining hydrophone streamer tow depth. It can be controlled and monitored from the shipboard lab with the DigiScan system and it is self correcting (dynamic) to maintain depth of flight. In order to remain compatible with the tow depth of the sound source array, the bird was set to fly as shallow as possible, which proved to be about 4 m (12 ft). The streamer was towed 50 m astern of the fantail. It was noted that the length of the “lead in” cable deployed had a direct affect on the ability of the bird to control the depth. Too much “lead in” cable caused the eel to sink. Further investigation on placing positive buoyancy devices on the lead in cable should be undertaken. It was clear that the optimum tow distance placed the front of the eel adjacent to the GI gun, a distance of 50 m behind the vessel. Figure 5 below demonstrates the geometry of the seismic survey.

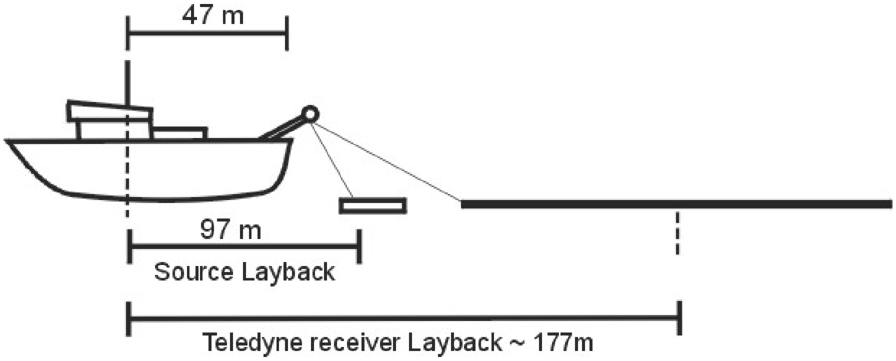


Figure 5: Schematic of seismic survey geometries

Filters

Seismic signals were first passed through a Krohn-Hite Model 3905B multi-channel filter and band passed between 45 and 500 Hz with a 20 dB gain amplification before going to the EPC hardcopy recorder. Signals to the digitizer were unfiltered and unamplified.

Digital Acquisition

Seismic and Huntec signals were digitally recorded with the GSCDIGS units. The following parameters were used for digital acquisition:

GSCDIGS (GDAIMS v. 1.4)
- GI Gun (Channel 1)
  - sample rate 250 μs (0.25 ms), number of samples 10240
- Huntec Sparker (Channel 1: Internal, Channel 2: External)
  - Sample rate 50 μs (0.05 ms), number of samples 8192

Deep water delays managed on the fly through software window and recorded in the SEG-Y header.
Data written to harddrive and backed up on DVD media.

The GSCDIGS system is built upon a sigma-delta A/D converter. This converter provides the ability of employing high sample rates and high dynamic range, avoiding the need for anti-alias filtering and constant gain adjustment. The result is ease of use to the end user and higher and consistent data quality. Acquisition and interface software (GDAim v. 1.4) was designed and built by D. Heffler of GSC-A. The software allows for realtime monitoring of signals including time series and power spectral density views. Data are recorded in 24-bit format. Data are stored on disk as individual SEGY files in long integer format. Deep water delay times and navigation data are written to the SEGY headers. Data are immediately suitable for commercial seismic processing and interpretation software as a result of the data format and information in the headers. Data are recorded on commercially available DVD media, providing ease of backup and recovery.

For the Huntec system, the GSCDIGS system manages the master trigger and the fire trigger to accommodate heave compensation, and it integrates the fish depth. It also successfully tracks multiple shots in the water, often used in deep water data acquisition. The result is that all records are referenced from sea level and so Huntec records are specifically referenced with water depth. Similarly, seismic signals must be provided the master trigger and multiple shots in the water can be tracked, so all data are referenced to sea level.

The software GDMux v 1.21 allows for concatenation or partitioning of SEG-Y files generated by GDAim into respective line segments, based on start and end-of-line times. It also allows for trace padding to account for deep water delays. **Note that exporting data from GDMux v. 1.21 as floating point data, stores data as IEEE floating point**

(not IBM floating point). GDShow allows for quality control assessment of SEG-Y files by viewing them as seismic profile sections.

Disk	Start Day	UTC time	End Day	UTC time	Lines
DVD 1	193/2004	20:19	194/2004	09:06	6-12
DVD 2	194/2004	22:59	202/2004	01:46	1-54

Table 1: Seismic reflection digital DVD log

Analogue Acquisition

All seismic reflection profiling and Huntec profiling data were output to EPC9800 thermal graphic recorders. Delays were managed from the MITS system. Analogue data were also logged on the Sony PC208 DAT tape recorder. The following channels were used:

Channel 1	Seismics shot trigger
Channel 2	Teledyne seismic signal
Channel 3	DTS Trigger
Channel 4	blank / DTS external
Channel 5	DTS internal
Channel 6	
Channel 7	
Channel 8	

Table 2: Sony DAT channel designations

Wide-angle seismic reflection and refraction

Four wide angle reflection/refraction deployments using a total of 26 ocean bottom seismometers (OBS) were conducted during Hudson 2004-030. Table 5: OBS station Location information) and Appendix II: Report on Ocean Bottom Seismic Profiles) detail OBS station location information and operations. The first two profiles were conducted on the slope near Haddock Channel. *deployment 1*: Line 6 was shot across OBS stations 1 and 2. *deployment 2*: consisted of OBS stations 3-6 and Line 7. *Deployment 3*: Line 17 across OBS stations 7-16 in the region of Mohican Channel; and *deployment 4*: consisted of OBS stations 18-27 and Line 28 on the central Scotian Slope. The sound source used in each case was a 2 x 210 in3 GI

Figure 6: Ocean bottom seismometer (OBS) being launched

gun array, except for Line 28; one gun had failed in this experiment. These sources are described in detail elsewhere in this report. Line 6 (OBS deployments 1 and 2) was shot to investigate detailed structure around shallow salt diaper targets. The purpose of the other profiles (deployments) was to define the velocity structure of the upper sediment layers, and in particular of velocity anomalies due to the likely occurrence of gas hydrates. Details of these experiments are provided in Appendix II. The presence of gas hydrates on Lines 7 and 17 is expected due to the existence of a bottom simulating reflector (BSR) on seismic reflection profiles, as well as on a previous OBS deployment near Line 17 in 2002. Line 28 was conducted as a control line, where a BSR is absent in reflection profile but the stratigraphy is similar to Line 17.

Figure 7: OBS external geophone

The OBS' used on Line 6 (OBS stations 1 and 2) were GSC-A owned and operated systems. The OBS' used for all the other experiments were of the new older Dalhousie model (see Appendix II). The systems had just been modified with an external geophone that deploys from an arm after the instrument settles to the seafloor (Fig. 7). This configuration should provide better coupling to the seafloor with less interference from the main instrument package. These experiments represent the first trial of this modification. A sampling rate of 558 Hz @ 16 bits and gain settings of 66 dB (geophones) and 46 dB (hydrophone Lines 1 and 3) and 56 dB (hydrophone Line 2) were used.

For Line 6, 2 instruments were deployed (Fig. 6) about 16 km apart in a strike profile across two shallow diapir structures. A shot spacing of 15 m with the 2 x 210 in^3 GI gun array was used. For Line 7, four instruments were deployed in two groups of two. This was a reconnaissance line which also served as a test of the new deployed geophone packages. On each of Lines 17 and 28, a total of 10 instruments were deployed as a central array with an approximate spacing of 100m between each OBS. Shot spacing was 20 m. On all lines, shot times were triggered by the Frydecky firing box in order to shoot by distance interval and logged by the Dalhousie Zyfer GPS clock in order to record exact firing times. Times logged in the shot table were taken from the clock time break (CTB) output of the Real Time Systems Long Shot seismic source controller. These times are the aim point shot times with a 50 ms delay following the trigger.

Data recorded on the OBS hard drives were downloaded to PC and written to DVD. Preliminary SEG-Y files were generated using the Zyfer GPS navigation and OBS deployment positions.

The Huntec Deep Tow System

Huntec DTS fish on the aft deck

Figure 8: Huntec DTS

The Huntec (DTS) (Fig. 8) typically uses a boomer source, but for deep water or hard seafloor substratum a sparker attachment is used to increase the source energy. Higher frequencies and source repeatability are sacrificed as a result. The sparker tip was used during the deep water portion of this cruise and the system was typically towed around 100 m below sea surface. Deep-towing the sparker improves source characteristics and repeatability (see Appendix I). The source was operated at 480 Joules output (4 kVolt setting). For the work on Western Bank, the system was converted back to a boomer source. It was operated at the same power level. For the Scotian Slope surveys, seismic signals were received on the internal hydrophone and on a 24 ft-long, 24-element (AQ-16 cartridges), oil filled streamer towed behind the fish. The hydrophone elements were arranged in the following manner: A section of 10 x 1 ft hydrophone spacing wired in parallel, and a section of 14 cartridges with 1 ft spacing, in parallel. The two sections are wired in parallel. For the Scotian Shelf surveys, a 10-element, (1'-spacing) streamer was used as the external (switched on Day 200). The signals were displayed in analogue hard copy on an EPC9800 thermal chart recorder with a 500 ms sweep rate and filtered between 500 and 3500 Hz for the sparker and 500 and 5000 Hz for the boomer. Only the external hydrophone received signal was printed for the slope work, but both internal and external were displayed for the shelf survey. Firing rates varied but were typically 1-1.5 s for the slope and 0.6 s for the shelf. Data were recorded in analogue on the Sony DAT recorder and digitally on the GSCDIGS system. They were digitized at 50 µs for a record length of 500 ms and written to hard drive and DVD media. Table 3 below shows the Huntec Digital DVD Log.

DVD	Start Day	UTC time	End Day	UTC time	Lines
DVD 1	195/2004	21:08	196/2004	09:48	14-16
DVD 2	196/2004	23:23	197/2004	10:03	17-22
DVD 3	197/2004	19:40	198/2004	10:17	23-27
DVD 4	198/2004	00:01	199/2004	11:08	23-31
DVD 5	199/2004	23:42	200/2004	2105	33-36
DVD 6	201/2004	01:36	202/2004	00:01	37-53
DVD 7	202/2004	00:01	202/2004	01:32	54

Table 3: Huntec Digital DVD Log

Sidescan Sonar

The Simrad Model 992 dual frequency Side Scan Sonar was deployed while rigged to an Open Seas "STABS" (**S**ubmercible **T**owed **A**pparatus **B**uoyancy **S**ystem) and depressed by a 120 kg weight (Fig. 9), all attached to an 800 m coaxial towcable on a remotely controlled Markey winch. The system was used on the Scotian Shelf, Western Bank “Cold” Area for the Geoclutter component of this expedition. The 120 kHz channels were of principal interest, to generate wide swaths for regional surveying. It was found that 300 m range (600 m total swath width) was the maximum operational range because of thermocline effects. Line spacings of 400 m were run in the area to get full coverage with overlap, as a result. The 120 kHz data recorded to an Alden9315 CTP printer with 1:1 speed correction and ship position on the hardcopy. A 3 to 4 minute layback of towed vehicle from ship position was common at 3.5 to 4.5 knot survey speeds.

Figure 9: Simrad 992 sidescan sonar mounted under the STABS buoyancy system in its cradle on the afterdeck.

Simrad Sidescan data were digitized and stored in SEG-Y format with GSCDIGS unit #7. Table 4 below is a summary of the sidescan data archive. Data were sampled with a 100 ms sample interval for a 450 ms sample window per channel in the following configuration:

Channel 1 = 120kHz left side data
Channel 2 = 120kHz right side data
Channel 3 = 330kHz left side data
Channel 4 = 330kHz right side data

DVD	Start Day	UTC time	End Day	UTC time	Lines
DVD 1	201/2004	01:12	201/2004	08:28	37-42
DVD 2	201/2004	08:28	201/2004	11:03	42-44
DVD 3	201/2004	11:03	201/2004	18:35	44-50
DVD 4	201/2004	18:35	202/2004	00:02	51-53
DVD 5	202/2004	00:02	202/2004	01:38	54

Table 4: Sidescan data archive table.

Data from the sidescan's head sensor were logged to a SCTL*.04E file in ASCII with the following format:
"Time(HHMMSS), DEG Compass, Fish Depth, Fish Altitude, Roll, Pitch, Temperature"

Stations

Sample stations consisted of piston cores (PC), trigger weight cores (twc), fixed reference piston cores (FRPC), the Dalhousie University heat flow probes, and corer free-fall cone penetrometers (FFCPT). Station information is summarized in Table 8 below.

Piston cores

The piston coring system used was the AGC Long Corer (Fig. 10). This device obtains a 10 cm diameter core sample. Barrel lengths are 10 ft (3.05 m), and typically the system was rigged with five barrels. The core head is 3 m long, 0.6 m diameter and weighs 2000 lb (900 kg). The core pipe has a 4.25" ID (10.8 cm), with 3/8" (9.5 mm) wall thickness, with exterior couplings secured by set screws. The liner was CAB plastic in 10 ft. (3.05 m) lengths. A split piston with two O-rings and variable orifice size was used. For most sites, a standard core catcher was used. The trip arm supported a 4.25" (10.8 cm) diameter gravity corer with a 6 ft (1.82 m) barrel and 300 lb (135 kg) head. The corer used 3/4" (19 mm) wire cable on the Pengo winch. The corer was operated using a handling system including a rotating core-head cradle, outboard support brackets, a monorail transport system, and a lifting winch. The system was broken down at the barrel joints and moved to a processing half-height container, where the cores were extracted from the barrels, split into 1.53 m (or less) section lengths and labelled.

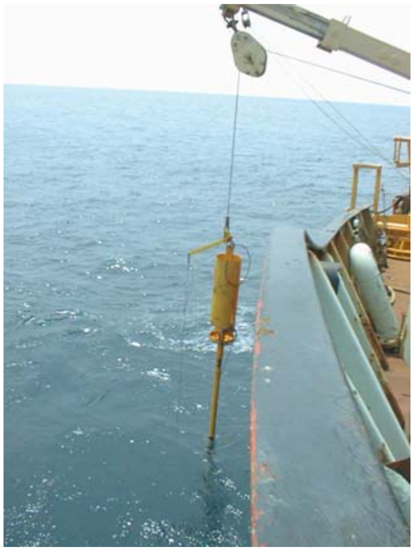


Figure 10: Piston core loaded and locked

Piston coring was successful on each run attempted, although imploded liners caused difficulty in extracting cores from the barrels. There were also a number of problems with ship's equipment for core handling. 1) On several occasions the core handling crane on the foredeck was unable to rotate outboard with the weight of the corer suspended from it over the side of the ship. 2) The crane boom had a slow creep, making it difficult to hold the core steady. The boom would tend to retract under its own weight. 3) The most significant issue is that the pengo wire is in bad condition. It is brittle and easily burs as a result. There is a strong possibility of loss of equipment if it is not replaced.

Fixed-reference piston core

Figure 11: Fixed reference corer (FRPC)

The fixed-reference piston corer (FRPC) uses a design whereby the piston is fixed to the frame of the core device and the pipe lowers into the seafloor strictly under its own weight around the piston (Fig. 11). The fixed piston prevents any rebound effect as may be caused by the core wire. The design is summarized in the cruise report for expedition 94021B. The outer frame is 25 ft. (7.6 m) high. The 20 ft (6.1 m) 4.25" (10.8 cm) ID barrel takes a standard diameter core liner. The weight at the top of the barrel is 1300 lb (590 kg). In an attempt to stabilize the corer as it is lowered through the water column, lead weights were added to each foot. In addition, the piston was tied with breakable line to the lower end of the barrel to prevent it from riding up inside the barrel during deployment.

Two attempts were made with the FRPC. On the first run, the barrel apparently was not tightened to the core head and was lost as a result. Only one (1) 20’ liner was supplied to arm the FRPC. Two 10’ pieces had to be taped. On the second attempt, a 4+ m core was recovered, although apparent penetration was much greater. There was some difficulty in extracting the liner from the barrel.

Onboard core processing and subsampling

A total of 71 m of deep sea sediment was obtained from 8 cores (6 Piston (PC), 6 Trigger Weight (TWC) and 1 Fixed Reference Piston (FRPC)) and 2 TWC obtained during two Free Fall Cone Penetrometer deployments. All cores were processed according to standard GSC Atlantic core procedures (refer to GSC Open File #1044).

All cores were identified alphabetically by section at the time of dismantling individual 10 ft. core barrels from the bottom to top, commencing at the bottom-most core barrel and proceeding to the uppermost barrel containing sediment. In the half height container, 6 cm whole round samples for gas analysis were taken from the base of each barrel. These whole round samples were trimmed to 5 cm^3, put in cans and frozen (refer to Geochemistry section below).

As the 1.5 m sections of core were extruded from the barrels they were labelled, brought into the GP Lab and stored horizontally on the benches. Each core, starting with the base section AB, was processed using the following procedure. End caps were removed, if the sediment was not too fluid, and the section length was recorded. Infra red camera images were taken at 10 cm intervals down section (refer to Thermal Photography section below). When possible, torvane measurements and constant volume samples were taken at the top and base of each section (refer to Physical Properties section below). Upon completion of the physical property measurements, 20 ml samples for pore water analysis (ammonia, sulphate and salinity) were taken. Inert packing was placed in the voids created by the subsampling, and the ends of each core section were capped, taped and wax-sealed to prevent further oxidation and desiccation.

The 1.5 metre core sections of whole round core were stored in a refrigerated seagoing container maintained at 4.7°C. All core cutters and catchers were labelled, measured in half liners, waxed and stored accordingly to preserve the sediment integrity. Any and all extruded core sections due to sediment expansion or core processing methods were likewise labelled and stored. All sediment samples were catalogued and location information within the container was recorded in an excel spreadsheet. All core sections, pieces and associated cutters/catchers have been documented on master field sheets as well as in the “ED_at_Sea” data archive, an interface written for an Oracle-PC database system.

Physical properties measurements

Undrained shear strength measurements and sediment bulk density samples were taken at the ends of each piston core section immediately after completion of thermal photography (Fig. 12). Undrained shear strength was measured using a hand-held Soiltest CL600 Torvane according to ASTM Test Method D2573-94 Standard Test Method for Field Vane Shear Test in Cohesive Soil. The Torvane dial reading ranges from 0 to 10 and reports values in kg/cm^2 units (1 kg/cm^2 = 9.80665 kPa). It has three adapter vanes as described below:

CL-602 Sensitive vane has a range of 0 to 0.2 Kg-force/cm^2
Su = dial reading * 0.2 Kg-force/cm^2
CL-600 Regular vane has a range of 0 to 1.0 Kg-force/cm^2
Su = dial reading * 1 Kg-force/cm^2
CL604 High capacity vane has a range of 0 to 2.5 Kg-force/cm^2
Su = dial reading * 2.5 Kg-force/cm^2

The CL-602 sensitive vane was used for all measurements taken on the cores.

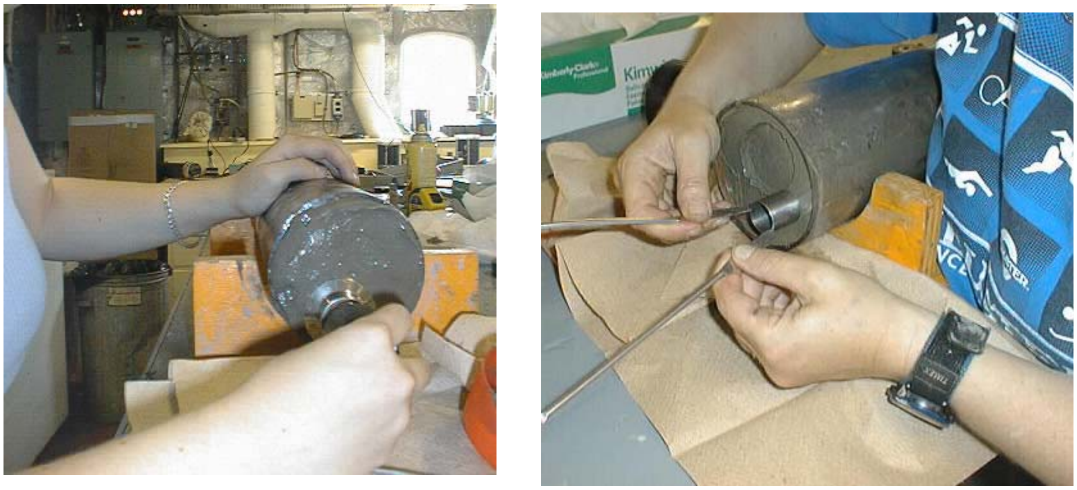


Figure 12: Taking a shear strength measurement with a Torvane (left) and a constant volume

Constant volume samples were taken by inserting stainless steel tubes of a known volume. Two samplers, B1 (9.989 cm^3) and B2 (9.907 cm^3), were used at the top and the base of each section respectively. The sampler was carefully inserted into the sediment at a constant rate using two spatulas. The sampler with sediment was then removed, taking care to preserve the integrity of the sample, trimmed with a wire saw, extruded into a pre-tarred labelled airtight 1 oz screw-top glass bottle. The bottle cap was then labelled and sealed using electrical tape to prevent the lid from loosening. The sample will be weighed, dried at 105°C for 24 hours and re-weighed to determine bulk density, dry density and water content according to ASTM Test Method D 2216-90 (revision of 2216-63,2216-80) Standard method for laboratory determination of water (moisture) content of soil and rock.

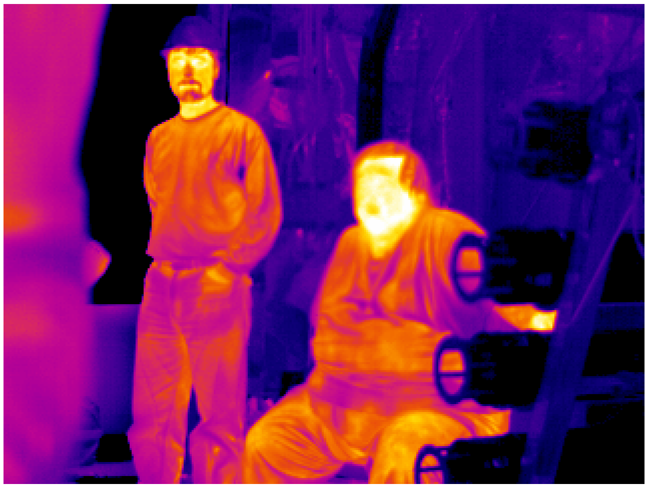


Figure 13: Thermal image of John and Marty – hot stuff!

Torvane and constant volume samples were only taken when the sediment was undisturbed and no gas or sand was present.

Thermal Photography

Thermal photography (Fig. 13) was conducted at ten-cm intervals on all cores to visualize any change in thermal properties down core, in the event that hydrates might have been encountered. Results will require further analysis of these images.

Geochemistry

Approximately 20 ml of sediment were collected from each end of each core section (1 to 1.5 m long) as soon as the core sections were available. The sediment subsamples were put into 7 dram polystyrene vials. Each vial contained a coarse filter paper placed over 4 one millimeter holes drilled in the base of the vial The sample vials were inserted into a 50 ml plastic centrifuge tube and centrifuged for 20 minutes in an IEC HN centrifuge (10 cm head radius) at 2000 rpm. Approximately 1 ml of pore water was collected in the centrifuge tube for each sample. Pore water samples were stored in 7 ml plastic vials at 4ºC. The sediment samples were frozen and returned to the land laboratory for organic carbon analyses.

The pore water samples were immediately analyzed for ammonium, sulfate and salinity (Cranston, 1997; Deep Sea Research, Part II, vol. 44, no. 8, 1705-1723). Ammonium analyses were done on 0.1 ml of pore water using a colourimetric method calibrated with ammonium chloride standards. The precision and accuracy of the method based on replicate analyses is estimated to be ± 10% of the concentration. Sulfate was determined on 0.05 ml of pore water by precipitating sulfate with barium and measuring the turbidity of the solution. The method is calibrated with sea water and magnesium sulfate solutions. The precision and accuracy of the method is estimated to be ± 2 mM. Salinity was measured on 0.1 ml of pore water using a conductivity meter. The method was calibrated using sea water standards. Precision and accuracy of the method is estimated to be ± 0.3 $^{o}/_{oo}$.

Heat Flow

Heat flow measurements were taken using the Dalhousie heat flow probe (Fig. 14) and Seabird 19 CTD at two locations in the Haddock Channel and Mohican Channel as a preliminary assessment of the thermal regime at locations of strong bottom simulating reflectors (BSR) indicative of gas hydrates. A total of four successful measurements were made using a 6-m long probe and 32 sensor thermistor string. Details are provided in Appendix III: Heat flow).

Figure 14: Dalhousie heat flow probe being launched.

Deployments of the heat flow probe and CTD were made on July 11 (Day 193) and July 16 (Day 198). Details of station locations are given in Table 8 below and in

Appendix III. A total of 4 successful stations were made using a 6-m long probe: Site 4 (2 stations) and Site 5 (2 stations).

Figure 15: FFCPT mounted on the corer, resting on the rails before launch.

Corer-Free Fall Cone Penetrometer Tool

The Free Fall Cone Penetrometer Test, or FFCPT was developed by Brooke Ocean Technology Ltd. and Christian Situ Geoscience Inc. as a method for rapid profiling of the near-surface sediment column, yielding geotechnical parameters analogous to conventional CPT methods (e.g. strength parameters and lithologic proxies). This expedition offered the first opportunity to field test the instrument. The configuration used for this cruise employed the GSCA large-diameter piston coring system as a delivery device. The FFCPT probe was mounted on the end of the core barrel in place of the cutting shoe (Fig. 15). This probe houses the electronics and hydraulic systems for sensing water pressure around the tip during penetration (dynamic pore water pressure), hydrostatic pressure at the top of the instrument (open to the water column), optical backscatter at a location just behind the conical point (mudline detector), as well as acceleration over 3 ranges (+/- 2g, +/- 5g, +/- 20g). Each trigger event creates a set of datafiles, stored in Flash memory within the FFCPT probe. Upon recovery, the datafiles are offloaded using Windows HyperTerminal software to the host computer for processing, interpretation and hardcopy output.

Two methods of deployment were used. For the first two stations (001 and 005) the system was lowered into the seabed on the winch, at maximum payout speed. However the data indicated that the dynamic strength profile of the sediment was not high enough to substantially decelerate the corer, especially near the mudline. The penetration ended when the corehead impacted the mudline, indicating that more core barrels should have been mounted. The last two tests (stations 013 and 015) were carried out by tripping the corer from a free fall height of between 2.4 and 4.0 m, respectively, using the pilot gravity corer as a trip weight. The resulting test data were of much higher quality and will be put through the full FFCPT analysis.

Appendix IV: Free Fall Cone Penetrometer) documents the details of procedures at each test site. At stations 13 and 15, the piston core was allowed to trigger and freefall as in a normal coring operation. This presented some operational concerns to the crew, as there was no liner in the corer, so the piston was offered no resistance during freefall or a pre-trigger event. It also prevented the use of a secure lanyard from the CPT probe to the head of the coring tool, which presented some concern to the operators. In addition, it would have been preferable to have a greater free-fall distance as it appeared the corer had not reached full velocity on free fall. This presented a quandary to the crew as well, as no trigger arm lines were made for the proper lengths. Future tests will need to address some of these engineering and operational concerns.

Results

Line and station locations

The next succession of figures shows track lines and station locations (Figs. 16-19 and Tables 5-8). The accompanying CD contains ASCII files of navigation (day time and position) data at 2 second and 60 second intervals. The following tables document station location information

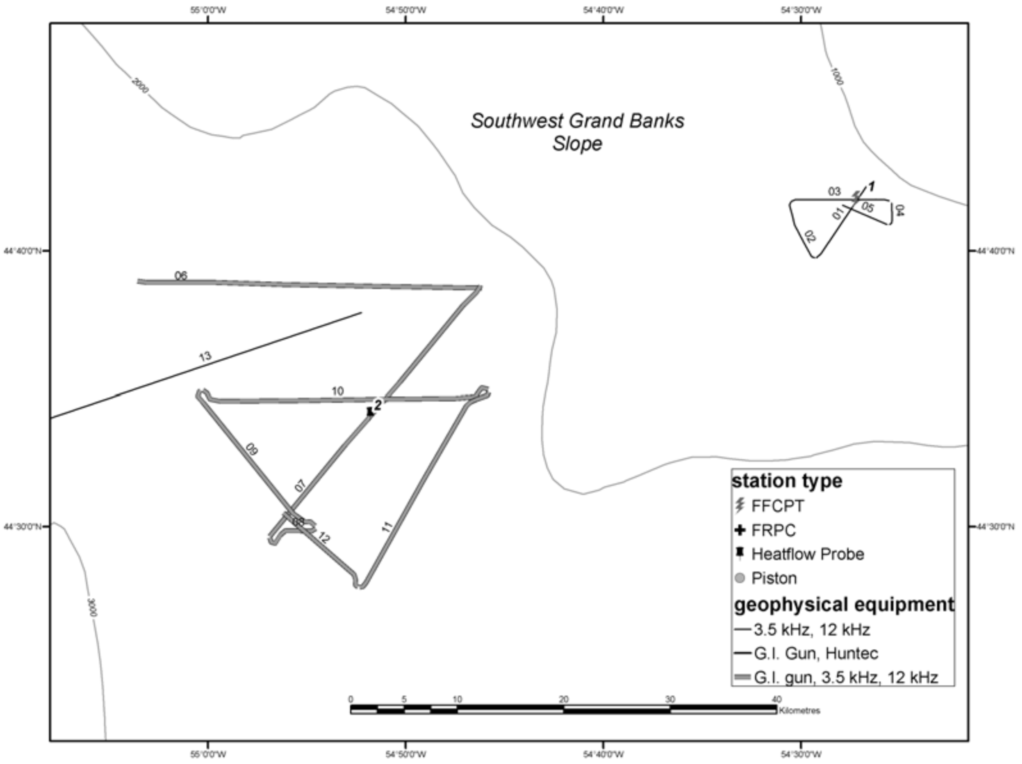


Figure 16: Cruise track and station locations, Haddock Channel region, SW Grand Banks.

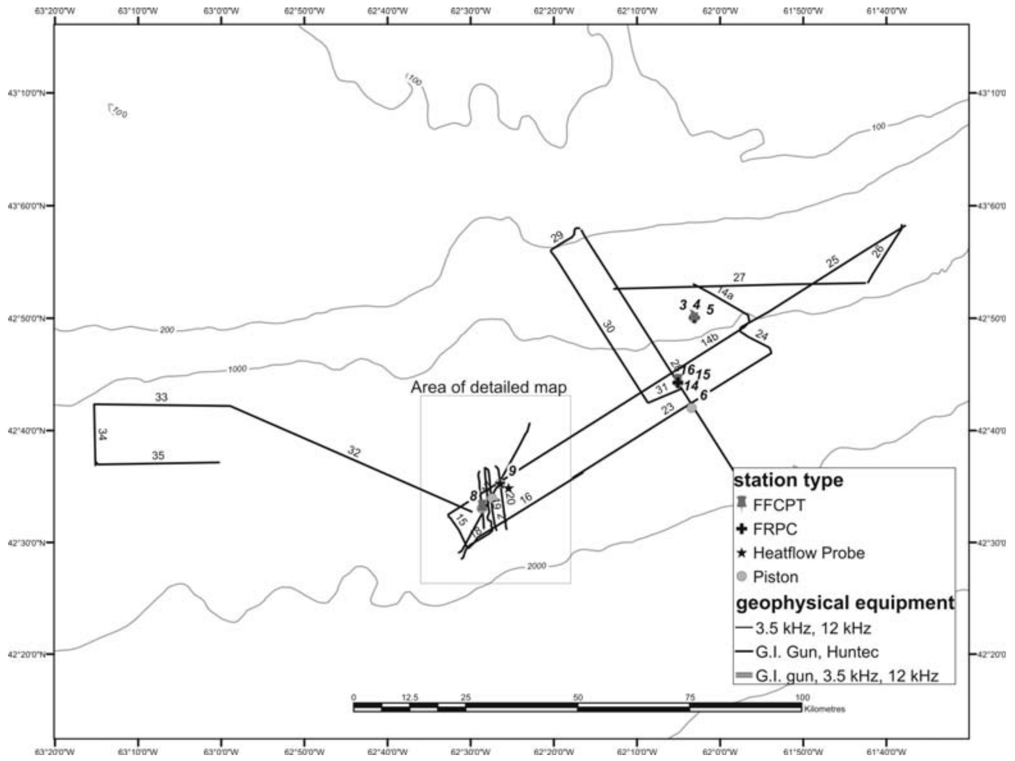


Figure 17: Cruise track and station locations, central Scotian Slope.

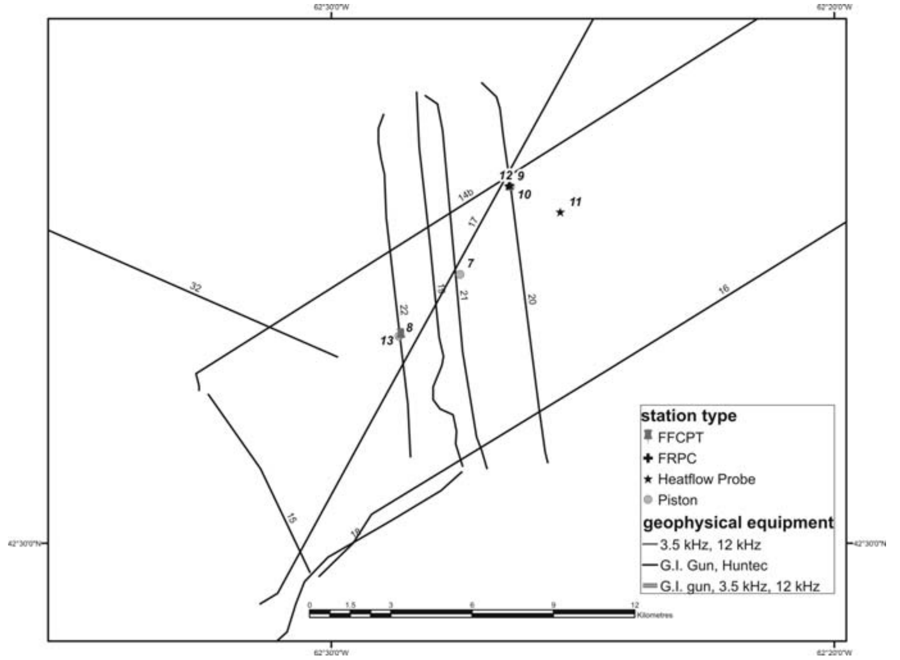


Figure 18: Cruise track and station locations, Torbrook Block, central Scotian Slope

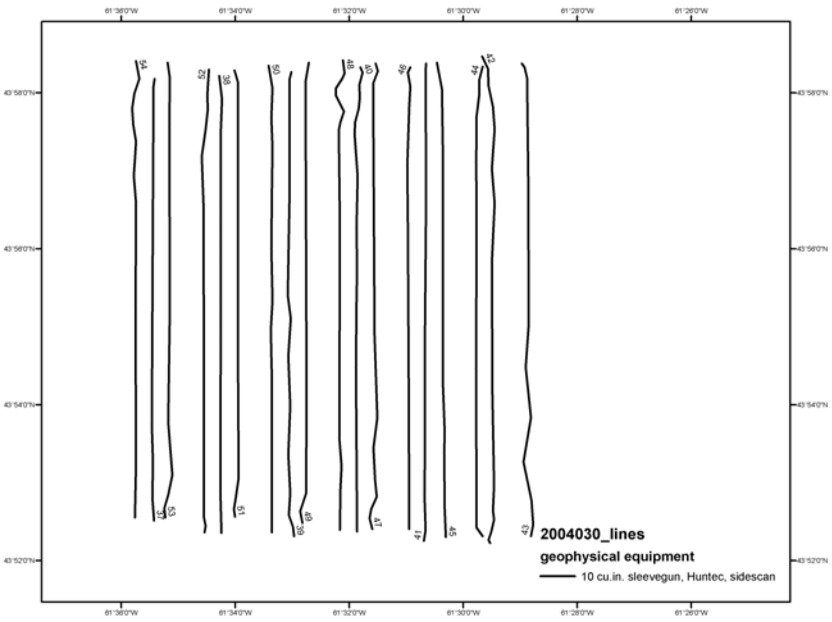


Figure 19: Track lines for Western Bank survey

Table 5: OBS station Location information

OBS STN #	*Day*	*Time*	*Latitude*	*Longitude*	*Comments*
1	193	1906	44 38.8382	55 01.5531	OBS 1 dropped
2	193	1820	44 38.7312	54 48.8336	OBS 2 (recorded as GSCA-T)
3	193	1744	44 34.6413	54 51.0335	OBS 3
4	193	1731	44 34.4519	54 51.2032	OBS 4 (recorded as OBS 3 in data logger)
5	193	1618	44 30.5928	54 55.7991	OBS 5 (recorded as OBS 2 in data logger)
6	193	1608	44 30.3997	54 56.0062	OBS 6 (recorded as OBS 1 in data logger)
7	196	2209	42 35.1955	62 26.6719	OBS I (Station 7) deployed
8	196	2203	42 35.1470	62 26.7223	OBS D (Station 8) deployed
9	196	2201	42 35.0993	62 26.7510	OBS L (Station 9) deployed
10	196	2159	42 35.0530	62 26.7776	OBS N (Station 10) deployed
11	196	2157	42 35.0025	62 26.8163	OBS K (Station 11) deployed
12	196	2155	42 34.9623	62 26.8501	OBS A (Station 12) deployed
13	196	2153	42 34.9103	62 26.8810	OBS H (Station 13) deployed
14	196	2151	42 34.8636	62 26.9210	OBS G (Station 14) deployed
15	196	2149	42 34.8138	62 26.9611	OBS C (Station 15) deployed
16	196	2145	42 34.7653	62 26.9965	OBS B (Station 16) deployed
18	198	2207	42 43.4651	62 04.4104	OBS B (Station 18) deployed
19	198	2214	42 43.5156	62 04.4415	OBS G (Station 19) deployed
20	198	2218	42 43.5553	62 04.4808	OBS C (Station 20) deployed
21	198	2226	42 43.6021	62 04.5165	OBS N (Station 21) deployed
22	198	2232	42 43.6524	62 04.5569	OBS H (station 22) deployed

23	198	2239	42 43.7062	62 04.5929	OBS K (Station 23) deployed
24	198	2243	42 43.7454	62 04.6311	OBS A (Station 24) deployed
25	198	2247	42 43.7963	62 04.6630	OBS I (Station 25) deployed
26	198	2252	42 43.8450	62 04.7001	OBS L (Station 26) deployed
27	198	2257	42 43.8866	62 04.7337	OBS D (Station 27) deployed

Table 6: Geophysical line numbers

Line	**Start**	**End**	**Seismics**			**OBS**	**Huntec**		**Sidescan**		**DAT**	**3.5 Khz**	**12 KHz**
			Teledyne		Gun volume								
			Rec. #	DVD #			Rec. #	DVD #	Rec. #	DVD #	Tape #	Rec. #	Rec. #
1	193/0645	193/0718										1	1
2	193/0718	193/0745										1	1
3	193/0745	193/0822										1	1
4	193/0822	193/0834										1	1
5	193/0834	193/0904										1	1
6	193/2029	193/2307	1	1,2	2x210^{3}in.	X						1	1
7	193/2322	194/0154	1	1,2	2x210^{3}in.	X						1	1
8	194/0207	194/0219	1	1,2	2x210^{3}in.	X						1	1
9	194/0224	194/0348	1	1,2	2x210^{3}in.	X						1	1
10	194/0411	194/0607	1	1,2	2x210^{3}in.	X						1	1
11	194/0630	194/0813	1	1,2	2x210^{3}in.	X						1	1
12	194/0813	194/0900	1	1,2	2x210^{3}in.	X						1	1
13	194/1640	195/0720										2	1
14a	195/2225	195/2338	2	2	210^{3}in.		1	1			1	3	
14b	195/2345	196/0625	2	2	210^{3}in.		1	1			1 to 3		
15	196/0635	196/0714	2	2	210^{3}in.		1	1			3		
16	196/0714	196/0947	2	2	210^{3}in.		1	1			4		
17	196/2334	197/0338	2	2	2x210^{3}in.	X	1	2			5		
18	197/0408	197/0437	2	2	2x210^{3}in.	X	1	2			6		
19	197/0443	197/0546	2	2	2x210^{3}in.	X	1	2			6		
20	197/0613	197/0715	2	2	2x210^{3}in.	X	1	2			6, 7		
21	197/0735	197/0843	2	2	2x210^{3}in.	X	1	2			7		
22	197/0905	197/1002	2	2	2x210^{3}in.	X	1	2			7, 8		
23	197/1958	198/0037	3	2	210^{3}in.		2	3			9, 10		
24	198/0045	198/0129	3	2	210^{3}in.		2	3, 4			10		
25	198/0129	198/0440	3	2	210^{3}in.		2	3, 4			10 to 12		
26	198/0506	198/0613	3	2	210^{3}in.		2	3, 4			12		
27	198/0614	198/1016	3	2	210^{3}in.		2	3, 4			12, 13		
28	199/0024	199/0618	3	2	210^{3}in.	X	3	4			14 to 16		
29	199/0637	199/0704	3	2	210^{3}in.	X	3	4			16		
30	199/0704	199/1023	3	2	210^{3}in.	X	3	4			16, 17		
31	199/1023	199/1107	3	2	210^{3}in.	X	3	4			17		
32	199/2325	200/0346	4	2	210^{3}in.		4	5			18 to 20		
33	200/0347	200/0608	4	2	210^{3}in.		5	5			20		

34	200/0625	200/0724	4	2	210^{3}in.		5	5			21		
35	200/0740	200/0936	4	2	210^{3}in.		5	5			21, 22		

Line	Start	End	Seismics			OBS	Huntec		Sidescan		DAT	ELAC DIGITAL BATHY
			Teledyne		Gun volume							
			Rec. #	DVD #			Rec. #	DVD #	Rec. #	DVD #	Tape #	
36	200/1650	200/2105	4	2	210^{3}in.		5	5			22, 23	X
37	201/0111	201/0210	5	2	10^{3}in.		6	6	1	1	24	
38	201/0227	201/0337	5	2	10^{3}in.		6	6	1	1	24	
39	201/0353	201/0454	5	2	10^{3}in.		6	6	1	1	25	
40	201/0514	201/0622	5	2	10^{3}in.		6	6	1	1	25	
41	201/0640	201/0741	5	2	10^{3}in.		6	6	1	1	26	
42	201/0800	201/0914	5	2	10^{3}in.		6	6	1	1, 2	26	
43	201/0930	201/1030	5	2	10^{3}in.		6	6	1	2	27	
44	201/1047	201/1200	5	2	10^{3}in.		6	6	1, 2	2, 3	27	X
45	201/1216	201/1320	5	2	10^{3}in.		6	6	2	3	27, 28	X
46	201/1336	201/1443	5	2	10^{3}in.		6	6	2	3	28	X
47	201/1455	201/1603	5	2	10^{3}in.		6	6	2	3	28, 29	X
48	201/1634	201/1734	5	2	10^{3}in.		6	6	2	3	29	X
49	201/1744	201/1844	5	2	10^{3}in.		6	6	2	3	29, 30	X
50	201/1900	201/2012	5	2	10^{3}in.		6	6	2	3	30	X
51	201/2021	201/2119	5	2	10^{3}in.		6	6	2	4	30	X
52	201/2132	201/2255	5	2	10^{3}in.		6	6	3	4	31	X
53	201/2307	202/0000	5	2	10^{3}in.		6	6	3	4	31	X
54	202/0028	202/0137	5	2	10^{3}in.		6	6	3	5	32	X

Table 7: List of geophysical records

Teledyne Records							
Record #	Start Time	End Time	Line #	Record #	Start Time	End Time	Line #
1	193/1947	194/0900	6 to 12	2	195/2215 196/2328	196/0950 197/1002	14 to 22
3	197/1945 199/0025	198/1017 199/1107	23 to 31	4	199/2340 200/1650	200/0940 200/2100	32 to 36
5	201/0052	202/0137	37 to 54				

Huntec Records							
Record #	Start Time	End Time	Line #	Record #	Start Time	End Time	Line #
1	195/2217	196/0947	14 to 22	2	197/1940	198/1017	23 to 27

	196/2332	197/1003					
3	199/0027	199/1108	28 to 31	4	199/2345	200/0351	32
5	200/0353 200/1645	200/0939 200/2105	33 to 36	6	201/0100	202/0137	37 to 54

3.5 KHZ Records

Record #	Start Time	End Time	Line #	Record #	Start Time	End Time	Line #
1	193/0651 193/1920 194/0333	193/1205 194/0307 194/0908	1 to 12	2	194/1640	195/0720	13
3	195/1812 195/2211 196/0952 196/1631	195/1820 195/2259 196/1540 196/1736	14a	4	196/1742 196/1902	196/1811 196/1812	NA

12 KHz Records

Record #	Start Time	End Time	Line #	Record #	Start Time	End Time	Line #
1	193/0639 193/1535 194/1108 194/1357 194/1631	193/0916 194/0951 194/1131 194/1440 195/0720	1 to 13	2	196/1013 196/2216 OBS deployments & retrievals	196/1135 196/2344	NA

Sidescan Records

Record #	Start Time	End Time	Line #	Record #	Start Time	End Time	Line #
1	201/0112	201/1126	37 to 44	2	201/1128	201/2136	44 to 51
3	201/2139	202/0145					

Geophysical
Softcopy records

DVD's

DVD #	Start Day	End Day	Line #	DVD #	Start Day	End Day	Line #
Huntec				**Teledyne**			
1	195/2108	196/0948	14 to 16	1	193/2019	194/0906	6 to 12
2	196/2323	197/1003	17 to 22	2	193/2019	202/0138	1 to 54
3	197/1940	198/1017	23 to 27	**Sidescan**			

4	198/0001	199/1108	24 to 31	1	201/0112	201/0828	37 to 42
5	199/2342	200/2105	32 to 36	2	201/0828	201/1103	42 t0 44
6	201/0136	202/000	37 to 53	3	201/1103	201/1835	44 to 50
7	201/0136	202//0137	37 to 54	4	201/1835	202/0002	51 to 53
OBS				5	202/0002	202/0138	53
1	193/2029	197/0905	6to12,17to22				
2	199/0024	199/1107	28 to 31				
3	GSCA OBS Drops 1 & 2						

DAT Tapes							
Tape #	Start Time	End Time	Line #	Tape #	Start Time	End Time	Line #
1	195/2250	196/0122	14a, 14b	2	196/0122	196/0424	14b
3	196/0425	196/0715	14b, 15	4	196/0715	196/0947	16
5	197/0035	197/0343	17	6	197/0344	197/0649	18 to 20
7	197/0652	197/0952	20 to 22	8	197/0952	197/1033	22
9	197/1950	197/2240	23	10	197/2240	198/0135	23 to 25
11	198/0135	198/0415	25	12	198/0421	198/0725	25 to 27
13	198/0725	198/1016	27	14	199/0024	199/0255	28
15	199/0259	199/0600	28	16	199/0600	199/0900	28 to 30
17	199/0900	199/1130	30, 31	18	199/2329	200/0223	32
19	200/0223	200/0306	32	20	200/0320	200/0616	32, 33
21	200/0628	200/0930	34, 35	22	200/0930	200/1925	35, 36
23	200/1925	200/2105	36	24	201/0050	201/0340	37, 38
25	201/0340	201/0626	39, 40	26	201/0626	201/0930	41, 42
27	201/0930	201/1228	43 to 45	28	201/1228	201/1531	45 to 47
29	201/1532	201/1828	47 to 49	30	201/1828	201/2130	49 to 51
31	201/2130	202/0009	52, 53	32	202/0010	202/0137	54

Table 8: Station locations and details

Stn #	*Type*	*Day/Time*	*Lat deg*	*min*	*Lon deg*	*min*	*Depth (m)*	*PC*	*TWC*
01	FFCPT	193/1006	44°	41.86962	-54°	27.213	1013	-	-
02	Heatflow Probe	193/1237	44°	34.11294	-54°	51.7719	1800	-	-
03	Piston	195/1550	42°	50.0502	-62°	3.1584	896	1061	144
04	FRPC	195/1812	42°	50.02908	-62°	3.10962	980	-	-
05	FFCPT	195/2008	42°	50.08824	-62°	3.10158	894	-	-
06	Piston	196/1157	42°	42.0186	-62°	3.4434	1317	959.5	26
07	Piston	196/1540	42°	33.9804	-62°	27.44286	1549	1193	28
08	Piston	196/1836	42°	33.0648	-62°	28.6584	1581	1085	20
09	Piston	197/1745	42°	35.274	-62°	26.442	1529	1025.5	32
10	Heatflow Probe	198/1240	42°	35.28648	-62°	26.47782	1545	-	-
11	Heatflow Probe	198/1349	42°	34.90092	-62°	25.4487	1523	-	-

12	Heatflow Probe	198/1718	42°	35.2956	-62°	26.44218	1545	-	-
13	FFCPT	198/1907	42°	33.07074	-62°	28.61694	1581	-	13
14	Piston	199/1225	42°	44.262	-62°	5.052	1210	1015.5	38
15	FFCPT	19 /1954	42°	44.2752	-62°	5.08308	1200	-	39
16	FRPC	200/1428	42°	44.274	-62°	5.094	1200	395	-
							TOTAL	6734.5	340

Haddock Channel

A prominent BSR was recognized during expedition 2002-046 in the Haddock Channel area of the SW Grand Banks of Newfoundland (Fig. 20). In addition, industry profiles showed that upslope of this BSR, salt diapir structures rise within a few hundred milliseconds of the seafloor (Fig. 21). Six OBS experiments were deployed in the area to investigate the shallow structure around these salt features and to investigate the velocity structure of the BSR (Fig. 22). The pattern of seismic lines over these OBS', acquiring reflection data is shown in Figure 16. Data quality appears to be excellent for both reflection and OBS results. OBS analysis will take some time to conduct. Reflection data show the prominent BSR at 450 ms depth below the sea floor. They also show the salt structures either outcropping or sub-cropping very close to the sea floor (Fig. 21).

An example of data for OBS D (Station 5) on Line 1 is shown below (Fig. 22). The data are of excellent quality showing a strong wide angle reflection from the BSR as well as strong refractions. It is clear that the deployed geophone signals have very high signal-to-noise. Observation of refracted arrivals is particularly clear. Reverberations of the direct arrival are still much more pronounced on the geophone as compared to the hydrophone, but careful deconvolution should help to enhance the primary arrivals. The direct arrival is sharp with minimal ringing.

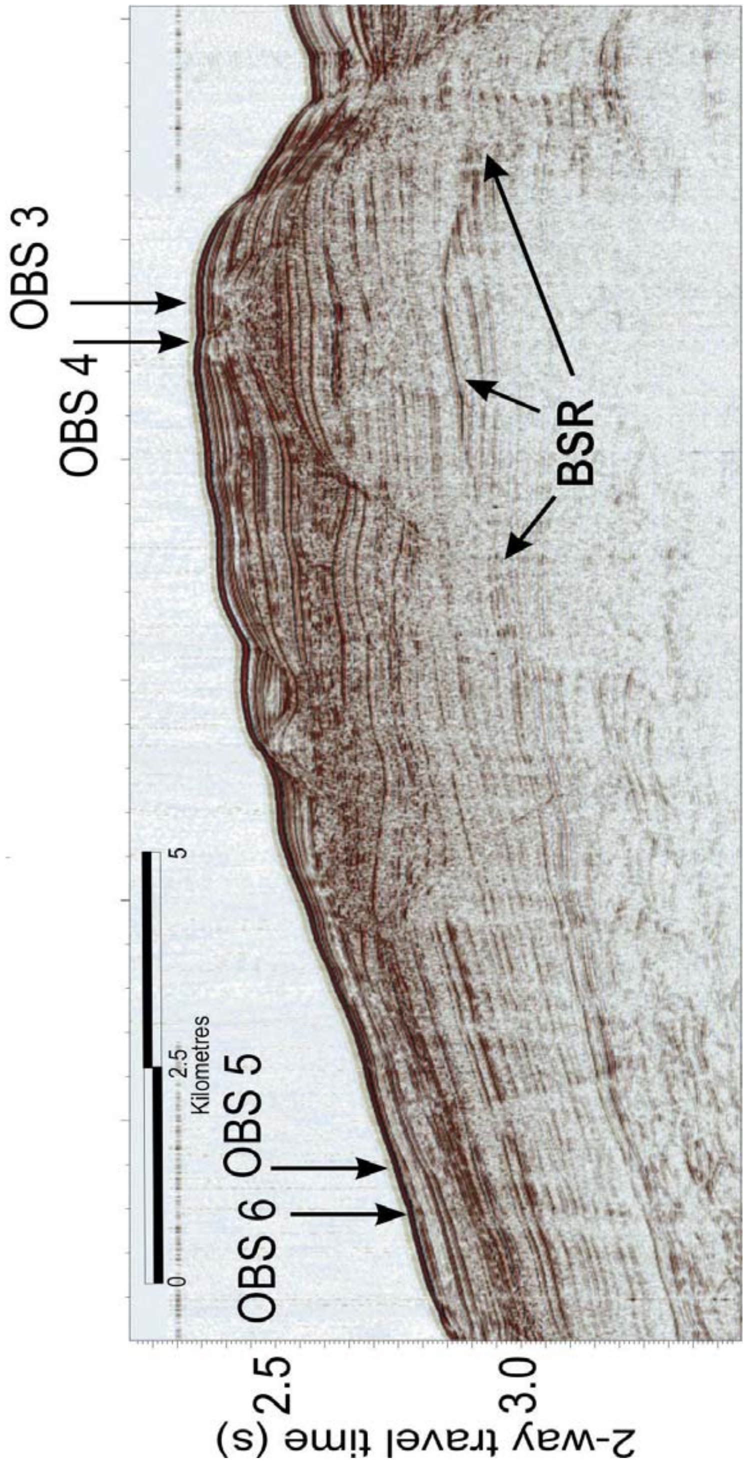


Figure 20: Seismic reflection Line 7, over BSR in Haddock Channel area. Note locations of OBS stations.

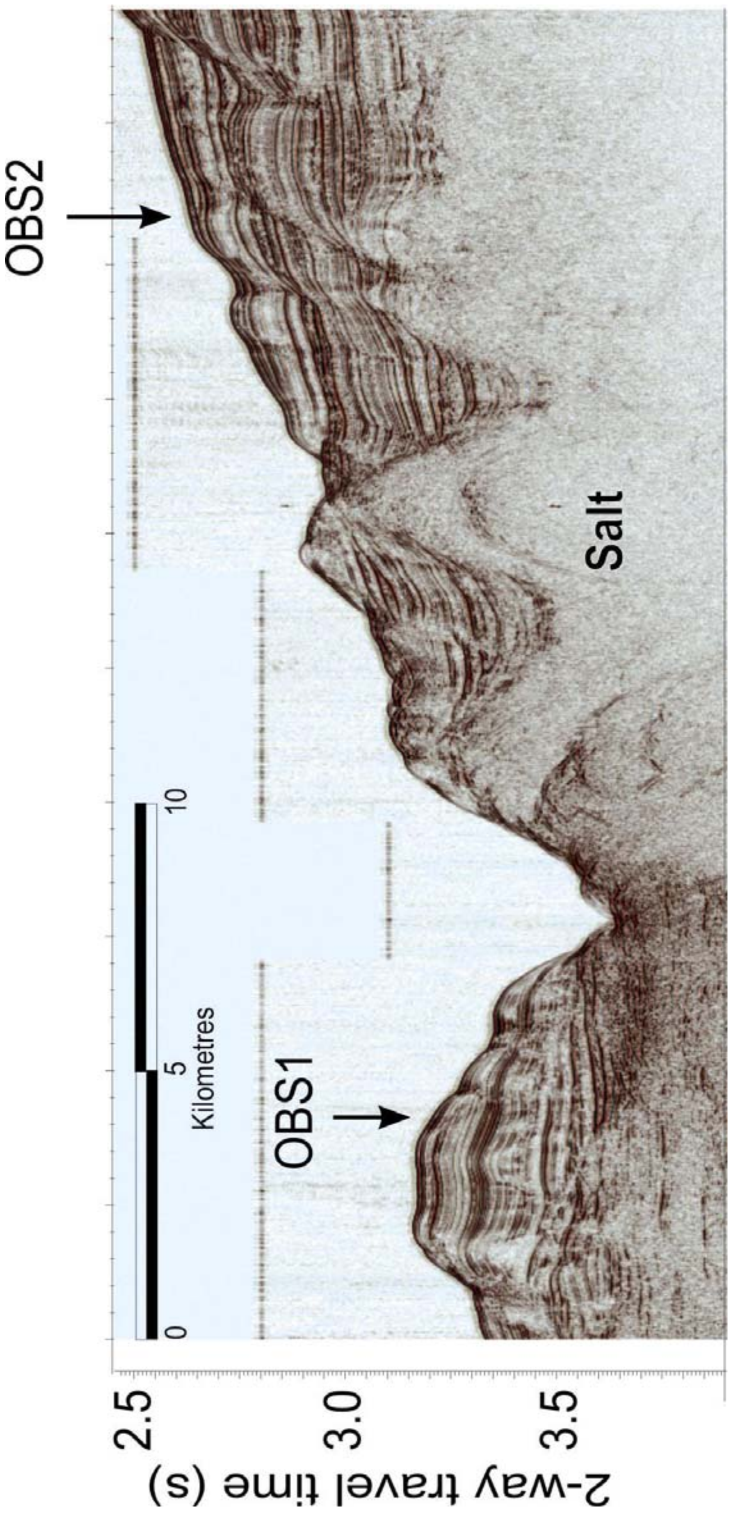


Figure 21: Seismic reflection data of Line 6, Haddock Channel. Note the locations of OBS 1 and 2 and shallow salt structures.

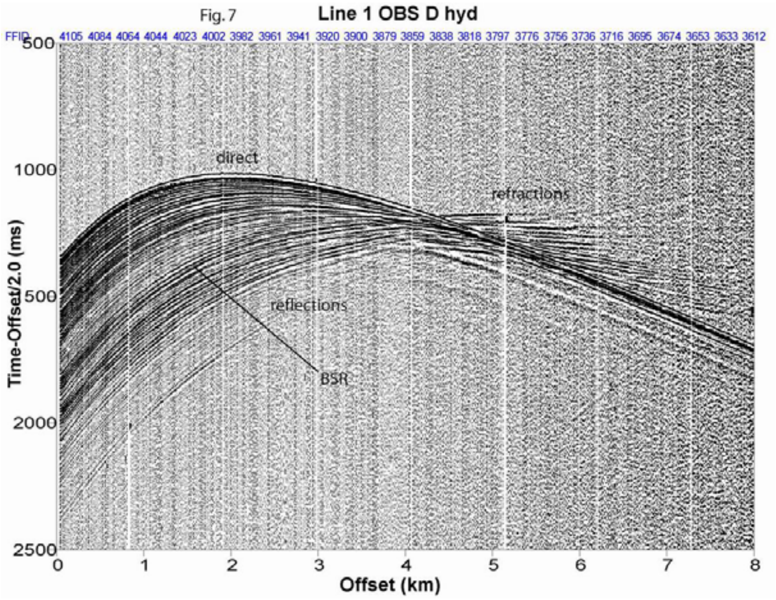


Figure 22: OBS results from one of the newly developed deployed geophones, Haddock Channel area (see Appendix for more details)

Strong bottom water gradients in the 50-100 m immediately above seafloor were measured with the Dalhousie heat flow probe at Site 4 (Haddock Channel) by the CTD, as well as non-linear gradients in the upper 3-4 m of the heat flow probe. This result is indicative of a strong bottom boundary flow in this region. Further work will be required to more fully determine the affects of these variations.

Mohican Channel and the central Scotian Slope

The principal objective for the program in Mohican Channel was to collect OBS and heat flow data over the region of the mapped BSR (Fig. 23) and compare with the areas without a BSR (Fig. 24). In addition, it was the intent to sample the “vents” – mounds that appear to be surface expressions of gas or fluid flow from deep in the section (Figs. 25-28). It was hoped that gas and/or hydrate might be recovered. Analysis of the gas may indicate its origin (methanogenic versus thermogenic, for example). Seismic lines and samples were also taken to establish the shallow stratigraphy for the region and further the geotechnical database. Seismic sections in the figures below summarize the target sites for each of the stations.

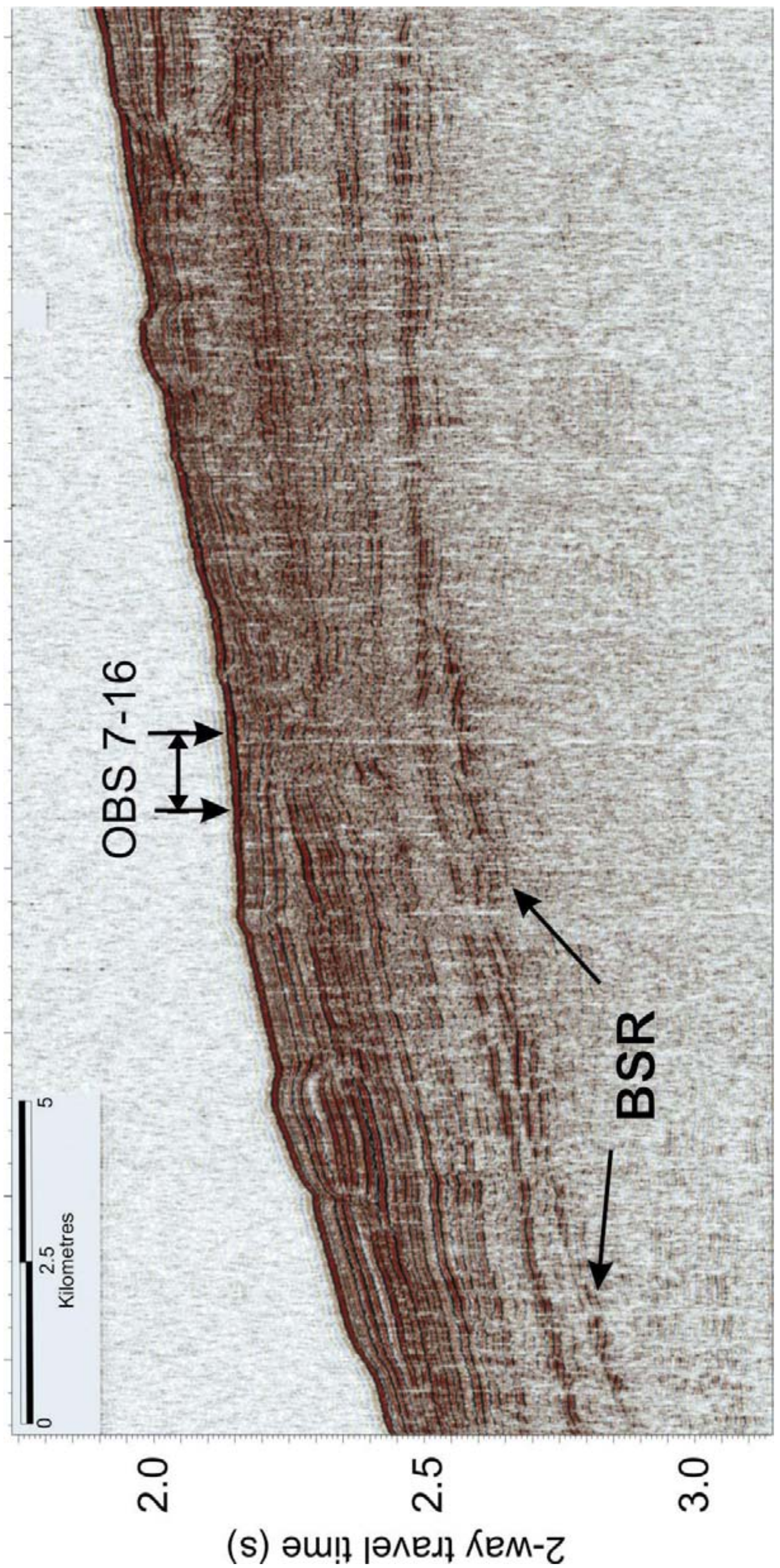


Figure 23: Reflection seismogram (Line 17) over OBS sites 7-16. Note the BSR at 450 ms depth.

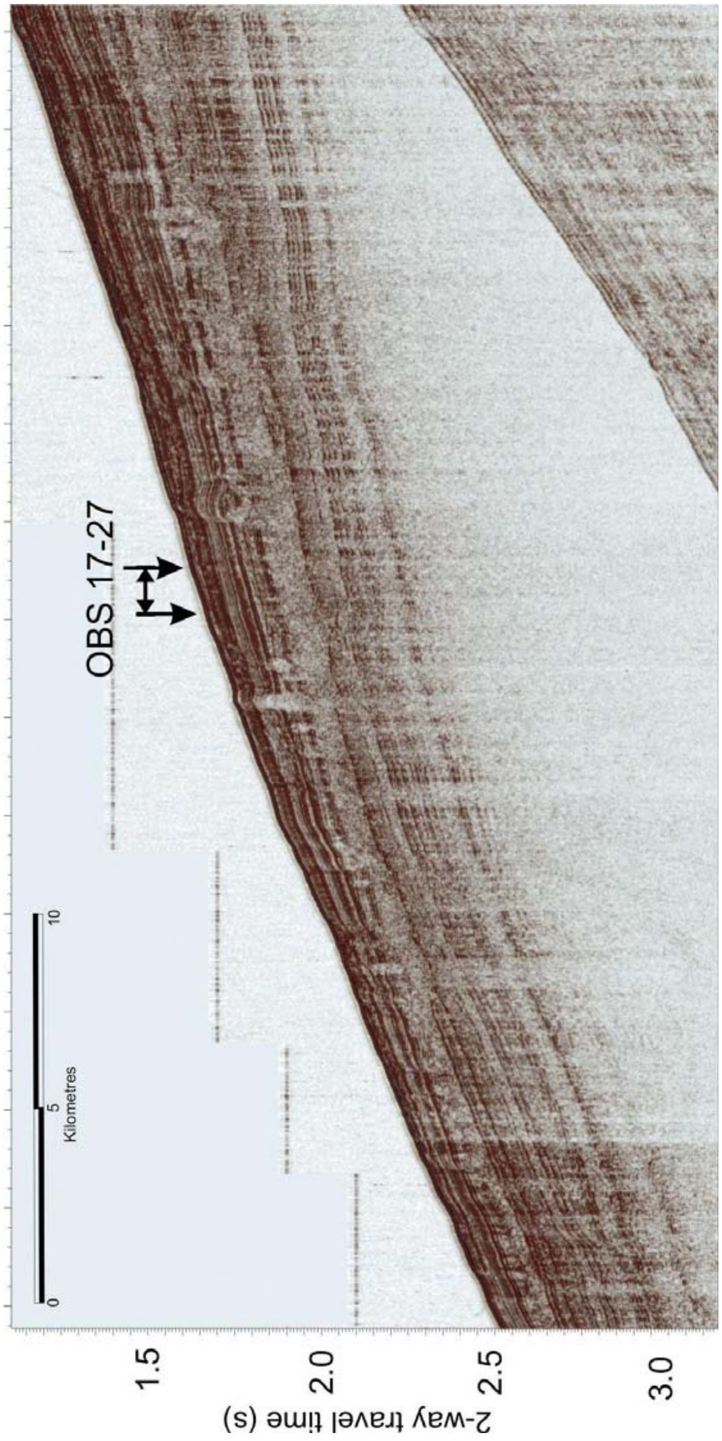


Figure 24: Reflection seismogram in dip orientation over OBS sites 17-27. Note the relatively coherent stratigraphy and lack of BSR.

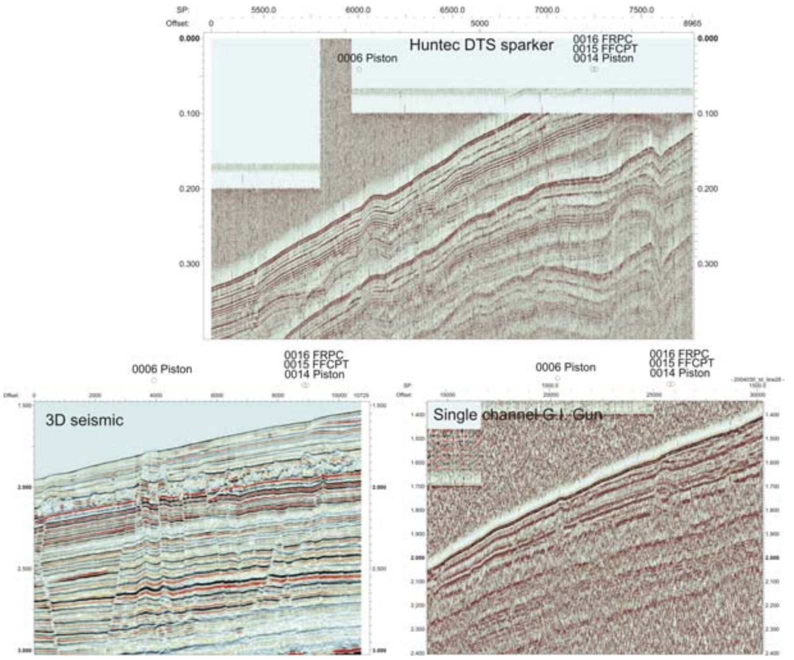


Figure 25: Seismic sections (Line 28) over stations 6 and 14-16

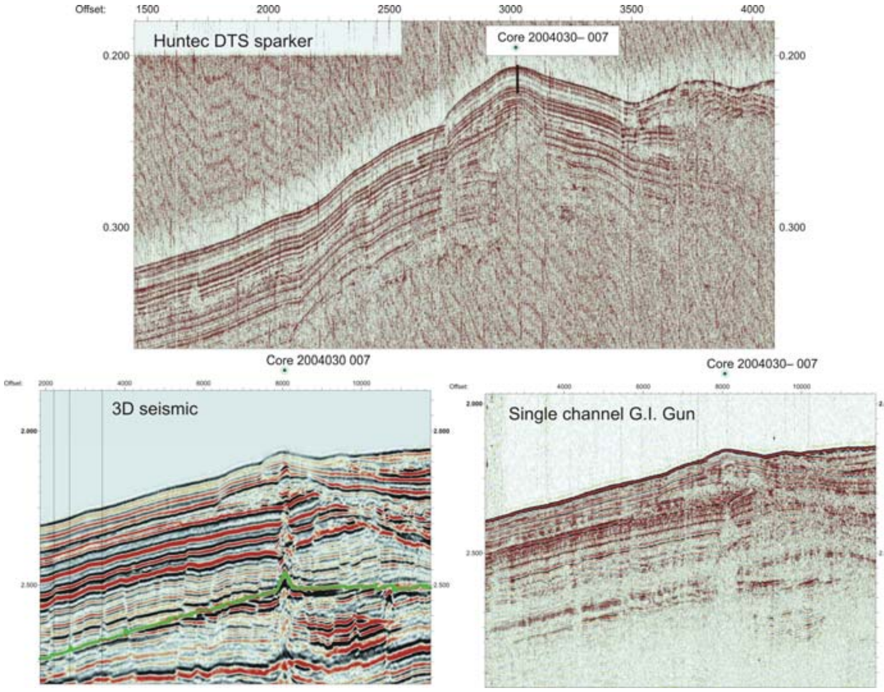


Figure 26: Seismic sections (Line 21) at core site 007

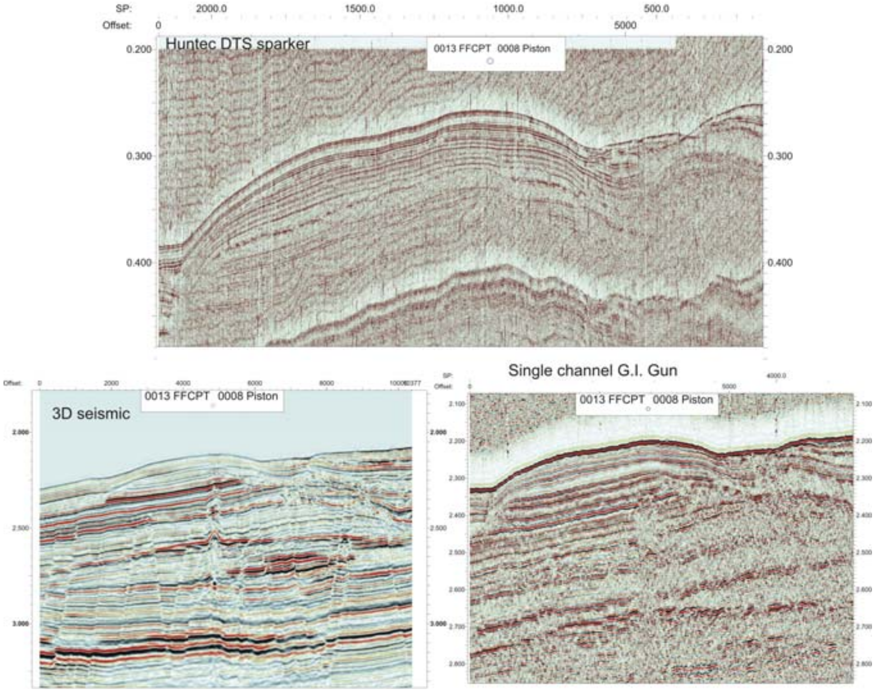


Figure 27: Seismic sections (Line 22) over stations 08 and 17

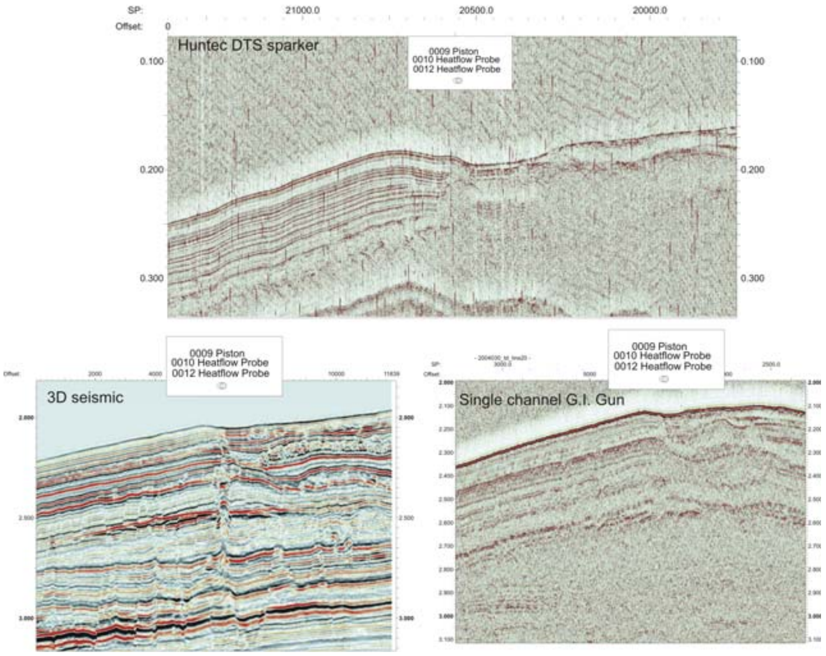


Figure 28: Seismic sections (Line 20) over stations 9, 10 and 12

Heat flow measurements from the Mohican Channel area showed small water temperature gradients above the seafloor and linear thermal gradients below ~0.5 m sub-seafloor, which will allow very accurate determinations of heat flow (Fig. 29).

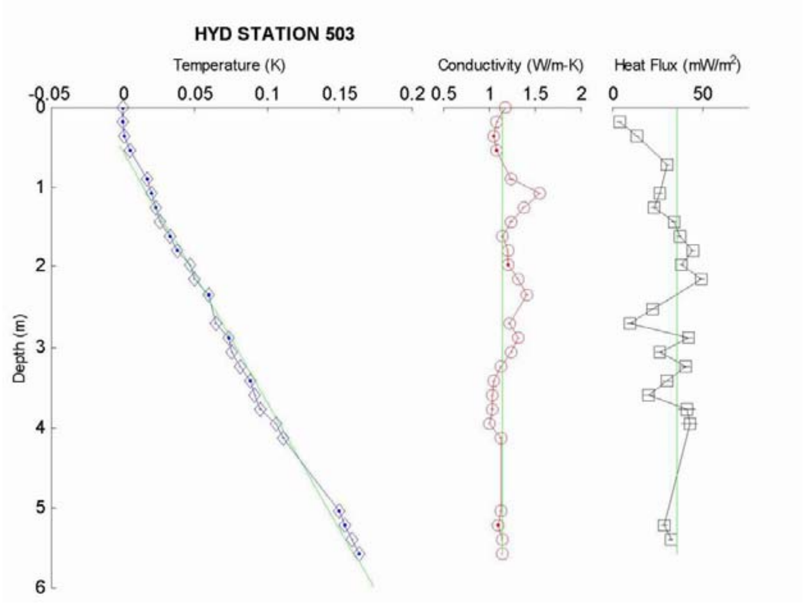


Figure 29: Heat flow results from Station 12 (see Appendix for further details)

124 pore water samples were extracted from the cores taken during this expedition. The average concentration gradients (concentration change downcore) are presented in the table below.

Table 9: Geochemistry results: ammonium, sulfate and salinity gradients.

CORE	Ammonium Gradient (mM/m)	Sulfate Gradient (mM/m)	Salinity Gradient ($^{o}/_{oo}$ / m)
3	0.38	-3.7	-0.36
6	0.36	-4.8	-0.39
7	0.25	-5.5	-0.41
8	0.16	-2.8	-0.14
9	0.37	-8.4	-0.73
14	0.27	-3.2	-0.23
16	0.31	-2.7	-0.4

The sulfate gradient becomes more negative and the ammonium gradient becomes more positive as a sediment environment becomes more reducing. This is due to the process of organic carbon being oxidized in the sediment column. As carbon is oxidized, it consumes oxidants such as sulfate (therefore sulfate decreases downcore) and releases nitrogen as ammonium (thus ammonium increases downcore). At some depth downcore, all sulfate in the pore water is consumed. For the results shown in Table 9: Geochemistry results: ammonium, sulfate and salinity gradients., the sulfate concentration reached 0 mM at depths of 3 to 9 m downcore. The organic carbon is no longer oxidized at these depths, as there is no oxidizing agent available (all of the oxygen, nitrate and sulfate has been consumed). However, the organic matter continues to be consumed by fermentation processes, which produce methane.

Based on previous work in this area, when sulfate gradients drop below -5 mM/m, gas-charged sediments are found in the lower sections of the core. Cores 7 and 9 were gas-charged. The sulfate gradients were -5.5 and -8.4 mM/m respectively. Core 6 had a sulfate gradient of -4.8 mM/m, suggesting that gas could be present in significant quantities.

The results in Table 9 show a range of salinity gradients that correlate with the loss of sulfate from the pore water ($r^2 = 0.78$, n=6). The salinity decreases 2 to 3 $^o/_{oo}$ downcore, due to the consumption of sulfate anions. The sulfate is precipitated as sulfides, thus reducing the concentration of dissolved ions in the pore water.

One purpose for doing the salinity measurements was to look for abnormal decreases in salinity (> 3 $^o/_{oo}$). Such large decreases could be due to the presence of gas hydrates, a frozen mixture of methane (and sometimes other gases) and fresh water. When sediment containing gas hydrate is brought to the sea surface, the decrease in pressure allows the frozen gas and fresh water mixture to thaw. The fresh water dilutes the pore water and decreases the salinity. The results for these cores do not indicate the presence of hydrates in the samples.

“Geoclutter” and the Western Bank “cold” area

A 10 x 10 km area of northern Western Bank was surveyed in grid fashion to complete a sidescan mosaic of the entire region and to collect high resolution subbottom information (Figs. 1 and 19). This particular area was selected to confirm that there are little in the way of surficial geologic features that might be construed as military sonar targets (geoclutter). In other words, this is a “clutter-free” zone for future sonar trials. Sidescan data demonstrate that the seafloor is dominated by sand (Fig. 30). There are occasional high reflectivity zones interpreted as gravel patches or outcrop of till as shown in the subbottom records (Figs. 30 and 31) and there are low-relief bedforms. Trawl marks are the only other features identified of any note (Fig. 31). Subbottom profiles (Huntec boomer and 10 in^3 sleeve gun) show a thin (1-10 m-thick) sand unit over presumed till (Fig. 30). This sand unit thickens to the south. The upper surface of the till shows occasional relief interpreted to be infilled erosional channels. The till unconformably overlies a Tertiary surface at tens of metres depth.

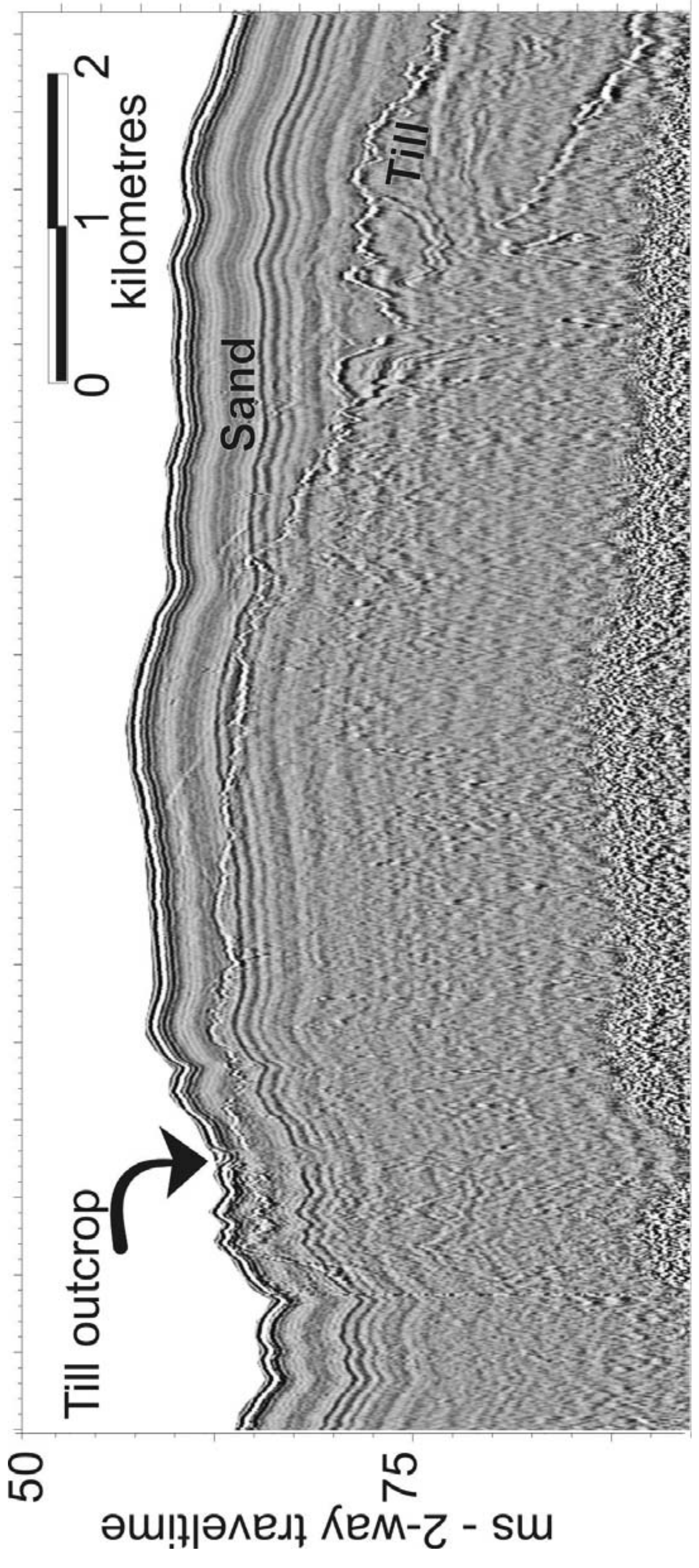


Figure 30: Huntec Line 50, showing sand over probable till. This record has been swell corrected (statics), filtered (500-2750 Hz), exponential gain recovery, tapered trace mix (5 adjacent traces) and muted to the seafloor.

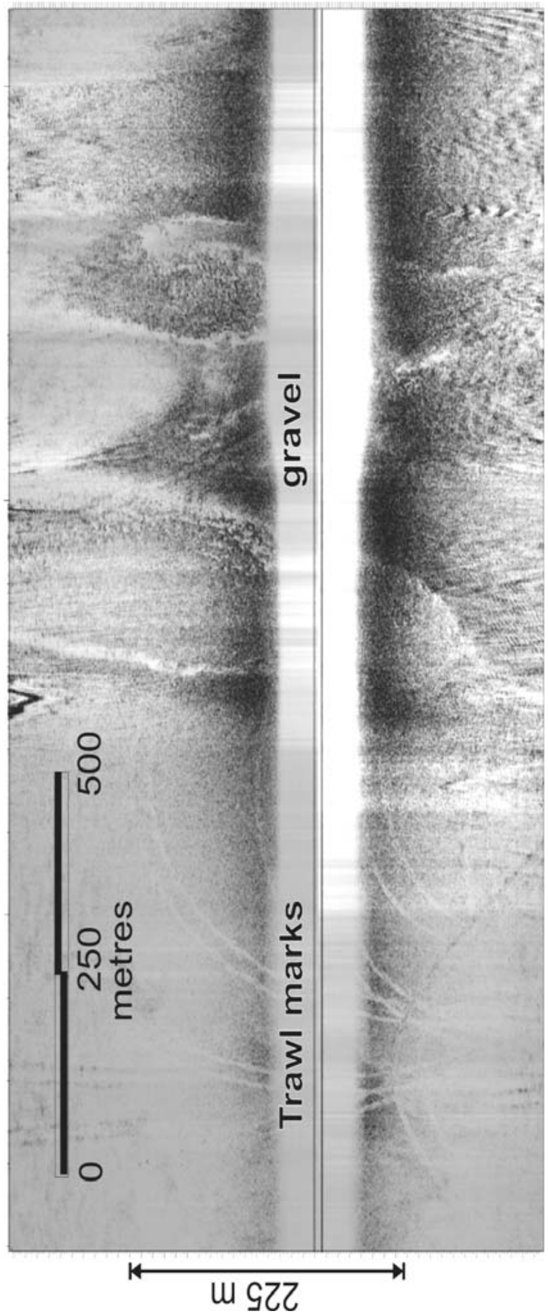


Figure 31: Sidescan sonogram example from Line 50 on Western Bank. Note the trawl marks and the darker region representing gravelconstructed into bedforms, or possible till outcropping.

Appendices

Technical Reports

Appendix I: Seismic Source Signatures

David C. Mosher, Geological Survey of Canada - Atlantic

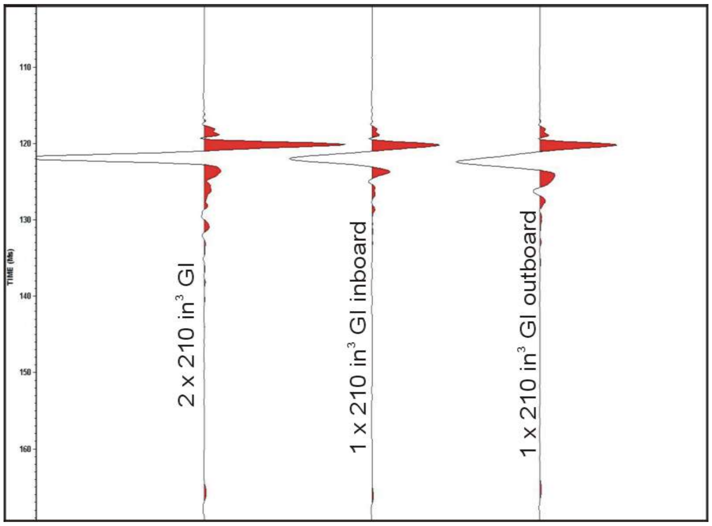
Signature tests were conducted with a calibrated hydrophone for both the GI guns and the Huntec sparker system. An OAS model E-2SD hydrophone cartridge was used for the tests. This hydrophone is omni-directional with a sensitivity of -87 dB re 1V/µbar, and a flat response from 0 to 5 kHz. It was attached to 150 m of cable and suspended about 50 m below the source (actual distances to be determined from trigger to arrival time). The hydrophone signal was digitized by the GSCDIGS systems. In the case of the GI guns, signals were digitized on GSCDIGS unit 8. Huntec signals were digitized on GSCDIGS unit 3. GSCDIGS systems accommodate ±18 Volts with 24 bit data. Amplitude values are recorded in counts, thus there are 2^{24} counts for 36 Volts, which is 2.15 µV per count.

Source signatures: GI Guns

GI gun discharge with the FRC suspending a hydrophone.

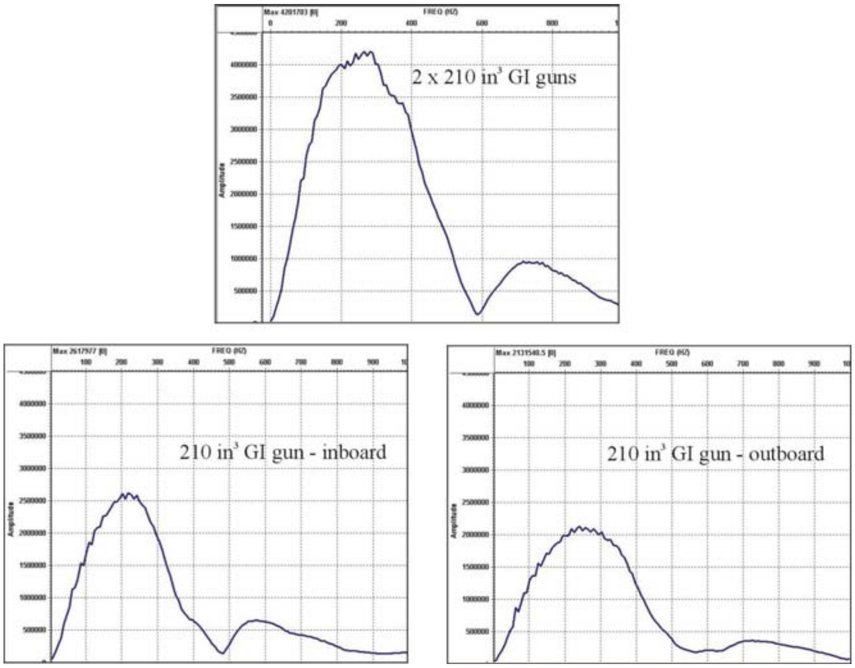
GI Gun signature tests were digitized at a sample rate of 8 kHz over a window of 1280 ms (125 µs sample interval and 10240 samples). The guns hang 1.2 m below surface and the hydrophone was suspended nearly directly below the guns with a 50 m length of cable. An FRC was used to deploy the hydrophone close to the guns. Air pressure was maintained between 1750 and 1820 psi (12,065 and 12,548 kPa). Tests on both guns firing synchronously and each gun separately were conducted. Neither filters nor gains were applied. There is a 50 ms delay between trigger time and fire time in the system. Rise time for the first arrival in each test was about 109 ms, suggesting source/receiver separation of 88 m. In the two gun array, the guns were arranged as described above. Numerous shots were acquired for each configuration. In post-processing, data were averaged over the number of quality shots. Results are shown in the figure below.

Gun	**File**
2x210 in^3 GI gun Array	Teledyne2K_2004_195_21_54_22.sgy
Inboard 210 in^3 GI gun	Teledyne2K_2004_195_21_56_49.sgy
Outboard 210 in^3 GI gun	Teledyne2K_2004_195_21_57_57.sgy
Noise test	Teledyne2K_2004_195_21_59_24.sgy



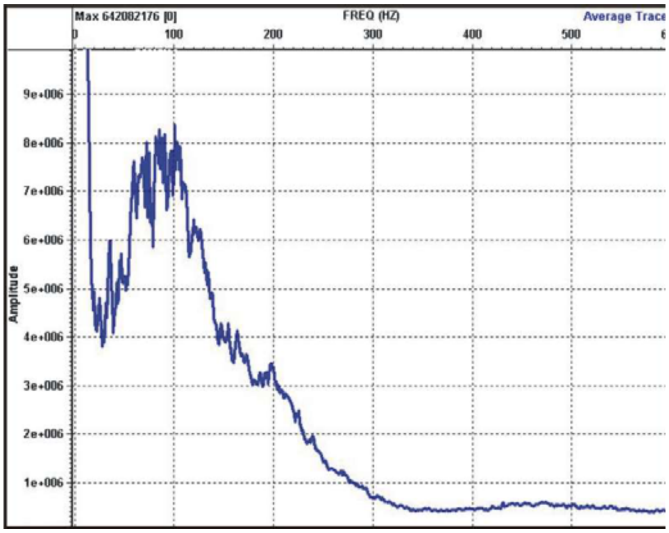
GI Gun source signatures, plotted to relative scale. On the far left is the 2 gun array, and the two to the right are single guns. Tow depth was 1.2 m and pressure was about 1725 psi. In all cases, note the small bubble pulse near the bottom of the image.

Signature tests conducted for the GI guns, as described above show a high quality seismic signature with sharp rise time and very low bubble pulse energy. Source amplitude is proportional to one-third the volume, so as volume is increased, source amplitude is only marginally increased. We would have to increase the volume of a single gun 8-fold to double its amplitude. By partitioning the air into 2 guns, however, we achieve almost 60% more efficiency than doubling the volume; 410*1/3 / (2*(210*1/3) = 0.62.



Power spectra for the source signatures shown in the above signature tests. Relative energy in the two gun array is nearly double that of each single gun separately. The frequency bandwidths are nearly equivalent, however, so no high frequencies are lost.

As shown in these signature tests, the source amplitude is not doubled, but nearly so, with the two gun array. The figure above shows the relative power spectral density for these data.



Amplitude spectrum of unfiltered reflection data from the 2 x 210 in^3 GI gun array received on the Teledyne streamer. The very low frequencies result from streamer motion.

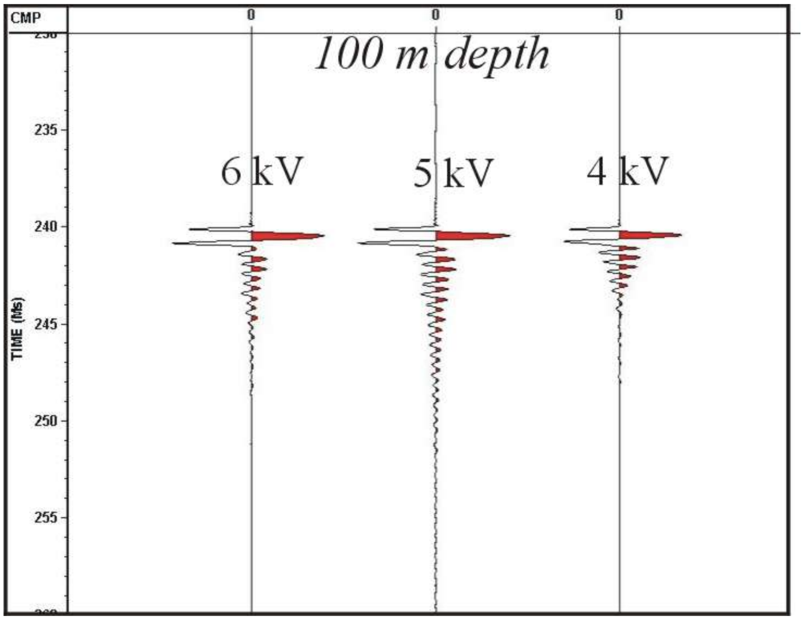
The figure to the right shows a power spectral density plot of reflected data received on the Teledyne array. They show a shift to lower frequencies, probably as a result of the earth filter and the deeper tow depth of the streamer than the gun array.

Source Signatures: Huntec Sparker

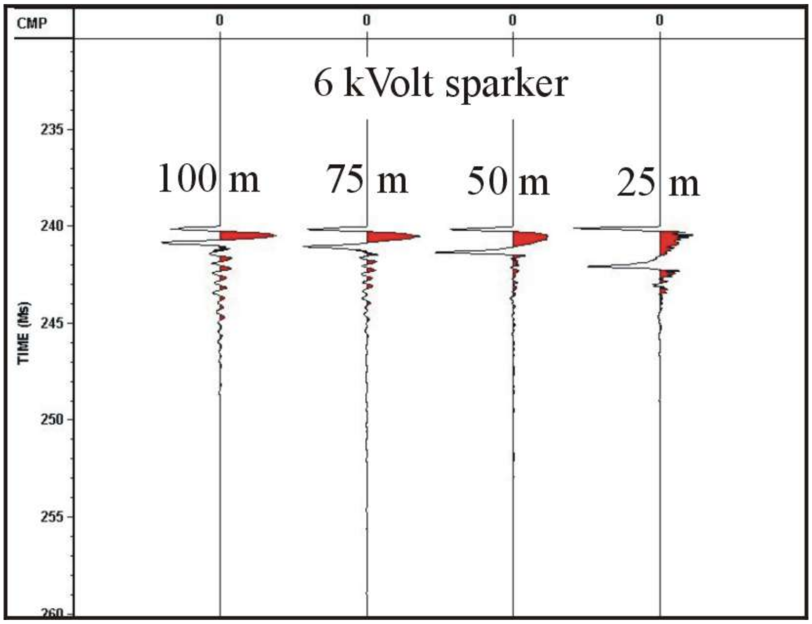
Huntec sparker tests were conducted off the fantail of the vessel while adrift. The Huntec tow body was lowered to 25, 50, 75 and 100 m for consecutive test and output was changed from 4, 5 and 6 kVolts (480, 750 and 1080 Joules, respectively). The delay between the master and fire triggers was recorded in each case but the fire time signal can be recognized on the received signal, so accurate travel times can be calculated. The hydrophone was deployed with 50 m of cable from the sea surface, but it was clearly affected by ship's forward motion, as was the tow body. Actual source-receiver separation can be derived by the differential of the fire time and the arrival time.

Source	Source depth	Fire delay	File
4kVolts	100 m	183 ms	DTS_Int_Hphone_2004_200_10_03_16.sgy
5kVolts	100 m	183 ms	DTS_Int_Hphone_2004_200_10_04_36.sgy
6kVolts	100 m	183 ms	DTS_Int_Hphone_2004_200_10_06_16.sgy
6kVolts	75 m	145 ms	DTS_Int_Hphone_2004_200_10_08_45.sgy
5kVolts	75 m	145 ms	DTS_Int_Hphone_2004_200_10_09_50.sgy
4kVolts	75 m	145 ms	DTS_Int_Hphone_2004_200_10_11_12.sgy
4kVolts	50 m	108 ms	DTS_Int_Hphone_2004_200_10_13_31.sgy
5kVolts	50 m	108 ms	DTS_Int_Hphone_2004_200_10_15_08.sgy
6kVolts	50 m	108 ms	DTS_Int_Hphone_2004_200_10_17_06.sgy
6kVolts	25 m	65 ms	DTS_Int_Hphone_2004_200_10_19_29.sgy
5kVolts	25 m	65 ms	DTS_Int_Hphone_2004_200_10_20_57.sgy
4kVolts	25 m	65 ms	DTS_Int_Hphone_2004_200_10_20_54.sgy

Sparker systems operate by creating an explosive spark between electrodes that vaporizes the water. The resulting vapour bubble then collapses under ambient pressure. The sparker signature, therefore, is highly dependent upon energy input (voltage), relative positions of the electrodes, conductivity (salinity) of the medium in which it is immersed, and tow depth (pressure field). The Huntec sparker system was tested at a variety of depths and input voltages, therefore. Below are a few example source signatures in the time domain. At equivalent depths, source characteristics are similar but vary slightly in amplitude as a result of input voltages.

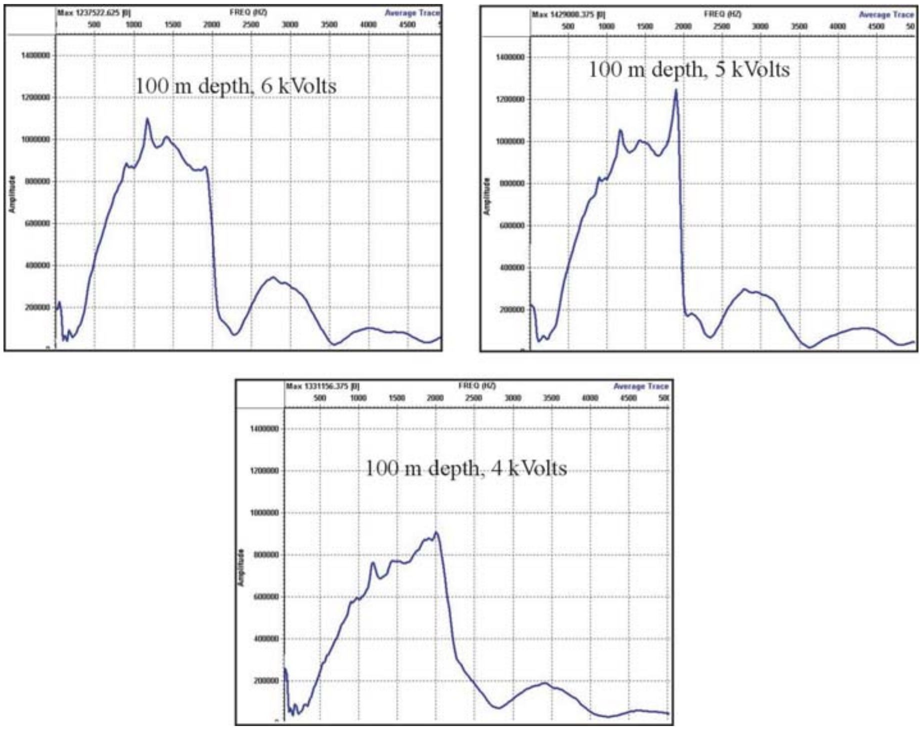


Huntec sparker signatures at 100 m depth with 3 different voltages. The characteristics of these three pulses are similar and amplitudes differ only slightly.

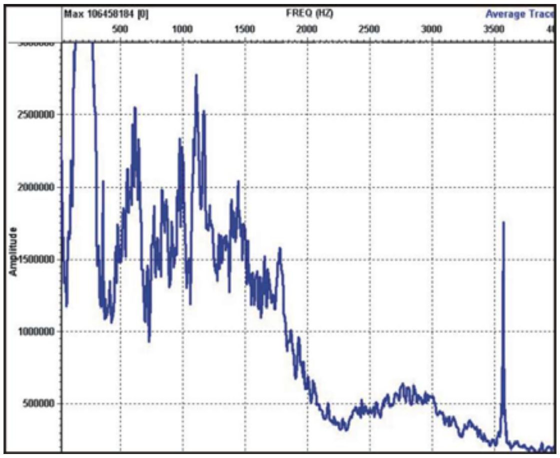


Huntec sparker signatures at 6 kVolts and variable depths. Note the extreme difference in pulse characteristics between 100 and 25 m depth.

At different water depths, however, the differences in source characteristics are dramatic. At greater depths, the initial amplitude resulting from the spark is smaller, but the vapour bubble collapses much more rapidly under the higher ambient pressure, causing a shortening of the pulse. This rapid collapse also causes oscillations in the bubble resulting in a ringing characteristic. Below are the source spectra characteristics of the sparker at 100 m depth and various voltages, followed by a spectral plot of field data from the reflection record.



Source spectral characteristics for the Huntec sparker at 100 m and varying voltage inputs.



Power spectral plot of an unfiltered 4 kV sparker field reflection record with the tow body at a depth of 90 m. The very low frequencies are noise from streamer motion. The effective bandwidth appears to be about 500-2000 Hz.

Appendix II: Report on Ocean Bottom Seismic Profiles

Keith Louden, Department of Oceanography, Dalhousie University

Summary. Three deployments of Ocean Bottom Seismometers (OBS) were conducted during Hudson 2004-030: Line 1 in the region of Haddock Channel; Line 2 in the region of Mohican Channel; and Line 3 on the Scotian Slope. The purpose of these profiles was to define the velocity structure of the upper sediment layers, and in particular of velocity anomalies due to the likely occurrence of gas hydrates. The presence of gas hydrates on Lines 1 and 2 is expected due to the existence of a bottom simulating reflector (BSR), which had been previously identified from industry reflection profiles, as well as previous higher resolution OBS and reflection profile near Line 2 in 2002. Line 3 was conducted as a control line, where a BSR is absent but sediment properties are similar to those at the nearby Line 2.

Logistics. The OBS used were of the new older Dalhousie model and were prepared by R. Iuliucci and C.LeBlanc. Location of the profiles is shown in Figs. 3-5. Details of the OBS instrument locations and data sheets are given in Table 2. A sampling rate of 558 Hz @ 16 bits and gain settings of 66 dB (geophones) and 46 dB (hydrophone Lines 1 and 3) and 56 dB (hydrophone Line 2) were used. Burn rates for the wire releases were typical (ie ~6-10 mins). Variation of the hydrophone sensitivity was observed on a few instruments, which caused some clipping of the near field direct arrivals. The reason for this variation is not obvious, as all hydrophones were recently calibrated and only those which were close to original specifications were used.

On Line 1 (Fig. 4) a total of 4 instruments were deployed in the afternoon of DN 193 in two groups of two OBS. This was a reconnaissance line which also served as a test of the new deployed geophone packages. Shooting of the two GI gun array with total volume of 420 cu. in. was conducted overnight (Fig. 4) with a shot spacing of 15m and the instruments were recovered without difficulty over a 2.5 hr period in the morning of DN 194.

On each of Lines 2 and 3, a total of 10 instruments were deployed as a central array with an approximate spacing of 100m between each OBS. For Line 2, instruments were deployed on DN 196-197. Shooting of the 2-GI gun array was conducted overnight (Fig. 5) with shot spacing of 20m and the instruments recovered over a 5.5 hour period on DN 197. For Line 3, the instruments were deployed on DN 198 and shooting conducted at 20m intervals overnight (Fig. 6). Soon after the start of shooting, one of the hoses to the GI guns failed, so most of the line was shot with a single gun with 210 cu in. The OBS were retrieved on DN 199 over an interval of 6 hrs. Communication of the acoustic release over a ~1 hr interval was systematically blocked for an unexplained reason.

On all lines, shot times were triggered by the Frydecky timing box (Beta version) in order to shoot by distance interval and logged by the Dalhousie Zyfer GPS clock in order to record exact firing times. Times logged in the shot table were taken from the clock time break (CTB) output of the Real Time Systems Long Shot seismic source controller. These times are the aim point shot times with a 50 msec delay following the trigger.

Data. Data recorded on the OBS hard drives were downloaded to PC and written to DVD. Preliminary SEG-Y files were generated using the Zyfer GPS navigation and OBS deployment positions. An example of the data for OBS D (Station 5) on Line 1 is shown in Figs. 7-8. The data are of excellent quality showing a strong wide angle reflection from the BSR as well as strong refractions. It is clear that the deployed geophone signals have very high signal-to-noise. Observation of refracted arrivals is particularly clear. Reverberations of the direct arrival are still much more pronounced on the geophone as compared to the hydrophone, but careful deconvolution should help to enhance the primary arrivals. The direct arrival is sharp with minimal ringing.

Recommendations

(1) The 2-GI gun source proved excellent for the purpose of recording high quality wide-angle seismic data on the OBS for offsets of at least 10 km.
(2) Shooting on distance using the Frydecky timing box (Beta version) worked without problem. However, it is absolutely critical to have an accurate recording of the time of each shot for use with the OBS.
(3) The OBS data are of excellent quality for determination of velocity anomalies associated with the BSR.
(4) The new deployed geophone package worked very well, with a significant improvement of signal-to-noise. This will help to remove reverberation of the direct arrival by deconvolution. Further tests need to be conducted to determine if the reverberations are real or artifacts due to motion of the neighbouring OBS and its anchor.
(5) Use of a 24-bit ADC for future upgrades of the OBS would eliminate the problem with occasional overloading by the direct wave.

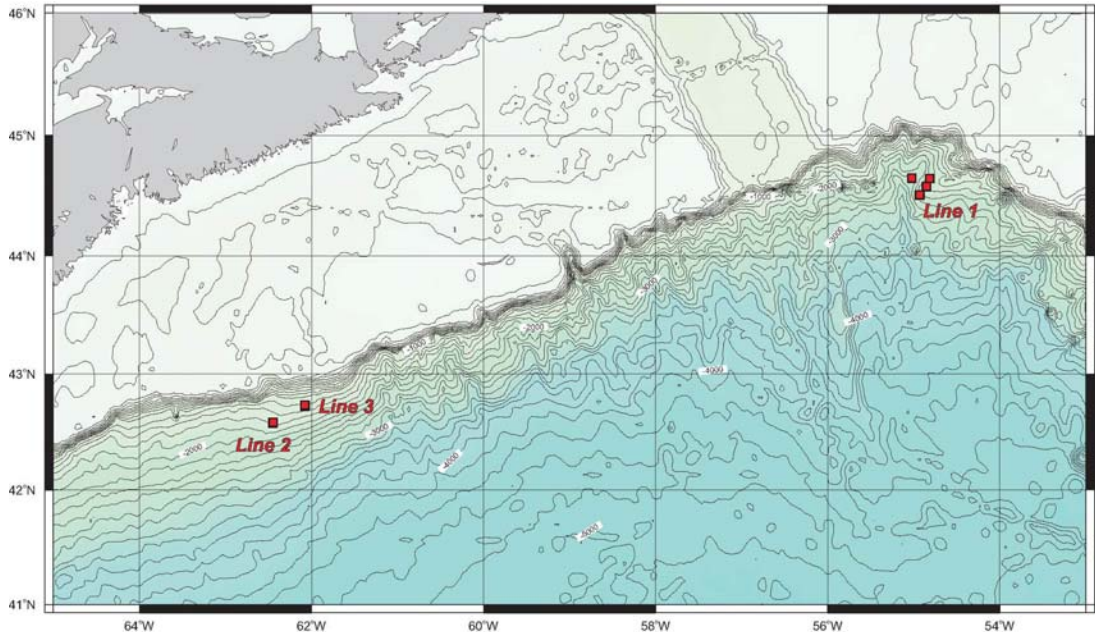


Figure 1 - General OBS deployment locations

Hudson 2004-030 OBS Data sheet 1

Deployment:

OBS	Station	Pinger	Strobe	Beacon	Freq	Time clock reset	Time recording	Backup release	Deployed (day/time)	Water depth (m)	lat (deg)	lat (min)	lat (deg)	lat (dec degrees)	long (min)	long (dec degrees)
LINE 1																
OBS L	6	90	B1140	1953	A: 154.585	193/1151	193/1120	194/1500	193/1608	1970	44	30.40	44.506662	-54	56.01	-54.933437
OBS D	5	90	B1963	N09-004	B: 159.480	193/1227	193/1120	194/1500	193/1618	1954	44	30.59	44.509880	-54	55.80	-54.929985
OBS K	4	80	N09-005	F11-065	A	193/1305	193/1120	194/1500	193/1713	1655	44	34.45	44.574198	-54	51.20	-54.853387
OBS H	3	80	B1964	N09-002	B	193/1323	193/2000	194/1500	193/1744	1658	44	34.64	44.577355	-54	51.03	-54.850558
LINE 2																
OBS B	16	30	19676	no s/n	B	195/2040	196/2000	197/1600	196/2145.44		42	34.77	42.579420	-62	27.00	-62.449940
OBS C	15	10	M12-094	J10-044	77 (156.875	195/2313	196/2000	197/1600	196/2149.26		42	34.81	42.580230	-62	26.96	-62.449350
OBS G	14	00	26445	N09-003	B	195/2336	196/2000	197/1600	196/2151.38		42	34.86	42.581060	-62	26.92	-62.448680
OBS H	13	80	B1964	N09-002	B	196/1230	196/2000	197/1600	196/2153.56		42	34.91	42.581840	-62	26.88	-62.448020
OBS A	12	20	N09-006	B1957	B	195/2358	196/2000	197/1600	196/2155.53		42	34.96	42.582710	-62	26.85	-62.447500
OBS K	11	80	N09-005	F11-065	A	196/1144	196/2000	197/1600	196/2157.35		42	35.00	42.583380	-62	26.82	-62.446940
OBS N	10	60	M12-091	M09-008	A	196/0044	196/2000	197/1600	196/2159.58		42	35.05	42.584220	-62	26.78	-62.446290
OBS L	9	90	B1140	B1953	A	196/1320	196/2000	197/1600	197/2201.48		42	35.10	42.584990	-62	26.75	-62.445850
OBS D	8	90	B1963	N09-004	B	196/1257	196/2000	197/1600	197/2203.28		42	35.15	42.585790	-62	26.72	-62.445370
OBS I	7	40	A1175	9718	77	196/0019	196/2000	197/1600	196/2209.22		42	35.20	42.586590	-62	26.67	-62.444530
LINE 3																
OBS B	18	30	19676	no s/n	B	198/1643	198/2200	199/1800	198/2207.10		42	43.47	42.724418	-62	4.54	-62.075708
OBS G	19	00	26445	N09-003	B	198/1135	198/2200	199/1800	198/2212.22		42	43.52	42.725260	-62	4.44	-62.074025
OBS C	20	10	M12-094	J10-044	77	198/1109	198/2200	199/1800	198/2218.39		42	43.56	42.725922	-62	4.48	-62.074680
OBS N	21	60	M12-091	M09-008	A	198/1145	198/2200	199/1800	198/2226.33		42	43.60	42.726702	-62	4.52	-62.075275
OBS H	22	80	B1964	N09-002	B	198/1202	198/2200	199/1800	198/2232.49		42	43.65	42.727540	-62	4.56	-62.075948
OBS K	23	80	N09-005	F11-065	A	198/1224	198/2200	199/1800	198/2239.11		42	43.71	42.728437	-62	4.59	-62.076548
OBS A	24	20	N09-006	B1957	B	198/1408	198/2200	199/1800	198/2243.13		42	43.75	42.729090	-62	4.63	-62.077185
OBS I	25	40	A1175	R09-017	C (160.725)	198/1235	198/2200	199/1800	198/2247.43		42	43.80	42.729938	-62	4.66	-62.077717
OBS L	26	90	B1140	B1953	A	198/1352	198/2200	199/1800	198/2252.36		42	43.85	42.730750	-62	4.70	-62.078335
OBS D	27	90	B1963	N09-004	B	198/1328	198/2200	199/1800	198/2257.05		42	43.89	42.731443	-62	4.73	-62.078895

Hudson 2004-030 OBS Data sheet 2

		Retrieval:						Drift Calibrations:								
OBS	Station	Time release (day/time)	Time on surface	Lat (deg)	Lat (min)	Long (deg)	Long (min)	Time 1st calib.	initial calibration value (heff)	GPS	initial offset (s)	Time final calib.	final calibration value (heff)	GPS	final offset (s)	Drift (GPS)
LINE 1																
OBS L	6	194/1003	194/1038	44	30.5553	-54	56.117	193/1151	1.0034	1.0017	-0.0017	194/1132	1.0036	1.0021	-0.0021	-0.0004
OBS D	5	194/1008	194/1038	44	30.6308	-54	55.9712	193/1227	1.0038	1.0012	-0.0012	194/1138	1.0024	1.0006	-0.0006	0.0006
OBS K	4	194/1152	194/1223	44	34.5379	-54	51.116	193/1305	1.0018	0.9999	0.0001	194/1305	0.9975	0.9957	0.0043	0.0043
OBS H	3	194/1143	194/1213	44	34.6627	-54	50.882	193/1323	1.0026	1.0008	-0.0008	194/1256	1.0035	1.0020	-0.0020	-0.0012
LINE 2																
OBS B	16	197/1121	197/1148	42	34.8411	-62	27.2653	195/2040	0.9999	0.9981	0.0020	196/1237	0.9976	0.9958	0.0042	0.0023
OBS C	15	197/1133	197/1220	42	34.8757	-62	27.2121	195/2313	1.0017	0.9998	0.0002	197/1133	1.0010	0.9994	0.0006	0.0004
OBS G	14	197/1232	197/1258	42	34.9712	-62	27.0951	195/2336	0.9980	0.9962	0.0038	197/1337	0.9988	0.9969	0.0031	-0.0008
OBS H	13	197/1338		42	35.0977	-62	27.0738	196/1230	0.9986	0.9967	0.0033	197/1448	1.0003	0.9984	0.0016	-0.0017
OBS A	12	197/1608	197/1630	42	35.2885	-62	26.877	195/2358	0.9973	0.9955	0.0046	197/1705	1.0027	1.0008	-0.0008	-0.0054
OBS K	11	197/1340	197/1431	42	35.4493	-62	26.9344	196/1144	0.9977	0.9958	0.0042	197/1458	0.9930	0.9912	0.0088	0.0046
OBS N	10	197/1241	197/1307	42	35.1543	-62	26.9249	196/0044	0.9968	0.9950	0.0050	197/1341	0.9939	0.9920	0.0080	0.0029
OBS L	9	197/1527	197/1552	42	35.4871	-62	27.007	196/1320	0.9967	0.9949	0.0051	197/1631	0.9973	0.9955	0.0045	-0.0006
OBS D	8	197/1515	197/1542	42	35.3448	-62	26.8639	196/1257	1.0033	1.0014	-0.0014	197/1610	1.0027	1.0008	-0.0008	0.0006
OBS I	7	197/1350	197/1420	42	35.0977	-62	27.0582	196/0019	1.0013	0.9995	0.0006	197/1540	0.9965	0.9947	0.0053	0.0047
LINE 3																
OBS B	18	199/1830	199/1801	42	43.4243	-62	4.5425	198/1643	1.0028	1.0010	-0.0010	199/1738	1.0012	0.9993	0.0007	0.0017
OBS G	19	199/1707	199/1738	42	43.5032	-62	4.5494	198/1135	1.0016	1.0000	0.0000	199/1821	1.0025	1.0006	-0.0006	-0.0007
OBS C	20	199/1806	199/1826	42	43.5321	-62	4.5903	198/1109	0.9964	0.9945	0.0055	199/1920	0.9962	0.9944	0.0056	0.0002
OBS N	21	199/1806	199/1825	42	43.7064	-62	4.7626	198/1145	1.0000	0.9982	0.0019	199/1927	0.9973	0.9954	0.0046	0.0027
OBS H	22	199/1626	199/1644	42	43.6641	-62	4.5722	198/1202	0.9998	0.9974	0.0026	199/1716	1.0009	0.9993	0.0007	-0.0019
OBS K	23	199/1633	199/1650	42	43.7104	-62	4.6404	198/1224	0.9974	0.9955	0.0045	199/1725	0.9927	0.9909	0.0091	0.0047
OBS A	24	199/1806	199/1825	42	43.5786	-62	4.6513	198/1408	1.0016	0.9997	0.0003	199/1932	1.0051	1.0036	-0.0036	-0.0039
OBS I	25	199/1536	199/1600	42	43.7649	-62	4.6897	198/1235	1.0030	1.0012	-0.0012	199/1630	0.9998	0.9979	0.0021	0.0032
OBS L	26	199/1309	199/1329	42	43.7908	-62	4.7527	198/1352	0.9975	0.9956	0.0044	199/1430	0.9981	0.9962	0.0038	-0.0006
OBS D	27	199/1322	199/1344	42	43.872	-62	4.7869	198/1328	1.0021	1.0002	-0.0002	199/1330	1.0016	0.9998	0.0002	0.0004

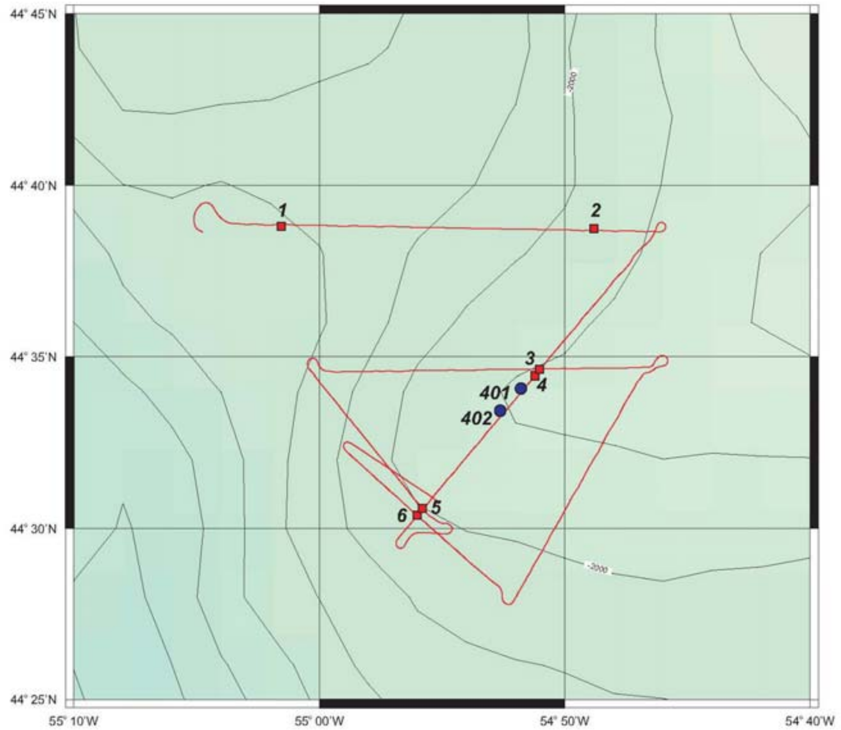


Figure 4 - OBS and Line locations at first deployment site, Haddock Channel. Deployments 1 to 6

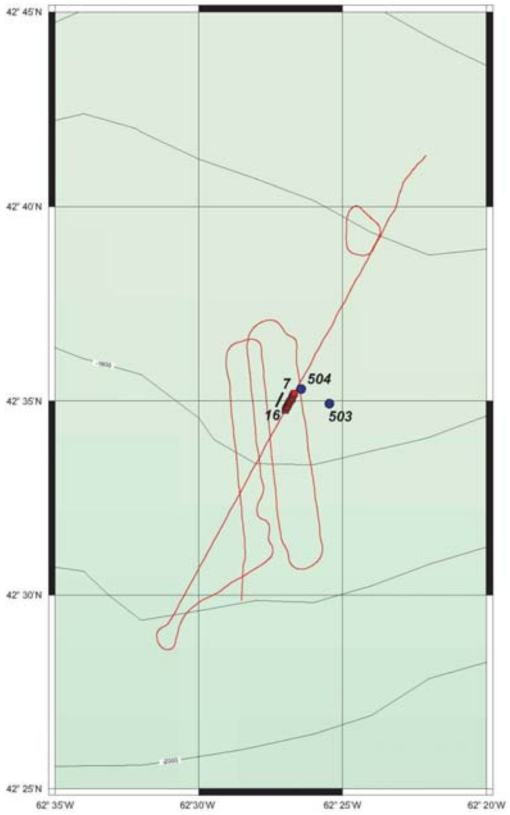


Figure 5 - OBS deployment and line locations at second deployment site – Mohican Channel over BSR (OBS deployments 7-16)

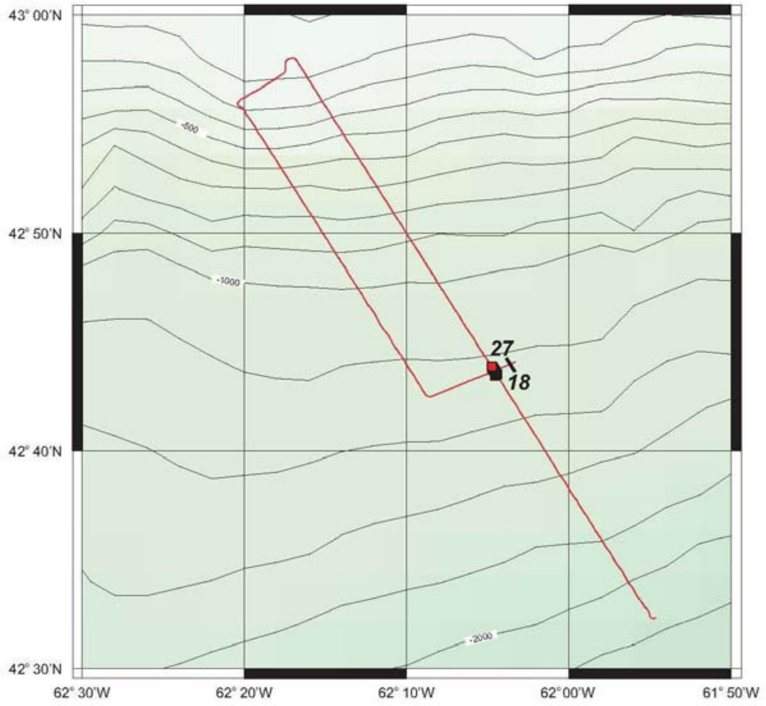
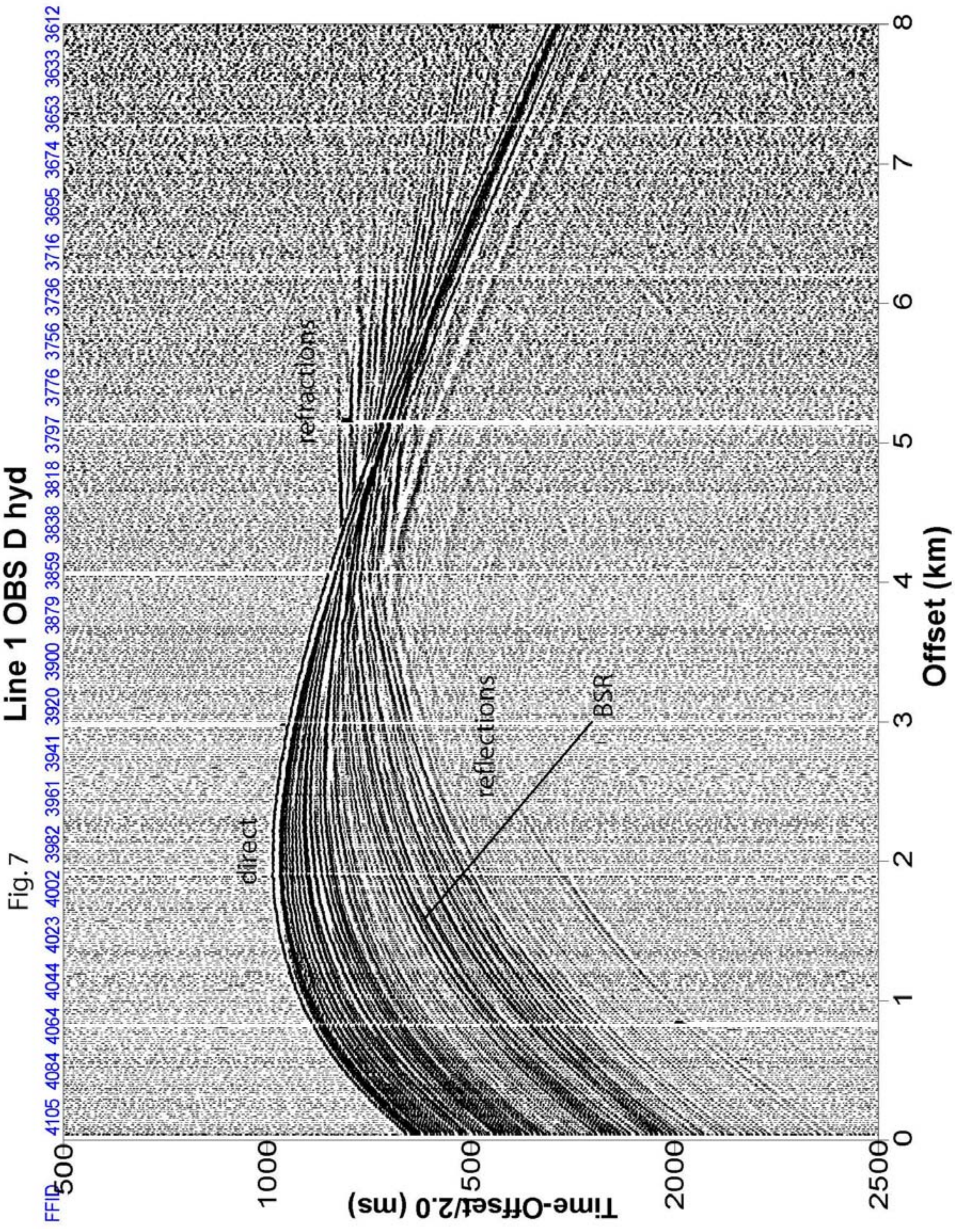


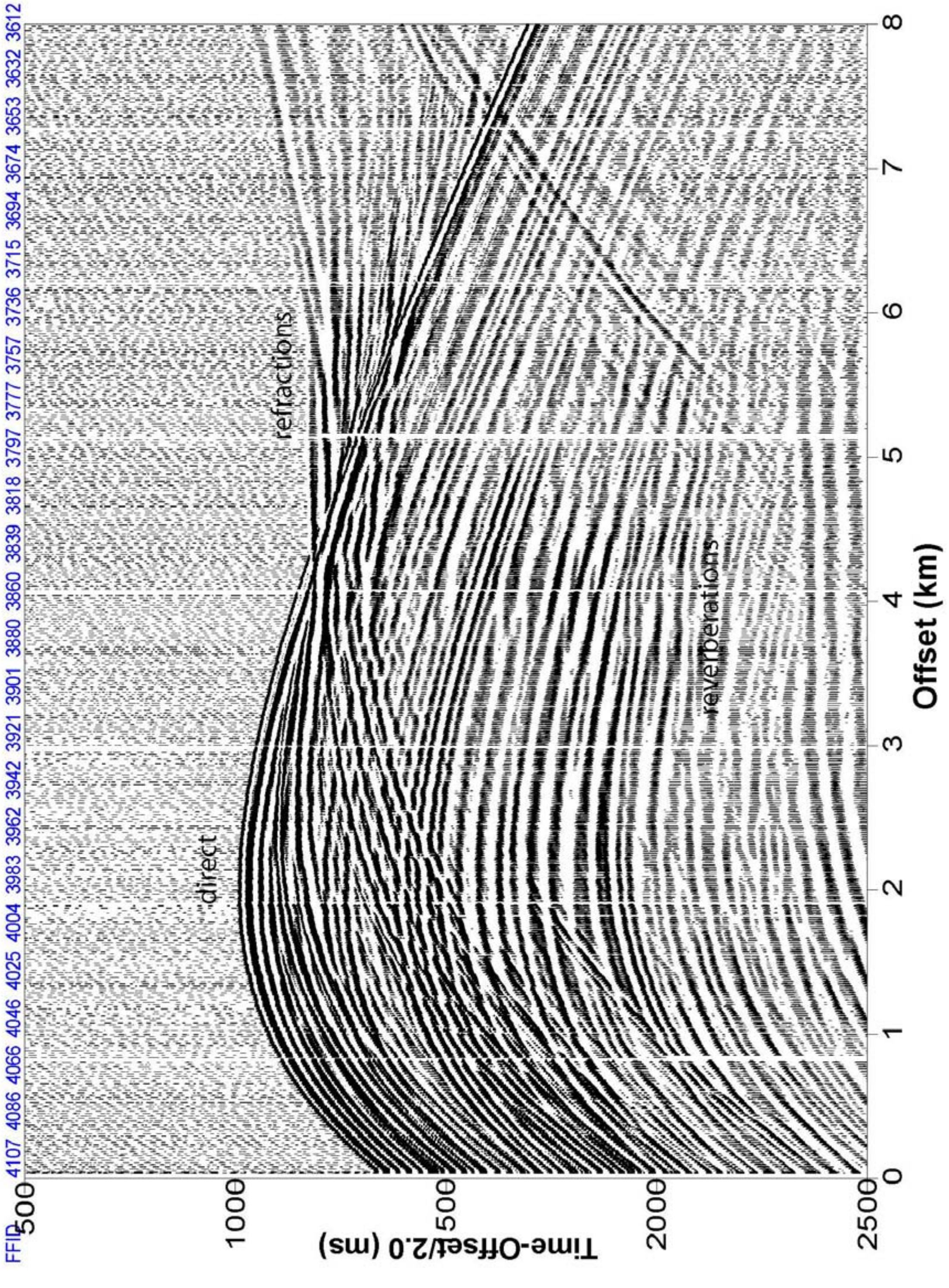
Figure 6 - OBS and line locations at third deploy site – Mohican Channel, off BSR. OBS deployments 18 to 27.

Fig. 7



OBS geophone data at Haddock Channel, with external geophone package

Fig. 8


Line 1 OBS D vert geo
FFID
4107 4086 4066 4046 4025 4004 3983 3962 3942 3921 3901 3880 3860 3839 3818 3797 3777 3757 3736 3715 3694 3674 3653 3632 3612
500
1000
1500
2000
2500
Time-Offset/2.0 (ms)
0 1 2 3 4 5 6 7 8
Offset (km)
direct
refractions
reverberations

Appendix III: Heat flow

Keith Louden, Department of Oceanography, Dalhousie University

Summary. Heat flow measurements were taken using the Dalhousie heat flow probe and Seabird 19 CTD at 2 locations in the Haddock Channel and Mohican Channel as a preliminary assessment of the thermal regime at locations of strong bottom simulating reflectors (BSR) indicative of gas hydrates. A total of 4 successful measurements were made using a 6-m long probe and 32-sensor thermistor string.

Operations. Deployment of the heat flow probe and CTD was made on July 11 (DN 193) and July 16 (DN 198). Details of station locations and times are given in Table 1. A total of 4 successful stations were made using a 6-m long probe: Site 4 (2 stations) and Site 5 (2 stations). Fig. 1 shows the location of the two sites. Figs. 4 and 5 show detailed locations. The weather was excellent for all deployments. Instrument HF2 was used and performed well at Site 4, except that 4 of the thermistors toward the bottom of the tube were not properly recorded. These sensors were important due to the presence of bottom water variations at this site and it was decided to try another instrument. HF1 was subsequently tested on deck and recorded all thermistors. However, when used at Site 5 the instrument did not function properly and stations 501 and 502 had to be repeated after switching back to HF2. This resulted in a loss of approximately 3 hours of operations.

Data. The data are of good quality with 27-28 thermistors recording on all sites. Fig. 2 shows results for station 503. Preliminary results indicate that the measurements will be useful in estimating sediment temperatures associated with the transition from hydrate to free gas at the depth of the BSR. Strong bottom water gradients in the 50-100m immediately above seafloor were measured at Site 4 (Haddock Channel) by the CTD, as well as non-linear gradients in the upper 3-4 m of the heat flow probe. This is indicative of a strong bottom boundary flow in this region. Further work will be required to more fully determine the affects of these variations. In contrast, Site 5 (Mohican Channel) showed small water temperature gradients above the seafloor and linear thermal gradients below ~0.5 m sub-seafloor (e.g. Fig. 2), which will allow very accurate determinations of heat flow. Based on these preliminary measurements, a more complete program of heat flow should be planned for the Mohican Channel region.

Table 1 **Hydrate Heat Flow Survey**
HUDSON 2004-030

ID	Latitude	Longitude	Pen	DEPTH	Time on bottom	BWT	Tilt
	N	*W*		*m*	*DN HM*	^{o}C	*deg*
HYD401	***44° 34.10'***	***54° 51.79'***	***6***	***1703***	**193 1237**	**3.60**	**4**
HYD402	***44° 33.45'***	***54° 52.63'***	***6***	***1730***	**193 1352**	**3.60**	**6.5**
HYD501*	***42° 35.28'***	***62° 26.45'***	***6***	***1545***	**198 1240**	**3.72**	
HYD502*	***42° 34.90'***	***62° 25.45'***	***6***	***1520***	**198 1349**	**3.73**	
HYD503+	***42° 34.91'***	***62° 25.46'***	***6***	***1526***	**198 1559**	**3.73**	

HYD503a	*42° 34.92'*	*62° 25.46'*	*6*	*1526*	198 1607	3.74	0
HYD504	*42° 35.30'*	*62° 26.44'*	*6*	*1545*	198 1718	3.72	1

Notes:

- * Instrument malfunction
- \+ early heat pulse

Operational Statistics	Site	HF 4	HF 5
	start	193 1200	198 1200
	stop	193 1500	198 1800
	total hours	3.0	6.0

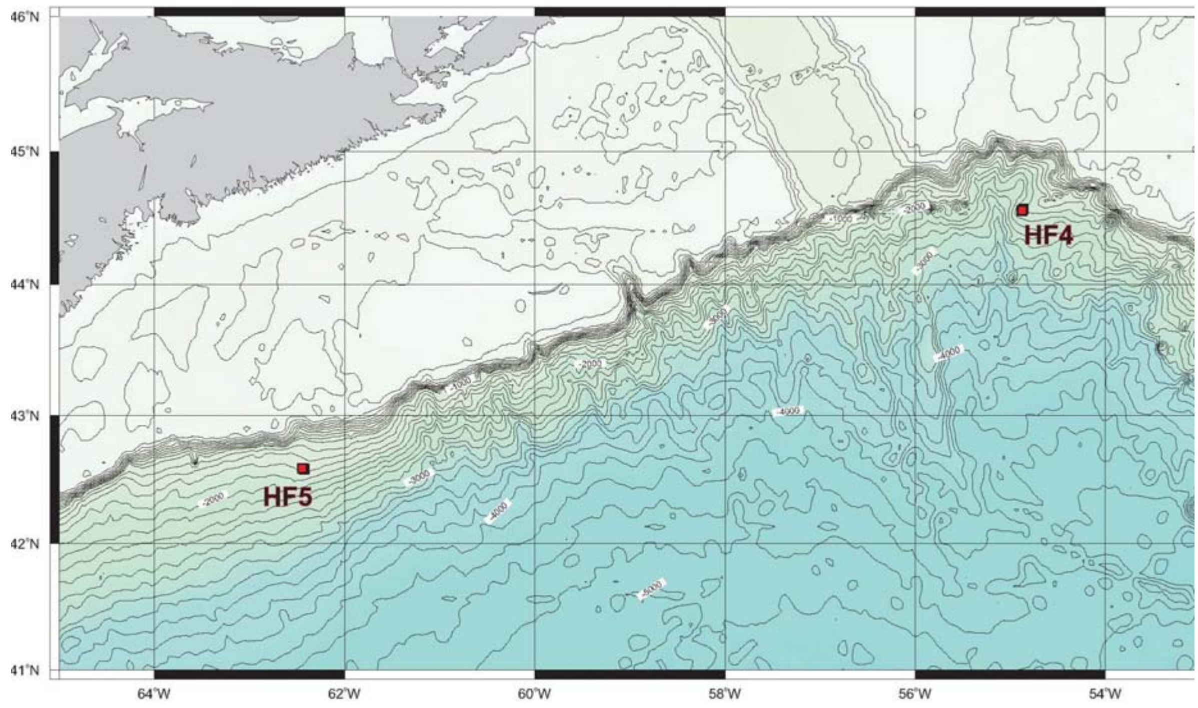


Figure 1 - Locations of heat flow deployments

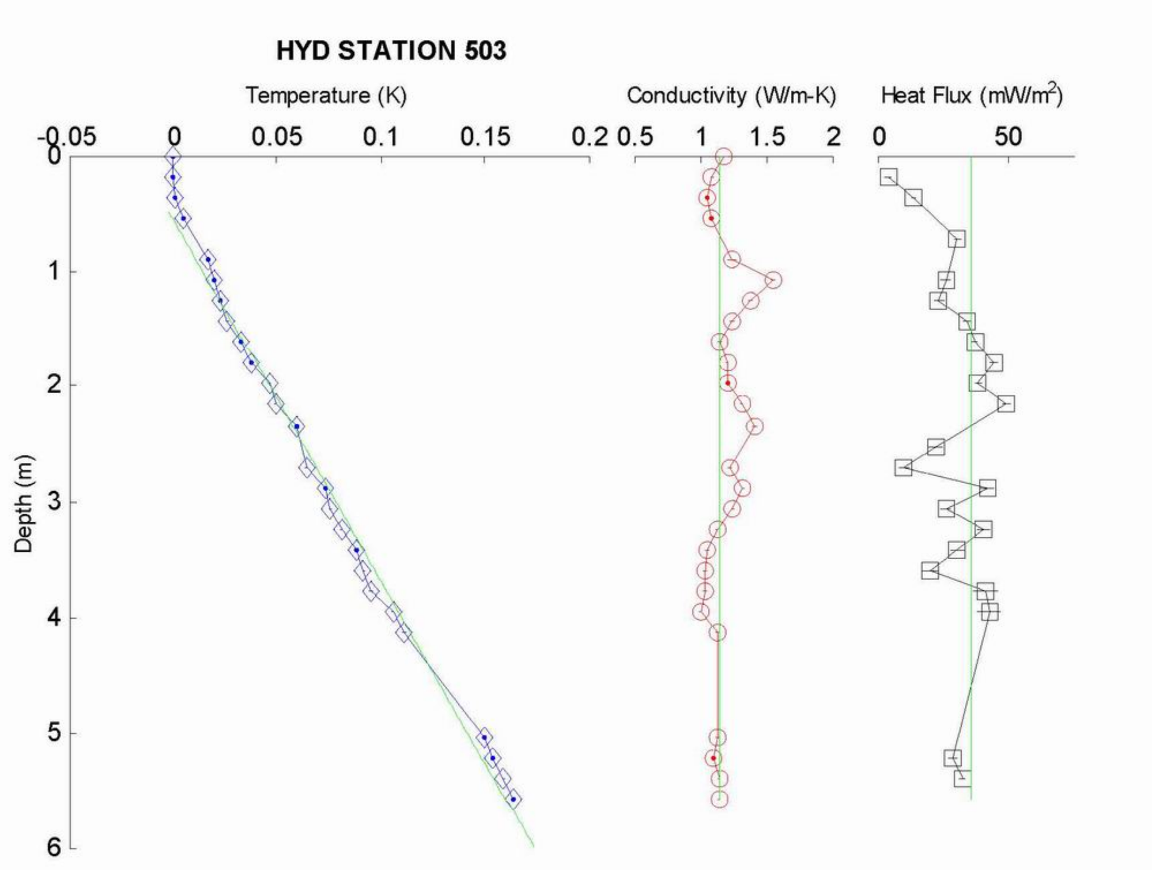


Figure 2 - Heat flow results from Station 12, Mohican Channel

Appendix IV: Free Fall Cone Penetrometer

Harold Christian, ChristianSitu and Brook Ocean Technology

BACKGROUND

Financial support for the migration of the FFCPT technology into a piston coring configuration was provided by the Petroleum Research Association of Canada (PRAC). The tests conducted during this cruise fulfilled a PRAC requirement for field verification of the technology, in preparation for commercial application.

EQUIPMENT AND METHODS

The FFCPT probe operates fully autonomously in this configuration, wherein system operational parameters such as trigger channel, trigger threshold, rearming channel, rearm threshold and data buffer characteristics are set at the time of activation on the bench.

The probe houses electronics and hydraulic systems for sensing water pressure around the tip during penetration (dynamic porewater pressure), hydrostatic pressure at the top of the instrument (open to the water column), optical backscatter at a location just behind the conical point (mudline detector), as well as acceleration over 3 ranges (+/- 2g, +/- 5g, +/- 20g).

Data is captured into two files after each trigger event. The system is activated to capture data initially into a low speed (2 Hz) buffer file. This file is later used to check calibration constants for the Tail Pressure gage. Once the system senses that the preset trigger condition has been met, it also begins logging data into a high speed (2 kHz) buffer. After the buffer is full (maximum duration of 20.925 sec) the system switches back to low speed and checks to see if it should rearm itself for another high speed data capture. Once the rearm condition is met, it will go into a standby mode, awaiting another trigger event.

Triggering can be done off any of the channels, at any signal level. Similarly, rearming can be done from any channel, at any signal level. Ideally the system should be set so that it always remains armed for data capture following any trigger events.

The data interpretation is done within custom FFCPT View software. Signal conditioning is done at this time. Each trigger event creates a set of datafiles, stored in Flash memory within the FFCPT probe. Upon recovery, the datafiles are offloaded using Windows HyperTerminal software to the host computer for processing, interpretation and hardcopy output.

Two methods of deployment were used. For the first two stations (001 and 005) the system was lowered into the seabed on the winch, at maximum payout speed. However the data indicated that the dynamic strength profile of the sediment was not high enough to substantially decelerate the corer, especially near the mudline. The penetration ended when the corehead impacted the mudline, indicating that more core barrels should have been mounted. The last two tests (stations 013 and 015) were carried out by tripping the corer from a free fall height of between 2.4 and 4.0 m, using the pilot gravity corer as a trip weight. The resulting test data were of much higher quality and can be put through the full FFCPT analysis.

A settling period of 45 seconds was allowed after impact, to ensure that the datafiles had been written to the Flash card and the probe was rearmed. Two pullout events were recorded (stations 005 and 013), giving useful data on the sediment suction behaviour. Capturing pullout events is not an objective of the test however.

DATA INTERPRETATION

After the datafiles were transferred to the host computer, they were processed and displayed within FFCPT View software (Version 3.1). This custom interface was written for analyzing FFCPT data collected with previous FFCPT models and is of limited usefulness in reviewing and displaying data collected with the piston coring FFCPT equipment due to system configuration variances. However, flat ascii files were created after signal conditioning was completed, then the geotechnical analysis and sediment behaviour interpretation was completed using spreadsheet methods.

The interpretation of FFCPT data involves determining the descent velocity immediately prior to impact, then selecting the portion of the dataset containing the FFCPT penetration into the sediment, thereafter one of the acceleration channels is chosen and for forward integration against time, which yields the time-velocity curve (after impact). The integration process typically results in a non-zero residual velocity value, which is then used to adjust the impact velocity so that the at-rest velocity (integration residual) is reduced to zero. The velocity-time curve is then itself integrated, yielding the distance versus time curve.

The depth at impact, as determined from the ship's echosounder, defines the zero baseline for the Tail Pressure channel. The tip differential pressure is already compensated for hydrostatic pressure since its back side is open to the water column (inside the core barrel), so it is a direct high resolution measurement of the excess dynamic porewater pressure response to FFCPT penetration. Typically in very soft to soft clay, the dynamic porewater pressure response is in excess of hydrostatic, due to the low permeability of sediment surrounding the probe.

The undrained shear strength is calculated from the dynamic penetration resistance, which is obtained from Newton's Law (F=mA). A second, fully independent estimate of undrained shear strength is calculated from the dynamic porewater pressure. Both of these strength calculations utilize published empirical relationships developed from numerous analyses of static cone penetration test data.

One long term objective is to develop greater understanding of the relationship between the CPT cone and pore pressure factors used in evaluating undrained shear strength, as it applies to tests conducted at high rates of penetration, as is the case with the FFCPT. To date, there seems to be very close agreement between the various cone penetrometers, especially with respect to the porewater pressure prediction of undrained shear strength.

It is also possible to calculate a continuous profile of sediment type, by plotting FFCPT analysis parameters (excess pore pressure ratio and normalized dynamic penetration resistance) on a CPT classification chart, commonly known as a Bq – Qn chart. Data from each test are plotted and each data point is assigned a numeric code, according to which region, or Sediment Behaviour Type, it falls into. This chart has been developed based on thousands of CPT soundings and sampled boreholes for which the soil classification was available.

More experience is needed with FFCPT data before it can be concluded that the chart is also valid at high penetration rates. To date, there appears to be close agreement between FFCPT SBT predictions and actual sediment type based on grain size testing.

FIELD RESULTS

The results of the FFCPT testing are summarized in Table A (Appendix A). The system operated well and had no electronic or mechanical problems. It was concluded that the best trigger method was to use the tip differential pore pressure channel, set to a trigger threshold of +5 m in head. Rearming was best done using the Tail Pressure (water depth) channel, set to a value much greater than the maximum water depth, which ensured that the system rearmed itself after all trigger events. The maximum operating range of the equipment is 3,400 m however the maximum water depth encountered was only 1,581 m.

In general the sites tested comprised soft normally consolidated silty clays to clays, in some cases there was a stiff layer present at the seafloor, extending to several metres in thickness. The differential porewater pressure measurements were used to evaluate the undrained shear strength profile. The dynamic penetration resistance profile was calculated from the vertical acceleration data and was also used to predict the undrained strength profile. Sediment Behaviour Type (SBT) was predicted from CPT classification charts, based on the combined dynamic penetration resistance and dynamic pore pressure response.

A detailed site-by-site log of FFCPT setup and performance is given below along with the graphical output from the data interpretation.

HUDSON 2004030 FFCPT SUMMARY LOG

STATION 001 FFCPT

Datafile: HUD0100.b01 / Day: 193 / Time: 1006 GMT / Site: St. Pierre Slope

The FFCPT was configured to trigger on the Mudline Detector at a level of 1,600 mV and rearm on the Mudline Detector at a level of 1,300 mV. The equipment was winched into the bottom at a speed of 97 m/s and penetrated to the corehead (10.4 m). There was no damage.

The datalogger recorded one datafile (HUD0100.b01), which was created with the system still at the rail. The OBS signal levels in the datafile never fell below 1,343 mV, so the probe did not rearm after being triggered at the rail. In future the rearm level should be set as high as possible, so that it will always rearm.

Testing on the bench showed that the response of the Mudline sensor is dependent on the reflectivity of the material near the OBS port. White paper and orange plastic were found to induce triggering (ie. signals exceeded the trigger threshold) however dark green rubber did not. The signal response of the detector has a peak in a certain wavelength of light, as indicated by previous datasets sometimes showing signals falling off to the baseline with penetration into darker-coloured sediment.

It was concluded that the Mudline Detector could not be relied upon to trigger the probe, as the seafloor sediment colour is often quite dark. Bench testing in the shop should be done to determine the range of sensitivity of the mudline detector in various colours of sediment.

The system penetrated soft clay and came to rest with the corehead at the mudline, so the penetration process was incomplete.

STATION 005 FFCPT

Datafile: HUD0504.b01 / Day: 196 / Time: 1935 GMT / Site: Mohican Channel

The FFCPT was configured to trigger on the Tip Differential Pressure at a level of 3 m and rearm on the Tail Pressure at a level of 2,000 m. The equipment was winched into the bottom at a speed of 97 m/s and penetrated to the corehead (10.4 m). There was no damage.

The datalogger recorded 24 datafiles, some of which were created by false trigger events during lowering and raising through the water column. Several data records were obtained recording the impact event (HUD0504.b01), the system at rest in the seabed (HUD0505.b01 and HUD0506.b01) and the pullout event (HUD0507.b01). The rearming worked well and ensured the probe recovered into a ready state after each false trigger event. In future, the trigger level could be increased to 5 m to prevent false triggering. The data buffer split of 50 / 50 % was also too biased toward the pre-trigger data, in future deployments using the winch-in method a 20 / 80 split should be used, especially if more core barrels are mounted.

The pore pressure response was very good however there was some surging due to vessel heave that was transmitted down the wire. This surging was also observed on the accelerometer signals, which did not vary much from 1 g until the corehead impacted the mudline. The weight of the system was carried on the wire up until that time, indicating that longer penetration was possible had more core barrels been in place. The system penetrated soft clay and came to rest due to friction buildup on the core barrels.

The accelerometer signal will likely not be very useful in determining the depth of penetration, when the system is lowered on the winch in this manner. It may be advantageous to free fall the system with a longer core barrel, to generate higher decelerations for integration. However the tip pore pressure data are acceptable.

STATION 013 FFCPT

Datafile: HUD01332.b01 / Day: 198 / Time: 1907 GMT / Site: Torbrook Block

The FFCPT was configured to trigger on the Tip Differential Pressure at a level of 3 m and rearm on the Tail Pressure at a level of 3,000 m. The equipment was rigged like a piston corer using the upper half of the split piston. A free fall distance of 2.4 m was used. The safety wire was removed. No water hose was used inside the core barrel. The system penetrated to 13.2 m. There was no damage.

The datalogger recorded 41 datafiles, most of which were created by false trigger events during lowering and raising through the water column. Several data records were obtained recording the impact event (HUD01332.b01), the system at rest in the seabed (HUD01333.b01, HUD01334.b01) and the pullout event (HUD01335.b01, HUD01336.b01, HUD01337.b01). The system was triggered at 5 m on the differential gage and rearmed at 3000 m on Tail Pressure. A 50 / 50 % pre-trigger / post-trigger data buffer split exactly the impact event.

The pore pressure response was very good with no vessel heave effect during penetration into the seabed. There was excessive hydrodynamic drag created by the bullnose shape of the corehead, which prevented it from reaching terminal velocity before impact. Accelerations were slowly increasing toward 0.5g during the free fall period. The entire penetration through the sediment lasted about 3 sec. The system came to rest in soft clay largely due to friction buildup on the core barrels. A stiff layer several metres in thickness was noted at the mudline.

STATION 015 FFCPT

Datafile: HUD01503.b01 / Day: 199 / Time: 1955 GMT / Site: Torbrook Block

The FFCPT was configured to trigger on the Tip Differential Pressure at a level of 3 m and rearm on the Tail Pressure at a level of 3,000 m. The equipment was rigged like a piston corer using the upper half of the split piston. A free fall distance of 2.4 m was used. The safety wire was not used. No water hose was used inside the core barrel. The system penetrated to 12.0 m. There was no damage.

The datalogger recorded 14 datafiles, some of which were created by false trigger events during lowering and raising through the water column. Several data records were obtained recording the impact event (HUD01503.b01) and while the system was at rest in the seabed (HUD01504.b01) but none during pullout. The system was triggered at 5 m on the differential gage and rearmed at 3000 m on Tail Pressure. A 50 / 50 % pre-trigger / post-trigger data buffer split exactly the impact event.

The pore pressure response was very good with no vessel heave effect during penetration into the seabed. Excessive hydrodynamic drag created by the bullnose shape of the corehead again prevented the system from reaching terminal velocity before impact. Accelerations were slowly increasing toward 0.5g during the free fall period. The entire penetration through the sediment lasted about 3 sec. The system came to rest in soft clay largely due to friction buildup on the core barrels. A stiff layer several metres in thickness was noted at the mudline.

Table A. Summary of Free Fall Cone Penetrometer Test results.

STA No.	SITE ID	LATITUDE	LONGITUDE	WATER DEPTH (m)	DAY	TIME	METHOD	APPARENT PEN. (m)	ACTUAL PEN. (m)	IMPACT VELOCITY (m/s)	DATAFILE NAME	INTERPRETED SEDIMENT TYPE
001	St. Pierre Slope	44 41.8696 N	54 27.2130 W	1013	193	1006	Winched	10.4	10.4	1.6	HUD00100	Very soft to soft silty clay, olive green
005	Mohican Channel	42 50.0880 N	62 03.1020 W	894	196	2009	Winched	10.4	10.4	1.6	HUD00504	Very soft to soft silty clay, olive green
013	Torbrook Block	42 33.0707 N	62 28.6169 W	1581	198	1907	Tripped	13.2	13.8	7.1	HUD01334	Firm over very soft silty clay, olive green
015	Torbrook Block	42 44.2752 N	62 05.0831 W	1200	199	1955	Tripped	12.0	11.6	3.6	HUD01503	Firm over very soft silty clay, olive green

Appendix V: Geochemistry/Hydrocarbon Program

R.E. Cranston and K.W.G. LeBlanc

Approximately 20 ml of sediment were collected from each end of each core section (1 to 1.5 m long) as soon as the core sections were available. The sediment sub-samples were put into 7 dram polystyrene vials. Each vial contained a coarse filter paper placed over 4 one millimetre holes drilled in the base of the vial. The sample vials were inserted into a 50 ml plastic centrifuge tube and centrifuged for 20 minutes in an IEC HN centrifuge (10 cm head radius) at 2000 rpm. Approximately 1 ml of pore water was collected in the centrifuge tube for each sample. Pore water samples were stored in 7 ml plastic vials at 4 ºC. The sediment samples were frozen and returned to the land laboratory for organic carbon analyses.

The pore water samples were immediately analyzed for ammonium, sulfate and salinity (Cranston, 1997; Deep Sea Research, Part II, vol. 44, no. 8, 1705-1723). Ammonium analyses were done on 0.1 ml of pore water using a colourimetric method calibrated with ammonium chloride standards. The precision and accuracy of the method based on replicate analyses is estimated to be ± 10% of the concentration. Sulfate was determined on 0.05 ml of pore water by precipitating sulfate with barium and measuring the turbidity of the solution. The method is calibrated with sea water and magnesium sulfate solutions. The precision and accuracy of the method is estimated to be ± 2 mM. Salinity was measured on 0.1 ml of pore water using a conductivity meter. The method was calibrated using sea water standards. Precision and accuracy of the method is estimated to be ± 0.3$^{o}/_{oo}$.

Seven cores totalling 67 m in length provided 124 pore water samples. The average concentration gradients (concentration change down core) are presented in Table 1.

Table 1

CORE	Ammonium Gradient (mM/m)	Sulfate Gradient (mM/m)	Salinity Gradient ($^{o}/_{oo}$ / m)
3	0.38	-3.7	-0.36
6	0.36	-4.8	-0.39
7	0.25	-5.5	-0.41
8	0.16	-2.8	-0.14
9	0.37	-8.4	-0.73
14	0.27	-3.2	-0.23
16	0.31	-2.7	-0.4

The sulfate gradient becomes more negative and the ammonium gradient becomes more positive as a sediment environment becomes more reducing. This is due to the process of organic carbon being oxidized in the sediment column. As carbon is oxidized, it consumes oxidants such as sulfate (therefore sulfate decreases down core) and releases nitrogen as ammonium (thus ammonium increases down core). At some depth down core, all of the sulfate in the pore water is consumed. For the cores in Table 1, the sulfate concentration reached 0 mM at depths of 3 to 9 m down core. The organic carbon is no longer oxidized at these depths, as there is no oxidizing agent available (all of the oxygen, nitrate and sulfate have been consumed). However, the organic matter continues to be consumed by fermentation processes, which produce methane.

Based on previous work in this area, when sulfate gradients drop below -5 mM/m, gas-charged sediments are found in the lower sections of the core. Cores 7 and 9 were gas-charged. The sulfate gradients were -5.5 and -8.4 mM/m respectively. Core 6 had a sulfate gradient of -4.8 mM/m, suggesting that gas could be present in significant quantities.

The results in Table 1 show a range of salinity gradients that correlate with the loss of sulfate from the pore water ($r^2 = 0.78$, n=6). The salinity decreases 2 to 3 $^{o}/_{oo}$ down core, due to the consumption of sulfate anions. The sulfate is precipitated as sulfides, thus reducing the concentration of dissolved ions in the pore water.

One purpose for doing the salinity measurements was to look for abnormal decreases in salinity (> 3 $^{o}/_{oo}$). Such large decreases could be due to the presence of gas hydrates, a frozen mixture of methane (and sometimes other gases) and fresh water. When sediment containing gas hydrate is brought to the sea surface, the decrease in pressure allows the frozen gas and fresh water mixture to thaw. The fresh water dilutes the pore water and decreases the salinity. The results for these cores do not indicate the presence of hydrates in the samples.

Along with the nutrient analyses of pore waters described above, sub-samples were taken for future hydrocarbon analyses. The purpose of these gas analyses is twofold; 1) to determine if the hydrocarbons are thermogenic, and 2) to ascertain the potential for gas hydrates at depth.

To realize the above hypotheses, 19 sub-samples were taken from 6 of the 7 cores for gas analyses. The 7th core was a “fixed reference piston core” from which only pore water samples were taken. A 6cm section was cut from the bottom of selected core barrels. This sample was then sliced into a 6cm x 6cm x 6cm cube, (216 cc’s) and placed into a 470 mL can. This procedure is performed with a custom made slicing tool. Next, 170 mL of a 0.5% sodium azide solution was added to the sample. This weak poison prevents the production of unwanted hydrocarbon gas due to bacterial activity. The can is flushed with nitrogen to keep the sample under inert conditions and sealed with a lid. The sample is then frozen until analyses can be performed.