REPORT ON CRUISE 2003-015

CCGS *Matthew* surveys in the Bras d'Or Lakes, Nova Scotia, 10-24 May 2003

John Shaw, D. Russell Parrott, Eric Patton, Anthony Atkinson, Darrell Beaver, Angus Robertson and Paul Girouard

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GENERAL INFORMATION

Vessel CGGS *Matthew*
Dates 10 –24 May 2003
Areas of operation Bras d' Or lakes, Nova Scotia

GSC personnel	John Shaw	*Chief scientist*
	Russell Parrott	*Co-chief scientist*
	Robert Murphy	*Sampling*
	Tony Atkinson	*Electronics*
	Darrell Beaver	*Multibeam collection and processing*
	Angus Robertson	*Navigation and sampling*
	Paul Girouard	*Navigation and network*
	Eric Patton	*GIS specialist*

CRUISE OBJECTIVES

This cruise was a deliverable of Activity 1 in Geological Survey of Canada Project X29: Marine Environmental Quality. Activity 1 is concerned with the production of maps of submarine topography, backscatter and surficial geology. An understanding of the sea-level history of the lakes is critical to the production of the surficial geology map. The specific objectives of the cruise were:

- Groundtruth multibeam bathymetry data in the Bras d'Or Lakes, Nova Scotia, using acoustic systems, bottom sampling equipment, and underwater cameras.
- Collect new multibeam bathymetry data in unmapped areas.
- Collect cores that will be used to understand the sea-level history of the lakes.

CCGS *MATTHEW*

CCGS *Matthew* is an inshore hydrographic survey vessel with the following particulars:

Length overall	51.25 m
Breadth	10.50 m
Displacement (light)	745 tonnes
Displacement (loaded)	950 tonnes
Speed	12 knots
Range	4000 nautical miles
Crew	12 persons
Scientific staff	8 persons

For the duration of the cruise *Matthew* was a base for the hydrographic launch *Plover*. The launch was brought to the field onboard *Matthew*, and once deployed remained in the water for the duration of the cruise. *Plover* conducted EM-3000 multibeam surveys, and was crewed by a DFO coxswain and the GSCA multibeam technologist (Darryl Beaver).

CRUISE NARRATIVE

Note: Times are Atlantic Daylight Saving Time (i.e., Nova Scotia time), which is Z-3 hours.

Day 130 Saturday 10th May

CCGS *Matthew* remains at Dartmouth due to gale force winds. GSCA staff mobilize the ship at the Bedford Institute of Oceanography wharf.

Day 131 Sunday 11th May

08:30 CCGS *Matthew* departs Dartmouth. In the afternoon Beaver, Atkinson and Murphy drive to Baddeck, and check the tide gauge.

Day 132 Monday 12th May

11:00 *Matthew* arrives at Baddeck and ties up at the public wharf. 08:45 Shaw, Parrott, Robertson, Girouard and Patton leave the Bedford Institute of Oceanography in a government van, arriving at Baddeck at 13:35. Beaver, Atkinson and Murphy check the tide gauge. GSCA staff mobilize the *Matthew,* which remains at the wharf. The day is mostly overcast and cool, with light winds. Light rain begins around dusk.

Day 133 Tuesday 13th May

There is light rain at dawn, and a light to moderate easterly wind. The EM-3000 launch *Plover* is deployed at 08:00. The water in Baddeck has been contaminated, and a boil water order is in effect. Because the *Matthew* needs water replenishment every two days, efforts are made to secure a supply of clean and certified drinking water. Possible sources are a tanker delivery or water at the Gypsum Wharf in St. Patricks Channel. If water cannot be secured at Baddeck, the alternative is a 24-hour steam outside the lakes every two days of work. The ship remains at the wharf. The rain eases in the afternoon, the wind drops, then veers to southwest 10 knots. The *Plover* returns to the vessel at 17:00. In the evening a truck brings a tanker load of water to the wharf. Water is taken aboard and the tanker is parked on the wharf. Multibeam data are processed on board.

Day 134 Wednesday 14th May

In the morning additional water is taken on board. The launch *Plover* leaves the Baddeck wharf at about 08:00. *Matthew* departs the wharf at 08:20. Gear is deployed at 08:30 and line running begins soon afterwards. Line speed is about 4 knots. The gear consists of the Seistec system and the Simrad sidescan sonar system. The weather is overcast with a light southwesterly breeze. The lake has a very slight chop. Line running ends at 16:50 and gear recovery commences. Lines 1-13 are completed. Gear is on board at 17:02 and *Matthew* proceeds towards an anchorage in St. Andrews Channel, southeast of Kempt Head. The anchor was dropped at 17:30 and the launch was tied alongside for the night.

Day 135 Thursday 15th May

The morning dawns overcast with stratocumulus, very cold, with a light southwesterly breeze and a very slight chop on the water. 07:55 anchor being weighed. 08:00 *Matthew* is under way. Sampling begins at 08:30. We commence with a grab sample, and then deploy the camera at the same station. We then move to the next station, deploy the camera, and then collect a grab sample. We maintain this pattern throughout the day. Murphy and Patton operate the van Veen grab sampler, bag the samples, and operate the camera. Atkinson takes digital photographs of the samples immediately after opening the van Veen. Parrot is stationed in the laboratory where he notes sample times, water depths, coordinates etc., and fills out the log sheets. Shaw takes notes and enters data into the expedition database (ED). Sampling continues until about 16:25. We collected 11 grab samples and completed eleven photograph stations (with five shots at each). The last station is 2003-015-022, a camera station. The day remains overcast and a stiff, cold northerly breeze sets up in the late afternoon. The vessel heads north towards Baddeck at 16:30, and ties up at the wharf at 17:25. In the evening Murphy and Atkinson take photographic film to North Sydney for development. The prints show that the camera system had worked well.

Day 136 Friday 16th May

The morning dawns very cold, with broken low cloud and a light breeze from the north giving a slight chop. The launch *Plover* departs at 07:45 to continue surveys in St. Patricks Channel. After taking on more water from the tanker, *Matthew* departs at 08:05. At 09:07 *Matthew* passes under the bridge at Iona Narrows. We start deploying gear in Great Bras d'Or at 09:33. It is sunny, with scattered to broken cumulus and a light breeze. The lines begin with L. 136-1. The weather remains sunny, with very light winds. We finish part way along L. 136-18 at about 17:05. We start recovery of gear at 17:07 and by 17:15 it is all aboard. *Matthew* proceeds to anchorage 1.3 nm southwest of the narrows of Barra Strait. The launch Plover is moored alongside shortly after, having traveled south from the survey area in St. Patricks Channel.

Day 137 Saturday 17th May

The day dawns CAVU, with no wind and calm water. The launch *Plover* departs *Matthew* at 07:30. At 08:55 we commence grab sample –023, a precursor to a core at the same location. Sampling continues, with a break for lunch after camera station 032. A roll of 36 exposures is removed from the camera after this station. Sampling recommences at 12:20 with camera station 033. We complete sampling at 14:50. The tally for the day was 18 samples comprising 2 gravity cores, 7 cameras and 9 grab samples. *Matthew* proceeds north towards the Barra Strait, and deploys the inflatable boat at 15:05. Parrot is dropped off at the Iona wharf where he takes the station wagon and drives it back to Baddeck. At 15:15 crew of the inflatable report that the tide is high, and conditions are suitable for *Matthew* to pass under the bridge. The southwesterly breeze has picked up by this time. The inflatable is taken aboard at 15:30. *Matthew* passes under Barra bridge (with a moderate to stiff crosswind) at 15:40, proceeds north, and is tied up at 17:20.

Day 138 Sunday 18th May

The early morning is cool, with light winds and a clear sky. The launch departs at 07:30 and *Matthew* at 08:00. Peter Stewart of ApplAnix Ltd. arrives aboard to work on the motion sensing equipment for the new EM-2002 multibeam systems that is nearing operational status on board

Matthew. We are approaching the head of St. Andrews Channel at 09:15 when the navigation feed fails. *Matthew* circles while Girouard replaces the ship's Baytek Multiplexer with a GSCA spare, and navigation is functioning correctly by 09:40, at which time we begin deploying the sidescan sonar and Seistec systems. Lines are run from the head of St. Andrews Channel around southwest around Kempt Head and then northeast along Great Bras d' Or. We start with L. 138-1 and end just after the start of L. 138.19. Line running finishes at 16:30 and gear is aboard by 16:37. *Matthew* proceeds to the planned anchorage. The wind picks up early in the morning, just after the commencement of line running, and blows down the channels from the northeast at 20 to 25 knots. *Matthew* anchors in relatively calm water off the Bell House at 17:10. Skies are clear and sunny all day.

Day 139 Monday 19th May

The day dawns with a cloudless sky and light winds. We breakfast at 06:00 rather than 07:00. The multibeam launch *Plover* departs at 06:30 and *Matthew* weighs anchor almost immediately and proceeds east towards the entrance to the Bras d' Or Lakes. At 08:05, just after we pass under the Seal Island Bridge, we are ahead of schedule - we need to pass through the narrows at slack water – so we begin to deploy Seistec. The line is run (at slack current) until we pass the outer channel buoys at 09:18 and recover the gear. *Matthew* turns and proceeds into the channel again. A grab sample and a camera sample (041 and 042) are taken on the sandy bottom just north of the Seal Island Bridge. The vessel proceeds southwest along the channel. Samples 043 and 044 are collected in the channel at 11:45, after which *Matthew* proceeds into the main lake, towards the next sample site. We complete a camera, grab and digital video station (045, 046, and 047) at a location where pits occur on the sea floor. Then we move south and do a digital video station (048) at the same location as samples 19 and 20. We move north to the site of a sinkhole filled with mud. However, the camera does not function. We abandon the attempt and move to St. Patricks Channel for samples 49-52. We finish at 16:40 and are tied up at Baddeck at 17:05. The day is cloudless and warm, with no wind. At times the lake is completely calm, although Beaver (in the multibeam launch) reports 20-knot winds in St. Patricks Channel near Nyanza. *Navicula* docks at Baddeck before midday and Fred Jodrey arrives in the early afternoon.

Day 140 Tuesday 20th May

The dawn brings a cool cloudless morning, with a flat calm at Baddeck. *Plover* departs at 07:30. Beaver, Murphy and Atkinson help Jodrey complete preparations for vibracoring on board *Navicula*. Girouard assists Captain Bray with some navigation problems. Parrott leaves in the station wagon at 07:55. Girouard remains on board *Navicula* to assist with the navigation problems. *Matthew* departs the wharf at 08:10, leaving behind the FRC (Fast Rescue Craft), the cook, a seaman, and Paul Girouard, the latter still attending to navigation problems on *Navicula*. Sampling begins at 09:30 at station 053, at the head of St. Andrews Channel. The FRC returns to *Matthew* at 10:45 and Girouard, the cook and a seaman come aboard with supplies. Sampling continues. At the deep site (059) we decide not to take photographs in case the camera starts leaking. Sampling finishes at 16:20 at which time the vessel drops anchor on the shoal south of Kempt Head in St. Andrews Channel. *Plover* returns and is moored alongside about 17:15. The tally for samples during the day is 8 camera stations and 9 grab samples. The day remains sunny, with some high cirrus cloud, and a light breeze from the northeast.

Day 141 Wednesday 21st May

The multibeam launch departs at 07:30 and *Matthew* weighs anchor at 07:45. Sidescan sonar is deployed at 08:05 for several lines in front of the Bell Mansion at Red Head. Then Seistec is deployed (09:13) and the vessel heads west into St. Patricks Channel. The line ends west of Nyanza at 11:42 and the vessel anchors while we extract sampling coordinates and have lunch. The anchor is weighed at 12:35. We start operations at three sites, collecting a core, a grab sample and a photograph at each. At one site we collected two cores (076, 077) after noticing peat and wood at the base of core 076. Sampling finishes at 16:15 after grab sample 079. The vessel returns to Baddeck. The day was sunny and warm, with a stiff southwesterly breeze after midday. Staff members Beaver, Murphy, Atkinson and Jodrey leave in a rental car just before supper. Shaw, Robertson, Girouard and Patton leave about 18:30 in a rental van and drive to Dartmouth.

DATA ACQUISITION AND PROCESSING

The following geophysical and sampling equipment was used during survey *Matthew* 2002066:

- Simrad MS992 sidescan sonar system in a neutrally-buoyant tow configuration
- IKB Seistec high resolution sub-bottom profiler
- AGCDIG 4 channel digital geophysical data acquisition system
- Regulus survey navigation package with input from differential GPS
- Simrad EM3000 multibeam bathymetry system
- Linux workstations running GRASS with GSCA extensions
- Caris HIPS multibeam bathymetry data cleaning software running on Windows NT
- GSCA ice hole camera
- van Veen grab sampler
- Small gravity corer

Simrad sidescan sonar system

High-resolution, acoustic images of the seabed were produced with a Simrad MS992 dual frequency (120 and 330 kHz) sidescan sonar system mounted in a neutrally buoyant tow body and deployed 13 metres behind a dead weight depressor (a 120 kg. iron blister weight on a swivel) as shown in Figure 1. The tow fish was deployed about 50 metres behind the vessel. This configuration was chosen to reduce artifacts seen on the sidescan sonar records due to vessel-induced heave, and thereby improve resolution. The sidescan sonar system was capable of resolving objects down to a size of about 0.15 m. An ORE TrackPoint II acoustic position system was used to position the tow fish. Within the lab (Fig. 10) a hardcopy graphic record of the 330 kHz portion of the sidescan sonar data was produced on an Alden 9315CTP thermal recorder set at a fixed speed of 1.7 knots. This produced records with a 2 to 1 aspect ratio at the slowest survey speeds of 3.5 knots. A hardcopy graphic record of the 120 kHz portion of the sidescan sonar data was produced on an EPC Labs GSP1086-2 thermal recorder. Lines were run at 100-metre range, providing a swath of 200 metres.

Sidescan sonar data from survey *Matthew* 2003015 (both 120 and 330 kHz) were collected digitally using an AGCDIG digitizer with version 2.3 software. A sample interval of 80 microseconds was used. 3400 samples per ping were collected at 200-metre range and 1700 samples at the nominal 100-metre range setting. Digital gain settings for the sidescan sonar system and digitizers were logged on field sheets. During the survey, data were imported into a Linux workstation at a resolution of 0.35 metres (across track). The seafloor was detected and slant range and beam corrections were applied to the raw data to remove geometric distortions present in sidescan sonar data. The data were integrated with navigation and imported into the GRASS GIS system at 0.5 metre resolution for data near the disposal site and 1.0 metre resolution for regional data. The sidescan sonar data from adjacent survey lines were integrated to produce a sidescan sonar mosaic. A variable layback, based on tow fish positions from the TrackPoint II positioning system, was applied to the sidescan sonar data.

Figure 1: *Neutrally buoyant sidescan sonar tow fish (shown on the left) and deadweight depressor used by GSCA. The tow fish was towed about 13 metres behind the deadweight depressor. The TrackPoint II beacon visible on the front of the tow fish was not used on the cruise.*

IKB Technologies Seistec Sub-bottom profiler

The Seistec boomer/line-in-cone array was towed from the port side of the stern (Fig. 2). The system discharged at 105 Joules every 3/8 of a second. Records were printed on an EPC 9800 graphic recorder and signals were digitized on an AGC DIG. EPC records were displayed at 1/16 of a second and 100 lines per inch. The cone signal (internal) was displayed on channel 1 and the streamer signal (external) was displayed on channel 2 of the EPC. Internal and external signals were recorded on channels 1 and 2 of the DIGs respectively. Water column delays were applied to the EPC and DIGS, as required, using the system's timing computer. EPC records were annotated for day/time, SOL/EOL, and navigation fixes using the Seawatch software annotation system.

Parameter	Value
Channel 1	Internal
Channel 2	External
A/D Gain	2
Sampling interval	32µsec
Range	85 metres
Number of Samples	2048

Table 1: *Seistec parameters.*

Figure 2: *Seistec sub-bottom profiler showing the catamaran used to tow the boomer and line-and-cone array at the surface. Power and signals are contained in the tow cable bundle on the front of the catamaran.*

AGC DIG digital data acquisition

The sidescan sonar and sub-bottom profiler data were digitized and logged on an AGCDIG digital data recorder, developed by the Geological Survey of Canada (Atlantic), running version 2.3 software. The clock in the AGCDIG was synchronized to the GPS time signal. No gains or corrections were applied by the digitizer to the raw logged data. Channel configurations for the logged data were:

Sidescan sonar - 80 microseconds sample interval

Channel	Use
0	120 kHz port
1	120 kHz starboard
2	330 kHz port

3	330 kHz starboard

Sub-bottom profiler – IKB Seistec - 38 microseconds sample interval

Channel	Use
0	STB Seistec line cone receiver
1	STB GF10/15P streamer hydrophone

Table 2: *Sidescan sonar configuration.*

Navigation

Figure 3 shows the navigation setup. Positioning aboard the vessel was done with navigation software *Regulus* build 24659. The required computers were set up on the vessel prior to the mission departure from BIO. The primary computer was placed in the navigation room on the bridge deck and received differential GPS signals from the bridge receiver (*Magnavox*). The GPS feed consisted of position, coarse over ground and speed over ground. The navigation data along with the heading from the *Anschutz Kiel* gyro and depth below keel from the *ELAC LAZ 4400* echo sounder were combined through a *Baytec* multiplexer which fed the combined data to a line splitter for distribution over the ship's RS-232 data distribution network. The video feed from this computer was split by a *VideoView* signal splitter in the navigation room and fed to the bridge. The bridge crew was able to monitor the navigation for geophysical line running from the central telegraph on the bridge and from the starboard wing telegraph for sampling stations. The two bridge monitors could not be viewed at the same time due to the signal cable configuration.

A second computer was placed in the after lab on the main deck. Again, this computer was connected to a line splitter that received positioning data from the line splitter in the navigation room. Data from this data splitter was also forwarded to the *Seistec* AGCDIGS computer, the *Simrad MS992* sidescan AGCDIGS computer, the sidescan, the record annotator and the digital underwater camera. This Regulus computer allowed a visual positioning display of the vessel over charts and multibeam. A third computer was placed in the navigation room. Waypoints or sampling station markers could be initially set up on this computer whilst underway with the survey without distracting the bridge crew. The navigation tasks went well for the duration of the mission except for a 20-minute period of downtime on Julian day 138 when GPS signal feed was lost on all three computers. It was determined that the multiplexer was faulty and a spare unit was then brought into service, rectifying the problem.

The *Seistec* and *Simrad MS992* data rolls and DIGS tapes were annotated following traditional GSCA procedures as listed in the GSCA Expedition Manual for Operations at Sea. The raw navigation data was cleaned and processed using standard GSCA dos programs. Navigation tasks were undertaken by Paul Girouard and Angus Robertson.

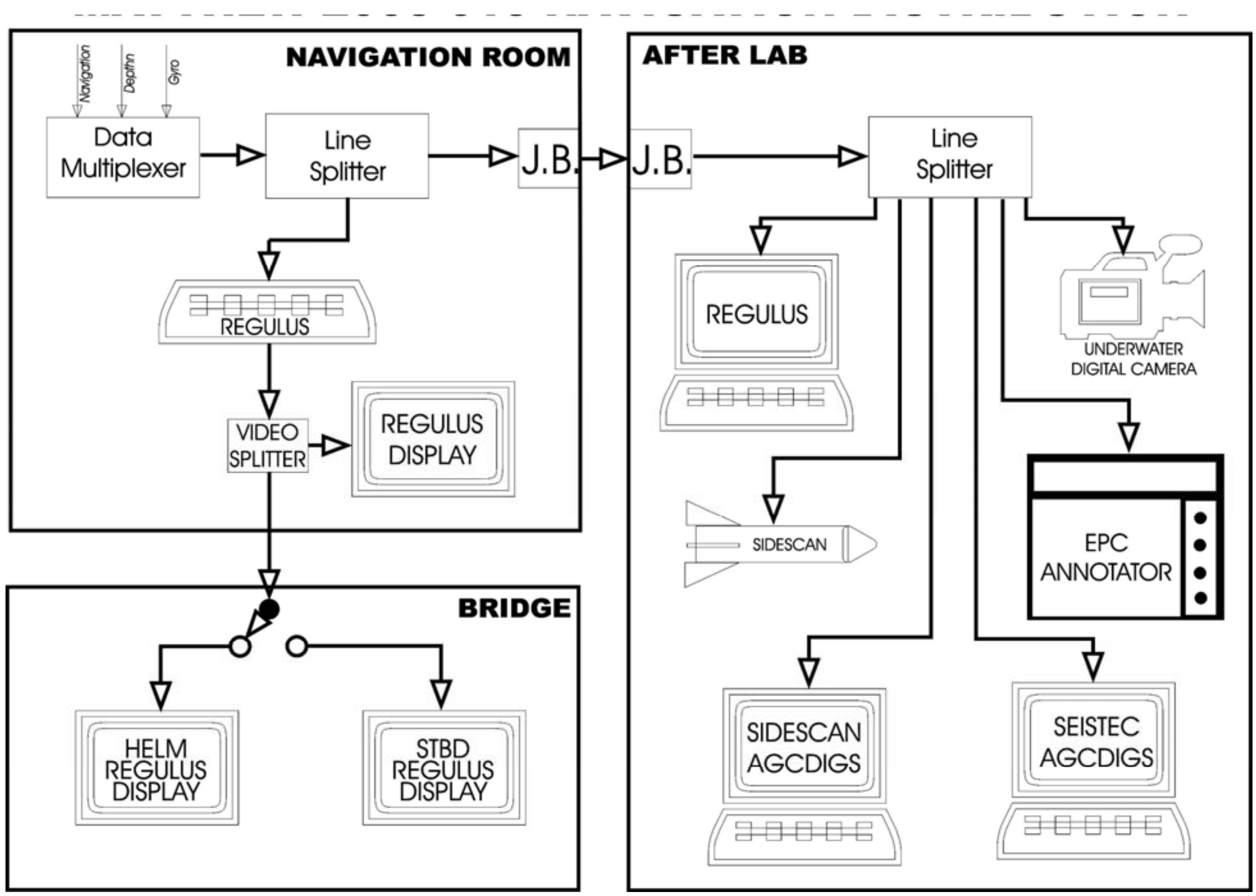

Figure 3: *Navigation setup.*

Multibeam Bathymetry

Multibeam bathymetric data were collected using a Simrad EM3000 multibeam bathymetry system mounted in the hydrographic survey launch Plover (Figure 4). The EM3000 system uses 300 kHz transducer with 127 beams with a beam width of 1.5^o x 1.5^o. The system provides a depth resolution of 1 cm with an accuracy of 5 cm RMS. Each beam insonifies an area of approximately 1.35 m^2 at 50 metres water depth. An Applied Analytics Corporation POS-MV 320 attitude sensing system with integrated differential GPS navigation system was used to position the vessel and determine the attitude. The system integrates data from an inertial measurement unit and differential GPS signals. A positional accuracy of 2-10 mm can be obtained using phase differential of the GPS carrier frequency. A heading aiding accuracy of 0.1^o - 0.5^o can be obtained from the raw GPS data. A Kalman filter is used to improve the heading estimate to 0.05^o - 0.1^o. Vessel attitude is measured using an inertial measurement unit to provide an accuracy of 0.0003^o for pitch, roll and heading.

Survey lines were run at various spacing throughout the survey area to provide 200 percent coverage of the seafloor in water depths greater than about 20 metres. During the survey, data were processed using version 5.0 of the HIPS data-cleaning program (CARIS by Universal Systems Limited, Fredericton, NB) on a Windows NT workstation to remove spurious soundings and navigation data and to correct for tidal variations. Data were also imported into a Linux based workstation and processed using the MBTools software developed by the Lamont-Doherty Institute. The processed data were imported into the GRASS GIS system where shaded-colour relief images were generated and overlaid on scanned bathymetry maps of the area. Tidal corrections were made using measured tides (see below) from the tide gauge in Baddeck, NS provided by the Canadian Hydrographic service.

Multibeam Backscatter

The strength of an echo from the seafloor is known as the acoustic backscatter intensity. Acoustic backscatter intensity values are controlled by the physical properties of the seafloor sediments such as the velocity of sound, the density and roughness of the sediment. Backscatter generally increases as the sediments on the seafloor become denser and less porous, and increase in grain size. Mapping the distribution of backscatter provides valuable information on the character and distribution of sediments within an area.

Figure 4: *Multibeam bathymetry launch Plover.*

Seafloor Photographs

Photographs were taken at camera stations with the "Ice hole" camera developed by GSCA (shown in Figure 5). Images were obtained using 200 ASA colour print film. After the first two rolls had been shot – i.e., up to and including station 18 - they were taken to North Sydney and developed in order to confirm that the camera was functioning properly. We specified that the strip of negatives should not be cut into lengths. The negatives were digitized and stored on CD-ROM.

Figure 5: *GSCA "Ice hole" camera showing the flash on the left of the frame, the pinger in the centre and the camera case on the right of the frame. The cable for the bottom contact trigger weight is hanging from the left end of the camera case.*

Seafloor Grab Samples

A 0.1 cubic metre van Veen grab sampler (Fig. 7, left) was used to collect 44 sediment samples in the survey area. A photograph was taken of each grab sample on the deck.

Tides and Currents

During the survey, tides were recorded at Grand Narrows on a Sutron tide gauge installed and maintained by the Canadian Hydrographic Service (CHS). Because of logistical requirements, the gauge, which had been running for some time, was removed by CHS on 28 May. The interesting aspect of the tidal data (Figure 6) is that the range of fluctuations caused by atmospheric conditions is almost 0.6 m, far exceeding the tidal variation (about 0.1 m). This is consistent with conditions reported by Petrie et al. (2003). Despite the small tidal range, strong tidal currents occur at Grand Narrows; the strength of these currents, combined with the narrowness of the channel and the intricacy of the approaches meant that *Matthew* only entered the Bras D'Or Lake once during the surveys. Strong currents occur at the entrance to the Bras d'Or Lakes, which meant that the vessel waited until slack water before transiting the narrow dredged channel. A sub-bottom profiler line was surveyed through the channel at slack water on Day 139.

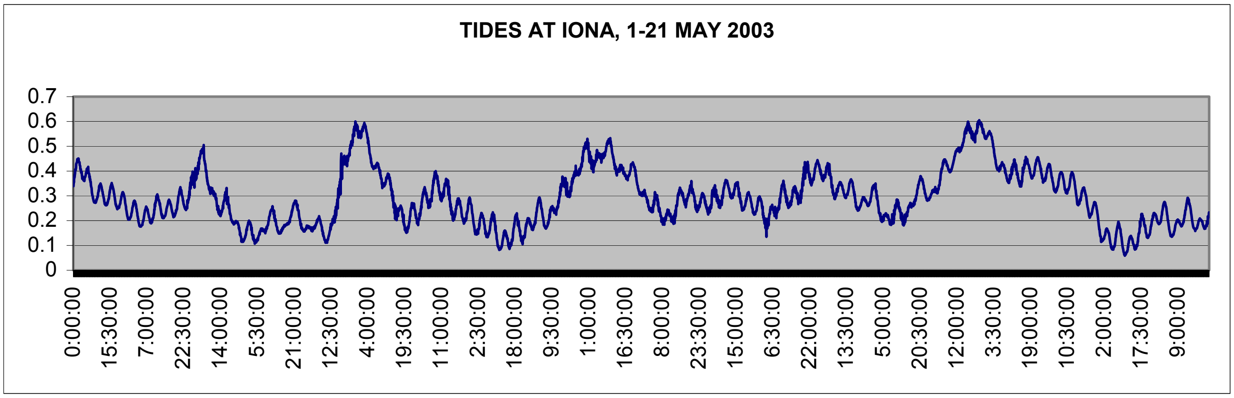

Figure 6: *Tides at Grand Narrows, 1-21 May 2003*

Coring equipment

The corer was a Lehigh gravity corer (Fig. 7, right) was deployed over the stern from the 'A' frame using a 25 HP SWAN winch on the quarterdeck. The corer was equipped with a 2.5 metre barrel and plastic liner. Some vibracorer experiments were conducted from CCGS *Navicula* (Fig. 8) during the cruise.

Figure 7: *van Veen grab sampler (left) and gravity corer (right).*

Figure 8: *CCGS Navicula, used for auxiliary vibracoring operations.*

Scorpio underwater camera system

The Scorpio camera (Fig. 9) was used to take digital bottom flash photographs on stations 47 and 48. The camera system consisted of the following: Scorpio Underwater Camera, underwater light, underwater flash, 50 metre cable, camera fame, deck unit, notebook computer, Video monitor, digital VCR, Video annotation unit.

The camera rig was manually lowered to near the seabed. A bottom contact pendant weight with a 54-inch (137 cm) leader indicated if the camera was higher or lower than 54 inches (137 cm) above the seabed. The height was manually adjusted as required. With focus set for 2.5 feet (76 cm), pictures were taken as points of interest came into view of the topside video display, which is also a feature of this unit. The ship was set to drift as the photo transect proceeded. With a little planning this proved to be a very satisfactory method with speeds ranging from 0 to 0.4 knots on a beautiful and calm day. Photos were stored in the camera and downloaded after recovery. The video feed from the camera was recorded on the digital VCR with annotations of UTC time, Latitude, and Longitude. As the camera loses most of its settings when quiescent for about 30 minutes, and the Scorpio software is ‘flakey’, there was difficulty in restarting the unit if it had not been deployed soon after it was setup. Although two stations were completed, a third station had to be abandoned after the camera could not be made to work after some delay in beginning the station.

Photos were downloaded without incident. This was due to improvements made to the USB interface and the fact that photos were acquired using NORMAL resolution instead of FINE resolution. This is worthy of note because a great deal of difficulty was encountered downloading photos on Hart 2003-009, the cruise immediately before this one. The Scorpio camera holds great promise for underwater imaging and will become steadily more reliable and seamless as refinements are made to the system and improvements are made to the software.

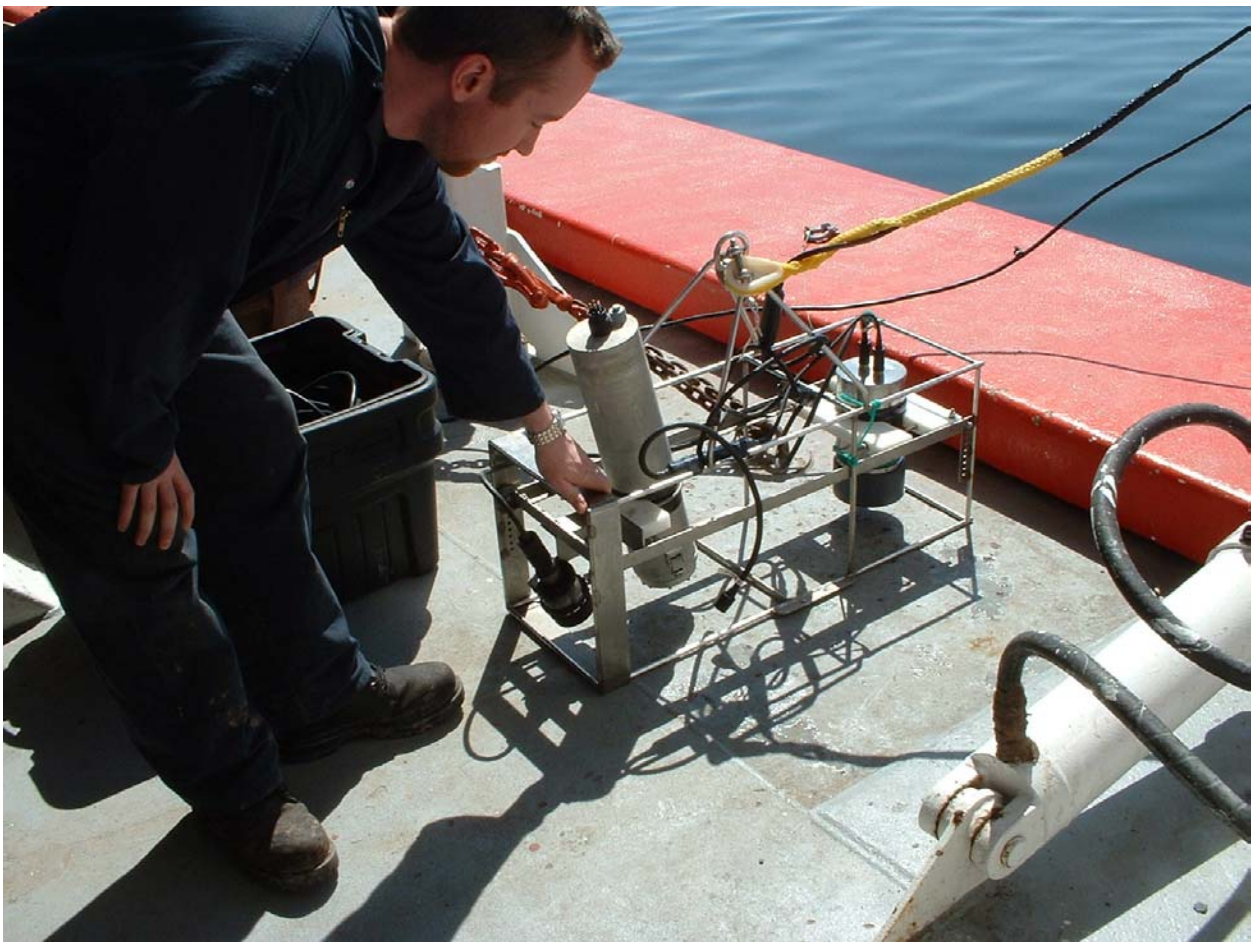

Figure 9: *Scorpio digital camera on deck of Matthew.*

Expedition database

Samples were entered into the expedition database (ED). However, early in the process the operator left out sub-sample information, as he was unfamiliar with the system. Also, until late in the day the cruise identification for the seismic daytime was entered incorrectly. Neither fault could be rectified because the system denies access once a sample has been entered. This is an irritating flaw, especially considering that entering the data is time consuming and distracting. There seems little point in using this system at sea unless access is granted to rectify mistakes.

Laboratory setup

At the rear of the laboratory, by the door to the well deck, we mounted the sidescan sonar electronics (Fig. 10). Just forward was the electronics for the Seistec system (Fig. 11). Against the wall by the well deck door was the navigation setup, including the main display (Fig. 12). Forward of the side door were computers, Unix computers, and a setup for cleaning, display and backup of multibeam bathymetric data (Fig. 13).

Figure 10: *Sidescan sonar electronics in the laboratory.*

Figure 11: *Seistec lab setup.*

Figure 12: *Navigation display in the laboratory.*

Figure 13: *Multibeam processing setup.*

SUMMARY OF SCIENTIFIC RESULTS

Previous research

Seismic reflection profiles and piston cores from the Bras d'Or Lakes collected on cruise 85-036 (CSS *Dawson*) provide information on the late Quaternary history of the Lakes. The longest cores from the Lakes penetrate only the Holocene postglacial sequence, so that the character of Pleistocene glacial and late glacial sediments must be inferred from seismic profiles by comparison with better-known deposits on the continental shelf (King and Fader, 1986). The sequence of acoustic units recognized in the Bras d'Or Lakes (Lynch 1995) is:

Unit 1 is interpreted as glacial diamict (or till) and overlies bedrock over most areas, but is absent in northern Great Bras d'Or Channel. Airgun seismic profiles show that Unit 1 is typically 30 m thick in central Bras d'Or Lake, with greater thicknesses where drumlins are developed. Drumlins are also recognised in East Bay. In St. Andrew's Channel, Unit 1 is 30-40 m thick on the deep channel floor.

Unit 2 was deposited very close to an ice margin and has the acoustic character of muddy debris flow deposits. It has weak acoustic stratification, forms a drape a few metres thick over parts of Unit 1, and resembles Facies C of Emerald Silt (King and Fader, 1986) from the Scotian Shelf. In some basins Unit 2 is tens of metres thick, with positive surface relief.

Unit 3 is a drape of acoustically well-stratified sediment. The acoustic character resembles that of the Emerald Silt (Facies A and B) of the Scotian Shelf (King and Fader 1986), a silty mud deposited from proglacial sediment plumes. In central Bras d'Or Lake Unit 3 is typically about 5 m thick and generally thins towards shallower water. This suggests deposition from proglacial plumes distant from the high sedimentation rates found near the ice margin, with the upslope thinning resulting from slight winnowing by waves in shallower water. Rapid local thickening is found near Baddeck, suggesting proximity to an ice margin here.

Unit 3 is either absent or < 2 m thick in northeastern West Bay, suggesting that there may have been later stagnant ice in this area. In contrast, much thicker sequences of Unit 3 are found in north-eastern East Bay, St. Andrew's Channel and Great Bras d'Or Channel, indicating a prolonged period of proglacial deposition, presumably during the late phase G of Grant (1994). Abrupt changes in thickness of this unit on either side of a bedrock ridge suggests that this ridge represents the site of a stable ice margin, so that stratified sediment to the northeast was probably deposited at the same time as till to the southwest. Seaward of this ridge, Unit 3 is interbedded with acoustically incoherent wedges of Unit 2, interpreted as proglacial debris flows. In some areas where Unit 3 is thick, acoustic penetration is masked by shallow gas.

Unit 3 is truncated by a widespread erosion surface in water depths of < 50 m, with strong planation at depths of about 20 - 25 m. A small delta (sic) has prograded across this erosion surface south of Barra Strait, with topsets indicating a water level as shallow as 16.5 m, apparently under conditions of falling water level. In West Bay, a smooth planar surface at -21 m with an erosional notch contrasts with rougher seabed in shallower water.

Unit 4 consists of mud with variable degrees of acoustic stratification. The unit partially drapes over existing topography, but is typically twice as thick in basins as over ridges. Its thickness appears strongly influenced by tidal currents between Great Bras d'Or Channel and Barra Strait. In central St. Andrew's Channel, a 10-m thick debris flow deposit (unit 2, recognized from its rough surface relief and acoustically incoherent character) occurs at the base of Unit 4.
Piston cores 16 and 18 from East Bay both penetrate the entire thickness of Unit 4 and were stopped by a bed of sand and gravel (clasts <1 cm). Both core sites are located about 5 m deeper than a nearby erosional terrace. The basal sand and gravel are interpreted as sediment swept off the erosional terrace in the littoral zone and corresponds to a strong reflection in seismic reflection profiles. Overlying sediment consists principally of mud, in some places with many silty laminae.

Detailed biostratigraphic studies reveal three different depositional environments within Unit 4. The basal metre of sediment in core 16 contains sparse marine dinoflagellates (de Vernal and Jetté 1987) and very rare marine diatoms (Lortie 1987). Although the sparse flora might be interpreted as reworked older material, the marine character of this interval is confirmed by isotopic analysis of organic carbon (Hillaire-Marcel, 1987). It is overlain by 1 m of sediment with mostly cold freshwater diatoms and freshwater dinoflagellate cysts. That layer is overlain by 1.5 m containing a rich variety of marine diatoms and dinoflagellate cysts, with evidence of an upward decrease in salinity and temperature. The transition between freshwater and marine diatom floras is marked by a mixed assemblage of freshwater, brackish water and marine species. No material suitable for radiocarbon dating has been found in the cores. Correlation of the tree pollen assemblages in Core 16 with the regional palynostratigraphy of Livingstone (1968) suggests that the basal marine interval dates from the *Picea* and *Betula* zone at 10 to 9 ka, the lacustrine interval from 9 ka to 4-5 ka, and the upper marine interval is younger than 4-5 ka (de Vernal and Jetté 1987).

Surficial sediment distribution in the Bras d'Or Lakes (Fig. 8 in Shaw et al., 2002) was based on some 100 grab samples collected by Vilks (1967) who conducted a bottom sampling survey for the purpose of evaluating the distribution of benthic foraminifera in the lakes. The sampling pattern was a grid with stations at one minute of latitude and 1.7 minutes of longitude. Examination of the backscatter imagery, however, reveals that sampling on such a grid tells little about the actual distribution of bottom types in the lakes.

The postglacial lake-level history of the area has attracted continuing interest. Miller and Livingstone (1992) showed that sea level in the lakes rose over the past 4000 years to within 1.5 m of the present level by 950 BP. Perceptively they pointed out the rate of increase over this period fell within the regional range of relative sea-level rise in the Maritimes of 10-30 cm /century, but that the latter rate was less than the rate of 30-35 cm/century indicated by local tide gauges over the last 100 years. As suggested by Shaw and Ceman (1999), the longer-term average rates of sea-level rise in Atlantic are perturbed by short-term eustatic pulses over a range of about 0.8 m and with a periodicity of many hundreds of years.

Sinkholes in St. Patricks Channel

The launch Plover collected EM-3000 multibeam bathymetry data in St. Patrick's Channel, to augment the small amount collected in Bell Bay in the fall of 2002. The new multibeam data were of the highest quality because of close line spacing and negligible refraction effects. The coverage extended from Baddeck to near MacIvers Point, and included small embayments but not Nyanza Bay – which was not mapped due to lack of time. The new mapping revealed that sinkholes occur in St. Patricks Channel. The Bras d'Or Lakes region has extensive outcrops of rocks of the Lower Carboniferous Windsor Group, consisting of siltstone, gypsum, anhydrite and limestone. Sinkholes - formed by solution - are common on land in the region. Grant (1988) reported them mainly in the northwest: Wycogomagh Bay, western Great Bras d'Or, Denys Basin, with an area of karst topography at Little Narrows. Grant (1988) stated that 'widespread dissolution of gypsum bedrock has profoundly modified bedrock topography…" (p. 37). Collapse depressions ranged in size from individual sinkholes to small gorges to large valleys. Valleys are unroofed former cave systems. Grant also noted that collapse continues today wherever gypsum is in the subsurface, and that "sinkholes regularly appear in till areas and even on modern floodplains…" (p. 37).

The CHS multibeam bathymetry imagery shows that sinkholes are equally common on the floor, and occur in two major clusters and several minor groupings or individuals. Both major clusters are in the Great Bras D'Or Lake, one just north of the Iona Narrows, and the other a few kilometers farther north. The southern cluster includes an extremely large sinkhole. The new multibeam mapping reveals a cluster of three overlapping holes at Herring Cove (Figure 14, left). A 38 m-deep hole is located in Campbells Cove (Figure 14, right), but the hydrographic chart indicates a maximum depth of only 24 m. This could be explained in several ways. Perhaps the deepest areas were missed in the hydrographic survey. This seems unlikely in such a small area. The second explanation is that the sinkhole has deepened since the survey (1939-1946). This seems possible because the steep sides have a freshly furrowed appearance, and the bottom of the hole has irregular relief. This contrasts with the sinkholes in Herring Cove, which have a sediment fill. How could the sinkhole have deepened? The answer is the kind of collapse described by Grant (1988). Further investigation of this question requires an examination of the original hydrographic soundings.

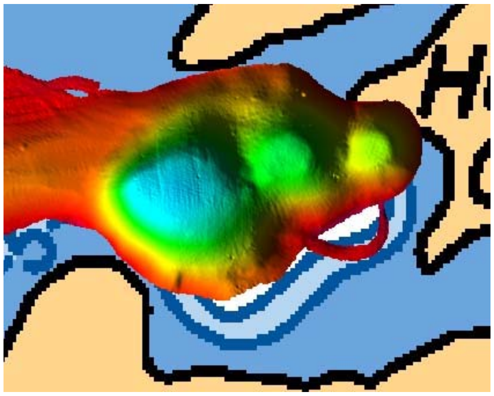 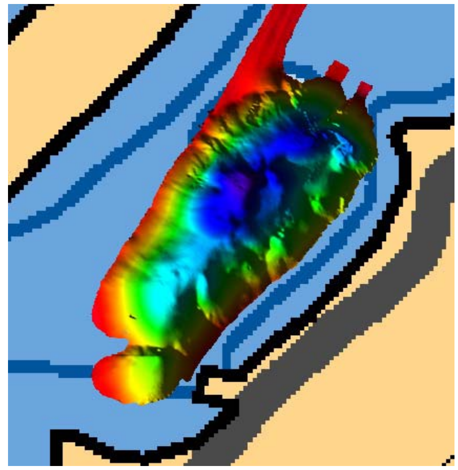

Figure 14: *Deep sinkhole in Herring Cove, Bell Bay (left) and Campbells Cove, St. Patricks Channel (right). This hole has a maximum depth of 38 metres, whereas the maximum depth indicated on the chart is only 24 metres. The images are to the same scale: the left hand image measures 166 m along the base.*

Submerged river valley in St. Patricks Channel

Surveys in 1996 revealed submerged river channels in St. Patricks Channel, buried in postglacial mud and reaching 25 m below modern sea level. After several days of multibeam surveys by the launch *Plover* during cruise 2003-015 the situation regarding these ancient river valleys in St. Patrick's Channel became clear. The multibeam imagery revealed an incised meandering river valley south of Baddeck, with point bars. East and west of Baddeck the valley is buried by mud. The area seen on the multibeam imagery was protected from mud deposition by current action in a relatively confined channel. The imagery (Figs. 15 and 16) offers a rare glimpse into an ancient landscape.

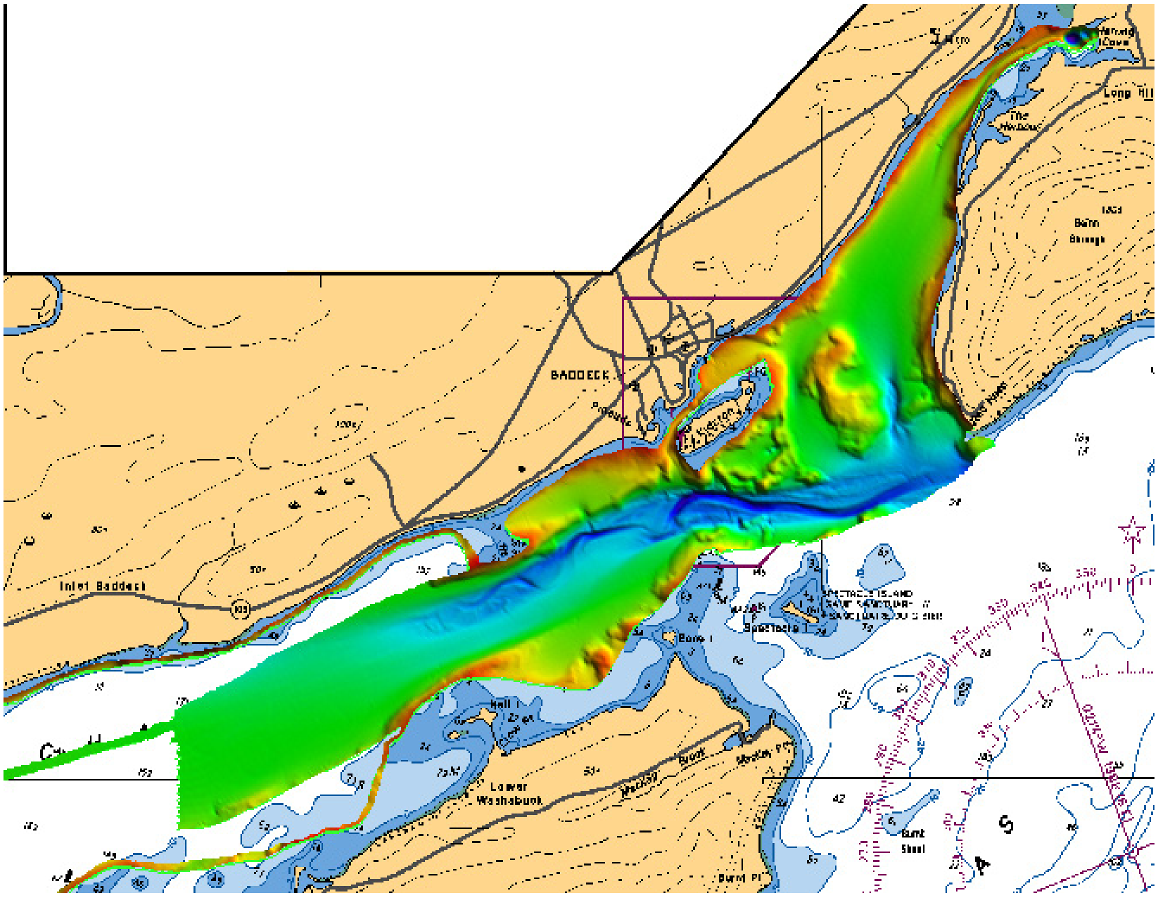

Figure 15: *Multibeam bathymetric image (derived from HIPS) showing the partly buried river valley near Baddeck.*

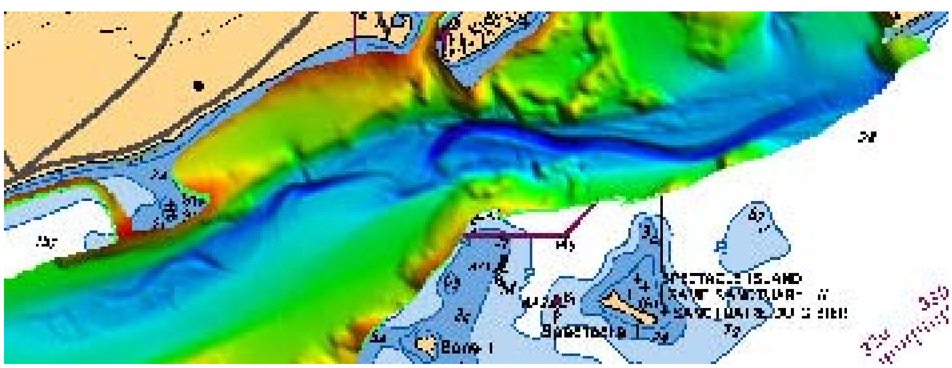

Figure 16: *Enlarged view of the partly buried river valley near Baddeck. At high resolution the imagery shows point bars, indicative of a gravel-dominated fluvial system.*

Marine geology of the lakes

The geophysical surveys –Seistec sub-bottom profiler and sidescan sonar – confirmed existing ideas about the stratigraphy of the lakes, and have assisted with the development of new ideas based on the multibeam bathymetry data collected by CHS and GSC. The stratigraphy described by Lynch (1985) was commonly observed: bedrock overlain by till, a drape of glaciomarine sediments, and acoustically transparent postglacial mud. The latter unit contains shallow gas in the basin immediately west of Kempt Head.

We attempted to determine the sill depth for the lakes. This has been cited as 8 m below sea level. We ran a survey line out the narrows, which revealed the strong influence of tidal processes on sedimentation in this area. Landward of the narrows, as far as the Seal Island Bridge, the multibeam imagery shows a smooth area on the sea floor with a deep channel at the narrows. The Seistec survey revealed that the smooth sea floor is a landward (i.e., southwest along the channel) wedge of well-sorted medium sand, with acoustic masking by gas in some places. Sediment thickness along the survey line varied from 10 to more than 15 m. This is interpreted as an elongated flood-tidal delta. We were unable to get penetration in the dredged channel, and so are unable to determine the thickness of unconsolidated sediments and hence the true sill depth. However, along the survey line the base of the deposits underlying the flood-tidal 'delta' ranged from 25 m to more than to 32 m.

From the vessel we observed the eroding glacial bluffs on both sides of the entrance to the lakes, but principally on the north side, where Grant (1988) mapped 'ice-contact stratified drift'. These bluffs are undoubtedly the source of sediment in the gravel barriers and spits that extend as far as Carey Point, at the entrance. The longshore transport direction is from northeast to southwest, towards the channel entrance. We can envisage the following processes: erosion of coastal bluffs, transport of gravel (in the swash zone) and sand (mostly below the low tide level) towards the southwest, and into the tidal channel. The sand is then transported through the narrows by tidal currents and deposited in the prograding tidal wedge between Seal Island Bridge and the narrows.

Surveys by Parrott in 2002 (in prep.) revealed evidence of ebb tidal deposits in the channel northeast of the narrows. The dredged channel cuts through a lobe of gravelly ebb-delta deposits. However, it appears that the channel started to fill, and a second wedge advanced towards the first. This has only partly been dredged. The ebb-delta deposits appear to be gravelly. Large sandy bedforms flank the wedges on the south side of the dredged channel. Farther to the southwest in the narrow part of Great Bras d' Or, near Upper Kempt Head, acoustic data and sample 43 show that the seafloor is underlain by at least 20 m of gas-charged sandy silty mud. This may be mainly suspended material carried into the lakes from the ocean, via the narrows. In other words, there is a progressive decrease in grain size from the narrows to the lakes through Great Bras d'Or Channel.

References

Boehner, R.C. 1985. Carboniferous Basin Studies, Salt, Potash, Celestite and Barite-New Exploration Potential in the Sydney Basin, Cape Breton Island. Mines and Mineral Branch Report of Activities 1984, Nova Scotia Department of Mines and Energy Report 85-1,153-164.

Calder, J.H. 1998. The Carboniferous evolution of Nova Scotia. In Lyell: the past is the key to the present. Edited by D.J. Blundell and A.C. Scott. Geological Society, London, Special Publication 143: 261-302.

Canadian Hydrographic Service (CHS) 1990. Great Bras d'Or, St. Andrew's Channel and St. Ann's Bay, Chart 4277 (1:40,000), Edition 1983, Fisheries and Oceans Canada.

Canadian Hydrographic Service(CHS) 1993. Great Bras d'Or and St. Patrick's Channel, Chart 4278 (1:40,000), Edition 1986, Fisheries and Oceans Canada.

Canadian Hydrographic Service (CHS) 1991. Bras d'Or Lake, Chart 4279, 1:60,000, Edition 1986; Fisheries and Oceans Canada.

Cooper, C. 1993. Seabed disturbance from mobile fishing gear in the Bras d'Or Lakes; Project Summary, Industry Services and Native Fisheries, No. 44, October 1993; Department of Fisheries and Oceans, Halifax, N.S. 4 p.

de Vernal, A. and **Jetté, H. 1987.** Analyses palynologiques de sédiments holocènes du lac Bras d'Or (carotte 85-036-016P), Île du Cap-Breton, Nouvelle-Écosse. *In:* Recherches en cours, Partie A, Commission géologique du Canada, Étude 87-1A, 11-15.

de Vernal, A. and **Mott, R.J. 1986.** Palynostratigraphie et paléoenvironnements du Pléistocene supérieur dans la région du lac Bras d'Or, île du Cap-Breton, Nouvelle Écosse *Canadian Journal of Earth Sciences* 23: 491-503.

de Vernal, A., Causse, C., Hillaire-Marcel, C., and **Mott, R.J. 1986**. Palynostratigraphy and Th/U ages of upper Pleistocene interglacial and interstadial deposits on Cape Breton Island, eastern Canada. *Geology* 14: 554-557.

Grant, D.R. 1988. Surficial Geology, Cape Breton Island, Nova Scotia; Geological Survey of Canada Map 1631A, 1:125,000 scale (see Grant 1994).

Grant D.R. 1994. Quaternary Geology, Cape Breton Island, Nova Scotia. Geological Survey of Canada Bulletin 482, Natural Resources Canada, Ottawa, 159 p.

Hillaire-Marcel, C. 1987. Composition isotopique du carbone organique des carottes du forage 85-036-016 dans le lac Bras d'Or, Île du Cap-Breton, Nouvelle Écosse. *In:* Recherches en cours, Partie A, Commission géologique du Canada, Étude 87-1A, 889-896.

Keppie, J.D. 2000. Geological Map of the Province of Nova Scotia, Map ME 2000-1, 1:500,000; Nova Scotia Department of Natural Resources.

King, L.H. and **Fader, G.B. 1986.** Wisconsinan glaciation of the continental shelf, south-eastern Atlantic Canada. Geological Survey of Canada Bulletin, No. 363, 72 p.

Livingstone, D.A. 1968. Some interstadial and postglacial pollen diagrams from eastern Canada. *Ecological Monographs* 38: 87-125.

Lortie, G. 1987. Diatomées et evolution holocène du lac Bras d'Or, Nouvelle Écosse. *In:* Recherches en cours, Partie A, Commission géologique du Canada, Étude 87-1A, 859-864.

Lynch, D.W. 1995. Late Quaternary acoustic stratigraphy and glacial history of the Bras D'Or Lakes using seismic data and cores. Unpublished B.Sc. Honours Thesis, Geology Department, Saint Mary's University, Halifax, Nova Scotia, 63 p. plus 2 maps.
Miller, R.F. 1997. Late -glacial (Allerød-Younger Dryas) Coleoptera from central Cape Breton Island, Nova Scotia, Canada. *Canadian Journal of Earth Sciences* 34: 247-259.
Miller, K.R., and **Livingstone, D.A. 1993.** Late-Holocene changes in sea level and environment on eastern Cape Breton Island, Nova Scotia, Canada. *The Holocene* 3: 211-219.
Mott, R.J. and **Stea R.R. 1993.** Late Glacial (Allerød-Younger dryas) buried organic deposits, Nova Scotia Canada. *Quaternary Science Reviews* 12: 645-657.
Piper, D.J.W., Mudie, P.J., Aksu, A.E. and **Skene, K.I. 1994.** A 1 Ma record of sediment flux south of the Grand Banks used to infer the development of glaciation in south-eastern Canada. *Quaternary Science Reviews* 13: 23-37.
Roland, A.E. 1982. Geological background and physiography of Nova Scotia. The Nova Scotian Institute of Science, Halifax, N.S., 311 p.
Ryan, R.J. and **Zentilli, M. 1993.** Allocyclic and thermochronologic constraints on the evolution of the Maritimes Basin of eastern Canada. *Atlantic Geology* 29: 187-197.
Shaw, J. and **Ceman, J. 1999** Salt-marsh aggradation in response to late Holocene sea-level rise at Amherst Point, Nova Scotia. *The Holocene* 9: 439-451.
Shaw, J., Taylor, R.B. and **Forbes, D.L. 1993** Impact of the Holocene transgression on the Atlantic coastline of Nova Scotia. *Géographie physique et Quaternaire* 47: 221-238.
Shaw, J., Forbes, D.L., Ceman, J.A., Asprey, K.A., Beaver, D.E., Frobel, D. and **Jodrey, F. 1995.** Marine geological surveys in Chedabucto and St. George's Bays, Nova Scotia, and Bay of Islands, Newfoundland. Cruise Report 94138. Geological Survey of Canada Open File 3230, 13 p., maps, figs.
Stea, R.R., and **Mott, R.J. 1998.** Deglaciation of Nova Scotia: Stratigraphy and chronology of lake sediment cores and buried organic sections: Géographie physique et Quaternaire, v.41, p. 279-290.
Stea, R.R., Mott, R.J., Belknap, D.F., and Radtke, U. 1992. The pre-Late Wisconsinan chronology of Nova Scotia, Canada. *In:* The last interglacial-glacial transition in North America. Edited by P.U. Clark and P.D. Lea, Geological Society of America, Special Paper 270, p.185-206.
Stea, R.R., Boyd, R., Fader, G.B.J., Courtney, R.C., Scott, D.B. and **Pecore, S.S. 1994.** Morphology and seismic stratigraphy of the inner continental shelf off Nova Scotia, Canada: Evidence for a -65 m lowstand between 11,650 and 11,250 C^{14} yr B.P. *Marine Geology* 117: 135-154
Stea, R.R., Piper, D.J.W., Fader, G.B.J. and **Boyd, R. 1998.** Wisconsinan glacial and sea-level history of Maritime Canada and adjacent continental shelf: A correlation of land and sea events. *Geological Society of America Bulletin*110: 821-845.
Taylor, R.B., MacLean, B. and **Beaver, D. 1989.** Cruise Report 88-018 Phase 13 (G), M.V. Navicula; Southwest Cape Breton Island, Nova Scotia. Unpublished Report, Atlantic Geoscience Centre, 31 p.
Vilks, G. 1967. Quantitative analysis of foraminifera in Bras d'Or Lakes. Bedford Institute of Oceanography Report 67-1, 84 p.
Wang, Y. and **Piper, D.J.W. 1982.** Dynamic geomorphology of the drumlin coast of southwest Cape. Breton Island *Maritime Sediments and Atlantic Geology* 18: 1-2.

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Appendix 1: Seismostratigraphic sequence in the Bras d'Or Lakes
(modified from Lynch, 1995).

Unit 4. Surficial muds, Holocene age.
    Facies 1A - stratified (near surface)
    Facies 1B - amorphous transparent (St. Andrew's Channel & St. Patrick's Channel)
    Facies 1C - weakly stratified

Unit 3. Proglacial sediments (Emerald Silt equivalent on Scotian Shelf)

Unit 2. Incoherent to weakly stratified.
    Facies 3a - thick sequence filling valleys, with positive surface relief
    Facies 3b - thin drape over till

Unit 1 Glacial till

Bedrock

Appendix 2: Samples

Note: depths in metres. Cam. = camera station. SDT = seismic day time.

No.	Type	Time	Latitude	Longitude	Depth	Comments
1	Grab	135113330	46.080998	-60.685455	101	Soft very dark grey/black clayey mud; a few small shell frags; brown surface layer.
2	Cam.	135115640	46.081408	-60.685738	101	
2	Cam.	135115710	46.081428	-60.685725	101	
2	Cam.	135115740	46.081447	-60.685710	101	
2	Cam.	135115830	46.081470	-60.685700	101	
2	Cam.	135115912	46.081500	-60.685668	101	
3	Cam.	135122034	46.082635	-60.702707	23	
3	Cam.	135122112	46.082608	-60.702773	23	
3	Cam.	135122151	46.082567	-60.702840	23	
3	Cam.	135122235	46.082533	-60.702923	23	
3	Cam.	135122314	46.082498	-60.703002	23	
4	Grab	135123141	46.082403	-60.702583	25	Clayey silty mud; mottled very dark /greybrown. Brown surface veneer; scattered shell frags.
5	Grab	135125040	46.086107	-60.709478	24	Clayey silty mud mottled,very dark grey and brown; Brown surface veneer 1-2cm; few small shells.
6	Cam.	135130655	46.086140	-60.709477	22	
6	Cam.	135130749	46.086210	-60.709445	22	
6	Cam.	135130834	46.086257	-60.709397	22	
6	Cam.	135130930	46.086305	-60.709282	22	
6	Cam.	135131023	46.086362	-60.709240	22	
7	Cam.	135134924	46.058892	-60.705565	62	
7	Cam.	135135001	46.058945	-60.705612	62	
7	Cam.	135135050	46.059015	-60.705668	62	
7	Cam.	135135142	46.059087	-60.705715	62	
7	Cam.	135135230	46.059155	-60.705752	62	
8	Grab	135140135	46.058758	-60.705010	66	Very dark clayey mud; brown veneer 1cm; scattered small shell fragments and a few thin worms.
9	Grab	135142258	46.053922	-60.722115	23	Poorly sorted fine gravel,<4 cm, sub-rounded, in a matrix of brown sandy mud.
10	Cam.	135144030	46.054098	-60.721690	25	
10	Cam.	135144100	46.054153	-60.721658	25	

10	Cam.	135144144	46.054223	-60.721615	25	
10	Cam.	135144240	46.054320	-60.721505	25	
10	Cam.	135144333	46.054402	-60.721425	25	
11	Cam.	135155702	46.043372	-60.712908	53	
11	Cam.	135155745	46.043363	-60.713002	53	
11	Cam.	135155825	46.043338	-60.713067	53	
11	Cam.	135155913	46.043300	-60.713190	53	
11	Cam.	135155950	46.043277	-60.713310	53	
12	Grab	135160928	46.043348	-60.712827	55	Gravelly mud. Angular gravel (up to 10cm) in a mixture of brown sandy mud.
13	Grab	135163133	46.033818	-60.738182	125	Very dark grey clayey mud; thin (<1cm) brown surface veneer.
14	Cam.	135164700	46.034895	-60.738338	133	
14	Cam.	135164754	46.035065	-60.738472	0	
14	Cam.	135164836	46.035198	-60.738577	133	
14	Cam.	135164914	46.035320	-60.738693	133	
14	Cam.	135165006	46.035475	-60.738817	133	
15	Cam.	135171656	46.017260	-60.767727	57	
15	Cam.	135171725	46.017192	-60.767777	57	
15	Cam.	135171806	46.017110	-60.767838	57	
15	Cam.	135171856	46.017018	-60.767908	57	
15	Cam.	135171936	46.016948	-60.767953	57	
16	Grab	135172658	46.017597	-60.768083	55	Very dark grey clayey mud; thin (<1cm) surface veneer.
17	Grab	135174710	45.995690	-60.763172	71	
18	Cam.	135180000	45.995877	-60.763878	71	
18	Cam.	135180042	45.995873	-60.763903	71	
18	Cam.	135180127	45.995835	-60.764178	71	
18	Cam.	135180210	45.995798	-60.764342	71	
18	Cam.	135180307	45.995743	-60.764518	71	
19	Cam.	135183135	45.985862	-60.774275	27	
19	Cam.	135183230	45.985582	-60.774565	27	
19	Cam.	135183310	45.985388	-60.774770	27	
19	Cam.	135183353	45.985172	-60.774987	27	
19	Cam.	135183455	45.984852	-60.775243	27	
20	Grab	135184736	45.986032	-60.773732	32	
21	Grab	135190559	45.983838	-60.780525	32	
22	Cam.	135191733	45.983758	-60.780653	30	
22	Cam.	135191820	45.983675	-60.781013	30	
22	Cam.	135191924	45.983577	-60.781562	30	
22	Cam.	135192012	45.983492	-60.781962	30	
22	Cam.	135192051	45.983395	-60.782283	30	
23	Grab	137115410	45.903460	-60.622007	25	Same site as the core station 24. Reddish brown mud - clay/silt . Some worm tubes.
24	Core	137121222	45.903283	-60.622410	25	SDT 2003015 136150700 149 cm.

25	Grab	137124133	45.888697	-60.687437	25	SDT 2003015 136142300.
26	Core	137125423	45.888938	-60.687250	27	SDT 2003015 136142300 78 cm.
27	Grab	137133217	45.893357	-60.676808	20	SDT 2003015 136143000.
28	Cam.	137133330	45.893438	-60.676315	23	SDT 2003015 136143000.
28	Cam.	137133414	45.893450	-60.676007	23	SDT 2003015 136143000.
28	Cam.	137133500	45.893420	-60.675707	23	SDT 2003015 136143000.
28	Cam.	137133548	45.893365	-60.675427	23	SDT 2003015 136143000.
28	Cam.	137133622	45.893315	-60.675240	23	SDT 2003015 136143000.
29	Cam.	137135606	45.879748	-60.664322	34	SDT 2003015 136162700.
29	Cam.	137135642	45.879642	-60.664150	34	SDT 2003015 136162700.
29	Cam.	137135722	45.879523	-60.663942	34	SDT 2003025 136162700.
29	Cam.	137135756	45.879428	-60.663772	34	SDT 2003015 136162700.
29	Cam.	137135834	45.879305	-60.663568	34	SDT 2003015 136162700.
30	Grab	137140832	45.881008	-60.664267	35	SDT 2003015 136162700.
31	Grab	137142340	45.882502	-60.687868	24	SDT 2003015 136141600.
32	Cam.	137143420	45.882143	-60.686917	25	SDT 2003015 136161600.
32	Cam.	137143506	45.882112	-60.686677	25	SDT 2003015 136161600.
32	Cam.	137143546	45.882097	-60.686432	25	SDT 2003015 136161600.
32	Cam.	137143644	45.882100	-60.686007	25	SDT 2003015 136161600.
32	Cam.	137143730	45.882127	-60.685637	25	SDT 2003015 136161600.
33	Cam.	137152544	45.871203	-60.703438	23	SDT 2003015 136140100
33	Cam.	137152620	45.871348	-60.703412	23	SDT 2003015 136140100
33	Cam.	137152658	45.871513	-60.703372	23	SDT 2003015 136140100
33	Cam.	137152746	45.871710	-60.703345	23	SDT 2003015 136140100
33	Cam.	137155858	45.870997	-60.740862	23	SDT 2003015 136140100
34	Grab	137153334	45.871287	-60.702763	23	SDT 2003015 136140100. Rounded, sub-rounded and sub-angular gravel in a sandy mud matrix

35	Grab	137155932	45.871007	-60.740737	29	SDT 2003015 136134000. Stiff mottled (reddish brown/dark grey) clayey mud.
36	Cam.	137160940	45.871053	-60.740630	29	SDT 2003015 1361340.
36	Cam.	137161014	45.871092	-60.740380	29	SDT 2003015 1361340.
36	Cam.	137161056	45.871120	-60.740047	29	SDT 2003015 1361340.
36	Cam.	137161128	45.871147	-60.739788	29	SDT 2003015 1361340.
36	Cam.	137161218	45.871177	-60.739380	29	SDT 2003015 1361340.
37	Cam.	137165550	45.878272	-60.785417	58	SDT 2003015 136131500.
37	Cam.	137165624	45.878243	-60.785485	58	SDT 2003015 136131500.
37	Cam.	137165706	45.878148	-60.785608	58	SDT 2003015 136131500.
37	Cam.	137165748	45.878012	-60.785738	58	SDT 2003015 136131500.
37	Cam.	137165824	45.877887	-60.785820	58	SDT 2003015 136131500.
38	Grab	137170555	45.878002	-60.783948	56	SDT 2003015 136131500.
39	Grab	137173428	45.888550	-60.843580	20	SDT 2003015 136123730. Moderately well-sorted, fine (pea) gravel with some brown sand.
40	Cam.	137174226	45.888895	-60.843555	21	SDT 2003015 136123730.
40	Cam.	137174300	45.889027	-60.843477	21	SDT 2003015 136123730.
40	Cam.	137174340	45.889157	-60.843342	21	SDT 2003015 136123730.
40	Cam.	137174436	45.889338	-60.843073	21	SDT 2003015 136123730.
40	Cam.	137174530	45.889487	-60.842772	21	SDT 2003015 136123730.
40	Cam.	137174602	45.889565	-60.842570	21	SDT 2003015 136123730.
40	Cam.	137174640	45.889643	-60.842293	21	SDT 2003015 136123730.
40	Cam.	137174724	45.889722	-60.841940	21	SDT 2003015 136123730.
40	Cam.	137174808	45.889762	-60.841492	21	SDT 2003015 136123730.
40	Cam.	137174850	45.889742	-60.841042	21	SDT 2003015 136123730.
41	Cam.	139130934	46.255435	-60.469930	19	SDT 2003015 139111500.
41	Cam.	139131024	46.255342	-60.470180	19	SDT 2003015 139111500.

41	Cam.	139110600	46.249078	-60.475728	19	SDT 2003015 139111500.
41	Cam.	139131154	46.255147	-60.470593	19	SDT 2003015 139111500.
41	Cam.	139131238	46.255053	-60.470803	19	SDT 2003015 139111500.
42	Grab	139130934	46.255435	-60.469930	19	SDT 2003015 139111500.
43	Grab	139143058	46.115048	-60.642857	28	SDT 2003015 138191200.
44	Cam.	139144020	46.115043	-60.642790	28	SDT 2003015 138191200.
44	Cam.	139144100	46.114958	-60.642887	28	SDT 2003015 138191200.
44	Cam.	139144136	46.114983	-60.642960	28	SDT 2003015 138191200.
44	Cam.	139144218	46.114982	-60.643020	28	SDT 2003015 138191200.
44	Cam.	139144258	46.114922	-60.643078	28	SDT 2003015 138191200.
45	Cam.	139153218	46.006943	-60.771798	49	
45	Cam.	139153308	46.006907	-60.771845	49	
45	Cam.	139153342	46.006888	-60.771888	49	
45	Cam.	139153428	46.006855	-60.771968	49	
45	Cam.	139153506	46.006820	-60.772045	49	
46	Grab	139154020	46.006930	-60.771492	48	
47	Video	139160000	46.007188	-60.769400	52	SDT 2003015 134141300.
47	Video	139160250	46.006922	-60.769755	52	SDT 2003015 134141300.
47	Video	139160340	46.006882	-60.769913	52	SDT 2003015 134141300.
47	Video	139160430	46.006810	-60.770038	52	SDT 2003015 134141300.
47	Video	139160520	46.006772	-60.770177	52	SDT 2003015 134141300.
47	Video	139160830	46.006535	-60.770738	52	SDT 2003015 134141300.
47	Video	139160936	46.006460	-60.770920	52	SDT 2003015 134141300.
47	Video	139161011	46.006425	-60.771008	52	SDT 2003015 134141300.
47	Video	139161040	46.006412	-60.771095	52	SDT 2003015 134141300.
47	Video	139161138	46.006388	-60.771257	52	SDT 2003015 134141300.
47	Video	139161152	46.006370	-60.771290	52	SDT 2003015 134141300.
47	Video	139161226	46.006317	-60.771373	52	SDT 2003015 134141300.
47	Video	139161310	46.006285	-60.771493	52	SDT 2003015 134141300.
47	Video	139161326	46.006277	-60.771538	52	SDT 2003015 134141300.
47	Video	139161338	46.006268	-60.771570	52	SDT 2003015 134141300.
47	Video	139161410	46.006238	-60.771650	52	SDT 2003015

						134141300.
47	Video	139160536	46.006752	-60.770220	52	SDT 2003015 134141300.
47	Video	139160626	46.006665	-60.770363	52	SDT 2003015 134141300.
47	Video	139160706	46.006620	-60.770495	52	SDT 2003015 134141300.
47	Video	139160744	46.006588	-60.770608	52	SDT 2003015 134141300.
47	Video	139160810	46.006558	-60.770683	52	SDT 2003015 134141300.
47	Video	139160820	46.006547	-60.770707	52	SDT 2003015 134141300.
47	Video	139161428	46.006220	-60.771693	52	SDT 2003015 134141300.
47	Video	139161440	46.006210	-60.771717	52	SDT 2003015 134141300.
47	Video	139161448	46.006202	-60.771735	52	SDT 2003015 134141300.
47	Video	139161514	46.006175	-60.771795	52	SDT 2003015 134141300.
47	Video	139161526	46.006165	-60.771820	52	SDT 2003015 134141300.
47	Video	139161534	46.006157	-60.771838	52	SDT 2003015 134141300.
47	Video	139161554	46.006138	-60.771880	52	SDT 2003015 134141300.
47	Video	139161618	46.006115	-60.771928	52	SDT 2003015 134141300.
47	Video	139161658	46.006082	-60.772000	52	SDT 2003015 134141300.
47	Video	139161730	46.006055	-60.772063	52	SDT 2003015 134141300.
47	Video	139161740	46.006048	-60.772085	52	SDT 2003015 134141300.
47	Video	139161814	46.006022	-60.772152	52	SDT 2003015 134141300.
47	Video	139161832	46.006008	-60.772187	52	SDT 2003015 134141300.
47	Video	139161906	46.005982	-60.772255	52	SDT 2003015 134141300.
47	Video	139161936	46.005963	-60.772317	52	SDT 2003015 134141300.
47	Video	139161946	46.005957	-60.772335	52	SDT 2003015 134141300.
47	Video	139162034	46.005928	-60.772432	52	SDT 2003015 134141300.
47	Video	139162048	46.005920	-60.772460	52	SDT 2003015 134141300.
47	Video	139162118	46.005907	-60.772520	52	SDT 2003015 134141300.
47	Video	139162136	46.005895	-60.772555	52	SDT 2003015 134141300.
47	Video	139162146	46.005892	-60.772575	52	SDT 2003015 134141300.
47	Video	139162236	46.005863	-60.772663	52	SDT 2003015 134141300.

47	Video	139162244	46.005858	-60.772677	52	SDT 2003015 134141300.
47	Video	139162310	46.005840	-60.772718	52	SDT 2003015 134141300.
47	Video	139162310	46.005840	-60.772718	52	SDT 2003015 134141300.
47	Video	139162400	46.005797	-60.772792	52	SDT 2003015 134141300.
47	Video	139162420	46.005780	-60.772818	52	SDT 2003015 134141300.
47	Video	139162428	46.005775	-60.772827	52	SDT 2003015 134141300.
47	Video	139162436	46.005768	-60.772838	52	SDT 2003015 134141300.
47	Video	139162500	46.005748	-60.772867	52	SDT 2003015 134141300.
47	Video	139162610	46.005703	-60.772963	52	SDT 2003015 134141300.
47	Video	139162752	46.005653	-60.773095	52	SDT 2003015 134141300.
47	Video	139162809	46.005650	-60.773115	52	SDT 2003015 134141300.
47	Video	139162826	46.005647	-60.773142	52	SDT 2003015 134141300.
47	Video	139162901	46.005643	-60.773183	52	SDT 2003015 134141300.
47	Video	139162910	46.005643	-60.773195	52	SDT 2003015 134141300.
48	Video	139165926	45.985525	-60.772252	28	SDT 2003015 134173027.
48	Video	139170018	45.985475	-60.772277	28	SDT 2003015 134173027.
48	Video	139170030	45.985463	-60.772282	28	SDT 2003015 134173027.
48	Video	139170100	45.985445	-60.772298	28	SDT 2003015 134173027.
48	Video	139170118	45.985442	-60.772310	28	SDT 2003015 134173027.
48	Video	139170128	45.985442	-60.772323	28	SDT 2003015 134173027.
48	Video	139170138	45.985443	-60.772335	28	SDT 2003015 134173027.
48	Video	139170218	45.985475	-60.772382	28	SDT 2003015 134173027.
48	Video	139170240	45.985488	-60.772405	28	SDT 2003015 134173027.
48	Video	139170400	45.985542	-60.772482	28	SDT 2003015 134173027.
48	Video	139170410	45.985540	-60.772492	28	SDT 2003015 134173027.
48	Video	139170458	45.985527	-60.772548	28	SDT 2003015 134173027.
48	Video	139170524	45.985527	-60.772575	28	SDT 2003015 134173027.
48	Video	139170630	45.985522	-60.772605	28	SDT 2003015 134173027.
48	Video	139170646	45.985517	-60.772605	28	SDT 2003015

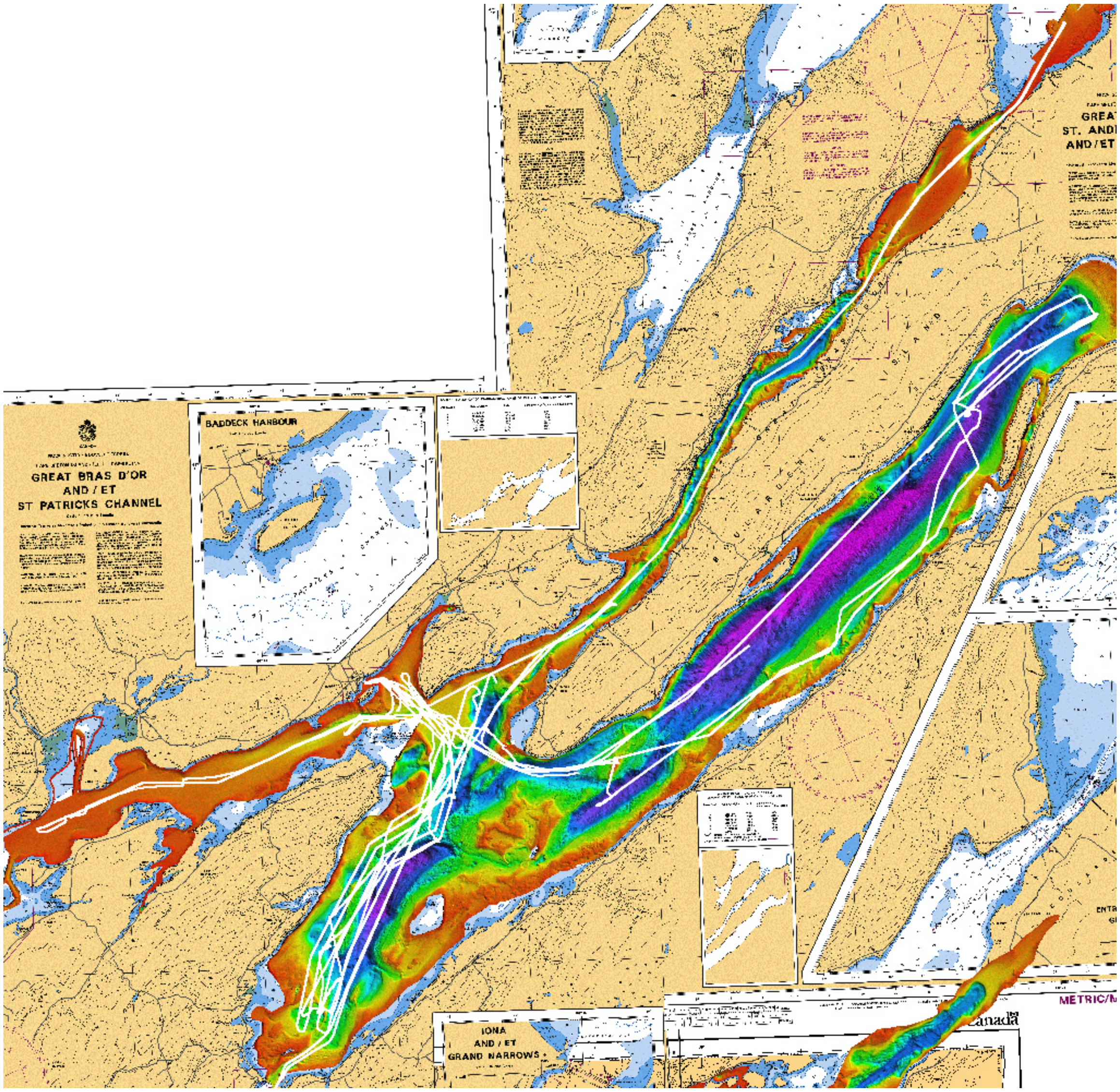
					134173027.
48	Video 139170718	45.985522	-60.772602	28	SDT 2003015 134173027.
48	Video 139170830	45.985558	-60.772563	28	SDT 2003015 134173027.
48	Video 139170910	45.985568	-60.772512	28	SDT 2003015 134173027.
48	Video 139170940	45.985575	-60.772453	28	SDT 2003015 134173027.
48	Video 139171056	45.985582	-60.772303	28	SDT 2003015 134173027.
48	Video 139171118	45.985583	-60.772257	28	SDT 2003015 134173027.
48	Video 139171140	45.985578	-60.772208	28	SDT 2003015 134173027.
48	Video 139171250	45.985535	-60.772038	28	SDT 2003015 134173027.
48	Video 139171308	45.985527	-60.771993	28	SDT 2003015 134173027.
48	Video 139171338	45.985507	-60.771918	28	SDT 2003015 134173027.
48	Video 139171356	45.985497	-60.771868	28	SDT 2003015 134173027.
48	Video 139171428	45.985458	-60.771770	28	SDT 2003015 134173027.
48	Video 139171428	45.985458	-60.771770	28	SDT 2003015 134173027.
48	Video 139171452	45.985433	-60.771698	28	SDT 2003015 134173027.
48	Video 139171534	45.985392	-60.771577	28	SDT 2003015 134173027.
48	Video 139171550	45.985382	-60.771535	28	SDT 2003015 134173027.
48	Video 139171640	45.985297	-60.771382	28	SDT 2003015 134173027.
48	Video 139171658	45.985272	-60.771325	28	SDT 2003015 134173027.
48	Video 139171718	45.985242	-60.771260	28	SDT 2003015 134173027.
48	Video 139171750	45.985193	-60.771145	28	SDT 2003015 134173027.
48	Video 139171816	45.985148	-60.771055	28	SDT 2003015 134173027.
48	Video 139171846	45.985095	-60.770955	28	SDT 2003015 134173027.
48	Video 139171858	45.985078	-60.770915	28	SDT 2003015 134173027.
48	Video 139171934	45.985047	-60.770778	28	SDT 2003015 134173027.
48	Video 139172008	45.985002	-60.770657	28	SDT 2003015 134173027.
48	Video 139172020	45.984987	-60.770615	28	SDT 2003015 134173027.
48	Video 139172120	45.984910	-60.770382	28	SDT 2003015 134173027.
48	Video 139172216	45.984847	-60.770162	28	SDT 2003015 134173027.

48	Video	139172220	45.984842	-60.770147	28	SDT 2003015 134173027.
48	Video	139172240	45.984813	-60.770065	28	SDT 2003015 134173027.
49	Grab	139185030	46.087310	-60.750428	0	Well-sorted muddy medium/fine greyish brown sand.
50	Cam.	139190106	46.087685	-60.749962	28	
50	Cam.	139190152	46.087713	-60.749882	28	
50	Cam.	139190226	46.087763	-60.749812	28	
50	Cam.	139190300	46.087828	-60.749727	28	
50	Cam.	139190338	46.087907	-60.749637	28	
51	Cam.	139192204	46.081838	-60.757555	28	
51	Cam.	139192240	46.081855	-60.757302	28	
51	Cam.	139192358	46.081850	-60.756827	28	
51	Cam.	139192444	46.081827	-60.756555	28	
51	Cam.	139192530	46.081795	-60.756275	28	
51	Cam.	139192616	46.081768	-60.755993	28	
52	Grab	139193334	46.081470	-60.757740	28	
53	Cam.	140125547	46.220628	-60.372727	28	SDT 2003015 138134730.
53	Cam.	140125728	46.220642	-60.372477	28	SDT 2003015 138134730.
53	Cam.	140125633	46.220637	-60.372632	28	SDT 2003015 138134730.
53	Cam.	140125811	46.220628	-60.372333	28	SDT 2003015 138134730.
53	Cam.	140125903	46.220652	-60.372145	28	SDT 2003015 138134730.
54	Grab	140130441	46.220633	-60.372923	28	SDT 2003015 138134730.
56	Cam.	140134105	46.207955	-60.411173	116	SDT 2003015 138131800.
56	Cam.	140134150	46.207982	-60.411045	116	SDT 2003015 138131800.
55	Grab	140132717	46.207638	-60.411045	115	SDT 2003015 138131800.
56	Cam.	140134226	46.207990	-60.410925	116	SDT 2003015 138131800.
56	Cam.	140134226	46.207990	-60.410925	116	SDT 2003015 138131800.
56	Cam.	140134354	46.208043	-60.411150	116	SDT 2003015 138131800.
57	Cam.	140140810	46.191115	-60.446293	67	SDT 2003015 138144700.
57	Cam.	140143110	46.191617	-60.445573	67	SDT 2003015 138144700.
57	Cam.	140143210	46.191643	-60.445650	67	SDT 2003015 138144700.
57	Cam.	140143721	46.191228	-60.445618	67	SDT 2003015 138144700.
58	Grab	140143755	46.190923	-60.445645	65	SDT 2003015 138144700. Mottled dark brown clayey mud; brown surface.

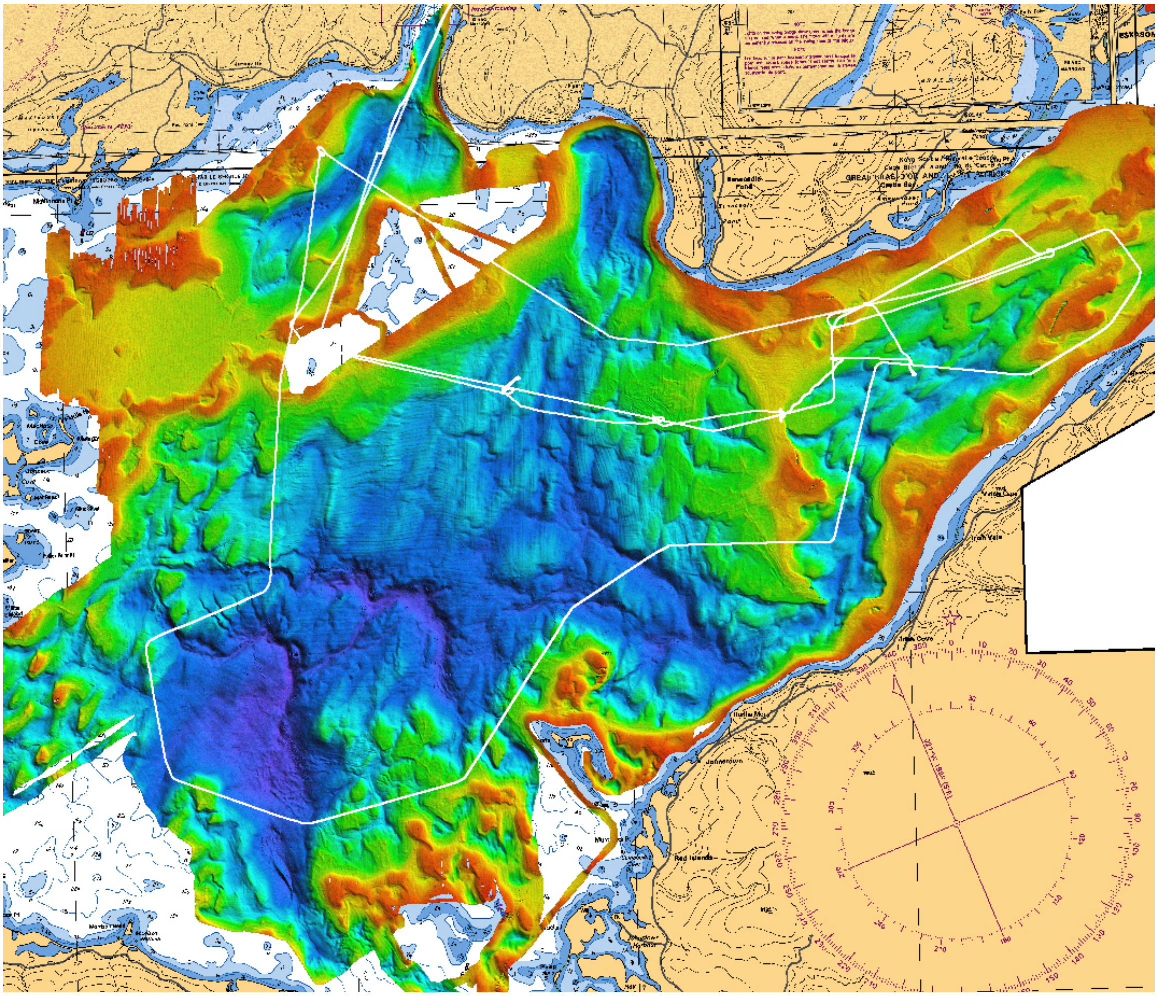
59	Grab	140153601	46.177823	-60.441618	212	SDT 2003015 138150000. Very soft mottled dark grey/brown clayey mud.
60	Grab	140160003	46.140638	-60.464905	25	SDT 2003015 138154000. Brown muddy sand, poorly sorted, grit and pebbles."
61	Cam.	140161200	46.140352	-60.465230	25	
61	Cam.	140161224	46.140303	-60.465287	25	
61	Cam.	140161258	46.140190	-60.465392	25	
61	Cam.	140161352	46.139983	-60.465598	25	
61	Cam.	140161500	46.139708	-60.465957	25	
62	Cam.	140163932	46.108500	-60.509733	35	
62	Cam.	140164044	46.108300	-60.510107	35	
62	Cam.	140164138	46.108165	-60.510335	35	
62	Cam.	140164259	46.108017	-60.510520	35	
62	Cam.	140164412	46.107855	-60.510607	35	
63	Grab	140165029	46.108367	-60.509440	38	SDT 2003015 1381616. Mud - Mottled dark grey & brown; small cohesive blocks on top.
64	Grab	140171848	46.101168	-60.528871	26	SDT 2003015 1381628. Brown muddy gravelly sand.
65	Cam.	140172917	46.101112	-60.528990	26	
65	Cam.	140172949	46.101118	-60.528977	26	
65	Cam.	140173032	46.101115	-60.528998	26	
65	Cam.	140173106	46.101100	-60.529033	26	
65	Cam.	140173158	46.101042	-60.529035	26	
66	Cam.	140181516	46.055972	-60.626640	171	
66	Cam.	140181621	46.055852	-60.627075	171	
66	Cam.	140181231	46.056145	-60.626138	171	
66	Cam.	140181901	46.055343	-60.628068	171	
66	Cam.	140181949	46.055193	-60.628387	171	
67	Grab	140184003	46.056658	-60.625386	171	Dark grey/Light grey mottles mud, brown veneer.
68	Grab	140190200	46.070062	-60.622348	22	SDT 2003015 138162800. Poorly sorted muddy sandy fine gravel.
69	Cam.	140191241	46.070220	-60.622053	29	SDT 2003015 1381628.
69	Cam.	140191316	46.070210	-60.621990	29	SDT 2003015 1381628.
69	Cam.	140191349	46.070170	-60.621945	29	SDT 2003015 1381628.
69	Cam.	140191427	46.070150	-60.621877	29	SDT 2003015 1381628.

69	Cam.	140191534	46.070128	-60.621720	29	SDT 2003015 1381628.
72	Grab	141163043	46.057755	-60.889271	13	Grey silty mud, brown surface veneer.
70	Core	141161004	46.058025	-60.889000	14	SDT 2003015 1411422.
71	Cam.	141162341	46.058138	-60.889097	13	
71	Cam.	141162416	46.058170	-60.889112	13	
71	Cam.	141162505	46.058240	-60.889110	13	
71	Cam.	141162551	46.058332	-60.889117	13	
73	Grab	141165119	46.066388	-60.839398	18	Gray Silty mud, brown surface veneer.
71	Cam.	141162640	46.058455	-60.889150	13	
74	Cam.	141170158	46.066173	-60.840015	17	
74	Cam.	141170230	46.066287	-60.839955	17	
74	Cam.	141170346	46.066585	-60.839810	17	
74	Cam.	141170437	46.066765	-60.839790	17	
74	Cam.	141170521	46.066873	-60.839750	17	
75	Core	141171032	46.066448	-60.839818	17	SDT 2003015 1411347.
76	Core	141173752	46.077043	-60.785567	21	SDT 2003015 1411310.
77	Core	141175012	46.077080	-60.785603	23	SDT 2003015 1411310.
78	Cam.	141180249	46.077115	-60.785447	23	
78	Cam.	141180332	46.077168	-60.785352	23	
78	Cam.	141180515	46.077332	-60.785188	23	
78	Cam.	141180422	46.077280	-60.785272	23	
78	Cam.	141180558	46.077348	-60.785160	23	
79	Grab	141181114	46.077097	-60.785545	23	

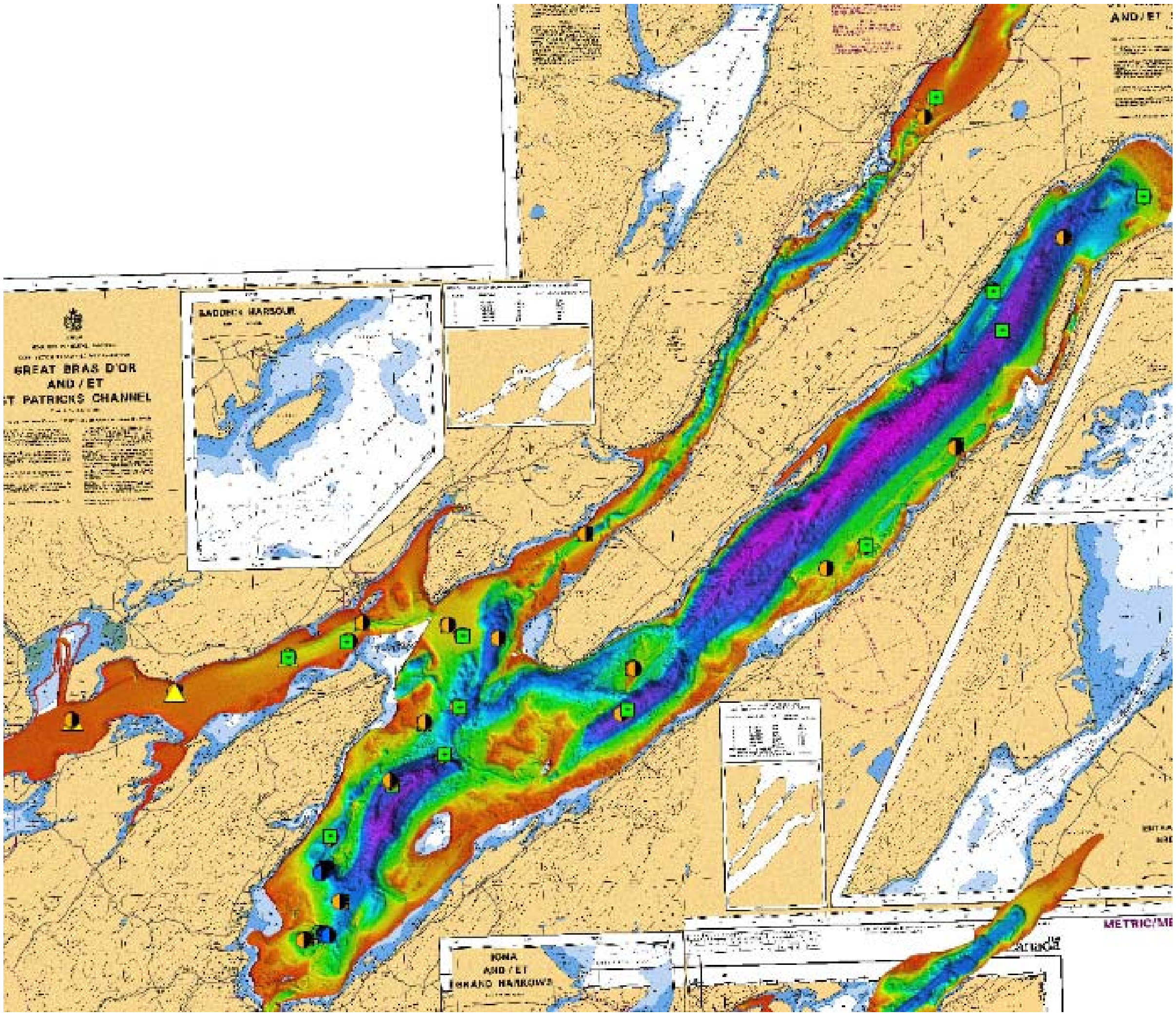
Appendix 3: Tracks and sample locations



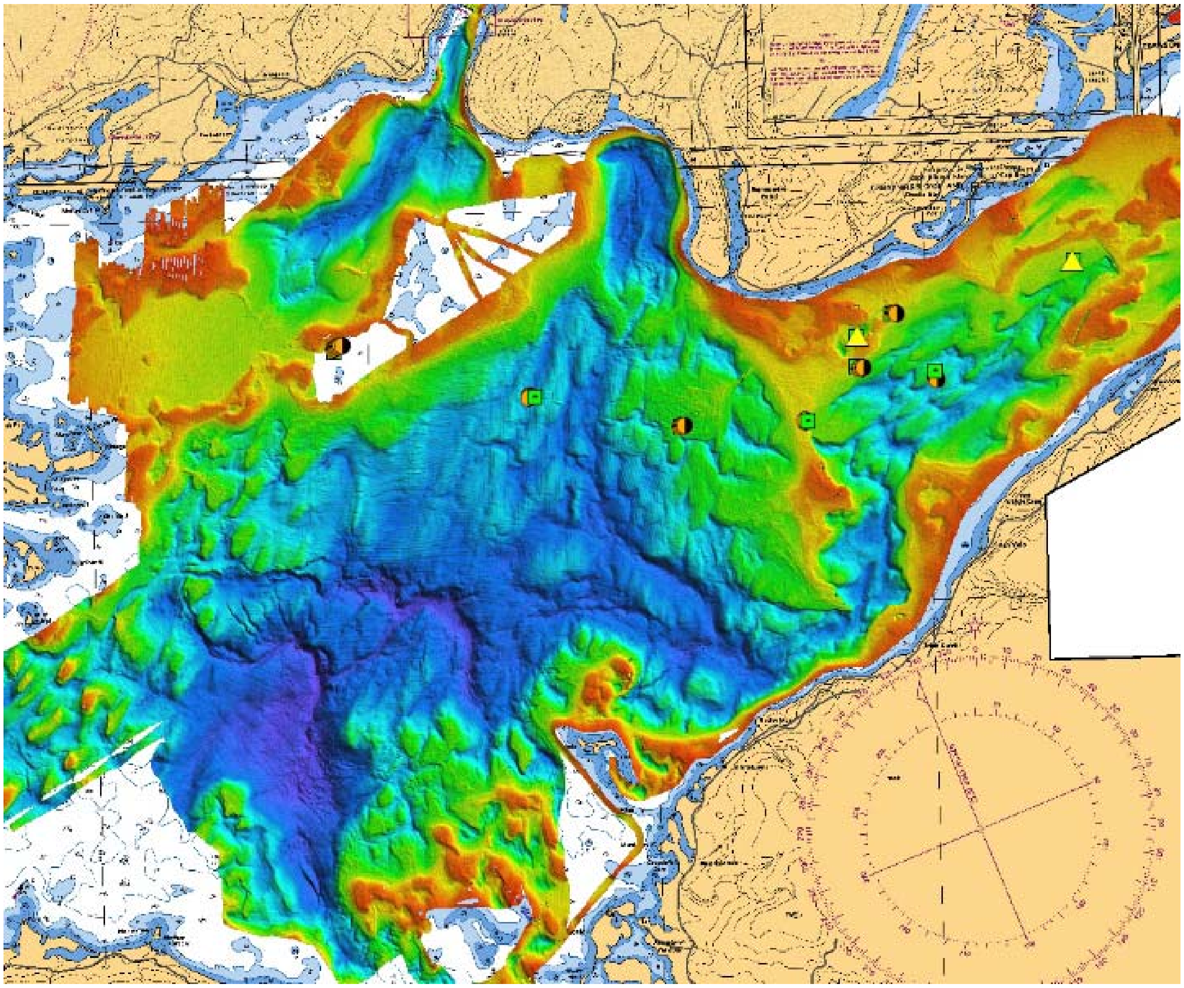
Ships' tracks: northern parts of the lakes.



Ships' tracks: southern parts of the lakes.



Stations: northern parts of the lakes. Core (yellow triangle); grab sample (green square); camera (orange/black circle); video drift (blue/black circle).



Stations: southern parts of the lakes. Core (yellow triangle); grab sample (green square); camera (orange/black circle); video drift (blue/black circle).

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Records

Sidescan				Seistec			
Record #	Start Time	End Time	Line #	Record #	Start Time	End Time	Line #
1	1341134	1341954	134-1 to 134-13	1	1341150 1341200	1341154 1341950	134-1 134-1 to 134-13
2	1361238	1362010	136-1 to 136-19	2	1361235	1361835	136-1 to 136-15
3	1381236	1381932	138-1 to 138-18	3	1361839	1362010	136-16 to 136-19
4	1411103	1411442	Bell-1 to Bell-2, 141-4 to 141-8	4	1381309	1381738	138-1 to 138-13
				5	1381740	1381930	138-13 to 138-18
				6	1391101	1391220	Seal-1
				7	1411212	1411442	141-5 to 145-8

DIGS Tapes

Sidescan				Seistec			
Tape #	Start Time	End Time	Line #	Tape #	Start Time	End Time	Line #
1	1341230	1341950	134-1 to 134-13	1	1341204	1341950	134-1 to 134-13
2	1361244	1361955	136-1 to 136-19	2	1361244	1361955	136-1 to 136-19
3	1381256	1381930	138-1 to 138-18	3	1381256	1381930	138-1 to 138-18
5	1411058	1411440	Bell-1 to Bell-2, 141-4 to 141-8	4	1391112	1391217	Seal-1
				5	1411212	1411440	141-5 to 141-8

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Line No.	Start	End	Sidescan		Seistec		Line No.	Start	End	Sidescan		Seistec	
			Rec. #	Tape #	Rec. #	Tape #				Rec. #	Tape #	Rec. #	Tape #
134-1	1204	1322	1	1	1	1	138-1	1317	1347	3	3	4	3
134-2	1322	1342	1	1	1	1	138-2	1347	1354	3	3	4	3
134-3	1346	1410	1	1	1	1	138-3	1354	1409	3	3	4	3
134-4	1410	1447	1	1	1	1	138-4	1409	1434	3	3	4	3
134-5	1447	1505	1	1	1	1	138-5	1434	1448	3	3	4	3
134-6	1505	1543	1	1	1	1	138-6	1448	1510	3	3	4	3
134-7	1552	1632	1	1	1	1	138-7	1510	1520	3	3	4	3
134-8	1632	1648	1	1	1	1	138-8	1520	1534	3	3	4	3
134-9	1648	1736	1	1	1	1	138-9	1534	1606	3	3	4	3
134-10	1742	1802	1	1	1	1	138-10	1606	1619	3	3	4	3
134-11	1802	1837	1	1	1	1	138-11	1619	1633	3	3	4	3
134-12	1837	1850	1	1	1	1	138-12	1633	1703	3	3	4	3
134-13	1850	1954	1	1	1	1	138-13	1703	1743	3	3		3
							138-14	1743	1800	3	3	5	3
							138-15	1800	1817	3	3	5	3
136-1	1249	1349	2	2	2	2	138-16	1817	1834	3	3	5	3
136-2	1349	1409	2	2	2	2	138-17	1834	1922	3	3	5	3
136-3	1409	1423	2	2	2	2	138-18	1922	1930	3	3	5	3
136-4	1423	1457	2	2	2	2							
136-5	1457	1505	2	2	2	2							
136-6	1505	1518	2	2	2	2	Seal-1	1391101	1391220	N/A	N/A	6	4
136-7	1518	1531	2	2	2	2							
136-8	1531	1543	2	2	2	2							
136-9	1543	1607	2	2	2	2	Bell-1	1411120	1411130	4	5	N/A	N/A
136-10	1607	1630	2	2	2	2	Bell-2	1411142	1411151	4	5	N/A	N/A
136-11	1630	1706	2	2	2	2	141-4	1411151	1411202	4	5	N/A	N/A
136-12	1706	1738	2	2	2	2	141-5	1411223	1411246	4	5	7	5
136-13	N/A	N/A	N/A	N/A	N/A	N/A	141-6	1411246	1411335	4	5	7	5
136-14	1738	1759	2	2	2	2	141-7	1411335	1411400	4	5	7	5
136-15	1759	1835	2	2	2	2	141-8	1411400	1411440	4	5	7	5
136-16	1835	1905	2	2	3	2							
136-17	1905	1929	2	2	3	2							
136-18	1929	1950	2	2	3	2							
136-19	1950	2010	2	2	3	2							