# Environmental conditions and dispersion processes within the Old Harry Influence Area

# COR1503 – Expedition Report

***June 8 to 14, 2015***


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## Expedition Summary

The COR1503 expedition took place from June 8th to 14th 2015 on board the research vessel (R/V) Coriolis II. Even though the expedition was marked by rough sea conditions, it allowed the acquisition of ~1300 km of geophysical lines, the collection of sediment samples at 10 stations and the profiling of the water column at 4 stations. In addition, an area of ~220 km$^2$ around the Old Harry prospect site (Fig. 1) was mapped at high-resolution, while numerous pockmarks were identified during the cruise. Moreover, methane measurement in the water column were carried out above two pockmarks and reveal an increased concentration of methane near the sediment/water interface in both cases. Finally, the expedition was also a unique opportunity for 6 students to receive hands-on training in marine geology.

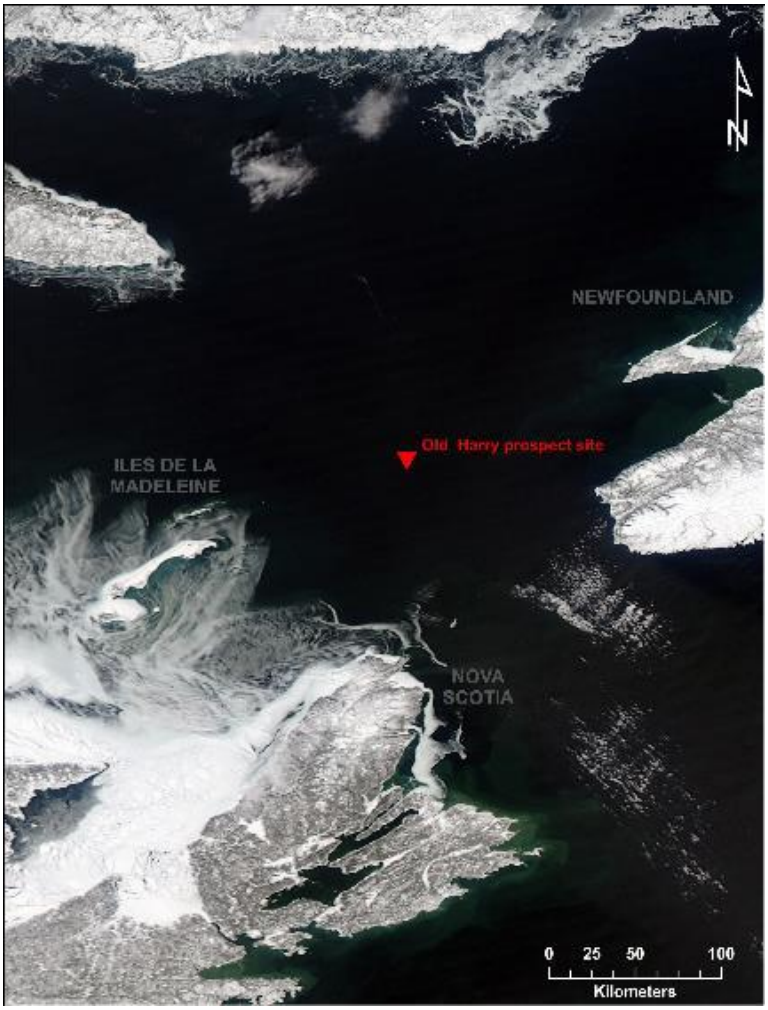


Figure 1. Old Harry prospect site location in the Gulf of St. Lawrence (background image: natural-color image acquired on February 11, 2013 with NASA's *Aqua* satellite, http://earthobservatory.nasa.gov).

# 1. Introduction – expedition background

The Gulf of St. Lawrence is under debate for the development of oil and gas exploitation. This two-week long multidisciplinary oceanographic expedition was carried out around the Old Harry prospect site (Fig. 1) and along the French Shore of Newfoundland, a region that we have identified as the Old Harry Influence Area (OHIA). Old Harry has been identified as a site with a potential exploitation of non-renewable resources (*i.e.,* offshore hydrocarbons). For these reasons, the main objective of this expedition is to gather new science-based *in situ* observations in order to evaluate the potential risks of oil and gas exploitation on the marine ecosystem of the Gulf of St. Lawrence. Consequently, the nature and the topography of the seabed as well as the water mass circulation and the ecosystem structure and function have to be studied to characterise the area. This two-week long expedition was equally divided into two legs. The first leg of the cruise (08/06/2015–14/06/2015) focused on mapping and sampling the seafloor with geophysical surveys and coring, in addition to sampling and measuring the properties of the water column. The second leg (14/06/2015- 20/06/2015) focused on measuring benthic and water column physical and biogeochemical properties. **The aim of this report is to summarize all the activities realized during the 6-day expedition of the leg 1 of the Old Harry project in the Gulf of St. Lawrence.**

# 2. Scientific objectives

The general objective of the leg 1 expedition was **to perform detailed geophysical surveys (high-resolution multibeam bathymetry and seismic profiles), and to collect different types of sediment samples in the Old Harry Influence Area (OHIA) on board of the R/V Coriolis II** in order to: **(1)** generate high-resolution maps of the bottom geomorphology and bathymetry, **(2)** determine the surface distribution of the sediments and the sedimentological processes, **(3)** determine the distribution and the geochemical and mineralogical characteristics of the surface sediments, **(4)** identify and sample (sediment and water) pockmarks and gas seepage areas, **(5)** identify areas prone to natural hazards such as submarine landslides, **(6)** determine Late Quaternary stratigraphy and sediment architecture. Finally, a key objective of the expedition was to train several students in

marine geology, while a filmmaker was also onboard the expedition to make a film on the work of scientists and students at sea. This film is part of the *Plan Large* initiative of the *Paraloeil Cinéma* where filmmakers and scientists were matched.

# 3. Shipboard participants

## *3.1 Chief scientist*

Prof. Guillaume St-Onge, ISMER-UQAR

## *3.2 Scientists and students*

Prof. Jean-Carlos Montero-Serrano, ISMER-UQAR
Prof. Huixiang Xie, ISMER-UQAR
Gilles Desmeules, technician, ISMER-UQAR
Quentin Beauvais, technician, ISMER-UQAR
Pierre-Arnaud Desiage, PhD student, ISMER-UQAR
Marie Casse, PhD student, ISMER-UQAR
Audrey M. Rémillard, PhD student, ISMER-UQAR
Louise Lafargue, MSc student, ISMER-UQAR
Adriana Gamboa, PhD student, ISMER-UQAR/UPTOS
Julieta Kaminsky, MSc student, ISMER-UQAR
Coralie Monpert, Hydrographer, CIDCO
Félix Lamarche, Filmmaker, Plan Large film project (Paraloeil production)

**ISMER**: *Institut des sciences de la mer de Rimouski* - Rimouski, Québec, Canada.
**UQAR:** *Université du Québec à Rimouski*
**UPTOS:** *Universidad Politécnica Territorial del Oeste de Sucre "Clodosbaldo Russián"*

## *3.3 Ship's crew*

In addition to the scientific team, 12 crew members were on board during the entire expedition (Table 1).

# 4. Cruise organization – logistics

To perform adequately both geophysical survey and core sampling, a precise work schedule including all participants has been determined ensuring data collection 24h/24 (Table 2). Scientists, technicians and students worked on a 12h/day shift (8:00 to 20:00/

Table 1. Ship's crew.

| Name | Role | Affiliation |
|---|---|---|
| **Yan St-Arneault** | Captain | Reformar |
| **Marc-André Nadeau** | 1st officer | Reformar |
| **Christian Larouche** | Chief engineer | Reformar |
| **Aron Tullipan** | 2nd engineer | Reformar |
| **Antoine April** | Helmsman | Reformar |
| **Louis-Nicolas Méthé** | Helmsman | Reformar |
| **Tommy Chouinard** | Cook | Reformar |
| **Jocelyn Boudrias** | Cook | Reformar |
| **Gilles Pelletier** | Deckhand | Reformar |
| **Mikel Dufour** | Deckhand | Reformar |
| **Charles-Félix Thiboutot** | Deckhand | Reformar |
| **Kevin Doiron** | Deckhand | Reformar |

20:00 to 8:00). Sediment samples and cores were collected during the day, from 8:00 to approximately 20:00 and geophysical surveys were then conducted during the evening and night, from 20:00 to 8:00. During the first two days, only geophysical data were acquired. Meanwhile, all students on board received training in geophysical acquisition. The coring sites were chosen according to the geophysical data acquired during the night. Selection of the coring sites for the day took place around 6:00 when the chief scientist looked at the geophysical data acquired during the night. Coring sites were then communicated to the bridge. During transit to a coring site, the multibeam echosounder stayed on in order to maximise the area of mapping.

Table 2. List of participants, role and working shifts.

| Name | Role | Shift |
|---|---|---|
| **Guillaume St-Onge** | Chief scientist | 8:00-20:00 + |
| **Jean-Carlos Montero-Serrano** | Responsible of coring and water sampling operations | 8:00-20:00 |
| **Huixiang Xie** | Responsible of water sampling over pockmarks | 8:00-20:00 |
| **Gilles Desmeules** | Technician | 8:00-20:00 + |
| **Quentin Beauvais** | Technician, co-responsible of geophysical survey | 20:00-8:00 |
| **Pierre-Arnaud Desiage **** | Student, co-responsible of geophysical survey | 20:00-8:00 |
| **Marie Casse **** | Student, coring and sampling | 8:00-20:00 |
| **Audrey M. Rémillard **** | Student, coring and sampling | 8:00-20:00 |
| **Louise Lafargue** | Student, geophysical survey | 20:00-8:00 |
| **Adriana Gamboa** | Student, coring and sampling | 8:00-20:00 |
| **Julieta Kaminsky** | Student, benthos sampling | 8:00-20:00 |
| **Félix Lamarche** | Filmmaker | 8:00-20:00 + |
| **Coralie Monpert** | CIDCO hydrographer responsible of multibeam acquisition | 20:00-8:00 |

** Co-responsible of the cruise report

# 5. Material, methods, and expedition overview

This section presents all the methods used during the expedition. For a more detailed summary of all operations, see the expedition log (Section 6, p. 23).

## *5.1 Plankton net*

The plankton net is used to collect plankton, a diverse group of organisms living in the water column. Here, we used a small mesh net (20 μm) (see Appendix I, p. 30). The sampling depths varied between 100 m and 25 m (Table 3). Organisms recovered were stored in formaldehyde solution to preserve them.

Table 3. Location, date, hour, and depth of plankton nets deployments.

| Plankton Net | Date – Hour (UTC) | Lat. (N) | Long. (W) | Depth water (m) | Depth sampling (m) |
|---|---|---|---|---|---|
| COR1503-01PLA | 14/06/2015 – 12:09 | 48°0.905 | 60°23.706 | 478 | 100 |
| COR1503-02PLA | 14/06/2015 – 11:21 | 47°15.692 | 61°21.498 | 38 | 25 |

## *5.2 GPS (spot)-emitting drifters*

In order to estimate surface current in the OHIA, four sets of three GPS(Spot)-emitting drifters were launched during the expedition, two sets for each leg. During leg 1, three drifters were deployed at two different times, when arriving and leaving the OHIA (see Appendix II, p. 31).

## *5.3 Rosette-CTD (Sea-Bird SB-911)*

The rosette is composed of 12 Niskin-type bottles of 12 L with an automatic closing system that allows the sampling of seawater at specific depths. A CTD probe, which continuously measures the conductivity, temperature, density, dissolved oxygen, pH and the fluorescence is also attached to the rosette.

### *5.3.1 CTD profiles and seawater sampling*

Seawater sampling was carried out 7 times (01R to 07R) at 4 different sites (Fig. 2; Table 4). The sampling depths were determined from temperature and salinity profiles (CTD profiles) in order to collect seawater samples from the surface, intermediate (thermocline),

and bottom layers of the water column. The seawater sampled with the Niskin-type bottles were transferred into 20 L acid-cleaned LDPE-collapsible cubitainers. Location and water depths of CTD profiles and water sampling are reported in Figure 2 and Table 4. The aim of the first three seawater sampling (01R, 02R, and 03R) is to measure dissolved methane ($CH_4$) concentration in pockmark-rich zones (see Fig. 3). $CH_4$ was measured using a static headspace method. Water samples were transferred to a 50 mL glass syringe (see Appendix III, p.32), into which 5 mL $CH_4$-free $N_2$ was introduced to obtain a 1:6 gas:water ratio. The syringe was vigorously shaken for 6 min. and the equilibrated headspace gas was injected into a Peak Performer 1 FID gas chromatograph for $CH_4$ quantification. The analyzer was standardized by frequent injections of a gaseous $CH_4$ standard of 4.8 parts per million by volume (ppmv) traceable to the National Institute of Standards and Technology (NIST). Vertical profiles of the concentration of dissolved methane ($CH_4$) showed consistent patterns throughout the water column except near the bottom where $CH_4$ could differ by several factors from one place to another (Fig. 4). $CH_4$ in the bottom water was relatively higher than that in the immediate overlying water. More investigations are needed to identify the sources of $CH_4$ in the bottom water. Water samples 04R to 07R were taken on the same site (see Fig. 2). These samples were collected in order to calibrate neodymium (Nd) isotopic data derived from Fe-Mn oxyhydroxide coatings of sediment particles. This calibration will allow using this proxy to reconstruct changes in water mass provenance through time. The characteristics of the water profiles are presented in Appendix IV (p. 33).

Seawater samples were labelled as follow:

Example: COR150301-01

COR→ Coriolis II
15 → Year 2015
03 → Mission #03 in 2015
01→ Station number

* Seawater station numbers do not follow sediment station numbers (see Section 5.3).

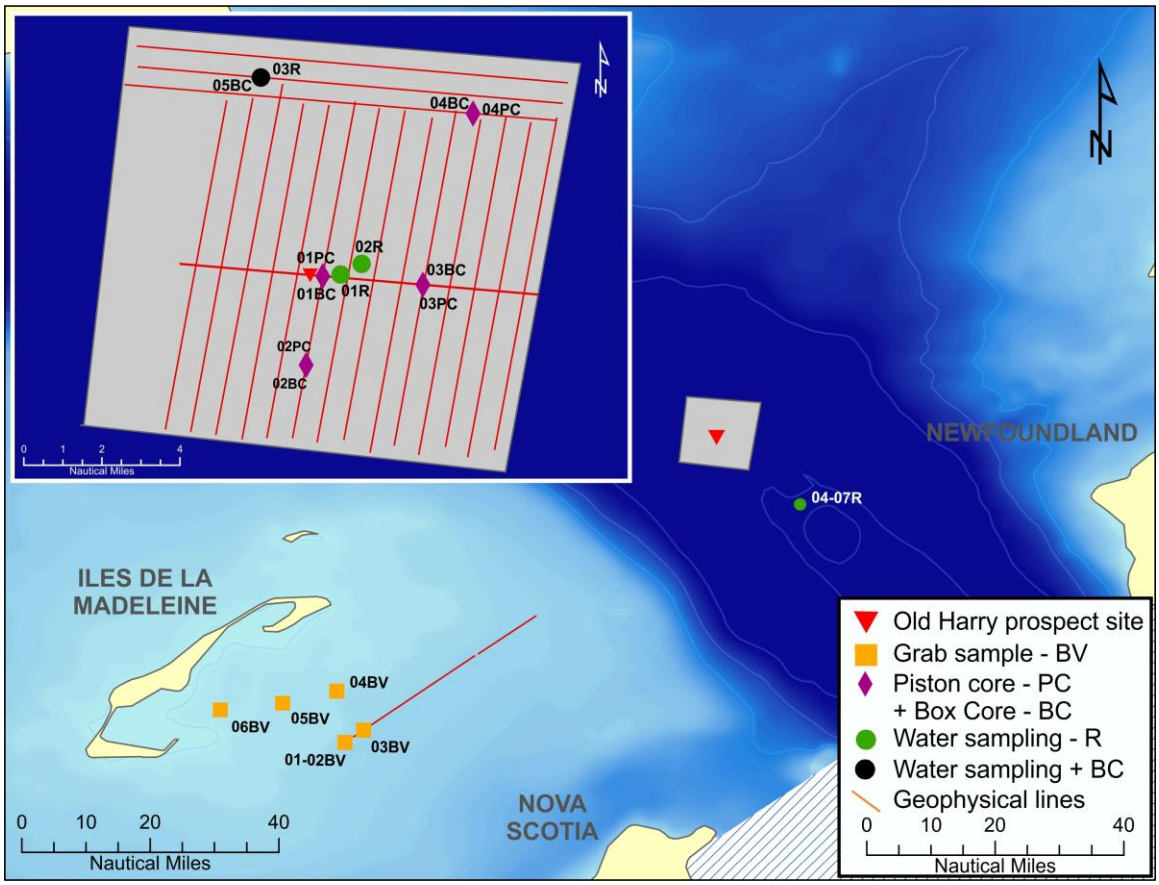


Figure 2. Location of CTD profiles (and water samples) and sediment samples in the OHIA (Van Veen grab, box, piston and trigger weight core).

Table 4. Location and depths of water sampling stations.

| CTD-Rosette station | Date – Hour (UTC) | Lat. (N) | Long. (W) | Max. depth (m) | Water sampling depth (m) |
|---|---|---|---|---|---|
| COR150301-01R | 11/06/2015 – 18:06 | 48°3.112 | 60°22.879 | 476 | 5, 10, 25, 50, 100, 150, 200, 300, 400, 445, 455, 465 |
| COR150301-02R | 13/06/2015 – 01:40 | 48°3.383 | 60°22.342 | 475 | 5, 10, 25, 50, 100, 150, 200, 300, 400, 449, 459, 469 |
| COR150301-03R | 13/06/2015 – 22:16 | 48°08.180 | 60°24.884 | 466 | 5, 10, 25, 50, 75, 100, 150, 200, 300, 400, 433, 453 |
| COR150301-04R | 14/06/2015 – 01:24 | 47°52.696 | 60°10.633 | 496 | 485 |
| COR150301-05R | 14/06/2015 – 02:22 | 47°52.736 | 60°10.735 | 496 | 50, 485 |
| COR150301-06R | 14/06/2015 – 03:26 | 47°52.720 | 60°10.478 | 496 | 10, 50 |
| COR150301-07R | 14/06/2015 – 04 :01 | 47°52.664 | 60°10.513 | 496 | 10, 50, 250, 48 |

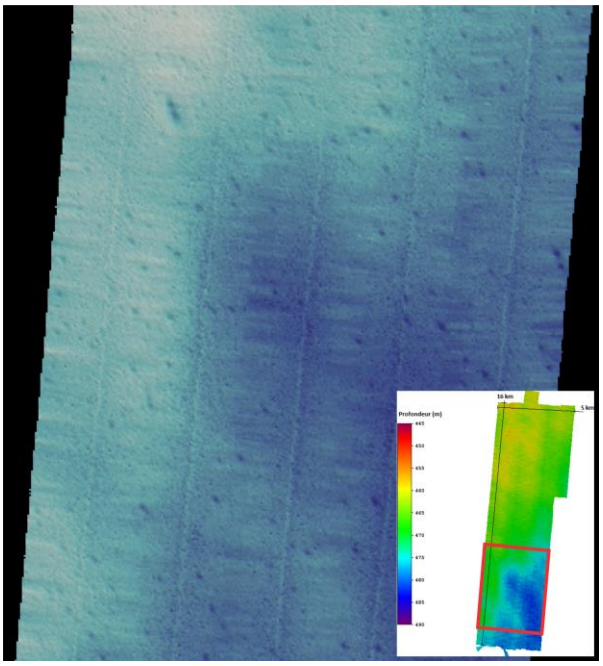

Figure 3. High-resolution bathymetric map (from the echosounder EM302) of the eastern area (about 4 km x 4 km) near the OHIA. The small depressions (more than 50 on this image) indicate the presence of pockmarks on the seafloor (modified from Coralie Monpert, CIDCO).

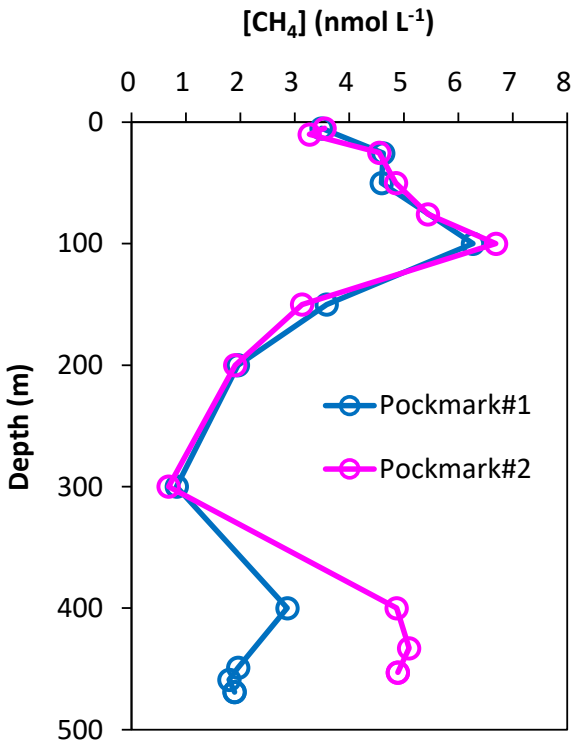


Figure 4. Typical profiles of methane ($CH_4$) in seawater over pockmarks on the seafloor of the OHIA.

## *5.4 Sediment sampling*

### *5.4.1 Van Veen grab sampler*

The Van Veen grab sampler is a clamshell device of 0.2 x 0.2 x 0.2 m with a maximum 0.008 $m^3$ capacity of sediment sampling. Its deployment is easy and quick. While the instrument goes down in the water, the two levers are spread and locked like an open scissor. When the grabber touches the seafloor it unlocks and when pulled upward, it closes and collects the surface sediment. In total, the Van Veen grab sampler was used 8 times but the first two times the grabber did not collect any sediments (Fig. 2). Sampling characteristics are presented in Table 5 and pictures in Appendix V (p. 37).

### *5.4.2 Box corer*

The box corer collects up to 0.125 $m^3$ of soft sediments at the seafloor. It is used for minimum disturbance of the sediment/water interface. When the sediment volume is sufficient (which was the case for each deployment), it is possible to subsample the box core with 10-cm diameter and 60-cm long PVC tubes (push cores) using a vacuum pump to reduce compaction. During the leg 1 expedition, the box corer was deployed 1 time (01BC), and subsequently 4 times during the leg 2 so that every piston core had a companion box core, except for 05BC which was retrieved in the seawater sampling site 3 (03R) instead of 05PC which did not collected any sediment. In total, 3 push cores were subsampled in the leg 1 box core and 1 in each box cores of the leg 2 (Table 6, p. 16). Pictures are presented in Appendix VI (p. 39).

Each Van Veen grab and box core were subsampled once on deck. Using two truncated 60-ml syringes and a small vial, the first 1 cm of sediment was subsampled for chlorophyll-a, organic matter content, and microbial community composition analyses respectively. Surface sediment was also sampled with plastic cubes for magnetic analysis. Once subsampled, each Van Veen grab and box core were sieved (0.5 mm) in order to clear out the sediment and keep benthic organisms only. The organisms were stored in plastic containers, sealed in formalin (4%) and will be used for a study on biodiversity.

### *5.4.3 Gravity corer (Lehigh)*

The gravity corer has a maximum length of 3 m and penetrates the sediment under a 136-kg weight. A core catcher keeps the sediment in the corer when the latter is pulled upward. When the gravity corer is used for the releasing of the piston corer, it is referred to as the trigger weight core (TWC). During the expedition, the gravity corer was used for these two purposes. A total of 2 gravity cores were deployed, but no sediment was recovered (Table 7, p. 16).

### *5.4.4 Piston corer (Benthos)*

The piston corer is used with a weight of 900 kg. When the companion trigger weight core touches the seafloor, it causes the rise of the trip arm and induces the piston corer free fall. A core catcher keeps the sediment in the corer when the latter is pulled upward. This coring instrument allows the collection of long cores up to a maximum of 9-m length due to the suction exerted by the piston in the tube. The piston corer was deployed 4 times during the expedition, and thus a total of 4 piston cores and 4 trigger weight cores were sampled (Tables 8 and 9, p. 17; Fig. 2). Sample locations on seismic profiles and pictures are presented in Appendix VII (p. 40).

### *5.4.5 Sediment sample identification*

Sediment samples were labelled as follow:

Example: COR1503-01PC-AB

COR→ Coriolis II
15 → Year 2015
03 → Mission #03 in 2015
01 → Station # 1
PC → Corer type (piston corer)
AB → Core section where applicable

Sediments from the box corer (BC), piston corer (PC), trigger weight corer (TWC), and gravity corer (GC) follow the station numbers.

Table 5. Location, date, hour, and depth of Van Veen grab samples (BV).

| Name | Date - Hour (UTC) | Latitude (S) | Longitude (W) | Depth (m) | Comment(s) |
|---|---|---|---|---|---|
| COR1503-01BV | 14/06/2015 – 11:43 | 47°15.685 | 61°21.443 | 38 | The BV did not collect any sediments |
| COR1503-01BV | 14/06/2015 – 12:00 | 47°15.673 | 61°21.477 | 38 | The BV did not collect any sediments |
| COR1503-01BV | 14/06/2015 – 12:08 | 47°15.691 | 61°21.477 | 38 | Silty red sand. Sediment was stored in a bucket for Alexandra Rao (ISMER-UQAR) |
| COR1503-02BV | 14/06/2015 – 12:20 | 47°15.691 | 61°21.477 | 38 | Silty red sand |
| COR1503-03BV | 14/06/2015 – 13:10 | 47°17.604 | 61°18.588 | 39 | Coarse silty red sand |
| COR1503-04BV | 14/06/2015 – 14:27 | 47°23.688 | 61°22.726 | 34 | Silty red sand |
| COR1503-05BV | 14/06/2015 – 17:31 | 47°21.812 | 61°31.161 | 30 | Silty red sand |
| COR1503-06BV | 14/06/2015 – 18:29 | 47°20.763 | 61°40.832 | 23.5 | Silty red sand |

Table 6. Location, date hour, sampling depth of each box core (BC), and length of the subsampled push cores. N/A = Not applicable.

| | | | | | | Push cores length/compaction (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Name (leg 1) | Name (leg 2) | Date - Hour (UTC) | Lat. (N) | Long. (W) | Depth (m) | A | B | C | Comment(s) |
| COR1503-01BC | N/A | 12/06/2015 – 00:06 | 48°03.054' | 60° 23.364' | 470 | 47.5/0 | 38.5/5 | 37/3 | Silty sand |
| COR1503-02BC | T3a | 15/06/2015 – 16:50 | 48°00.815' | 60°23.742' | 479 | 57/1 | N/A | N/A | Silty sand |
| COR1503-03BC | T3b | 15/06/2015 – 18:22 | 48°02.875' | 60°20.742' | 480 | 65/0 | N/A | N/A | Silty sand |
| COR1503-04BC | T3c | 15/06/2015 – 21:32 | 48°07.210' | 60°19.412' | 479 | 61.5/0.5 | N/A | N/A | Silty sand |
| COR1503-05BC | T3d | 15/06/2015 – 22:59 | 48°08.176' | 60°24.936' | 461 | 40/N/A | N/A | N/A | Silt and pebbles |

Table 7. Location, date, hour, depth, and length of gravity cores (GC). N/A = Not applicable.

| | | | | | | Section length (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Name | Date - Hour (UTC) | Lat. (N) | Long. (W) | Depth (m) | Length (m) | AB | BC | CD | Comment(s) |
| COR1503-01GC | 14/06/2015 - 14:54 | 47°23.717 | 61°22.713 | 34 | N/A | N/A | N/A | N/A | The GC did not collect any sediment |
| COR1503-02GC | 14/06/2015 - 16:36 | 47°23.718 | 61°22.714 | 34 | N/A | N/A | N/A | N/A | The GC did not collect any sediment |

Table 8. Location, date, hour, depth, and length of piston cores (PC). N/A = Not applicable.

| Name | Date - Hour (UTC) | Lat. (N) | Long. (W) | Depth (m) | Length (m) | Section length (cm) | | | | | Comment(s) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | AB | BC | CD | DE | EF | |
| COR1503-001PC | 11/06/2015 - 20:04 | 48°3.048 | 60°23.330 | 475 | 6.04 | 150 | 157 | 147 | 150 | N/A | The small amount of sediment contained in the top of the core (around 40 cm) was recovered in a plastic bag (COR1503-01PC-EF). The base of the core corresponds to red clay containing sand grains and few gravel and pebble |
| COR1503-002PC | 13/06/2015 - 13:09 | 48°0.792 | 60°23.765 | 478 | 6.46 | 154 | 153 | 155 | 153 | 31 | DE/EF transition: the sediments were recovered in a plastic bag (+6cm) |
| COR1503-003PC | 13/06/2015 - 16:49 | 48°02.845 | 60°20.755 | 482 | 561 | 152 | 150 | 130 | 129 | N/A | - |
| COR1503-004PC | 13/06/2015 - 19:59 | 48°07.220 | 60°19.412 | 485 | 735.5 | 151.5 | 154 | 154 | 154 | 113 | 7 cm of sediments recovered at the base of the core in a plastic bag. DE/EF transition: the sediments were recovered in a plastic bag (+9cm) |
| COR1503-005PC | 14/06/2015 – 15:24 | 47°23.722 | 61°22.726 | 34 | N/A | N/A | N/A | N/A | N/A | N/A | The PC was used as a GC and did not collect any sediment (no TWC) |

Table 9. Location, date, hour, depth, and length of trigger weight cores (TWC). N/A = Not applicable.

| Name | Date - Hour (UTC) | Lat. (N) | Long. (W) | Depth (m) | Length (m) | Section length (cm) | | Comment(s) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | AB | BC | |
| COR1503-001TWC | 11/06/2015 - 20:04 | 48°3.048 | 60°23.330 | 475 | 2.71 | 150 | 121 | A pebble was observed and a small shell was recovered from the core cutter in a small plastic bag. Grey clay |
| COR1503-002TWC | 13/06/2015 - 13:09 | 48°0.792 | 60°23.765 | 478 | 229 | 114 | 115 | - |
| COR1503-003TWC | 13/06/2015 – 16:49 | 48°02.845 | 60°20.755 | 482 | 241.5 | 122 | 119.5 | - |
| COR1503-004TWC | 13/06/2015 – 19:59 | 48°07.220 | 60°19.412 | 485 | 198 | 101 | 97 | A shell in the core cutter was recovered in a plastic bag |

## *5.5 Water and sediment sample storing*

Cores were stored in the cold room (4°C ) located on the deck in the laboratory container. Other sediment samples were stored in the 4°C refrigerator (cubes, plastic bags, and samples for organic matter analysis) and in the -80°C freezer (samples for chlorophyll-a and isotopic analysis, and microbial community composition) in the wet laboratory. Seawater samples were stored in the 4°C refrigerator located in the container. All samples (sediment and water) are stored at ISMER-UQAR.

## *5.6 SeaSPY magnetometer*

Marine Magnetics' SeaSPY marine magnetometer measures the total magnetic field. The measured magnetic intensity (nT) depends on the sediment and rock types that composed the seafloor. The SeaSPY measurement range is from 18 000 to 120 000 nT with an absolute accuracy of 0.1 nT. The magnetometer is towed behind the ship at a maximum distance. The data are acquired using the SeaLink software that records data in *xyzi* format and are not corrected for diurnal or bathymetric variations (post-processing). Line characteristics and location are reported in Table 10 and Figure 5.

## *5.7 Geophysical surveys*

### *5.7.1 Edgetech X-star 2.1 subbottom profiler*

The Edgetech X-star 2.1 is high-resolution hull-mounted subbottom profiling system that images the surficial sediment stratigraphy. It transmits FM-type acoustic wave with a frequency between 0.5 and 12 kHz (frequency centered between 4.5 to 6 kHz). The beam opening angle varies according to the frequency between 50° for 4.5 kHz and 25° for 6 kHz. The acoustic impulse varies from 5 to 50 ms. The subbottom profiler is composed of 9 transducers that act as transmitters and receivers. The data are in *jsf* format and are displayed and recorded using the Discover X-star 2.1 software. During the expedition, we recorded data using the Hull_2_12_20FM and Hull _2_10_20FM pulse with a frequency of 1 Hz (1 impulse every second) and 2 Hz during transits in deep waters (> 500 m). Line characteristics and location are reported in Table 10 and Figure 5.

Table 10. Date, hour and coordinates of the start and end of the marine magnetometer (MAG) and Edgetech subbottom profiler (SBP) lines.

| Name | Start hour (UTC) | Start coordinates | | End hour (UTC) | End coordinates | | Instruments | Date | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | Lat. (N) | Long. (W) | | Lat. (N) | Long. (W) | | | |
| Line_001 | 17:03:00 | 48°07,069 | 60°19,288 | 18:44:00 | 47°58,497 | 60°20,878 | SBP | 2015-06-10 | MAG not deployed |
| Line_002 | 19:08:00 | 47°58,556 | 60°21,505 | 19:29:00 | 48°00,300 | 60°21,330 | SBP + MAG | 2015-06-10 | Black out on board, line stopped |
| Line_002 Bis | 20:15:00 | 47°58,727 | 60°21,510 | 21:40:00 | 48°07,298 | 60°19,921 | SBP + MAG | 2015-06-10 | Line_002 restart and named Line_002 Bis |
| Line_003 | 21:47:42 | 48°07,130 | 60°20,616 | 00:10:00 | 47°58,560 | 60°22,206 | SBP + MAG | 2015-06-10(11) | |
| Line_004 | 00:40:00 | 47°58,870 | 60°22,795 | 01:59:00 | 48°07,303 | 60°21,228 | SBP + MAG | 2015-06-11 | |
| Line_005 | 02:07:00 | 48°07,361 | 60°21,889 | 04:21:00 | 47°58,809 | 60°23,482 | SBP + MAG | 2015-06-11 | |
| Line_006 | 04:34:00 | 47°58,919 | 60°24,107 | 06:11;00 | 48°07,531 | 60°22,503 | SBP + MAG | 2015-06-11 | |
| Line_007 | 06:39:00 | 48°07,444 | 60°23,174 | 09:15:00 | 47°58,917 | 60°24,769 | SBP + MAG | 2015-06-11 | |
| Line_008 | 09:22:00 | 47°58,888 | 60°25,403 | 10:55:00 | 48°07,480 | 60°23,831 | SBP + MAG | 2015-06-11 | |
| Line_009 | 11:18:00 | 48°07,980 | 60°24,360 | 13:15:00 | 47°58,999 | 60°26,074 | SBP + MAG | 2015-06-11 | |
| Line_010 | 13:21:00 | 47°59,080 | 60°26,715 | 14:40:00 | 48°07,620 | 60°25,125 | SBP + MAG | 2015-06-11 | |
| Line_011 | 15:03:00 | 48°07,562 | 60°25,793 | 16:44:00 | 47°59,136 | 60°27,366 | SBP + MAG | 2015-06-11 | End recording for MAG |
| Line_101 | 03:10:00 | 47°58,677 | 60°20,203 | 04:24:00 | 48°07,109 | 60°18,645 | SBP | 2015-06-13 | |
| Line_102 | 04:32:00 | 48°07,002 | 60°17,975 | 05:51:00 | 47°58,430 | 60°19,587 | SBP | 2015-06-13 | |
| Line_103 | 05:56:00 | 47°58,615 | 60°18,937 | 07:10:00 | 48°07,123 | 60°17,339 | SBP | 2015-06-13 | |
| Line_104 | 07:24:00 | 48°07,045 | 60°17,371 | 08:30:00 | 48°07,959 | 60°28,415 | SBP | 2015-06-13 | |
| Line_105 | 08:37:00 | 48°08,413 | 60°28,073 | 09:40:00 | 48°07,483 | 60°17,181 | SBP | 2015-06-13 | |
| Line_106 | 09:44:00 | 48°07,972 | 60°17,092 | 10:51:00 | 48°08,906 | 60°28,120 | SBP | 2015-06-13 | |
| Line_110 | 23:17:00 | 48°03,380 | 60°27,001 | 23:58:00 | 48°02,591 | 60°17,793 | SBP | 2015-06-13 | |
| Line_IM | 07:58:00 | 47°35,390 | 60°51,638 | 08:57:00 | 47°29,385 | 61°00,814 | SBP | 2015-06-14 | |
| Line_IM2 | 09:02:00 | 47°29,201 | 61°01,207 | 10:51:00 | 47°16,507 | 61°20,183 | SBP | 2015-06-14 | Start IM2 after SVP |

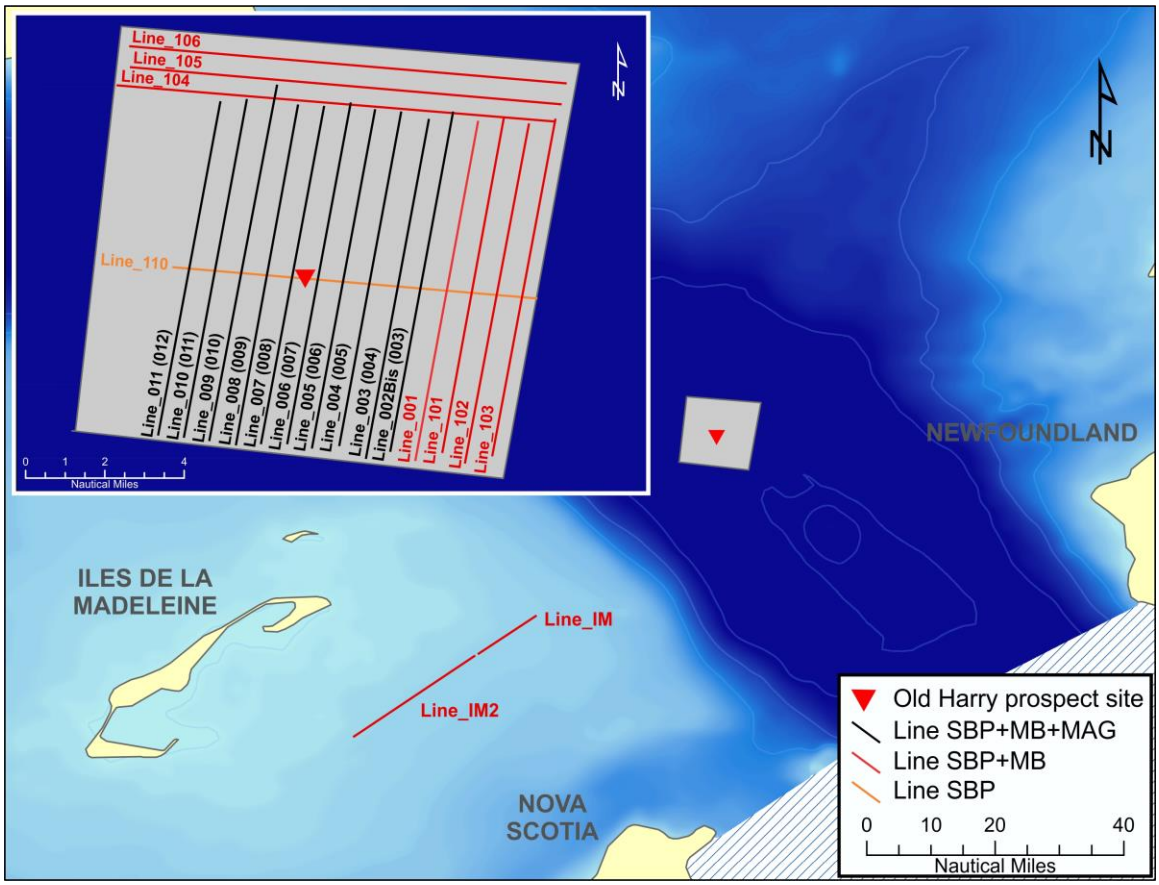


Figure 5. Location of the geophysical lines in the OHIA.

### 5.6.2 SQUID 2000 sparker

The Applied Acoustics SQUID 2000 sparker is a seismic instrument towed behind the ship with a frequency ranging from 0.3 to 3.8 kHz. It allows the visualization of marine sediment stratigraphy. The lower frequency allows a better penetration in coarse sediments although the resolution is lower than the Edgetech. Unfortunately, the sparker was severely damaged during its first deployment. It was therefore not used throughout the expedition.

### *5.7.3 Kongsberg Maritime EM 2040 & EM 302 multibeam echosounder*

The Kongsberg Maritime EM 2040 and EM 302 multibeam echosounder measure relative water depths. A transducer (TX) emits an acoustic wave which is reflected by the seafloor and recorded by a receiver (RX). The time between the acoustic wave transmission and reception is transformed in depth using the speed of sound in water. The system processor then converts the sound signal from the various beams allowing the mapping of the seafloor

over a large swath. The EM 2040 multibeam echosounder can be used with a frequency between 200 and 400 kHz owing to the depth and the wanted resolution. The EM 302 uses a frequency of 30 kHz which allows mapping in deep waters. In order to accurately localise the sounding points, both EM 2040 and EM 302 multibeam echosounder were coupled to an inertial platform (Applanix POS/MV). The latter calculates six different movements of the ship (pitch, roll, heave, yaw, surge, and lurch) and is equipped with a DGPS. The data were integrated to Kongsberg SIS software in real time. During the expedition, the EM 2040 was used in shallow waters of Magdalen Shelf (i.e., depths above 150 m) and the EM 302 was used in deep waters of the Laurentian Channel. The data were recorded in *.all* format and will be post-processed in Caris HIPS and SIPS software using notably CTD, velocity profiles and tidal data. Line characteristics and location are reported in Table 11 and Fig. 5. During the multibeam survey, a velocity profile was recorded using a *Minos* SVP (Sound velocity profiler) of *AML oceanographic* at every 2-4 hours to a maximum depth of 200 m.

Table 11. Date and hour and coordinates of the start and end of the multibeam echosounder lines (MB: EM 2040; MB3: EM 302).

| Name | Start hour (UTC) | Start coordinates | | End hour (UTC) | End coordinates | | Instruments | Date | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | Lat. (N) | Long. (W) | | Lat. (N) | Long. (W) | | | |
| Line_001 | 17:03:00 | 48°07,069 | 60°19,288 | 18:44:00 | 47°58,497 | 60°20,878 | MB3 | 2015-06-10 | |
| Line_002 | 19:08:00 | 47°58,556 | 60°21,505 | 19:29:00 | 48°00,300 | 60°21,330 | MB3 | 2015-06-10 | Black out on board, line stopped |
| Line_003 | 20:15:00 | 47°58,727 | 60°21,510 | 21:40:00 | 48°07,298 | 60°19,921 | MB3 | 2015-06-10 | Line_002 restart and named Line_003 |
| Line_004 | 21:47:42 | 48°07,130 | 60°20,616 | 00:10:00 | 47°58,560 | 60°22,206 | MB3 | 2015-06-10(11) | |
| Line_005 | 00:40:00 | 47°58,870 | 60°22,795 | 01:59:00 | 48°07,303 | 60°21,228 | MB3 | 2015-06-11 | |
| Line_006 | 02:07:00 | 48°07,361 | 60°21,889 | 04:21:00 | 47°58,809 | 60°23,482 | MB3 | 2015-06-11 | |
| Line_007 | 04:34:00 | 47°58,919 | 60°24,107 | 06:11;00 | 48°07,531 | 60°22,503 | MB3 | 2015-06-11 | |
| Line_008 | 06:39:00 | 48°07,444 | 60°23,174 | 09:15:00 | 47°58,917 | 60°24,769 | MB3 | 2015-06-11 | |
| Line_009 | 09:22:00 | 47°58,888 | 60°25,403 | 10:55:00 | 48°07,480 | 60°23,831 | MB3 | 2015-06-11 | |
| Line_010 | 11:18:00 | 48°07,980 | 60°24,360 | 13:15:00 | 47°58,999 | 60°26,074 | MB3 | 2015-06-11 | |
| Line_011 | 13:21:00 | 47°59,080 | 60°26,715 | 14:40:00 | 48°07,620 | 60°25,125 | MB3 | 2015-06-11 | |
| Line_012 | 15:03:00 | 48°07,562 | 60°25,793 | 16:44:00 | 47°59,136 | 60°27,366 | MB3 | 2015-06-11 | |
| Line_101 | 03:10:00 | 47°58,677 | 60°20,203 | 04:24:00 | 48°07,109 | 60°18,645 | MB3 | 2015-06-13 | |
| Line_102 | 04:32:00 | 48°07,002 | 60°17,975 | 05:51:00 | 47°58,430 | 60°19,587 | MB3 | 2015-06-13 | |
| Line_103 | 05:56:00 | 47°58,615 | 60°18,937 | 07:10:00 | 48°07,123 | 60°17,339 | MB3 | 2015-06-13 | |
| Line_104 | 07:24:00 | 48°07,045 | 60°17,371 | 08:30:00 | 48°07,959 | 60°28,415 | MB3 | 2015-06-13 | |
| Line_105 | 08:37:00 | 48°08,413 | 60°28,073 | 09:40:00 | 48°07,483 | 60°17,181 | MB3 | 2015-06-13 | |
| Line_106 | 09:44:00 | 48°07,972 | 60°17,092 | 10:51:00 | 48°08,906 | 60°28,120 | MB3 | 2015-06-13 | |
| Line_IM | 07:58:00 | 47°35,390 | 60°51,638 | 08:57:00 | 47°29,385 | 61°00,814 | MB | 2015-06-14 | |
| Line_IM2 | 09:02:00 | 47°29,201 | 61°01,207 | 10:51:00 | 47°16,507 | 61°20,183 | MB | 2015-06-14 | Start IM2 after SVP |

# 6. Expedition log

## *Day 1: Monday, June 8th 2015*

** The first two days, we used Eastern Daylight Time (EDT, UTC -4:00) time for day-to-day activities and the expedition log.*

The R/V Coriolis II left the port of *Rimouski-Est* at 18:00. At 19:19, the Edgetech subbottom profiler (SBP) and the multibeam echosounder EM2040 (MB) were started. At 20:47, the sound velocity profiler (SVP) was performed.

## *Day 2: Tuesday, June 9th 2015*

During the second day, we transited to the Old-Harry Influence Area (OHIA) site. During transit, the multibeam EM2040 (MB) and the Edgetech subbottom profiler (SBP) acquired data. During the morning, we prepared the push cores. Around 11:00, the sea was much more agitated (±2-3 m) and these bad conditions lasted until the next day.

## *Day 3: Wednesday, June 10th 2015*

** From Day 3 and until the end of the expedition, Atlantic Day Time (ADT, UTC -3:00) was used for the day-to-day activities and the expedition log.*

During transit, the multibeam EM2040 (MB) acquired data as well as the Edgetech subbottom profiler (SBP). Due to the bad sea conditions and the increasing seafloor depth, the MB EM2040 was stopped and was replaced by the MB EM302 which started at 11:46 for transit. We reached the OHIA site around 12:00. The SVP was deployed at 12:31 (48º08’47.30’’N/60º19’32.90’’W). Three GPS(Spot)-emitting drifters were deployed overboard around 12:40. The line 001 started à 14h03 (MB+SBP only). The line 001 stopped at 15h44 and the marine magnetometer (MAG) was deployed around 16:00. The seismic line 002 started at 16h08 (MB+SBP+MAG). At 16:19, there was a power failure and all the screens (MB+SBP) shut down. The MAG restarted itself few minutes after. At 16:42, the SBP and the MB EM302 functioned again and the ship transited to restart the line 002. The new MB line 002 was named 003 and the new SBP line was named ‘002bis’ and both restarted at 17:15 (MB+MAG+SBP). From here and until the end of the mapping,

the SBP, the MAG and the MB EM302 lines do not have the same number (*e.g.* MB line 009 = SBP and MAG lines 008). MB line 003 (SBP+MAG line 002) stopped at 18:40 and MB line 004 (SBP+MAG line 003) started at 18:47. MB line 004 stopped at approximately 21:10. At 20:54, the SBP interrupted and was restarted few minutes later with the name '003bis'. The SVP was performed at 21:37. The MB line 005 (SBP+MAG line 004) started 21:40 and stopped at 22:59. MB line 006 (SBP+MAG line 005) started 23:07 and stopped at 1:24. Several pockmarks (> 50) between approximately 30 and 60 m in diameter were observed and identified in the logbook. Note that the bad sea conditions that started the day before sustained all day long. Therefore, data from the SBP were not of high-quality and no coring operations were possible.

## *Day 4: Thursday, June 11th 2015*

MB line 007 (SBP+MAG line 006) started at 1:34 and stopped at 3:11. The SVP was deployed around 3:30. MB line 008 (SBP+MAG line 007) started at 3:39 and stopped at 6:15. MB line 009 (SBP+MAG line 008) started at 6:22 and stopped at 7:55. Again, over 40 pockmarks were observed and identified in the logbook during the acquisition of these three lines. The SVP was deployed at 8:00. Around 6:00, the chief scientist looked at the subbottom profiler data in 'fast forward' and chose different coring sites for the afternoon if the weather would become better. MB line 010 (SBP+MAG line 009) started at 8:18 and stopped at 10:15. MB line 011 (SBP+MAG line 010) started at 10:21 and stopped at 11:40. The SVP was performed at approximately 11:45. MB line 012 (SBP+MAG line 011) started at 12:03 and stopped at 13:44. While acquiring MB line 012, the crew prepared the piston core. After MB line 012, the MAG was recovered. The ship then transited to the first "pockmark" site. At 13:54 (during the transit), the echosounder EK60 was started. At 15:06, the CTD-rosette (COR1503-01R) was deployed to the maximum depth of 476 m and water samples were taken at 465, 455, 445, 400, 300, 200, 150, 100, 50, 25, 10, and 5 m for methane analyses (Huixiang Xie). The ship then transited to the first coring site which is on the MB line 006. Around 16:30, the crew started to deploy the piston corer. Around 18:00, the trigger weight core (TWC) and the piston core (PC) were both on the deck and we started to cut them in sections. The 01TWC was full of sediment and was separated in two sections AB (150 cm) and BC (121 cm). The core catcher was filled with grey clay. A

pebble was observed and a small shell was recovered in a small plastic bag. The 001PC was cut into 4 sections: AB (150 cm), BC (157 cm), CD (147 cm), and DE (150 cm). The liner in the top section of the piston corer was shattered. The small amount of sediment (~50 cm) in that section was recovered in a plastic bag (COR1503-01PC-EF). The core catcher + cutter were full of sediment (COR1503-01PC-cutter). Sediment was present between the base of the liner of section AB and the core cutter and was sampled in a plastic bag (COR1503-01PC-base). Both the core cutter and the base of the core are composed of red clay containing sand grains and few gravel and pebble. Around 19:20 the ship transited to the first seismic line 001 (sparker), but the sparker was damaged during its deployment.

### *Day 5: Friday, June 12th 2015*

The ship transited to Cap-aux-Meules (Îles-de-la-Madeleine) and arrived approximately at 7:00. The ship left the port at 13:00 and transited again to OHIA. During transits, the subbottom profiler acquired data as well as the multibeam echosounders (Line "transit_IM_01" and "transit_IM_02"). The EM2040 and the EK60 were used on the Magdalen Shelf. From the slope to deeper waters, the EK60 was stopped and the EM302 was used, i.e. from 18:19 to the end of the line (7:47). At 19:47, the ship reached the OHIA and the crew deployed the box corer a first time at 20:02. Unfortunately, the box corer did not reach the seafloor or did not close adequately. A second attempt was performed successfully at 21:06. From this box core, three push cores (COR1503-01BC-A, B, and C) were sampled as well as surface sediment on one half of the box. Note that for each push core, the top was filled with 2.5 cm of styrofoam.

### *Day 6: Saturday, June 13rd 2015*

At 22:40 (01:40 UTC), the rosette-CTD (COR1503-02R) was deployed to the maximum depth of 475 m and water samples were taken at 469, 459, 449, 400, 300, 200, 150, 100, 50, 25, 10, and 5 m for methane analyses (Huixiang Xie). Bottle eleven did not close and no seawater was therefore collected at 10 m. The ship transited to the beginning of line 101 for geophysical acquisition. During the transit, the subbottom profiler (SBP) and the multibeam echosounder EM302 (MB) acquired data. Line 101 started at 00:10 (03:10 UTC) and stopped at 1:24 (4:24 UTC). A SVP was performed at 12:40 (3:14 UTC). Line

102 started at 1:32 (4:32 UTC) and stopped at 2:51 (5:51 UTC). Line 103 started at 2:56 (5:56 UTC) and stopped at 4:10 (7:10 UTC). A SVP was performed at 4:16 (7:16 UTC). Line 104 started at 4:24 (7:24 UTC) and stopped at 5:30 (8:30 UTC). Line 105 started at 5:37 (8:37 UTC) and stopped at 6:40 (9:40 UTC). The SBP was interrupted and restarted at 5:44 as line "105bis". Line 106 started at 6:44 (9:44 UTC) and stopped at 7:51 (10:51 UTC). A SVP was performed at 7:59 (10:59 UTC). At 8:14 (11:14 UTC), the ship transited to the second piston coring site. During the transit, the SBP and the echosounder EK60 acquired data (line transit_106_to_site 2) and stopped at 9:05. At 9:10 (12:10 UTC), a small plankton tow was performed in order to collect plankton at a depth of 100 m (COR1503-01PLA; André Rochon). At 9:40, the crew deployed the piston corer. From this site, a trigger weight core (TWC) of 229 cm and a piston core (PC) of 646 cm were collected (COR1503-02TWC and COR1503-02PC). Between sections DE and EF (COR1503-02PC), ~6 cm of sediment was collected in a plastic bag. The ship transited to the third sampling site. Transit started at 12:02 and stopped at 12:32. During transit, the SBP and the echosounder EK60 acquired data (line transit_to_site 3). The piston corer was deployed around 13:49 and from this site, a TWC of 241.5 cm and a PC of 561 cm were collected (COR1503-03TWC and COR1503-03PC). Three GPS(Spot)-emitting drifters were deployed overboard and the ship transited to the fourth sampling site while the SBP and the echosounder acquired data as 'line transit_to_site 4' (from 15:53 to 16:21; 18:53 to 19:21 UTC). The piston corer was then performed at ~16:59 (19:59 UTC). A TWC of 198 cm and a PC of 735.5 cm were collected from this site (COR1503-04TWC and COR1503-04PC). Between sections DE and EF of COR1503-04PC, ~9 cm of sediment was collected in a plastic bag. The ship transited to the third rosette-CTD site (COR1503-03R), which was deployed at 19:16 (22:16 UTC), and then to line 110 from 19:53 to 20:15 (22:53 to 23:15 UTC). The latter was surveyed with the SBP and EK60 from 8:17 to 20:58 (23:17 to 23:58 UTC).

## *Day 7: Sunday, June 14th 2015*

From 9:01 to 9:57 (00:01 to 00:57 UTC), the ship transited to a fourth rosette-CTD (COR1503-04R) site while the SBP and the echosounder E302 acquired data. The rosette-CTD was deployed 3 more times at the same site (COR1503-05R; 06R, and 07R) (*c.f.*

Table 5). From 1:35 to 4:43 (4:35 to 7:43 UTC) the ship transited towards the Magdalen Islands' shelf and the SBP and EM302 recorded data (line 'last day IM') and stopped at 3:45 (6:45 UTC). The EM302 stopped at 3:45 (6:45 UTC) and the MB2040 started at 3:50 (6:50 UTC). A SVP was performed at 4:50 (7:50 UTC). From 4:58 to 5:57 (7:58 to 8:57 UTC), the ship continued its transit towards the Magdalen Islands as 'transit IM' (SBP + EM2040). The line changed for 'line IM2' from 6:02 to 7:51 (9:02 to 10:51 UTC) (follow 'line IM' which was interrupted to perform a SVP at 6:01 (9:01 UTC).At 8:21 (11:21 UTC), a small plankton tow was performed in order to collect plankton at a depth of 25 m (COR1503-02PLA; André Rochon). At the same site, the Van Veen grab sampler was deployed two times (COR1503-01BV and COR1503-02BV). From 9:38 (12:38 UTC) to 10:13 (13:13 UTC) the ship transited to BV03 site (very short transit, only the EM2040 and the EK60 echosounder acquired data). The Van Veen grab sampler was deployed around 10:15 (13:15 UTC). From 10:19 (13:19 UTC) to 11:00 (14:00 UTC), the SBP and the EM2040 acquired data, while the ship transited to the first gravity core site. At 11:27 (14:27 UTC) the BV04 was performed and revealed a silty red sand. At 11:54 (14:54 UTC), a gravity core was deployed (COR1503-01GC) and didn't collect any sediment. At the same site, a piston core has been used as a gravity core (without the piston) (COR1503-05PC) at 12:24 (15:24 UTC) and didn't collect any sediment. Finally, another attempt with the gravity core has been made at the same site (COR1503-02GC) at 13:36 (16:36 UTC) and the GC was empty. **The ship transited to the Magdalen Islands and arrived at the port of Cap-aux-Meules around 17:30 (20:30 UTC).**

## 7. Conclusion and preliminary results

Even though the expedition was challenging due to rough sea conditions, the mission was still very successful with the acquisition of ~1300 km of geophysical lines, the collection of sediment samples at 10 stations and the profiling of the water column at 4 stations. A total of 6 grab samples, 1 box core (+ 4 collected in leg 2 so that each piston core has its companion TWC and BC), 4 piston cores and 7 seawater samples from 3 stations were recovered and will be analysed in details in the laboratory to achieve some of the "Old Harry" objectives. In addition, the area of the OHIA was successfully mapped at high-resolution, revealing submarine structures of interest such as several pockmarks

(Fig. 3). According to the methane analysis performed on board, the methane concentration over some of these pockmarks is higher near the bottom (Fig. 4), suggesting that some of them may be active today. Finally, the expedition was also a unique opportunity for students to receive hands-on training in marine geology and for some of them to collect the material and data necessary to pursue their respective degrees.

# Appendix I – Plankton net

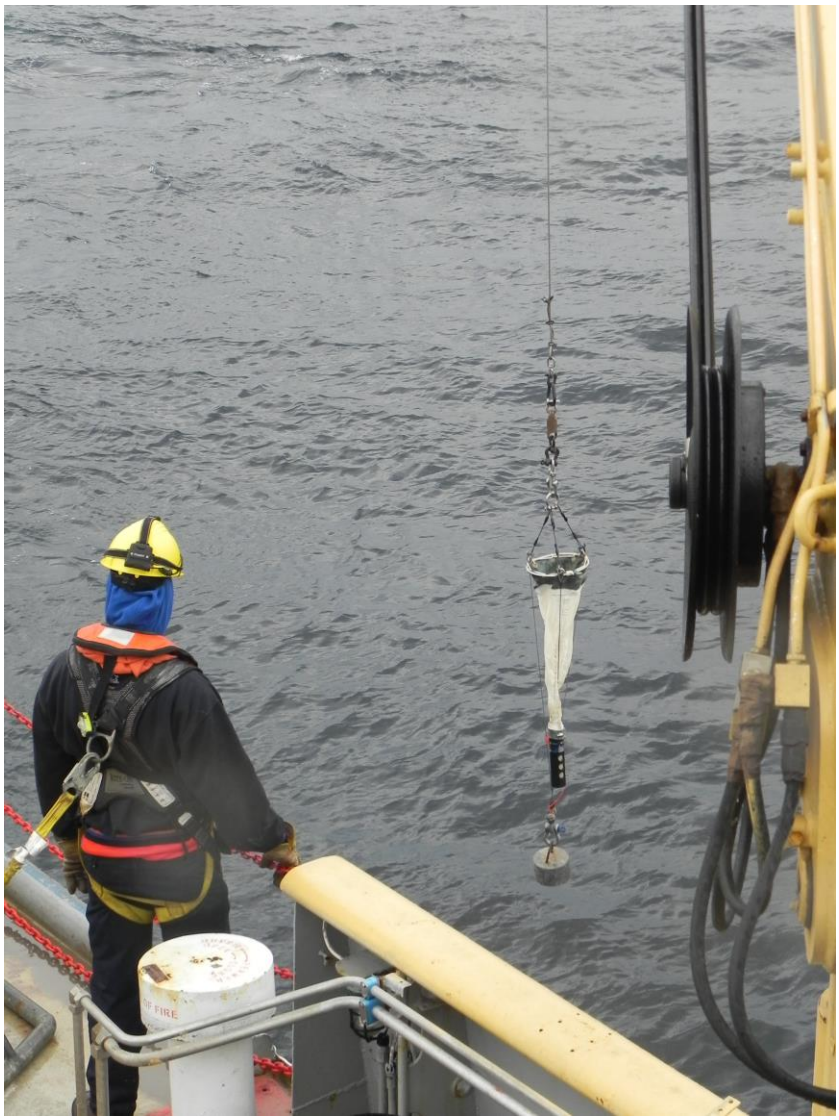

Figure 6. Plankton net sampling.

# Appendix II – GPS-emitting drifters

Figure 7. GPS(Spot)-emitting drifters deployment.

# Appendix III – Water sampling

Figure 8. Water sampling for methane measurements using the CTD-rosette.

# Appendix IV – CTD profiles

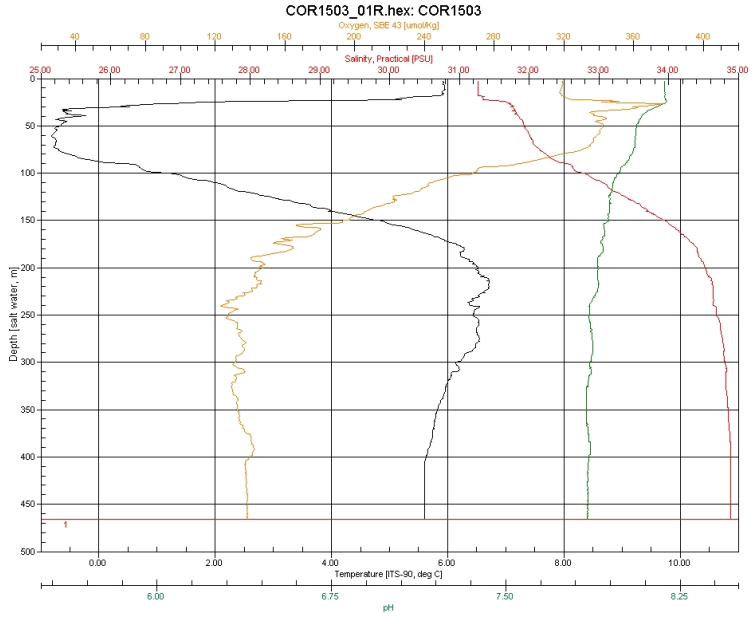


Figure 9. COR1503-01 CTD profile.

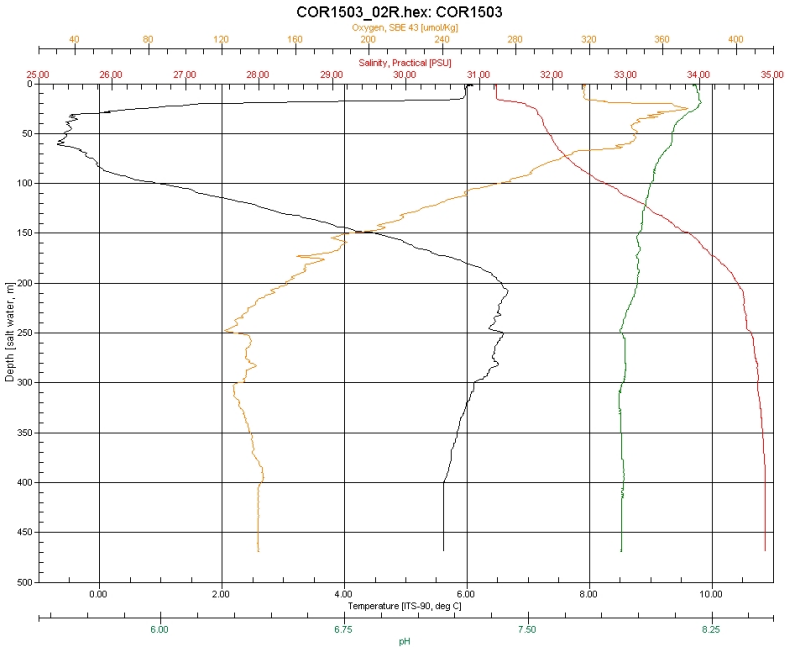


Figure 10. COR1503-02 CTD profile.

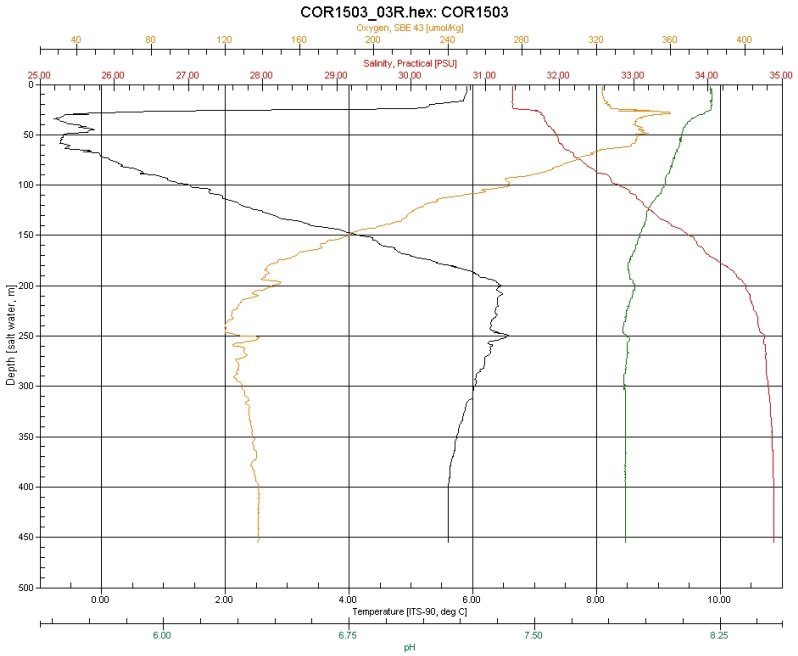


Figure 11. COR1503-03 CTD profile.

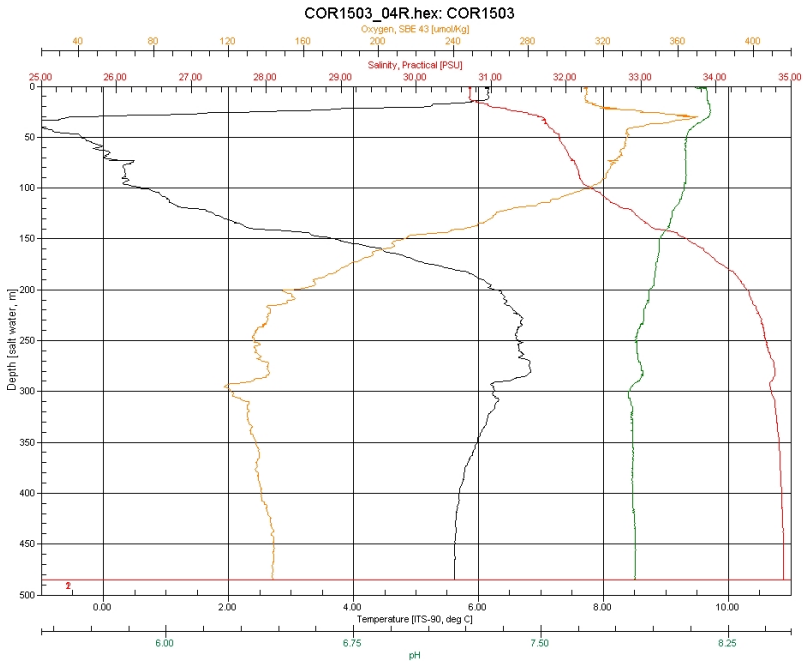


Figure 12. COR1503-04 CTD profile.

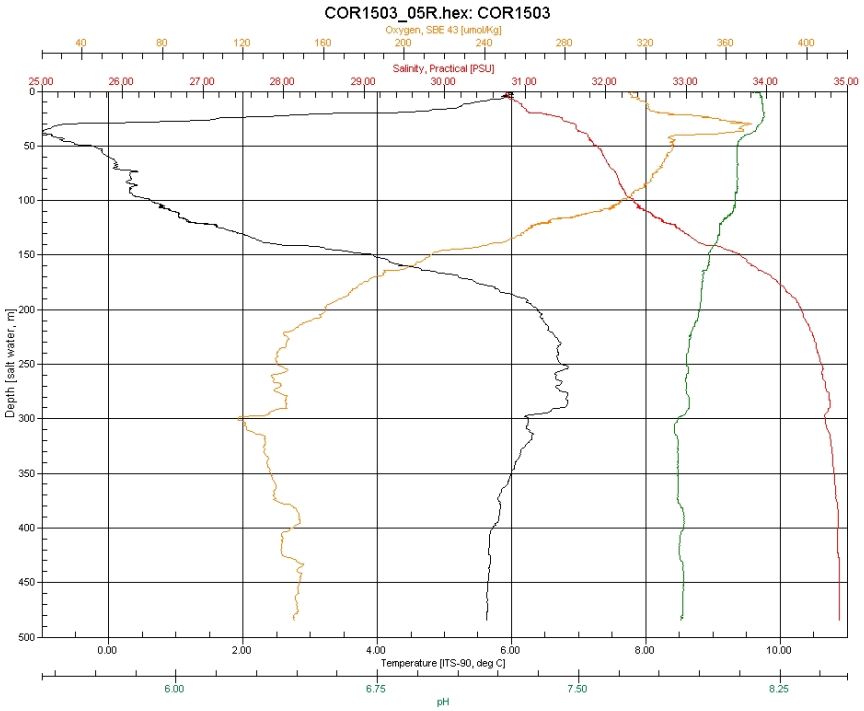


Figure 13. COR1503-05 CTD profile.

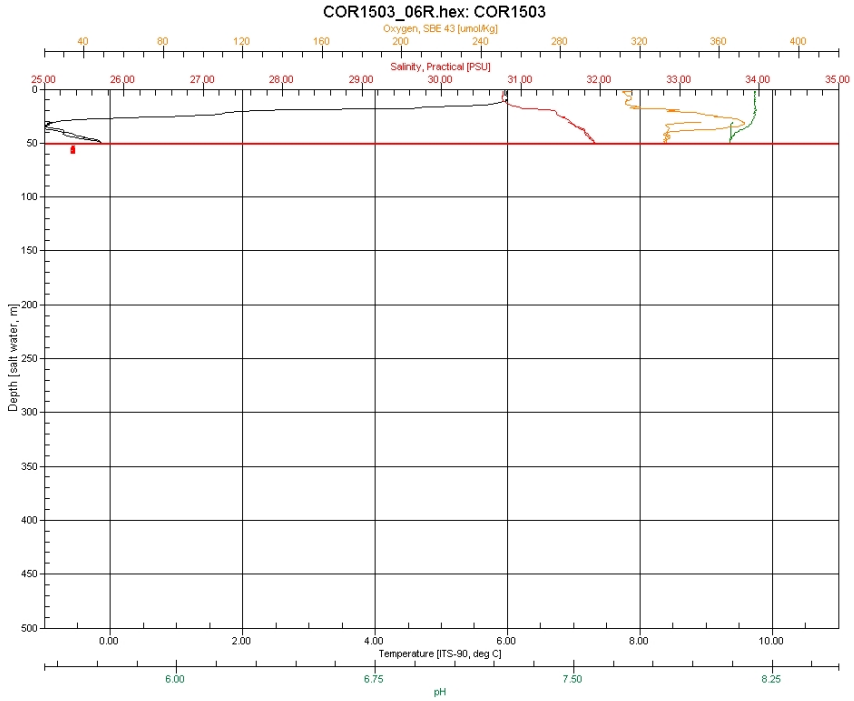


Figure 14. COR1503-06 CTD profile.

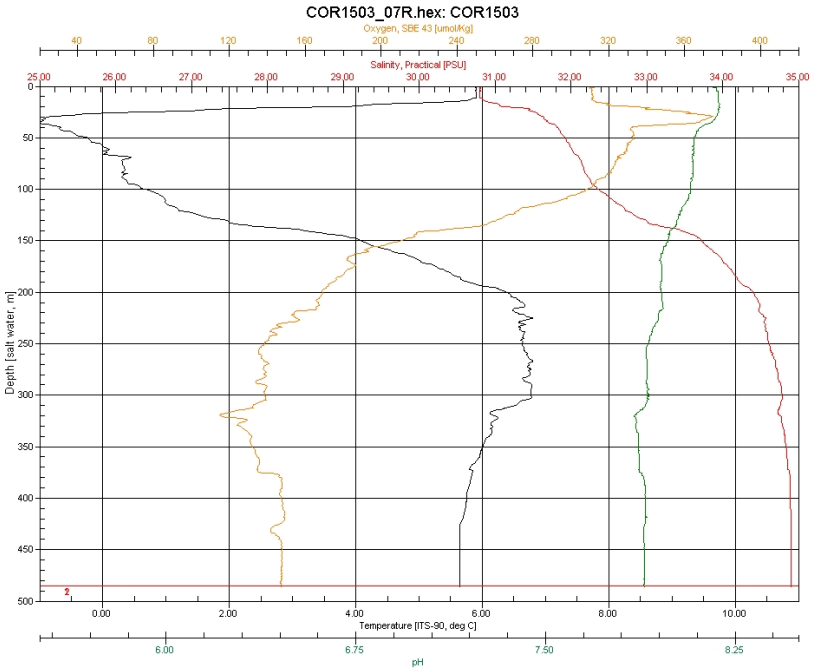


Figure 15. COR1503-07 CTD profile.

# Appendix V – Van Veen grab samples

Figure 16. COR1503-BV01 picture (sediments for Alexandra Rao).


Figure 17. COR1503-BV02 pictures.

Figure 18. COR1503-BV03 pictures.

Figure 19. COR1503-BV04 and -BV05 pictures.

# Appendix VI – Box cores


Figure 20. COR1503-01BC pictures.

# Appendix VII – Piston and trigger weight cores

## A. Sample location on seismic profiles

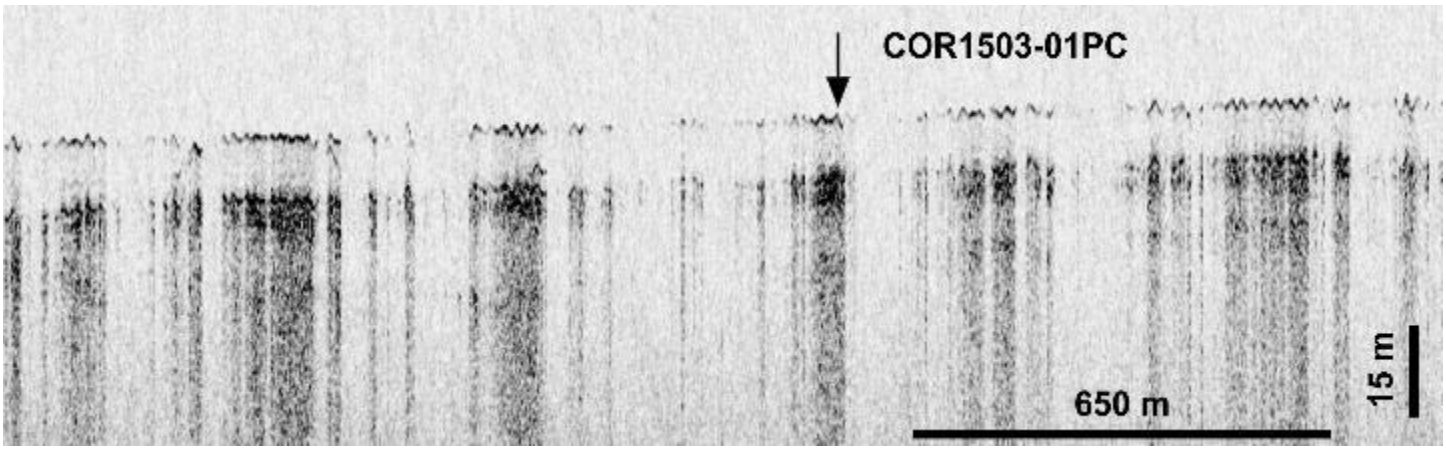


Figure 21. COR1503_001PC (and 001TWC) location on seismic profile.

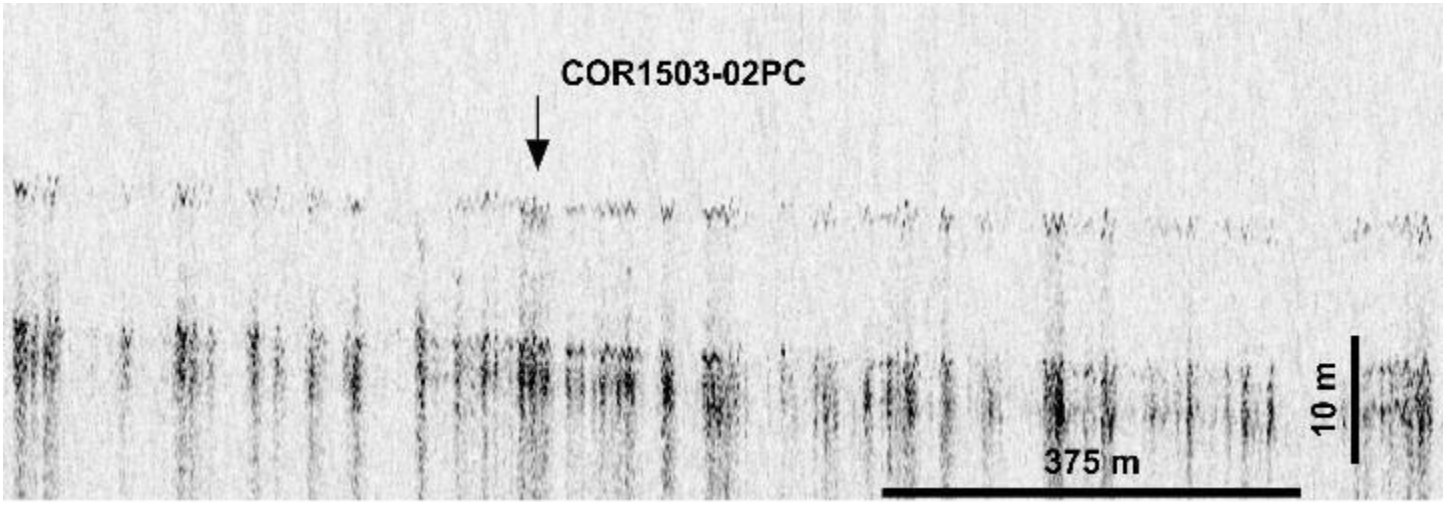


Figure 22. COR1503_002PC (and 002TWC) location on seismic profile.

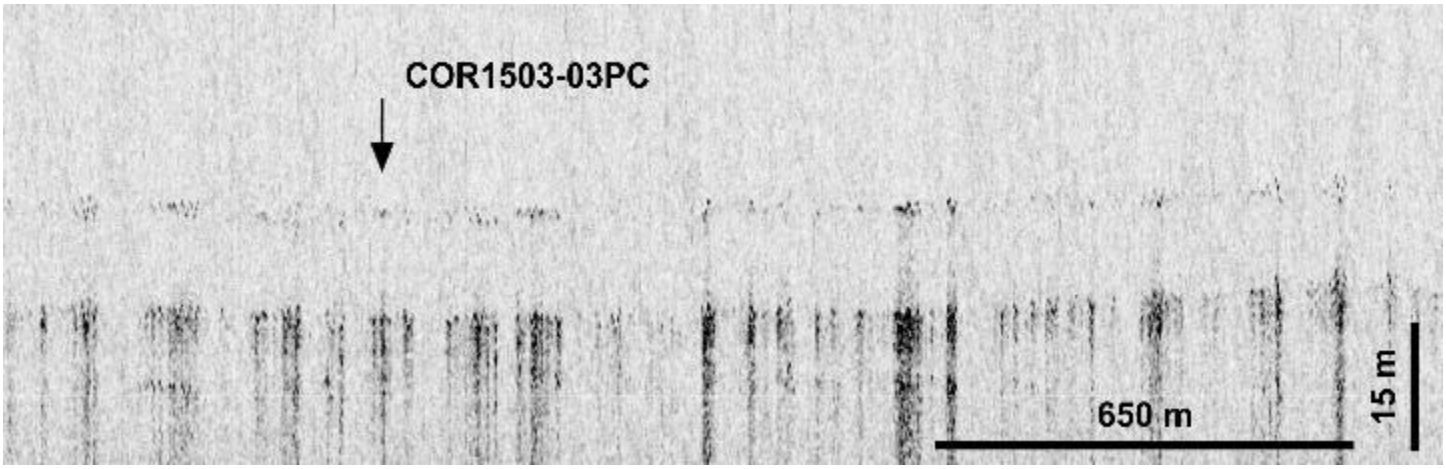


Figure 23. COR1503_003PC (and 003TWC) location on seismic profile.

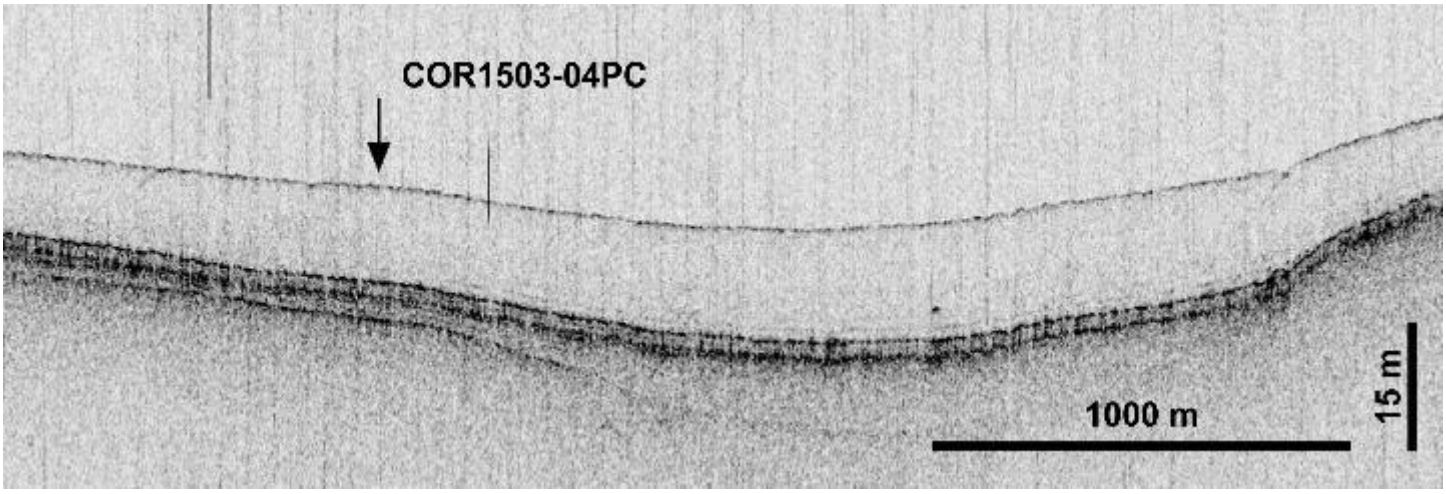


Figure 24. COR1503_004PC (and 004TWC) location on seismic profile.

## B. Sample pictures


Figure 25. COR1503-01PC (and 01TWC) pictures.

Figure 26. COR1503-02PC (and 02TWC) pictures.

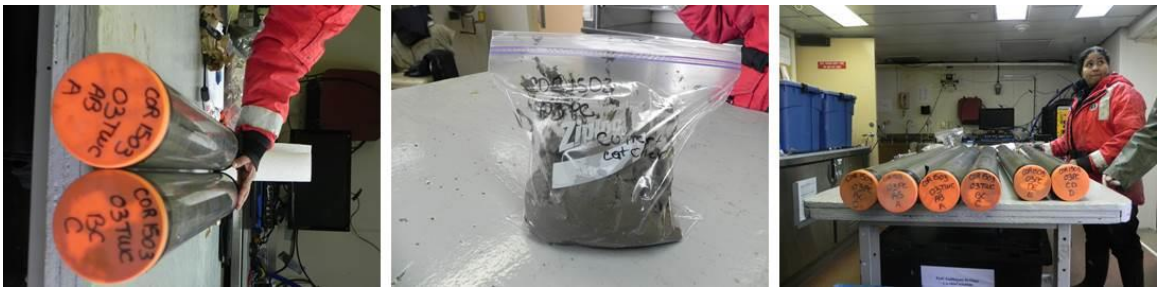

Figure 27. COR1503-03PC (and 03TWC) pictures.

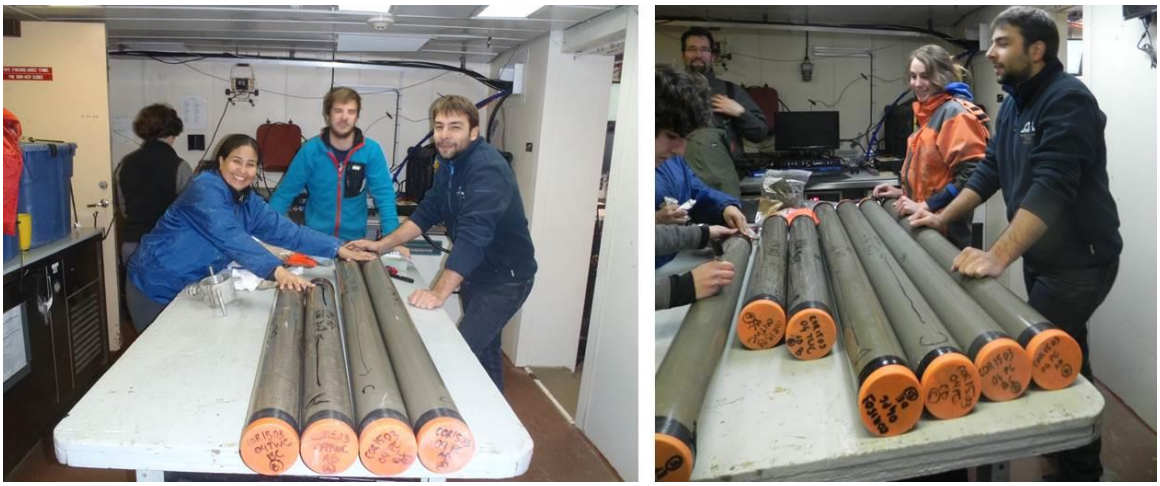

Figure 28. COR1503-04PC (and 04TWC) pictures.