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2017CORIOLIS expedition: geological investigation of seabed seeps and deglacial processes in the Sydney Basin, offshore Nova Scotia, June 24–July 6, 2017

A. Normandeau

2017

Celebrating 175 yrs

Canada

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2017CORIOLIS expedition: geological investigation of seabed seeps and deglacial processes in the Sydney Basin, offshore Nova Scotia, June 24–July 6, 2017

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Publications in this series have not been edited; they are released as submitted by the author.

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Acknowledgments

On behalf of the scientific staff of the *2017CORIOLIS* cruise, the Geological Survey of Canada (Atlantic) at BIO, the Nova Scotia Department of Energy and the University of Calgary, I would like to thank the Commanding Officer Albert Spears, the deck crew led by boatswain Mikel Dufour as well as the entire ship's complement for continuous support in the execution of the scientific objectives. Additionally, Brian Todd is thanked for reviewing this cruise report.

- *Alexandre Normandeau, Chief Scientist, 2017CORIOLIS*

Introduction

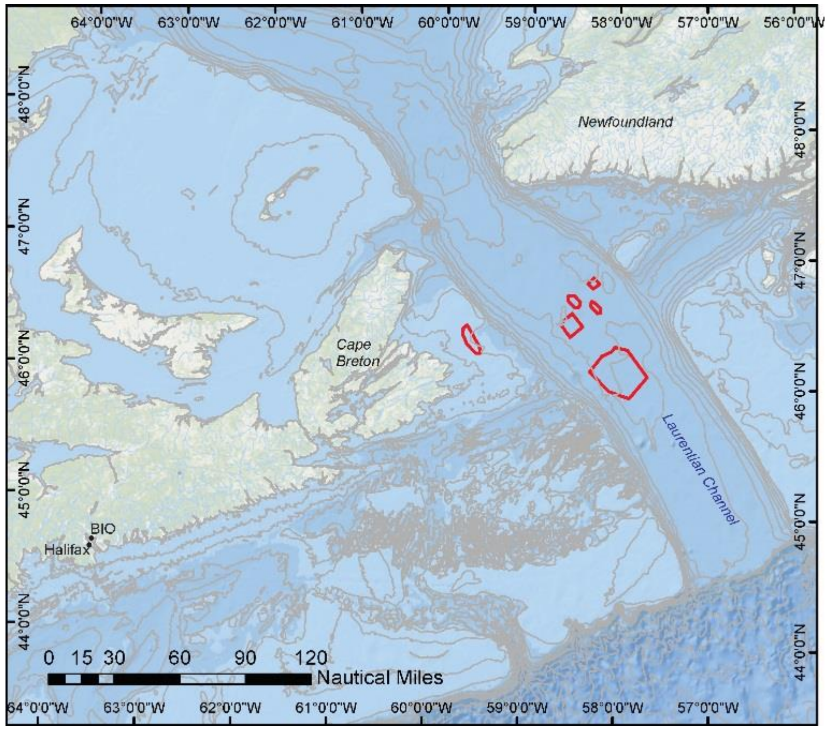

Figure 1: Location of the study area. Red polygons are areas that were investigated during the *2017CORIOLIS* cruise.

The *2017CORIOLIS* cruise was a joint mission between the Geological Survey of Canada (GSC), the Nova Scotia Department of Energy (NSDOE), the University of Calgary and Genome Canada. The study area is located in the Sydney Basin, mostly in the Laurentian Channel, Gulf of St. Lawrence, between Cape Breton (Nova Scotia) and Newfoundland (Fig. 1).

Recent multibeam sonar seafloor mapping accomplished by the Department of Fisheries and Oceans (DFO) revealed the presence of numerous pockmarks on the seabed of the Laurentian Channel that could represent active hydrocarbon seeps. These hydrocarbon seeps are relatively common features in petroleum basins around the world and the sampling of their sediment informs on hydrocarbon source and migration pathways. Additionally, the recent seafloor mapping revealed the presence of large moraines put in place during the last deglaciation. These moraines have not been properly dated due to a lack of sediment cores in the region. The lack of multibeam sonar bathymetry data in parts of the region also limits our understanding of geohazards on the sidewalls of the Laurentian Channel. Therefore, the objectives of this cruise were to:

1) Investigate the presence and activity of hydrocarbon seeps on the seabed and sample its sediment for geochemical analysis;
2) Examine the timing and pattern of retreat of the ice margin in the Laurentian Channel;
3) Assess the presence of geohazards on the margin of the Laurentian Channel that could limit the siting of submarine infrastructures;
4) Understand the microbiology of bacteria living in the sediments.

In order to determine the most appropriate areas for sampling, a multidisciplinary approach was applied which utilized all available multibeam sonar and sub-bottom geophysical data as well as a real-time assessment of seabed and water column anomalies using a water-column echosounder.

The R/V *Coriolis II*

The R/V *Coriolis II* (Fig. 2) is a 50 m-long ship built in 1990 owned by Reformar. The vessel contains a 21 m^2 dry lab, a 21 m^2 wet lab and has a capacity of 28 people. For the *2017CORIOLIS* cruise, 14 scientists and 14 crew members were on board. The ship is equipped with two mulitbeam sonar echosounders, an EM-2040 for shallow depths (≤ 400 m) and an EM-302 for deeper waters. It is also equipped with a Simrad EK-60 water column echosounder, and Edgetech X-Star and Knudsen sub-bottom profilers. For coring operations, it is equipped with a 9 m-long piston corer along with 1.5 and 3 m gravity corers (used as trigger weight corers or independently), as well as a multicorer. The laboratories have a fume hood and two -80° C freezers, although one of them was not functional during the *2017CORIOLIS* cruise.

Figure 2: The R/V *Coriolis II* (source: Reformar)

Participants

Scientific participants of the 2017CORIOLIS cruise were from the Geological Survey of Canada (Atlantic), Aptec and the University of Calgary (Table 1, Fig. 3).

Table 1: Participants of the *2017CORIOLIS* cruise

Surname	Given name	Organization	Role
Normandeau	Alexandre	GSC-A	Chief Scientist
Jarrett	Kate	GSC-A	Lab leader
Patton	Eric	GSC-A	Navigation
Robertson	Angus	GSC-A	Core technician
Bentley	Jeremy	GSC-A	Core technician
MacIntyre	Makeala	GSC-A	Core processing
Ouellette	Danika	GSC-A	Core processing
Campbell	Lori	GSC-A	Core processing
Pambianco	Chiara	GSC-A (volunteer)	Core processing
Webb	Jamie	Aptec	Geochemist
Gittins	Daniel	U. Calgary	Geomicrobiology
Li	Carmen	U. Calgary	Geomicrobiology
Stacey	Deidra	U. Calgary	Geomicrobiology
Rattray	Jayne	U. Calgary	Geomicrobiology

Figure 3: Participants of the *2017CORIOLIS* cruise. From left to right: Chiara Pambianco, Danika Ouellette, Jayne Rattray, Kate Jarret, Makeala MacIntyre, Julien Desrochers (CIDCO), Eric Patton, Jamie Webb, Lori Campbell, Jeremy Bentley, Carmen Li, Daniel Gittins, Deidra Stacey, Alexandre Normandeau and Angus Robertson.

Summary of Activities

The *2017CORIOLIS* cruise started at the Bedford Institute of Oceanography (BIO), where mobilization took place. Mobilization required the removal of Reformar's laboratory container and its replacement with a refrigerated container (reefer). The core processing laboratory equipment was also installed during that period. It included a core splitter, core photography table, a spectrophotometer, a constant volume and shear strength table, a gas analysis room and a geomicrobiology analyzes table. Following the mobilization, a piston coring test was performed in the Bedford Basin in order to familiarize the coring technicians with the R/V *Coriolis II* equipment.

The cruise was separated into six areas of interest (Fig. 4) which were defined based on the NSDOE's seismic interpretations. These areas coincided with areas of interest for the GSC-A in terms of paleoenvironmental studies. Zones 1, 2 and 3 were located on the Newfoundland side of the Laurentian Channel. The seafloor had been mapped by the Department of Fisheries and Oceans (DFO). Therefore, sampling locations were selected prior to the cruise in these zones. On the other hand, no data were available in zones 4, 5 and 6, thereby requiring multibeam sonar seafloor mapping surveys to be accomplished in those regions. For these reasons, nighttime operations were devoted to the mapping of zones 3 and 4 in the Laurentian Channel while daytime operations began with the sampling of zones 1, 2 and 3 (Table 2). Following the first three days of sampling, a large portion of zones 4 and 5 were mapped, allowing sampling locations to be selected.

Sampling consisted of piston coring, gravity coring and grab sampling. Most of the piston coring targeted pockmarks with evidence of gas in the sub-bottom data (e.g., wipeouts). These cores were split and described on board the ship. Two cores were collected for paleoenvironmental work, one on the Laurentian moraine (14PC) and another where deglacial sediments could be penetrated with the piston core (25PC). These cores were not split on board and were kept for the standard suite of analysis in the GSCA core processing facility at BIO. In some cases, duplicate and triplicate gravity cores were collected from the port frame for geomicrobiology purposes.

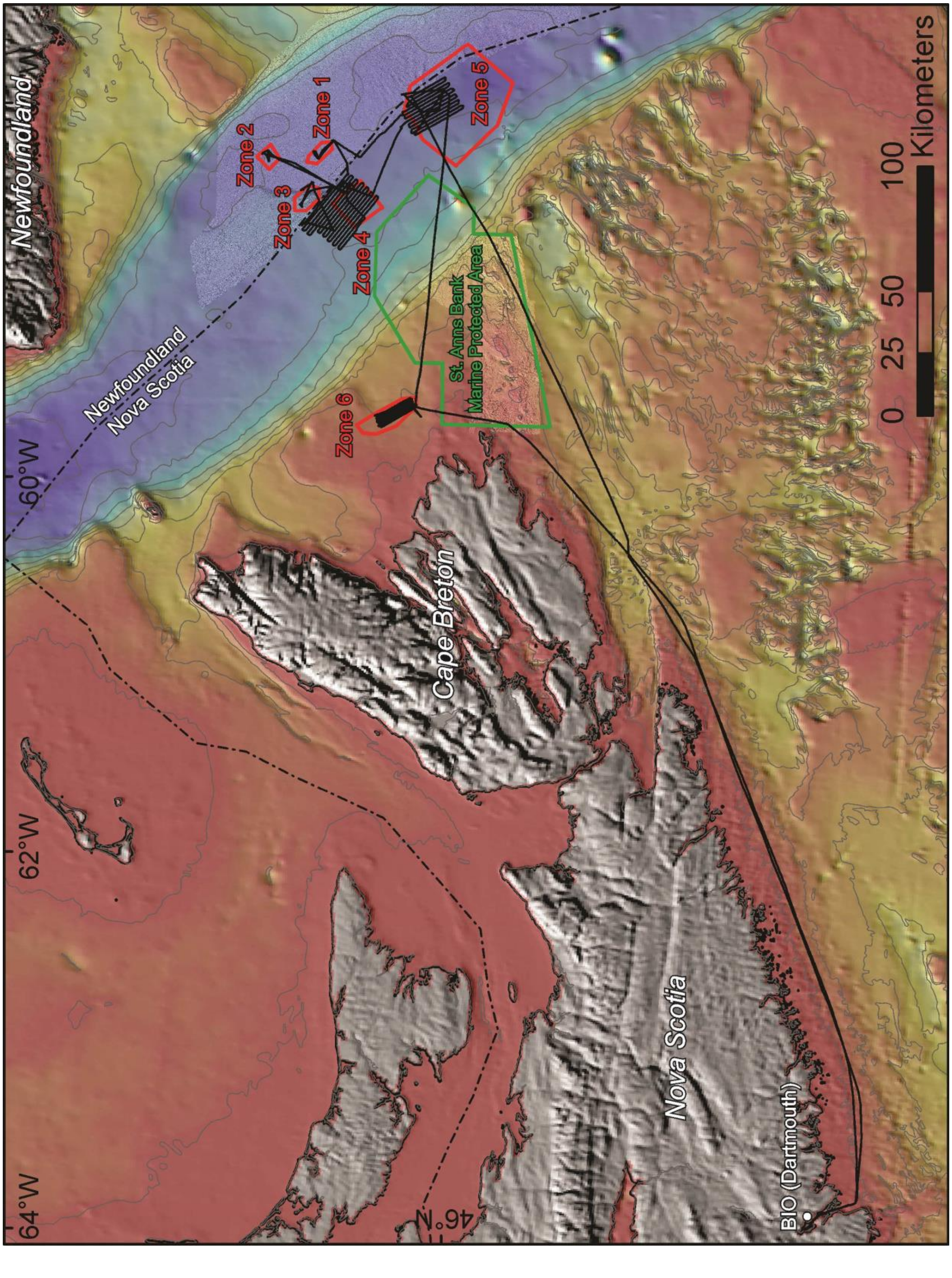
Newfoundland
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
St. Anns Bank
Marine Protected Area
Newfoundland
Nova Scotia
60°W
62°W
64°W
46°N
Cape Breton
Nova Scotia
BIO (Dartmouth)
0 25 50 100
Kilometers

Table 2: Detailed schedule of the cruise.

Date	Time	Location	Activity	Coring	Surveys	Notes
June 24	7:00 – 16:00	BIO	Mobilization			
June 25	8:00 – 16:00	BIO	Mobilization			
June 26	8:00	BIO	Mobilization			
	13:00	Bedford Basin	Engine, track point and piston coring test			
	18:30	Transit	Transit towards the Laurentian Channel			
June 27	00:00	Transit	Hydroacoustic surveys		EM2040, EK-60, 3.5 kHz,	
	18:30	Laurentian Channel (zone 5)	Hydroacoustic surveys		EM302, EK-60, 3.5 kHz	
June 28	07:30	Laurentian Channel (zone 1)	Coring operations	2 PC, 2 failed MC		Lost MC components. MC could no longer be used.
	19:30	Laurentian Channel (zone 4)	Hydroacoustic surveys		EM302, EK-60, 3.5 kHz	
June 29	7:00	Laurentian Channel (zone 2)	Coring operations	2 PC, 2 GC		Broke the PC holds and needed some welding done.
	19:00	Laurentian Channel (zone 4)	Hydroacoustic surveys		EM302, EK-60, 3.5 kHz	
June 30	7:00	Laurentian Channel (zone 3)	Coring operations	3 PC, 2 GC		
	17:30	Laurentian Channel (zone 4)	Hydroacoustic surveys		EM302, EK-60, 3.5 kHz	
July 1	7:00	Laurentian Channel (zone 4)	Coring operations	3 PC, 2GC		
	19:00	Laurentian Channel (zone 5)	Hydroacoustic surveys		EM302, EK-60, 3.5 kHz	
July 2	7:00	Laurentian Channel (zone 5)	Coring operations	3 PC, 3GC		
	20:00	Laurentian Channel (zone 5)				Due to weather conditions, it was decided we would not survey during the night
July 3	8:00	Laurentian Channel (zone 5)	Coring operations	2 PC, 2 GC		

	16:00	Transit	Transit towards zone 6		EM302, EK-60, 3.5 kHz	
	22:00	Zone 6	Hydroacoustic surveys		EM2040, EK-60, 3.5 kHz	
July 4	08:30	Zone 6	Coring operations	3 failed GC		Broke A-Frame. PC was no longer an option.
	15:00	Zone 6	Hydroacoustic surveys		EM2040, EK-60, 3.5 kHz	
July 5	8:00	Zone 6	Coring operations	2 failed GC, 2 Van Veen		
	12:00	Transit	Transit towards BIO		EM302, EK-60, 3.5 kHz	
July 6	10:30	BIO	Arrival at BIO			

Multibeam echosounder (***EM302 or EM2040***), EK-60, Chirp 3.5 kHz, Piston coring (***PC***), Gravity coring (***GC***), Multi-coring (***MC***).

Daily Narrative

(All times in Atlantic Daylight Time)

JD 175, Saturday, June 24, 2017

Mobilization started at 0700 and the R/V *Coriolis II* arrived at 0800. The tilt load arrived at 1000, removed Reformar’s laboratory container, and replaced it by GSC’s reefer. The core splitter and the core liner rack were also brought on board.

JD 176, Sunday, June 25, 2017

Mobilization started at 0800. The laboratory equipment was installed in the wet and dry laboratory, as well as the TrackPoint and other major equipment. Mobilization was mostly completed during the afternoon.

JD 177, Monday, June 26, 2017

The vessel departed BIO at 1300. An engine room test for the R/V *Coriolis II* was conducted and the multibeam sonar, Edgetech sub-bottom profiler and the EK-60 were tested in Bedford Basin. From 1415 to 1630, a test deployment of the piston corer was undertaken to familiarize the deck crew with the procedures. From 1630 to 1715, a TrackPoint test was performed and the vessel returned to BIO. While returning to dock, a fire drill was conducted and the ship was back at the dock by 1800. The vessel departed BIO for the Laurentian Channel at 1830. The weather was windy, with swells of 1–2 m and the science staff then realized that the ship rolls quite a bit.

JD178, Tuesday, June 27, 2017

The vessel transited overnight towards zone 5, where the first survey lines were to be accomplished, and arrived at 1830. During the transit, a multibeam sonar test line was performed at 8 knots to evaluate the possibility of running the lines at that speed. Following the test, it was decided we would run the lines at 7 knots. The chirp settings were also tested during the transit. The Hull_2_12_20FM pulse was used for shallow water and was modified to Hull_2_5_50WB for deeper waters at 1800. At 1835, a SVP was deployed from the CTD Rosette winch on the port side and was recovered at 1900. We started recording the multibeam sonar, chirp and EK-60 data in zone 5 at 1915.

JD 179, Wednesday, June 28, 2017

At 0500, the multibeam sonar lines were stopped and we progressed north towards the coring sites in zone 1. At 0700, we arrived at the southern end of the zone and began a short survey of pockmarks in order to select suitable coring targets. At 0835, we arrived on the first coring site (01PC) and the piston corer was deployed. At 0915, it hit bottom and was back at the surface at 0930. At 1030, the multi-corer was deployed (02MC) from the port frame and was back on deck at 1100. Unfortunately, it did not trigger and was thus empty; the safety pin had not been removed. At 1115, the multi-corer was redeployed (02MC) and was back on deck at 1135. This time, none of the liners stayed on the frame. A malfunction in the multi-corer system led to its loss in the Laurentian Channel; it was thus decided to no longer use the multi-corer. We transited towards the second coring site (03PC) and at 1300, the piston corer was ready on deck. It hit bottom at 1400 and was back on deck at 1430. The third liner imploded in the corer, which led to a difficult recovery. It took 2 hours to remove the liner from the barrels. At 1630, it was decided to take a gravity core at the third site (04GC) instead of another piston core because of time constraints. A minor incident on deck led to the delaying of the gravity core until after dinner. At 1800, the gravity corer was deployed and recovered at 1840. We then started to sail towards zone 4 for the hydroacoustic surveys. At 1940, a SVP was collected and surveys began at 2000.

JD 180, Thursday, June 29, 2017

The survey lines were stopped at 0500 in order to transit towards zone 2. At 0640 survey lines over the targets began and at 0800, we were above the first target of the day (05PC), which showed faint wipeout below a pockmark on the chirp profile. At 0900, the crew momentarily lost control of the piston corer on deck and it broke one of the holders. Operations ceased on deck while the holder was welded. At 1100, welding was complete and the piston coring operations resumed. At 1120, the piston corer touched bottom and was back up on deck at 1130. At 1230, while the liners were being removed from the piston corer, a gravity core was collected from the port frame until 1315 (06GC). At 1430 the piston corer was redeployed on site 07PC and at 1530 it was back on deck. At 1615, the gravity corer was deployed from the port frame (08GC) while the liners were removed from the piston corer, which lasted until 1645. At 1700, we began sailing back towards zone 4 where the surveys took place over night. At 1915, a SVP was performed and at 1940, the surveys began.

JD181, Friday, June 30, 2017

The surveys stopped at 0630 and we headed towards zone 3 for a site survey across pockmarks. The site survey started at 0715. Unfortunately, the site survey did not show any sign of gas escape in any of the selected sites. We nevertheless headed towards a site that appeared more promising (09PC). We arrived on site at 0815 and at 0900 the piston corer was deployed and hit bottom at 0905. At 1040, it was back on deck and ready for a second core. However, since the operations would overlap with lunchtime, it was decided to collect two gravity cores before lunch, which were back on deck at 1130 (10GC-11GC). At 1200, the piston coring operations resumed and hit bottom at 1240 (12PC). While preparing the piston corer for a third core, a gravity core was collected on the same site (13GC), which finished at 1330. At 1430, a third piston core (14PC), this time aiming the Laurentian moraine, began. At 1500, the piston corer hit bottom. During the upward movement, the trigger weight core intertwined with the piston corer, which delayed recovery. At 1700, the piston coring operations were finished and we started transiting towards zone 4. At 1900, we stopped for a SVP and we were back on track for the survey lines at 1930.

JD 182, Saturday, July 1, 2017

We started transiting towards the site survey at 0615 where we passed over 20+ pockmarks. We arrived at the first site at 0815 which showed a pockmark with an iceberg-scoured unit less than a meter below the seafloor. The piston corer (15PC) hit bottom at 0910 and was back on deck at 0945, after untangling the TWC wire. During the recovery of the liners, a gravity core (16GC) was collected from the port frame at 1005. In order to preserve the surface, the gravity corer's liner was removed vertically. We then transited towards the second site and did a gravity core (17GC) upon arrival since the piston corer could not be performed before lunch. The gravity corer was back on deck at 1125. At 1200, the piston coring operations resumed and hit bottom at 1230 (18PC). By 1300, the piston corer was back on deck and a gravity core was collected during the recovery of the liner (19GC). We transited towards the third site and by 1500, a problem with the hydraulic winches delayed the transit by 75 minutes. At 1615, the problem was resolved and we were ready for the third piston core of the day (20PC). At 1635, it hit bottom and came back up at 1645. At 1700, we started transiting towards zone 5, which was a bit less than 2 hours away. A SVP was done at 1930 and the surveys started for the night.

JD 183, Sunday, July 2, 2017

At 0700, we started transiting towards the first site of the day and arrived at 0815. Piston coring operations began and it hit bottom at 0910 (21PC). While we recovered the liners from the piston corer, the gravity corer (22GC) was deployed from the port frame and hit bottom at 0955. We started transiting towards the second site of the day and deployed the gravity corer (23GC) since the piston corer could not be deployed before lunch. Upon recovery, the core catcher fell on deck along with the sediments contained in the liner. At 1230, operations on deck resumed and at 1400, the piston corer was back on deck (24PC). The liner was stuck in the barrels and we needed to remove all the barrels in order to recover the liners. A third piston core (25PC) was collected and hit bottom at 1530. Upon recovery, the trigger weight core and the piston core wires were tangled. At 1720, the piston corer was back on deck. At 1830, the gravity corer (26GC) was deployed from the port frame and was back up at 1850. At 1915, a SVP was deployed and the surveys began at 2000. However, the wave height increased during the evening and the ship was now rolling a lot. It was decided that no one would be allowed on deck during the night; we brought all the cores from the reefer into the wet lab. After considerations with the science staff, it was also decided to not run the multibeam lines during the night because the ship would roll too much for the staff to process the cores safely. We thus stayed on position all night while the core processing was being done.

JD184, Monday, July 3, 2017

At 0800, we were ready to deploy the piston corer on the same site as the previous day. It was deployed at 0915 and was back up by 0940 (27PC). During the recovery of the liner, the gravity corer was deployed from the port frame (28GC) and hit bottom at 1030. A second gravity core was deployed and hit bottom at 1110 (29GC). At 1300, the piston corer was ready to be deployed on the same site (30PC). At 1315, deployment of the piston corer began and hit bottom at 1325. By 1500, all the equipment was secured on deck we started transiting towards zone 6. We arrived at zone 6 at 2130 and started the survey lines for the night.

JD185, Tuesday, July 4, 2017

At 0500, the chirp malfunctioned and had to be stopped. It was restarted at 0545. At 0700, the survey lines were stopped and we started the site surveys over a field of small (≤ 20 m in diametre) pockmarks. The sub-bottom data did not show any indication of active pockmarks and we decided to core the largest ones. The survey lines were finished at 0830 and we were on the first site of the day at 0845. During the initial deployment of the piston corer (31PC), a problem with the hydraulics was reported. A piece of wood had been placed inadvertently near the A-frame and broke the hydraulic pipes. The crew tried to resolve the problem but at 1340, it was decided that piston coring operations would no longer be an option until we got back to shore for repairs. Since it was the last day before departure for BIO, we decided instead to collect gravity cores during the afternoon. We installed the 10-foot pipe on the gravity corer for port-frame operations. Two deployments on site 32 and one on site 33 were made and were unsuccessful because of the sandy bottom and the lower speed of the winch on the port frame. After these unsuccessful attempts, we decided to move on and map the seafloor for the rest of the afternoon starting at 1515.

JD 186, Wednesday, July 5, 2017

The morning was dedicated to gravity coring (34GC and 35GC) but, as the previous day, they were unsuccessful. Two grab samples (36VV and 37VV) were instead collected and at 1100, we started sailing back towards BIO while recording multibeam sonar, chirp and EK-60 data.

JD187, Thursday, July 6, 2017

The vessel arrived at BIO at 1030.

Preliminary Results

Hydroacoustic data

The *2017CORIOLIS* cruise allowed the collection of ~2150 km of 3.5 kHz sub-bottom profiler data, multibeam echosounder and water column imagery (EK-60) including the transits. Excluding the transits, 1300 km of data were collected for the study of seabed seeps and the timing of retreat of the ice-margin in the region.

The multibeam sonar bathymetry surveys targeted the Laurentian moraine which, in combination with DFO's data, is now 60% mapped. Numerous iceberg scours are present both on, and adjacent to, the moraine (Fig. 5–6). Iceberg scours running parallel to the moraine's front were also observed (Fig. 6). In zone 5, numerous pockmarks were mapped in a large depression devoid of iceberg scours (Fig. 6–7). The continuum between the Laurentian moraine and the large depression shows a constant diminution in backscatter strength (Fig. 5A). This trend is likely reflective of the coarser grain-size and rougher seafloor on the moraine and the smoother seafloor in the large depression (Fig. 7).

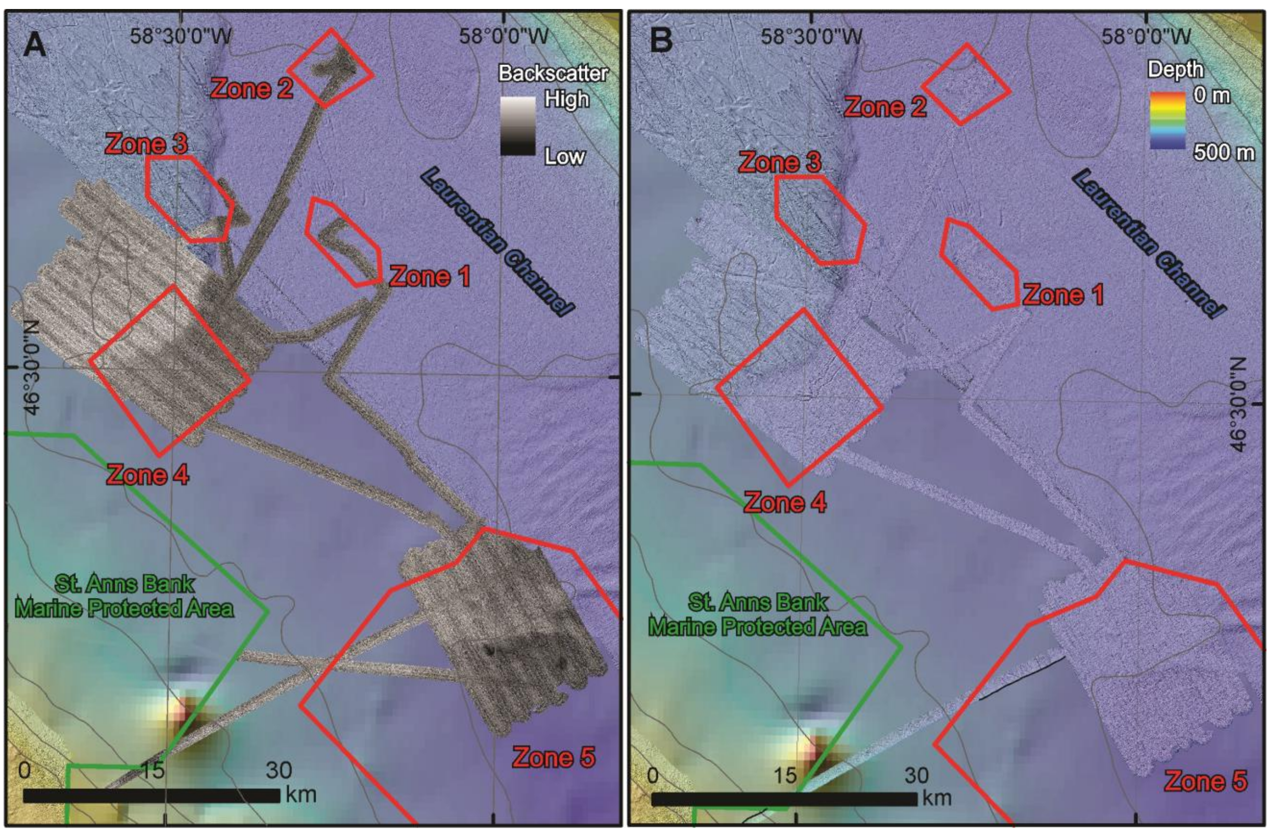

Figure 5: Backscatter (A) and multibeam (B) data collected in the Laurentian Channel during *2017CORIOLIS* cruise

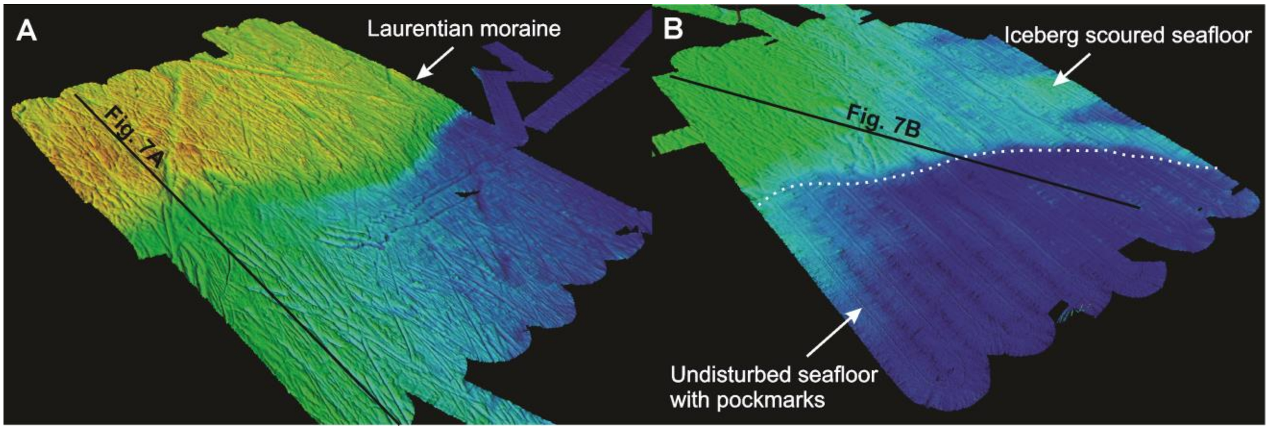

Figure 6: 3D perspective of the newly acquired multibeam data illustrating A) the Laurentian moraine (zone 4) and B) undisturbed seafloor near zone 5.

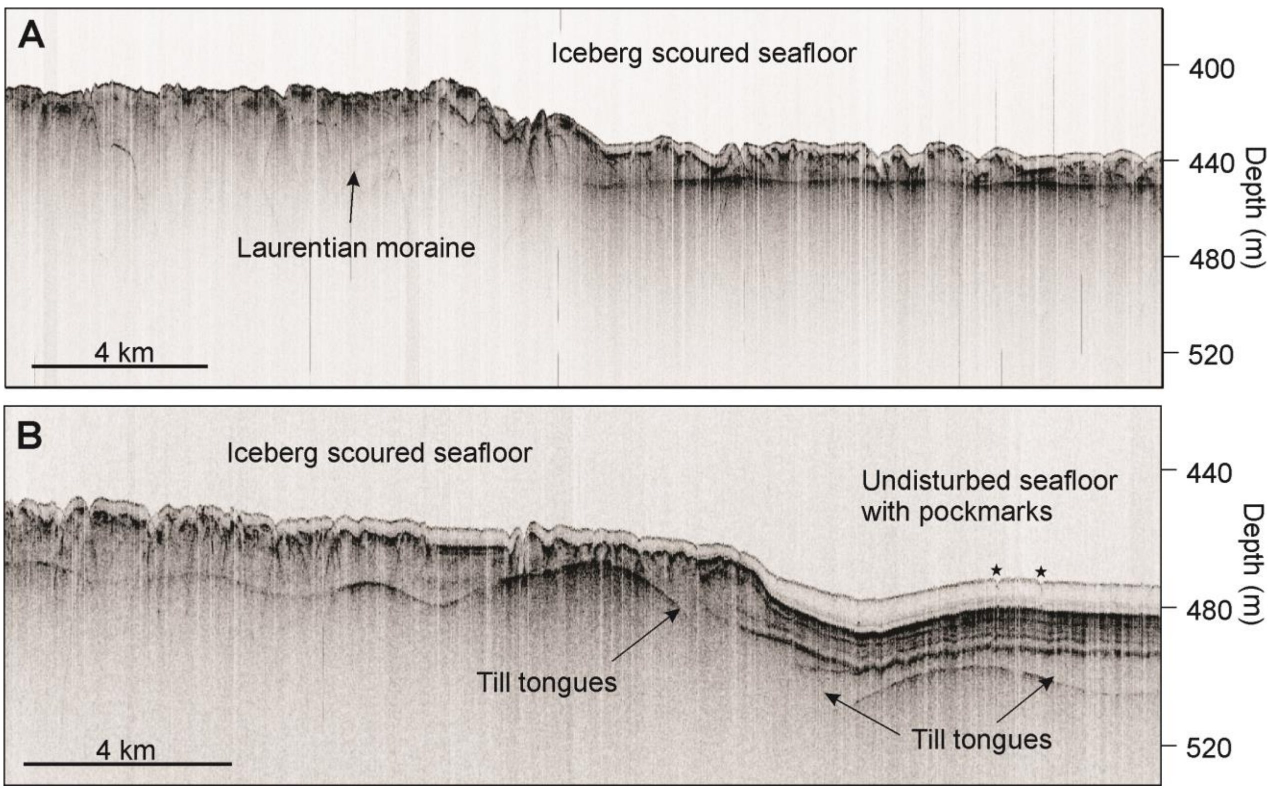

Figure 7: A) Chirp profile over the Laurentian moraine; B) Chirp profile over zone 5 illustrating the distinction between iceberg-scoured and undisturbed seafloor with pockmarks. Stars represent pockmarks.

Offshore Cape Breton, a small area of the seafloor (Fig. 8) was also mapped and revealed the presence of small channels following the outline of bedrock outcrops and depocentres along with ≤ 20 m wide pockmarks (Fig. 9). Pockmarks were not clearly resolved on the sub-bottom profiles. The backscatter imagery allows the clear identification of bedrock relative to sediment over the region where the higher intensities are related to bedrock (Fig. 8).

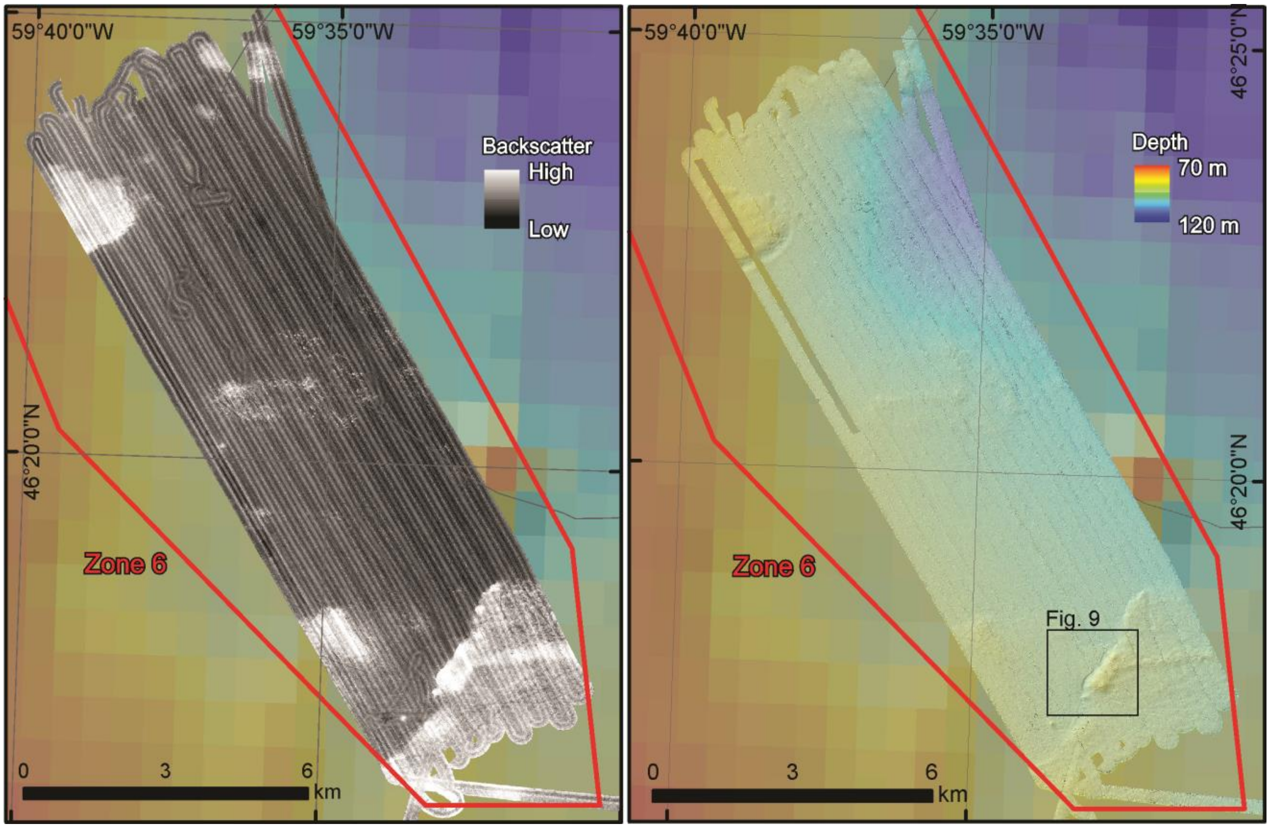

Figure 8: Backscatter (A) and multibeam (B) data collected near Cape Breton during the *2017CORIOLIS* cruise

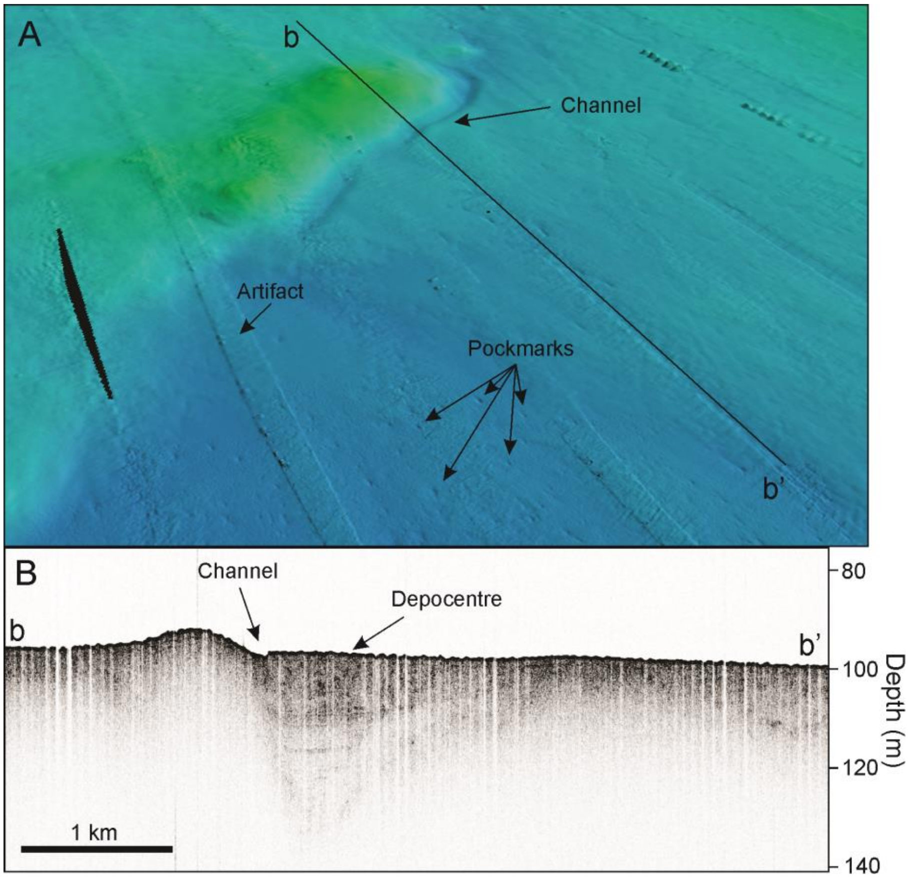

Figure 9: A) 3D view of a channel near a bedrock high; B) Sub-bottom profile of the channel and a depocentre.

Sediment samples

A total of 37 sample operations were accomplished during the *2017CORIOLIS* cruise. Of these 37 operations, 31 were successful and recovered sediments. A total of 15 piston cores, 14 gravity cores and 2 grab samples were collected. Recovery length for the piston cores were typically ~ 8 m long whereas the gravity core lengths were typically 1 m long. A total of 110 m of piston core, 37.5 m of trigger weight core and 14.5 m gravity core were recovered. Detailed sample descriptions are provided in Table 3.

Table 3: Sampling during the *2017CORIOLIS* cruise

Name	Lat (°N)	Long (°W)	Length	Depth	Day	Target
2017CORIOLIS-0001PC	46.660244	-58.23916	757.5	459	Jun-28	pockmark
2017CORIOLIS-0002MC	46.660434	-58.23884	0	459	Jun-28	pockmark
2017CORIOLIS-0003PC	46.642295	-58.268038	833	458	Jun-28	pockmark
2017CORIOLIS-0004GC	46.591801	-58.177758	131	457	Jun-28	pockmark
2017CORIOLIS-0005PC	46.82201	-58.238614	851	466	Jun-29	pockmark

2017CORIOLIS-0006GC	46.830179	-58.260992	142.5	466	Jun-29	pockmark
2017CORIOLIS-0007PC	46.830273	-58.260104	751	469	Jun-29	pockmark
2017CORIOLIS-0008GC	46.83069	-58.259632	131	466	Jun-29	pockmark
2017CORIOLIS-0009PC	46.697807	-58.432022	832.5	458	Jun-30	pockmark
2017CORIOLIS-0010GC	46.699054	-58.430485	99	458	Jun-30	pockmark
2017CORIOLIS-0011GC	46.666336	-58.400531	74.5	454	Jun-30	pockmark
2017CORIOLIS-0012PC	46.666258	-58.400918	864	455	Jun-30	pockmark
2017CORIOLIS-0013GC	46.667186	-58.400471	105	455	Jun-30	pockmark
2017CORIOLIS-0014PC	46.661315	-58.46008	391	420	Jun-30	moraine
2017CORIOLIS-0015PC	46.54102	-58.400391	370	450	Jul-01	pockmark
2017CORIOLIS-0016GC	46.541195	-58.400988	86	446	Jul-01	pockmark
2017CORIOLIS-0017GC	46.539103	-58.41979	113	447	Jul-01	pockmark
2017CORIOLIS-0018PC	46.539206	-58.419563	622	450	Jul-01	pockmark
2017CORIOLIS-0019GC	46.539481	-58.420324	127	450	Jul-01	pockmark
2017CORIOLIS-0020PC	46.449507	-58.461736	582.5	440	Jul-01	pockmark
2017CORIOLIS-0021PC	46.196032	-57.900993	846	475	Jul-02	pockmark
2017CORIOLIS-0022GC	46.19604	-57.901202	128	475	Jul-02	pockmark
2017CORIOLIS-0023GC	46.209974	-58.011034	0	470	Jul-02	pockmark
2017CORIOLIS-0024PC	46.210366	-58.01044	872	470	Jul-02	pockmark
2017CORIOLIS-0025PC	46.223765	-58.00278	651	460	Jul-02	Deglacial sediment
2017CORIOLIS-0026GC	46.210294	-58.010697	66	460	Jul-02	pockmark
2017CORIOLIS-0027PC	46.196195	-57.900572	857.5	475	Jul-03	pockmark
2017CORIOLIS-0028GC	46.196159	-57.900549	120	475	Jul-03	pockmark

2017CORIOLIS-0029GC	46.196134	-57.90046	119	475	Jul-03	pockmark
2017CORIOLIS-0030PC	46.196085	-57.900429	682	475	Jul-03	pockmark
2017CORIOLIS-0031PC	46.285795	-59.565016	0	90	Jul-04	pockmark
2017CORIOLIS-0032GC	46.285565	-59.564839	0	95	Jul-04	pockmark
2017CORIOLIS-0033GC	46.28519	-59.561743	0	94	Jul-04	pockmark
2017CORIOLIS-0034GC	46.343766	-59.568120	0	95	Jul-05	pockmark
2017CORIOLIS-0035GC	46.302641	-59.556035	0	96	Jul-05	pockmark
2017CORIOLIS-0036VV	46.301988	-59.555177	0	97	Jul-05	pockmark
2017CORIOLIS-0037VV	46.28783	-59.558545	0	96	Jul-05	pockmark

Equipment and Procedures

Kongsberg EM302 and EM2040 hull-mounted multibeam sonar system

The R/V *Coriolis II* has two hull-mounted multibeam sonar systems: the EM302 and EM2040. The EM302 is a 30 kHz deep-water system with depth capabilities of 7000 m. It has 432 soundings per swath and can cover up to 5.5 times the water depth. The EM2040 is a shallow-water system that can be operated at 200, 300 or 400 kHz and can survey a maximum depth of ~600 m. It has 400 pings per swath and allows a coverage of 5.5 times water depth. The depth capabilities and coverage of both systems were evaluated by CIDCO prior to the *2017CORIOLIS* cruise. At 400 m, i.e., the survey depth of this cruise, the coverage is 600 m using the EM2040 and 1500 m using the EM302. Therefore, the EM302 was used to map zones 1 to 5, which allowed three times the coverage of the EM2040. Because of this choice, there was compromise on resolution where data was gridded at a 10 m-resolution instead of the finer resolution achievable with the EM2040.

An Applanix POS M/V positioned near the centre of gravity of the ship recorded the motion of the vessel and was integrated in the multibeam echosounders acquisition software (SIS). Sound velocity through the water column was obtained by using a SVP every evening. Due to time constraints with the crew, sound velocity profiles could only be done once per survey day. Fortunately, the SV profiles are not expected to vary greatly in the Laurentian Channel. The static and dynamic calibration (patch tests) had already been done on the ship and were not required for this survey.

Preliminary data were processed on the ship to verify incoming data quality and to provide updated coverage daily for science planning. The data were processed using Caris HIPS/SIPS 9.1 during the night watches and gridded surfaces were ready to view in the morning.

Overall, the system performed relatively well. Attitude artefacts appeared in smoother areas of the seafloor. The hydrographers on board could not resolve the reasons for these artefacts. These do not affect the interpretation of the data and the data overall are good for geological interpretation purposes.

Edgetech X-Star 2.1 sub-bottom profiler

Sub-bottom profiles were collected using the hull-mounted Edgetch X-Star 2.1. This sub-bottom profiler transmits FM acoustic waves at a frequency varying between 0.5 and 12 kHz, centred on 4.5 or 6 kHz. The sub-bottom profiler consists of 9 transducers acting as TX and RX. In deep waters exceeding 100 m, the Hull-50W mode was used while in shallow waters (below 100 m), the Hull_20FM mode was used. Ping rate varied between 1 and 1.5. The raw JSF data were converted to SegY following a routine conversion (see Annex 3). The SegY data were then converted into JP2 format using GSCA software and exported to SHP format for visualization in ArcGIS.

The data were generally good quality. However, heave artefacts are omnipresent in the data since there is no heave compensator with the ship's system. These heave artifacts do not alter the interpretation of the data but will be removed in post-processing. Additionally, blank spots sometimes obscured the data, which is believed to be related to cavitation at the transducers. This happened at speeds of 6–8 knots. The data were better at higher speeds (11 knots).

EK-60 echosounder

A Simrad EK-60 echosounder was used to image the water column and assess possible leaks at the seafloor. Three frequencies (38, 120 and 200 kHz) were used with different powers, pulse, pulse rate and band pass (Table 4). The data were recorded continuously with the ER60 v2.4.3 software.

Table 4: Description of the EK-60 echosounder

Frequency	Power	Pulse	Pulse rate	Band pass
38 kHz	2000W	256 us	64us	3675 Hz
120 kHz	250W	64 us	16 us	11800 Hz
200 kHz	150W	128 us	32 us	15730

Van Veen grab sampler

The Van Veen grab sampler is a rapid and simple method to collect sediment samples at the seabed (Fig. 10A). When the grab sampler touches bottom, it closes, holding surficial sediments. It can collect up to 0.008 m^3 of sediment. This sampler was used only on the last day of the cruise to recover sandy bottom sediments, when gravity cores were unsuccessful. The grab sampler performed well.

Lehigh gravity corer

The gravity corer was deployed from the port frame using 1.5 or 3 m barrels (Fig. 10B). Five ~23 kg weights were used at first but were then reduced to two since recovery was maximal. Additionally, since the aim of this corer was to collect surface sediment, there was a need to preserve the surface, which is why the weight of the corer was reduced. A second Lehigh gravity corer was used with the piston core as a trigger weight core (TWC).

Benthos piston corer

The Benthos piston corer weights 2000 kg and has a piston attached to the corer's cable, which assures the sealing of the PVC tube (Fig. 10C). When the TWC touches bottom, the trip arm triggers the descent of the piston corer into the sediments. Three 305 cm (10 ft) barrels were coupled on this piston corer, allowing a maximum core length of 9 m. The piston corer was deployed from the 9 tons stern A-Frame.

Overall, the piston corer performed very well, recovering over 8 m of sediment in many cases. Liner implosions were minimal. During the last two days of coring, a hydraulic leak was observed on the A-Frame. A hydraulic cable was damaged during the movement of the A-frame when a piece of wood was inadvertently placed near the A-Frame. The crew searched for a cable replacement but the ship did not have a spare one. Therefore, piston coring was stopped and the A-Frame could no longer be used. This was unfortunate because the seafloor was sandy and did not allow the gravity corer to penetrate the seafloor.

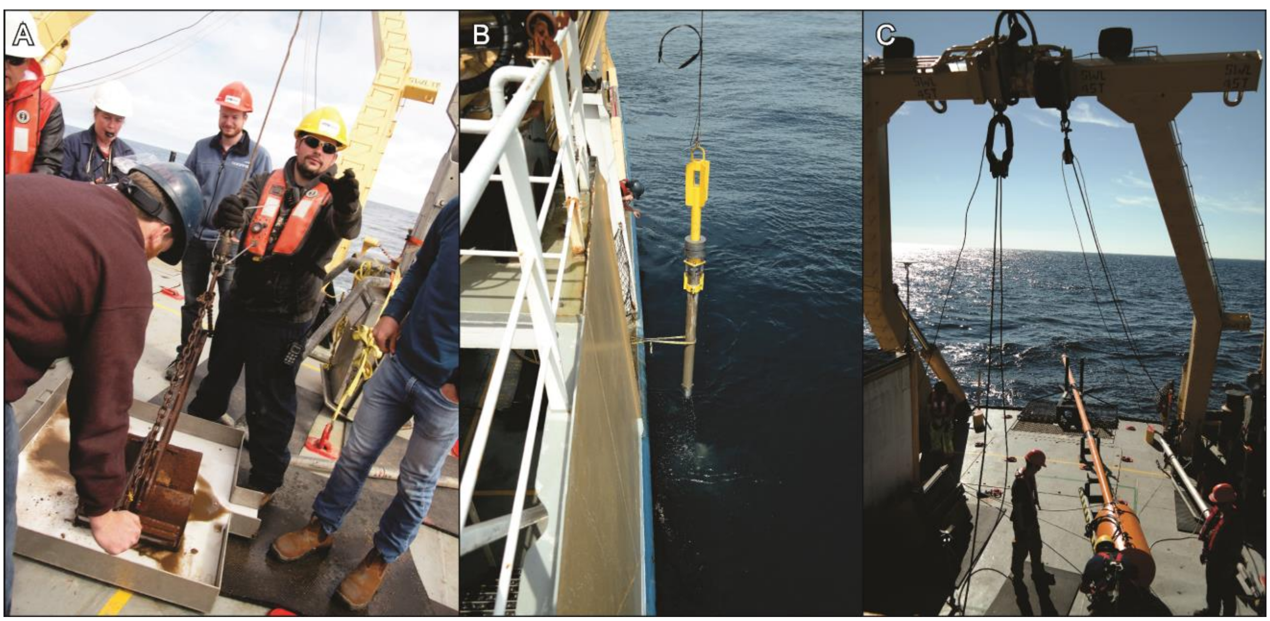

Figure 10: Coring systems used on the R/V *Coriolis II*. A) Van Veen grab sampler; B) Lehigh gravity corer from the port frame; C) Benthos piston corer from the A-frame. Photos provided by Daniel Gittins and Danika Ouellette.

Onboard core processing and subsampling

Of the 160 m of sediment cores collected, 144 m were analyzed on board while the rest were kept whole for the standard suite of analysis at the GSCA core processing facility. The cores were analyzed in a similar way to Campbell and MacDonald (2016). Cores were split longitudinally within 24 hours of being collected using the GSC-A Duits splitter (Fig. 11). The two core halves were designated as archive and working and were labelled with an up arrow, cruise number, sample number and section information. The archive half was photographed, measured for colour reflectance, and described visually. The working half was first analyzed by Jamie Webb and the University of Calgary researchers for selection of subsample locations before being measured for physical properties. The core halves were then wrapped and placed in labelled plastic D-tubes and stored at 4° C in a refrigerated container until their return to BIO.

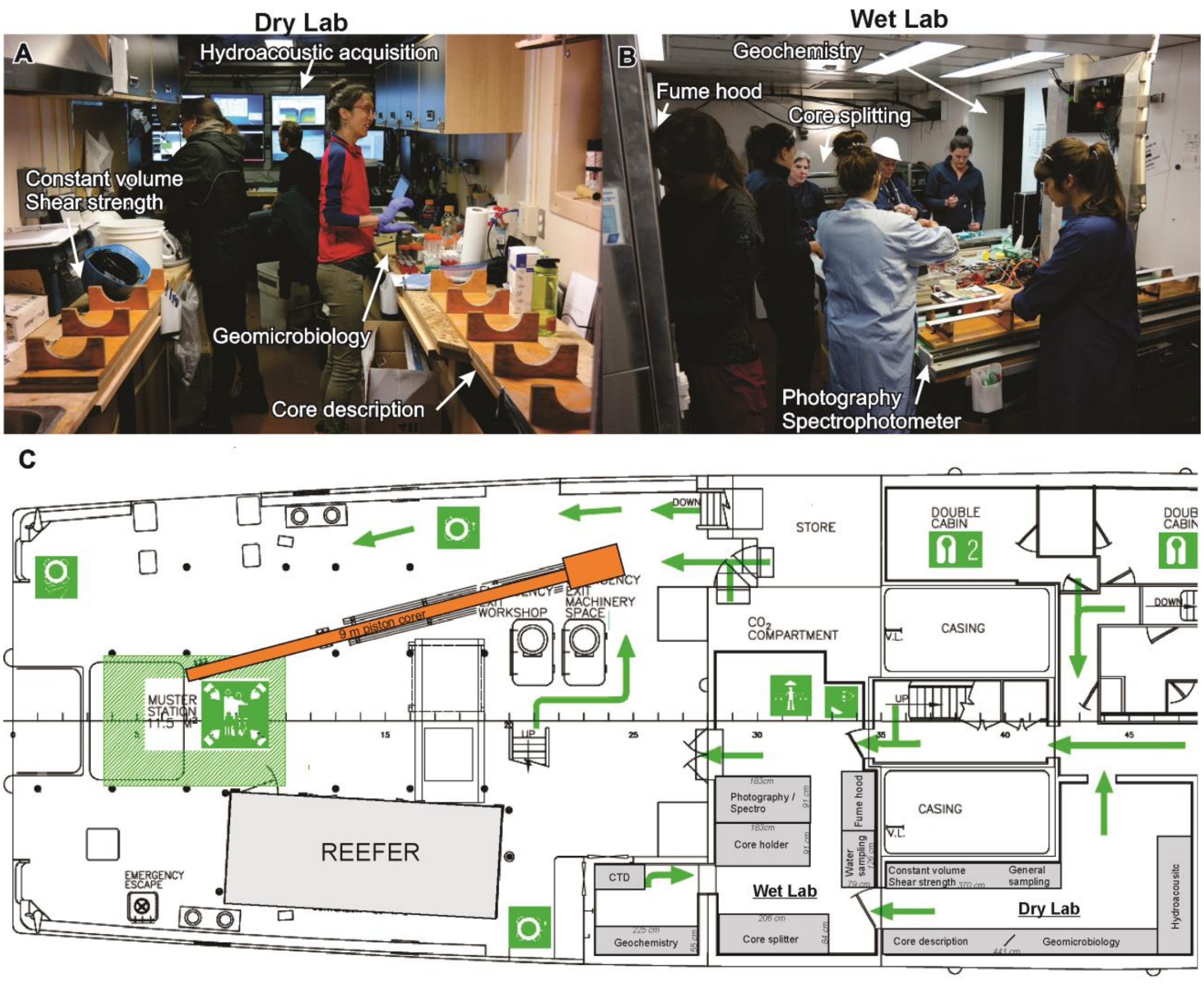

Figure 11: Configuration of laboratory space in the wet and dry laboratory of the R/V *Coriolis II*.

Core Photography

The archive half of the core was photographed using a Nikon D300 12.3 megapixel digital camera. Overlapping digital photographs were taken using the newly built camera frame (Fig. 11B). The images were saved in raw, tiff and jpeg formats.

Reflectance Spectrophotometry

Spectral reflectance measurements on the split core surface were made over wavelengths of 400 to 700 nm using the Konica Minolta Spectrophotometer CM-2600d. Tristimulus values (X, Y and Z) and L*a*b* values were derived from the colour reflectance spectra according to the Commission Internationale d'Eclairage (CIE) method. The L* value ranges from zero (black) to 100 (white) whereas the a* value represents green (-) to red (+) and the b* value represents blue (-) to yellow (+). A zero calibration and a white calibration (using a white ceramic calibration cap) were performed every evening to compensate for the effects of any change in the optical system and changes in ambient and internal temperature. Measurements were taken every 5 cm on the sediment cores that were previously covered with Glad® Cling Wrap.

Sample Description

Following the above-mentioned analysis, the archive half of the cores were described. The description included the condition of samples (e.g. cracks, disturbance, oxidation), consistency (e.g. soft, hard, firm), reaction to hydrochloric acid (indicator of calcium carbonate), colour (based on the Munsell soil colour charts) and visual core description (colour, texture, grain size, bedding, contacts, bedforms, structures, presence of organic material, bioturbation and any other visible feature).

Discrete Core Measurements

Constant volume sampling

Constant volume samples were taken using a stainless steel cylindrical sampler of known volume which was lightly greased with vegetable oil spray to minimize friction. The sampler was inserted into the sediment to remove sediment from the core. The sediment sample was extruded from the cylinder, stored in a glass bottle of known weight, sealed to prevent desiccation and stored in a refrigerated container at 4º C. Bulk density and water content values were then calculated at the GSCA core processing facility.

Undrained shear strength

Undrained shear strength was measured using a hand-held Hoskin Scientific Torvane. The Torvane was gently inserted in the sediment at the bottom and top of the cores and rotated at a constant rate until the sediment failed.

Geochemical subsampling
Jamie Webb

All the cores aimed at pockmarks were subsampled for geochemical analysis. Gas whole round samples were taken 5 cm from the base of the core and divided in two, with each half placed in a separate IsoJar, and then flushed with nitrogen. No gas cracking and bubbling or positive gas detector measurement were observed; therefore, no additional gas samples were taken. Following the splitting of the cores, the presence of hydrocarbon fluorescence was assessed under UV light. Anoxic sediments from a minimum of 1 m from the top of the core were sampled at three locations where fluorescing sediment, sandier intervals or darkened organic rich bands were observed. The samples were then divided in two and wrapped in aluminum foil before being placed in a -20° C freezer to limit bacterial growth.

Samples were then transported under continued -20° C to the Applied Petroleum Technology labs in Norway. Samples were then thawed and those contained within the isojars were analysed for headspace gas. The type and concentrations of gas present was quantified using Gas Chromatography (GC). If sufficient hydrocarbon gases were present, these were further analysed for carbon and hydrogen isotopes to determine their origin (thermal or bacterial). Aluminum foil wrapped sediment samples were also thawed and first analysed for Total Organic Carbon content, then ultrasonically extracted and subjected to Gas Chromatography of the Extractable Organic Matter (GC-EOM). If after this screening the presence of liquid hydrocarbon was indicated in any of the samples, these samples were then further analysed by first separating and quantifying the hydrocarbon into components through Medium Pressure Liquid Chromatography (MPLC) and asphaltene separation. The saturate fraction was then subjected to Gas Chromatography (GC) and Gas Chromatography Mass Spectrometry (GCMS). The aromatic fraction was also subjected to GCMS. Through these analyses, the biological marker compounds in the fractions can be quantified and identified, in order to determine maturity, origin and secondary processes (including biodegradation). Following these analyses, if again sufficient hydrocarbon is present, the extracts are subjected to GCMS of diamondoids (carbon molecules arranged in a diamond lattice) and saturate and aromatic isotopes. Diamondoids are largely used as an assessment of maturity in highly mature hydrocarbons and the isotopes are used to assess the source origin.

The results from these analysis will be publicly available from NSDOE post December 2017

Geomicrobiology
Carmen Li

Cores were sampled for geochemical analysis and microbiology with the goal of cross correlating the results. Post-cruise research of the cores includes studying the aerobic, anaerobic, and dormant microorganisms possibly associated with subsurface hydrocarbon reserves, taxonomic characterization of microorganisms using DNA, RNA, cell counts, FISH (fluorescent *in situ* hybridization) and lipid analyses, sulfate measurements, and establishing the baseline microbial community of the study area.

Subsamples were aseptically transferred from select depths of each trigger weight core and piston core (as defined by our collaboration with APT Canada), gravity core, and grab samples into sterile containers of various sizes (2 mL tubes, 15 mL tubes, 90 mL jars, 1-litre mason jars) while onboard the R/V *Coriolis II*. Subsamples were either frozen immediately at -80° C (for DNA analysis), -20° C (for lipids analysis and sulfate measurements), 4° C (for bulk samples taken for potential culturing), or treated with preservatives and then kept at 4° C (for cell counts) or -20° C (for RNA and FISH analyses). At the completion of the cruise, all samples were taken on a direct flight from Halifax back to Calgary in coolers insulated with ice packs and stored at their respective temperatures in Dr. Casey Hubert's research lab at the University of Calgary.

Reference

Campbell, D.C., MacDonald, A.W.A., 2016. CCGS Hudson Expedition 2015-018, geological investigation of potential seabed seeps along the Scotian Slope, June 25–July 9, 2015. doi:10.4095/299390

Appendix A: Hydroacoustic data collected during *2017CORIOLIS*

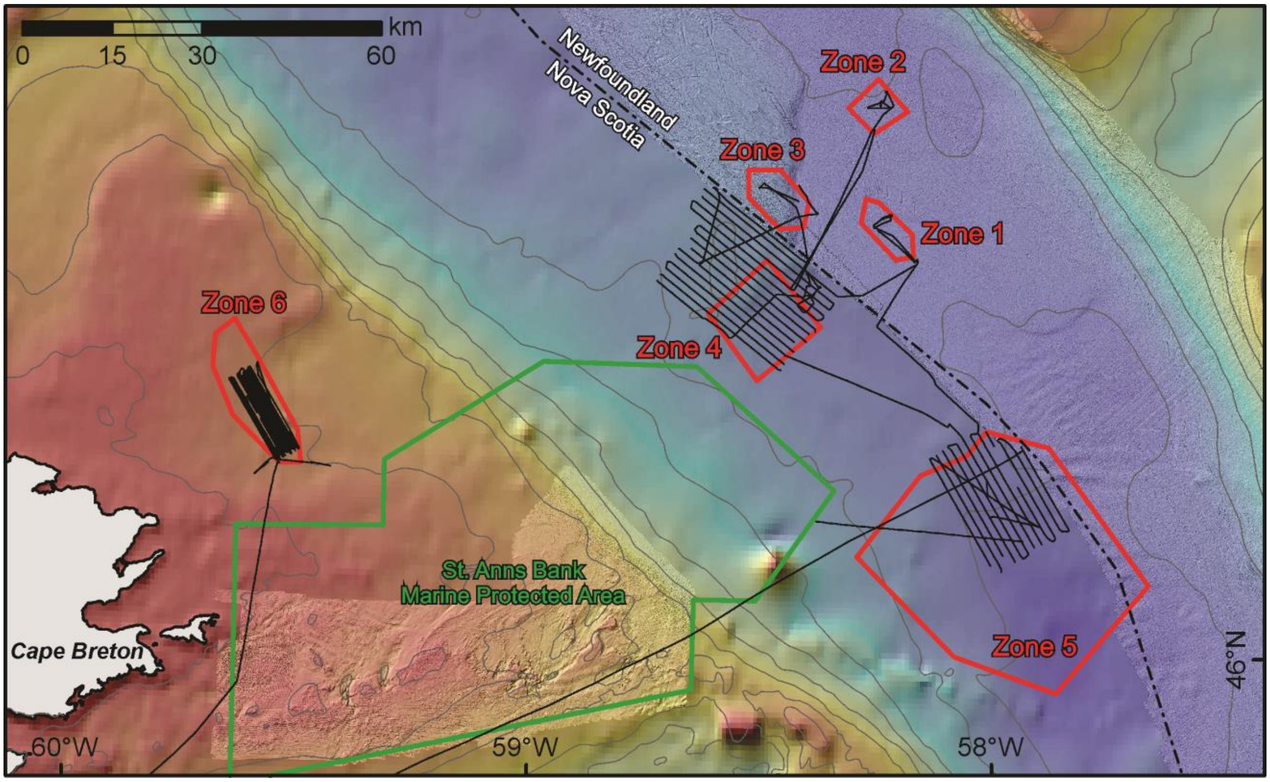

Figure A1: Overview of sub-bottom profiles collected during *2017CORIOLIS*.

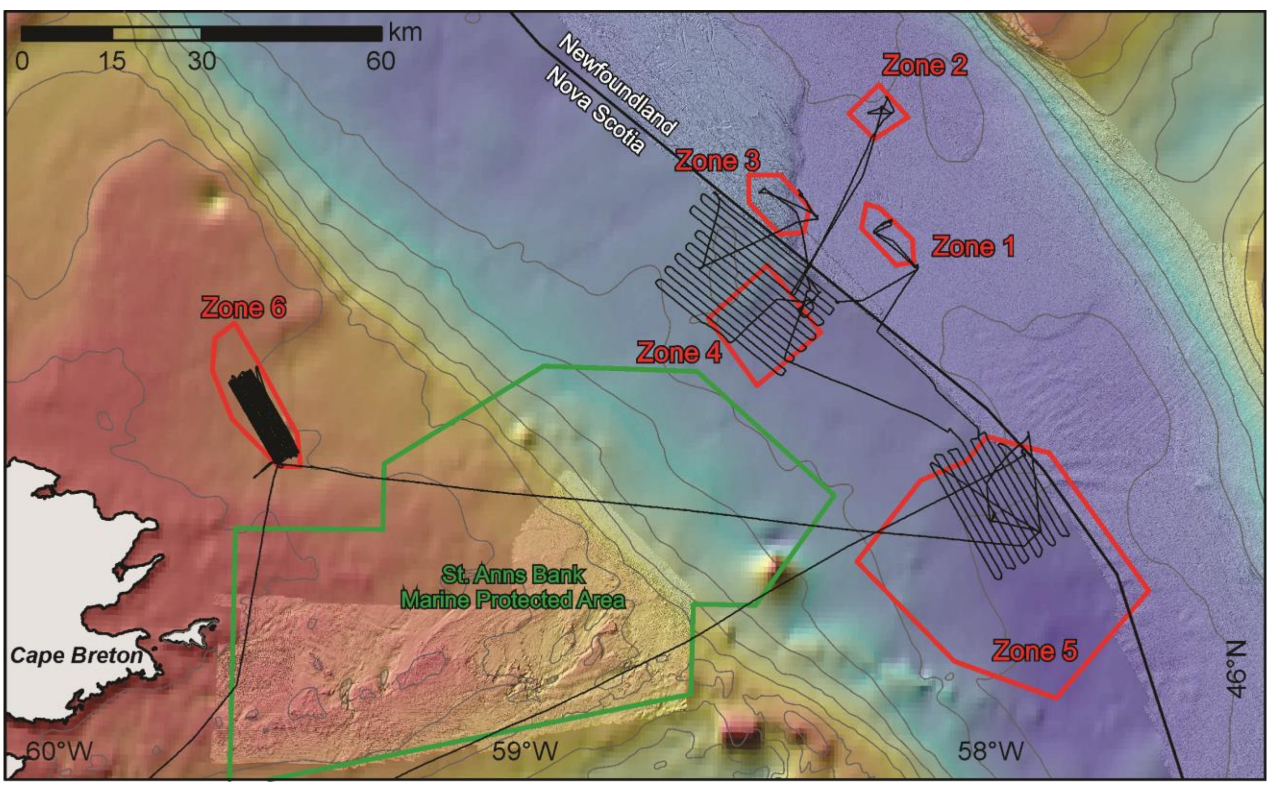

Figure A2: Overview of multibeam sonar data collected during *2017CORIOLIS*.

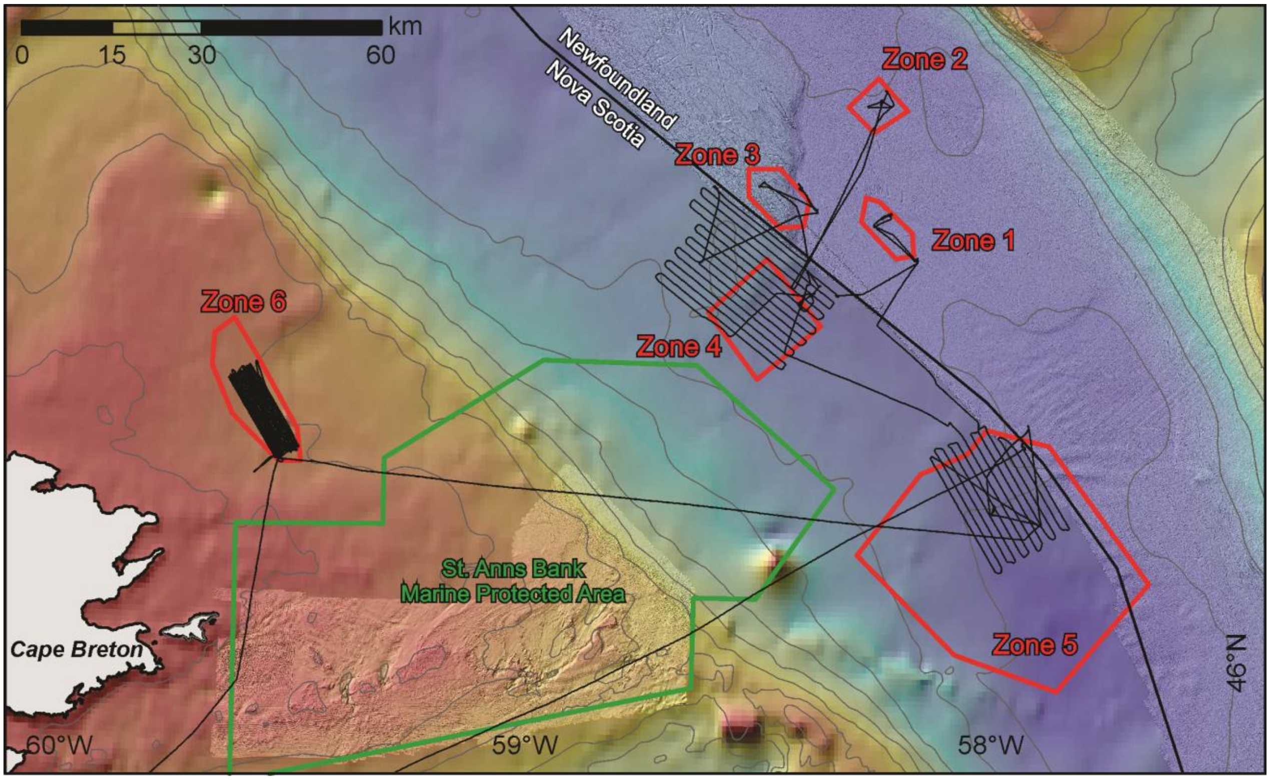

Figure A3: Overview of EK-60 data collected during *2017CORIOLIS*.

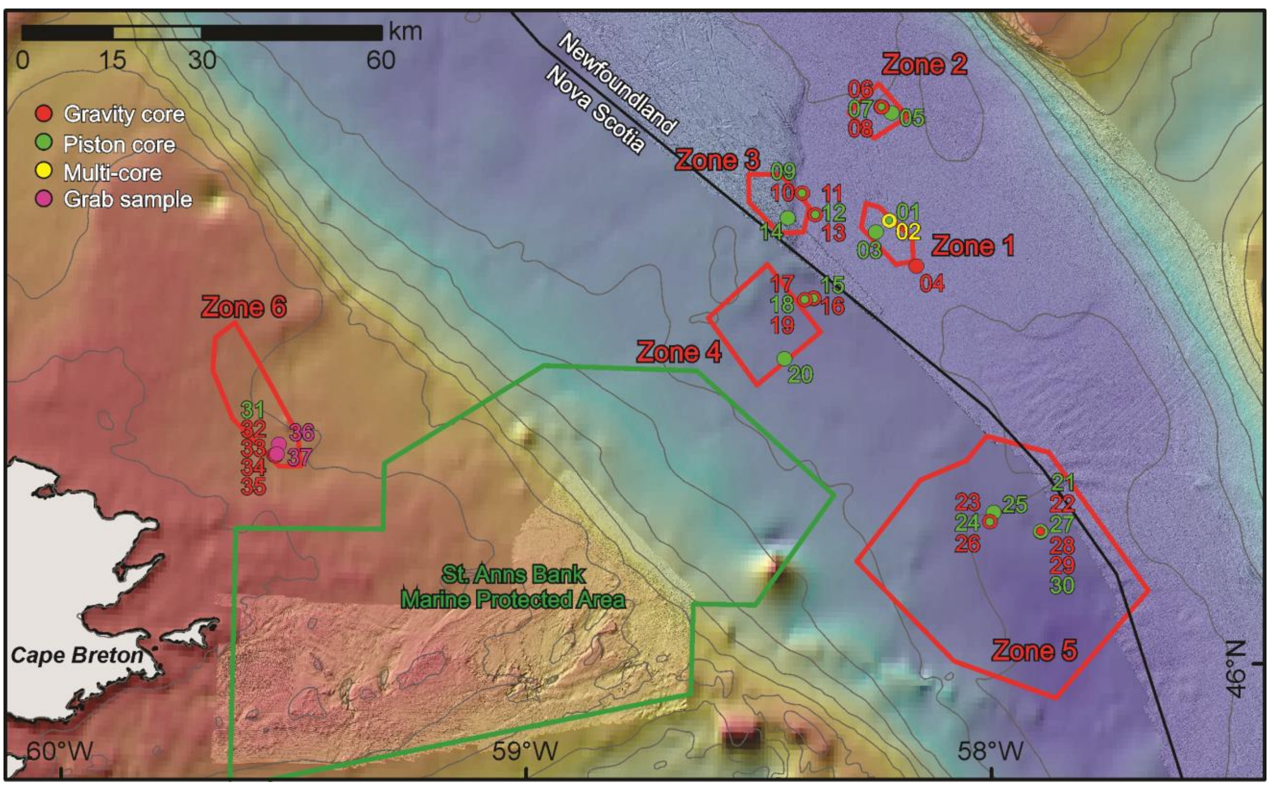

Figure A4: Overview of cores collected during *2017CORIOLIS*.

Appendix B: Detailed location of cores collected during *2017CORIOLIS*

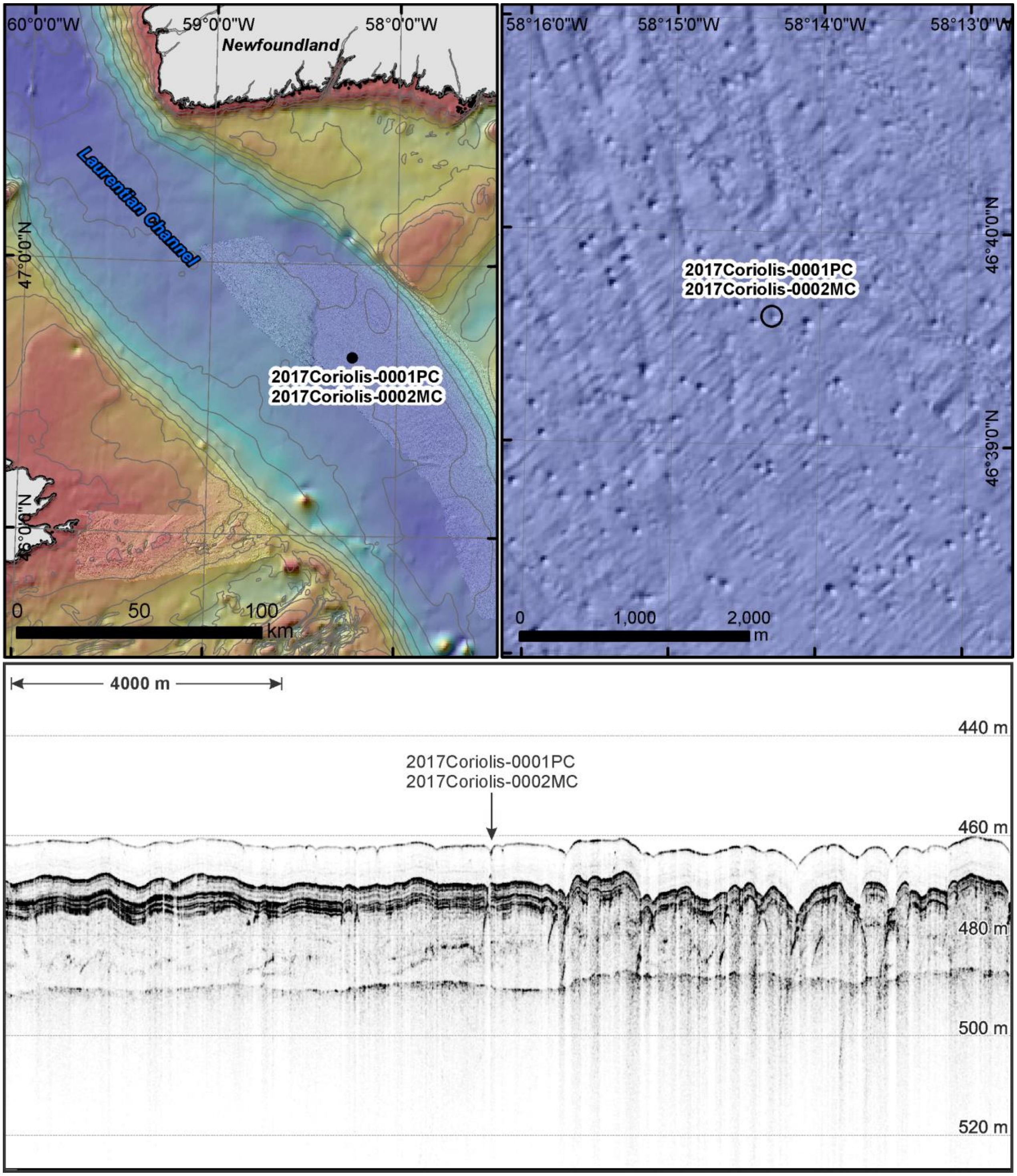

Figure B1: Location of cores 01PC and 02MC.

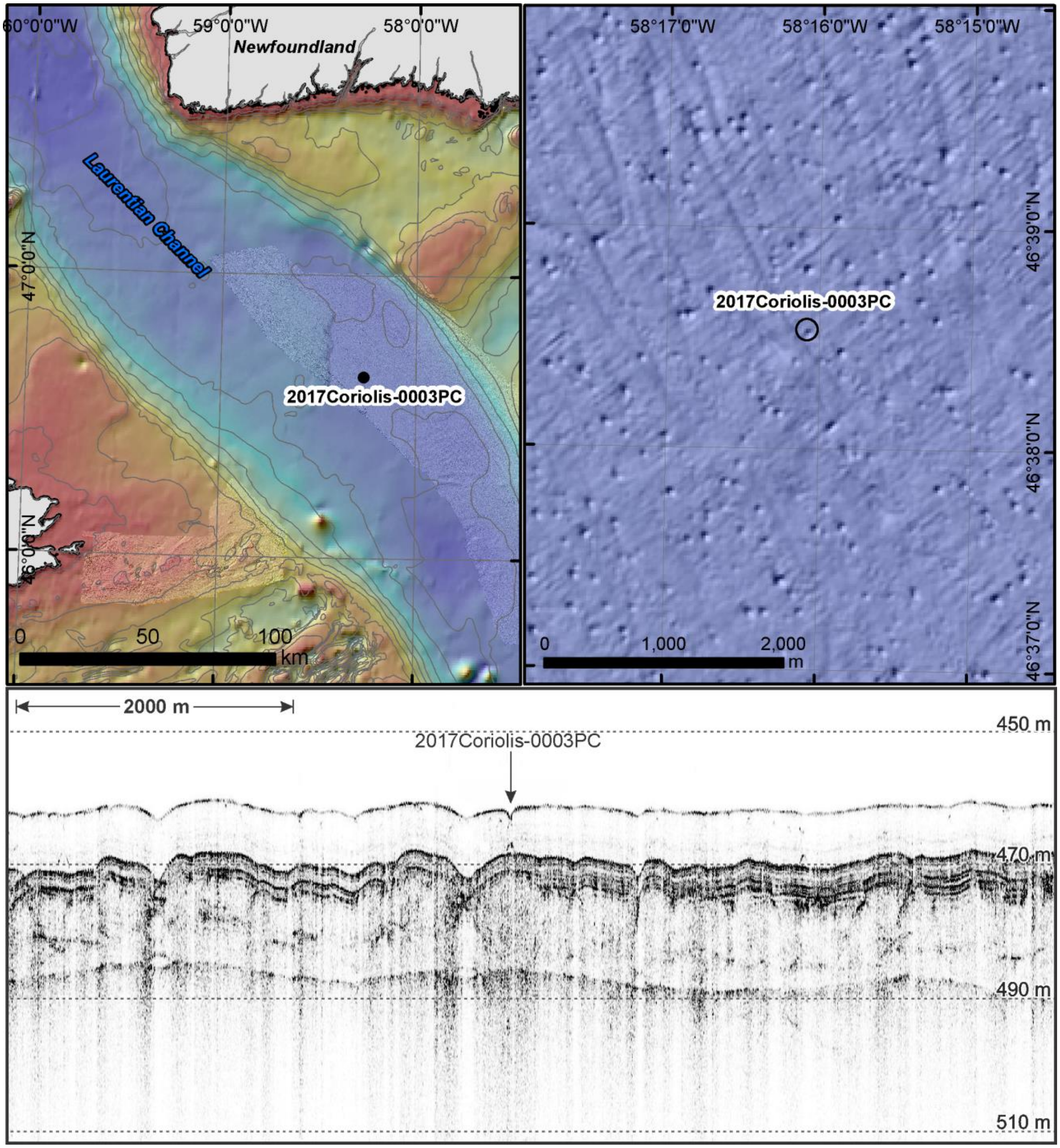

Figure B2: Location of core 03PC.

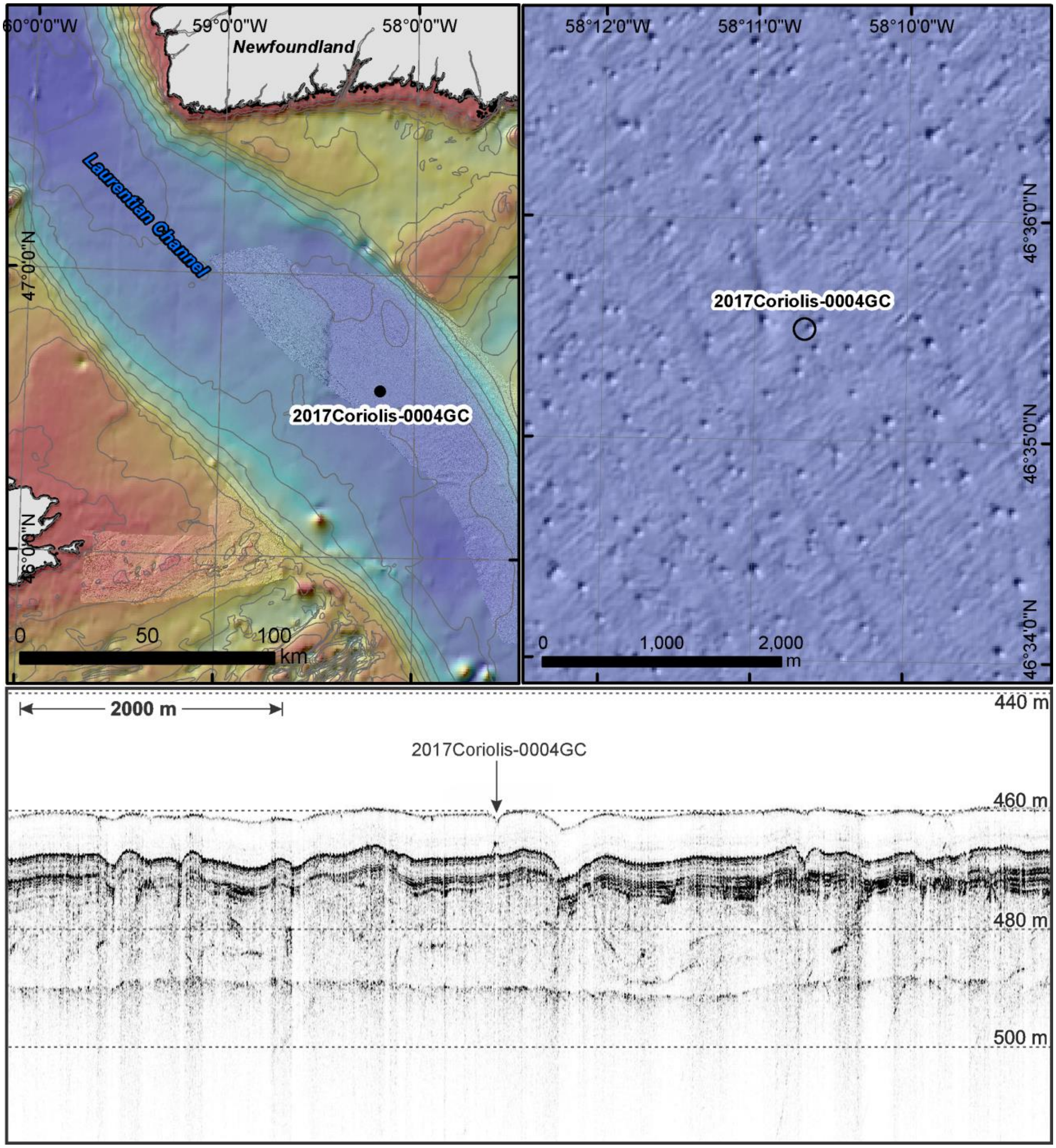

Figure B3: Location of core 04GC.

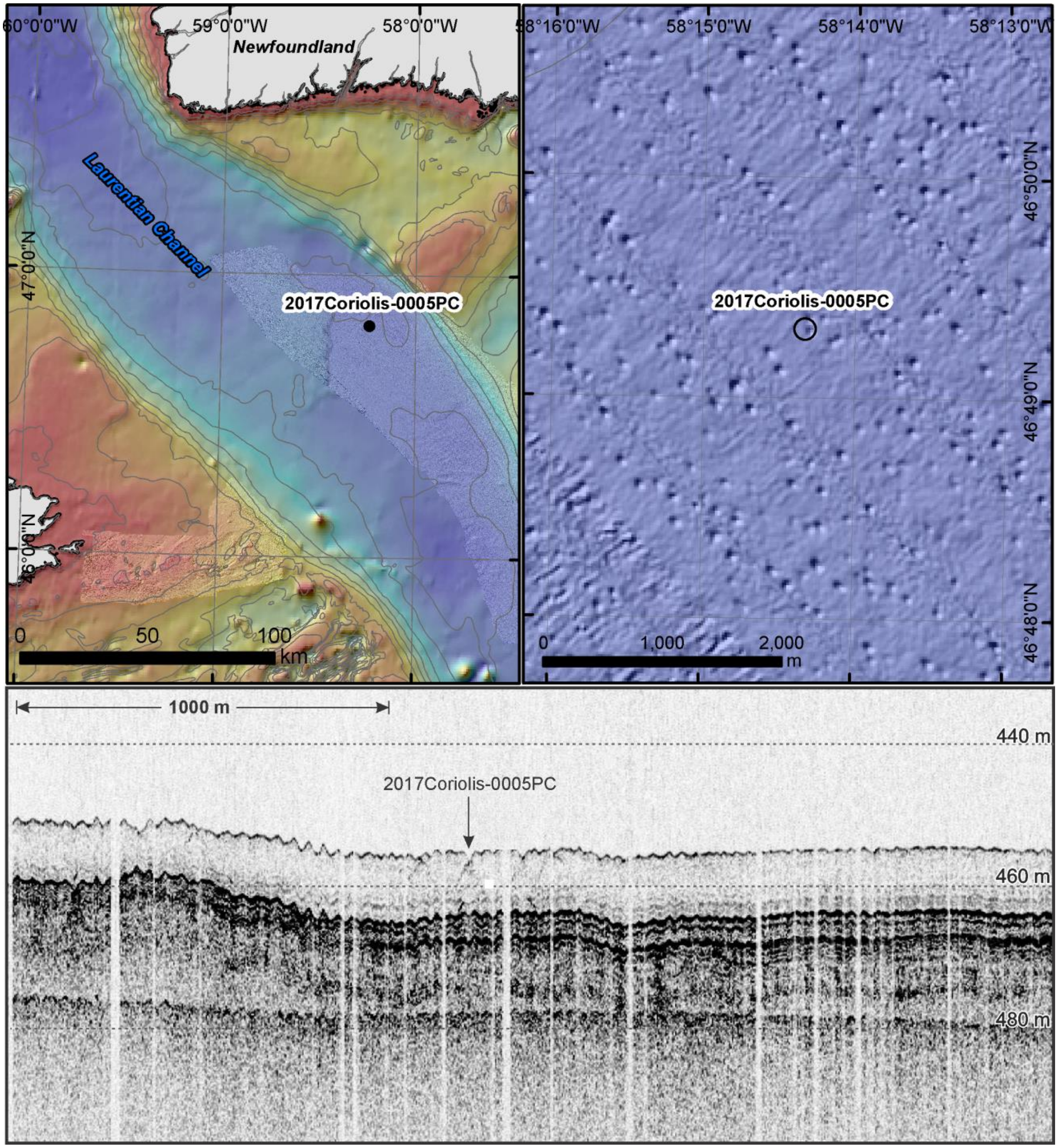

Figure B4: Location of core 05PC.

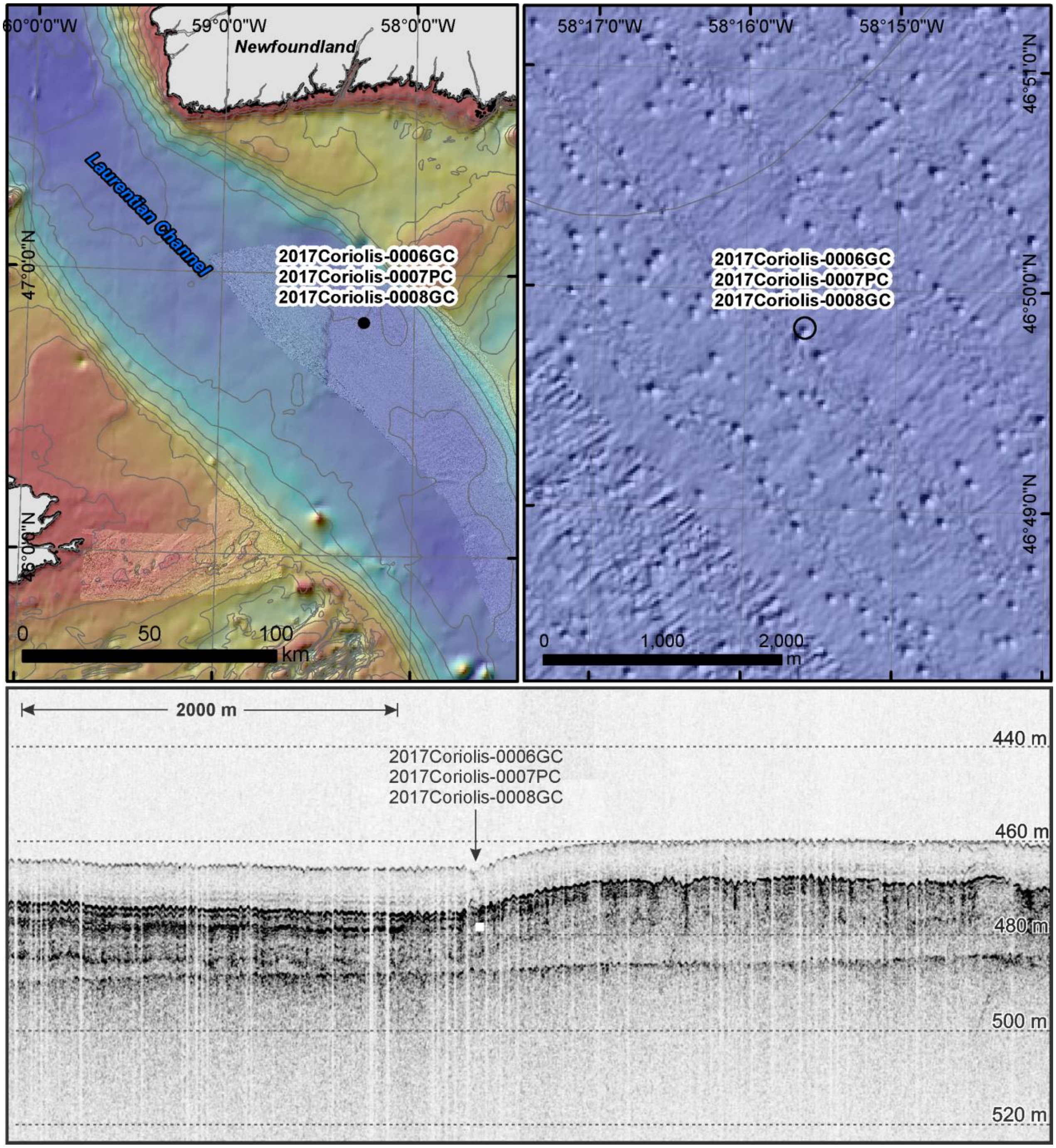

Figure B5: Location of cores 06GC, 07PC and 08GC.

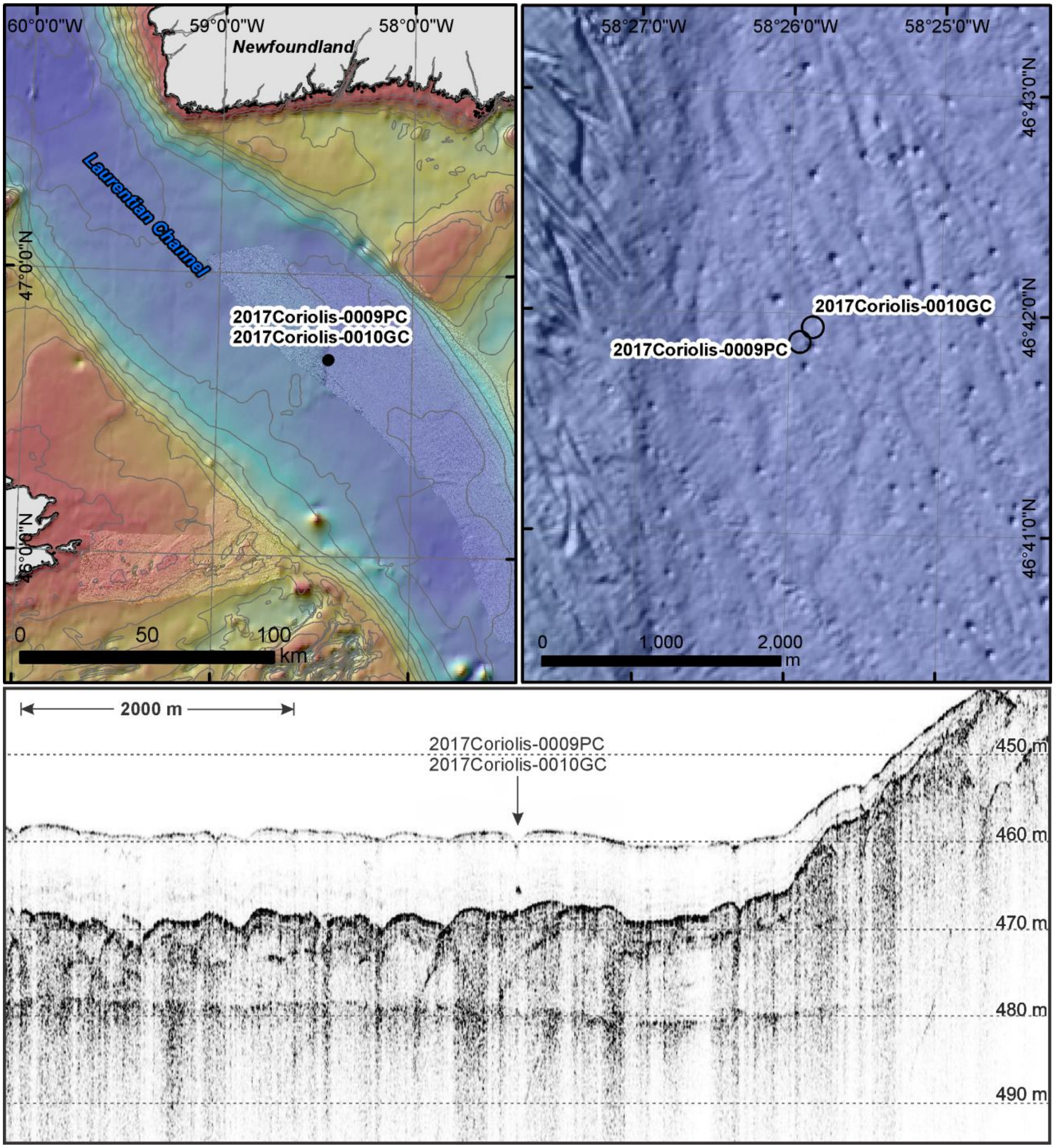

Figure B6: Location of cores 09PC and 10GC.

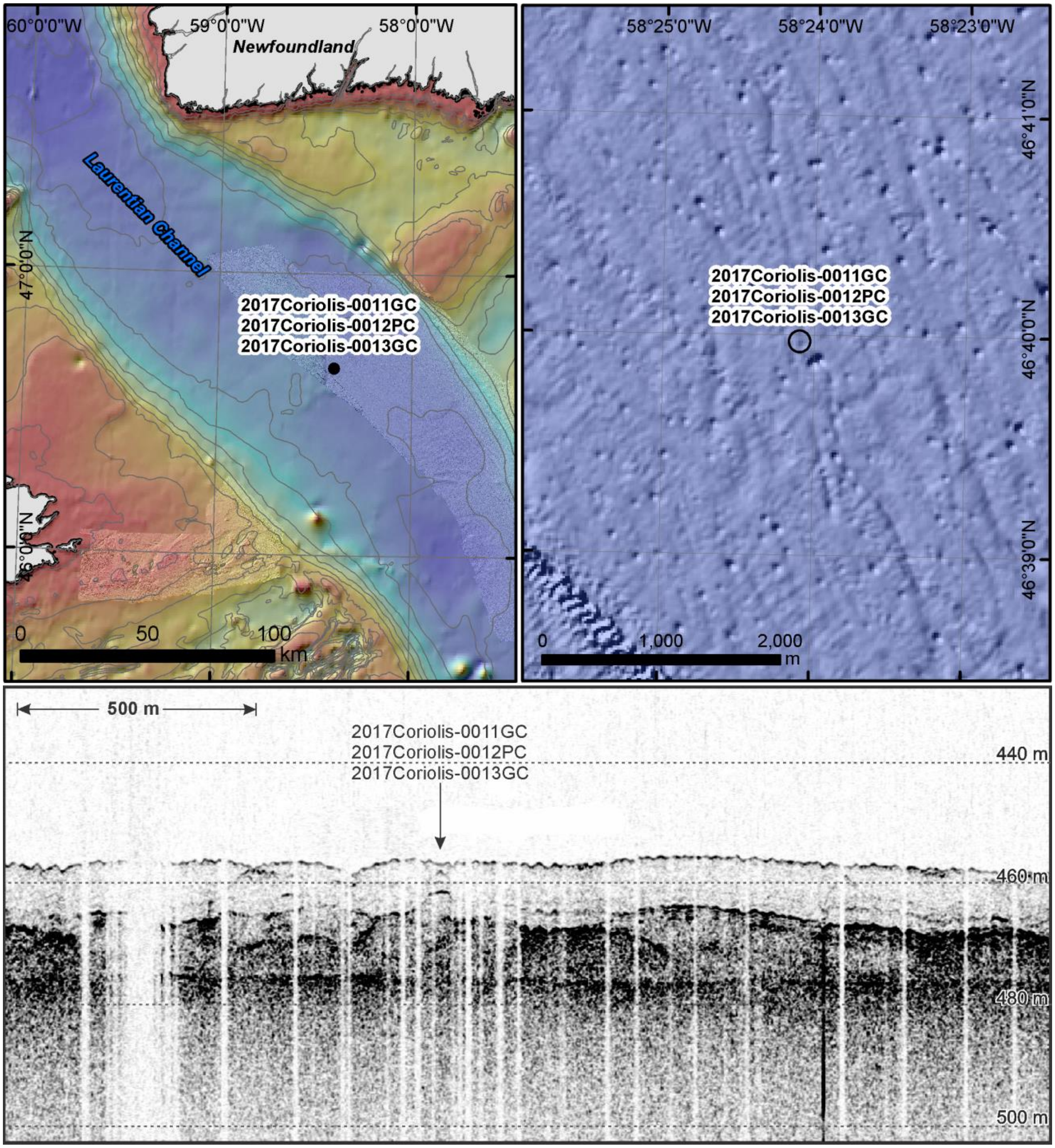

Figure B7: Location of cores 11GC, 12PC and 13GC.

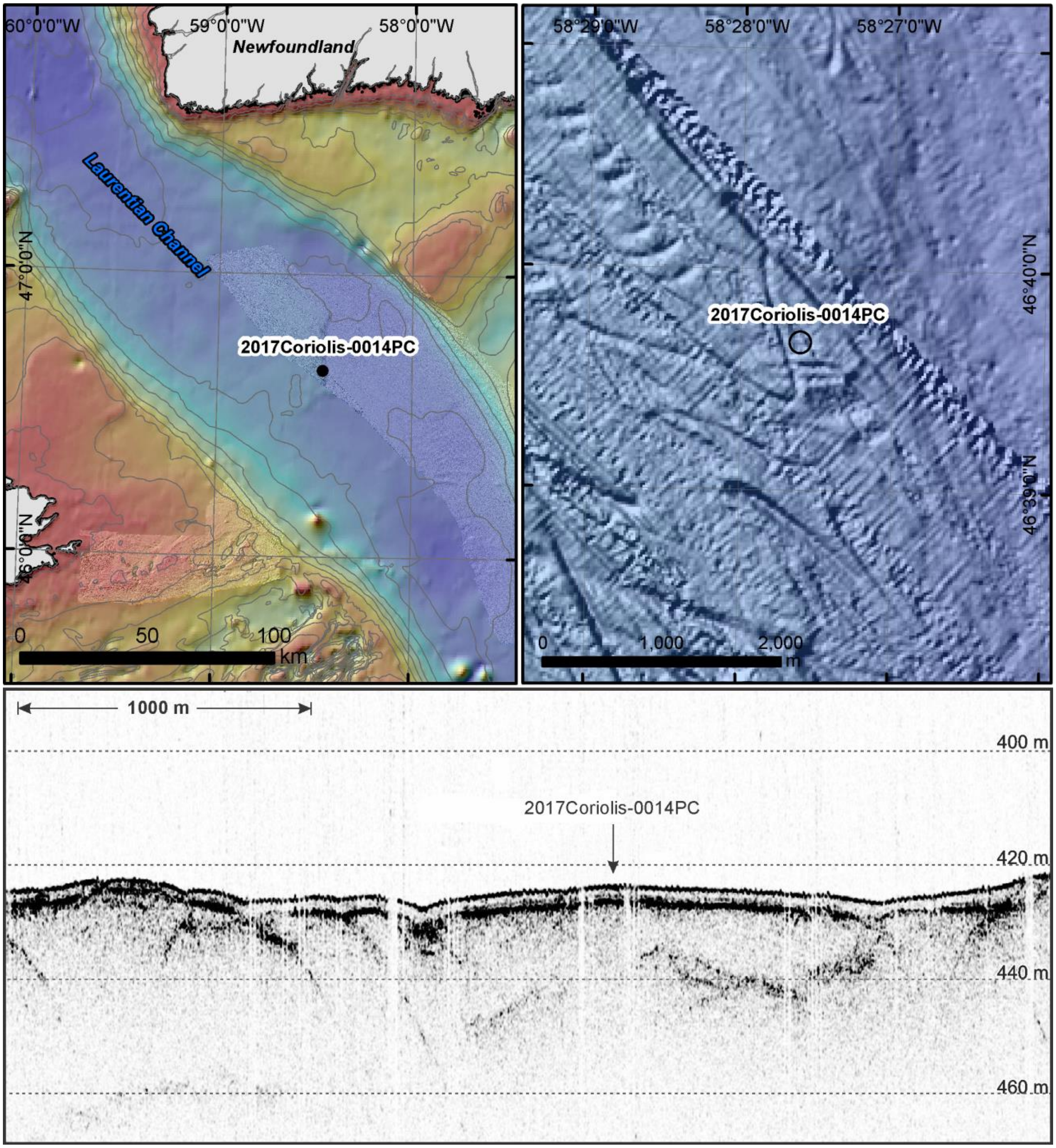

Figure B8: Location of core 14PC.

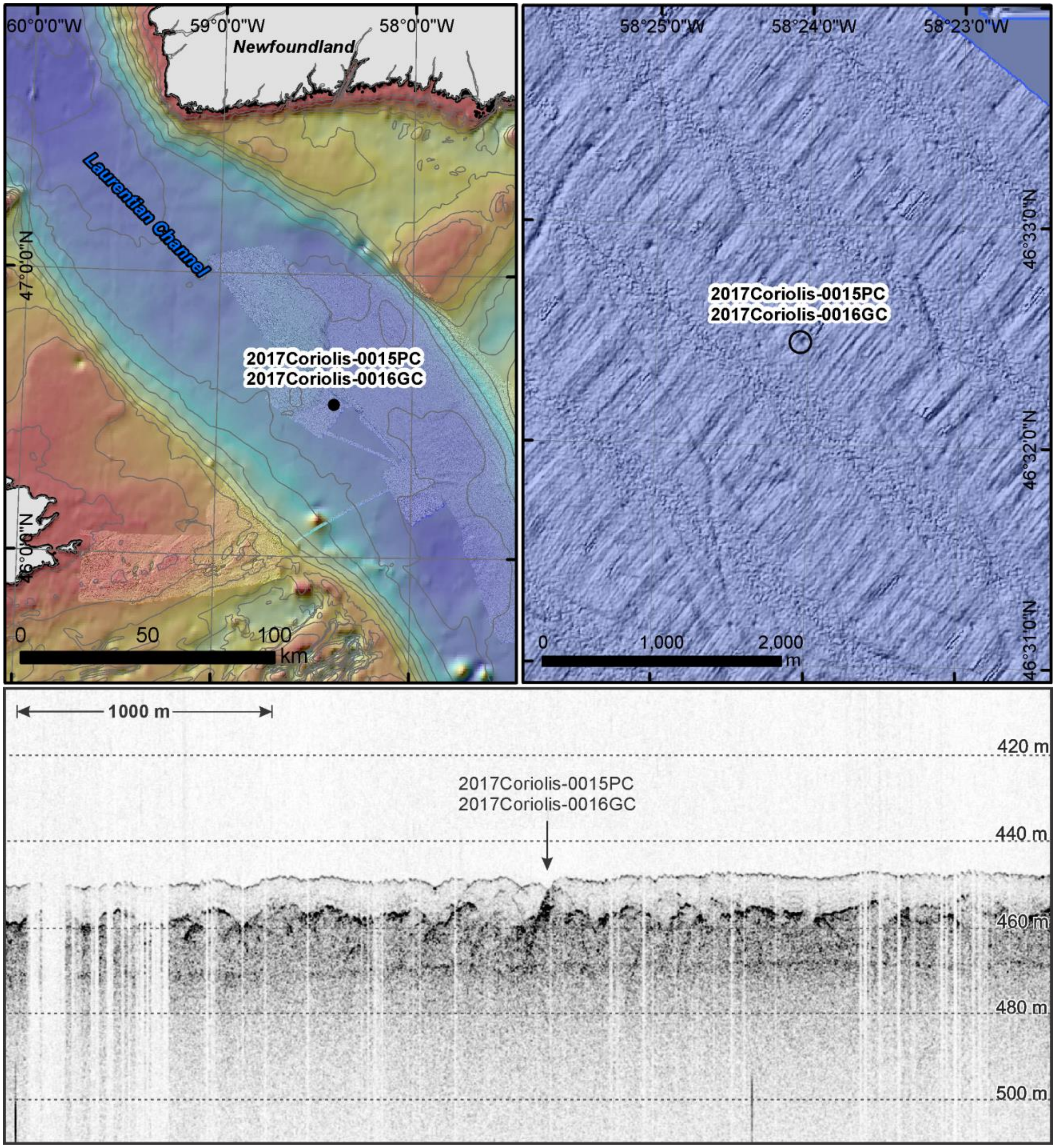

Figure B9: Location of cores 15PC and 16GC.

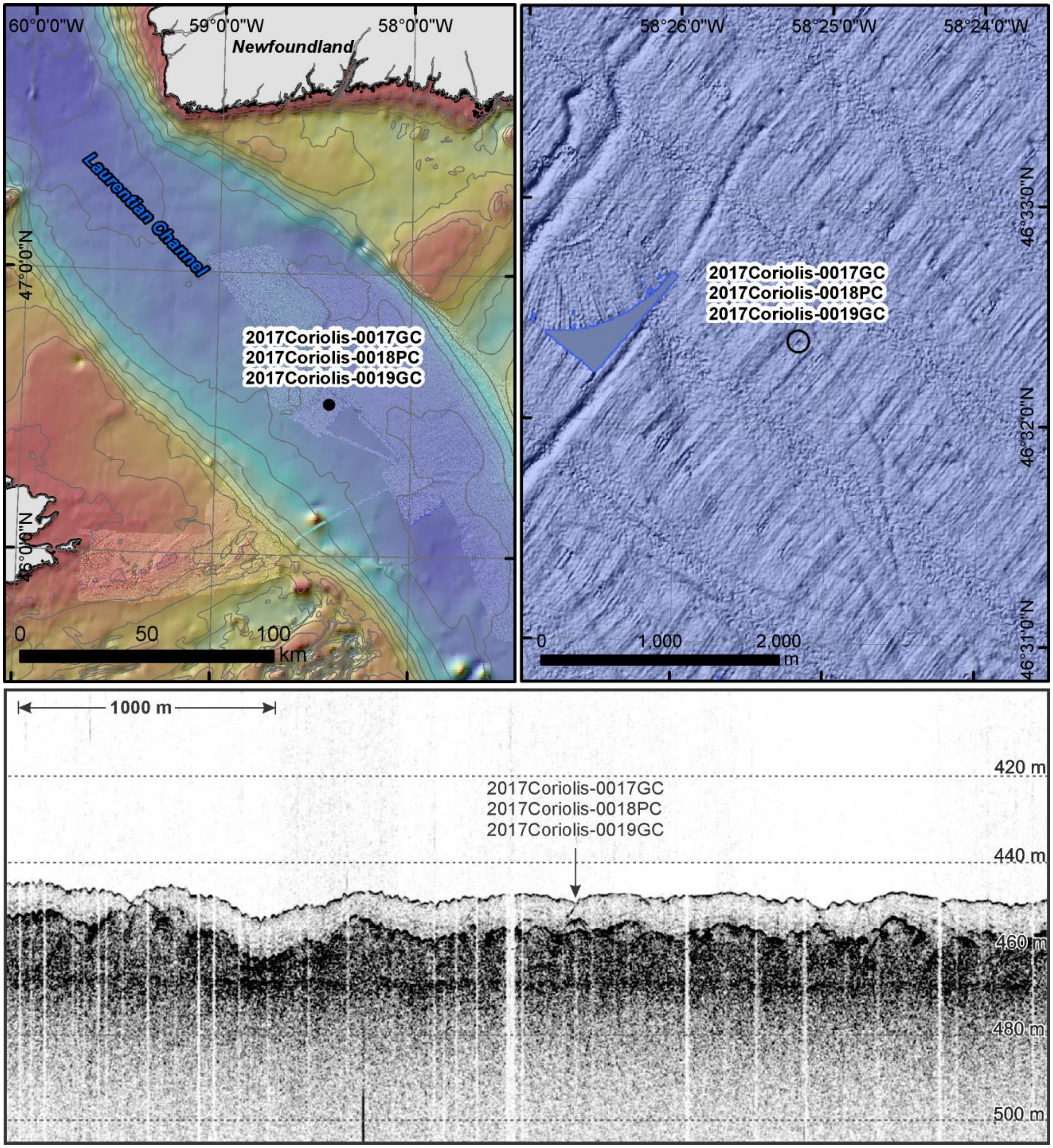

Figure B10: Location of cores 17GC, 18PC and 19GC.

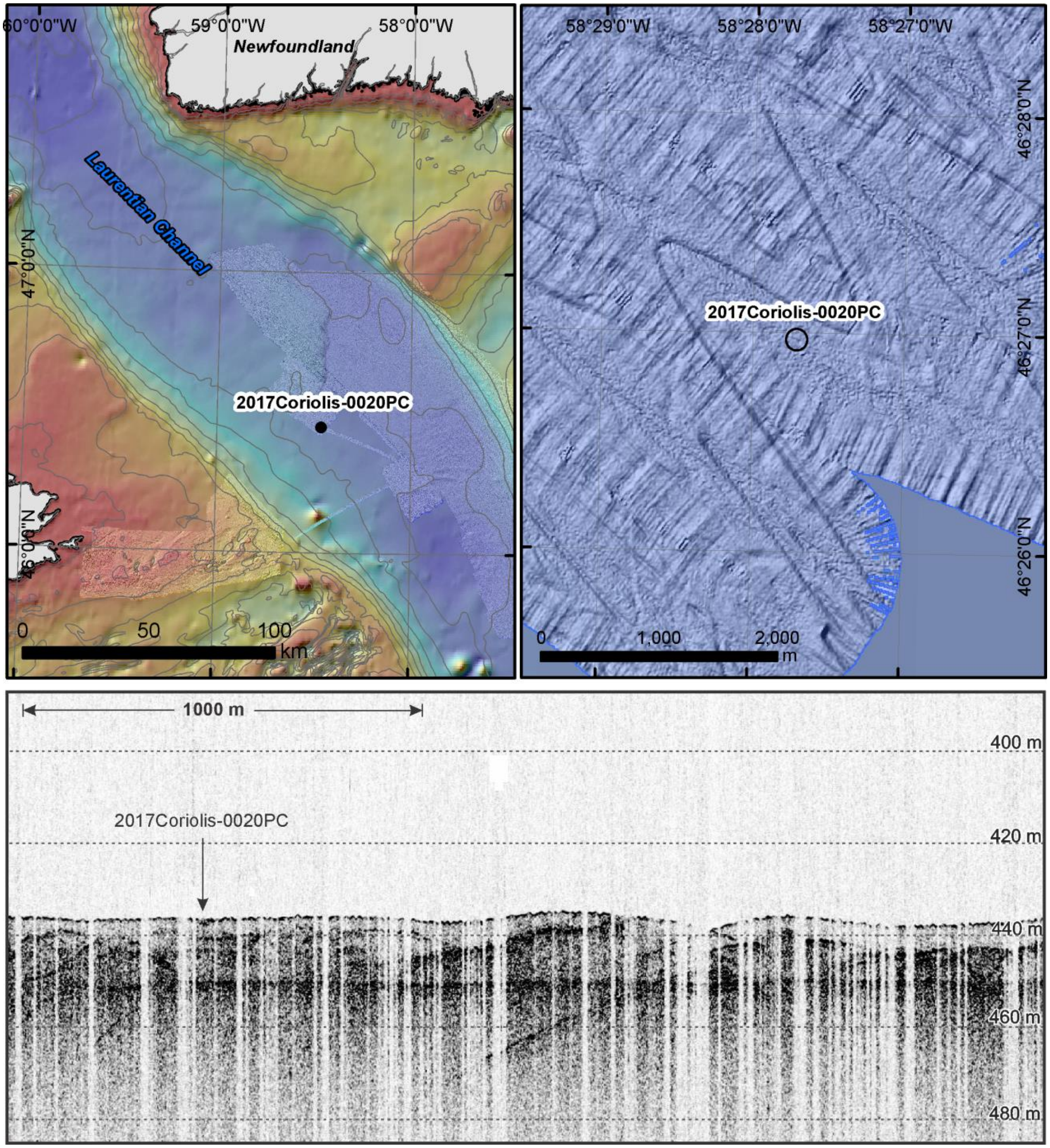

Figure B11: Location of core 20PC.

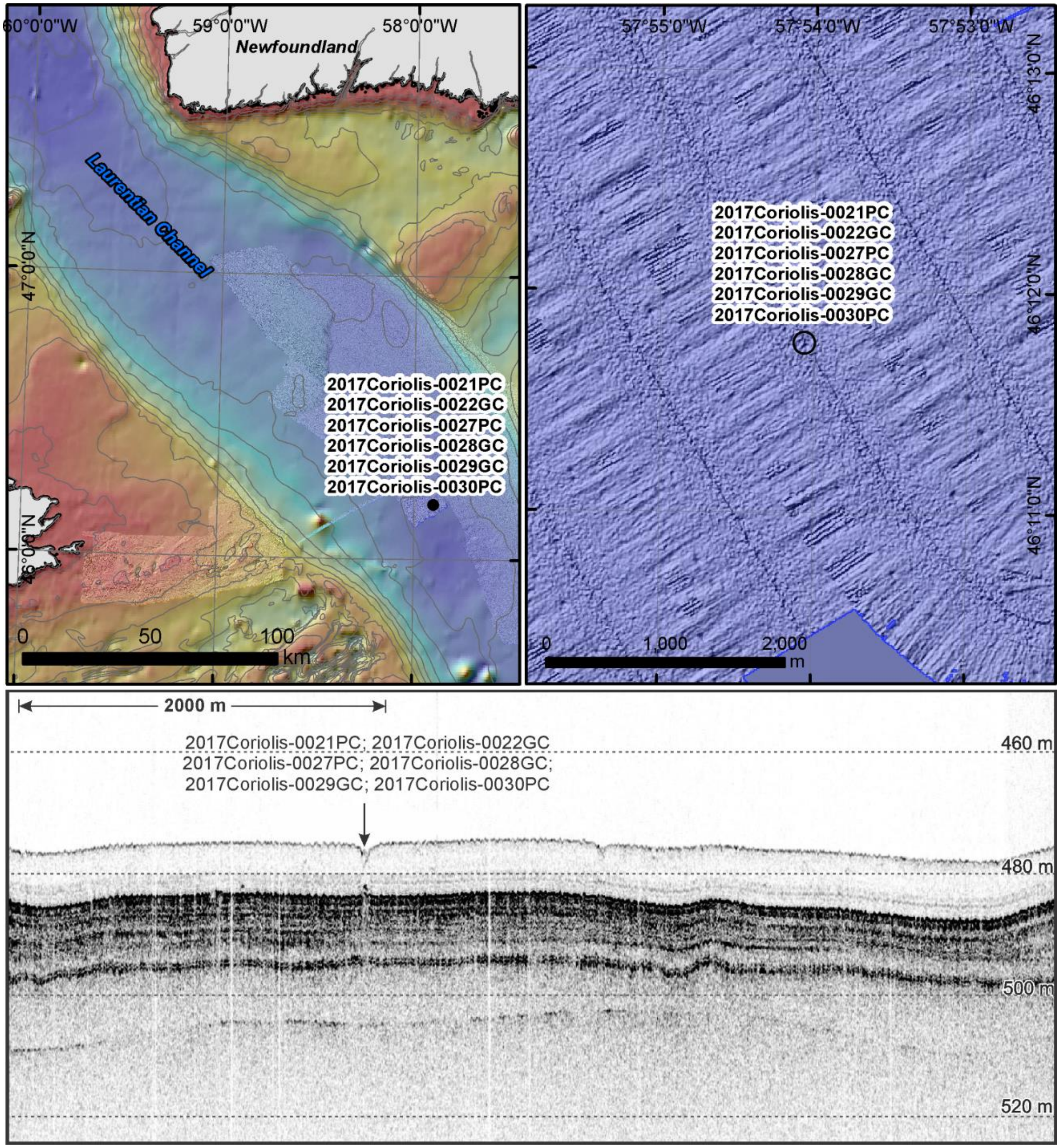

Figure B12: Location of cores 22GC, 28GC and 30PC.

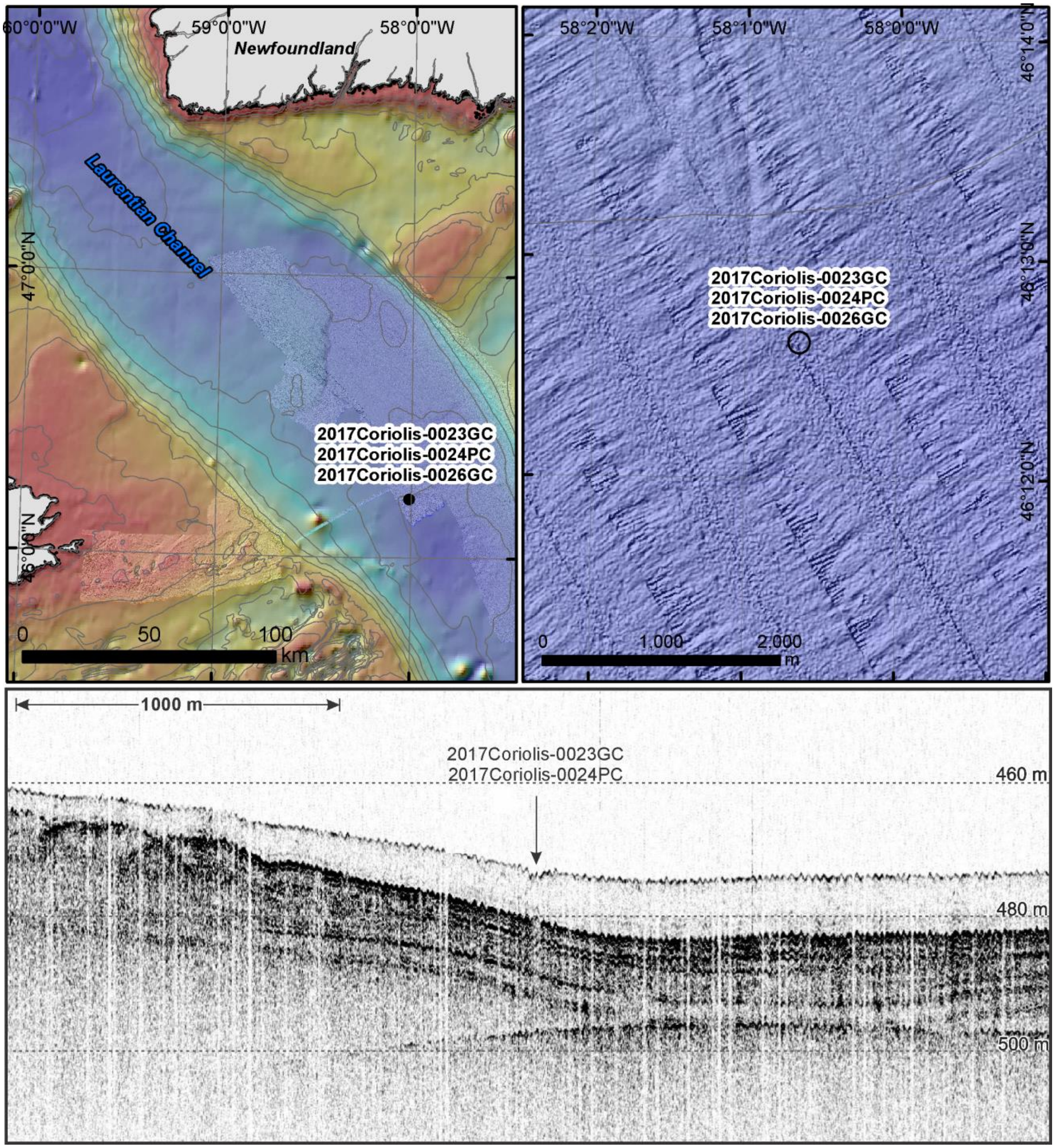

Figure B13: Location of cores 23GC, 24PC and 26GC.

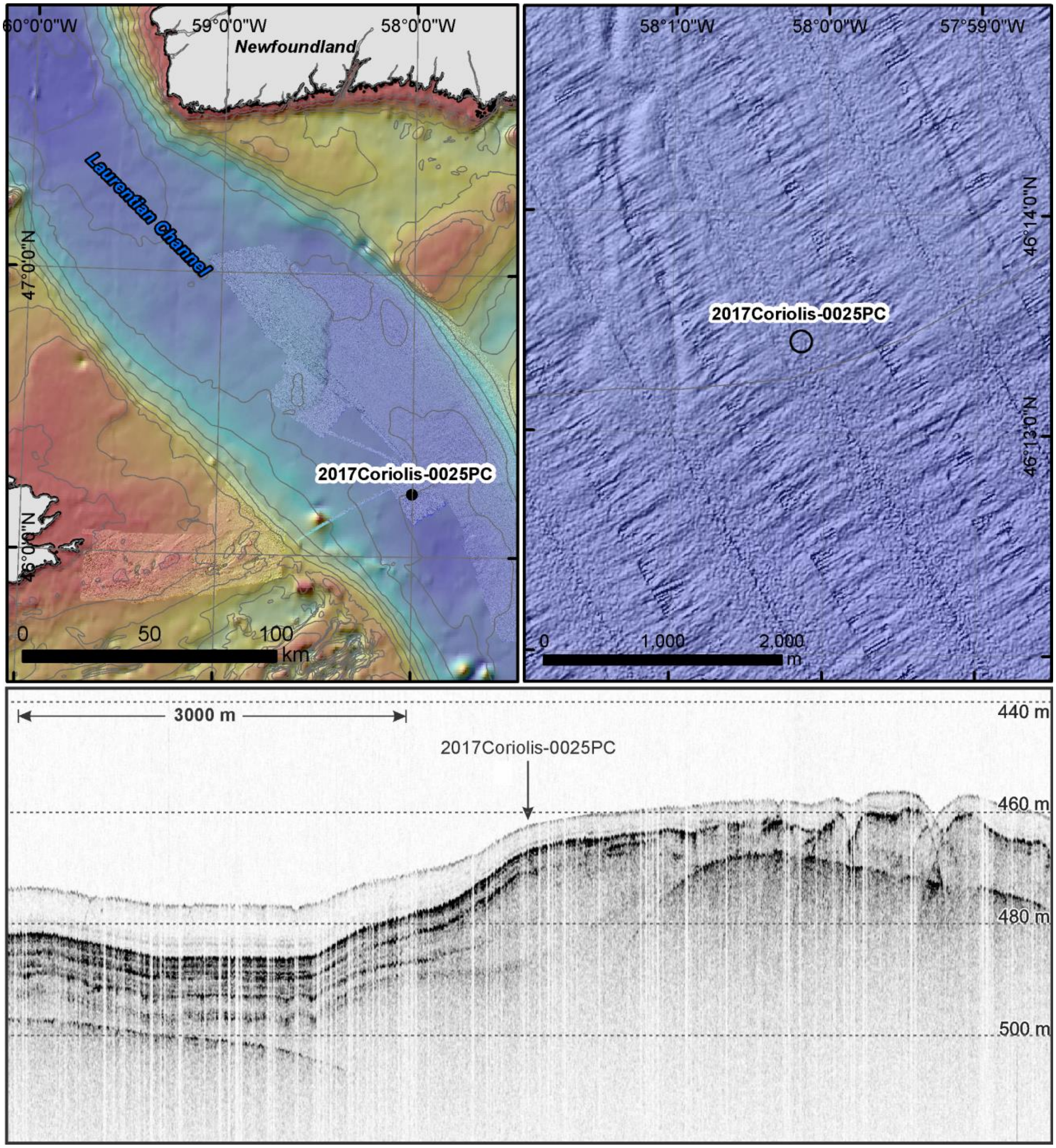

Figure B14: Location of core 25PC.

Appendix C: JSF to SegY conversion procedure for the Edgecth X-Star 2.1

1) Raw JSF are recorded on board with Discover 2.1

2) In XSTAR version 2.0 the raw JSF files are recorded as another version of JSF

Default parameter

Sonar: Control Panel

Playback : Select original file

Record Format → ET Format (Unmodified sonar messages)-> choose a 2.0 dossier

Start Record

Start Playback

Stop Playback

Stop Record

3) In XSTAR version 2.5 recorded the previously recorded JSF (2.0) in SGY

Sonar Control Panel

Playback -> Record SEGY-Standard → choose a SegY dossier

Start Record

Stop Playback

Stop Playback

Stop Record

The line is now converted into a SegY readable by SegY softwares.