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R/V *William Kennedy* expedition 2023004: seabed sampling and geophysical surveys – Eastern Shore, Nova Scotia

J.B.R. Eamer, C. Greaves, V. Maselli, E.L. King, J. Shaw, D. Manning, J. Higgins, S. Hayward, and P. Meslin

2024

Canada

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Cover photo: Cameron Greaves on the working deck of the RV William Kennedy, contemplating the work done and the work still to do. Photograph by C. Greaves. NRCan photo 2023-409

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Acknowledgements

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1. Background and objectives

A combination of local glacio-isostatic crustal subsidence (crustal adjustments linked to loading/unloading of glacial ice) and rising eustatic (global) sea-level has resulted in Nova Scotia experiencing an amplified rate of sea-level rise (James et al., 2014). In order to understand how coastlines in Atlantic Canada will respond to future sea-level rise, developing knowledge on coastal response to similar changes in past relative sea-level (RSL) will help with future decision making.

Nova Scotian coastlines are paraglacial, where the geomorphology and morphodynamics of the coasts are largely controlled by the glacigenic deposits originating from previous glaciations (Carter et al., 1989). These coastlines are gravel and sand dominated, frequently organized into barrier beach systems between glacial drumlins or bedrock and show differing controls on coastal stability (Forbes et al., 1995a). On the eastern mainland of Nova Scotia, Chedabucto Bay has been interpreted as experiencing a post-glacial RSL lowstand followed by sea level rise of several tens of metres to present, and the bay contain well preserved drowned sand and gravel barrier beach systems (Forbes et al., 1995b; King, 2023). These drowned barrier beach deposits are rare in Nova Scotia; when sea-level rose from the previous lowstand, waves and currents on exposed coastlines generally reworked these deposits. This presents a rare opportunity to develop a paleogeographic reconstruction of this coastal system in Chedabucto Bay, which was sheltered from much of the energy of the Atlantic during previous sea-level rise and was likely preserved from modern sediment inputs from Milford Haven River (at the head of Chedabucto Bay).

Across Nova Scotia, RSL has generally risen during the Holocene, but at different rates due to the influence of glacio-isostatic adjustments (Shaw et al., 2002a). Currently, there is a RSL curve for Bras d’Or Lakes (Shaw et al., 2002b) and Halifax Harbour (Edgecombe et al., 1999), leaving an important gap between the two. Chedabucto Bay is situated within this gap, and a chronology for the barrier beach deposits can be developed and used to reconstruct the RSL history and paleogeography of the coastal suite of landforms in Chedabucto Bay. The production of a site-scale RSL studies is especially necessary to test and update regional RSL numerical models (Vacchi et al., 2018) and glacio-isostatic adjustment models for North America (Roy and Peltier, 2018). In addition to furthering our understanding of coastal change, seabed data collection can support the ongoing energy transition by characterizing the seabed for offshore energy infrastructure such as offshore wind turbines, landfall cables and hydrogen pipelines.

With these scientific questions and objectives established, the Program of Energy Research and Development from the Office of Energy Research and Development at Natural Resources Canada provided funding for a short, end-of-season expedition utilizing the RV William Kennedy. This was an opportunistic expedition, taking advantage of the ship while in transit back to its home port in Dartmouth to collect some essential seabed samples to ground-truth the extensive mapping and geophysical data as well as previous interpretations already existing in the study area. In addition, the opportunity to fill some important spatial gaps in geophysical data coverage was taken during nights, while seabed sampling was on hold.

2. Participants

Scientific participants of the 2023004 William Kennedy expedition entirely consisted of Geological Survey of Canada (Atlantic) personnel. They are listed in Table 1 and Figure 1.

Table 1. Scientific participants of the 2023 William Kennedy expedition

First name	Last name	Affiliation	Role
Jordan	Eamer	Geological Survey of Canada (Atlantic)	Chief scientist
Cameron	Greaves	Geological Survey of Canada (Atlantic) / Dalhousie University	M.Sc. student, planning, sampling, science/technical support
Scott	Hayward	Geological Survey of Canada (Atlantic)	3.5 khz operation and science/technical support
Jenna	Higgins	Geological Survey of Canada (Atlantic)	Curation and science/technical support
Desmond	Manning	Geological Survey of Canada (Atlantic)	Sampling and science/technical support
Patrick	Meslin	Geological Survey of Canada (Atlantic)	Mobilization

Figure 1. Science participants of the 2023004 William Kennedy expedition, from left to right: Jordan Eamer, Scott Hayward, Cameron Greaves, Desmond Manning, and Jenna Higgins. Not pictured is Patrick Meslin, who was instrumental in mobilizing the ship instrumentation and scientific equipment. Photograph by J.B.R Eamer. NRCan photo 2023-410

3. Summary of activities

The science crew assembled at the Bedford Institute of Oceanography early on November 13 and drove to Canso, Nova Scotia to mobilize and board the RV William Kennedy, which had arrived the night before. This expedition benefited from the opportunity provided by the ship and ship's crew passing by the study area during their transit back to winter port in Dartmouth, Nova Scotia. Mobilization of the ship led by Patrick Meslin began at 1400 UTC, continued through the day without incident, Patrick departed Canso to return to BIO at 1800 UTC, and the ship departed port at ~2250 UTC on JD 317.

Having departed port after dark, surveying using the sub-bottom profiler was the first activity. Lines that were drawn in the planning phase in the northern part of the bay (abutting the shipping lanes) were surveyed all night by Scott Hayward. Other than minor deviations to avoid anchorages, nighttime operations proceeded without incident.

The daytime shift on JD 318 was dedicated to collecting cores. Two new coring setups were used on JD 318, a piston corer (used for only one core previously) and vibrocorer (not yet used operationally) both procured specifically for operations off of small vessels. Both performed well. Targets were selected in the planning phase from the extensive seismic data and previous interpretation of the seabed geology by J. Shaw and E. King but were refined based on the input from the 3.5 kHz sub-bottom profiler which ran continuously throughout the cruise.

The remainder of the cruise operated in this manner, with night-time operations on JD 319 dedicated to the southern and western portions of the bay, and coring/camera sampling focused on the western and central portions of the bay. The ship returned to port at ~0125 UTC on JD 320, and the crew did a partial demobilization and returned to BIO. The remainder of the demobilization took place alongside COVE in Dartmouth on the William Kennedy's return.

Table 2. Summary of activities

Date	JD	Location	SBP	Cores	Camera transects	Notes
13 Nov	317/318	Canso	X			Drive to Canso, ship mobilization, start SBP lines
14 Nov	318/319	Chedabucto Bay	X	12		SBP lines in NE, piston and vibrocoring in NE, SBP in south and west
15 Nov	319/320	Chedabucto Bay	X	13	2	Gravity cores and camera in west, transit back to Canso, return drive to BIO

4. Preliminary results

4.1 Cruise statistics

The 2023004 William Kennedy cruise allowed the collection of:

1. 4 piston cores
2. 8 vibrocores (1 with no recovery, 2 were short enough and with no structure as such were bagged)
3. 13 gravity cores
4. 2 camera transects (109 new seabed photos)
5. 31.1 km of new sub-bottom profiler data

A map of these data and samples collected is shown in Figure 2.

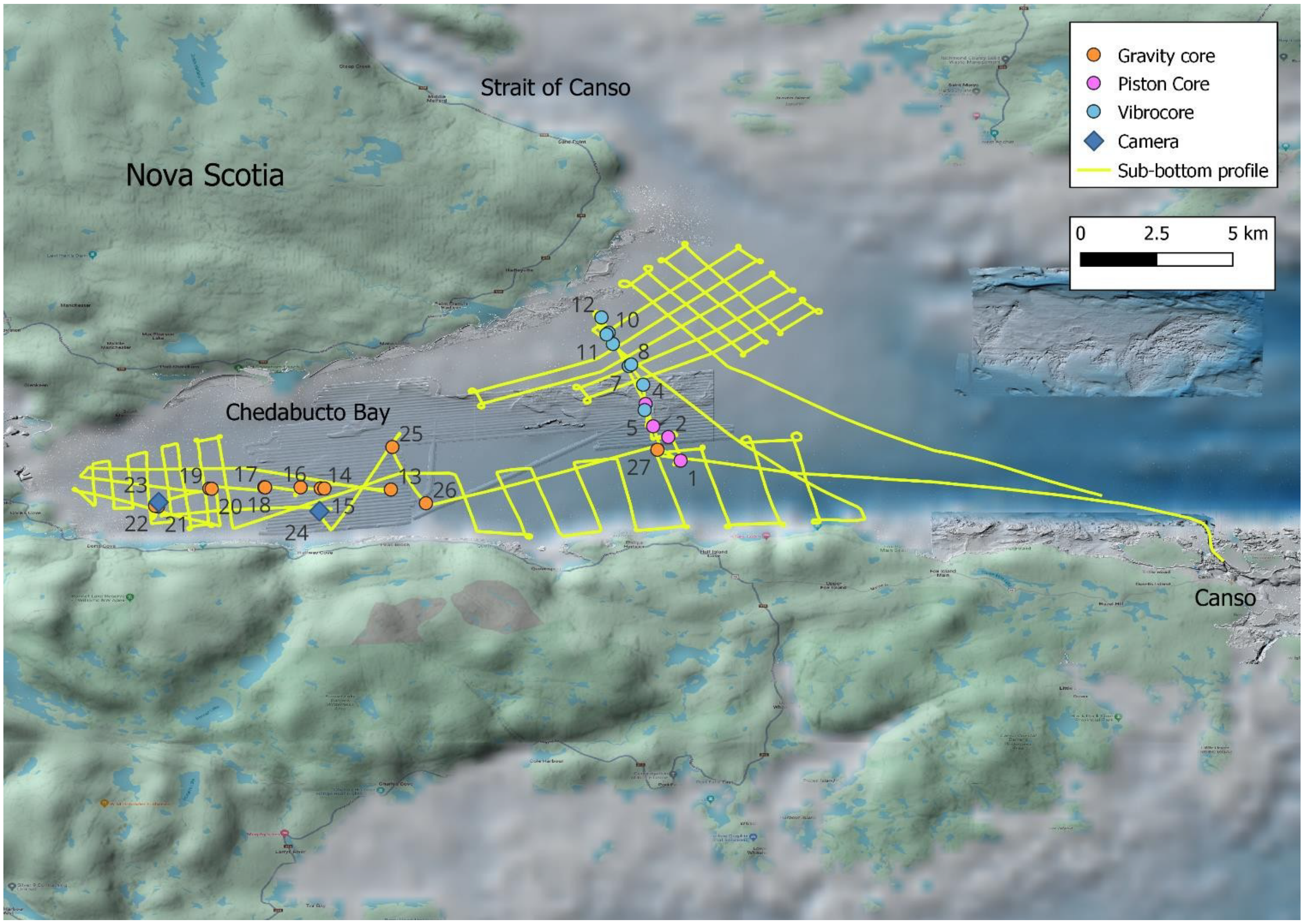

Figure 2. Map showing data and samples collected during 2023004. Station numbers match those in Table 3, Appendix A.

4.2 Key preliminary results

Deep, well sorted medium sands were collected at station 8 (Figure 3) and indicate through the level of grain size sorting that previous hypotheses of a coastal transgressive systems tract in this area are likely to be substantiated.

Previously developed surficial geology and seabed textural maps created by J. Shaw were ground truthed through camera transects, with station 24 showing a transition from bedrock and boulders to sands and gravels to muddy sediments as the transect continued south (Figure 4).

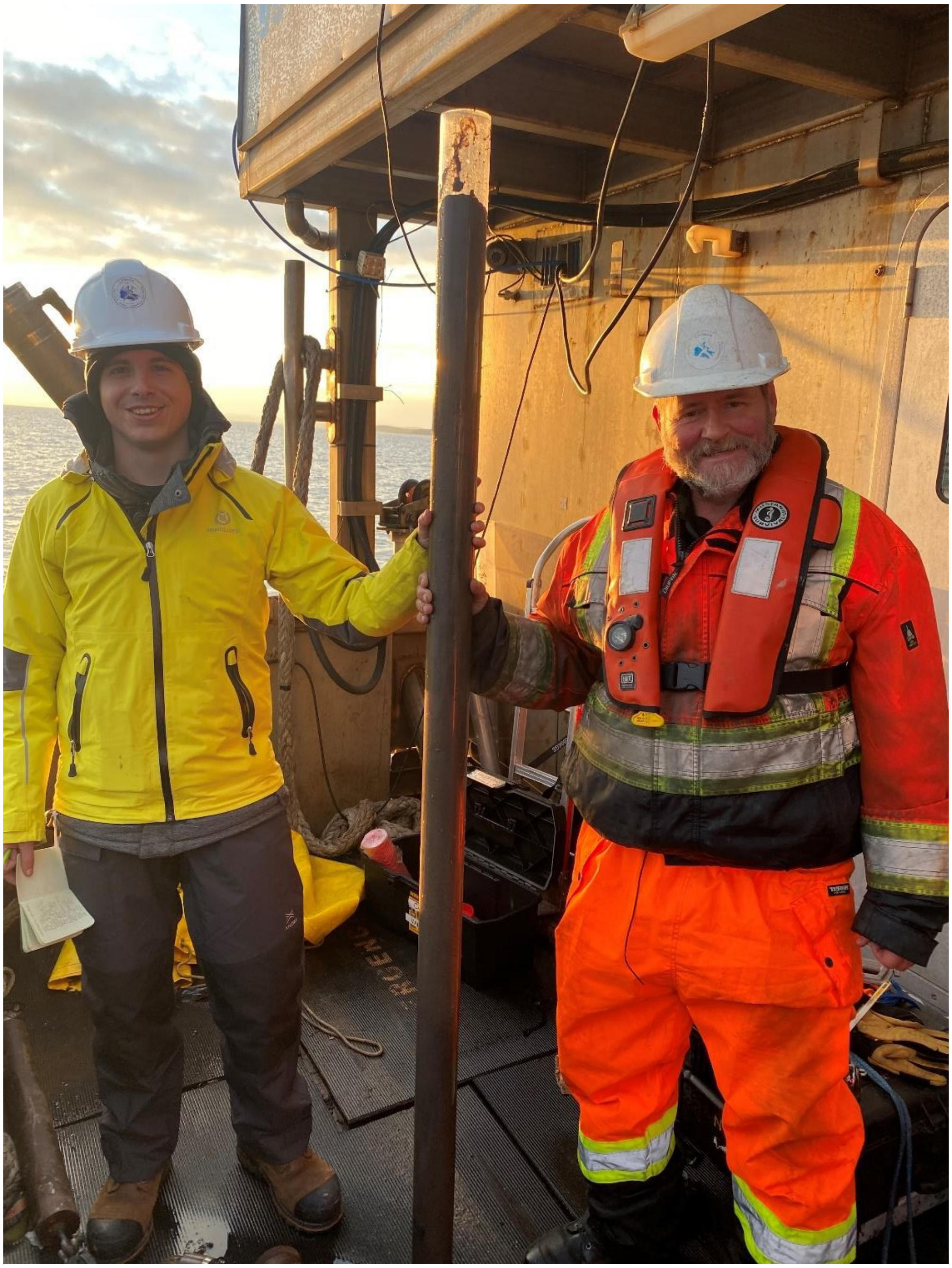

Figure 3. Nearly 2 metres of vibrocored well-sorted medium sands collect at station 8. Photograph by J.B.R Eamer. NRCan photo 2023-411

Figure 4. Select photos from station 24, showing a transition from bedrock/boulders to gravels to sand/mud. Photograph by J.B.R Eamer. NRCan photo 2023-412, 413, and 414

Despite a strong acoustic gas masking signal showing up in the sub-bottom profiler data (e.g., Figure 5), attempts to core into the gas-charged sediments (e.g., Stations 001, 026, 027) did not yield any degassing in the core liner or the smell of biogenic gas on deck.

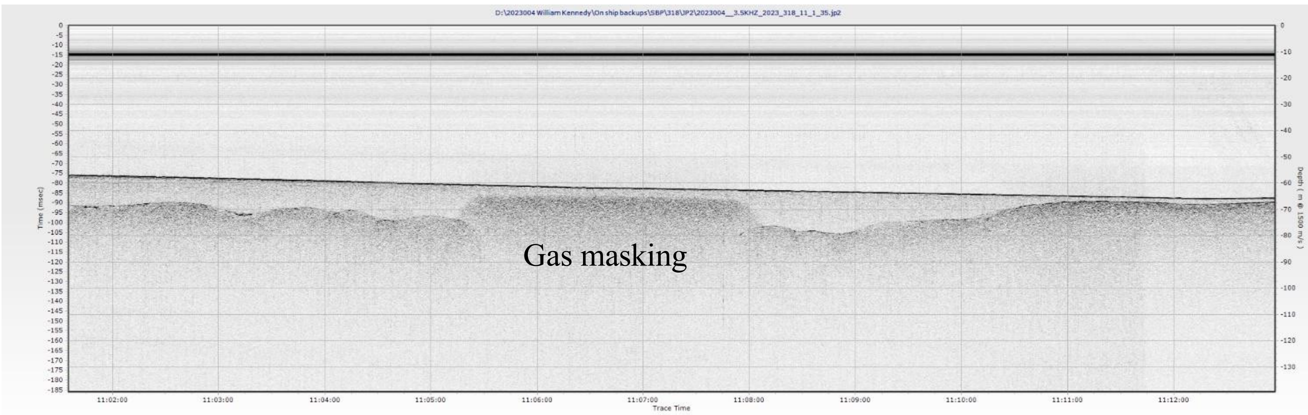

Figure 5. Gas masking in sub-bottom profile from 2023004_3.5KHZ_2023_318_11_1_35, between stations 1 and 3.

In the cruise planning stage, numerous infilled channels inferred to have formed during a lower relative sea-level in the bay were identified in seismic data in the western portion. Sub-bottom profiler data collected on this expedition resulted in the preliminary identification of several more infilled valleys in the northern portion of the bay as well (Figure 6), an intriguing contribution to the paleogeographic interpretation of the study area.

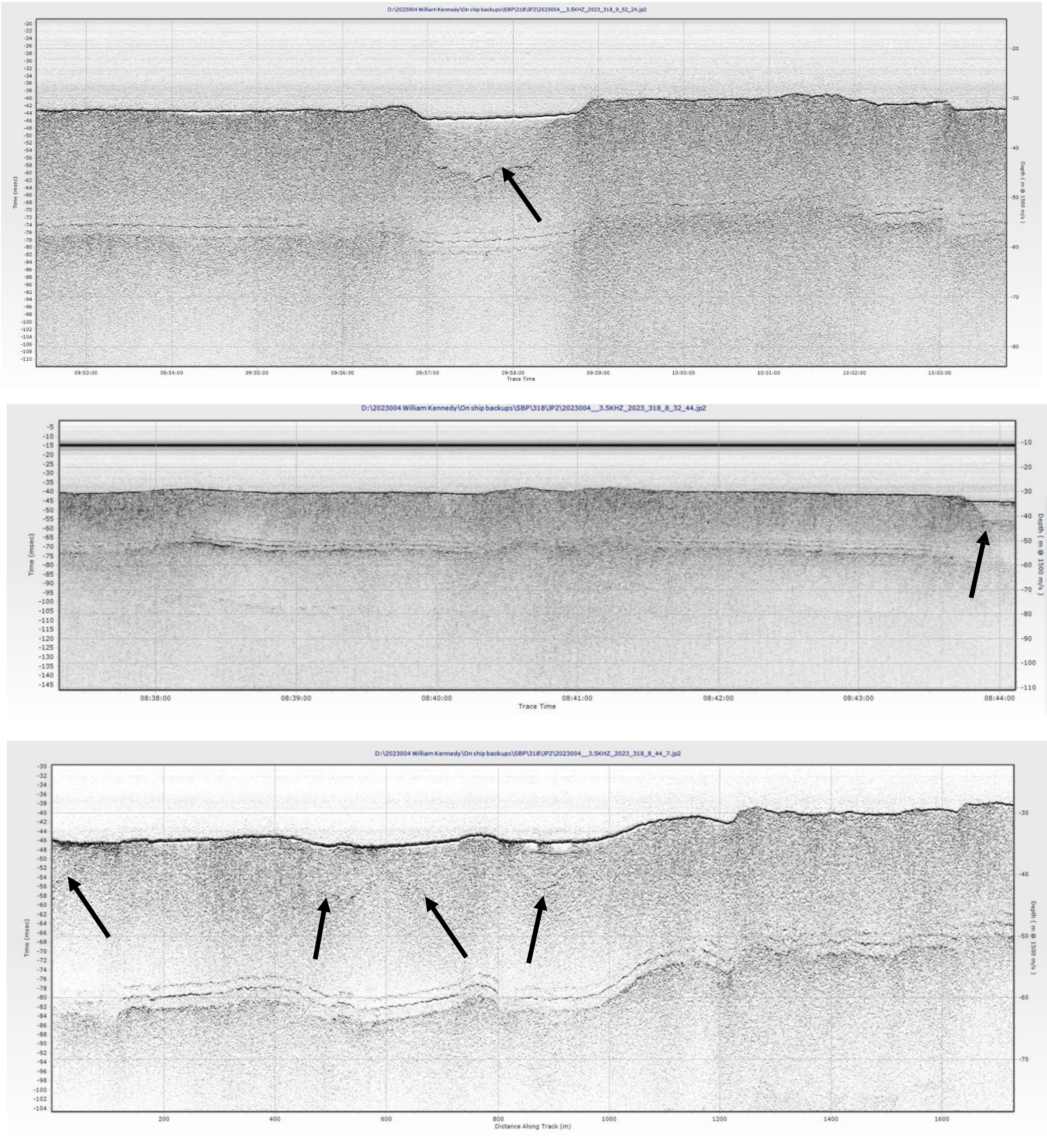

Figure 6. Sub-bottom profiles (top to bottom) 2023004__3.5KHZ_2023_318_9_52_24, 2023004__3.5KHZ_2023_318_8_32_44, and 2023004__3.5KHZ_2023_318_8_44_7 with arrows highlighting infilled channels in the northwestern part of the bay – these are all part of one line running parallel to the northern coastline, indicating the channels likely run perpendicular to the coastline.

5. Equipment and procedures

5.1 Sub-bottom profiler

A 3.5 kHz Knudsen Pinger sub-bottom profiler (Figure 7) was pole-mounted to the starboard side of the vessel, and recorded data almost continuously during the first 2 days of the cruise. The cowling had to be slightly modified to fit the adapter (shown attached to the pole in Figure 7). The pinger was used to acquire high-resolution subsurface data (sediment stratigraphy) and assisted in selecting core locations and identify features of interest on the seabed. The echo-control acquisition software was consistently monitored for depth ranging. Despite a consistently coarse sediment seabed, the system performed well and experienced no downtime for the duration of the cruise.

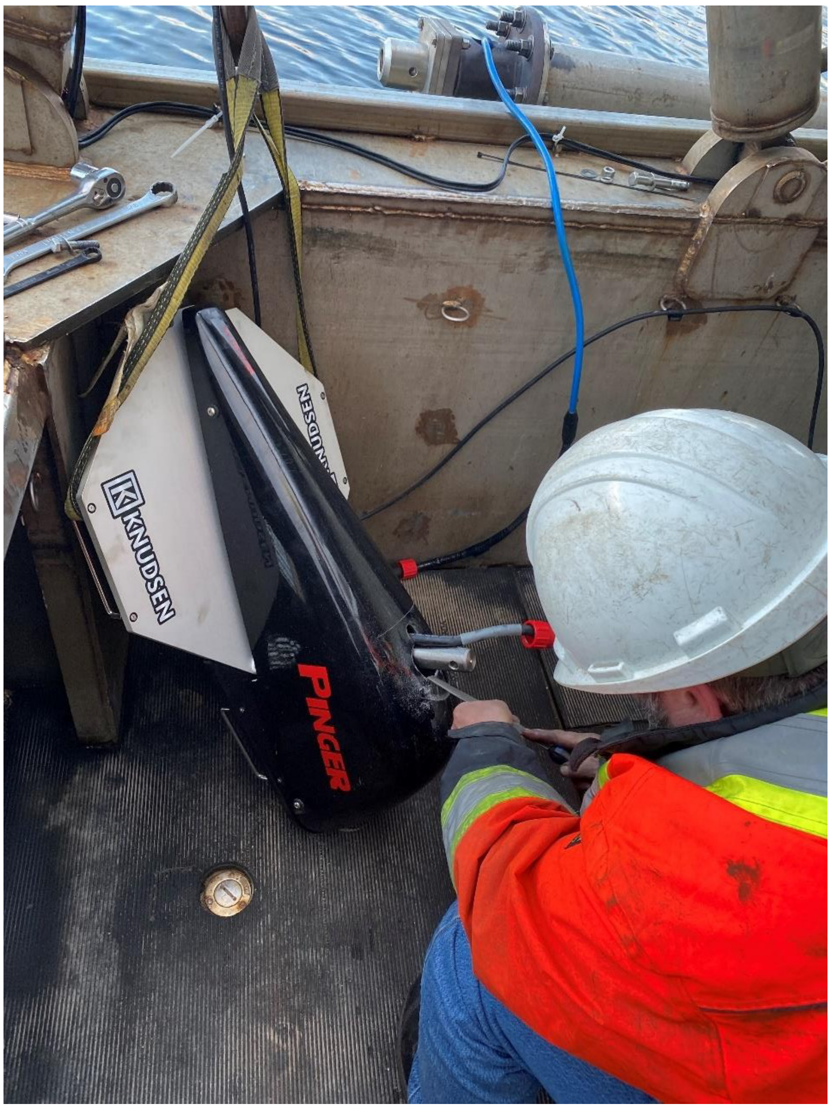

Figure 7. Light sanding of the cowling to allow the pinger to fit the pole mount adapter. Photograph by J.B.R Eamer. NRCan photo 2023-415

5.2 Coring equipment

Three types of coring systems were used during this expedition. A piston corer from Mooring Systems (Figure 8) was initially used to penetrate into the harder bottom consistently found in the study area.

Figure 8. Mooring systems piston corer setup, including pilot weight in the top right and trigger arm in the foreground. The corer is the same as is used for a simpler gravity coring setup. Photograph by J.B.R Eamer. NRCan photo 2023-416

The piston corer uses a pilot weight to allow a free-fall of the corer. Once the pilot weight touches the bottom, it releases the trigger which allows a freefall of the main corer. In addition, instead of a valve, a piston is inserted in the liner. When the corer penetrates the sediment, the piston is forced upward, which eliminates water being trapped above the sample. During ascent of the corer, the piston creates a vacuum inside the liner, which helps retain the sample in the liner. The corer was used four times and experienced moderately good recovery, however on the fourth core collection the piston broke apart (Figure 9) and the corer was no longer used for the duration of the expedition.

Figure 9. Pieces of the piston and pin recovered on deck. Photograph by J.B.R Eamer. NRCan photo 2023-417

A new vibracoring unit from OSIL (Figure 10) was utilized to collect 8 cores on this expedition, 5 of which had good recovery. It is a portable unit with no frame and works by vibrating the core head through a topside battery power source. The vibrations are transferred to the whole coring unit and into the substrate. This acts to reduce the friction resistance of the barrel in the sediment, allowing penetration of the barrel under gravity into sandy-sized sediments which can re-organize when a vibrating force is applied to them. The corer was lowered to within 2 metres of the seabed, then vibration was turned on. Following this, the corer was lowered at the slowest rate possible until slack was observed in the line and lowering was stopped. Once the line became taught more line was delivered, until the line no longer became taught. Because the unit had no frame, it was quite susceptible to conditions on this vessel (as it had no dynamic positioning). If there was any drift while attempting to allow the unit to penetrate the seabed, it's hypothesized that we would be pulling the corer by the line, counteracting the downward penetration force by gravity. Success using this corer was only achieved in fairly calm conditions with little current.

Figure 10. OSIL mini-vibrocorer (on left) and benthos gravity corer (on right). Photograph by J.B.R Eamer. NRCan photo 2023-418

The gravity corer (Figure 10) was sole coring device used on JD 319 as the piston mechanism for the piston corer was broken and the sea state meant recovery of cores using the vibrocorer was unlikely. During deployment, the gravity corer was stabilized around 10 meters above the seafloor before accelerating descent speed to maximum. Six ballast weighs of 20 kg were used above the core barrel to assist penetration in the seabed through gravity. A total of 13 cores were successfully collected using the gravity corer and penetration was generally excellent, although notably the observed penetration consistently outperformed the actual recovery in the liner.

5.3 GSCA 4K camera

The custom-built drop camera system from Natural Resources Canada (Figure 11), termed the 4K camera due to the ability to deploy the unit to 4000 m water depth, was deployed twice to image surficial sediments in the western portion of the study area (station 23, 24, Figure 2). It was used to acquire images of the seabed along transects. The drop camera was lowered on the seafloor and was triggered once a weight touched bottom. The vessel drifted with no propulsion and the camera was raised and lowered during the transect by a few metres each time. The vessel's GPS track was recorded during the image transect, the Regulus navigation system was used to record the location of each photo, and the start and end coordinates and time were recorded (Appendix A, Table 3).

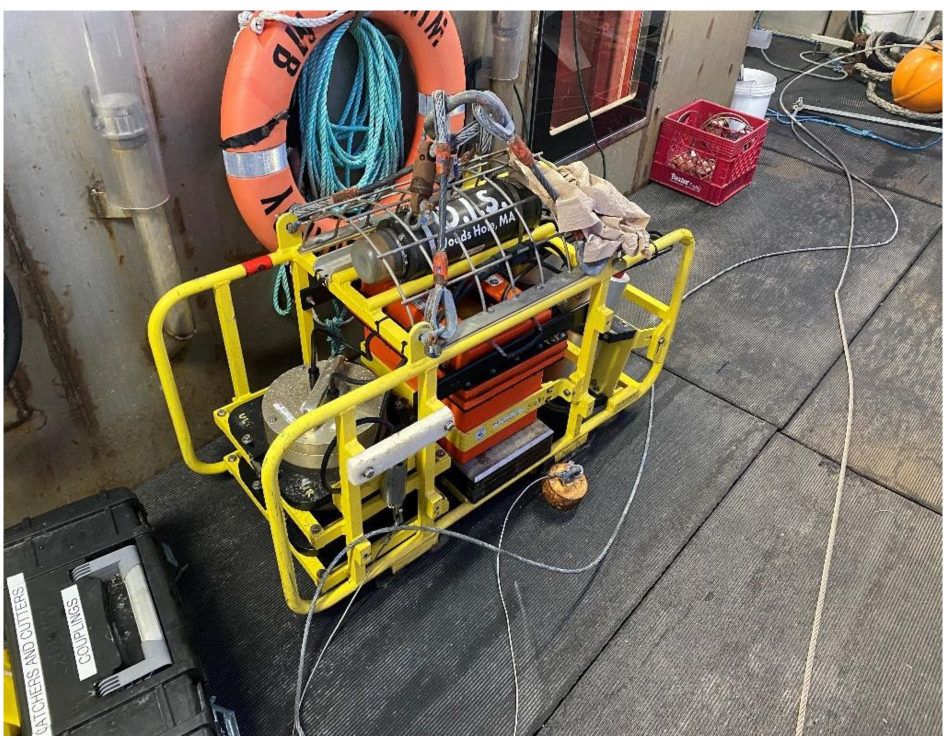

Figure 11. GSCA 4K camera system on the working deck of the William Kennedy. Photograph by J.B.R Eamer. NRCan photo 2023-419

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Appendix A: Station summary

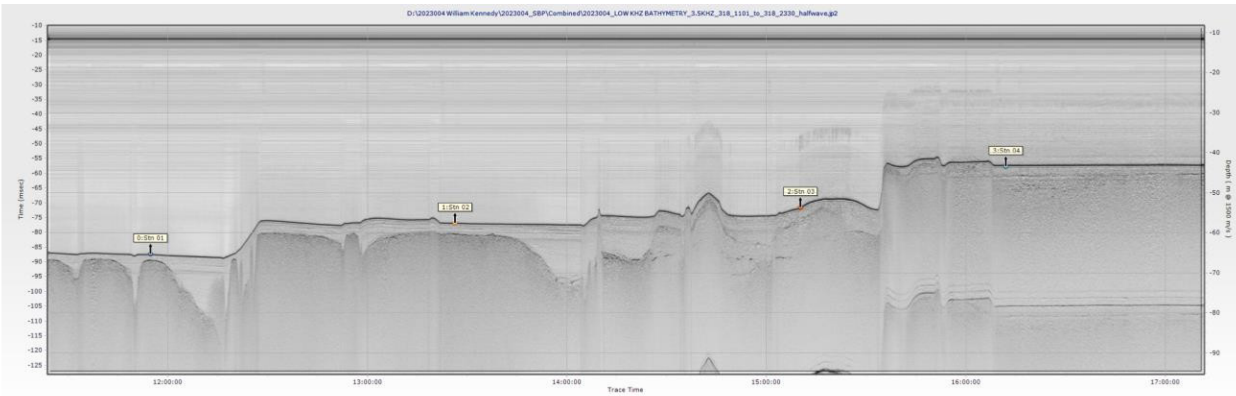
Table 3. Summary of stations in Chedabucto Bay, Nova Scotia.

2023004 Eastern Shore Nova Scotia stations																				
Vessel: RV William Kennedy Date: November 13-15, 2023																				
Station No.	Sample Type (GC, PC, VC, Camera, Box core)	J Day (317, 318, 319)	UTC at Bottom/ start	Lat Bottom	Long Bottom	UTC at end (camera)	Lat at end (camera)	Long at end (camera)	Location	Water Depth (m)	Water Depth at end (m)	Corer length (cm)	App. Penetration (cm)	Core length (cm)	No. of Sections	Bagged (cutter/ catcher/ both)	Based on Seismic? (Y/N)	Seismic line	Comments
0001	PC	318	11:54	45.384972	-61.213909				Scotian Shelf - Chedabucto Bay NS	58		300	150	109	1	Catcher	Y	9224_SEISMIC_SEISTEC_ 193_1250_193_1811	
0002	PC	318	13:26	45.394847	-61.219062				Scotian Shelf - Chedabucto Bay NS	51		300	250	162	2	Catcher	Y	9224_SEISMIC_SEISTEC_ 193_1250_193_1811	
0003	PC	318	15:10	45.399345	-61.225378				Scotian Shelf - Chedabucto Bay NS	47		300	115	54	1	Catcher	y	9224_SEISMIC_SEISTEC_ 194_1300_194_1756	
0004	PC	318	16:16	45.408655	-61.228557				Scotian Shelf - Chedabucto Bay NS	36		300	250	120	1	***	Y	9224_SEISMIC_SEISTEC_ 194_1300_194_1756	
0005	VC	318	18:30	45.406145	-61.228931				Scotian Shelf - Chedabucto Bay NS	36		200	50	33	1	***	Y	9224_SEISMIC_SEISTEC_ 194_1300_194_1756	
0006	VC	318	19:02	45.416740	-61.229570				Scotian Shelf - Chedabucto Bay NS	30		200	100	135	1	Catcher	Y	9224_SEISMIC_SEISTEC_ 193_1250_193_1811	
0007	VC	318	19:38	45.424560	-61.235577				Scotian Shelf - Chedabucto Bay NS	24		200	100	15	NA	None	Y	9224_SEISMIC_SEISTEC_ 193_1250_193_1811	bagged
0008	VC	318	19:56	45.425186	-61.234579				Scotian Shelf - Chedabucto Bay NS	29		200	0	187	2	None	Y	9224_SEISMIC_SEISTEC_ 193_1250_193_1811	
0009	VC	318	20:26	45.433815	-61.242218				Scotian Shelf - Chedabucto Bay NS	28		200	0	10	NA	None	Y	9224_SEISMIC_SEISTEC_ 193_1250_193_1811	bagged
0010	VC	318	20:48	45.438472	-61.243996				Scotian Shelf - Chedabucto Bay NS	25		200	0	39	1	Catcher	Y	9224_SEISMIC_SEISTEC_ 193_1250_193_1811	
0011	VC	318	21:08	45.437781	-61.244850				Scotian Shelf - Chedabucto Bay NS	23		200	0	0	NA	NA	Y	9224_SEISMIC_SEISTEC_ 193_1250_193_1811	
0012	VC	318	21:29	45.444874	-61.247000				Scotian Shelf - Chedabucto Bay NS	18		200	0	73	NA	***	Y	9224_SEISMIC_SEISTEC_ 193_1250_193_1811	

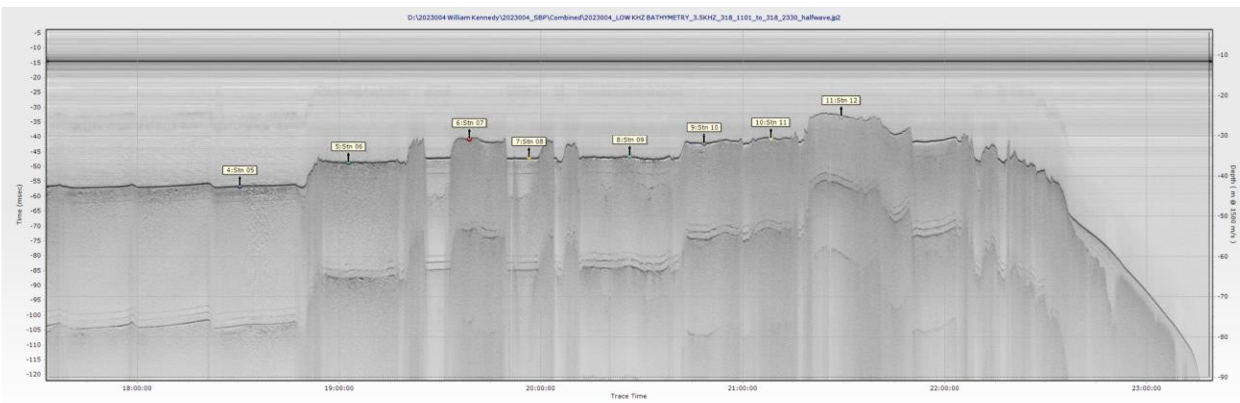
0013	GC	319	1137	45.372864	-61.335005				Scotian Shelf - Chedabucto Bay NS	44		300	150	92	1	catcher	y	94032_SEISMIC_HUNTEC_INT_328_0452_328_1200	94032 328 0452 HUNTEC
0014	GC	319	1205	45.373377	-61.364298				Scotian Shelf - Chedabucto Bay NS	40		300	100	42	1		Y	94032_SEISMIC_HUNTEC_INT_328_0452_328_1200	94032 328 0452 HUNTEC
0015	GC	319	1223	45.373309	-61.362759				Scotian Shelf - Chedabucto Bay NS	41		300	180	101	1	BOTH	Y	94032_SEISMIC_HUNTEC_INT_328_0452_328_1200	94032 328 042 HUNTEC
0016	GC	319	1319	45.37381	-61.372728				Scotian Shelf - Chedabucto Bay NS	39		300	300	188	1	BOTH	Y	94032_SEISMIC_HUNTEC_INT_328_0452_328_1200	
0017	GC	319	1342	45.373829	-61.387917				Scotian Shelf - Chedabucto Bay NS	37		300	150	44	1	BOTH	Y	94032_SEISMIC_HUNTEC_INT_328_0452_328_1200	
0018	GC	319	1404	45.373772	-61.387564				Scotian Shelf - Chedabucto Bay NS	37		300	300	180	1	BOTH	Y	94032_SEISMIC_HUNTEC_INT_328_0452_328_1200	
0019	GC	319	1432	45.373285	-61.410837				Scotian Shelf - Chedabucto Bay NS	34		300	300	190	1	BOTH	Y	94032_SEISMIC_HUNTEC_INT_328_0452_328_1200	
0020	GC	319	1505	45.373195	-61.409903				Scotian Shelf - Chedabucto Bay NS	34		300	300	148	1	BOTH	Y	94032_SEISMIC_HUNTEC_INT_328_0452_328_1200	
0021	GC	319	1534	45.365767	-61.432331				Scotian Shelf - Chedabucto Bay NS	29		300	200	121	1	BOTH	Y	9224_SEISMIC_SEISTEC_196_1509_196_1813	
0022	GC	319	1601	45.366058	-61.433535				Scotian Shelf - Chedabucto Bay NS	29		300	150	113	1	CATCHER	Y	9224_SEISMIC_SEISTEC_196_1509_196_1813	
0023	Camera	319	1710	45.367584	-61.432053	1733	45.363919	-61.4313	Scotian Shelf - Chedabucto Bay NS	30		NA	NA	NA	NA	NA	NA	NA	
0024	Camera	319	1833	45.363826	-61.364841	1916	45.356773	-61.36087	Scotian Shelf - Chedabucto Bay NS	32	37	NA	NA	NA	NA	NA	NA	NA	
0025	GC	319	2000	45.390668	-61.33439				Scotian Shelf - Chedabucto Bay NS	40		300	200	128	1	BOTH	Y	9224_SEISMIC_SEISTEC_190_1868_191_1859	
0026	GC	319	2026	45.367145	-61.320351				Scotian Shelf - Chedabucto Bay NS	47		300	150	77	1	None	Y	9224_SEISMIC_SEISTEC_190_1868_191_1859	
0027	GC	319	2132	45.389521	-61.223593				Scotian Shelf - Chedabucto Bay NS	54		300	300	196	1	catcher	Y	9224_SEISMIC_SEISTEC_194_1300_194_1756	

Appendix B: Core and photo transect locations and stratigraphy

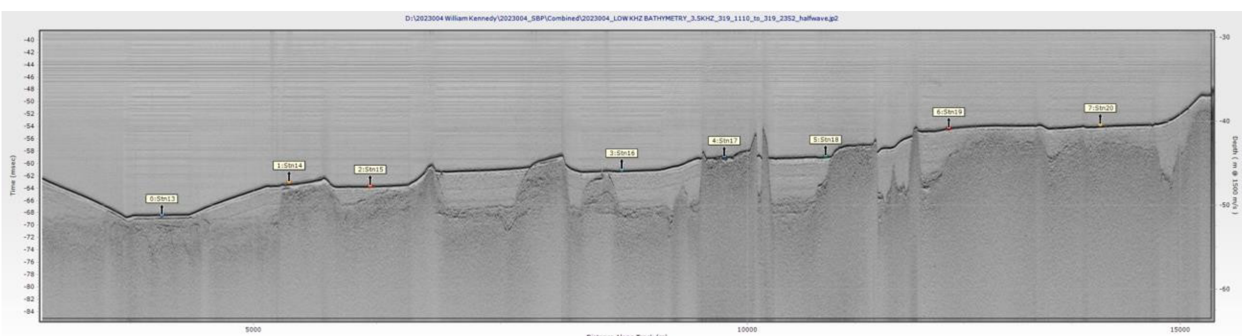
Stations 1 - 4



Stations 5 - 12



Stations 13 - 20



Stations 21 - 27