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CCGS Amundsen 2022805: Seafloor mapping and investigation of geohazards, offshore northern Labrador, Newfoundland and Labrador

L. Broom, R. Bennett, A. Normandeau, and T. Carson

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ACKNOWLEDGMENTS

We would like to thank the Captain of the CCGS Amundsen Pascal Pellerin and the ships officers and crew. We thank Amundsen Science, the Chief Scientist David Coté, and the entire science and technical crew. We also thank the Nunatsiavut Government for permission to work in their marine territories.

1. BACKGROUND

The work conducted on the Canadian Coast Guard Ship (CCGS) Amundsen (Figure 1) by the Geological Survey of Canada – Atlantic (GSC-A) was completed within the Newfoundland and Labrador Shelves project under the Marine Geoscience for Marine Spatial Planning program (MGMSP). The goal of MGMSP is to ensure that marine geoscience data can inform decisions regarding marine spatial planning and impact assessments. This includes obtaining seabed information on surficial geology, geological processes, and geohazards to support decisions on marine infrastructure, seabed resources, and marine conservation.

Since 2021, the GSC-A has started investigating the nearshore seabed along the Labrador Margin (Limoges et al., 2022; Normandeau et al. 2022). Fjord environments are susceptible to subaerial and submarine landslides, which can have the potential to produce tsunamis, posing a potential risk to public safety and marine infrastructure. A recent example of this type of event was the 2017 landslide and tsunami in Karrat Fjord, West Greenland (Gauthier et al. 2018). This subaerial landslide generated a tsunami that flooded the village of Nuugaatsiaq resulting in loss of lives and infrastructure. Nachvak Fjord is part of Torngat Mountains National Park and is frequently utilized by Labrador Inuit. It is also within a proposed Indigenous protected area. Previous bathymetric surveys in the region revealed a submarine landslide near the mouth of the fjord.

Figure 1: CCGS Amundsen in Nachvak Fjord. Photo courtesy of David Coté (DFO).

Expedition 2022805 (CCGS Amundsen 2022 leg 1) was a multidisciplinary cruise conducted with scientists from academia and government. This report addresses data specifically collected for, and archived at, the GSC-A.

2. OBJECTIVES

1. Characterize a submarine landslide deposit in Nachvak Fjord, Labrador. An autonomous underwater vehicle (AUV) collected high-resolution bathymetric data over the deposit, and gravity cores were collected to characterize and constrain the age of the event(s).
2. An experimental deployment of the AUV over an area with potential coral habitat. This deployment was conducted to find out if corals can be resolved by the AUV bathymetry and sidescan.

3. PARTICIPANTS

Four participants from the Geological Survey of Canada – Atlantic contributed to the 2022805 CCGS Amundsen expedition (Table 1). Alexandre Normandeau planned the GSC-A stations and provided onshore scientific support. The field team included Robbie Bennett, Tom Carson and Laura Broom who executed core collection and the AUV missions.

Table 1: Geological Survey of Canada participants onboard the 2022805 CCGS Amundsen Expedition.

First name	Last name	Organization	Role
Alexandre	Normandeau	Geological Survey of Canada	Research Scientist – Shore-based
Robbie	Bennett	Geological Survey of Canada	Physical Scientist
Laura	Broom	Geological Survey of Canada	Physical Scientist
Tom	Carson	Geological Survey of Canada	Technician

4. SUMMARY OF ACTIVTIES

The 2022805 Amundsen expedition was a multidisciplinary mission conducted through Amundsen Science. The expedition began in Quebec City, Quebec on September 9th, 2022 and ended in Iqaluit on September 22, 2022. The GSC-A data acquisition took place between September 13 and 16 . The GSC-A objectives during the 2022805 resulted in the collection of (Table 2; Figure 2):

1. 3 giant gravity cores
2. 3 box cores and one push core
3. 2 AUV dives

Table 2: Coring and AUV dive operations conducted by the Geological Survey of Canada

Station	Station type	Day (JD) & time (UTC)	Latitude	Longitude	Depth (m)	Core length (cm)	Location
0001	Box core	256/03:47	54.6182	-56.4451	359	N/A	Labrador Sea – Joey's Gully
0002	AUV	256/12:02	54.5894	-56.3218	520	N/A	Labrador Sea – Joey's Gully
0003	Box core	257/21:59	56.06611	-57.4605	274	N/A	Labrador Sea - Hopedale Saddle
0004	Giant gravity core	258/19:57	59.10332	-63.4163	214	461.5	Labrador Sea - Nachvak Fjord
0005	Giant gravity core	258/21:32	59.1098	-63.4304	138	661.5	Labrador Sea - Nachvak Fjord
0006	Box core	259/08:03	59.07611	-63.5303	204	44	Labrador Sea - Nachvak Fjord
0007	Giant gravity core	259/10:31	59.09549	-63.4248	199	625	Labrador Sea - Nachvak Fjord
0008	AUV	259/12:36	59.09439	-63.4228	199	N/A	Labrador Sea - Nachvak Fjord

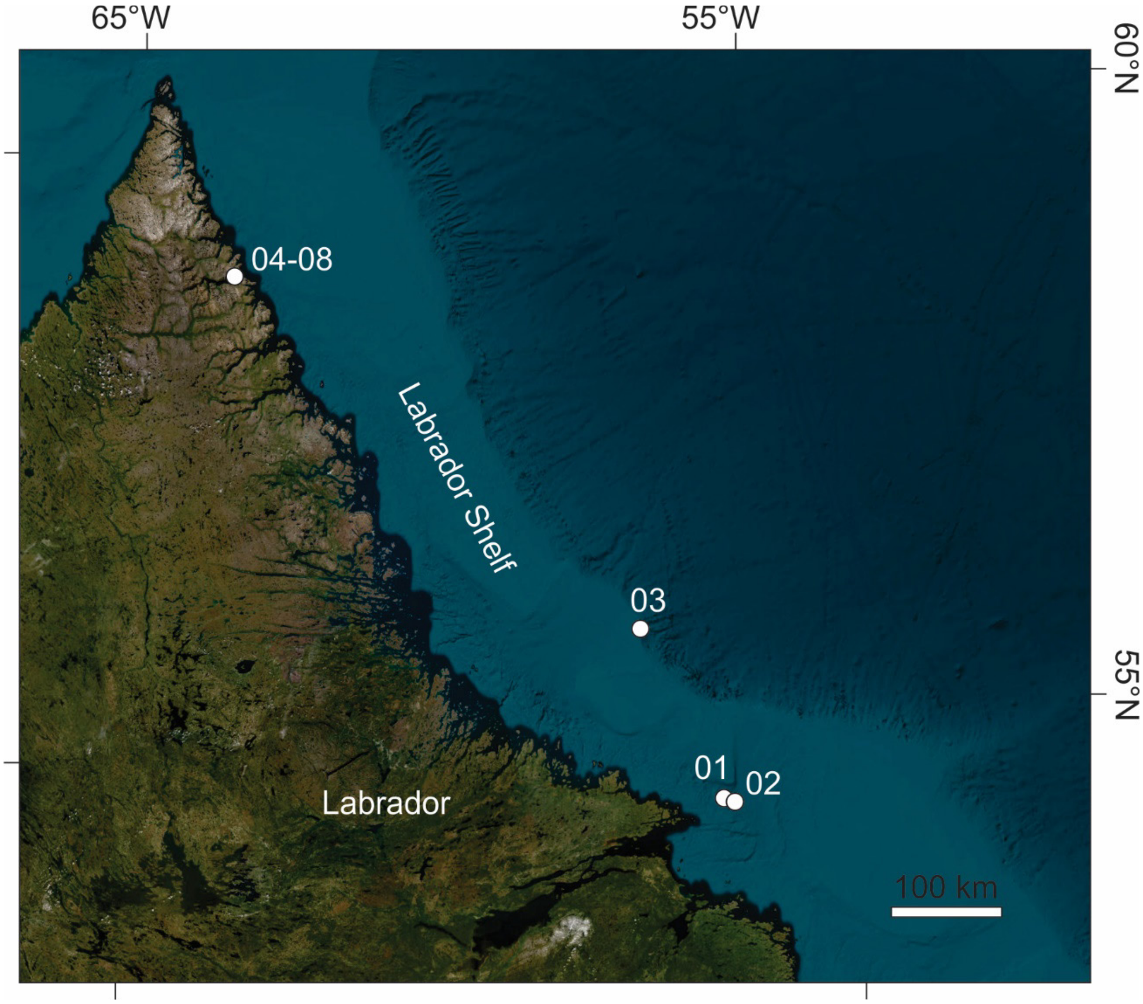

Figure 2: Location of gravity core, box core and AUV stations from 2022805. World imagery basemap from: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

5. EQUIPMENT AND PROCEDURES

5.1 Multibeam echosounder: Kongsberg EM304 30kHz

In 2022, Amundsen Science installed a hull-mount Kongsberg EM304 30kHz multibeam echosounder to upgrade from the previous system. The EM304 is a full ocean depth multibeam sonar capable of mapping shallow-waters as well as down to 11,000 metres. The ship was also equipped with a POSMV V5 positioning and orientation system. The multibeam echosounder was run continuously during transit.

5.2 Sub-bottom profiler: Knudsen 3260 3.5kHz

The sub-bottom profiler system installed on the Amundsen is a Knudsen 3260. It acquires sub-bottom profiles at 3.5 kHz to image the sub-seafloor stratigraphy. Sub-bottom profiles were collected in Nachvak Fjord during transit to and from coring stations (Figure 3).

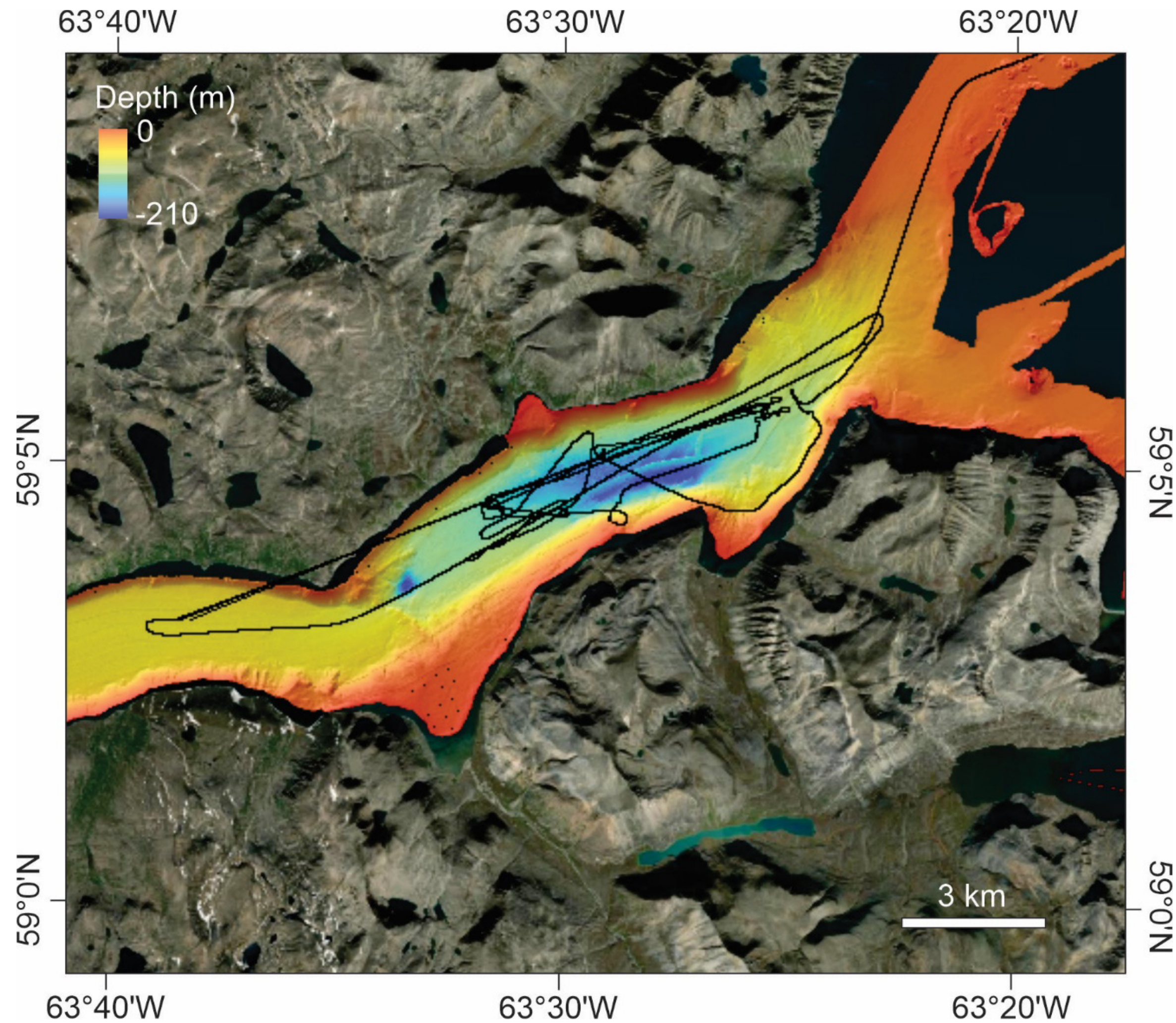

Figure 3: Black lines displaying extent of 3.5 kHz sub-bottom data collected in Nachvak Fjord, Labrador during 2022805 and the multibeam bathymetric data coverage from previous expeditions. World imagery basemap from: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

5.3 Coring

For giant gravity coring, the system used on the expedition encompassed using the piston coring system as a gravity core. The piston corer was assembled without the piston or trigger weight core and trip arm attached. A butterfly valve was placed at the top of the core liners to allow water to pass through during descent and closed during ascent to protect the sediment sample. This system consists of a nine metre long string with a 2000 lb core head (Figure 4). This setup was used because the fjord was expected to consist of soft, relatively easily penetrable sediments and the set-up time for using the piston core as a gravity core is less time consuming, which is useful on these multidisciplinary cruises when the time for day operations are shared amongst participants.

Figure 4: Gravity coring operations in Nachvak Fjord using the 9 m long core assembly. Photograph by L. Broom. NRCan photo 2023-050.

A total of three gravity cores were collected during 2022805 (Figure 5; Table 2). All were collected in Nachvak Fjord, targeting a submarine landslide deposit. Once the corer was recovered on deck it was taken apart sequentially, starting at the base. The three meter long plastic liners were cut down to 1.5 m sections and caps were fitted on both ends. The sections were then taken to the lab where they were labelled and processed. If material was present in the core cutter and catcher (the very base of the core system), this material was recovered either in bags or extruded from the cutter into a separate piece of core liner.

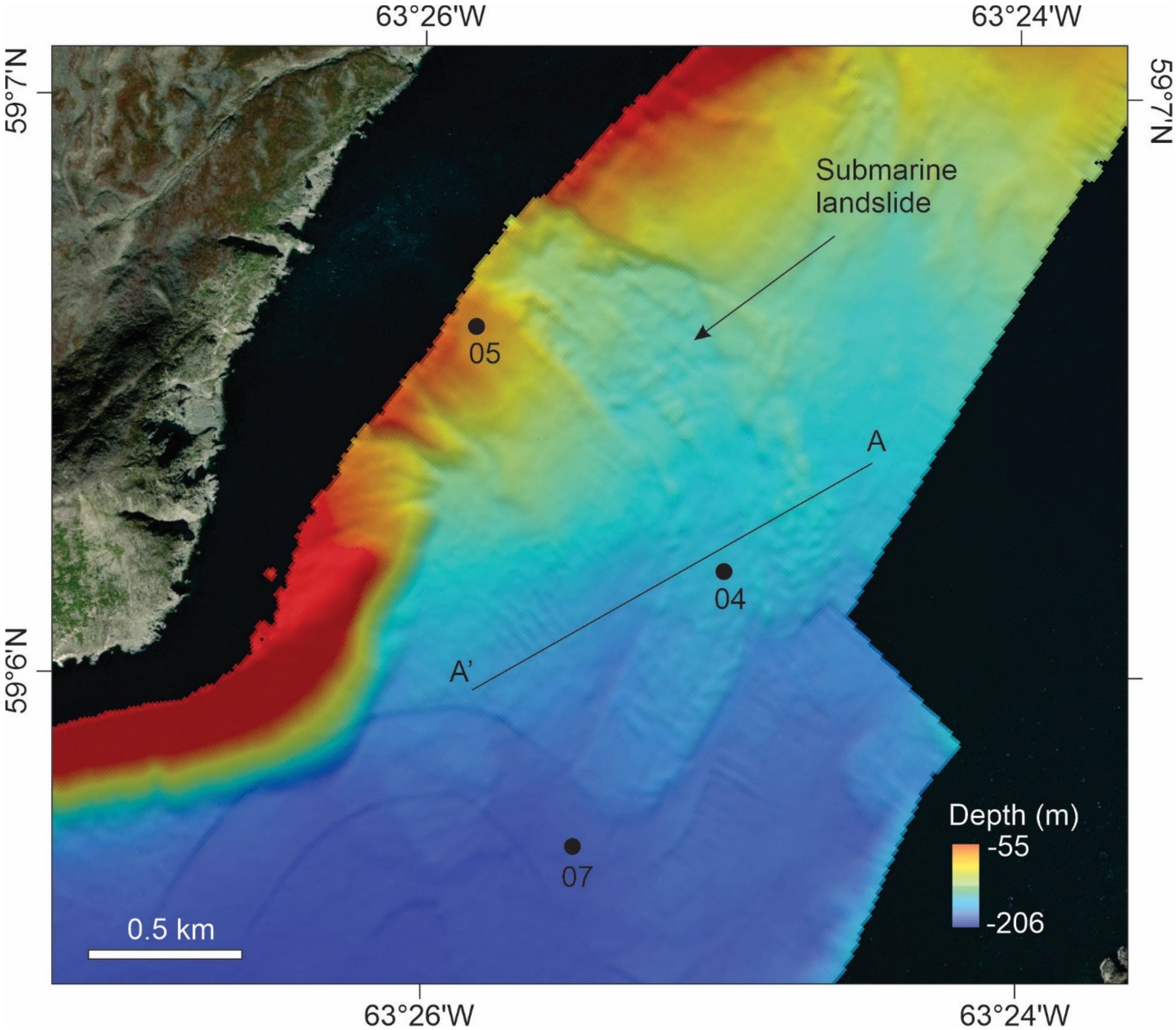

Figure 5: Locations of gravity cores (0004, 0005 and 0007) targeting a submarine landslide observed in multibeam bathymetric data. Sub-bottom profiler line for Figure 6 is shown from A to A'. World imagery basemap from: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

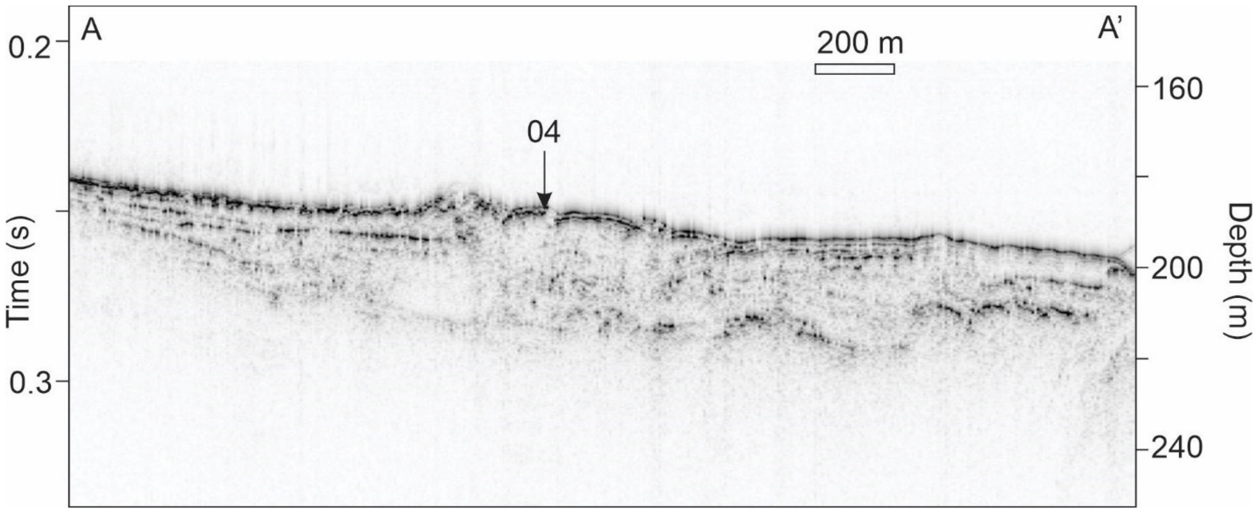

Figure 6: 3.5 kHz sub-bottom profiles showing the core location for core 0004. No Amundsen 3.5 kHz sub-bottom data was available around core 0005 or 0007.

Onboard processing of the cores consisted of taking one measurement and a subsample from the top and/or bottom of core sections where the material was suitable. Shear strength measurements were taken using a torvane that was inserted into the sediment at the bottom/top of the core liner and turned at a constant rate until the sediment failed. This measurement is used to help calibrate the shear strength measurements that will be taken along the length of the core at the GSC-A (Table 4). Constant volume samples were collected using a cylinder of known volume (Table 5). This measurement will help calibrate the bulk density measurements taken along the length of the core. Suitable sediment for these procedures is undisturbed mud. Sand, soupy mud or core disturbance will make the measurements unsuitable. The cores were then resealed with tape, the ends were covered with wax and the cores were stored upright in a refrigerated container at 4°C.

The box corer was deployed three times by the GSC-A during 2022805 (Figure 7; Figure 8). Out of the three deployments, only one of the box cores recovered material that could be subsampled with a push core. A small tube was inserted into the sediment with a vacuum pump attached to the other end to prevent compression of the sediment. Once the push core was inserted, the excess sediment was removed from the box corer with shovels, and the core was capped with endcaps, taped, sealed with wax and stored upright in the refrigerated container.

Figure 7: Box core collected from Nachvak Fjord, Labrador showing placement of push core (orange cap) collected by GSC-A. Photographs by L. Broom. NRCan photo 2023-051 and 2023-052.

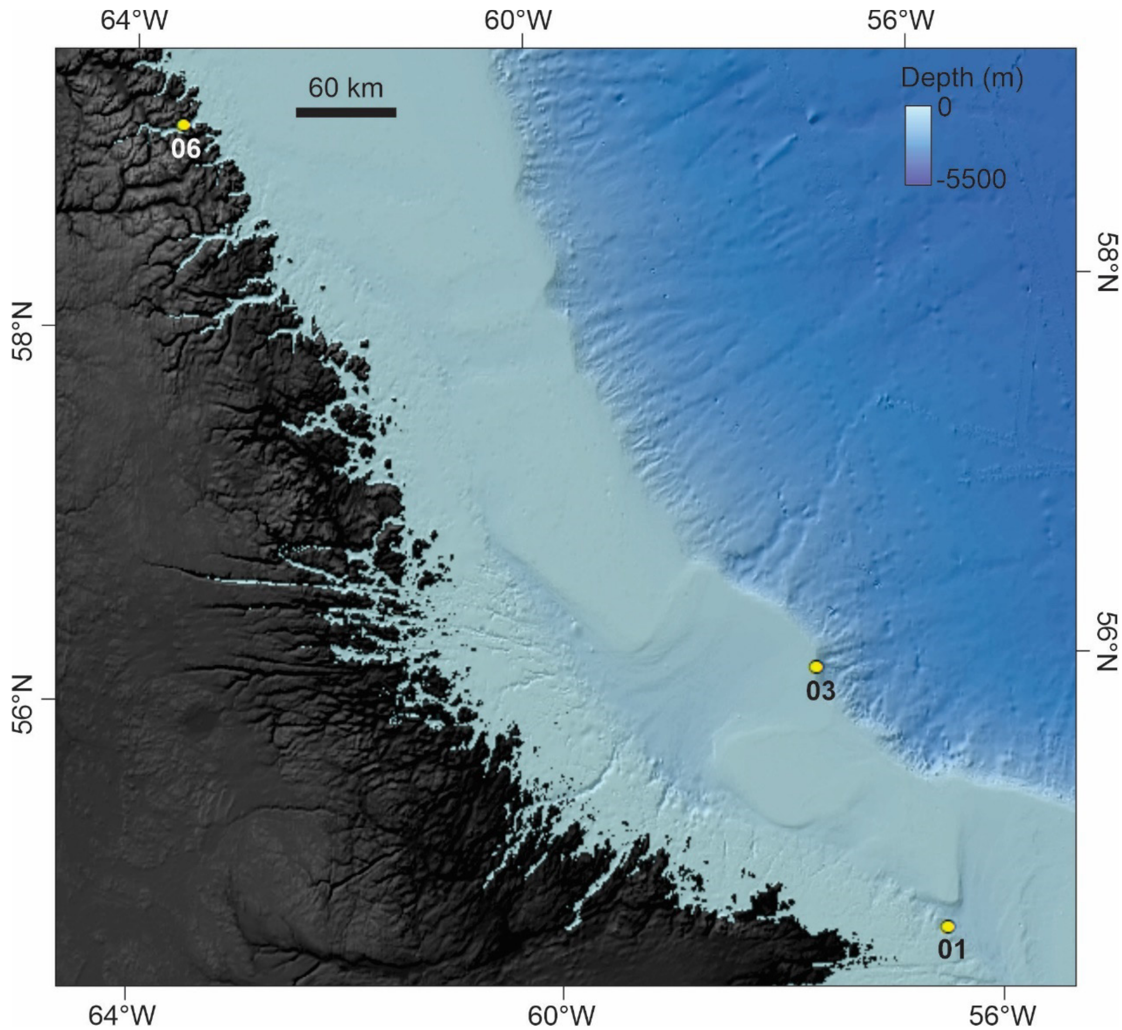

Figure 8: Box core locations for 2022805 (0001, 0003 and 0006) along the Labrador shelf. Topographic and bathymetric data source: GEBCO (2022).

5.4 AUV missions

The AUV used during this cruise was a Gavia, manufactured by Teledyne Marine (Figure 9). It is approximately 12.5’ in length and weighs 325 lbs. The main sensors on the AUV are: 1) an EdgeTech 2205 bathymetric sonar that collects side scan sonar and swath bathymetry at ~15 cm resolution; and 2) a sub-bottom profiler which operated between 12 – 23 kHz that is capable of imaging the upper 10 to 15 m of sediment. The Gavia AUV is a fully autonomous vehicle that does not receive corrections from the operator while on a mission.

The AUV is programmed with a mission plan using a laptop computer (or tablet) that is connected through its own Wi-Fi network. The AUV is deployed from the foredeck of the Amundsen using the starboard crane (Figure 10) and then towed to the mission site using a fast rescue craft (FRC). When at the appropriate release point, the AUV is untied from the FRC and activated using a ruggedized tablet connected via the AUV’s Wi-Fi network.

Figure 9: AUV used to collect high-resolution bathymetric data in Joey's Gully and Nachvak Fjord. Photograph by L. Broom. NRCan photo 2023-053.

Two AUV missions were conducted during 2022805. The first AUV mission was planned in Joey's Gully, an area with potential coral habitat. A two-hour mission was planned that covered 11.6 line km (Figure 11). The goal of this mission was to determine if it was possible to image corals using the AUV's bathymetric and sidescan sonar. This area was selected by DFO as it had a high potential for the presence of corals. Multibeam bathymetry collected by the Amundsen showed unusual crescentic depressions in the seafloor that are thought to be formed by glacial activity. These depressions have slopes on their margins that should be favorable for the presence of corals. This mission was not successful as detailed in section 6.1.

Figure 10: Retrieval of AUV using the CCGS Amundsen FRC. Photograph by L. Broom. NRCan photo 2023-054.

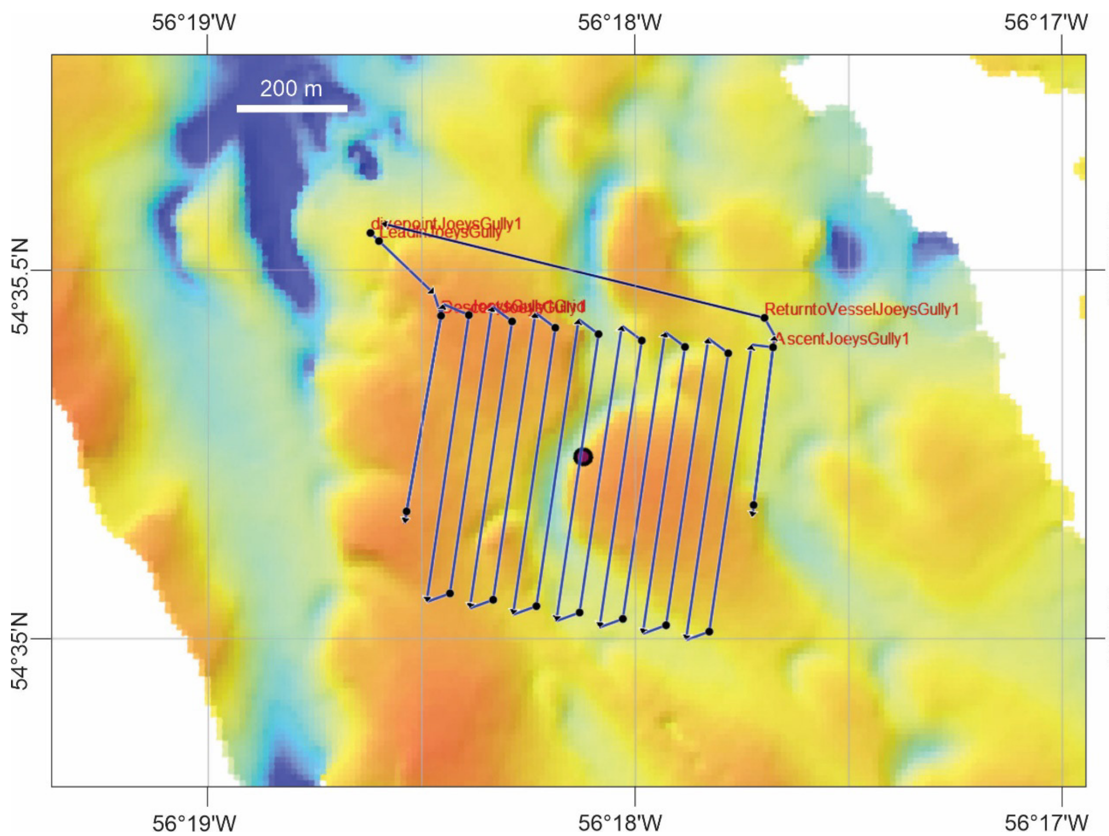

Figure 11: Planned AUV mission for Joey's Gully.

The second AUV deployment took place in Nachvak Fjord and aimed to map a submarine landslide deposit. A two-hour mission was planned to cover 12.5 line km (Figure 12). The mission site was selected to image an area of the landslide where it appears that an older deposit is overlapping a younger one. The AUV completed the mission and the data were successfully downloaded when the vehicle was brought back onboard the Amundsen.

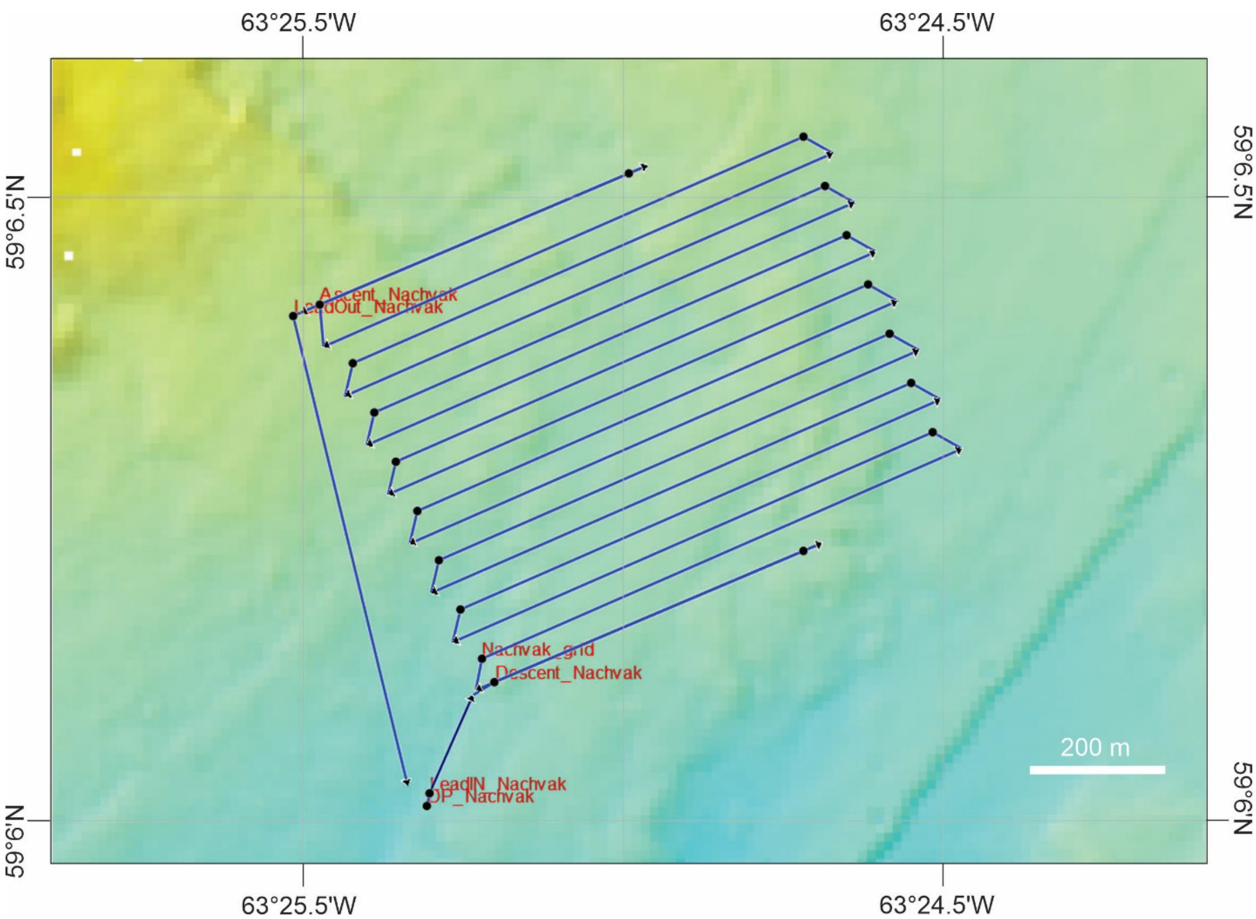

Figure 12: Planned AUV mission for Nachvak Fjord.

6. PRELIMINARY RESULTS

6.1 Joey's Gully (September 13, 2022)

The box core at Joey's Gully recovered rocky material, mostly consisting of cobbles (Table 3). No push core could be collected, and no sample was archived for the GSC-Atlantic.

The AUV did not successfully complete its mission to collect bathymetric data over a potential coral habitat in Joey's Gully. The AUV mission at this site was attempted twice and during both dives, the AUV resurfaced before completing its mission. After reviewing the AUV diagnostic data, the vehicle dove to ~180 m on the first attempt and ~300 m on the second attempt before aborting the mission. Further analyses after the cruise showed that the vehicle could not maintain its desired descent rate of 0.8 m/s. When this occurs, the AUV software interprets that the vehicle is not diving correctly and aborts the mission. In hopes of fixing this problem, the propellor RPMs were increased on subsequent dives to give the vehicle more thrust so it could descend more quickly.

Since the mission did not complete it is still unknown whether the AUV bathymetric and sidescan data can resolve corals on the seabed.

6.2 Box core operations (September 14, 2022)

The box core at Hopedale Saddle recovered cobbles and pebbles (Table 3). No push core could be recovered, and no subsample was archived for GSC-A.

6.3 Nachvak Fjord Submarine Landslide (September 15-16, 2022)

The gravity coring and AUV operations on the submarine landslide in Nachvak Fjord were successful. Three cores were collected: one from inside the landslide deposit (0004), one from outside the landslide deposit (0005), and one from the distal end of the landslide (0007) (Figure 5). The core lengths ranged from 461.5 to 661.5 m (Table 2) which is good recovery for this system. The sediment within the cores will be analysed back in the lab at the GSC-A where the goal is to characterize and radiocarbon date these landslide deposits. The AUV data will also be analysed at the GSC-A to characterise the landslide deposit over a higher (cm scale) resolution than the multibeam bathymetric data. While the ship was coring, the cliffs around the submarine landslide were observed for any evidence of a subaerial component. It was noted that there appeared to be a small subaerial slide on one section of the cliff (Figure 13; Figure 14). It is unknown at this point if it occurred synchronously with the submarine landslide or if it was an independent event with no submarine component.

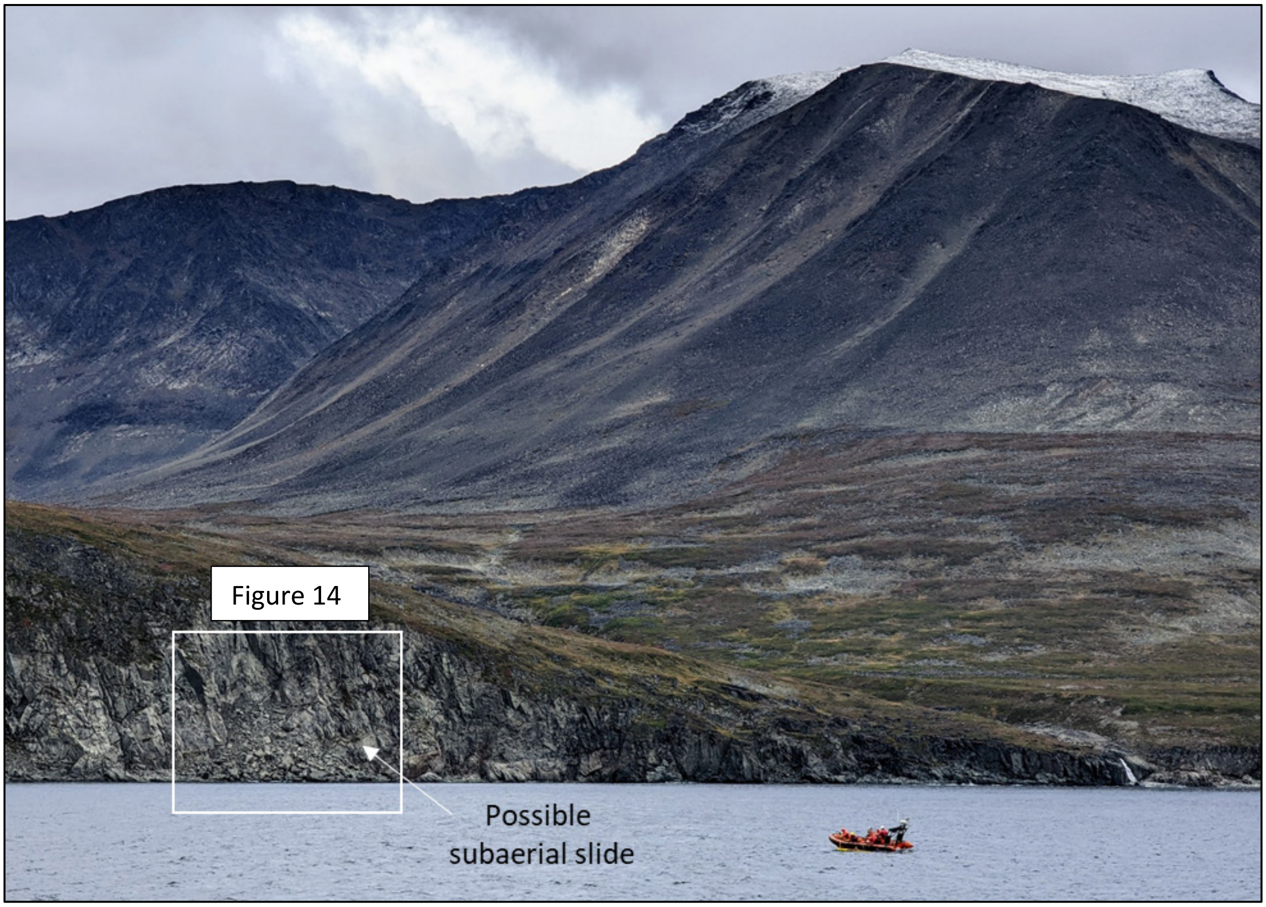

Figure 13: Retrieval of an AUV in Nachvak Fjord. Image shows a subaerial landslide along the cliff face above the submarine landslide in Nachvak Fjord. Photograph by L. Broom. NRCan photo 2023-055.

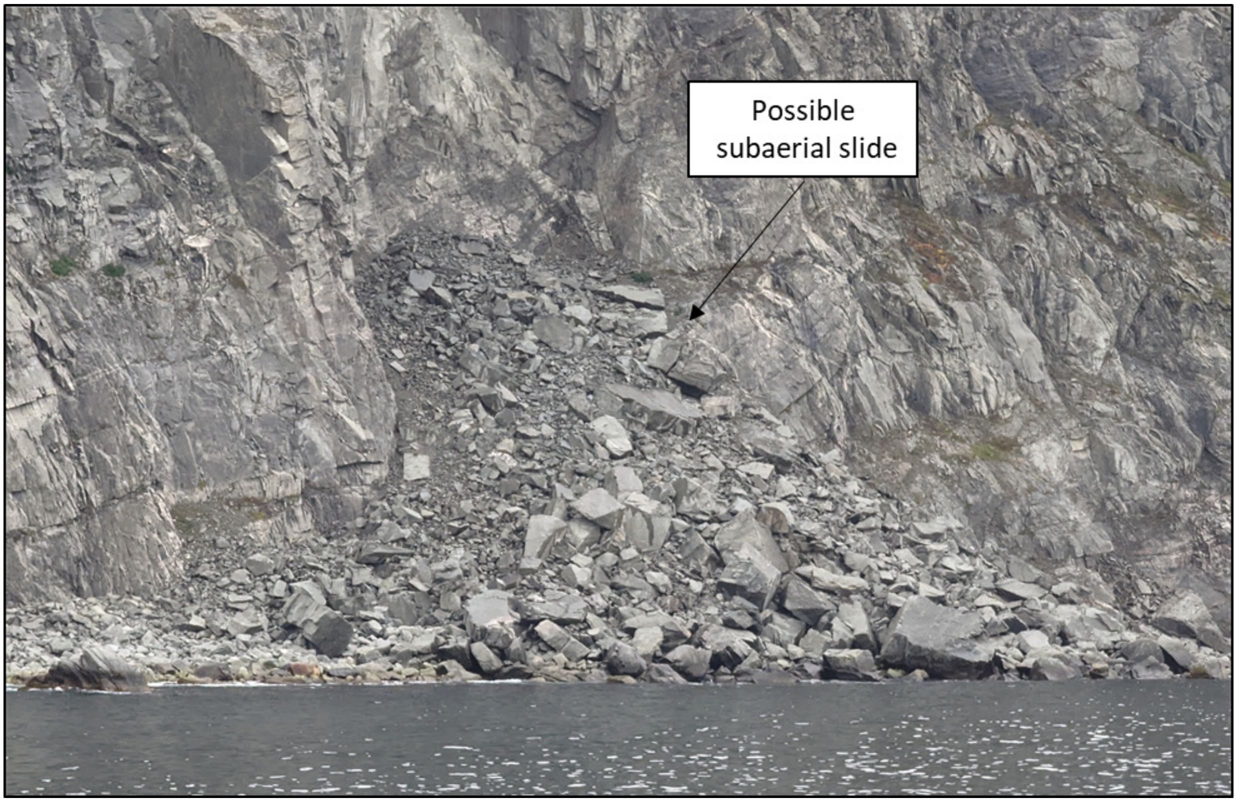

Figure 14: Possible subaerial landslide along the cliff face above the submarine landslide in Nachvak Fjord. Photograph by L. Broom. NRCan photo 2023-056.

7. REFERENCES

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Limoges, A., Normandeau, A., Sharpe, H., Philibert, G., Anthony, K., Gillies, C., MacMillan-Kenny, Z., Marigliano, L., Pijogge, L., To, A., Van Nieuwenhove, N., Winters, J., 2021 R/V William-Kennedy: Nunatsiavut Coastal Interactions Project and seabed mapping in Nain, Nunatsiavut, Newfoundland and Labrador. Geological Survey of Canada, Open File 8859, 2022, 95 pages, https://doi.org/10.4095/329513

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APPENDIX A: Station Summary

Table 3: Station summary of all box cores, gravity cores and AUV sites.

Station	Type	Julian Day	Time (UTC)	Latitude	Longitude	Depth (m)	Geographic Location	Corer Length (cm)	Core length (cm)	No. of sections	Bagged	Comments
0001	Box Core	256	03:47	54.6182	-56.4451	359	Labrador Sea - Joeys Gully				no	Mostly cobbles and unable to take a push core so no sample archived for GSC Atlantic.
0002	AUV	256	12:02	54.5894	-56.3218	520	Labrador Sea - Joeys Gully					AUV deployed for a 2 hour mission in attempt to see if the resolution of the data could visualize corals and sponges. AUV surfaced as it could not track the bottom. Redeployed and resurfaced with the same error. Dive was aborted., Deployed at 256 1202 and recovered 256 1039 54.59128N and 56.32834W.
0003	Box Core	257	21:59	56.06611	-57.4605	274	Labrador Sea - Hopedale Saddle				no	Cobbles and pebbles recovered, unable to take a push core in the box core.
0004	Giant Gravity Core	258	19:57	59.10332	-63.4163	214	Labrador Sea - Nachvak Fjord	900	461.5	4	no	Target is a landslide, piston corer used as a gravity core, gassy core with visible cracking.

Station	Type	Julian Day	Time (UTC)	Latitude	Longitude	Depth (m)	Geographic Location	Corer Length (cm)	Core length (cm)	No. of sections	Bagged	Comments
0005	Giant Gravity Core	258	21:32	59.1098	-63.4304	138	Labrador Sea - Nachvak Fjord	900	661.5	6	yes	Target is outside of the landslide, piston corer used as a gravity core, gassy core with visible cracking, shells at the base of CD, 10cm catcher bagged and 16 cm cutter in liner.
0006	Box Core	259	08:03	59.07611	-63.5303	204	Labrador Sea - Nachvak Fjord		44	1	no	
0007	Giant Gravity Core	259	10:31	59.09549	-63.4248	199	Labrador Sea - Nachvak Fjord	900	649	5	no	Target is the distal end of the landslide, piston corer used as a gravity core, gas cracking, 10 cm catcher and 14 cm cutter bagged together.
0008	AUV	259	12:36	59.09439	-63.4228	199	Labrador Sea - Nachvak Fjord					AUV deployed for a 2 hour 20 minute mission over submarine landslide where gravity cores 0004, 0005 and 0007 were taken, deploy at 259 1236 and recovered 259 1529 59.09375N and 63.41634W.

APPENDIX B: Onboard shear strength and constant volume sampling results

Table 4: Onboard shear strength measurements for 2022805 cores. Measurements were collected from the top or base of sections where suitable sediment was present and the reading was then multiplied by a conversion factor to calculate shear strength.

Sample Info					Measurement		Conversion factor	Calculated Shear Strength (kPa)	Comments
Cruise No.	Sample No.	Type	Section	Top/Base	Vane	Reading			
2022805	0004	GC	BC	BASE	L	0.3	19.614	5.9	
2022805	0004	GC	AB	TOP	L	0.25	19.614	4.9	Cracking because of gas
2022805	0004	GC	BC	TOP	L	0.17	19.614	3.3	
2022805	0004	GC	DE	BASE	L	0.15	19.614	2.9	
2022805	0005	GC	DE	BASE	L	0.24	19.614	4.7	
2022805	0007	GC	CD	BASE	L	0.33	19.614	6.5	
2022805	0007	GC	CD	TOP	L	0.2	19.614	3.9	

Table 5: Onboard constant volume sampling results for 2022805 cores. Constant volume samples were collected from the top or base of sections where suitable sediment was present. BD = bulk density, GD = grain density, WC = water content.

Stat #	Type	Section	Top/Base	vol (cm³)	empty bottle (g)	wet bottle & sample (g)	wet sample (g)	wet BD (g/cm³)	dry bottle & sample (g)	dry sample (g)	dry BD (g/cm³)	porosity	GD (g)	VR	WC wet	WC dry	Comments
0004	GC	AB	TOP	9.94	51.24	64.94	13.69	1.38	59.19	7.95	0.80	56.43	1.83	1.30	41.97	72.31	
0004	GC	BC	BASE	9.94	51.49	65.55	14.06	1.41	59.75	8.26	0.83	56.98	1.93	1.32	41.27	70.26	some sediment left in cv sampler
0004	GC	BC	TOP	9.94	50.96	65.27	14.31	1.44	58.89	7.93	0.80	62.69	2.14	1.68	44.60	80.49	
0004	GC	DE	BASE	9.94	51.51	65.75	14.24	1.43	59.57	8.06	0.81	60.69	2.06	1.54	43.41	76.70	
0005	GC	DE	BASE	9.94	51.59	66.32	14.73	1.48	59.78	8.19	0.82	64.20	2.30	1.79	44.38	79.80	
0007	GC	BC	BASE	9.94	51.19	64.80	13.61	1.37	58.74	7.55	0.76	59.51	1.87	1.47	44.53	80.29	gassy core some small cracking
0007	GC	CD	TOP	9.94	51.63	65.82	14.20	1.43	59.16	7.53	0.76	65.50	2.19	1.90	46.98	88.60	