National Research Vessels

SHIP-TIME PROGRAMME

RESEARCH SURVEY REPORT

Survey Code:	Survey Name:	Chief Scientist/ Institution
CE16010	The Newfoundland Ice Sheet glaciated Shelf (NIIS)	Dr Paul Dunlop, Ulster University

Section A: Award Summary

Title of Research Survey and Survey Code:	The Newfoundland Ice Sheet glaciated Shelf (NIIS)	
Co-Ordinator/ Chief Scientist:	Dr Paul Dunlop	
Vessel used for ship-time:	*RV Celtic Voyager* ☐ *RV Celtic Explorer* ☒	
Total number of days at sea:	3	
Total number of grant-aided ship-time days awarded:	3	
Dates of survey:	22/04/2016 to 24/0/2016	
Mobilisation/Demobilisation Ports	Mobilised in St Johns and demobilised in Argentia	
Survey Personnel:	*No. of Scientists* *5*	*No. of Students* *3*
Final Report Completed by:	Dr Paul Dunlop	**Date**: 03/05/2016

Section B: Description of the Research Survey

B1 Overview of survey personnel

Names	***Institute/ Department/***	***Position (undergraduate/***	***Number of Days***

	Course	***post graduate etc)***	
Scientists			
Dr Paul Dunlop	*Ulster University, School of Geography and Environmental Sciences*	*Senior Lecturer*	*3*
Jennifer Organ	*Geological Survey of Newfoundland and Labrador*	Project Geologist	3
Heather Campbell	*Geological Survey of Newfoundland and Labrador*	Project Geologist	3
Carina Gjerdrum	*Environment Canada.*	Wildlife Biologist - Seabird Issues	3
Oisín McManus	*INFOMAR Programme, Marine Institute*	Hydrographer/ geophysist	3
Students			
Serena Tarlati	*Ulster University, School of Geography and Environmental Sciences*	PhD Student	3
Denise McCullagh	*Ulster University, School of Geography and Environmental Sciences*	PhD Student	3
Robert Deering	Memorial University, Newfoundland, Dept. of Geography	PhD Student	3

B2 Objectives

Briefly outline the overall objectives of the research survey.
Please state if objectives have changed from the original proposal. If survey included a training element please outline clearly.

This overall aim of the project was to develop a better understanding of the formerly glaciated continental shelf focussing on a large area of Newfoundland's inner

southern shores from Bay d'Espoir to Burgeo where a number of Fjord mouth moraine systems that remain undated have been previously identified Figures 1 and 2.

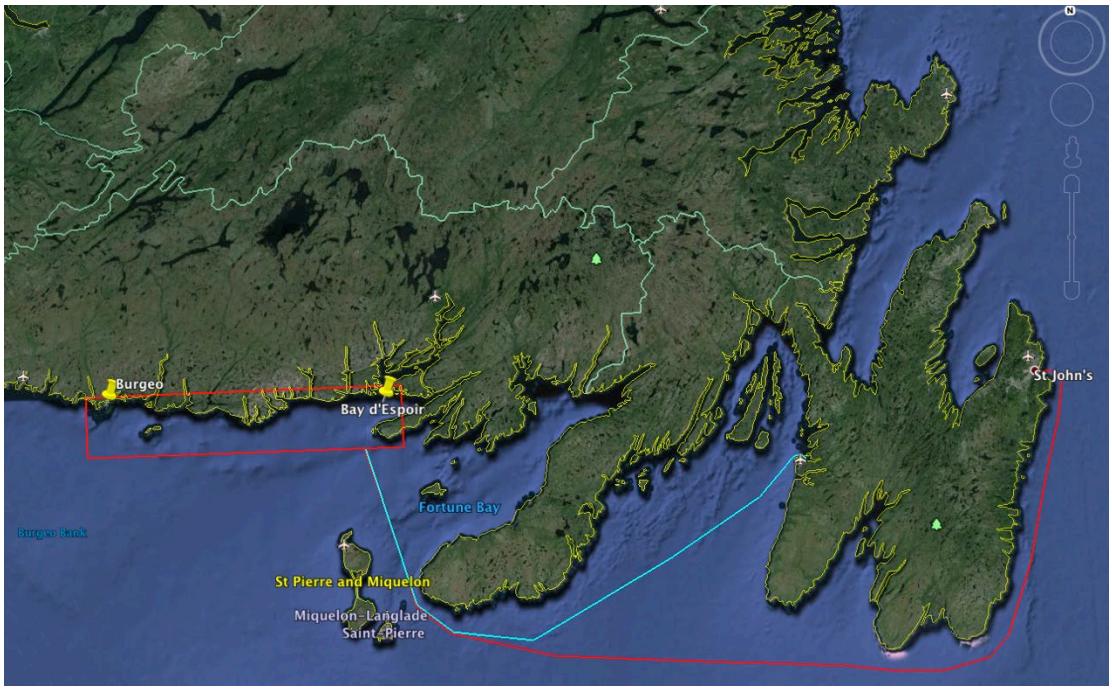


Figure 1. Location map of the survey area on the southern shores of Newfoundland, (red box) with the general transit lines taken to the area from St Johns (red) and back to the demobilsation port in Argentia (blue).

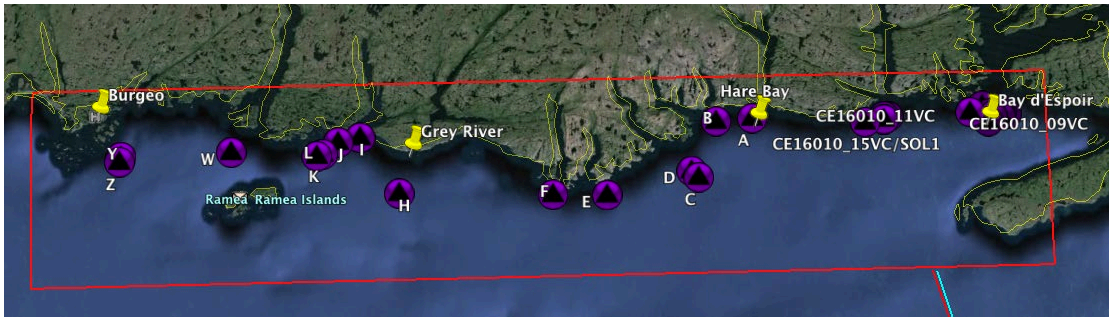


Figure 2. Close-up view of the study area showing most of the coring stations locations where samples were retrieved from during the cruise. A geophysical acquisition phase took place between Faceux Bay (situated between Bay d'Espoir and Hares Bay) and Burgeo where mulitbeam and seismic data was collected in addition to sediment cores.

The survey had three main scientific objectives, which were as follows:

(i) To contribute to the topographic mapping of the Newfoundland Shelf and Atlantic Seabed, and to refine site selection for coring with the acquisition of new multibeam echosounder bathymetric data

(ii) To determine the sub-seabed stratigraphy at target locations that were identified from published and legacy marine geophysical data and newly acquired data from through the acquisition of chirp and sparker seismic data. The seismic data will allow an optimal selection of coring sites based on stratigraphy and sub-bottom acoustic character.

(iii) To sample glacial deposits using vibro- and gravity-coring for sedimentological and geochronological analyses.

B3 Overview of research survey

Provide a narrative overview of the research survey including survey timelines
The information provided in this section should not exceed 5 pages (excluding tables and maps)

Day 1 & 2 Sediment coring

Cruise CE16010 set sail from St John's harbour at approximately 23.00hrs on Thursday 21st April to reach the first coring location at the Bay d'Espoir on the southern shores of Newfoundland (transit distance 230 nm). At Bay d'Espoir there is a large fjord mouth moraine system that currently remains undated and the plan was to retrieve sedimentary cores from here that would allow further study of its depositional environment and allow us to age constrain its deposition on the shelf.

The vessel arrived on station at the first coring location (CE16010_08) at UTC 00.35 on 22/04/2016 to begin collecting sediment samples with the vibrocorer. There were a total of 9 targets at this site and at the first few stations the corer worked well and retrieved 3 cores ranging from 3.5 to 4.7m in depth (Fig. 3).

Figure 3. Grey mud inside a section of core liner taken by the vibrocorer at Bay d'Espoir.

At station GE16010_02VC (lat 47.36.30, Long 56.07.77) in 234 m water depth the vibrocorer developed an electrical fault at the seabed which the ship technician could not fix when it was brought back onto the vessel. A decision was taken at this point to switch to using the 3 m gravity corer. This issue caused a long delay of around five hours at this location.

The gravity corer produced mixed results at the Bay d'Espoir site that ranged from no recovery of sediment at some sites to two cores retrieved that contained 2 m (Station CE16010_07GC) and 3 m (Station CE16010_04GC) of sediment. Departure time from Bay d'Espoir was UTC 14.29 on 23/04.2016. Total time spent at the site was approximately 14 hrs.

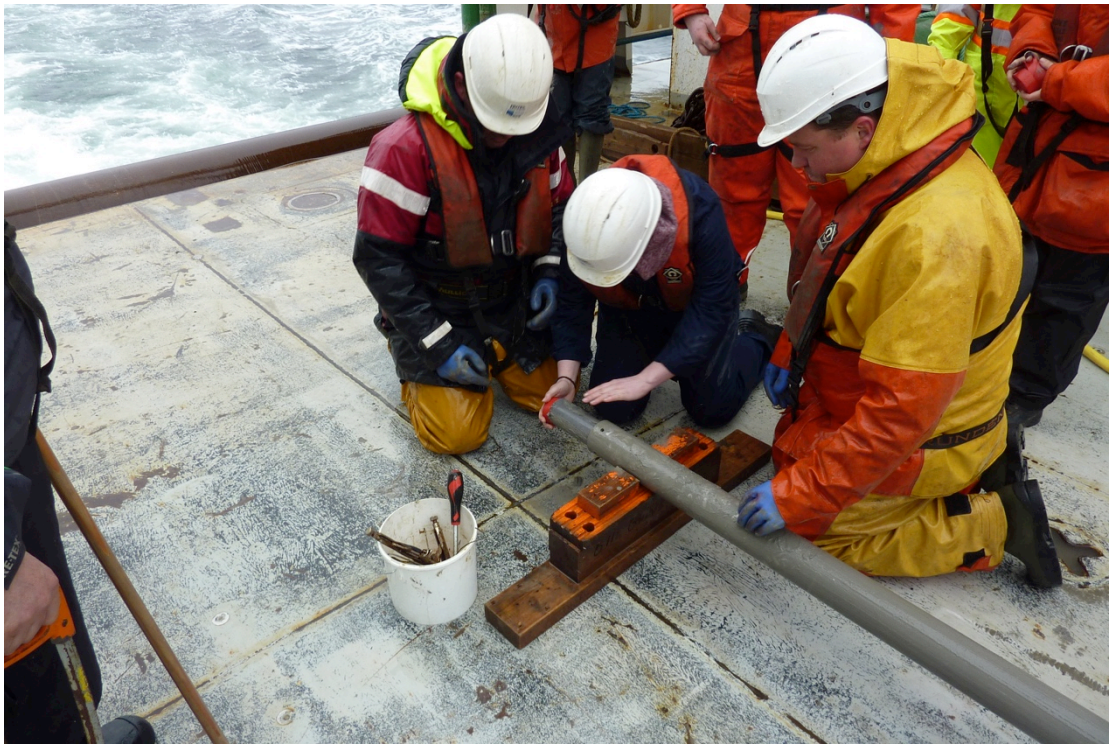


Figure 4. Gravity corer with the bottom of the core liner protruding being capped before it is cut into the next section.

The next coring location was the Facheux Bay fjord mouth moraine system that is located approximately 4.5 nautical miles west of the Bay d'Espoir site. The weather was fine with a clear blue sky and calm sea conditions making excellent conditions for coring. The plan was to collect 5 cores from the moraine system at the mouth of this fjord. The vessel arrived at the study area at UTC 15.29 on 23/04.2016 where the first core was taken at site 10GC (Lat 47.36418, Long. 56.18504) in a water depth of 141 m. Here an 80 cm core was retrieved that contained grey mud with gravels. Again, there were mixed results with the gravity corer, however, all but one station (14GC) produced a sample. The shortest core retrieved came from site CE16010_13GC (Lat. 47.360731, Long. 56.196593) and was 20 cm long and consisted of brown silt and mud with angular clasts up to 2 cm in size. The longest core at this site measured 2.5 m and was retrieved at location CE16010_15GC (Lat. 47.356838, Long 56.21.5755) and contained very compact grey mud with small (less than 1 cm) angular clasts. The last core was retrieved at this site at UTC 18.42 hrs and the total time spent here was approximately 3.25 hrs.

Day 2 & 3 Geophysical data acquisition and sediment coring

At approximately UTC 19.00 hours on 23/04/2016 we left the final coring station at Facheux Bay to undertake a new marine geophysical survey of the inshore region of the southern shore between this point and Bay de Loup just east of Burgeo situated 80 nm to the west. The plan on this leg of the cruise was to acquire new seismic (Spot profiler) and multibeam (EM2040) and whilst in transit to Burgeo. Given the location of other fjords situated between these two locations the hypothesis was that other fjord mouth moraine systems were likely to be located on the inner shelf but had never been imaged and a transit close the fjord mouths would provide the best opportunity of capturing them during our survey. Conditions were excellent for this leg of the journey with very fine weather and calm seas, which produced ideal conditions for collecting the geophysical data.

Both the seismic and multibeam systems worked very well during the entire leg of the geophysical section of the cruise and collected high quality data continuously. The seismic data captured the sedimentary and bedrock architecture of the sub-seafloor in good detail and will make become a valuable dataset for future stratigraphic interpretations of Quaternary and Holocene sedimentary processes in the region (Fig. 5). The mulitibeam data was also of excellent quality and during this section we imaged several moraine system at high resolution that included three previously identified moraines at Grey River, Bay de Loup and White Bear Bay and one previously unidentified fjord mouth moraine at the head of Hare Bay which the vessel detoured from the original route plan so that full moraine would be imaged properly (Figures 6 & 7).

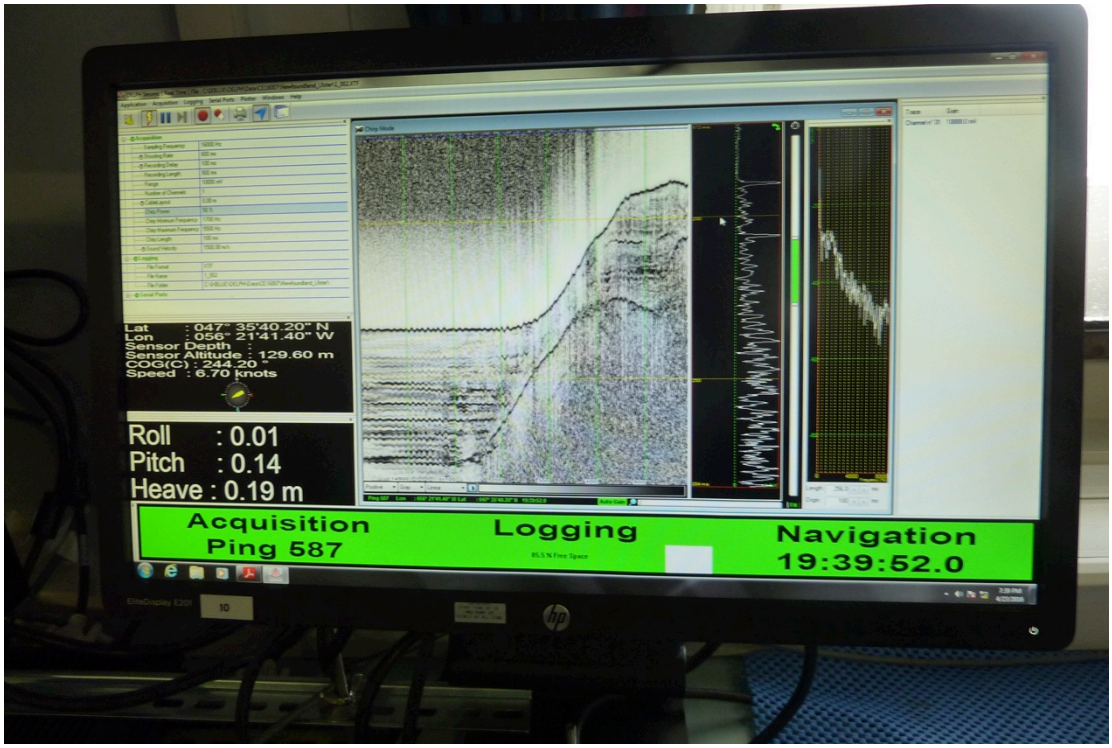


Figure 5. Example seismic profile showing the quality of the data. Note the various horizons that capture the sedimentary architecture of the seabed along the survey path.

Figure 6. Showing the ship tracklines of the multibeam and seismic survey conducted across the mouth of Hare Bay.

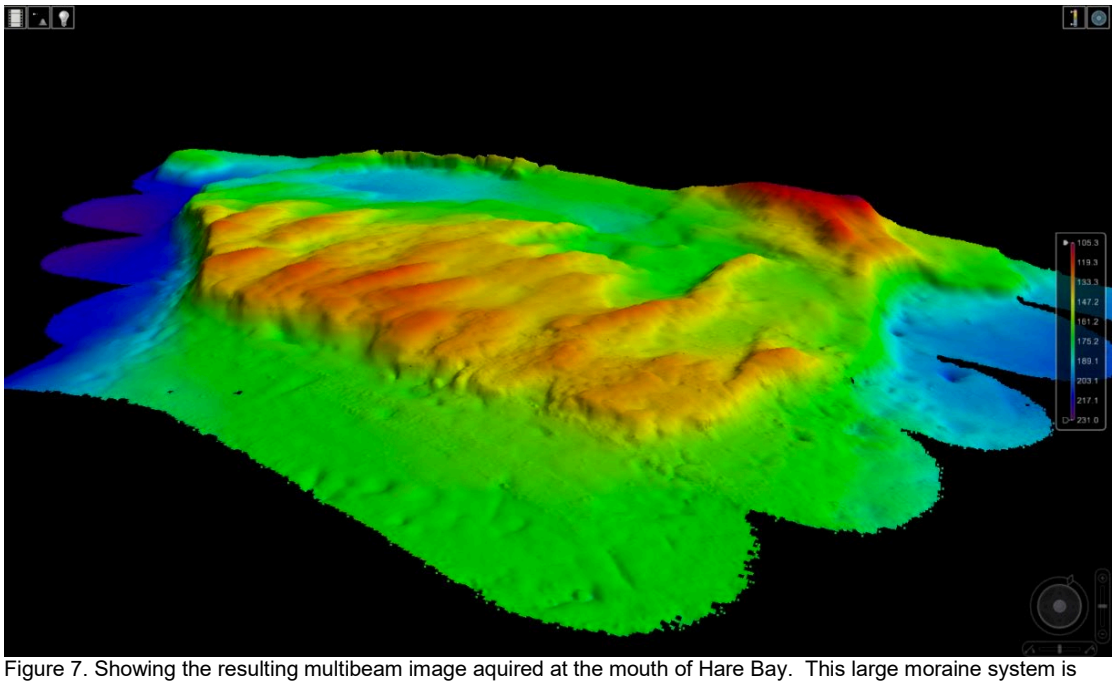


Figure 7. Showing the resulting multibeam image aquired at the mouth of Hare Bay. This large moraine system is similar in morphology and dimensions to the Facheux Bay and Bay d'Espoir moraine systems to the east.

The geophysical leg of the survey finished at approximately UTC 11.00 hrs on 24/04/2016 at Bay de Loup. The main focus of the final leg of the cruise returned to core acquisition again for locations that were picked using legacy seismic data and some new locations from interpretations made using the new seismic and mulitibeam data that was acquired on the geophysical section of the cruise.

Core collection was once again conducted using the 3 m gravity corer and the vessel arrived at the first coring station (CE16010_16GC) at UTC 11.15 where a 3 m core containing stiff grey mud with clasts was retrieved. Ten more locations were targeted between Bay de Loup and Hare Bay, including the previously identified

but undated Bay de Loup, White Bear Bay and Grey River moraine systems. Of the 11 sites targeted in total only 3 sites had no recovery. The rest had some recovery with two short cores containing 40 cm and 88 cm of sediment with the rest ranging between 1.5 and 3 m of recovery. The final core was attempted at station CE16010_26GC on the Hare Bay moraine (Fig. 7) where the vessel arrived at UTC 19.34.

The final part of the cruise was the leg to Argentia port where the cruise officially ended. No data acquisition took place during the journey back to Argentia from Hare Bay. The vessel left Hare Bay at approximately 19.45 for Argentia where the team demobilised at the port at approximately 10.30 am on 25/04/2016.

B4 Benefits, impact and contribution of the outputs to marine research and the marine sector in general.

Outline clearly the specific outcomes and benefits of the research survey.
The information provided in this section should not exceed 1/2 page (excluding tables and maps)

The following deliverables came about as a result of the survey:

1: Approximately 88 nautical miles of New multibeam seabed bathymetry, backscatter and seismic data along Newfoundland southern shore from Bay d'Espoir to Burgeo (see Fig. 2 and Map 1 in Appendix 1).

2: 23 m of new sediment samples in the form of vibro-or gravity-cores from targeted glacial sediments and fjord mouth moraines (See Table 1 for initial descriptions and Map 2 for locations in Appendix 1).

In addition to providing new data to better understand the glacial history of the Newfoundland shelf. The above data can be used to contribute to the background knowledge of the Atlantic Ocean under the Atlantic Ocean Research Alliance umbrella and will provide bathymetric data for the Atlantic seabed mapping initiative.

The expected outputs include:

- Undergraduate and postgraduate dissertations based on the collected datasets.

- Insights on the glacial and postglacial development of the Newfoundland continental shelf, especially in relation to the offshore flow of the former Newfoundland Ice Sheet.

- International peer-reviewed publications and presentations at national and international meetings with acknowledgements of MI/NDP funding and all project collaborators. The expansion of the dataset in key areas of the circum-North Atlantic Ocean to reconstruct and assess ice sheet wide syntheses and address wider glaciological questions, will undoubtedly be integrated in a large number of publications.

Specific benefits and impacts of the proposed research include:

1. Training and sea-going experience of the new generation of marine scientists;

2. Increase overall the research capabilities on the island of Ireland and specifically for the partner institutions involved in the project.

3. A consolidation and tangible outcome from a north-south collaboration between Ulster University and the Irish Marine Institute, as well as international collaboration between the Ulster, Memorial University, Geological Survey of Canada and Geological Survey of Newfoundland and Labrador.

International collaborations

A key aspect of this project is that it will build and strengthen existing international research collaborations between Irish and Canadian researchers. Dunlop, McHenry and Bell have been collaborating successfully to reconstruct the deglacial history of east Newfoundland and have attracted competitive research council funding from NERC to support this work. Results from this collaboration are now coming in and we plan to produce a collaborative paper for a sector leading journal using our results. This project strengthens this existing collaboration and increases the team's capacity by including John Shaw from the Geological Survey of Canada who has strong expertise in glacial marine processes on the Newfoundland shelf. By allowing the team to continue this research offshore we are in a better position to correlate deglacial signatures both on and offshore so that we can build a more comprehensive picture of deglaciation and past climatic warming for the region. It also brings new expertise to the team which will strengthen future research collaborations with the addition of experienced marine geologists who have an excellent track record on conducting research on submerged glaciated margins (Dunlop, Benetti, Plets, Shaw, Bell, Sacchetti). In addition, a new collaboration between Dunlop and the Geological Survey of Newfoundland and Labrador was initiated by this cruise. The survey provided two geologists to work on the cruise (Organ and Campbell). This cruise provided both geologists with marine data collection and cruise experience and sediment samples from the cores will be shared with them so that they can conduct new geochemical analysis to trace onshore geochemical signals offshore within the survey area.

B5 Data

Provide a description of the data collected from the research survey, the usage of the data and how it will be stored.

The information provided in this section should not exceed 1/2 page (excluding tables and maps)

23 m of sedimentary cores which will be stored at 4°C in a refrigerated core storage facility at Ulster University, Coleraine. Analyses will include:

- X-radiographs of the cores, usually prior to splitting, using a CARESTREAM DRX Evolution system at Ulster University, Jordanstown.
- Sediment physical properties (wet bulk density and magnetic susceptibility) will be measured prior to splitting using a GEOTEK© multi sensor core logger at either NUIM in Ireland or BOASCORF at NOC, Southampton.
- Lithofacies description
- Shear strength measurements

- Grain size analysis using a MALVERN Mastersizer (laser granulometry) at Ulster University
- Micropalaentological analysis and AMS radiocarbon analysis

Marine geophysical data will be stored on HDDs at Ulster University, Coleraine. Seismic data will be interpreted using Kingdom software and geomorphological analysis of the multibeam data will be done using Fledermaus and ArcGIS software.

B6 Contribution to marine research programmes

Outline specific National/EU/International research programmes this survey supported. Please include the funding sources for these programmes as well as the total amount of funding leveraged (Repeat the table below, if necessary).

National/EU/International Research programme(s):	
Total Programme cost:	
Value to Irish partners:	
Project duration:	
Contract no.:	
Project partners:	
Project web address:	

Appendices

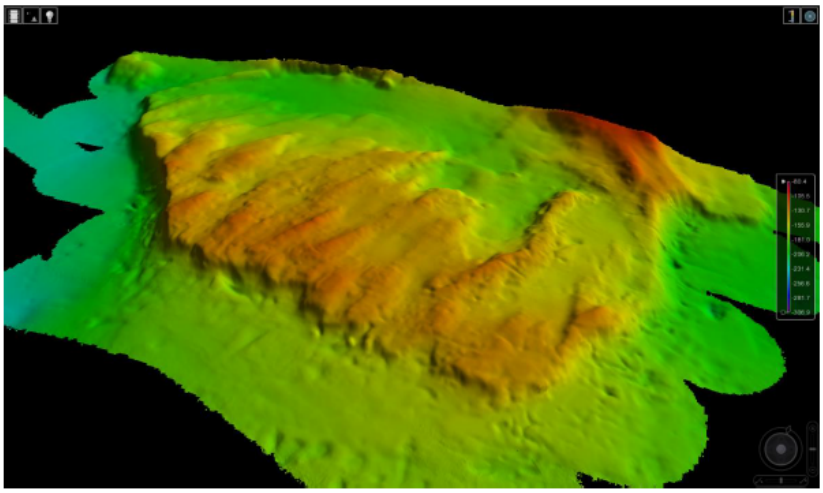
Please number and attach any relevant Appendices here.

Appendix 1

CE16010 Newfoundland Ice Sheet Glaciated Shelf Survey

RV Celtic Explorer **21st to 25th April 2016**

Surveyor: Oisín McManus, Marine Institute, Galway



Equipment Used: Kongsberg Simrad EM2040 MultiBeam EchoSounder

IXSEA Blue Sub-Bottom Profiler

Delivered: Processed Multibeam Bathymetry in *.tif* and *.txt* XYZ file formats

Processed Multibeam Backscatter in *.tif* and *.txt* XYZ file formats

CE16010_Ulster_Coring_Geophysics\Multibeam\Exports

All files are in WGS1984 Projection

XYZ files are comma separated, co-ordinate format DD MM.MM

Seismic Lines processed in Delph Roadmap Software

All RAW data including Simrad .all MBES data and .XTF Seismic Data

CE16010_Ulster_Coring_Geophysics\Seismic

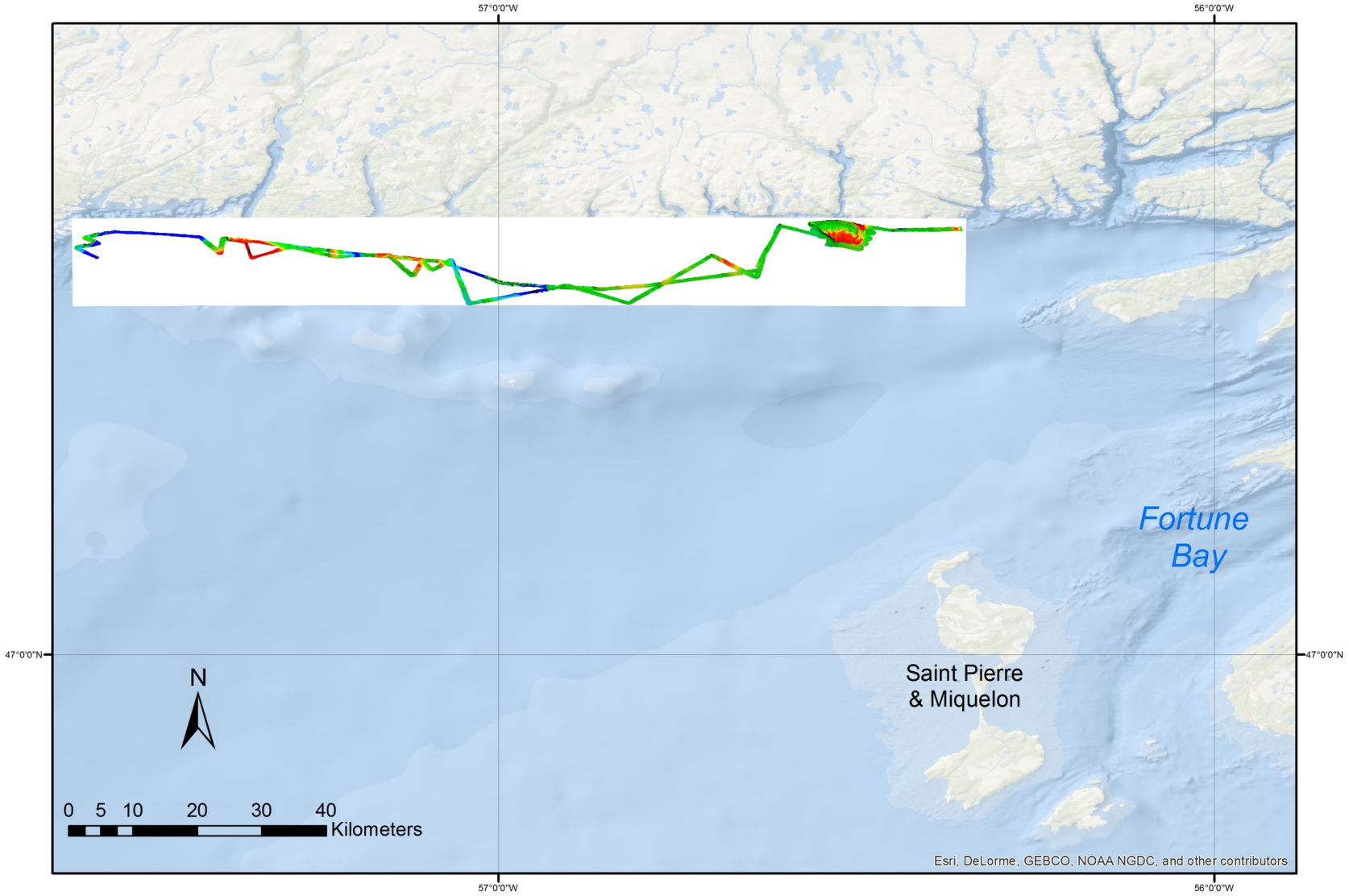
All files delivered on UU supplied Portable Hard Drive

Table 1. Core locations and initial descriptions based on observations made on deck. WD = water Depth, AOP= Apparent penetration, CC=Core Catcher

Station No.	Day of Year	Lat.	Long.	WD (m)	AP (m)	Length (m)	CC	Description
09VC-A	22/04/2016	47 36.23	56 10.87	170	5	0.51	Empty	grey silt mud, looks like marine mud
09VC-B	22/04/2016	47 36.21	56 10.87	170	4.5	4.5	grey mud	Stiff grey mud, grey silty mud, silty sand pebbles (0.5-2 cm), semi-rounded to rounded
08VC	22/04/2016	47 36.64	56 09.63	180	0	0	Empty	
01VC	23/04/2016	47 36.12	56 8.86	226	3.5	4.75	6cm clast	Sand to silt, fine med sand-silt matrix, pebble (5 cm)
06VC	23/04/2016	47 35.94	56 8.62	190	3.5	3.63	Empty	Grey silty mud, fine sand, dark grey mud, some pebbles (2-3 cm appear striated)
02VC	23/04/2016	47 36.27	56 7.80	246	0	0	Empty	
03VC	23/04/2016	47 36.20	56 07.66	279	0	0	Empty	
03VC	23/04/2016	47 36.20	56 07.66	279	0	0	Empty	
02VC	23/04/2016	47 36.30	56 07.77	234	0	0	Empty	
04GC	23/04/2016	47 36.04	56 07.17	330	3	3.02	Fine grained grey/black mud, some isolated coarse fragments	
05GC	23/04/2016	47 35.95	56 07.82	234	0	0	Empty	
07GC	23/04/2016	47 35.54	56 09.08	284	2	2.04	Empty	Uniform grey and tan mud/silt. Stiff grey uniform packed mud.upper part pebbles visible, 1 granitoid/triangle shaped.
10GC	23/04/2016	47 36.418	56 18.504	141	0.5	1.17	Grey/brown mud on core and end of core approx 1 ounce of material.	Compact grey mud. Gravel on top
12GC	23/04/2016	47 36.0532	56 19.1253	143	3	2.07	Grey compact mud. Approx. 2 ounces of material.	Compact uniform grey mud, large (2cm) triangle shaped pebbles towards the top
13GC-A	23/04/2016	47 36.0744	56 19:610	140	2	0.2	Brown mixed gravel and mud.	Brown/grey waterlogged mud and triangular gravel clasts. Approx. 10% gravel and 10% sand.
13GC-B	23/04/2016	47 36.0731	56 19.6593	139	0.2	0.49	Approx. 0.7 ounces of brown silt/mud matrix with rough angular clasts.	Mixed brown silt and clay with larger clasts (up to 2cm). Clasts are a sub-angular-sub-rounded triangular shape.
14GC-A	23/04/2016	47 35.8355	56 19.649	141	0.2	0.3	Grey silt/sand/clay/gravel.	Grey matrix with silt, clay, sand and large gravel (angular clasts). Abundant shells on top. Clasts up to 4cm in diameter.
14GC-B	23/04/2016	47 35.8324	56 19.7119	135	0	0	Empty	
15GC	23/04/2016	47 35.6838	56 21.5755	142	3	2.51	Thick compacte	Very compacted grey mud, some grit and pebbles

							d grey mud and a little grit. Triangular pebbles (subangular).	
16GC	24/04/2016	47 33.77	57 34.97	230	3	3.02	Grey stiff mud with some clasts	Stiff grey mud with clasts. slightly gritty with some silt content
17GC	24/04/2016	42 34.10	57 31.80	230	1	2.2	Grey silty mud, slightly gritty.	Grey silty mud, slightly gritty. With higher sand content and larger clasts towards the top.
18GC	24/04/2016	47 34.34	57 24.16	184	3	1.48	Grey mud.	Grey/brown sandy mud.
19GC	24/04/2016	47 34.87	57 22.37	146	1	0	No sample	
20GC	24/04/2016	47 34.02	57 15.81	209	0.5	1.41	Grey/brown mud, slightly gritty.	Grey/brown mud. slightly gritty
21GC	24/04/2016	47 32:95	57 04.88	160	0	0	Empty	
22GC	24/04/2016	47 31.12	56 46.23	158	3	0.88	Gritty, silty mud.	Sandy clay, with some smaller clasts (up to 2mm). Coarser towards the top, with some triangular shaped clasts.
23GC	24/04/2016	47 32.23	56 38.36	175	0	0.18	Coarse brown/mud with clasts. Component-angular, with lots of sand.	Mixed clay, sand and clasts (>2mm)
24GC	24/04/2016	47 35.94	56 36.46	217	3	3.01	Silty grey clay. Some clasts.	Homogeneous grey mud. Gritty grey/tan silty clay.
25GC	24/04/2016	47 34.81	56 31.89	129	1	0.4	Very hard grey mud with 1mm clasts visible in matrix. 2cm pebble (angular) and shell fragments. Bullet shaped 3.5cm clast.	Similar to Core catcher.
26GC	24/04/2016	47 34.44	56 30.68	158	0	0	Empty	

Map 1. The Southern shore of Newfoundland with the location of the multibeam survey shown inside the white box



Map 2. The Southern shore of Newfoundland showing the core locations