



Natural Resources
Canada

Ressources naturelles
Canada

**GEOLOGICAL SURVEY OF CANADA
OPEN FILE 7761**

**CCGS Tully 2014007PGC
Cruise Report**

**D.G. Lintern, C.D. Stacey, J. Shaw, N. Koshure, J.V. Barrie,
P. Bobrowsky, K. Conway, D. Huntley, R. Kung, G. Middleton,
P. Neelands, A. Robertson**

2015

Canada



GEOLOGICAL SURVEY OF CANADA OPEN FILE 7761

CCGS Tully 2014007PGC Cruise Report

**D.G. Lintern, C.D. Stacey, J. Shaw, N. Koshure, J.V. Barrie,
P. Bobrowsky, K. Conway, D. Huntley, R. Kung, G. Middleton,
P. Neelands, A. Robertson**

2015

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources Canada, 2015

doi:10.4095/296566

This publication is available for free download through GEOSCAN (<http://geoscan.nrcan.gc.ca/>).

Recommended citation

Lintern, D.G., Stacey, C.D., Shaw, J., Koshure, N., Barrie, J.V., Bobrowsky, P., Conway, K., Huntley, D., Kung, R., Middleton, G., Neelands, P., and Robertson A., 2015. CCGS Tully 2014007PGC Cruise report. Geological Survey of Canada, Open File 7761. 1 .zip file. doi:10.4095/296566

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



TABLE OF CONTENTS

LIST OF FIGURES	4
LIST OF TABLES	6
GENERAL INFORMATION	7
CRUISE OBJECTIVES	7
CRUISE PARTICIPANTS.....	8
ACKNOWLEDGEMENTS	9
SUMMARY OF ACTIVITIES	10
<i>Data Management</i>	13
<i>Public Engagement</i>	14
<i>Sediment dynamics of Chatham Sound</i>	15
<i>Palaeotsunami Investigation</i>	17
<i>Submarine Slide Hazard Assessment, Douglas Channel</i>	18
<i>Submarine Slide Hazard Assessment, Kitimat Arm</i>	29
<i>Devastation Channel Surveys</i>	36
Annex 1 Tour itinerary for North West College Students.....	56
Annex 2 Tour itinerary for students of Hartley Bay School	57
Annex 3 Marine Mammal Observations during a Natural Resources Canada Acoustic Survey of Kitimat Arm, Douglas Channel and Wright Sound, October 4 to October 9, 2014	58



LIST OF FIGURES

Figure 1 Expedition station and survey lines locations. Douglas Channel area.	11
Figure 2 Expedition station and survey line locations. Chatham Sound.	12
Figure 3 Scientists using the on board GIS to determine sampling strategies.	13
Figure 4 Students from Hartley Bay School join the ship by Rigid Hull inflatable launch, accompanied by their teacher Cam Hill.	14
Figure 5 3.5kHz line and stations to investigate sediment dynamics of trough feature in Chatham Sound.	15
Figure 6 3.5 kHz line 2014007PGC 001_278_0128. Piston Core 002 recovered 5.66 m of sediment. box core will be subsampled for Pb-210 to determine sedimentation rate, carbon and nitrogen content and dinoflagellates.	16
Figure 7 Coarse grained material 10 cm below the ground in Seal Cove, Prince Rupert. This is being investigated as having a tsunamigenic source.	17
Figure 8 Location of two camera transects 0016 (green) and 0019 (blue) on the ridge formed by the northern failure, failure A.	20
Figure 9 Gravelly mud seen in behind slide A, the Northernmost of the two large rock slides in Douglas Channel. The source of the gravel, and/or the absence of fine-grained material is under investigation.	21
Figure 10 Stations for investigation of northern extent of light-cloured clay bed previously seen at Slide A, and thought to be the results of a large flood event. A box core was taken to determine sedimentation rates at the northern location.	22
Figure 11 3.5 kHz line 2013007PGC 310_0240. Piston core 017 recovered 6.58 m of sediment. Box core 020 will be subsampled for Pb-210 to determine sedimentation rate, carbon and nitrogen content and dinoflagellates	23
Figure 12 Hunttec line and camera survey in Douglas Channel.	24
Figure 13 Piston core stations 018 for investigation of southern extent of light-coloured clay bed previously seen at Slide A, and thought to be the results of a large flood event. Camera Survey at Stn 029 to investigate Seabed features .	25
Figure 14 3.5kHz record in Wright Sound (Cruise 2014007PGC, JD 2781207–2781238) showing the acoustically transparent postglacial mud unit overlying acoustically stratified glaciomarine sediments. In the left half of the image glaciomarine sediments crop out at the sea floor and appear to have undergone some erosion.	26
Figure 15 a) Backscatter superimposed on shaded relief image, Wright Sound. Areas of high backscatter have a dark tone, while areas of low backscatter have a light tone. Also showing the location of the 3.5 kHz record of Figure 1 (yellow line), and location of photographs at station 29 (red line); b) Multibeam image of Wright Sound, with a colour scheme that accentuates the banked areas. These banks correspond with areas of thick postglacial mud with low backscatter. The estimated maximum thicknesses are 60 m (bank A), 50 m (B) and 80 m (C).	27
Figure 16 Station 29 photograph number 27. More gravel is evident than in the majority of photographs. The muddy bottom is bioturbated, with burrows, casts, worm tubes. An anemone is evident at upper left, and a sea star is present directly below the centre.	28

Figure 17 3.5 khz Line 2014007PGC 0018_278_1248. STN018 Piston core with a recovered length of 6.6 m. 28

Figure 18 Stations in Bish Cove collected to investigate sub seabed deformation which resembles, among other things, a fault. 30

Figure 19 3.5 khz Line 2014007PGC 0061280_1731-A. Piston Core 21 recovered 8.51 m of sediment. Site selected to sample soft sediment deformation above a fault-like feature at Bish Cove. Major deformation is observed at a depth of approximately 25 m. Offset reflectors could either be a result of irregular basement relief or an indication of fault motion. Box core 25 subsampled for Pb-210 activity, carbon and nitrogen content and dinoflagelates. Box core 26 - push core and slab core extracted for physical property (MSCL) and x-radiography analysis. 31

Figure 20 3.5 khz Line 2014007PGC 0061280_1731-B. Piston Core 28 recovered 9.71 m of sediment. Site selected to sample soft sediment deformation above a fault-like feature at Bish Cove. Major deformation is observed at a depth of approximately 25 m. Offset reflectors could either be a result of irregular basement relief or an indication of fault motion. 32

Figure 21 Piston core 027 taken to investigate the properties of a slide across from Maitland Island. 33

Figure 22 (top) 3.5khz line 0038_280_0020_130479 Longitudinal profile. 3.5khz line 0039_280_0239_130479 Transverse profile. Piston Core 27 recovered 11.95 m of sediment. Site of shallow MTD. 34

Figure 23 Location of piston core 024 at the pinchout at the bottom of the large slide complex in Kitimat Arm. 35

Figure 24Huntec line 1023_310_10_18_09. Piston Core 24 recovered 8.51 m of sediment. Core collected to measure Pb-210 activity under Kitimat Delta slide material in order to determine timing of deposition. 36

Figure 25 Huntec and 3.5 Survey lines side by side in Devastation Channel over a mass transport deposit. 37

Figure 26 The higher resolution Huntec shows details in the chaotic unit (A1 vs. B1) and shows a greater number of parallel reflectors (A2 vs. B2) which are not present in the 3.5 kHz. Both methods have the same depth of penetration in fjord bottom sediments (A3, B3). Although the Huntec resolution is clearly better, most key features can be identified in the 3.5 kHz image. 38



LIST OF TABLES

Table 1 Expedition participants.....	8
Table 2 Objectives and status.....	10
Table 3 Stations, grouped by type.....	39
Table 4 Piston core information.....	40
Table 5 Station 03 Chatham Sound trough, 54.2116, -130.3493 to 54.2193, -130.3493	41
Table 6 Station 16 Crest of Douglas Channel Slide A, 53.5015, -129.1835 to 53.5015, - 129.1864.....	43
Table 7 Station 19 Behind Ridge Crest, Douglas Channel Slide A, 53.5000, -129.1822 to 53.4988, -129.1829.....	45
Table 8 Station 29 Deep trough in Wright Channel, 53.3464, -129.2550 to 53.3466, - 129.2531.....	46
Table 9. Recommendations for implementation on future expeditions.....	50
Table 10. Chief scientists schedule and log.....	51

CCGS Tully 2014007PGC Cruise Report

October 1 – 11, 2014

Geological Survey of Canada, Pacific

GENERAL INFORMATION

Science Cruise Number: 2014007PGC

Ship's Patrol Number: 14-12

Name of Ship/Platform: CCGS John P Tully

Survey Area/Area of Operation: Chatham Sound, Douglas Channel, Kitimat Arm

Chief Scientist: Gwyn Lintern

Commanding Officer: Capt. Mike Corfield

Boson: John Gardner

CRUISE OBJECTIVES

- Engage with first nations on our North Coast scientific plans
- Conduct seabed surveys and coring to estimate the age of inventoried fjord wall submarine slides.
- Conduct seabed surveys and coring to estimate ages of debris flows and slope failures on the Kitimat Delta.
- Conduct seabed surveys and coring to estimate ages and activity of fault-like features in Douglas Channel and Kitimat Arm.
- Collect cores and grab samples for geotechnical characterization of fjord wall glaciomarine sediments (for calibration of backscatter).
- Conduct Free Fall Cone Penetrometer ground testing to characterize geotechnical conditions of bed.
- Conduct camera drops to determine seafloor parameters.
- Conduct shore party landings to assess locations for palaeotsunami work and shore transmission stations
- Conduct test of cellular data service in the Douglas Channel
- Conduct seabed surveys and coring in the Skeena Delta and Chatham Sound
- Pick-up/deploy DFO moorings
- Familiarize new researchers with the area and the practicalities of conducting their research
- We will have contingency plans to conduct similar work in Howe Sound, Sand Heads, Bute Inlet and Knight Inlet.

CRUISE PARTICIPANTS

Table 1 Expedition participants

Officers Deck

<i>Cabin</i>	<i>Name</i>	<i>M/F</i>	<i>Shift</i>	<i>Dates (on/off)</i>
Sup 1	<i>not available</i>			
Sup 2	<i>not available</i>			
Chief Scientist	Gwyn Lintern (GSC)	M	na	Sept 30 - Oct 11
	Lucius Perrault (DFO, 1 day only)	M	Day	Oct 1 - Oct 2
	Jesse Bolton (Gitga'at)	M	Day	Oct 4 - Oct 9

Main Deck

<i>Cabin</i>	<i>Name</i>	<i>M/F</i>	<i>Shift</i>	<i>Dates (on - off)</i>
B	Peter Bobrowsky (GSC)	M	Day	Oct 1 - Oct 11
	David Huntley (GSC)	M	Day	Oct 1 - Oct 11
C	Kevin MacKillop (GSC)	M	Day	Oct 1 - Oct 11
	Vaughn Barrie (GSC)	M	Day/Night	Oct 1 - Oct 11
D	Cooper Stacey (GSC)	M	Night	Oct 1 - Oct 11
	Kim Conway (GSC)	M	Day	Oct 1 - Oct 11
E	Robert Kung (GSC)	M	Night	Oct 1 - Oct 11
	Angus Robertson (GSC)	M	Night	Oct 1 - Oct 11
F	Peter Neelands (GSC)	M	Day	Oct 1 - Oct 11
	John Shaw (GSC)	M	Night	Oct 1 - Oct 11
G	Greg Middleton (GSC)	M	Day	Oct 1 - Oct 11
	Brett Pickrill (contractor)	M	Day	Oct 1 - Oct 11
H	Sophie Johannessen (DFO)	F	Night	Oct 1 - Oct 11
	Camille Brillon (GSC)	F	Day	Oct 4 - Oct 9

Crew Deck

<i>Cabin</i>	<i>Name</i>	<i>M/F</i>	<i>Shift</i>	<i>Dates (on/off)</i>
Crew 1	Nicole Koshure (Mammal Obs.)	F	Day	Oct 4 - Oct 9
Crew 2	Michelle Bolton (Gitga'at)	F	Day	Oct 4 - Oct 8

ACKNOWLEDGEMENTS.

We greatly appreciate the hard work and safe handling by the captain and crew of the Canadian Coastguard Ship John P Tully. We appreciate Ellen Torng, Cam Hill, and Chris Picard for arranging the visit to Hartley Bay, and the visits by high school and college students. Linda Berg and Mike Jacobs helped organize our visit to Kitamaat, where we appreciated being hosted by Chief Ellis Ross and the Haisla Council. We also thank Adrienne Jones and Philip Hill who reviewed this manuscript.

SUMMARY OF ACTIVITIES

This expedition is the second in a series of expeditions by Natural Resources Canada to investigate marine geohazards on the North Coast of British Columbia. A primary objective of this expedition was to inform local communities of the planned work. Other objectives were to map and sample known geological features and to investigate possible new geohazards by means of coring, bottom imaging, and subbottom survey, and to test prototype equipment. These objectives and the results are outlined in Table 2.

The station and survey line locations for this expedition were in the vicinity of Prince Rupert and Chatham Sound, and Douglas Channel north to Kitimat (Figure 1 and Figure 2).

Table 2 Objectives and status

Objective	Status
Engage with local communities and First Nations on our North Coast scientific plans	Met. Ongoing.
Conduct seabed surveys and coring to estimate the age of inventoried fjord wall submarine slides.	Met. Ongoing as slides uncovered
Conduct seabed surveys and coring to estimate ages of debris flows and slope failures on the Kitimat Delta.	Met, except 50ft cores
Conduct seabed surveys and coring to estimate ages and activity of fault-like features in Douglas Channel and Kitimat Arm.	Met. No active faults clearly identified. Lidar study required.
Collect cores and grab samples for geotechnical characterization of fjord wall glaciomarine sediments (for calibration of backscatter).	Not met. Postponed for geotechnical cruise.
Conduct Free Fall Cone Penetrometer ground testing to characterize geotechnical conditions of bed.	Not met. Postponed for geotechnical cruise.
Conduct camera drops to determine seafloor parameters.	Partially met. Ongoing.
Conduct shore party landings to assess locations for paleotsunami work and shore transmission stations	Partially met. Difficulties understood. Use of other vessels being investigated
Conduct test of cellular data service in the Douglas Channel	Met. Cell signal reaches Northern slide in Douglas Channel.
Conduct seabed surveys and coring in the Skeena Delta and Chatham Sound	Met.
Conduct coring in Bute Inlet Sound	Not met.
Pick-up/deploy DFO moorings	Met.
Familiarize new researchers with the area and the practicalities of conducting their research	Met.
Contingency plans to conduct similar work in Howe Sound, Sand Heads, Bute Inlet and Knight Inlet.	Contingency not required.

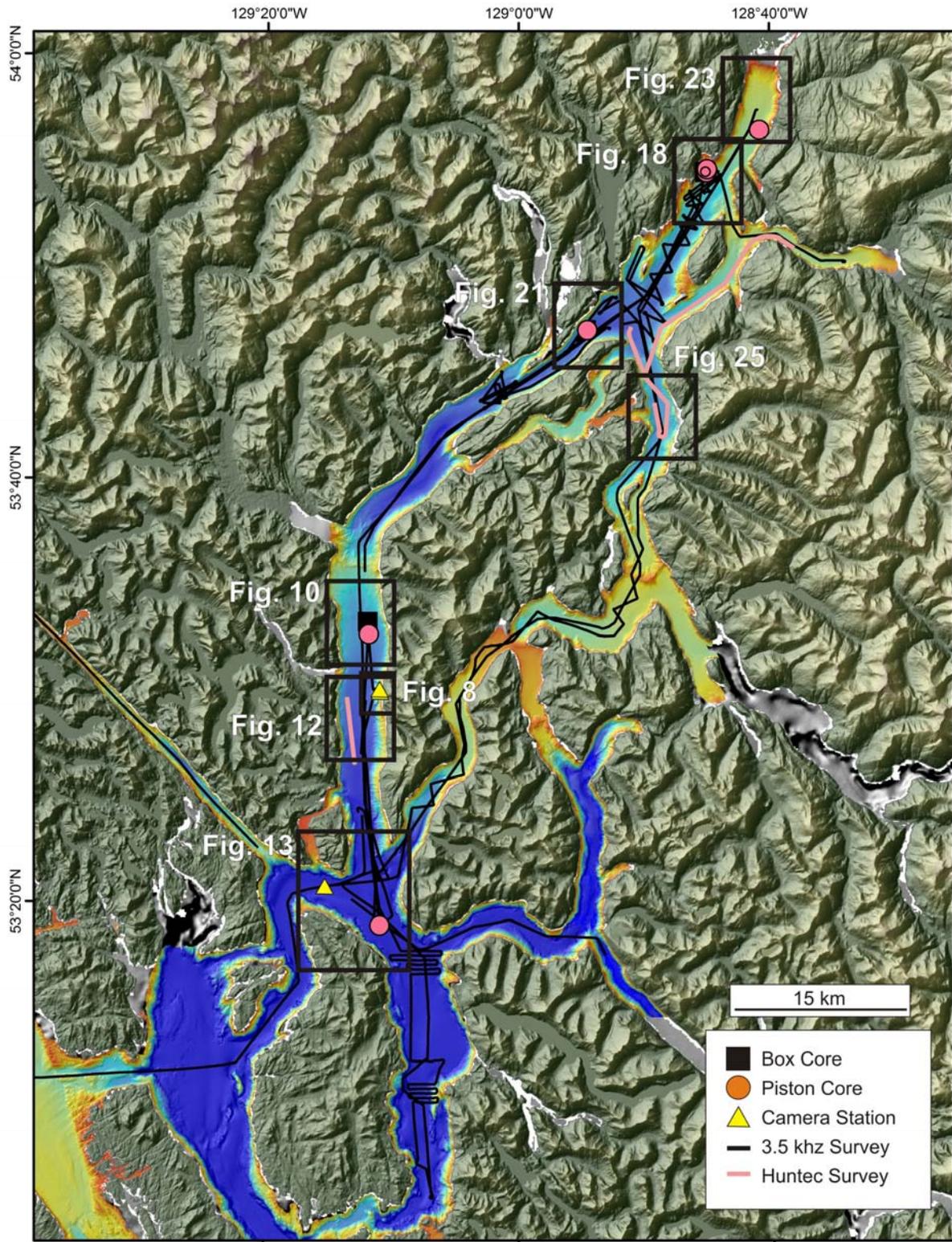


Figure 1 Expedition station and survey lines locations. Douglas Channel area.

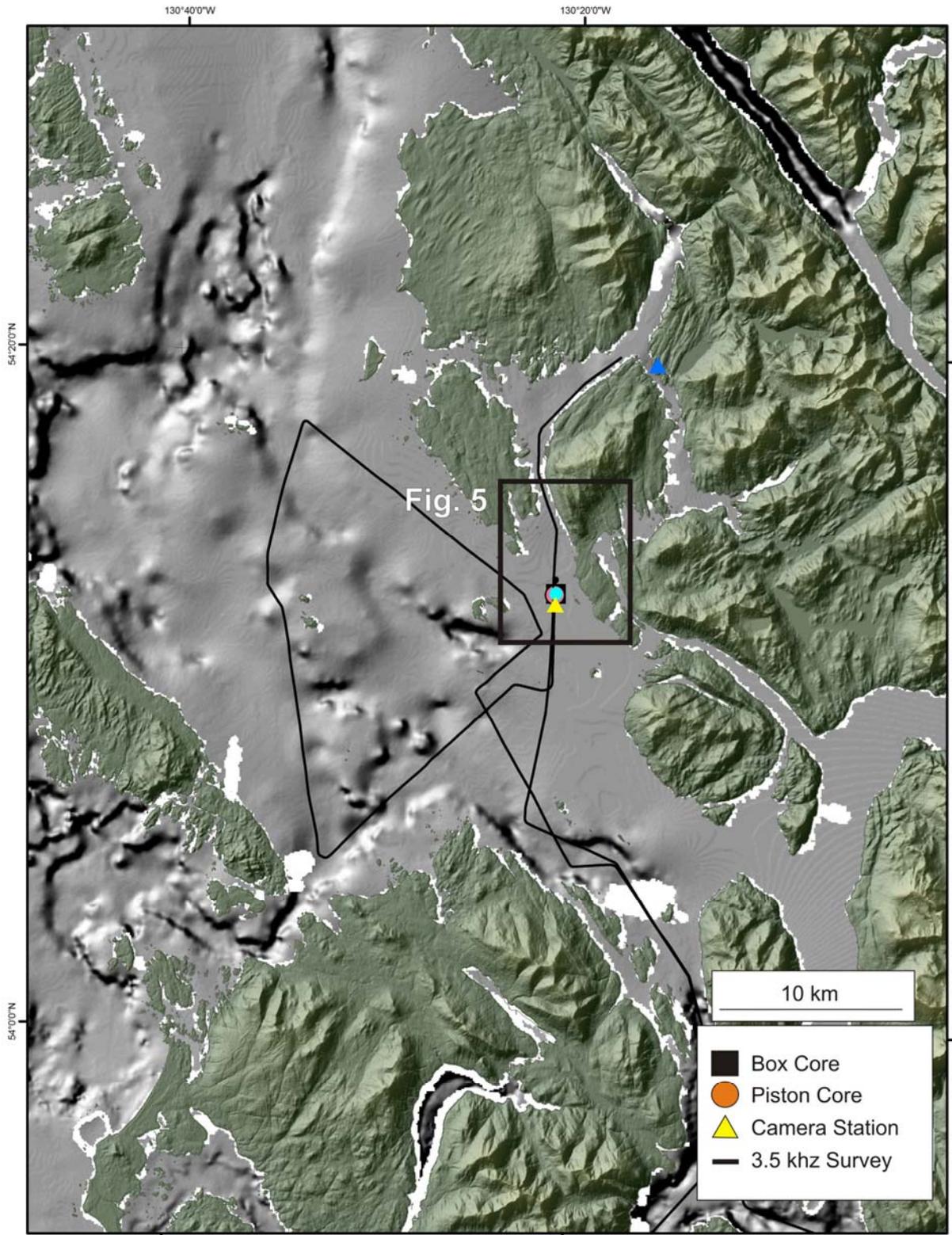


Figure 2 Expedition station and survey line locations. Chatham Sound.

Data Management

All positioning for the scientific work was taken from the ship's DGPS, providing typical accuracy of 10 metres or less. The DGPS feed was logged continuously into a navigation file, regardless of activities. DGPS feeds were also provided to Huntec DTS and chirp sonar data acquisition systems and recorded in the data files. Event positions were recorded in the navigation log for all samples at the time the sampler impacted on the seabed, and for line start and end times of geophysical surveys (Table 1). Depths are provided in most cases by the 12 kHz sounder in the lab.

Navigation and sample data were archived in the Expedition Database (ED) and are accessible via ED_Online at: http://ed.gdr.nrcan.gc.ca/index_e.php.

A Geographic Information System for the entire GSC data archives of the area was on board and proved to be an integral part of the expedition. The GIS was updated daily with the incoming data. The metadata and GIS experts on board were able to update the GIS on a daily basis with incoming data and display it on a large screen for scientists to base their next requests (Figure 3). This GIS is available to project participants for the duration of the project, and a public version will be generated for release by 2018 at the end of the field expeditions.

Due to the highly developed metadata and GIS systems on board, all station information presented in this report was complete, with very few exceptions, by the end of the cruise.

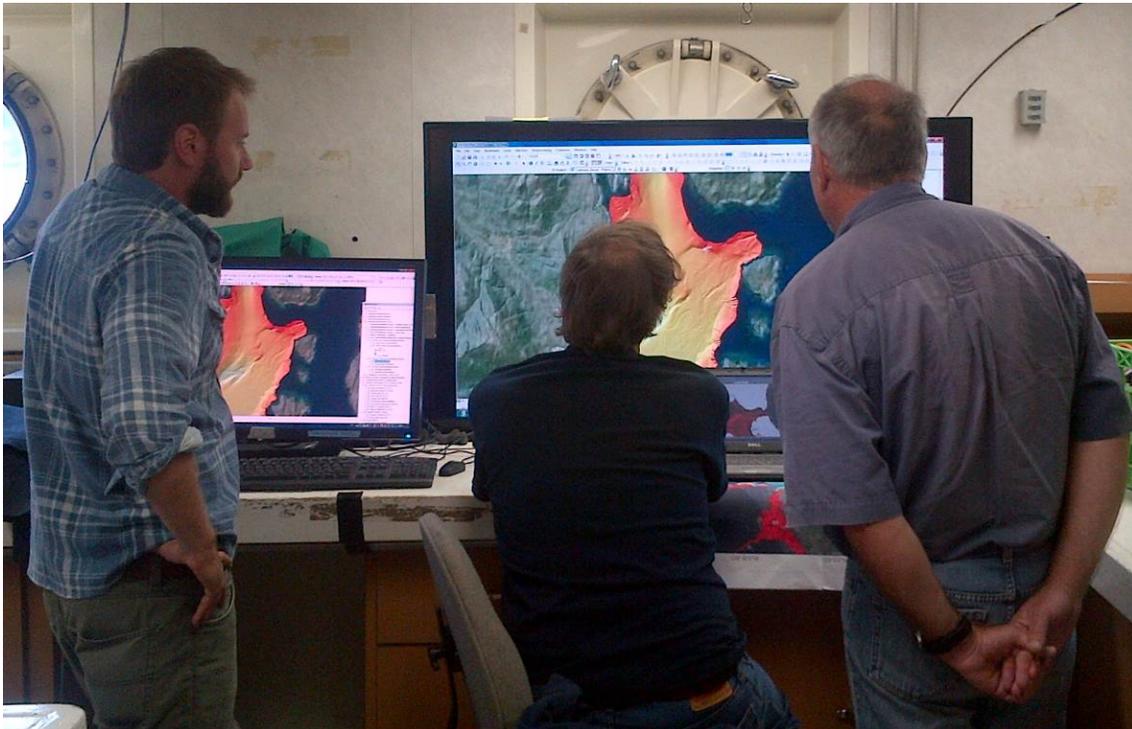


Figure 3 Scientists using the on board GIS to determine sampling strategies.

Public Engagement

A main objective of this mission was to provide information to local communities regarding the planned GSC work on geohazards in the North Coast. Community visits were made by the researchers at both Hartley Bay, and at Kitamaat, the two communities most at risk by geohazards in the channels. The invitation to the community of Kitkatlia was postponed due to essential participants not being available. An invitation was extended to students of Ocean Sciences at Northwest College. Four people attended this visit in Prince Rupert. Students from Hartley Bay High School were invited to tour the ship and were introduced to the science equipment and the Public Safety objectives (Figure 4).

Concern had been expressed about the ship's use of sonar to map the seabed. NRCan surpassed mitigation measures recommended in a letter of advice from DFO. The expedition hired two members of the Gitga'at community. The first member was hired as a wildlife monitor to watch and protect the science shore parties from wildlife attacks. The second Gitga'at member was hired as a Marine Mammal Observer to watch for whales within a restricted zone of 1 km, and advise the ship bridge and survey team when to cease work. The community Marine Mammal Observer was accompanied by a second contracted Marine Mammal Expert.

No major concerns about the work were registered by the communities visited. NRCan would like to continue engagement throughout the 4 remaining years of the project, and will be seeking information from the communities about their knowledge of geohazards in the region.



Figure 4 Students from Hartley Bay School join the ship by Rigid Hull inflatable launch, accompanied by their teacher Cam Hill.

Sediment dynamics of Chatham Sound

A short survey was done in Chatham Sound to determine some of the sediment dynamics characteristics in a nearshore trough (Figure 5). One survey line specifically targeted the trough, and two others crossed the trough on the transit to and from Prince Rupert. A bottom camera transect indicated a mostly muddy seabed with dark or cloudy images, indicating high water column turbidity in the area (Table 5). Prawns and shells could be seen in some of the photographs.

The coordinates for the station of interest are approximately 200 m from the centre of the trough. The subbottom survey indicates Holocene mud with interstitial biogenic gas within the top 5 m. The gas blanks the signal below this.

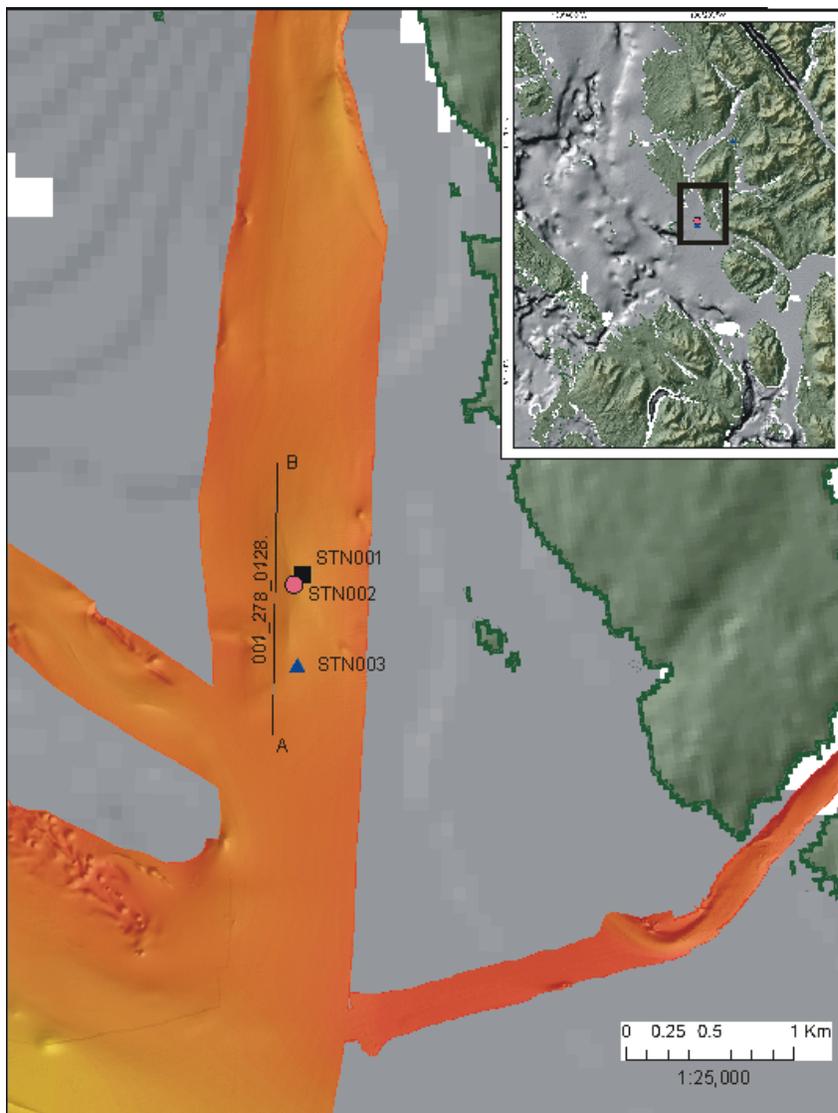


Figure 5 3.5kHz line and stations to investigate sediment dynamics of trough feature in Chatham Sound.

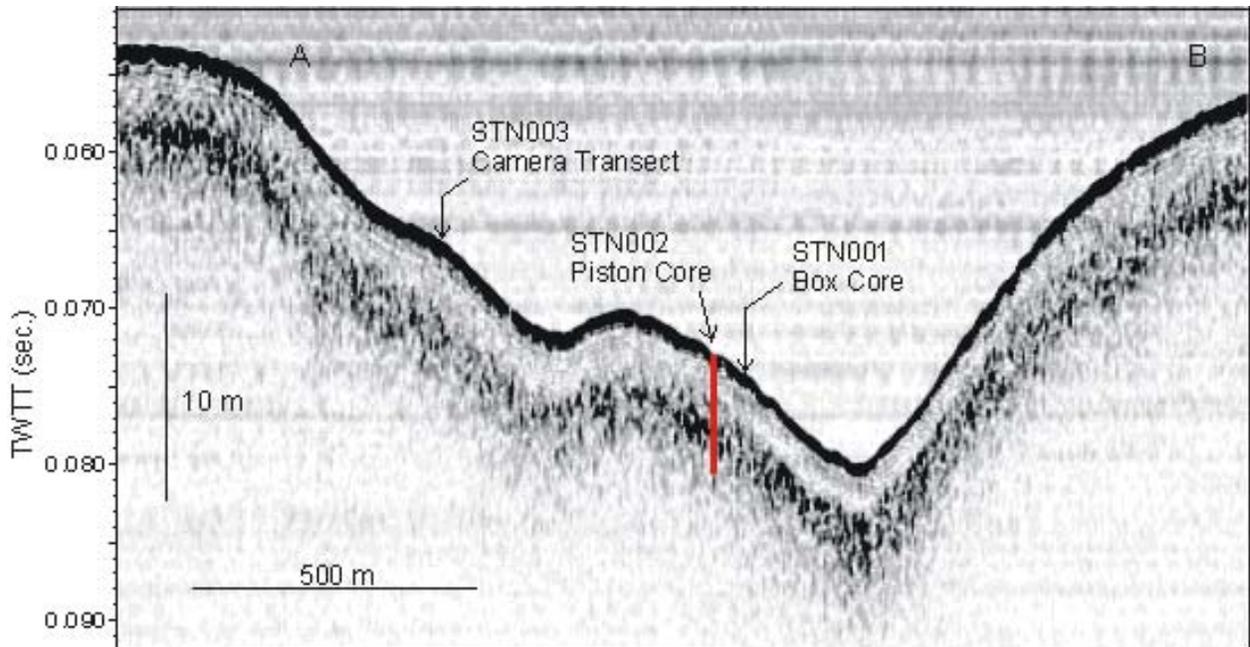


Figure 6 3.5 kHz line 2014007PGC 001_278_0128. Piston Core 002 recovered 5.66 m of sediment. box core will be subsampled for Pb-210 to determine sedimentation rate, carbon and nitrogen content and dinoflagelates.

Palaeotsunami Investigation

Researchers took opportunities to use the vessel's launch to investigate low lying areas for the existence of palaeotsunami deposits. Due to new Transport Canada restrictions regarding the number of personnel on watch in the bridge, reducing the number available for deck operations, it was not often possible to send the launch out. However the scientists did manage to visit several locations. Locations visited in the more southern channels (including Douglas Channel) proved either difficult to land the launch, or difficult to dig due to rocks, pebbles and roots. Hartley Bay was identified as a good place to investigate, but no digging was done pending permission from the Gitga'at Council. One location in Seal Cove, Prince Rupert, revealed a 15 cm thick coarse grained deposit just 10 cm below the ground, and underlying soil (Figure 7). There was no obvious nearby source for this coarse grained material. This is being investigated as having a possible tsunamigenic source.



Figure 7 Coarse grained material 10 cm below the ground in Seal Cove, Prince Rupert. This is being investigated as having a tsunamigenic source.

Submarine Slide Hazard Assessment, Douglas Channel

Work in Douglas Channel included:

- Investigation of slide A to determine if there is evidence that it is still moving (Figure 8)
- Investigation to determine the northern and southern extents of light-coloured clay beds which had previously been identified at slide A (Figure 10)
- Investigations on seabed features of interest on the west side of Douglas Channel and southern end of Douglas Channel

Conway et al (2012) identified two submarine slides and a bedrock fault-like system in Douglas Channel, near Hawkesbury Island and the community of Hartley Bay from multibeam data collected by the Canadian Hydrographic Service. These features were evaluated to be potentially tsunamigenic and an objective of the GSC expedition in 2013 (Hill, 2015) was to evaluate the age of the slides and the history of fault movement. From that work it appears that at least part of the movement was pre-glacial (10000 years old), however it remains unknown whether movement is still taking place, and therefore the research is carried over. The landward crest and trough of the slides were photographed to reveal information about recent movement. Immediately it became apparent that these areas may not be purely depositional in terms of fine-grained sediment, but instead may be even erosional (or possibly depositional from a shoreward source of coarse pebbles). Figure 9 is a photograph taken in behind Slide A, the northernmost slide.

Cores collected during the previous expedition had revealed clay layers at depth near the two submarine slides that are interpreted as a possible post glacial flood event. Two more cores were collected some distance north and south of the slides to determine the extent (and possible origin) of the clay deposit. These will be analyzed on the split cores at the GSC Pacific core lab.

Multiple attempts to track the fault-like feature seen in aerial topography failed. This feature is clearly visible in the topography and in aerial photography. Initially it was felt that it would appear in central Whale Channel, but was not seen in the subbottom data. A subbottom transect was collected further towards the west, and still no fault-like feature was apparent. What was apparent, however, is that there is a very thick deposit of recent sediment, which is likely loosely consolidated and might be obscuring attempts to map an underlying fault. Deeper penetration would likely require higher powered sub bottom methods on future expeditions. In the meantime, it is recommended that LiDAR data be used to determine movement of the fault-like feature on land.

Future plans to determine whether this mass (slide A) is moving include instrumenting the slide with pressure sensors and accelerometers. These data would preferably be

collected through the cellular network available from Hartley Bay. A test of cell signal was performed and determined that slide A was 'just' reachable by cell service. A few hundred meters northward, the cell signals disappear.

Two principal seismostratigraphic units in the fjords are: 1) a lower unit containing strong, continuous, parallel, draped internal reflections, containing relatively thick acoustically transparent intervals (**Figure 14**). This unit is interpreted as glaciomarine mud, deposited by glacial meltwater plumes. The upper unit is acoustically transparent, with gas masking in places (**Figure 14**) and low backscatter (Figure 15a). It is interpreted as postglacial mud. Its distribution is non-uniform: it occurs in banked deposits up to 80 m thick (Figure 15b), but is absent in some areas, so that the underlying unit is exposed at the seafloor (**Figure 14**), giving high backscatter (Figure 15a)

Bottom Photographs - The goal of photography at sample site 29 (Figure 16) was to determine the textural characteristics of the seafloor in this area of high backscatter interpreted as a zone of erosion or non-deposition. Most photographs showed a muddy sea floor with scattered clasts of gravel, mainly pebble-sized but with some cobbles. The mud was strongly bioturbated, with burrows, casts, and worm tubes. The gravel was sub-rounded. Some large clasts had sponges, and supported anemones. In many instances anemones could be seen protruding from the mud, suggesting a gravel layer just below the surface. Leaves such as sprigs of cedar were observed in some photographs.

It is concluded that the high backscatter areas represent non-deposition or erosion. Although mud predominates at the sea floor, the evidence suggests that an extensive gravel lag lies just below the surface. It is possible that periodic strong flow events remove this mud veneer, and that it returns during more quiescent periods. Large banks of mud (Figure 15) in close proximity to the scoured areas show that scouring is very restricted in extent, and that postglacial deposition rates vary greatly over short distances.

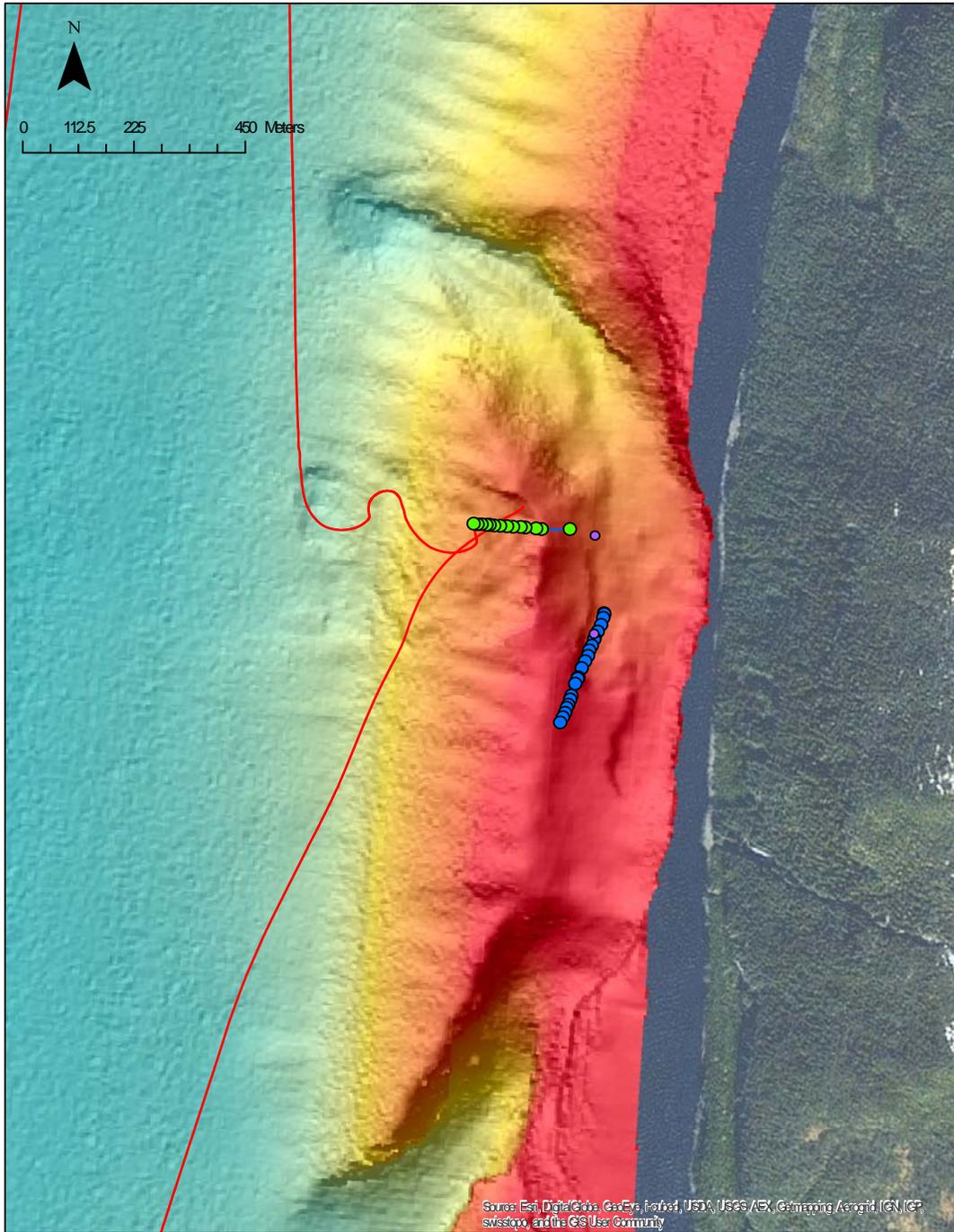


Figure 8 Location of two camera transects 0016 (green) and 0019 (blue) on the ridge formed by the northern failure, failure A.



Figure 9 Gravelly mud seen in behind slide A, the Northernmost of the two large rock slides in Douglas Channel. The source of the gravel, and/or the absence of fine-grained material is under investigation.

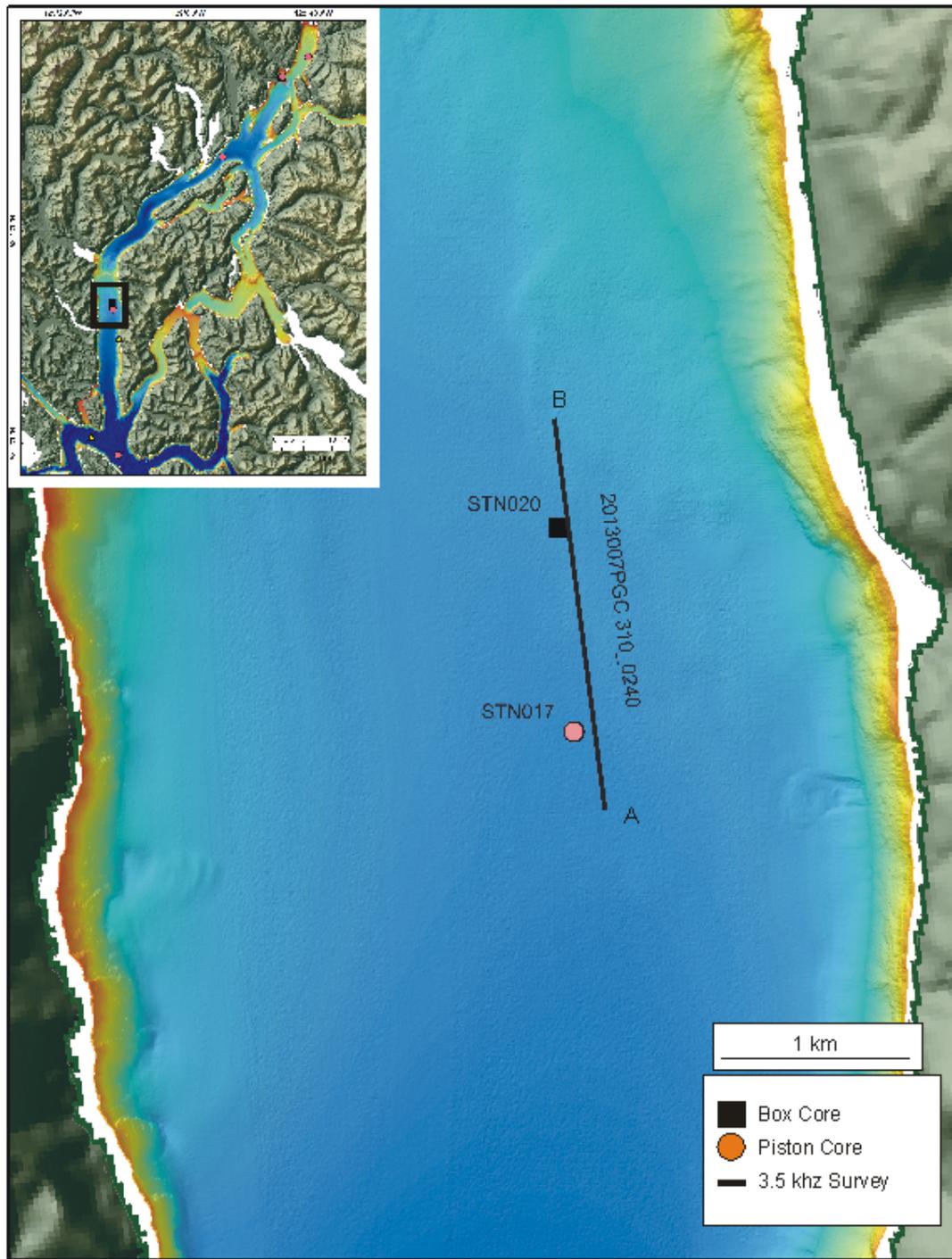


Figure 10 Stations for investigation of northern extent of light-cloured clay bed previously seen at Slide A, and thought to be the results of a large flood event. A box core was taken to determine sedimentation rates at the northern location.

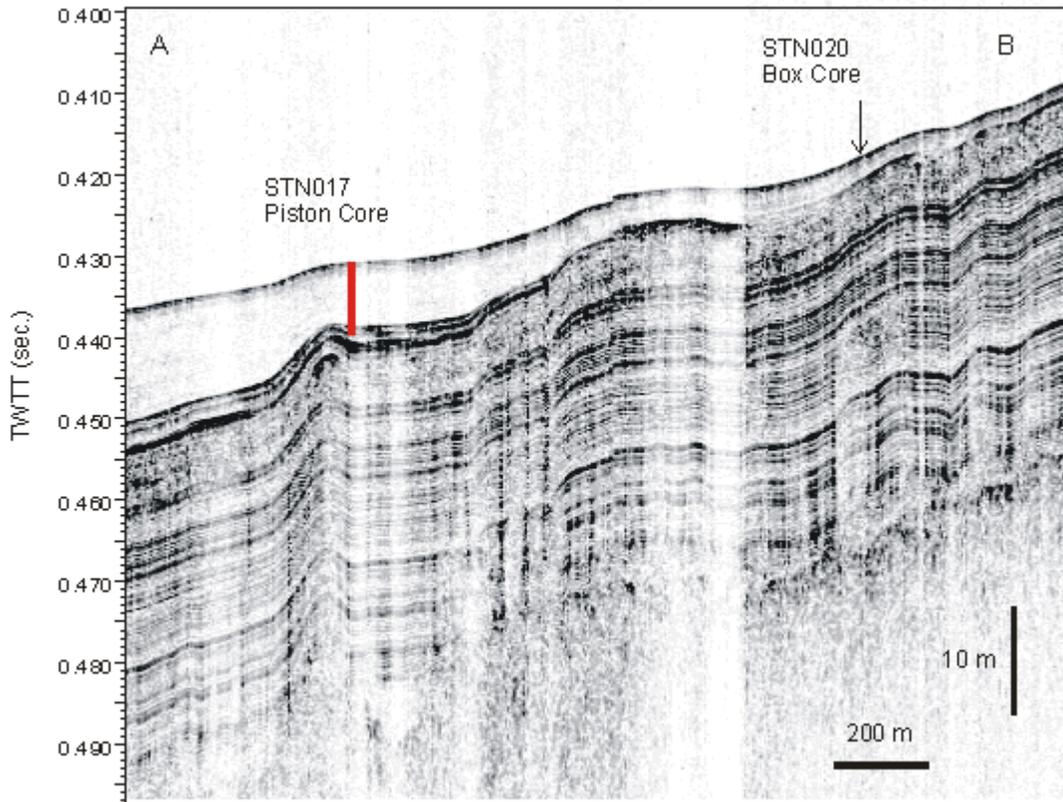


Figure 11 3.5 kHz line 2013007PGC 310_0240. Piston core 017 recovered 6.58 m of sediment. Box core 020 will be subsampled for Pb-210 to determine sedimentation rate, carbon and nitrogen content and dinoflagellates

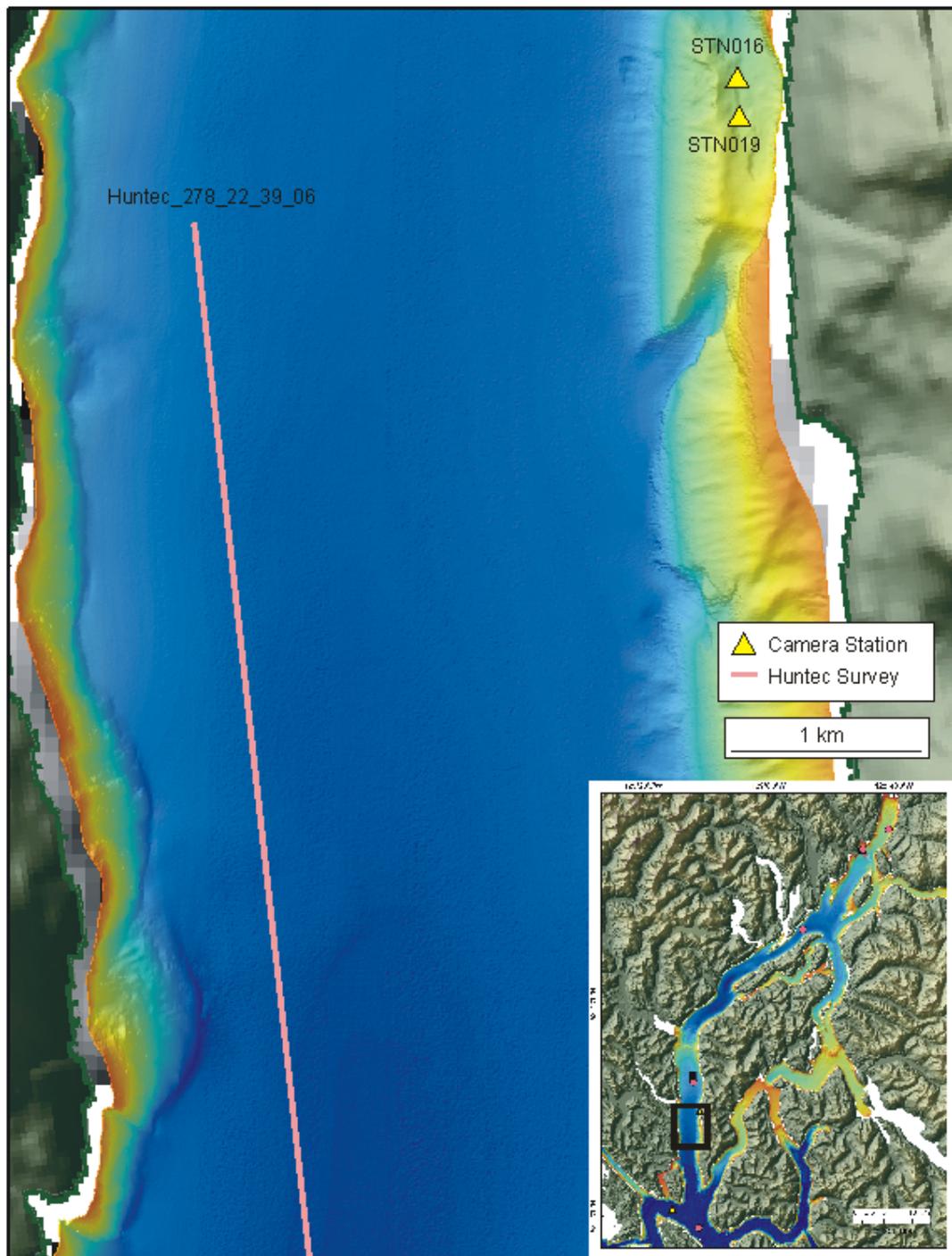


Figure 12 Hunttec line and camera survey in Douglas Channel.

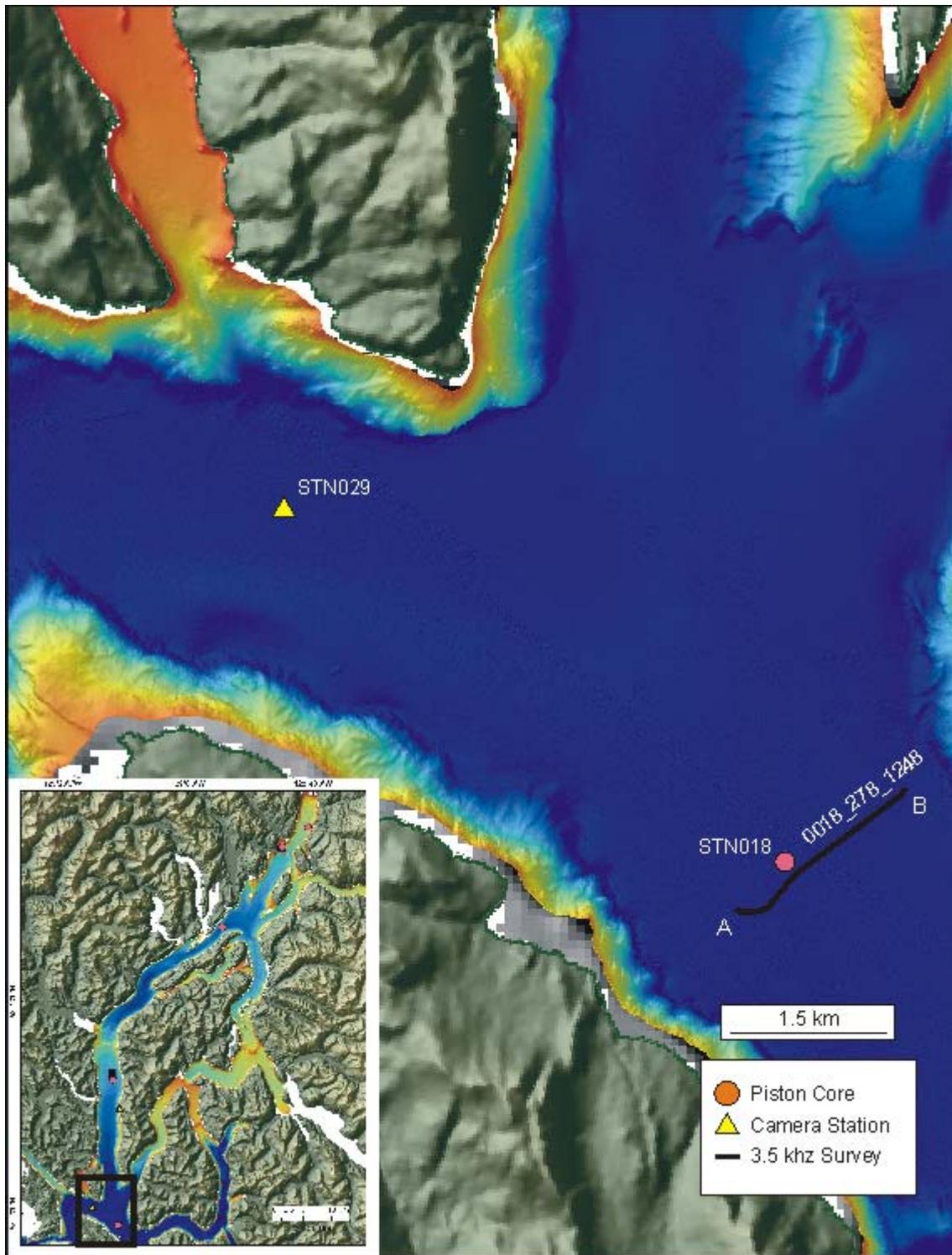


Figure 13 Piston core stations 018 for investigation of southern extent of light-coloured clay bed previously seen at Slide A, and thought to be the results of a large flood event. Camera Survey at Stn 029 to investigate Seabed features .

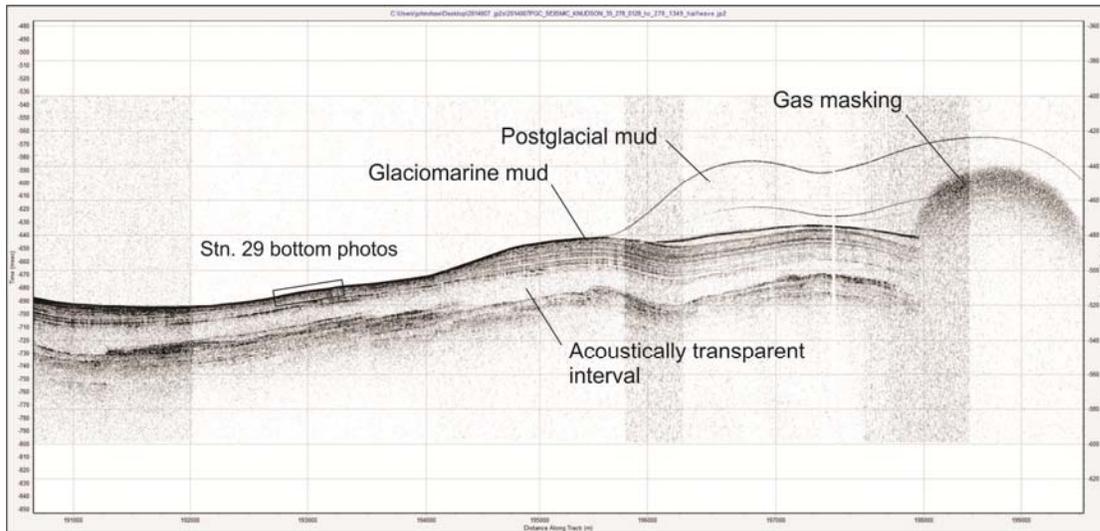


Figure 14 3.5kHz record in Wright Sound (Cruise 2014007PGC, JD 2781207–2781238) showing the acoustically transparent postglacial mud unit overlying acoustically stratified glaciomarine sediments. In the left half of the image glaciomarine sediments crop out at the sea floor and appear to have undergone some erosion.

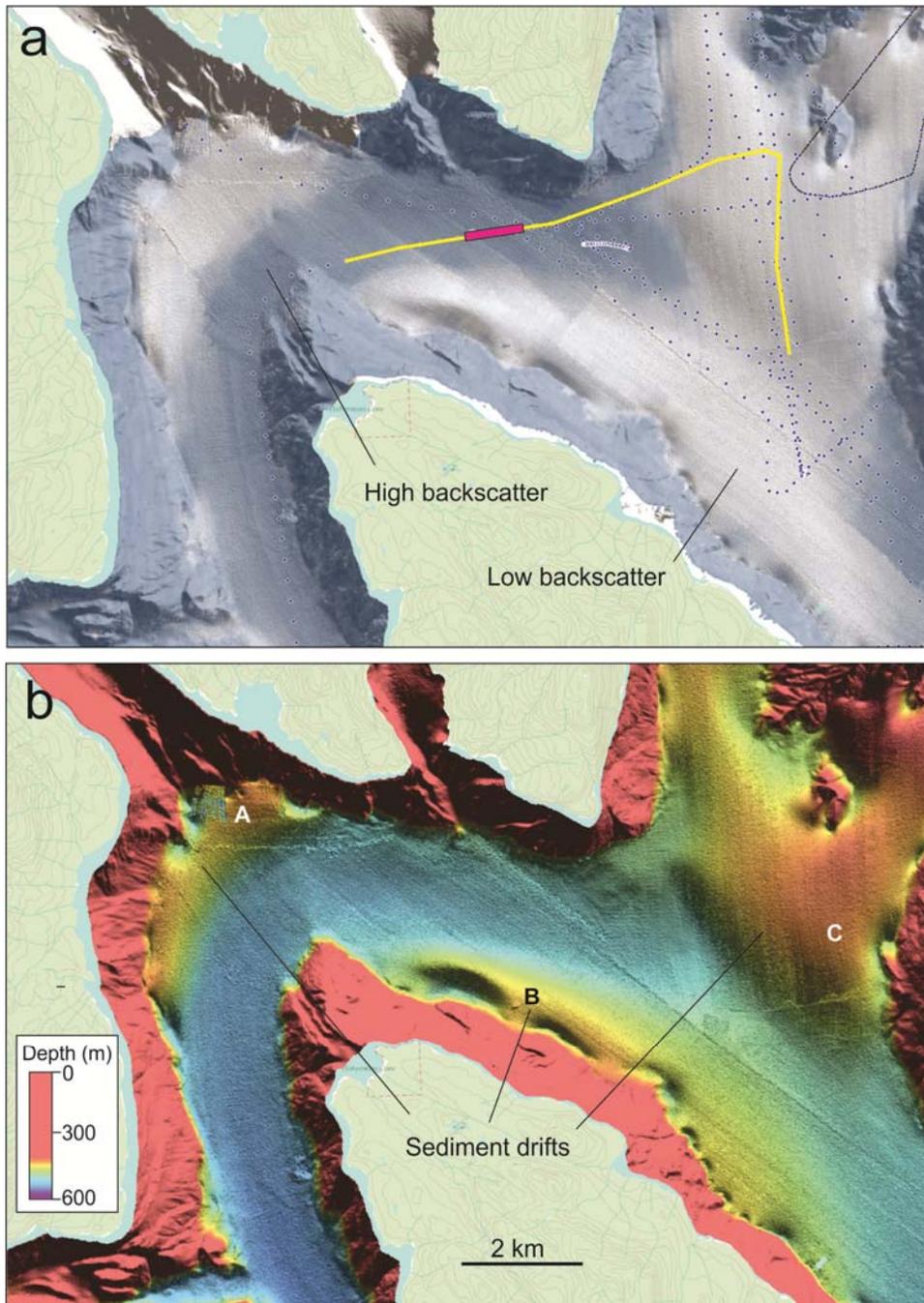


Figure 15 a) Backscatter superimposed on shaded relief image, Wright Sound. Areas of high backscatter have a dark tone, while areas of low backscatter have a light tone. Also showing the location of the 3.5 kHz record of Figure 1 (yellow line), and location of photographs at station 29 (red line); b) Multibeam image of Wright Sound, with a colour scheme that accentuates the banked areas. These banks correspond with areas of thick postglacial mud with low backscatter. The estimated maximum thicknesses are 60 m (bank A), 50 m (B) and 80 m (C).



Figure 16 Station 29 photograph number 27. More gravel is evident than in the majority of photographs. The muddy bottom is bioturbated, with burrows, casts, worm tubes. An anemone is evident at upper left, and a sea star is present directly below the centre.

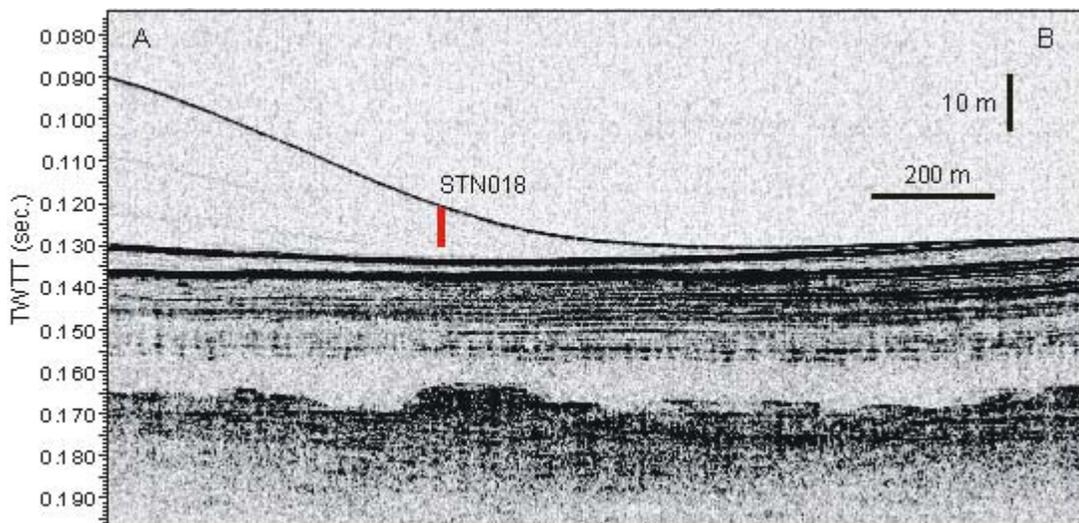


Figure 17 3.5 khz Line 2014007PGC 0018_278_1248. STN018 Piston core with a recovered length of 6.6 m.

Submarine Slide Hazard Assessment, Kitimat Arm

Kitimat Arm is the site of several known submarine landslides in historic times, some of which have generated tsunamis, with the largest documented case in 1975 having a wave height of 8.2 m (Luternauer, J. L., and Swan, D., 1978; Murty, 1979). A sidescan sonar survey of the Kitimat Arm seabed carried out in 1979 indicated the presence of rubbly submarine slide deposits over much of the proximal region of Kitimat Arm (Prior et al., 1982). A modern multibeam sonar survey in 2009 provided detailed bathymetric data over this region and the resulting shaded relief imagery provided a clearer picture of the slide morphology.

The main slide area of Kitimat Arm was sampled extensively during Hill (2015). The current 2014 expedition focused its sub-bottom capabilities in Kitimat Arm on three areas of interest. First, a focus on Bish Cove where there is some evidence of a fault-like feature. Second, the expedition filled in gaps not surveyed during the previous cruise. Third, the expedition surveyed specific areas where buried MTD's were found in the existing data in order to calculate the size and age of the previous slides.

The work conducted since Hill (2015) has indicated that a fault-like feature is present in the area of Bish Cove. This was investigated using both 3.5 subbottom sonar and both box and piston cores. The 3.5 did not show a strong fault coming to the surface- too much soft sediment- however, it did show deformation (Figure 20) which would be consistent with, among other things, a fault. Two piston cores and one box core were taken within this irregularity for further analysis.

Other survey and coring targets near Kitimat Arm looked specifically at the pinch out zone at the base of the large slide complex which originates at the delta. The intention was to core through the distal features of mass transport deposits that were buried more deeply than a core length on the upper delta.

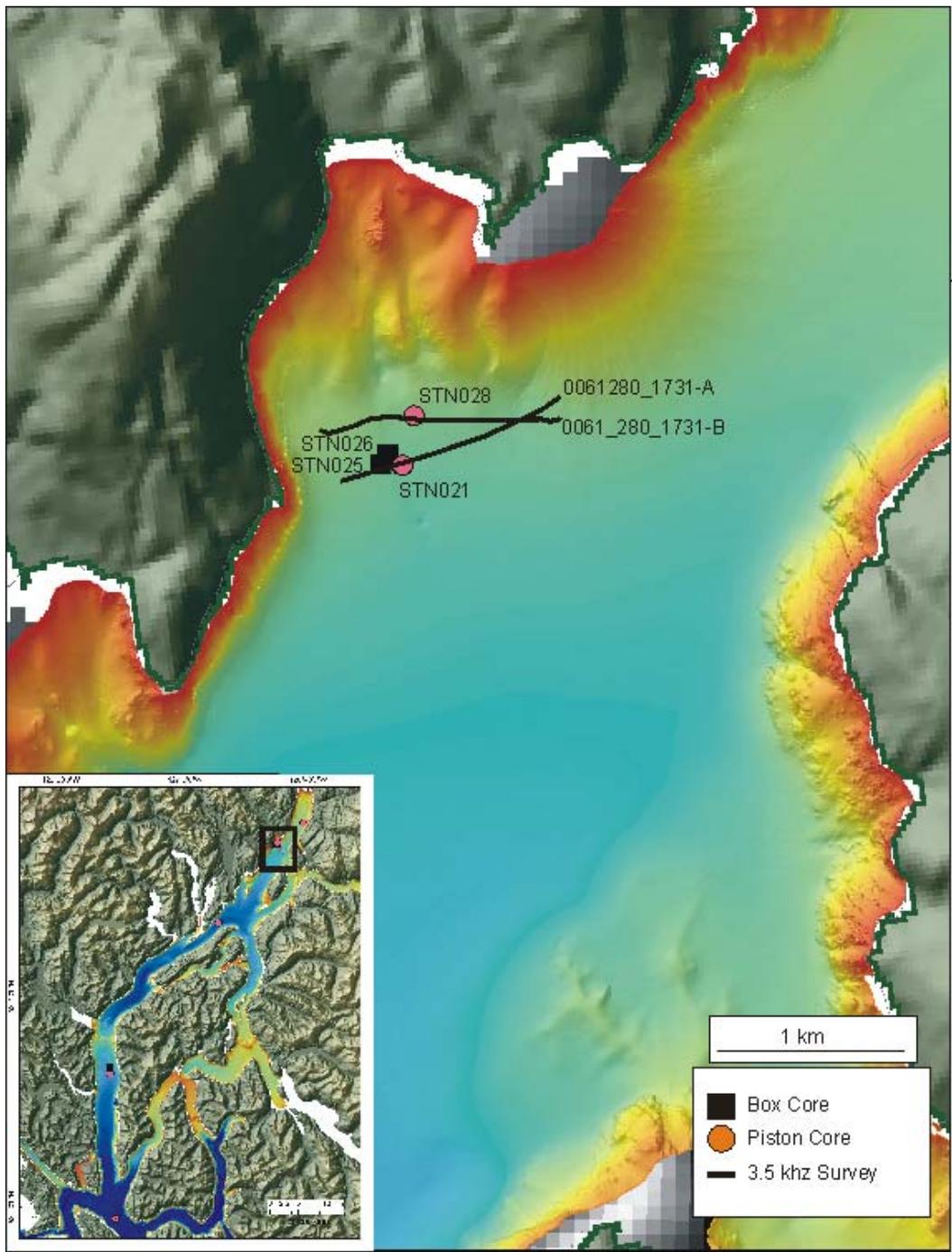


Figure 18 Stations in Bish Cove collected to investigate sub seabed deformation which resembles, among other things, a fault.

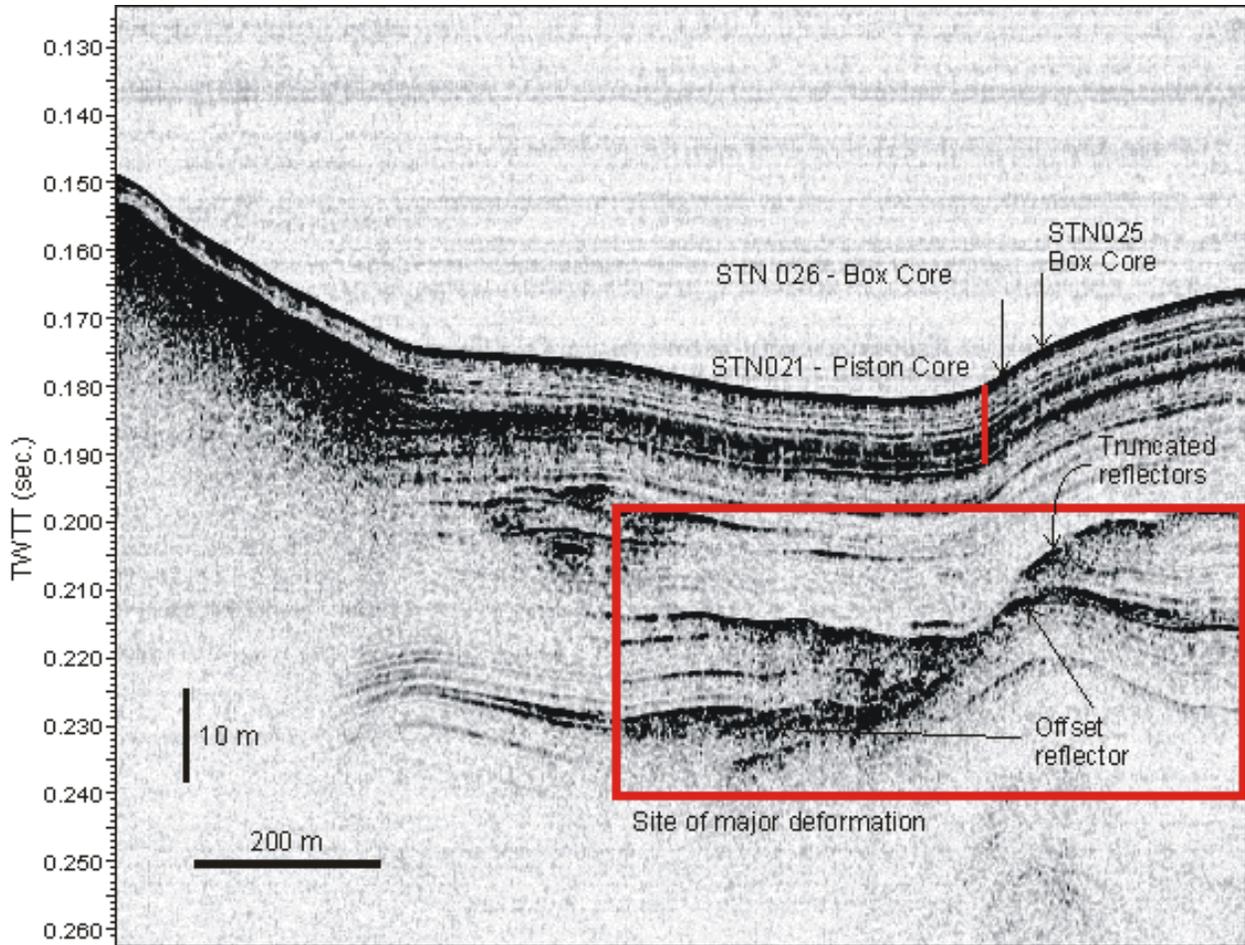


Figure 19 3.5 khz Line 2014007PGC 0061280_1731-A. Piston Core 21 recovered 8.51 m of sediment. Site selected to sample soft sediment deformation above a fault-like feature at Bish Cove. Major deformation is observed at a depth of approximately 25 m. Offset reflectors could either be a result of irregular basement relief or an indication of fault motion. Box core 25 subsampled for Pb-210 activity, carbon and nitrogen content and dinoflagelates. Box core 26 - push core and slab core extracted for physical property (MSCL) and x-radiography analysis.

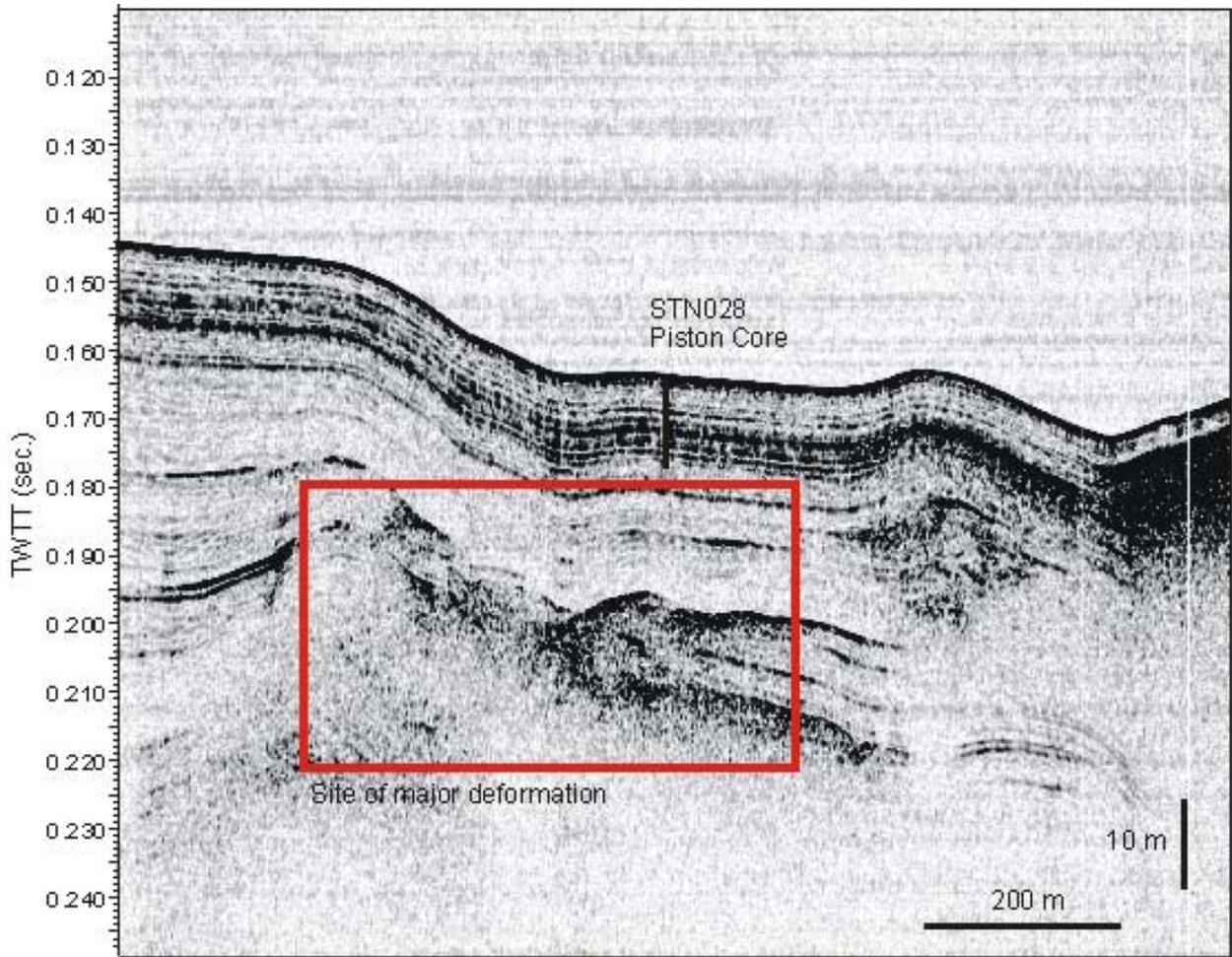


Figure 20 3.5 khz Line 2014007PGC 0061280_1731-B. Piston Core 28 recovered 9.71 m of sediment. Site selected to sample soft sediment deformation above a fault-like feature at Bish Cove. Major deformation is observed at a depth of approximately 25 m. Offset reflectors could either be a result of irregular basement relief or an indication of fault motion.

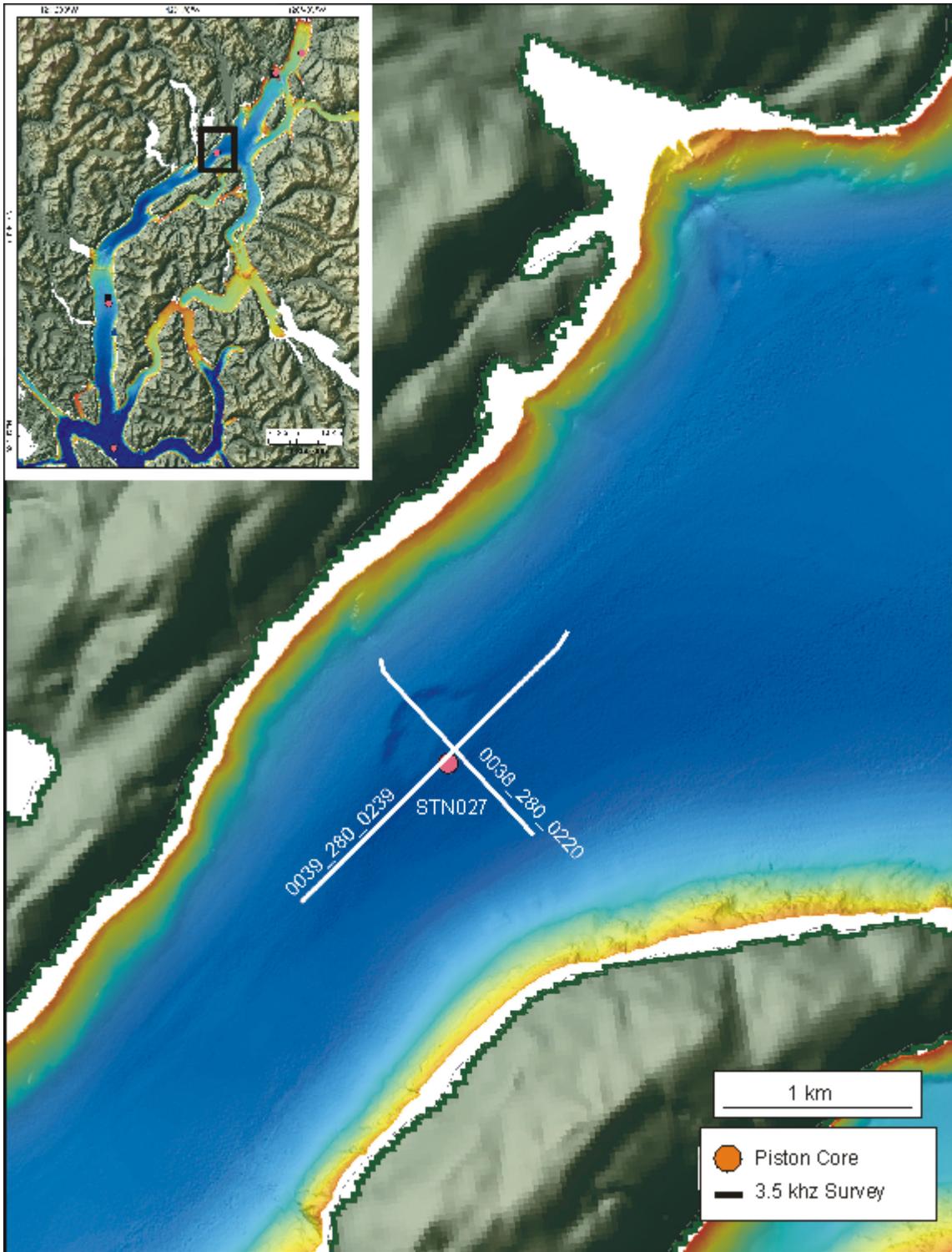


Figure 21 Piston core 027 taken to investigate the properties of a slide across from Maitland Island.

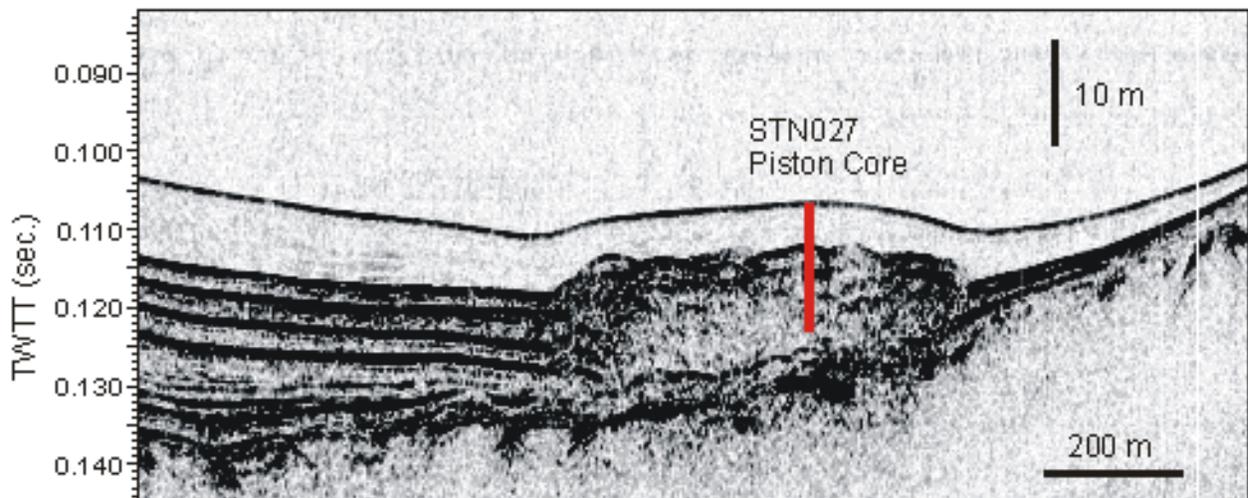
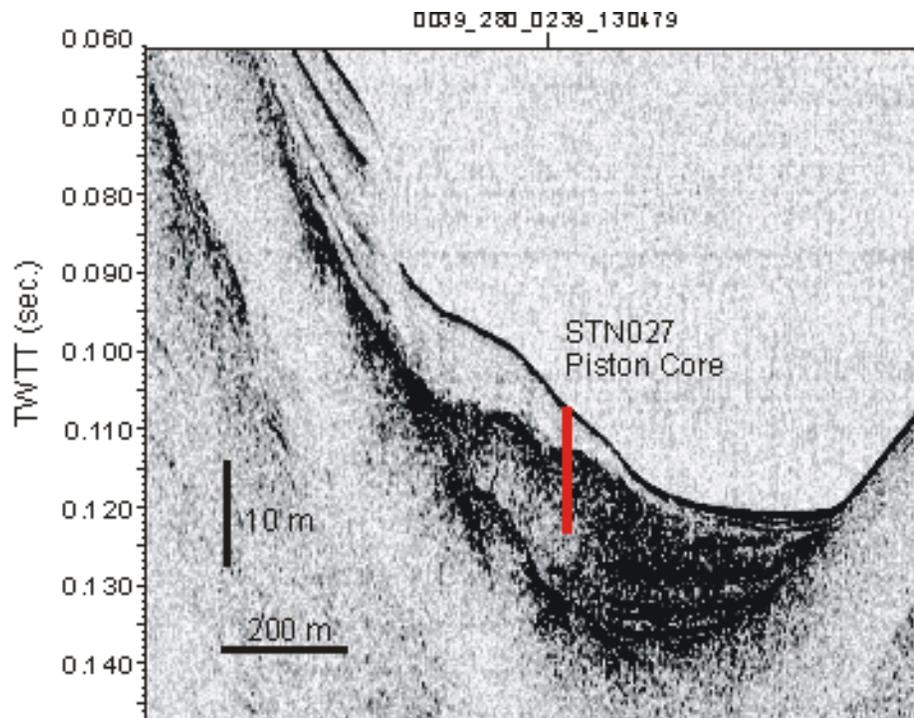


Figure 22 (top) 3.5kHz line 0038_280_0020_130479 Longitudinal profile. 3.5kHz line 0039_280_0239_130479 Transverse profile. Piston Core 27 recovered 11.95 m of sediment. Site of shallow MTD.

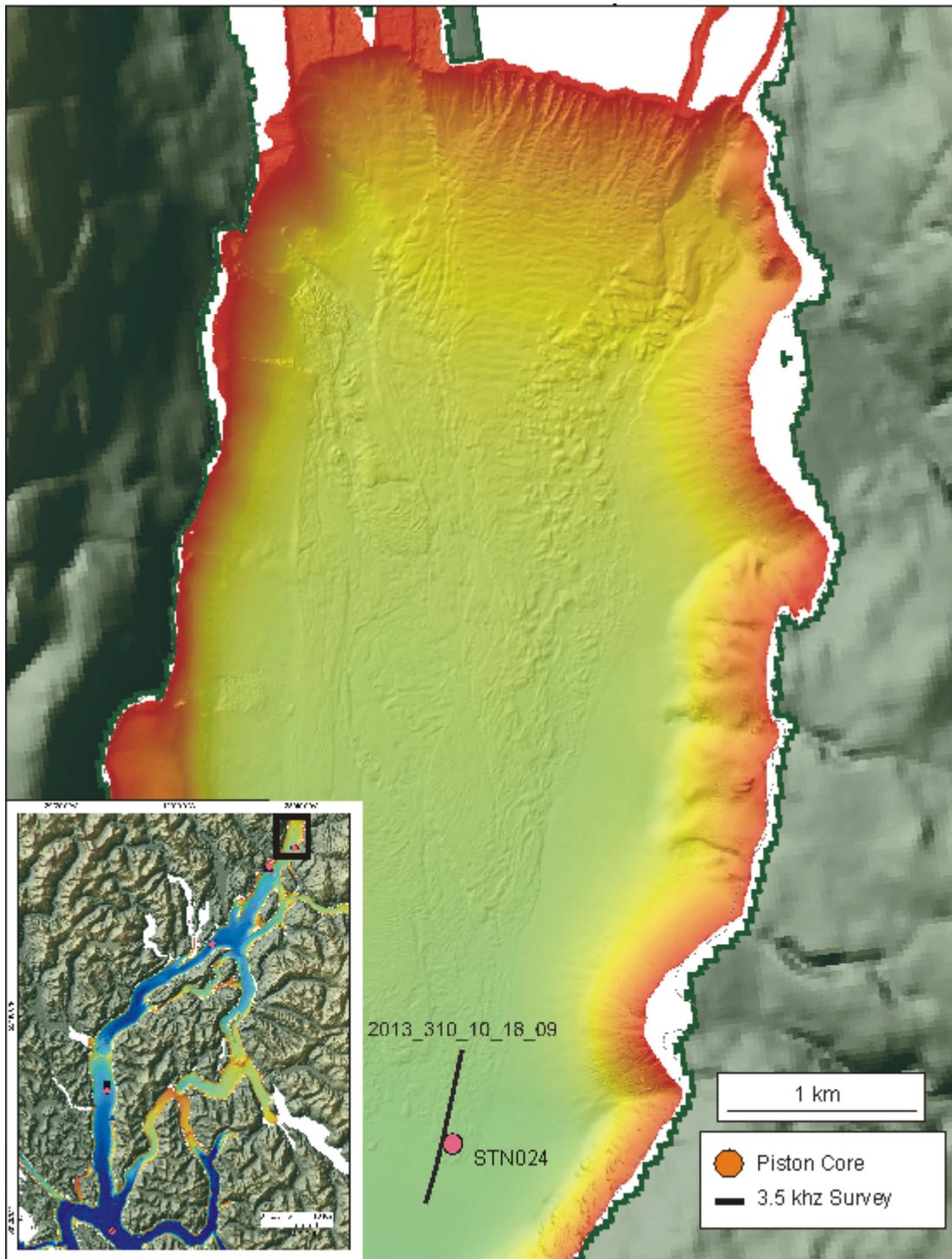


Figure 23 Location of piston core 024 at the pinchout at the bottom of the large slide complex in Kitimat Arm.

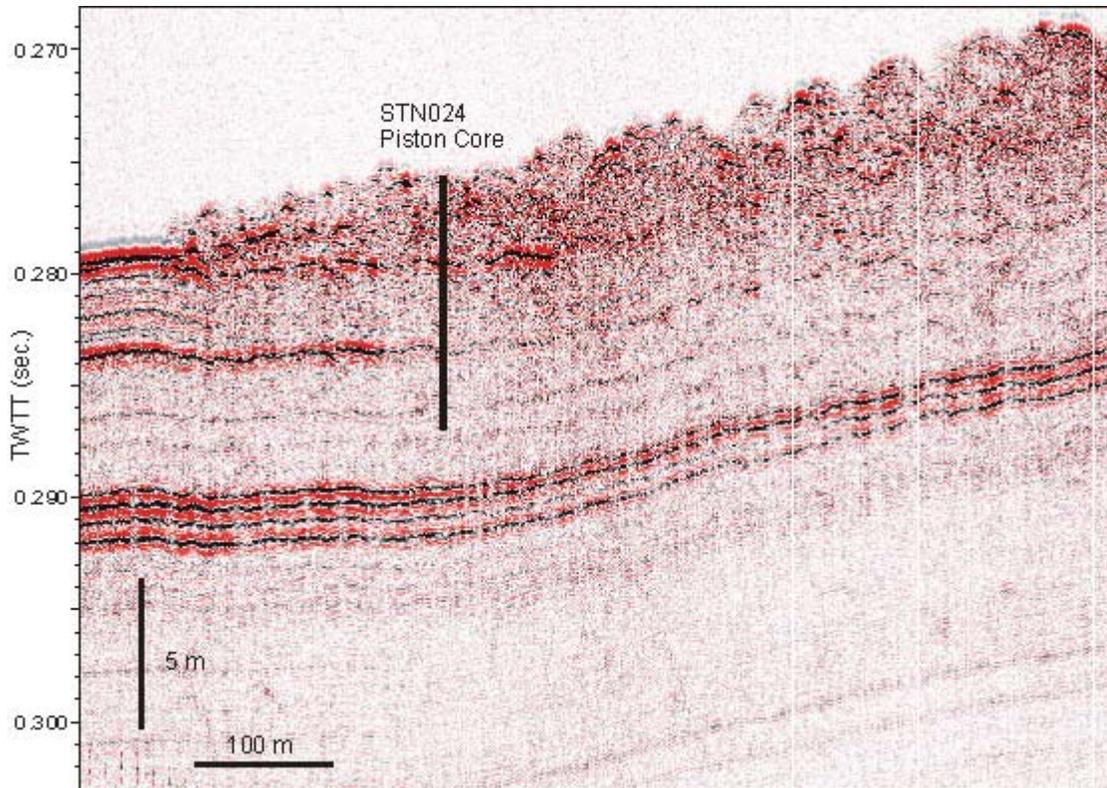


Figure 24Huntec line 1023_310_10_18_09. Piston Core 24 recovered 8.51 m of sediment. Core collected to measure Pb-210 activity under Kitimat Delta slide material in order to determine timing of deposition.

Devastation Channel Surveys

Multibeam bathymetry had indicated several mass transport deposits and other seabed features of interest in Devastation Channel and Verney Passage. We took the opportunity to survey these further with sub bottom techniques. A comparison of the towed Huntec and of the hull mounted 3.5 systems is illustrated in Figure 26. The higher resolution Huntec shows greater details in the chaotic unit and shows a greater number of parallel reflectors which are not present in the 3.5 kHz. Both methods have the same depth of penetration in fjord bottom sediments. Although the Huntec resolution is clearly better, most key features can be identified in the 3.5 kHz image.

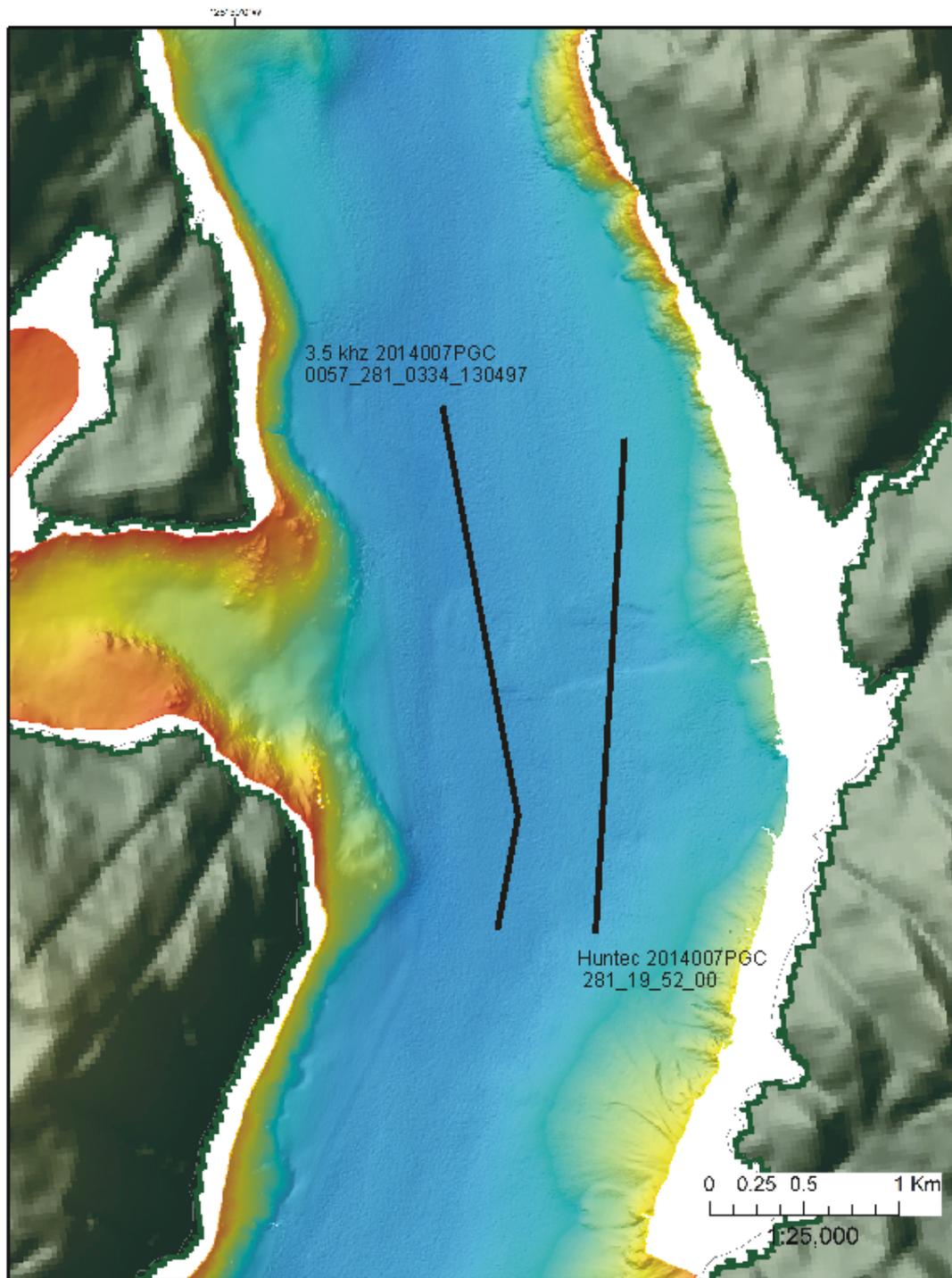


Figure 25 Huntec and 3.5 Survey lines side by side in Devastation Channel over a mass transport deposit.

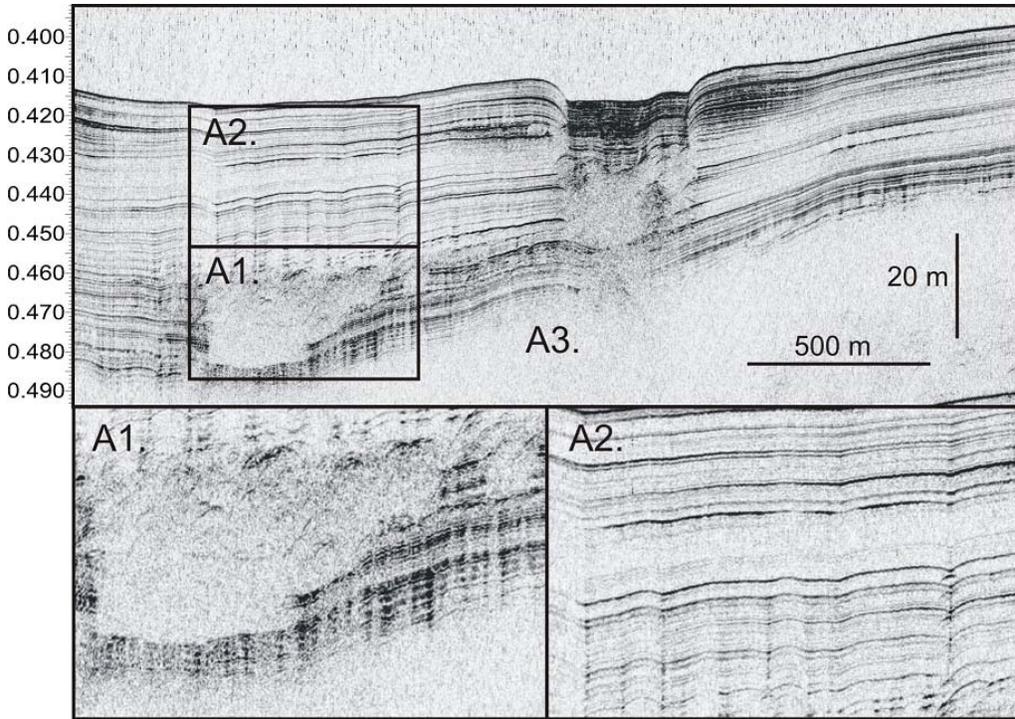


Fig. A Hunttec 2014007PGC 281_19_52_00

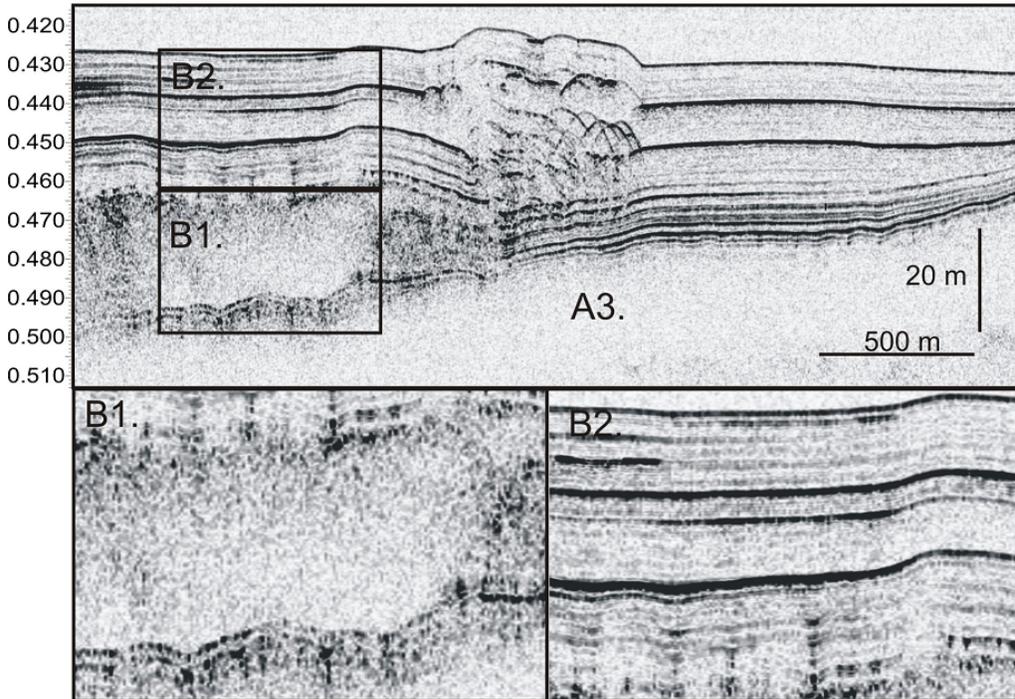


Fig. B 3.5 khz 2014007PGC 0057_281_0334_130497.

Figure 26 The higher resolution Hunttec shows details in the chaotic unit (A1 vs. B1) and shows a greater number of parallel reflectors (A2 vs. B2) which are not present in the 3.5 kHz. Both methods have the same depth of penetration in fjord bottom sediments (A3, B3). Although the Hunttec resolution is clearly better, most key features can be identified in the 3.5 kHz image.

Table 3 Stations, grouped by type.

STATION_NUM	STATION_TYPE	UTC_TIME	LATITUDE	LONGITUDE	DEPTH	LOCALE
1	Box Core	2771537	54.216058	-130.348582	67	Chatham Sound
20	Box Core	2800002	53.55475	-129.198742	314	Douglas Channel
25	Box Core	2810120	53.907987	-128.752261	226	Kitimat Arm
26	Box Core	2810206	53.908444	-128.75171	223	Kitimat Arm
3	Camera	2771810	54.211234	-130.348923	50	Chatham Sound
15	Camera	2781511	54.329629	-130.266637	-5	Fern Cove
16	Camera	2781528	53.501449	-129.182675	184	Douglas Channel
19	Camera	2790144	53.499597	-129.182501	188	Douglas Channel
29	Camera	2820716	53.346397	-129.254269	446	Wright Sound
22	FFCPT	2802227	53.907749	-128.750885	231	Kitimat Arm
23	FFCPT	2802241	53.908439	-128.751772	231	Kitimat Arm
2	Piston Core	2771658	54.21552	-130.349369	68	Chatham Sound
17	Piston Core	2781732	53.545086	-129.197547	329	Douglas Channel
18	Piston Core	2782032	53.315914	-129.182451	486	Whale Channel
21	Piston Core	2802107	53.907954	-128.750496	232	Kitimat Arm
24	Piston Core	2802341	53.941404	-128.680089	203	Kitimat Arm
27	Piston Core	2811512	53.784052	-128.90889	375	Kitimat Arm
28	Piston Core	2811711	53.910308	-128.749573	214	Kitimat Arm
4	Section	2781500	54.329629	-130.266637	-5	Fern Cove
5	Section	2781501	54.329629	-130.266637	-4.97	Fern Cove
6	Section	2781502	54.329629	-130.266637	-4.94	Fern Cove
7	Section	2781503	54.329629	-130.266637	-4.88	Fern Cove
8	Section	2781504	54.329629	-130.266637	-4.83	Fern Cove
9	Section	2781505	54.329629	-130.266637	-4.78	Fern Cove
10	Section	2781506	54.329629	-130.266637	-4.75	Fern Cove
11	Section	2781507	54.329629	-130.266637	-4.72	Fern Cove
12	Section	2781508	54.329629	-130.266637	-4.68	Fern Cove
13	Section	2781509	54.329629	-130.266637	-4.65	Fern Cove
14	Section	2781510	54.329629	-130.266637	-4.57	Fern Cove

Table 4 Piston core information

Stn	RecoveredLength	TriggerLength	#ofSections	Comments
2	566	108	4	AB=155cm, BC=155cm, cd=154cm, DE=102.
17	658	158	5	AB=152cm, BC=155cm, CD=154cm, DE=155cm, EF=42cm
18	660	164	5	AB=152cm, BC=156cm, CD=153cm, DE=155cm, EF=44cm
21	851	128	6	AB=152cm, BC=153cm, CD=153cm, DE=155cm, EF=153cm, FG=85cm.
24	669	105	5	AB=152cm, BC=155cm, CD=153cm, DE=157cm, EF=52cm.
27	1195	148	8	AB=153cm, BC=152cm, CD=156cm, DE=153 cm EF=155cm, FG=152cm, GH=154cm, HI=120cm.
28	971	113	7	AB=153cm, BC=151cm, CD=152cm, DE=156cm, EF=156cm, FG=152cm, GH=53cm.

Table 5 Station 03 Chatham Sound trough, 54.2116, -130.3493 to 54.2193, -130.3493

Photo	Depth (m)	PHOTO_COMMENTS	Geology	Biology	Habitat
001	49.7	Chatham Sound trough; cloudy dark image	mud with burrows	none	mud
002	49.7	Chatham Sound trough; cloudy dark image; suspended sediment	mud with burrows	shells	mud
003	49.7	Chatham Sound trough	mud with burrows	shrimp or prawns	mud
004	51.0	Chatham Sound trough; cloudy dark image; suspended sediment	mud with burrows	shrimp or prawns	mud
005	52.1	Chatham Sound trough; dark image; off bottom			
006	52.3	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
007	53.6	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
008	54.8	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
009	55.4	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
010	56.2	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
011	56.7	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
012	57.3	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
013	58.3	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
014	59.0	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
015	60.3	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
016	61.7	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
017	62.9	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
018	63.9	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
019	63.7	Chatham Sound trough; dark image - off bottom			
020	63.7	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
021	62.8	Chatham Sound trough	mud	shells	mud
022	62.1	Chatham Sound trough; dark image - off bottom			
023	62.1	Chatham Sound trough	mud	shells	mud
024	61.4	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
025	61.1	Chatham Sound trough; dark image - off bottom			
026	60.1	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
027	59.3	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
028	59.3	Chatham Sound trough; cloudy dark image; suspended sediment	mud	shells	mud
029	58.1	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud

030	58.0	Chatham Sound trough; good image	current scoured mud	shells and 6 shrimp or prawns	mud
031	56.7	Chatham Sound trough	mud	shrimp	mud
032	56.7	Chatham Sound trough	mud	6 shrimp or prawns	mud
033	55.5	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
034	55.5	Chatham Sound trough	mud	lines of shrimp or prawns in current	mud
035	54.1	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
036	53.8	Chatham Sound trough	mud	shrimp or prawns	mud
037	52.0	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
038	51.3	Chatham Sound trough; dark image - off bottom			
039	51.2	Chatham Sound trough; cloudy dark image; suspended sediment	mud	none	mud
040	49.9	Chatham Sound trough; cloudy dark image	mud	shrimp?	mud

Table 6 Station 16 Crest of Douglas Channel Slide A, 53.5015, -129.1835 to 53.5015, -129.1864

Photo	Depth (m)	PHOTO_COMMENTS	Geology	Biology	Habitat
001	192.14	Crest of Douglas Channel Slide A; good image;	muddy sandy gravel; gravel to 4 cm; subangular to rounded; woody organics and leaves common	Ophiuroids; gastropods; serpulid worms;	Colonized muddy gravel substrate with worm tubes; ophiuroids (brittle stars) very common.
002	183.44	Crest of Douglas Channel Slide A; good image;	muddy sandy gravel; gravel to 3 cm; rounded; woody organics and leaves common; shell debris;	Ophiuroids; gastropods; foraminifera;	Colonized muddy gravel substrate
003	186.69	Crest of Douglas Channel Slide A; good image;	muddy sandy gravel, gravel to 40 cm; rounded; abundant wood debris including cedar stems;	Ophiuroids; gastropods; foraminifera; abun encrusting organisms including serpulids and sponges	Colonized gravel surface; burrows;
004	193.54	Crest of Douglas Channel Slide A; good image;	boulders on muddy sandy gravel; to 1 m diameter; Boulders sit on thin green unit over grey (glacial?) muds	Encrusted boulder with worms, forams; sponges; shell frags on sediment	Boulders on muddy gravel
005	194.20	Crest of Douglas Channel Slide A; good image;	Muddy sandy gravel; gravel to 5 cm; rounded;	encrusting organisms including sponges (small 2 cm) and serpulid worms;	Gravel pavement on muddy sandy gravel substrate - stable surface.
006	198.10	Crest of Douglas Channel Slide A; good image;	Muddy sandy gravel; gravel to 15 cm; angular;	Ophiuroids; sponges; serpulids;	gravel pavement with muddy sandy gravel below - stable surface
007	202.59	Crest of Douglas Channel Slide A; good image;	Muddy sandy gravel; gravel subrounded to 2 cm; thin skiff of green mud on gravel lag(?)	Gastropods; forams; serpulids	gravel pavement with thin skiff of mud on surface (surface gravel lag unit?)
008	203.48	Crest of Douglas Channel Slide A; good image;	Gravelly sandy mud; gravel to 8 cm diam;	Ophiuroids and forams on sediment; serpulids on cobbles;	gravel clasts on sandy mud
009	205.77	Crest of Douglas Channel Slide A; good image;	Gravelly sandy mud; chips of glaciomarine visible on recent green sediment surface; woody debris	Ophiuroids, minor shells, bryozoans, forams	gravel clasts on sandy mud
010	205.84	Crest of Douglas Channel Slide A; good image;	Muddy sandy gravel; thin skiff of green recent sed on grey glacial (?) lag	Ophiuroids, minor shells,serpulids	Thin muds on gravelly lag.

011	205.69	Crest of Douglas Channel Slide A; good image;	Muddy sandy gravel; gravel to 3 cm; subrounded;	Ophiuroids, minor shells,serpulids	Discontinuous mud on gravel.
012	206.81	Crest of Douglas Channel Slide A; good image;	Gravelly sandy mud; gravel to 10 cm; subrounded; grey mud clasts (glaciomarine?)	Ophiuroids, minor shells,serpulids; sponges	gravel clasts on sandy mud
013	212.36	Crest of Douglas Channel Slide A; good image;	Gravelly sandy mud; gravel to 20 cm; subrounded;	Ophiuroids, minor shells,serpulids;	gravel clasts on sandy mud
014	214.83	Crest of Douglas Channel Slide A; good image;	Thin sandy mud on gravel surface; gravel to 3 cm; subrounded;	Ophiuroids; shell debris; two spot prawns; forams; sponges; bryozoans	discontinuous sandy mud on gravelly lag surface;

Table 7 Station 19 Behind Ridge Crest, Douglas Channel Slide A, 53.5000, -129.1822 to 53.4988, -129.1829

Photo	Depth (m)	PHOTO_COMMENTS	Geology	Biology	Habitat
001	191.1	Good image	Pebbles , muddy	Worm holes, brittlestars	Gravelly mud
002	191.1	Good image	Pebbles, mud	Worm holes, brittlestars	Gravelly mud
003	190.8	Good image	Mainly mud, some gravel	Worm holes, brittlestars	Mud, some gravel
004	190.0	Good image	Mainly mud, some gravel	Worm holes, brittlestars	Mud, minor gravel
005	188.4	Good image	Cobbles pebbles mud	Brittlestars, some attached fauna	Muddy gravel
006	186.7	Good image	Pebbly mud	Worm holes, brittlestars, attached fauna	Muddy gravel
007	186.7	Good image	Gravelly mud	Brittlestars, gastropod	Gravelly mud
008	184.2	Good image	Mud, minor gravel	Brittlestars	Mud minor gravel
009	182.5	Good image	Mud, minor gravel	Brittlestars	Mud
010	180.8	Good image	Mud	Brittlestars, wormholes	Mud
011	178.2	Good image	Mud, cobbles	Brittlestars, attached fauna	Mud, minor gravel
012	173.4	Good image	Mud	Brittlestars	Mud
013	167.7	Good image	Mud	Brittlestars	Mud
014	167.1	Good image	Mud	Brittlestars, worm holes	Mud
015	167.1	Good image	Muddy gravel	Brittlestars, worm holes	Muddy gravel
016	163.3	Good image	Muddy gravel	Attached fauna, gastropods	Muddy gravel
017	160.8	Good image	Muddy gravel	Attached fauna	Muddy gravel
018	160.2	Fine image	Gravelly mud	Attached fauna, wormholes	Gravelly mud
019	160.2	Fine image	Muddy gravel	Attached fauna	Muddy gravel
020	158.4	Good image	Muddy gravel	Worm holes	Muddy gravel
021	157.3	Good image	Muddy gravel	Attached fauna	Muddy gravel
022	155.8	Good image	Muddy gravel		0 Muddy gravel
023	154.3	Good image	Muddy gravel	Attached fauna	Muddy gravel
024	153.1	Good image	Muddy gravel	Attached fauna	Muddy gravel

Table 8 Station 29 Deep trough in Wright Channel, 53.3464, -129.2550 to 53.3466, -129.2531

Photo	Depth (m)	PHOTO_COMMENTS	Geology	Biology	Habitat
001	509.18	Deep trough in Wright Channel; Good photo	Gravelly mud	Sponge, gastropods, shell frags.,	Burrow traces, attached fauna on muddy gravel
002	509.18	Deep trough in Wright Channel; Dark image - suspended sediment	Sandy mud	Shell frags.,	Shell frags.
003	509.06	Deep trough in Wright Channel; Dark image - suspended sediment	Sandy mud	Shell frags.,	Shell frags.
004	509.06	Deep trough in Wright Channel; Dark image - suspended sediment	Sandy mud	Shell frags.,	Shell frags.
005	509.06	Deep trough in Wright Channel; Dark image - suspended sediment	Gravelly mud	Shell frags.,	Scattered cobbles
006	509.06	Deep trough in Wright Channel; Fair image	Muddy gravel	Shell frags., attached fauna, worm tubes,	Scattered cobbles, abundant burrows and worm tubes
007	509.06	Deep trough in Wright Channel; Fair image	Sandy mud	Shell frags, worm tubes, coral branch?	Thin sandy mud on gravel?
008	509.06	Deep trough in Wright Channel; Fair image	Muddy gravel	Forams, shell frags, worm tubes, attached fauna (anemone), shrimps	Attached fauna on muddy gravel
009	507.32	Deep trough in Wright Channel; Fair image	Muddy gravel	Forams, shell frags, worm tubes, attached fauna (anemone), shrimps	Attached fauna on muddy gravel
010	508.14	Deep trough in Wright Channel; Fair image	Sandy mud	Burrows, worm tubes, forams, shell frags.	Bioturbated sandy mud
011	507.00	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags.	Scattered cobbles, abundant burrows and worm tubes
012	507.00	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags., gastropods, shrimps, brittlestar	Thin sandy mud on gravel
013	508.68	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags., gastropods, anemones, sponge	Thin sandy mud on gravel
014	508.68	Deep trough in Wright Channel; Fair-good image	Gravelly mud	Burrows, worm tubes, forams, shell frags., gastropods, anemones, sponge, chiton	Thin sandy mud on gravel, rounded cobbles to 30 cm

015	507.47	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags., gastropods, glass sponge 20 cm	Thin sandy mud on gravel, rounded cobbles to 40 cm
016	506.09	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags., anemone	thin sandy mud on gravel subangular to 3 cm
017	505.96	Deep trough in Wright Channel; poor image - cloud of sediment	sandy mud?		
018	505.74	Deep trough in Wright Channel; Fair image	sandy mud	Burrows, worm tubes, forams, shell frags., brittle star; shrimp	thin sandy mud on gravel?
019	505.48	Deep trough in Wright Channel; Fair image	gravelly mud	Burrows, worm tubes, forams, shell frags., sponges, anemone	Thin sandy mud on sub-rounded gravel to 25 cm
020	505.54	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags.,	Thin sandy mud on sub-rounded gravel to 20 cm
021	505.54	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, anemones, flat worm, sponge, shrimp	Thin sandy mud on sub-rounded gravel to 20 cm
022	504.84	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, brittlestar	Thin sandy mud on gravel to 20 cm
023	505.22	Deep trough in Wright Channel; Good image	Gravelly mud	Burrows, worm tubes, forams, brittlestar, shrimp	Thin sandy mud on gravel to 20 cm
024	505.22	Deep trough in Wright Channel; Good image	Gravelly mud	Burrows, worm tubes, forams, brittlestar, bivalve	Thin sandy mud on gravel to 20 cm
025	505.15	Deep trough in Wright Channel; Fair image	Sandy mud	Burrows, worm tubes, forams, shell frags., cedar twig	Sandy mud, burrowed
026	505.15	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags., cedar twig	Gravelly mud, gravel to 10 cm, rounded
027	504.60	Deep trough in Wright Channel; Good image	Muddy gravel	Burrows, worm tubes, forams, shell frags., bivalves, anemone, cushion star, serpulid worms on gravel	Muddy gravel, gravel to 20 cm, rounded-sub-rounded
028	504.64	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags., bivalves, sponge	Gravelly mud, gravel to 25 cm
029	504.48	Deep trough in Wright Channel; Poor image	Sandy mud	Burrows, worm tubes, forams, shell frags.,	Sandy mud
030	504.14	Deep trough in Wright Channel; Good image	Gravelly mud	Burrows, worm tubes, forams, shell frags.,	Gravelly mud, gravel up to 25 cm, sub-angular
031	504.14	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags.,	Gravelly mud, minor gravel
032	504.14	Deep trough in Wright Channel; Poor image	Gravelly mud	Burrows, worm tubes, forams, shell frags.,	Gravelly mud, minor gravel

033	504.36	Deep trough in Wright Channel; Fair image	Sandy mud	Burrows, worm tubes, forams, shell frags.,	Gravelly mud
034	504.50	Deep trough in Wright Channel; Fair image	Gravelly mud	Burrows, worm tubes, forams, shell frags., sponge, shrimp	Gravelly mud-sub-angular gravel 25 cm
035	504.50	Deep trough in Wright Channel; Poor image	Mud, minor gravel	Burrows, worm tubes?	Mud, minor gravel
036	504.50	Deep trough in Wright Channel; Very poor image-dark	Sandy mud?	Burrows, worm tubes?	Sandy mud
037	504.20	Deep trough in Wright Channel; Poor image	Sandy mud	Burrows, worm tubes?	Sandy mud
038	504.20	Deep trough in Wright Channel; Poor image	Sandy mud	Burrows, worm tubes?	Sandy mud
039	503.89	Deep trough in Wright Channel; Fair image	Muddy gravel	Worm tubes, forams, shell frags, sponge, shrimps	Muddy gravel, gravel to 20 cm
040	503.89	Deep trough in Wright Channel; Fair image	Sandy mud, minor gravel	Worm tubes, shell frags., worm casts	Sandy mud, minor gravel
041	503.12	Deep trough in Wright Channel; Fair image	Muddy gravel	Worm tubes, shell frags., worm casts, sponge	Muddy gravel
042	503.62	Deep trough in Wright Channel; Fair image	Sandy mud	Worm tubes, shell frags., worm casts. Forams	Sandy mud
043	503.54	Deep trough in Wright Channel; Poor image	Sandy mud	Worm tubes, shell frags., worm casts, forams	Sandy mud
044	503.54	Deep trough in Wright Channel; Fair image	Sandy mud	Worm tubes, shell frags., worm casts, forams	Sandy mud
045	502.93	Deep trough in Wright Channel; Poor image	Sandy mud	Worm tubes, shell frags., worm casts, forams	Sandy mud
046	503.16	Deep trough in Wright Channel; Fair image	Muddy gravel	Worm tubes, shell frags., worm casts, forams	Muddy gravel
047	503.30	Deep trough in Wright Channel; Fair image	Muddy gravel	Worm tubes, shell frags., worm casts, forams	Muddy gravel, sub-angular - sub-rounded pebbles
048	502.30	Deep trough in Wright Channel; Fair image	Muddy gravel	Worm tubes, shell frags., worm casts, forams	Muddy gravel, sub-angular - sub-rounded pebbles
049	502.30	Deep trough in Wright Channel; Fair image	Sandy mud	Worm tubes, shell frags., worm casts, forams	Sandy mud
050	502.50	Deep trough in Wright Channel; Good image	Muddy gravel	Worm tubes, shell frags., worm casts, forams	Muddy gravel -boulders and cobbles

051	502.50	Deep trough in Wright Channel; Good image	Muddy gravel	Worm tubes, shell frags., worm casts, forams, large anemone	Muddy gravel - boulders
052	502.66	Deep trough in Wright Channel; Good image	Sandy mud	Worm tubes, shell frags., worm casts, forams, starfish	Sandy mud
053	502.72	Deep trough in Wright Channel; Fair image	Sandy mud	Worm tubes, shell frags., worm casts, forams, bivalve	Sandy mud
054	502.72	Deep trough in Wright Channel; Fair image	Muddy gravel	Worm tubes, shell frags., worm casts, forams, sponge	Muddy gravel -pebbles
055	501.79	Deep trough in Wright Channel; Fair image	Muddy gravel	Worm tubes, shell frags., worm casts, forams	Muddy gravel
056	501.59	Deep trough in Wright Channel; Fair image	Muddy gravel	Worm tubes, shell frags., worm casts, forams	Muddy gravel
057	501.15	Deep trough in Wright Channel; Fair image	Sandy mud	Worm tubes, shell frags., worm casts, forams	Sandy mud
058	501.73	Deep trough in Wright Channel; Fair image	Sandy mud	Worm tubes, shell frags., worm casts, forams	Sandy mud
059	501.73	Deep trough in Wright Channel; Fair image	Muddy gravel	Worm tubes, shell frags., worm casts, forams	Muddy gravel
060	503.09	Deep trough in Wright Channel; Fair image	Sandy mud	Worm tubes, shell frags., worm casts, forams	Sandy mud
061	502.10	Deep trough in Wright Channel; Fair image	Sandy mud	Worm tubes, shell frags., worm casts, forams	Muddy gravel

Table 9. Recommendations for implementation on future expeditions

Procedure	Recommendations
FFCPT	Did not trigger. KM determined the reason. KM will check whether calibration required for future cruises. FFCPT requires trackpoint (or alternate) on future deployments which would require altering the rope to a cable or pole.
Trackpoint	Outputs relative offsets only. BP suggests a system we own at DRDC which is better and outputs absolute lat/lon
Camera	Camera worked well. ROV required for back side of scarps (Kim)
Station planning	<p>Extract multibeam depth at coordinates, and line lengths for cruise plan.</p> <p>When making changes to stations for bridge need to discuss how best to make changes quickly with GIS and metadata specialists (when one or both might not be on watch).</p> <p>Large screen. Worked well. Check the large screen at PGC for resolution (must be 1920 at least). Video switch for 3.5 and other computers?</p> <p>CS spends a lot of time informing multiple parties of schedule - captain, bridge (captain not always present), deck technician, bosun, people on lab watch and other scientists. Future cruises, CS schedule should be posted on an independent screen (rather than paper copies). Suggest at entrance to lab.</p>
Huntec	Power supply appeared to be overheating so the console was not getting correct power. Send to Geoforce and/or to GSCA for repair. Repair deck cable at rod. Replace trigger cable. One bolt stripped on termination block- needs replacing.
CPT	CPT. Issue appeared to be with the National Instruments Ethernet Modem. Could not communicate with it. Further testing required. Test and calibrate before we bring out again.
Box core	Clips must be improved. Replace with small holes in bottom plate and hooks. When retrieving boxcore, place on timber, but need wedges.
Slab corer	Thinner sheet at back, possibly teflon? Wire cutter? Push from unconsolidated side.
Lab (general)	<p>The lab procedures are very good under the control of PN. Concern would be whether we have a secondary if PN not available. Printer was connected to one machine only, and it was a busy machine for metadata. Better networking arrangements required or CS to have own printer</p> <p>Software: Kingdom Suite, ARC and Office. Standalone copies are a requirement.</p>
Piston core	No issues. No bent or damaged barrels on this trip. However, some repair required from previous trips. Must equip Tully to be able to collect 50 ft cores (GM).
Pinger receiver	PGC pinger receiver needs repair.

Table 10. Chief scientists schedule and log

		Schedule	Notes
24-Sep-14 Wed	Day	Load most gear required for North Coast work	Piston Core left on shore. Most other gear loaded
01-Oct-14 Wed	Day	Morning: Ships provisioning. Load remaining gear, including piston core. Afternoon: Depart for Chatham Sound to Reach Discovery Passage Mooring site early AM	
	Night	In transit	
02-Oct-14 Thu	Day	Reach strait of Georgia Mooring site afternoon, deploy mooring. Perreault departs to Campbell River by RHIB. In transit.	No issues. Event waypoint marked but not given NRCan station name
	Night	In Transit	
03-Oct-14 Fri	Day:	AM. RHIB shore party tsunami reconnaissance from this day, every day until end of survey (2-3 scientists plus wildlife observer) PM RHIB pick up wild life observer (Jesse Bolton) in Hartley Bay	PB, DH, CS departed on RHIB in choppy weather. Out three hours. Tried to access several beaches. Returned with no samples. Scientists reported it was very difficult to see in driving rain. Raining hard. Rivulets were running everywhere from shore. Water falls were shooting out into channel and bringing debris and lots of sediment. Easy to see how this area is landslide prone.
	Night:	In Transit. Ships sonar survey of Grenville Channel (or Principe Channel if weather permits) and Southern Chatham Sound and Chatham Sound Site (Kung, Barrie off at 4am; Stacey, Shaw on at 4am)	Took Grenville on Ship's safe route

04-Oct-14 Sat	Day:	<p>Please no ship discharge during coring... AM: Chatham Sound, Box Core (x1), Piston Core (x2). 3 pm, Tie up Prince Rupert, students tour ship. Nicole Koshure (MMO) to join ship Ship departs 6:30 pm</p>	<p>Box core (001) Piston Core (002) Camera Transect (003) Fern Cove Tsunami sections (004-014) Cores good. Tied up early at 1300 due to tides nears Seal Cove. Nicole joined ship by 1400. RHIB departed with tsunami scientists by 1500. Found a core site in Fern Cove, Prince Rupert, that might indicate sandy tsunami material. Tour went as planned at 3 pm. Four students from Terrace (and one 4 year old) plus Chris Picard. The students had been given Kim's BC Submarine Mass Movement Open File as a reading project. All went well, stayed off the topics of politics and development, and discussed science. Captain could not untie overnight, so made the decision to leave early evening rather than stay the night.</p>
	Night:	<p>Transit to Hartley Bay via Principe Channel (or Grenville). Survey with ships sonar en route</p>	<p>Took Principe on Ship's safe route. Passage went well.</p>
05-Oct-14 Sun	Day:	<p>0730 On station for DCCPT1. RHIB to Hartley Bay Michelle Bolton on. Fuel dock at 0800 0830 Douglas Channel Camera Transects on slumps CPT1 1000 DCPC2 20ft piston core (short 3.5 survey might be required before these, and all, cores) Lunch 1300 DCPC1 20ft piston core 1430 RHIB for tsunami scientists 1430 Douglas Channel Seabed Survey DCSS1 (Huntec if no whales) 1630 Douglas Channel Camera Transects on CPT2 and CPT3 Dinner (camera people dinner put aside) 1700 RHIB returns tsunami scientists 1810 RHIB Four scientists to shore for Gitgaat meeting (Conway, Barrie, Stacey, Lintern) 2000 Launch RHIB to collect five scientists back (above plus Camille Brillon). Will be at field dock at 2015. To discuss RHIB or Gitgaat Boat (or?)</p>	<p>Camera transect (016) Piston Core (017) Piston Core (018) Camera Transect (019) Forgot to put raingear on for Michelle's transit back on RHIB. However, she found some from a friend. Arranged camera transect while RHIB was out. Camera pictures are dark, Angus suggests turbidity. Cores went well. Instructed tsunami scientists not to dig when they arrived in Hartley Bay, but instead just to determine if it would be a good place and seek permission. Meeting with Gitgaat arranged by Ellen Torng and Chris Picard. Meeting was relaxed with prepared sandwiches and coffee. Approximately 20 people. Questions ranged from development plans (which we couldn't answer), tanker wakes, whether it would be safe to dredge and deposit large quantities of sediment in Kitimat Arm. One participant wondered if the DC slides could be mitigated by controlled explosives... an interesting idea.</p>

	Night:	2100 Whale Channel seabed survey (3.5 sonar) WCSS3 then WCSS1 and WCSS2 Break off to arrive at DC--mKSK1-B for 0800 mooring recovery	Split shift the four night people, 1900 to 0300, and 0300 1100. After this moved on to full night shifts for all (12 hours). Did not see fault in Whale Channel. Kim and Vaughn believe the fault to possibly be further west. Also discussed that with these soft sediment, we would not expect to see a fault make it intact to the seabed surface, even if recently active. Require deep sesimics. LIDAR first.
06-Oct-14 Mon	Day:	0800 Recover DFO mooring Just North of Hartley Bay (DC-mKSK1-B) 0930 RHIB Gitga'at School on board. RHIB up to 24 high school students, plus some adults. To discuss groupings with captain. VHF Channel 8 (or 6 if 8 doesn't work) to reach Cam. 1400 transit for DCPC02 Cell signal reception testing, following bridges safe route. 1430 FFCPT and Trackpoint Trials DCPC02 1800 Boxcore at DCPC02 1900 Once boxcore on deck and confirmed good, transit for KASS2-WP50	Camille joined ship this morning. Mooring recovery went well after half hour of searching, Sophie got the 'best' correct range values she could and hoped for the best! The mooring popped up on our starboard bow (it was intended to pop up on our starboard stern). Could not use trackpoint on FFCPT due to rope, this needs addressing. FFCPT did not trigger. Trigger mechanisms are complicated and must be investigated. FFCPT (non) stations not entered into log sheets. Investigation on the transit back to IOS indicated that when the hard drive was wiped, it removed the configuration files. On uploading those again, the FFCPT worked (however, still no winch). Should calibrate pressure with depth. Must figure out a way to use trackpoint. School visit went well. Box core (020)
	Night:	2200 Start sonar survey KASS2-WP50 to KASS2-WP71 (Focus on Start and end areas-Cooper) then KASS2-WP50, KASS2-WP49 ... towards kitimat until need to break off to do dfo mooring (around WP 21) Transit to station DC-mFOC1-B for 0730	Made it to waypoint thirty something (counting down). Cooper added a track behind Nanakwa Shoal. Will do remainder of KASS2 in morning.
07-Oct-14 Tue	Day:	0730 Recover mooring DC-mFOC1-B, 0900 Rhib Tsunami scientists to Kitamaat MK Bay Marina 0930 Hunttec starting at KASS2-WP18 to KASS-WP33 4 knots 13 miles 1330 Transit to KABC-08 for Piston Core and FFCPT 1530 Transit to KAPC-01 for Piston Core and FFCPT 1700 DINNER Transit to KABC-08 for two box cores 1800 Two box cores (2nd one a few m from first)	Mooring recovery went well. First FFCPT deployed, second cancelled due to winch leak. Fix. Piston cores went well. Piston core (021) FFCPT(022 and 023) Piston Core (024) Box core (025 and 026)

	Night:	1900 Survey down Devastation Channel and Verney Passage. Safe route. 8 mph 2300 Survey VC2 6 mph 0100 Transit to DVG08, then slowly survey DVG07, DVG06 DVG01 safe speed	Went well, but missed the westernmost station on VC2 (Bridge did not have it). Will cover this area on transit back to IOS.
08-Oct-14 Wed	Day:	**Time to be confirmed, but morning. We are arranging a RHIB visit by Haisla FN (one boat) 0700 Piston Core KAPC02 (40 ft., only after Cooper has verified seismic contains no rock) 0930 When confirmed good transit to Coopers new piston core station (near KABC08) 53.910244, -128.750275 1000 Piston core Cooper's new station 53.910244, -128.750275 (near KABC08) Lunch 1200 RHIB with Hartley Bay and Tsunami scientists Finish survey lines in Kitimat KASS-01 to KASS-33 (Huntec preferred) 1630 RHIB departs for MK Bay Marina (4 scientists + 2 MMO's) 1845 RHIB picks up 4 scientists 1930 Transit to camera station near Hartley Bay (will bring to bridge) 0000 Depart for IOS	Visit to ship cancelled by Haisla members. Too busy. Next time. Piston core at KAPC02 captured 39 ft! Hartley Bay participants departed. Visited Haisla Chief Ellis Ross and council for a provided supper. Chief raised several issues, including the effect of nuclear fallout from Japan on salmon (none of us knew much about it). The council appeared interested in our research, and some remembered the events in the 70's, but had to move on to other issues as this was a regular council meeting. The information of two slides 1974 and 1975, not one, appeared to be news to some people in the room. News to us was that Kitamaat have an ambitious plan to build a quay wall on the delta. Meeting ended well. Extended Huntec survey to include what might be a large failure at the start of Devastation Channel, and then partially down Kildala Arm. Piston core (027) Piston core (028) Camera Transect (029)
	Night:	Transit	
09-Oct-14 Thu	Day:	Transit RHIB Tsunami scientists when possible	Transiting on outside. Tsunami work not possible
	Night:	Transit Quick Bute Survey?	
10-Oct-14 Fri	Day:	0700 Bute Head of Bute Inlet, piston core x2 Box core x 1, gravity core x 3 10 am depart for IOS	Transiting on outside. Bute work not possible
	Night:	Transit	
11-Oct-14 Sat	Day:	0700 Arrive IOS, Demob	

References

- Conway, K.W., Barrie, J.V, and Thomson, R. E., 2012.* Submarine slope failures and tsunami hazard in coastal British Columbia: Douglas Channel and Kitimat Arm. Geological Survey of Canada, Current Research (Online) no. 2012-10, doi:10.4095/291732
<http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/shorte.web&search1=R=291732>
- Hill, P.R., 2015.* CCGS Vector 2013007PGC Cruise Report; Geological Survey of Canada, Open File 7622, 57 p. doi:10.4095/296203
- Luternauer, J. L., and Swan, D., 1978.* Kitimat Submarine Slump Deposit(s): A Preliminary Report. Current Research, Part A, Geol. Surv. Can., Paper 78-1A, p. 327-332.
- Murty, T. S., 1979.* Submarine slide-generated water waves in Kitimat Inlet, British Columbia: Journal of Geophysical Research, v. 84, p. 7777-7779.
- Prior, D.B., Bornhold, B.D., Coleman, J.M., and Bryant, W.R., 1982.* Morphology of a submarine slide, Kitimat Arm, British Columbia. Geology, 10, 588-592.

Annex 1 Tour itinerary for North West College Students

Tour of the Coastguard Ship J.P. Tully

NRCan Cruise 2014007PGC, Geological Survey of Canada, Pacific

October 4, 2014

For students of Northwest Community College

Introduction - Gwyn Lintern (NRCan)

DFO Science in Douglas Channel - Sophie Johannessen (DFO)

Geographic Information Systems – Robert Kung (NRCan)

Seabed features of the Region – John Shaw (NRCan)

Tour of the lab – Peter Neelands (NRCan)

Douglas Channel Geohazards – Kim Conway (NRCan)

Kitimat Arm Geohazards – Cooper Stacey (NRCan)

Tour of the deck/equipment – Angus Robertson/Greg Middleton

Annex 2 Tour itinerary for students of Hartley Bay School

Tour of the Coastguard Ship J.P. Tully

NRCan Cruise 2014007PGC, Geological Survey of Canada, Pacific

October 6, 2014

For students of Hartley Bay School

Information Stations:

Deck and scientific equipment – Kim Conway

General tectonics of the North Coast – Vaughn Barrie

Kitimat and Douglas Channel Seabed Geohazards and Core demonstration – Cooper Stacey

Seabed mapping in Douglas Channel and Kitimat Arm – John Shaw

The FFCPT geotechnical tool – Kevin MacKillop

DFO oceanography in Douglas Channel and Kitimat Arm – Sophie Johannessen

Tour of Engine Room, ship and Bridge – Gwyn Lintern plus crew

Annex 3 Marine Mammal Observations during a Natural Resources Canada Acoustic Survey of Kitimat Arm, Douglas Channel and Wright Sound, October 4 to October 9, 2014

**Marine Mammal Observations during a Natural Resources Canada Acoustic Survey of Kitimat Arm,
Douglas Channel and Wright Sound, October 4 to October 9, 2014**

Prepared By

Nicole Koshure (M.R.M)

For

Fisheries and Oceans Canada

Suite 200 – 401 Burrard St., Vancouver, B.C., V6C 2S4

And

Natural Resources Canada

Geological Survey of Canada – Pacific

9860 West Saanich Rd., Sidney, B.C., V8L 4B2, Canada

October 15, 2014

INTRODUCTION

A geophysical survey was carried out along the north coast of British Columbia (B.C.), Canada, using active source acoustic experiments for seabed mapping. Data collected also provided information on seabed slope stability and the potential for tsunamis generation. The cruise was conducted aboard the 226-foot (68.9 m) oceanographic research ship *CCGS John P. Tully*, from October 4 – October 9, 2014. The objective of the expedition was to determine seabed geology, seabed sediment composition, geological hazards related to slope stability and to explore for evidence of previous tsunamis activity within the area of Kitimat Arm, Douglas Channel and Wright Sound. A variety of sampling methods were applied including piston and sediment box coring of the seafloor, and the use of a 3.5 KHz bottom profiler and underwater camera systems. In addition, the retrieval of pop-up mooring buoys collecting oceanographic data (e.g. sediment traps and microbial columns) was carried out in Douglas Channel.

Huntec System

In addition to the 3.5 KHz bottom profiler, a broad frequency high resolution Huntec DeepTow System, was deployed in order to obtain a sub-bottom profile of areas of the ocean floor. The estimated sound pressure level (SPL) for this system at its source is equivalent to 218 dB re 1 μ Pa, which is above the SPL considered to cause temporary threshold shifts and behavioural disturbance to marine mammals. Using an acoustic spreading loss equation, a 1,000 meter safety zone was determined to correspond to the radius at which SPLs will have diminished to approximately 160 dB re 1 μ Pa. During operation of this system, marine mammal observations were recorded by two dedicated observers. If any sightings were made within 1,000 meter safety zone the system was shut down.

Mitigation of adverse effects on marine mammals

The mitigation measures presently used by Fisheries and Oceans Canada (DFO) include the provision of marine mammal observers onboard vessels undertaking seismic work, with the conditions pertaining to this survey outlined in a letter of agreement between Dr. Gwyn Lintern of Natural Resources Canada (Geological Survey of Canada – Pacific) and Mr. Paul Cottrell of DFO (Marine Mammal Coordinator – Pacific), dated May 14th, 2014.

The mitigation measures required that two independent DFO-approved marine mammal observers followed the seismic program during the cruise. The observers were dedicated to maintaining constant observations for marine mammals in the ships vicinity a half hour prior to and during the operation of the Huntec System. To mitigate behavioural disturbance and prevent harm due to the likely presence of marine mammals a minimum safety zone of 1,000 meters was maintained during Huntec System activities.

Mitigation measures

As outlined in the agreement, a requisite safety zone of 1,000 meters around the vessel was established to conform to a 160 dB re 1 μ Pa sound pressure contour. This was greater than the minimum safety zone radius of 500 meters in the *Statement of Canadian Practice with Respect to the Mitigation of Seismic*

Sound in the Marine Environment. During operation the marine mammal exclusion zone was completely visible to the marine mammal observers and was expected to be monitored for 30 minutes prior to the initial start-up of the Hunttec System. If a shutdown was required for any reason (e.g., an animal entered the exclusion zone or for other operational reasons), no startup was initiated until the zone was visible to the observers and determined clear for a 30 minute period. The Hunttec System was shut down if any marine mammal (whale, dolphin, porpoise or pinniped) was observed within or about to enter the 1,000 meter exclusion zone or if any marine mammal was disturbed. A disturbance was defined as any change in behavior such as sudden spy-hopping or breaching in cetaceans, erratic swimming, or abruptly moving away from the vessel.

Description of onboard mitigation procedures

Both marine mammal observers visually scanned for marine mammals 30 minutes prior to Hunttec System startup and during its operation. Continuous observations were made from the bridge which provided a 360 degree viewing platform. Binoculars were used for long distance scans for marine mammals roughly every 10 minutes in additions to continuous scans without binoculars. Distance of animals from the ship was determined using reticulated binoculars, when an ocean horizon was visible. When an animal was sighted, the observer counted the number of reticles down from the horizon line and used the following formula to calculate distance from the ship:

$$\text{Distance (m)} = (\text{eye height (m)} + \text{above sea level height (m)}) \times 1000 / \text{No of MIL} \quad (1)$$

with each reticle of the binocular having a value of 5 MIL. The above sea level height (ASLH) of the bridge aboard the *M.V. Tully* is 12.8 meters. A table of distance from the ship for each reticle counted down from the horizon was calculated using equation (1) for quick reference by the marine mammal observers.

In addition to reticulated binoculars, distance estimates to sightings were also made with the help of chart plotting software and radar. Surveying was in variable water depths of approximately 200 to 500 meters and was limited to periods of time with moderate to calm wind conditions and visibility of greater than 1,000 meters. In periods of strong winds and/or seas exceeding 2 meter wave heights, it is not possible for marine mammal observers to effectively clear a 1,000 meter exclusion zone due to poor visibility generated by white foam from breaking waves blow in streaks. During this survey, visibility was typically very good during Hunttec System operation and did not preclude the systems use.

Marine mammal data collection

Marine mammal data collection included the date and time of species sighted, location relative to the vessel, estimated distance from the vessel, vessel position (latitude, longitude), water depth, visibility, species and number of animals and activity (Appendix 1). Vessel position was obtained from a handheld GPS that ran continuously during daytime operations. Water depth was obtained at the start and end of observations from the ship's depth sounder located on the bridge. The location of the sightings relative to the vessel was estimated in degrees, with 0° at the bow and 180° at the stern.

RESULTS

Research cruise summary

The research trip completed 5 hours and 55 minutes of Hunttec System operation spread over 4 days of surveying. Most of the trip was spent on the survey grounds deploying equipment, sampling the seafloor, retrieving pop-up equipment and acquiring seismic data. Hunttec System operation was never limited due to poor sea conditions or faulty equipment.

Data collection summary

The bridge of the ship provided a useful platform for collecting sightings data during Hunttec System operation. Out of approximately 19.5 monitoring hours, 30 animals were recorded in 26 discrete sightings (Table R-1). Overall Hunttec System operation was interrupted for approximately 3 hours and 10 minutes due to marine mammals entering or within the 1,000 meter exclusion zone (Table R-2). Delays were caused by humpback whales (*megaptera novaeangliae*), Dall's porpoise (*phocoenoides dalli*) and Stellar sea lions (*Eumetopias jubatus*) within the exclusion zone before startup of the Hunttec System. No "Shutdowns" occurred because of marine mammals entering the exclusion zone during operation of the Hunttec System.

Table R-1. Summary of marine mammal observations during Hunttec System operation occurring between October 5 to October 9, 2014 aboard the *CCGS John P. Tully*.

Species	Sightings	Number Animals	TOTAL		Sightings in Exclusion Zone
			Hunttec Delays	Hunttec Shutdowns	
Dall's porpoise	1	2	1	0	1
Humpback Whale	23	26*	4	0	4
Killer Whale	1	1	0	0	0
Stellar Sea Lion	1	1	0	0	1

*Note: This number does not represent 26 different humpback whale sightings as many of the same individuals were resighted during the same day and over multiple days. No photo identification techniques were used to identify individual whales.

Table R-2. Summary of the cumulative times of marine mammal observer hours and total Hunttec System operations occurring between October 5 to October 9, 2014 aboard the *CCGS John P. Tully*.

Total for Survey	Approximate Hours
MMO Observation	19:30
Hunttec Survey Time (incl. pre-observations time)	6:50
Hunttec Operation Time	5:55
Hunttec Delay Time	3:10

Marine mammal species sighted

A large proportion (88.5%) of any one species sighted during the research cruise was of humpback whales. Although the humpback whale was the most abundant species at 26 animals, many of these sightings represented multiple sightings of the same individual as we could not differentiate repeated sightings of the same individuals over the hours and days of monitoring in the same geographic areas without the application of photo identification techniques. Dall's porpoise were the next most abundance species observed with one sightings of two individuals occurring in Kitimat Arm. Single sightings of individual killer whales (*Orcinus orca*) (unknown population), and Stellar sea lions were also recorded. All observed marine mammals were identified by species.

Summary

Every effort was made to record the presence of marine mammals during daylight hours while the vessel was transiting or engaged in active surveying. Although animal detection decreased with increased wind, nearly all of the survey work was conducted during calm and clear conditions. At no time did seismic activity appear to disturb a marine mammal.