The Canadian Arctic Seabed: Navigation and Resource Mapping

Project Leader

John Hughes Clarke (University of New Brunswick)

Network Investigators

Guillaume St-Onge (Institut des sciences de la mer de Rimouski); Steve Blasco (Natural Resources Canada - Geological Survey of Canada (Atlantic)); André Rochon (Université du Québec à Rimouski); Patrick Lajeunesse (Université Laval)

Collaborators

Trevor Bell, Evan Edinger (Memorial University of Newfoundland); Robbie Bennett, Donald Forbes, Walli Rainey (Natural Resources Canada - Geological Survey of Canada (Atlantic)); Scott Dallimore (Natural Resources Canada - Geological Survey of Canada (Pacific)); Michel Allard, Louis Fortier, Jean-Eric Tremblay (Université Laval); Steve Brucker, Ian Church, James Muggah (University of New Brunswick)

PhD Students

Thomas Richerol (Université Laval)

MSc Students

Pierre-Arnaud Desiage (Institut des sciences de la mer de Rimouski); Duboc Quentin (Université du Québec à Rimouski); Jonathan Roger, Claudia Rousseau, Annie-Pier Trottier (Université Laval); Travis Hamilton (University of New Brunswick)

Abstract

This project undertakes the core seabed mapping component of the ArcticNet research program. Underway acoustic mapping of the seabed relief, sediment distribution and shallow subsurface sediments are the prime datasets used by researchers to understand the geological processes shaping the seafloor, to assess natural hazards and coastal habitats and to reconstruct the history of past climatic changes. These mapping results are applied to specific projects in this proposal including :

Marine geohazards to hydrocarbon development: Canada has potentially huge economic benefits to gain by having access to the natural resources of the Arctic Archipelago region. Exploitation in this manner however, can only proceed in a safe and responsible manner, by managing the potential detrimental impacts to the environment. A key requirement is to be able to assess potential natural hazards that might result in harmful affects both to persons and the environment. Natural hazards such as underwater landslides, collapse of offshore structures built on gassy seabeds and the impacts of glacial and sea ice must be known and their risk managed.

Opening new shipping lanes and improving navigational charting: Despite previous focused mapping programs in the bottleneck regions, the Archipelago region remains sparsely mapped with shipping normally restricted to narrow singular corridors that may be ice covered. Because the Amundsen is operating a multipurpose mission throughout the region, there is a golden opportunity to simultaneously map uncharted regions to provide alternate pathways.

Past to present evolution of sea-ice regime: Understanding past climatic history is the key to predicting potential future ramifications of a changing sea ice regime. To responsibly plan adaptation strategies, we need to be able to predict future climatic responses and their consequences. It is also the key to understanding the nature of these changes-i.e. are they part of a natural cycle or induced by present excess of greenhouse gases. The mapping is an essential precursor to designing seabed sampling strategies to recover undisturbed sediments.

Key Messages

The ArcticNet Navigation and Resource Mapping program directly addresses our knowledge gaps in three high priority areas:

Northern Offshore Oil and Gas Development: One of the major impediments to safe and environmentally responsible oil and gas development in the Canadian Arctic Archipelago is the lack of knowledge about the presence of potentially unsafe natural seabed features (so called geohazards).

Seabed Habitat related to Living Resources adjacent to communities: While the national focus in on the benefits of the non-living resource extraction, at the community level, far more reliance is placed on the ability to develop marine living resources. A first step towards this is properly delineating the submerged seabed morphology and habitats in the vicinity of those communities.

The need for improved charting in the North: To undertake the scale of marine shipping required to support non-living resource programs in the north, and to ensure access for the development of coastal living resources, the state of nautical charting has to be vastly improved. The ArcticNet mapping program now represents the most extensive source of modern high density bathymetric surveying in the Archipelago.

Implementation: In the 2013 field season, the CCGS Amundsen program was truncated as a result of the accident and thus the Beaufort Sea objectives were cancelled. Within the time of operations however, a dedicated survey was performed in Cumberland Sound and the first ever data collected in the approaches to the Peterman glacier. The Nuliajuk undertook

extensive coastal mapping in 2013 in both Nunatsiavut and Nunavut. This directly addresses the seabed habitat and charting priorities of this focus.

Plans: For 2014 and beyond, further Amundsen mapping initiatives in the Beaufort Sea are planned in partnership with the Oil and Gas Industry and BREA.This will follow up on the 2009/10/11 field seasons that focused on the impact of the potential development of hydrocarbon reserves. With the clearance from the NEB, and with over 2 billion dollars in lease blocks allocated, there remains a pressing need to understand and manage risks involved in deep water drilling in this Arctic Basin.

Objectives

For the 2011-2018 period, the scientific seabed mapping needs in the coastal Canadian Arctic are projected to be dominated by the increasingly open access to previously uncharted waters and the opportunities that provides for both living and non-living resource exploitation.

Mapping toward Non Living Resource Development: Exploitation of hydrocarbons is already scheduled for the Beaufort Sea; seabed pipeline access to the Sverdrup Basin (known reserves) is a necessary precursor to that development; exploration is proposed for known hydrocarbon provinces including Lancaster Sound, Baffin Bay and Labrador margin regions; and new initiatives in frontier programs such as the Makkovik and Saglek margins, Hudson Bay & Strait and Foxe Basin are starting.

In line with ArcticNet's Strategic Framework, the updated rationale of this project is to focus on better quantifying the spatial extent and risks associated with the seabed geological hazards that are so prevalent (iceberg/icekeel scouring, fluid and gas escape structures, mass wasting phenomena and seismicity hazards).

As part of this, improved safety of navigation is an essential prerequisite to any natural resource exploitation. The CCGS Amundsen seabed mapping system remains Canada's best and most available asset capable of expanding safe shipping corridors in the Arctic Archipelago. She will provide our main contribution to hydrocarbon geohazard mapping in the Western Arctic.

Mapping toward Living Resource Development: Examples of marine living resource exploitation include the Davis Strait and Cumberland Sound turbot fishery and the northern and striped shrimp fishery. For neither fishery is the seabed habitat on which these species reliant adequately known. Closer inshore, potential new fisheries such as the soft-shelled clam and Greenland cockle are being investigated yet little is known about either the coastal bathymetry or the availability of suitable seabed habitat for these species.

In parallel with the non-living resource exploitation and safety of navigation, there is thus a requirement to better understand the coastal seabed habitat on a community level. The mapping component of this work is being addressed in partnership with a coastal landscapes project, a seabed habitat/benthos project, and freshwater/marine coupling project. The deep water (>200 m) component was addressed by the Amundsen in Cumberland Sound in 2013. The shoaller draft, higher manoeuvrability, and lower cost of the GN vessel (Brucker et al., 2013) are, however, far better suited to investigating the coastal habitat and safety of navigation issues that also need to be addressed.

Introduction

This project implements underway geophysical mapping programs from the CCGS Amundsen and the RV Nuliajuk in support of a wide variety of Network Investigators, parallel ArcticNet projects and external partner objectives. There is continual networking activity between the groups that run the mapping (now Laval for Amundsen and UNB for Nuliajuk), the other

NI's, collaborators and external partners to ascertain the needs of the specific science programs to see how they can best be met using the capability of the Amundsen, and Nuliajuk, mapping suites.

Current foci for this program are the Beaufort Sea in the Western Arctic and the Eastern Baffin Shelf in the Eastern Arctic.

The focus in the Beaufort Sea has been on identifying the presence, extent and risk associated with various seabed geological hazards ("geohazards"). The prime hazards of concern are - ice keel scouring, expulsion of gas and fluid from the seabed, the potential for mass wasting (landslides) and the presence of buried shallow gas. Additional concerns are the geotechnical properties of the surficial (within 10m of the seabed) sediments as this will affect the ability to construct infrastructure in support of drilling and oil field development.

In the Eastern Arctic the 2013 mapping has generated the first surveyed shipping corridors into several previously completely uncharted coastal fjords (Brucker et al., 2013). This activity is an essential precursor to safe scientific operations in the area. The Government of Nunavut is leading a Fisheries Resource assessment program in this area and this requires the establishment of safe navigation corridors and anchorages. The same data can then be used to assess seabed habitat in support of the same program.

The continual collection of underway swath bathymetric data over 11 years of opportunistic transits and site surveys by the CCGS Amundsen (and, since 2012, the RV Nuliajuk) represents the single largest holding of high density, well navigated charting information in the Arctic Archipelago. The Amundsen actively uses this to safely meet her science objectives. That same data has been passed on to the Canadian Hydrographic Service to update their existing chart catalogue of the Archipelago region.

A deliberate by-product of the mapping and science programs is the generation of highly qualified personnel in the fields of Arctic marine geomatics and marine geology.

Activities

In the 2013/2014 year, the following research activities were performed:

CCGS Amundsen Mapping:

Greenland Halibut Habitat Mapping - Cumberland Sound (NI Hughes Clarke and collaborator Kennedy) to complement the ongoing GN and DFO funded Greenland Halibut studies in Cumberland Sound, a ~ 20 hour mapping program was undertaken by the CCGS Amundsen while she waited for helicopter-driven personnel transfers from Pangnirtung. The data were processed on board and the result passed by internet to the Nulaijuk one week later to aid them in the deployment of longlines and OTN acoustic modems as part of the inshore halibut fisheries research program.

Deep Water Coral Surveys, Baffin Bay (collaborator Edinger): In support of ROV and sampling operations, a dedicated multibeam survey was undertaken in a closed fishing area (Neves et al., 2013)

Petermann Ice Sheet Vicinity Mapping (for NI Barber) on an opportunistic basis, the Amundsen undertook the first ever detailed mapping in the vicinity of the Petermann Glacier ice shelf.

Parry Channel Ice-Stream Mapping (NI Blasco and collaborator Maclean) Due to unusually favourable ice conditions, virgin mapping coverage was obtained on the north side of Parry Channel. This revealed new evidence for paleo-ice stream activity (Maclean et al., 2013).

RV Nuliajuk Mapping:

Lake Melville, Nunatsiavut : (NI Bell and Sheldon) a dedicated mapping effort was undertaken from the RV

Nuliajuk in support of investigations for the proposed lower Churchill Falls project (Legere and Bell, 2013).

Clam Habitat Mapping, Qikiqtarjuaq vicinity (NI Bell and collaborator Kennedy): Following on from the 2012 mapping in the area, further mapping was done in 2013 to expand the coverage as well as a small boat groundtruthing program (Aitken et al., 2013).

Char Estuarine Habitat Mapping (NI Hughes Clarke and collaborator Kennedy): In response to a request from DFO, Aktijartukan fjord was identified as a location at which NGMP funded char monitoring and research would benefit from a knowledge of the adjacent fjord bathymetry and sediment distribution. The RV Nuliajuk undertook a detailed mapping investigation covering the entire fjord deeper than 20m as well as an approach corridor in support of GN Fisheries and Sealing Division mandated objectives.

Shipping Lanes Access, around Cumberland and Terra Incognita Peninsulas (NI Hughes Clarke and collaborator Kennedy): Using the RV Nuliajuk mapping system, inter island and along coastal corridors as well as specific strategic anchorages were mapped in support of GN objectives (Brucker et al., 2013).

Drowned Sea-Level Terraces, Cumberland Peninsula (NI's Forbes and Bell): Using the RV Nuliajuk multibeam system, drowned sea level terraces (Cowan et al., 2013) were identified and mapped around SE Baffin Island including the first ever observations in the following fjords : Kangert, Southwind, Akpait, Clephane, Ingnait, Touak, Aktijartuan and Kingnait . A subset of these will be proposed targets for Amundsen coring in 2014.

Other Platforms

Outer Beaufort Shelf PLF's: (collaborator Dallimore) a coring, subbottom profiling and ROV program was undertaken from the CCGS Laurier

Geohazard Mapping, Baffin Island Continental Slope: (collaborator Camplbell, GSC). A coring,and pole mounted multibeam survey was undertaken from CCGS Hudson.

R/V Louis-Edmond-Hamelin (NIs Lajeunesse and St. Onge):

1. Holocene sedimentation in southwestern Hudson Bay (Quentin Duboc, MSc student);
2. Bathymetry and seismic stratigraphy of Pingualuit crater lake (Pierre-Arnaud Desiage, MSc student);
3. High-resolution mapping of sublacustrine mass movements in Cape Bounty lakes (Melville Island; Annie-Pier Trottier, MSc student).

Results

As always the seabed mapping results of this project act as an underlying framework for multiple research projects for NI's both within this program and others.

CCGS Amundsen Mapping Program: The 2013 field season was cut short due to the tragic helicopter accident. Thus the Beaufort Sea objectives were not met. Significant mapping was however, undertaken in Cumberland Sound in support of the GN/DFO deep water turbot habitat studies. And as part of serendipitous mapping operations off the front of the Petermann Glacier, the first ever detailed seabed evidence for the grounding line and subglacial motion of the ice sheet was revealed.

Open water conditions in the western Parry Channel allowed for the acquisition of high quality multibeam and subbottom profiles of the seabed. (In previous years the acoustic noise generated by sea-ice against the ship’s hull degraded data quality). The seabed is saturated by well-defined east-west trending, Mega Scale Glacial Lineations (MSGL). The MSGL confirm the existence of a westerly advancing ice stream that occupied the entire Parry Channel during the last

glaciation that ended about 9,000 years ago in this area of Northwest Passage. On a regional scale, the lack of MSGL erosion, infill or alteration indicates the seabed has been subject to little change over the last 9,000 years.

Notably, as part of the helicopter recovery operation, the mapping team were the only part of the scientific party that remained onboard to support the recovery. The two UNB persons (Brucker and Hiroji) volunteered to stay on and contributed to the mapping and search design.

RV Nuliajuk Program: the 2013 field season represented the second successful field season of the multibeam equipped RV Nuliajuk. The shared interest between GN, ArcticNet and the CHS resulted in another 45 day mapping program in Lake Melville and South East Baffin Island.

The Lake Melville work provides essential baseline mapping of the delta fronts of the rivers that will be affected by the Lower Churchill hydroelectric power project. Comparing to 1950's surveys, it is clear that those deltas have rapidly migrated due to the sediment load coming down the rivers. The deeper delta fronts are now recognised to be areas of active landsliding (Legere and Bell, 2013). Using this new information, the changing character can be monitored to see how much the sediment trapping due to the proposed dams will affect the delta areas.

By utilizing data collected as part of the ArcticNet sea level project (NI's Bell and Forbes), totally new surveyed corridors into multiple previously unsurveyed fjords on the Cumberland peninsula were acquired. Submerged terraces at various depths were identified (Cowan et al., 2013).

As part of the GN objectives, a new inside passage, within the islands on the western side of Cumberland Sound, was partially surveyed. This route, known by the locals and used in their shallow draft vessels, represents a protected water way. With this new data, search and rescue operations could now be extended into this area.

And in partnership with the CHS, a previously unsurveyed inter-island gap in the approaches to Iqaluit was discovered. This would allow increased shipping traffic as the new passage is wider than the current approved one (Pike Resor Channel).

On-line Multibeam Data Management: The UNB-based multibeam data processing and on-line distribution model continues to be developed to maintain all this data online for national and international researchers. It now fully incorporates the new data from the Nuliajuk. (http://www.omg.unb.ca/Projects/Arctic/google/). With the release of the new Google API, the tool had to be significantly reprogrammed in December to support this, but was back on line within two weeks. With the loss of external survey staff salary support, however, it is not clear if the online database will be maintained beyond 2014.

Incorporation of Amundsen and Nuliajuk Multibeam Data into CHS Nautical Charts: The mapping data, generated by the Amundsen, and the Nuliajuk, is delivered to the Central and Arctic region of the Canadian Hydrographic Service annually. This data is continually used for incorporation into their charting products.

In 2013/14 the following nautical charting products have been released that incorporate ArcticNet data:

- Paper chart 7950 Jones Sound
- Paper chart 7184 Broughton Harbour
- CA573366 (paper chart 7184 1:20 000 compartment Broughton Harbour and Landing Beach)
- CA373338 (portion of paper chart 7710 Lambert Channel and Cache Point Channel)
- CA573399 (inset on 7511 – Resolute)
- CA373336 (portion of paper chart 7777 Coronation Gulf Western Portion)
- CA373337 (portion of paper chart 7777 Coronation Gulf Western Portion)

- Paper chart 7777 Coronation Gulf Western Portion

A concern for future work with the CHS was raised in 2013 however. With the cheaper cost of the Nulaijuk, the CHS for the first time actually purchased mapping days on the platform. Subsequent to the collection of the majority of the data however, an MOU was presented that requires strong restrictions on public access to the data. This does not match the open data philosophy that applies to all other ArcticNet data. This MOU has not been signed and at this time it remains unclear whether it is beneficial to ArcticNet science objectives to undertake future data collection that cannot be freely shared.

Discussion

Transfer of Leadership:

In 2014, the Seabed Mapping Project will switch lead NI's. In support of the scientific mapping needs, for the past decade, John Hughes Clarke at UNB has managed the operational mapping, the data processing and distribution, and the annual reporting. For 2014, this role will pass on to Patrick Lajeunesse at Laval. All Amundsen mapping logistics, operations, processing and dissemination willl be managed by his laboratory involving Gabriel Joyal, Annie-Pier Trottier, Etienne Brouard (PhD student) and Marie-Hélène Tremblay (MSc student).

Hughes Clarke will continue to manage just the RV Nuliajuk work as it is separately funded.

Due to the loss of personnel support funding outside the core ArcticNet source, the level of manning for the 2014 and future years will have to be decided based on future interest and financial support.

Dealing with Data Ownership Issues:

Current Distribution Model: One of the greatest benefits of the ArcticNet Seabed Mapping Projects over the past decade has been the open distribution of the growing seabed mapping database. Through an internet portal, the global scientific community has been able to browse the data for the entire Archipelago at resolutions as fine as 10m. Our greatest scientific insights into the seabed processes have come about from open availability of the serendipitous collection of transit data.

To get source data access requires just a query to UNB (merely to log usership) upon which a password was always freely given out. The latest season of data was always online within 6 months of the vessel docking. UNB typically receive 10-20 requests per year from all of academic, government and commercial organizations. Many of them request (and receive) bulk downloads of the entire Archipelago dataset.

Historic handling of Third Party Directed Mapping: The 2009-2011 oil and gas partnership programs involved the largest financial contributions to date to ensure focused mapping (and other) programs in the Beaufort Sea. As a result, for the first time, the issue of data access was raised. It is important to emphasize that this was a partnership, not a contract. Unlike commercial contractual arrangements, just a two year delay in the posting of those datasets was agreed upon. Within that time frame, ArcticNet NIs and federal agencies (GSC, CHS) did have full access to the data. At the conclusion of the 24 month delay, however, the data went up in exactly the same free manner as all the rest.

The Problem of Future Data Restrictions: For the 2013 year, however, CHS for the first time funded additional mapping days (on the Nuliajuk, not the Amundsen). Due to delays in the CHS commitment, the program went ahead without any confirmed support. After the majority of the work had been done, an MOU was presented that severely limited access to the data. At this time, this MOU remains unsigned and the status of the data access remain unclear. It does, however, highlight the perils of performing collaborative work in which the scientific community access is restricted.

It should be noted that for the past decade CHS have received all the Amundsen data without any restrictions. And for the current field seasons they continue to receive all that data.

Conclusion

In 2013, with the return of the Amundsen from drydock, the ArcticNet seabed mapping program was simultaneously active on two arctic platforms. The interest in seabed morphology extends from the shallow water need for safety of navigation to the deeper margin wherein Canada's greatest future hydrocarbon prospects lie.

Current highlights are threefold and include :

- Improved understanding of the glacial history and geohazard potential of the western arctic to promote responsible non-living resource exploitation.
- Building framework bathymetric and habitat databasesin the eastern arctic to facilitate future community marine living resource exploitation.
- Acquiring baseline bathymetric data in uncharted waters to update the nautical charting coverage, thereby improving safety of navigation across the whole archipelago.

All of these serve the underlying mandate of ArcticNet to study the impacts of climate change and modernization in the coastal Canadian Arctic. The mapping program is precisely the "development and dissemination of the knowledge needed to formulate adaptation strategies and national policies".

While the three highlights are our current foci, the greatest success of the program over the past decade has been the growth and open distribution of underlying knowledge about the seabed across the Canadian Arctic Archipelago.

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