

The Canadian Arctic Seabed: Navigation and Resource Mapping

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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 effects 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.
 - 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 is 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.
- In the 2012 field season, as the *CCGS Amundsen* was out of service, the focus of the Navigation and Resource Mapping shifted from the Oil and Gas focus to living resources and charting. The successful installation of a mapping sonar suite on the *RV*

Key Messages

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

Nuliajuk (Hughes Clarke et al., 2012) has resulted in a new ability to address inshore mapping requirements that the *Amundsen* could not reach.

For 2013 and beyond, with the return of the *Amundsen*, further 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 National Energy Board (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. For the 2012 field season a new autonomous inshore mapping capability has now been added to this through the equipping of the *RV Nuliajuk* as part of this project.

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 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 (Forbes et al., 2012). For 2012, with the *Amundsen* temporarily out of commission, the barge-based multibeam was successfully moved onto the Government of Nunavut (GN) fisheries research vessel, (*RV Nuliajuk*) to handle exactly these coastal issues close to the communities (Hughes Clarke et al., 2012). The shallower draft, higher maneuverability, and lower cost of the GN vessel are far better suited to investigating the coastal habitat and safety of navigation issues that 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 (NIs), parallel ArcticNet projects and external partner objectives. There is continual networking activity between the Ocean Mapping Group at the University of

New Brunswick (UNB) that run the mapping, 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 now 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 (Blasco, 2012). 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 (Bennett et al., 2012).

In the Eastern Arctic the 2013 mapping has generated the first surveyed shipping corridors into several previously completely uncharted coastal fjords (Hughes Clarke, 2012). This activity is an essential precursor to safe scientific operations in the area (e.g. Cowan et al., 2012). The Government of Nunavut is leading a Fisheries Resource assessment program in this area as 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 10 years of opportunistic transits and site surveys by the *CCGS Amundsen* (and, as of 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 byproduct 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 2012/2013 year, with the Amundsen out of commission, all mapping initiatives were undertaken on other platforms. The following research activities were performed:

- 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 et al., 2012).
- Outer Beaufort Shelf PLF's: (collaborator Dallimore) a coring, subbottom profiling and ROV program was undertaken from the *CCGS Laurier* (Dallimore et al., 2012).
- Western Hudson Bay (NI. St. Onge) CCGS Pierre Radisson cruise in western Hudson Bay (BaySys Expedition, August 27 - Sept. 3). They took box and gravity cores over a three day period.
- Clam Habitat mapping, Qikiqtarqjuaq (NI Hughes Clarke and collaborator Lynch) The *RV Nuliajuk* undertook mapping of seafloor regions believed to be potential clam habitats in support of GN Fisheries and Sealing Division mandated objectives.
- Shipping Lanes Access, Kekerton Islands, Cumberland Sound (NI Hughes Clarke and collaborator Lynch) using the *RV Nuliajuk* mapping system, approach corridors and the inner harbour of the Nunavut Park were mapped in support of GN objectives (Hughes Clarke, 2012).
- Drowned Sea-Level Terraces, Clyde River, Qik, Merchants Bay, Exeter Sound (NI's Forbes and Bell) using the *RV Nuliajuk* multibeam system, drowned sea level terraces were identified and mapped around SE Baffin Island (Cowan et al., 2012). These will be proposed targets for Amundsen coring in 2013.

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.

RV Nuliaajuk Program: The 2012 field season represented the first test of the newly equipped *RV Nuliaajuk*. This program was a serendipitous result of the *Amundsen* cancellation as it allowed staff and resources to be diverted. The shared interest between GN, ArcticNet and the Canadian Hydrographic Service (CHS) resulted in a 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. By comparison to the 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 et al., 2012). 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.

Work off Qikiqtarjuaq and around Kekerton in "white chart" areas has opened up new areas of the Baffin Island coast to safe marine navigation, as well as provided new information about seabed habitat to assess emerging fisheries such as clams (*Mya truncata*).

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. The 2012 field season was the first season to utilize the EM3002 multibeam newly installed on the *RV Nuliaajuk*. The new data source is being incorporated into the existing online ArcticNet data distribution node (<http://www.omg.unb.ca/Projects/Arctic/google/>). Differing depth ranges and achievable resolutions will require slight modifications to the data handling. An optional new custom area and

scale online gridding tool was developed in 2012 so that scientists can make products at higher resolution (than the default 10m) in shallower depths.

New algorithms were developed to automatically correct underway acoustic backscatter data for the changing oceanographic attenuation (Carvalho and Hughes Clarke, 2012) and to automatically detect mid water targets such as submerged mooring strings (Vidiera Marques and Hughes Clarke, 2012).

Incorporation of Amundsen and Nuliajuk Multibeam Data into CHS Nautical Charts: The mapping data, generated by the *Amundsen*, and in 2012 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 2012 the Coronation Gulf Electronic Navigational Charts (ENCs) (covering the Clipper Adventurer grounding site) have been released that extensively incorporate ArcticNet data:

- CA373341 – main ENC of 7777
- CA473342 - Kugluktuk Inset

Other ENCs under construction using ArcticNet data include:

- Resolute ENC CA573442
- 7950 Paper Chart (Jones Sound)
- ENC CA37336 (Coronation Gulf, chart 7777)
- ENC CA37338 (Coronation Gulf, Chart 7710)

There are several new formats for charts in Victoria Strait, Simpson Strait area, that incorporate ArcticNet data.

A major new initiative in 2012 was the significant effort of incorporating ArcticNet data into the CHS BathyDataBase to be automatically assessed against any product that is being worked on in the North.

The new partnership with the Atlantic region of CHS resulted in a Notice to Shipping being issued for a section of Goose Bay area (for Chart 4728) where the current depths (from the Nuliajuk survey) are now substantially shallower than when last surveyed (1950's).

Analysis of Oil and Gas Partnership geophysical mapping data:

Following the successful 2009/2010/2011 collaborative Amundsen programs on the Beaufort Shelf and Slope with Imperial Oil Limited (IOL) and British Petroleum (BP), two new research milestones were met in 2012:

- Analysis and interpretation of deep water Beaufort Sea multibeam sonar and subbottom profiles acquired in 2011 which constitute the down slope extension to areas mapped in 2009 and 2010
- Correlation of industry and government sediment core radiocarbon dates with subbottom profile data to establish first chronologic model for outer shelf and upper slope region of the central Beaufort Sea. Time period covers the last 14,000 years

Discussion

The intended outcome of the Seabed Mapping Project is to translate our growing understanding of the Arctic seabed into impact assessments, national policies and adaptation strategies. The three primary contributions that this project make is in geohazards, navigation and coastal habitat:

Geohazards: Our collaborating partners in the oil and gas industry have specific foci in areas of potential exploration or development. While their focus is localized, they benefit from a regional context provided by the broader-based interests of the geoscientists within the ArcticNet community.

NI's have interests that range from the immediately relevant (geohazards, e.g. Blasco et al., 2012) to the more overarching (ice sheet retreat and paleoclimate). Particular advances in the regional understanding have come about from morphologic interpretation (MacLean et al., 2012) and Holocene climate studies (Rochon et al., 2012). All this information is required to guide government regulation of the natural resource industry.

Navigation: Although originally perceived as primarily a science tool with only a minor contribution to charting, the Amundsen's (and now the Nuliajuk's) underway mapping has become critical to the very safety of the vessels themselves. Recent groundings have highlighted the very real dangers of operating in the Arctic Island Archipelago. The existing nautical charting information is focused primarily on the most active shipping lanes. Most of the new Beaufort Shelf lease blocks in which the Amundsen has been operating lie outside these regions and are known to contain poorly charted pingo-related shoals. In order to deliver on the mandated ArcticNet science mission, the Amundsen and the Nuliajuk need to operate well outside these lanes. The Amundsen now navigates using a dynamically-updated series of additional chart overlays showing the newest ArcticNet map coverage to extend the safe operating area. This was all developed as part of this project. In 2012 this real time map sheet development model was extended to the Nuliajuk so that she could also build her own corridors dynamically.

The Amundsen's growing database of swath bathymetry is now becoming one of the most extensive sounding databases in the Arctic Archipelago. In much of the area of operation, it represents the sole source of information and is thus unique and therefore critically relevant.

The data is provided to the CHS on an annual basis, and their long term intention is to integrate it with the existing charting information, thereby opening up new areas of the Archipelago to shipping and resource development. The time scales for routine chart

updates is several years however, and thus data which is suspected of being of immediate significance is extracted and passed on directly in the form of a memo to the CHS (as witnessed by the Goose Bay Notice to Shipping this year).

Most recently in 2012, the CHS have undertaken to incorporate the entire ArcticNet grid map archive (to end of 2011) into their BathyDatabase so that it can be pulled up, on a chart by chart basis, as new and revised compilations are being prepared.

Coastal Habitat: Until the introduction of the Nuliajuk, the research seabed mapping needs of the coastal landscapes group in nearshore seabed morphology had not been adequately addressed. The cost, deep draft, and limited manoeuvrability of the Amundsen meant that adequate near-community surveys could not be implemented. *CSL Heron* was originally used, but logistically that was impractical as the Amundsen was tied up simultaneously.

The need is to define the nearshore depths, relief and sediment types. This serves a variety of purposes beyond the landscape group's interest, including benthic fisheries resource assessment (the mandate of the Fisheries and Sealing Division of GN) and opening up safe inshore shipping access for the CHS charting.

Conclusion

Due to the Amundsen's absence, the 2012 field season was a unique opportunity to address more coastal and community-oriented mapping priorities that have been overlooked due to the Amundsen's deep draft and limited manoeuvrability. In the spring of 2012, the survey team from the Ocean Mapping group successfully installed an inshore mapping suite (previously deployed on the barge, the Nahidik or the Heron) onto the Nuliajuk. This introduced a valuable new collaborating partner for the Navigation and Resources Project - the Fisheries and Sealing Division of the Government of Nunavut.

Once again, we have established that the mapping, processing and interpretation capability of the ArcticNet team is not only unique, but has the full capability to meet the needs of both the academic and government seabed science community as well as the specific requirements of oil and gas seabed geohazard investigations.

In 2012, these mapping results have had direct input into the GN fisheries resource development project and the state of existing Arctic nautical charting. They thus clearly have contributed to impact assessments, national policies and adaptation strategies.

With the return of the Amundsen in 2013 and beyond, we will be extending the Beaufort Sea mapping through commitments from BREA and planned new collaborations with both the current and new oil and gas industry partners.

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