Ice and No Ice: The Canadian UNCLOS Bathymetric Mapping Program

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Abstract

Since CHC2006, Canada has mapped approximately 65% of the required area in the Atlantic and 15% of the Arctic area of the extended continental shelf using a combination of ship borne and through-ice methodologies. The mapping supports the 2013 Canadian submission of the outer limits of the continental shelf under Article 76 of the United Nations Convention of the Law of the Sea. Therefore, the mapping has been prioritized based on which formula will maximize the Canadian continental shelf. Data collection concentrated on capturing bathymetric data to define and the foot of the slope and the 2500-m isobath where that constraint formula will be used. Seismic surveys to determine sediment thickness have been conducted in the areas where the sediment formula will be used. In addition, refraction seismic surveys have been carried out in support of tests of appurtenance. This paper examines the surveys conducted in the different areas and the challenges posed, particularly in the Arctic where ice conditions dictate where data can or cannot be collected in any particular time frame.

Introduction

Canada signed the United Nations Convention on the Law of the Sea (UNLCOS) in 1982 and ratified the treaty on November 6, 2003 with the ratification becoming effective at the United Nations 1 month later, December 6, 2003. Canada has 10 years from ratification to submit evidence to support an outer limit of the continental shelf.

The Convention confirms coastal states exclusive sovereign rights to the resources of the continental shelf, and also defines the juridical continental shelf and sets out the process for determining the outer limits of a coastal state's right.

The 2004 Federal budget announced $70 million over 10 years for the collection of bathymetric and seismic data for the Canadian submission. The 2008 Federal budget announced an additional $20 million over the next two years to cover increased data collection and logistics costs as well as legal costs for submission preparation.

The overall objective of the Canadian project to delineate the outer limits of the Continental Shelf is a successful submission to the Commission on the Limits of the Continental Shelf (CLCS). The outputs are a series of successful data collection projects that will provide the data necessary to meet the requirements of Article 76 and for the submission to be prepared.

A risk analysis has been completed for the project and the Arctic identified as the area of greatest risk, due to the remoteness, short survey seasons, uncertainty of weather, and the availability and capability of icebreakers. A multi-year data collection plan has been prepared, designed to address and mitigate risk.

Background

Desktop studied carried out in the mid 1990's identified areas in the Atlantic and Arctic oceans where the continental shelf extended beyond the 200 nautical mile (NM) Exclusive Economic Zone (EEZ) totalling 1.75 million square kilometres. These studies also identified areas where the different formulae were most likely to maximize the size of Canada's continental shelf. In general terms, the sediment thickness formula and the 350 NM from the baselines of the Territorial Sea constraint formula maximizes Canada continental shelf off Labrador, off the Scotian Shelf and also in the western Arctic. The bathymetric formula and the 100 NM from the 2500 metre depth contour (isobath) constraint formula maximizes the continental shelf off the Grand Banks of Newfoundland and in the eastern Arctic.

Key data to be collected include bathymetry to define the foot of the slope, which is the starting point for both entitlement formulae, as well as to define the 2500 metre isobath where that constraint formula will be used and to provide information on geomorphology to support natural prolongations. Seismic data is required where the sediment thickness formula will be used to define an outer limit and also where deeper geological structures are required to support natural prolongation of submarine elevations and evidence to the contrary.

Prior to 2006

Bathymetry was collected along the foot of the slope off Labrador by *CCGS Amundsen* while returning from the Arctic in fall 2004. A bathymetric experiment was also conducted in the western Arctic in 2005 using *CCGS Amundsen* and an EM 300 Multi Beam Echo Sounder (MBES) system with two objectives, testing the MBES in ice covered waters and determining if the *CCGS Amundsen* could penetrate the ice to the 2500 metre depth contour. While the second objective was reached with some difficulty, the ability to collect multibeam data while breaking ice was very limited.

A planned bathymetric survey contract in 2005 in the Atlantic was postponed until 2006 when all bids received exceeded the budget for the project.

Data collection commenced in March 2006 with the LORITA (LOmonosov RIdge Test of Appurtenance) project, a joint Canada - Denmark refraction seismic survey on the southern end of Lomonosov Ridge . The objective of the survey was to collect seismic evidence to support the assumption that Lomonosov Ridge is a prolongation of the continental shelf of North America.

The work was carried out from Canadian Forces Station (CFS) Alert by a joint Canadian and Danish team of approximately 30, organized under a Memorandum of Understanding between the Geological Survey of Denmark and Greenland and the Geological Survey of Canada. Despite losing 60-70% of the time to inclement flying weather, the seismic data collection objective was achieved. In addition to joint data collection, it has been agreed that the data will be jointly interpreted to reach a single interpretation. The scientific results will also be jointly published.

These projects and the plans for the future surveys were discussed in a paper presented at the Canadian Hydrographic Conference in Halifax in June 2006. This paper will be an update on activities to delineate the outer limits of Canada's continental shelf since June 2006.

Atlantic

A $2 million contract bathymetric survey was conducted off the Grand Banks of Newfoundland in July, August and September 2006 by Fugro Jacques GeoSurveys using the vessel Kommander

Jack. This survey used an EM 120 MBES to map the 2500 metre isobath from southern Labrador to the Laurentian Channel and to run profiles perpendicular to the continental shelf every 30 NM. These profiles supplement existing bathymetry in the area and will be used to establish foot of slope. This project went very smoothly and was done using contract expertise except for a single government project monitor onboard the vessel.

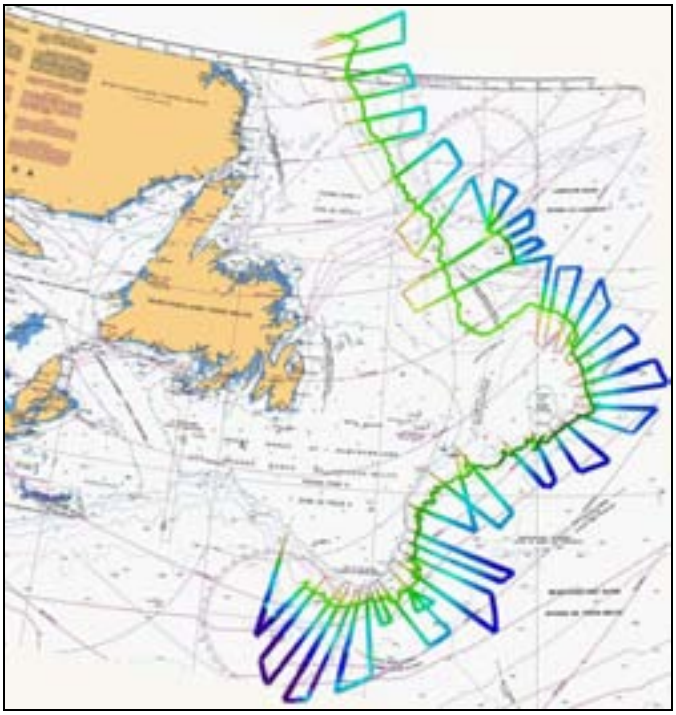

Figure 1: Bathymetric profiles - Atlantic

This was followed in 2007 by a $6M contract seismic survey off the Scotian Shelf conducted by GSI Limited. Despite challenges of meeting specifications while working in the changing currents of the Gulf Stream, 6900 km of multi-channel seismic data was collected to determine sediment thickness. This survey (green lines - Figure 2) was designed to tie into and use all available existing seismic data (black lines) and to extend to the 350 NM constraint line (red line). One government employee sailed as contract monitor and the services of a quality control expert were contracted.

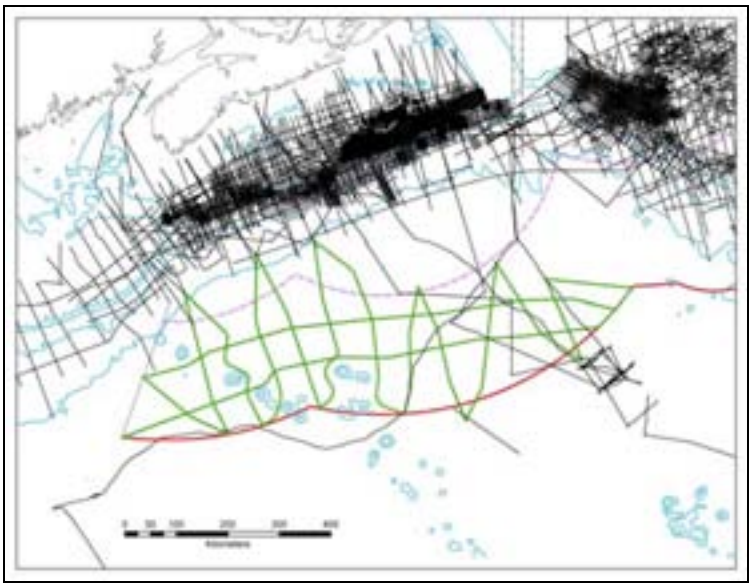

Figure 2: 2007 Seismic Survey

A seismic survey planned off the Labrador coast in 2008 has been postponed to 2009. Existing 1970's seismic data has been acquired from Germany and re processed. One reason for delaying is that the experts needed to develop the Request For Proposal (RFP), evaluate proposals and monitor the survey are also in the field in the March -April 2008 and August- September 2008 Arctic surveys. These same key personnel are also involved in the analysis of the data from the various seismic surveys. This delay also allows time to determine which Danish seismic data can be used in planning the seismic lines to be collected and allows time to have the request for proposal (RFP) on the street early.

Completing the data collection for the Atlantic in 2009 leaves time to return and collect additional data should the analysis indicate areas where additional data will improve the submission.

Arctic

The Arctic introduces the greatest area of uncertainty in the whole project to determine the outer limits of the continental shelf. The minimum requirement of the CLCS to define an outer limit is a series of straight lines connecting points no more than 60 NM apart. Each of these points must meet both an entitlement and a constraint formula criterion. The existing data is too sparse to meet the minimum requirements in many areas.

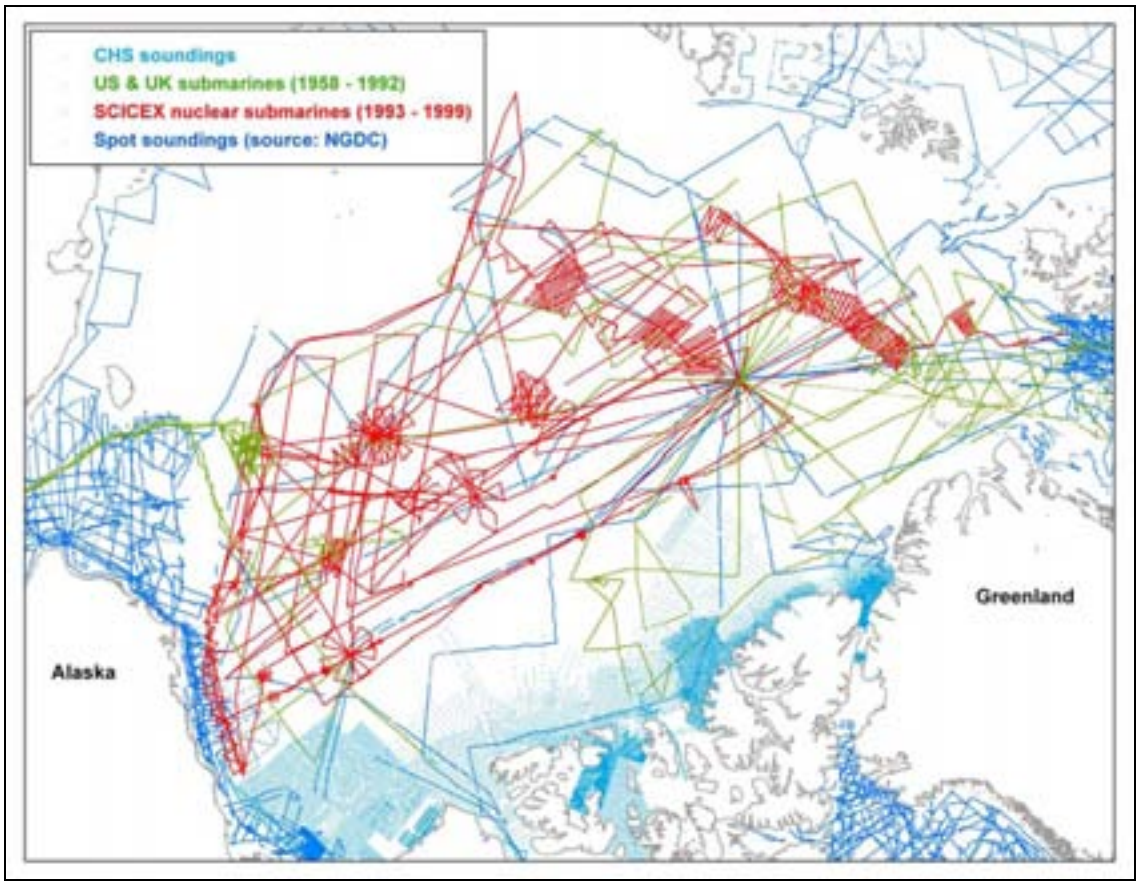

Figure 3: Arctic Bathymetry - source UNCLOS team

This image shows the bathymetric coverage of the Canadian side of the Arctic Ocean. In many areas there is not a single depth for 50-100 NM and no systematic coverage from which to select foot of slope and the 2500 metre isobath. The knowledge of sediment thickness from conventional seismic surveys is even more limited. There is however, space born gravity data that gives some indication of sediment thickness and also of the shape of bottom geomorphology. This information can serve as a planning tool for the strategic placement of survey lines and is useful as supplementary information to bridge small gaps in survey data.

Concern about the risk of bad weather, ice conditions, the availability of capable icebreakers and the need for new ice strengthened equipment led to a decision to advance the Arctic survey operation by a year, commencing the western Arctic in summer 2006 rather than 2007 as originally planned.

The environmental assessment performed on the seismic project included community consultation to explain the proposed project and answer questions. At the end of the process permission was secured from the Inuvialuit for seismic surveys in the western Arctic for the next five years subject to certain conditions. One condition was that mammal observers from the local community be carried on the vessel.

A new seismic system consisting of three Sercel 520 cubic inch air guns suspended from an ice strengthened sled weighing 2000 Kg was built at the Bedford Institute of Oceanography (BIO). A short analog streamer was assembled and designed to be towed from the air gun sled at a depth of 10 metres below the surface. Ten days were added to a Science cruise in the Canada Basin in

2006 to test the new gear and on an opportunity basis, determine the sediment thickness in various areas. An "A Frame" for deploying the gear was designed but could not be installed before the *CCGS Louis S. St. Laurent* sailed. However, an alternate procedure using the starboard crane and a tugger winch allowed the testing to proceed.

The test survey was successful. Operating procedures determined the maximum towing speed to be 5 knots and demonstrated that applying power to the third (centre) shaft caused the air gun to rise to the surface. A similar situation occurred when ice came between the vessel and the airgun sled. The tests also identified improvements to the design, most notably the requirement for a better seismic streamer and re-enforced the requirements for spares. Finally, the test surveys demonstrated that there is significant sediment at or near the 350 NM constraint line in the southern Canada Basin.

Plans were made to return in 2007 for a dedicated seismic survey using the *CCGS Louis S St-Laurent*. The preparation included a Memorandum of Understanding with Canadian Coast Guard to commit the *CCGS Louis S St-Laurent* and an escort vessel to the UNCLOS project, the installation of the A Frame, building a spare air gun sled and obtaining two new 100 metre digital streamers to replace the analogue streamer.

Work continued in the eastern Arctic with a March-April 2007 on-ice bathymetric survey based at CFS Alert. The primary objective was collecting soundings at the location of each seismic recorder during the LORITA project that could not be collected in 2006. Another objective was bathymetric profiles each 50 NM between Ellesmere Island and Lomonosov Ridge with a third objective of bathymetric profiles on both the east and west slopes of Lomonosov Ridge to determine foot of slope and the 2500 metre isobath.

Drummed fuel was delivered from Yellowknife and Resolute by C-130 Hercules and the hydrographers were in place on March 11. However, the two Bell Long Ranger helicopters did not arrive until April 12. They were over 30 days enroute from Goose Bay, Labrador due to inclement weather. Ice conditions in the survey area were challenging. It was difficult to find pans of ice 300 metres long to land the Dehavilland Twin Otter to cache fuel. The ice bridge between Ellesmere Island and Greenland did not form so the ice for 50 miles off Alert remained in motion for the duration of the survey period. This created unusual local weather conditions of ice fog even when the temperature was cold. Loose ice pans and winds created other interesting situations. During one storm a fuel cache equipped with a GPS satellite tracker moved 80 kilometres (km). Time lost due to weather that impacted helicopter flying exceeded 95% and little of the objectives were achieved.

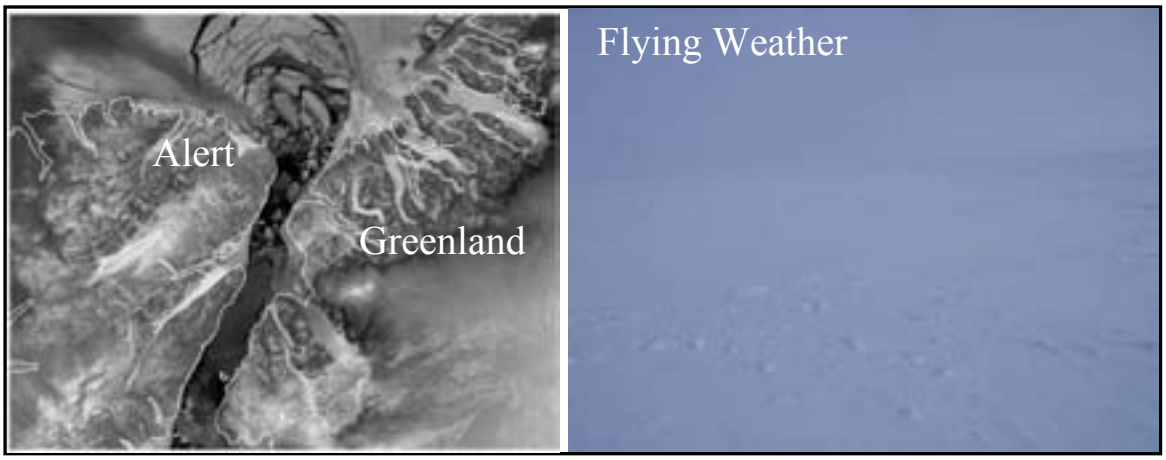

Figure 4: Ice / Weather conditions Alert April 2007

In August - September 2008 Canada also participated in a Swedish-Danish International Polar Year project that included a survey north of Greenland which planned to collect additional seismic and bathymetric data on Lomonosov Ridge. The scientific work was conducted from the Swedish icebreaker, *ODEN*, escorted by the new 75000 horse power (HP) Russian nuclear icebreaker, *50 Let POBEDY*. Ice conditions were severe in this area by late August - 100% covered in multiyear ice, three-five metres thick with pressure ridges to six metres.

Figure 5: *50 Let Pobedy* and *Oden* – Photo credit: Tim Janzen (CHS)

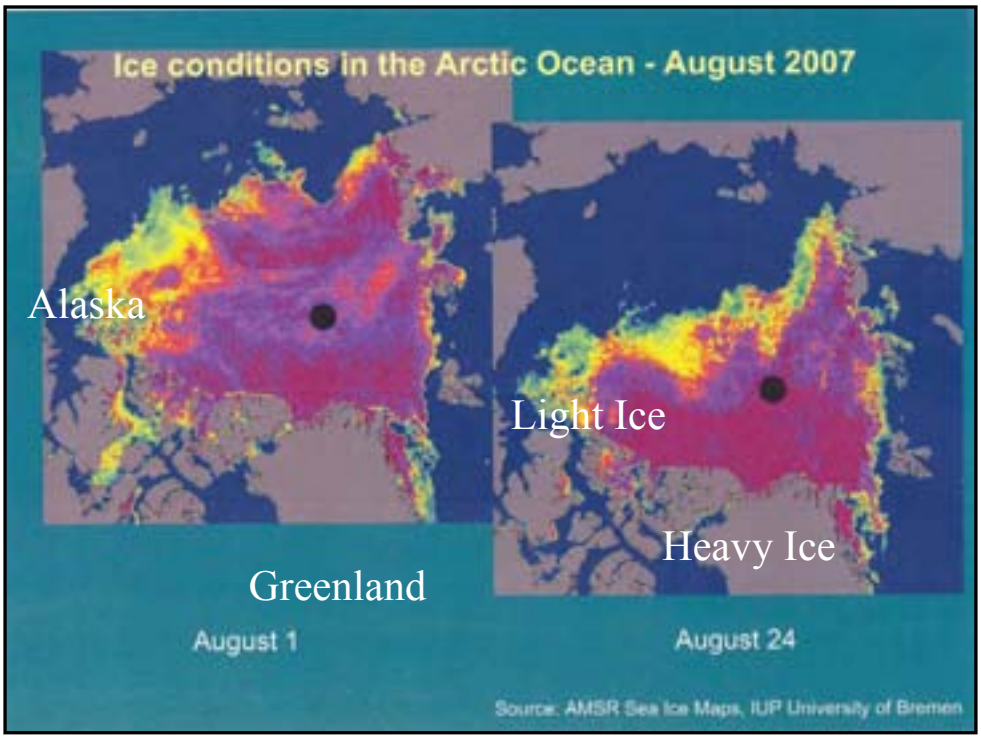

Figure 6: Summer 2007 Arctic Ice Conditions

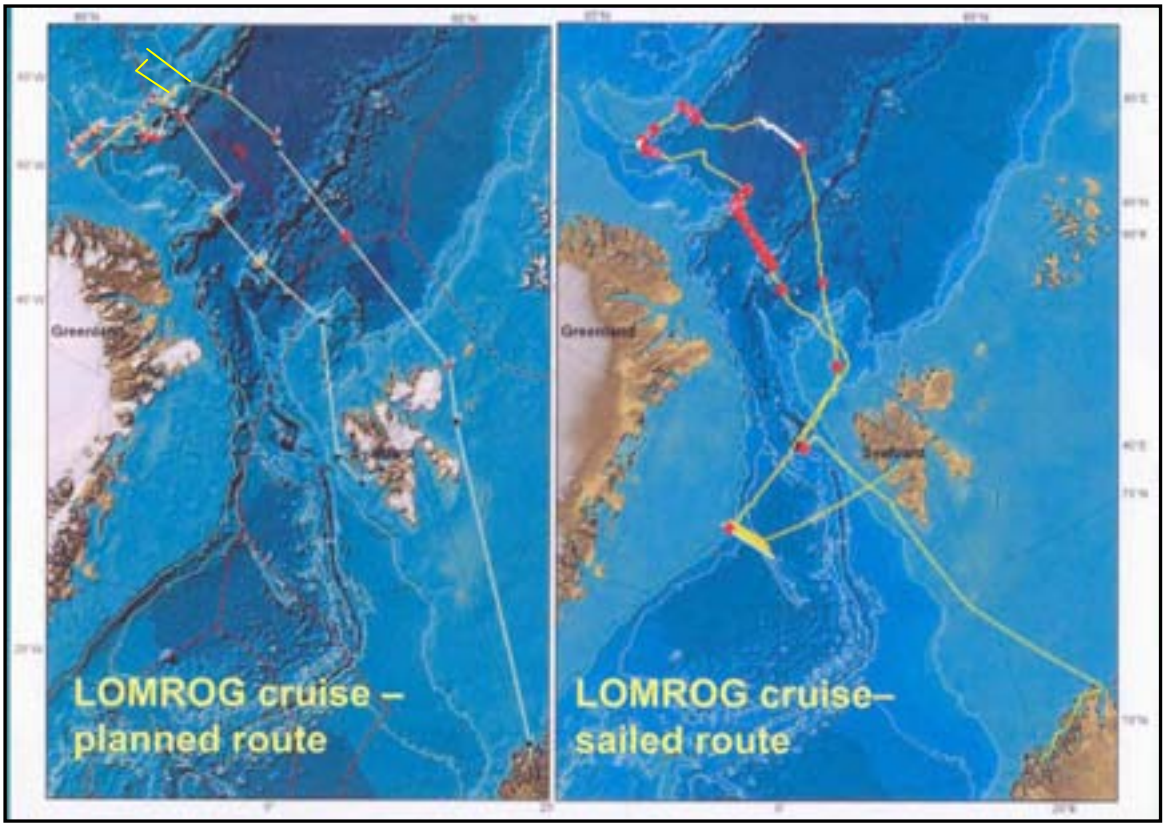

Figure 7: *Oden* Planned and Achieved -Source: Geological Survey of Denmark and Greenland

The Lomonosov Ridge plan included two bathymetric profiles on the west side of Lomonosov Ridge as well as collecting reflection seismic data along the LORITA refraction seismic line and also to collect additional data to the west of the LORITA line.

The *Oden* had difficulty following the *50 Let Pobedy* because the bow structure of the *Oden* was wider than the track of the lead vessel and the ice was both heavy and under compression. The *Oden* became stuck often and needed to be freed by the *50 Let Pobedy*. The noise and air introduced into the water by both icebreakers made bottom tracking with the EM 122 MBES difficult and the procedure developed was to stop each 15 minutes to confirm bottom.

When towing seismic, the air gun and streamer were towed at 20 metres below the surface. This put the seismic gear below the prop wash of the *Oden* and allowed the *Oden* to use full power. Despite these precautions, the seismic gear did come to the surface and became trapped in the jumbled ice behind the *Oden*. At times both the *Oden's* helicopter and the *50 Let Pobedy* were required to retrieve portions of the streamer from among the ice blocks.

A decision was made not to attempt the bathymetric lines west of Lomonosov Ridge due to ice conditions. After collecting seismic data on only 20 km of the LORITA line, the *50 Let Pobedy* decided not to exercise an option to extend the escort contract by 10 days due to the heavy ice and escorted the *Oden* to an area north of Greenland. In the end, the survey did not come into Canadian waters. One Canadian hydrographer was onboard *Oden.*

In parallel with the *Oden* cruise, there was a seismic and bathymetric survey in the western Arctic on board the CCGS *Louis S. St-Laurent* during a six-week survey (September 30 -October 11). A total of 3 Canadian Hydrographic Service hydrographers, 3 Geological Survey of Canada scientists and technicians, 6 contract technicians, 3 mammal observers from Paulatuk and one USA observer representing the United States Geological Survey made up the scientific complement.

Data was collected on the four primary seismic lines as planned except for a 20 km gap needed to connect to an existing seismic line run eastward from Northwind Ridge by the USA in 1993. The objective was to collect continuous sediment profiles back to the shelf from points, 50 NM apart along the 350 NM constraint line. Because the vessel was towing at 3-4 knots and could not use full power when the seismic gear was in the water, the plan was to work around the pans of multiyear ice rather than attempt to force a path through. A new virtual marine ice radar installed by the UNCLOS project proved very effective for planning routes around the old ice until the new ice forming became covered by snow near the end of the season.

Lighter ice conditions were encountered to the south and west and heavier ice nearer to the Canadian islands. The straightness or lack thereof of the resulting survey lines (black lines - Figure 8) versus the planned ones (red lines) reflect the degree of difficulty in getting through the ice.

In an attempt to collect an additional east-west line, the vessel was refuelled off Tuktoyaktuk at the end of September and steamed north to 77ºN with a plan to run one more seismic line to the east and continue through McClure Strait to Resolute where the scientific staff would disembark. However, in the time it took to steam to Tuktoyaktuk, refuel and return ice conditions had changed and it was not possible to head east. Instead, a seismic line was run south along the 350 NM constraint line and another attempt made at closing the gap with the 1993 USA line.

This coincided with shorter and shorter hours of daylight and colder temperatures that impacted the seismic gear. With air temperatures at -10ºC to -15ºC, cold airguns deployed into water at -4ºC frequently caused the guns to freeze open or shut on the first shot.

As with all successful projects it was a true team effort of Captain, Officer, crew and the scientific team. The quality of the seismic data collected has been described as spectacular and the coverage exceeded expectations. However, the seismic project would have ended prematurely except for the resourcefulness of the NRCan technicians and the engineering staff on board the CCGS Louis S. St-Laurent in repairing and making parts for the new compressor which developed serious problems after the first 350 hours of operations. They truly salvaged the season. A spare compressor will be added for 2008.

A total of 3000 km of seismic data and 7800 km of bathymetric data was collected.

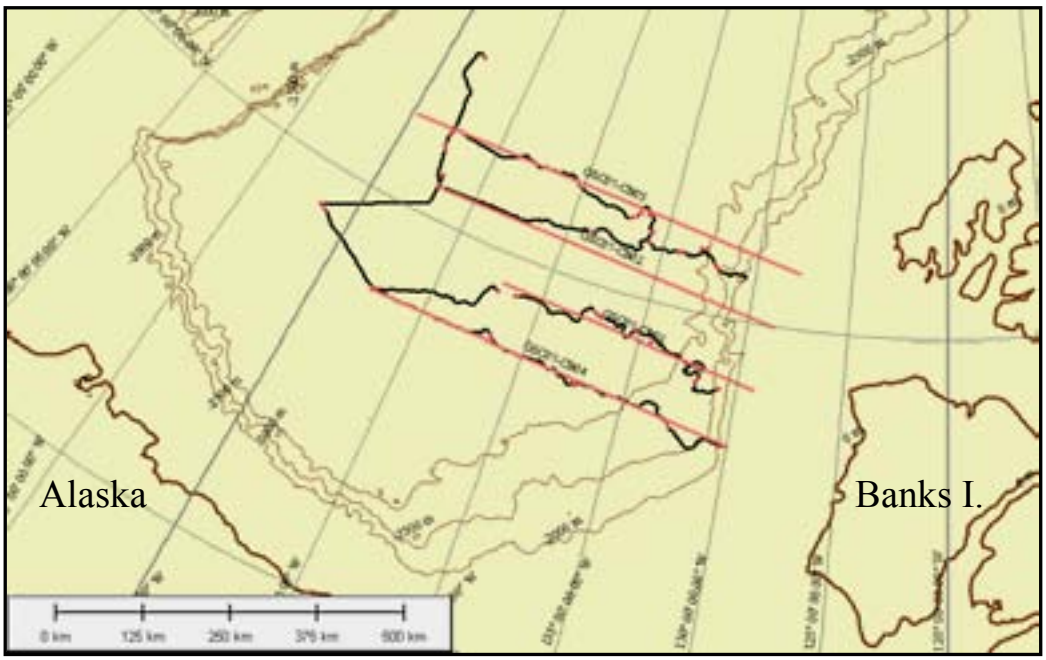

Figure 8: *Louis S. St-Laurent* 2007 – Planned (red) and Achieved (black) Seismic lines

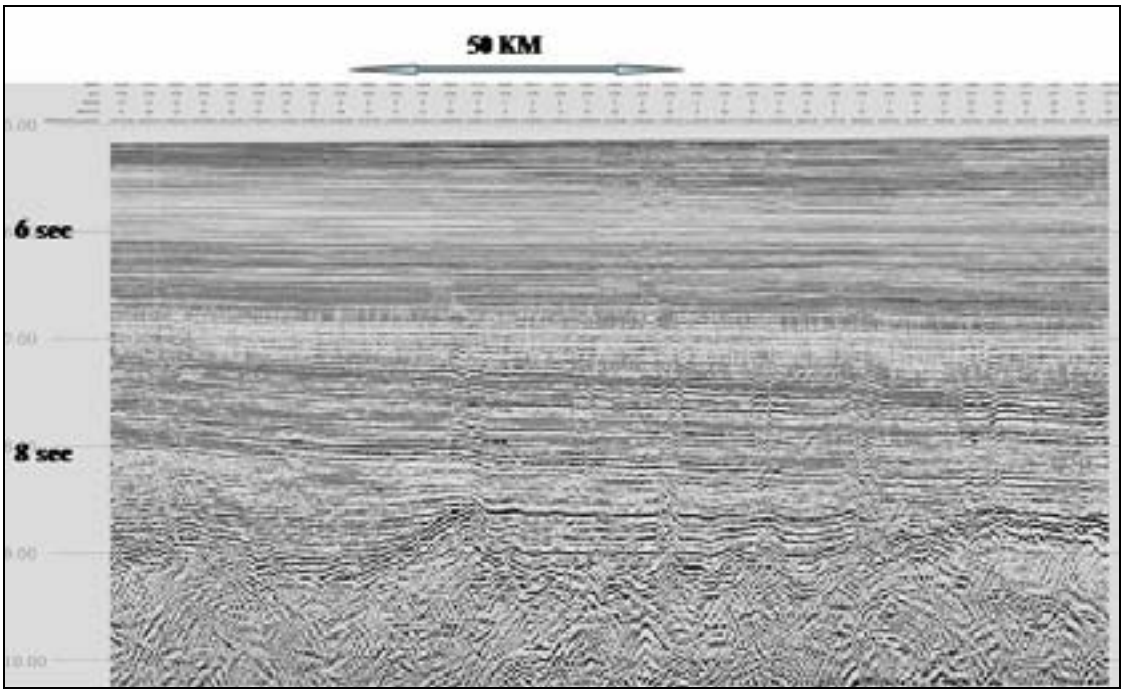

Figure 9: Sample 2007 seismic data from Beaufort Sea - Source: Dr. Ruth Jackson

Collaboration

Collaborative programs with Denmark continued with two workshops held to work on the joint interpretation of the seismic data from the LORITA project. The draft report has been prepared as well as a scientific paper that will be submitted for publication. Agreement has also been reached concerning access to Danish seismic data in the Labrador Sea to plan the 2009 Canadian seismic surveys as well as agreement in principle to another joint data collection project on the southern end of Lomonosov Ridge.

Two meetings were held with Russian officials responsible for the Russian submission. At the latter meeting in St. Petersburg (November 2007), Canadian, Danish and Russian participants presented overviews of the respective surveys conducted and agreed to a follow up workshop currently scheduled for the fall of 2008. This workshop will focus on the scientific data that Canada, Denmark and Russia have collected on Lomonosov Ridge to determine if there is consensus on key scientific questions, to identify gaps in the science and identify possible areas for future collaboration.

A number of meetings have also been held with the USA culminating in a planned joint Canada - USA survey in the western Arctic in September 2008. Canada and the USA each needs to collect the same type of data in the Canada Basin to determine foot of slope, the 2500 metre depth contour and sediment thickness. There is a potential for overlapping outer limits of the continental shelf and advantages to joint data collection and interpretation. The September 2007 cruise by the *CCGS Louis St. Laurent* included an American scientist. In 2008 the *USCHC Healy* and the *CCGS Louis S. St-Laurent* will work together during the month of September.

Future Plans

The on-ice Alpha Ridge Test of Appurtenance (ARTA) project on the Arctic Ocean north of Ellesmere Island commenced in March 2008. The objectives are twofold, a seismic survey to determine crustal structure of Alpha Ridge and a hydrographic survey to find foot of slope and 2500 metre isobath.

This will be followed by a continuation of the ship based seismic and bathymetric surveys in the western Arctic, using the *USCGC Healy* and the *CCGS Louis S. St-Laurent*. Both the *Healy* and *Louis S. St-Laurent* will be collecting bathymetric data while underway, with the *Healy* escorting the *Louis S St-Laurent* where seismic data is also being collected and the *Louis S St-Laurent* escorting the *Healy* in areas where bathymetry is required but not seismic.

It is planned to have a Request for Proposals (RFP) for a 2009 seismic survey in the Labrador Sea out in mid 2008 to allow sufficient lead time for proposals.

The annual winter on-ice surveys will continue each March-April and the icebreaker surveys each August-September. The icebreaker surveys will be two-ship operations commencing in 2008.

Alternate technologies for the Arctic survey work are also being investigated. This includes airborne deployment of seismic sensors during ARTA and the potential of using Unmanned Underwater Vehicles (UUV) for bathymetric data collection under the ice.

Conclusions:

As of December 2007, data collection in 65% of the Atlantic and 15% of the Arctic areas has been completed and the project is on target. A formative evaluation of the project is being conducted in 2008 to determine if there needs to be course corrections to mitigate risk and ensure that Canada will complete the mapping and have a credible submission ready for the December 2013 deadline.

The program is funded, is underway and will evolve as obstacles are encountered and overcome. To optimize the survey operations, we need cold, stable weather in winter, with lots of ice, and warm weather in summer, with unstable and light ice conditions. However, ice or no-ice is something over which we have no direct control and while it has been suggested that we alert a higher power of our needs, the program will be adjusted as necessary to deal with changing conditions and achieve the goal of a successful submission.

Biographies

Richard MacDougall

Dick MacDougall is the Director of the Law of the Sea Project and Fisheries and Oceans' member of the Management Board for Canada's UNCLOS program. He is a graduate of the Surveying Engineering program at the University of New Brunswick. In his 37 years with the Canadian Hydrographic Service he has worked in Atlantic and Central and Arctic Regions as well as Headquarters and has held a number of positions including field hydrographer, Hydrographer in Charge, Data Base Engineer, Manager of Chart Maintenance, Distribution, Nautical Geodesy and Tides and Acting Director, Marine Cartography. He was the Director,

Atlantic Region of the Canadian Hydrographic Service from January 1999 until December 2006 when he moved to his present position to focus full time on the UNCLOS program.

Wendell Sanford

A native of Halifax, Nova Scotia Mr. Sanford received his B.A. (Political Science) and B. Ed. from St. Mary's University, LLB from Dalhousie University (studying under Professors Douglas Johnston and Hugh Kindred), and Masters of Public Policy from Victoria University of Wellington, New Zealand. He joined the Department of External Affairs in 1978 and served as a consular officer for the Iran Task Force. Mr. Sanford's assignments have included Bangkok, Boston (twice), Wellington, and Los Angeles. In Ottawa Mr. Sanford has worked in the Legal Advisory and Legal Operations divisions, the South and South East Asia Relations Division, the Economic Analysis Division and as Deputy Director of the Program Analysis Division. From 1992 to 1994 Mr. Sanford was the Deputy Coordinator in the Office of the Ambassador for Fisheries Conservation. From 1996 – 1998 Mr. Sanford was an exchange officer within the New Zealand Ministry of Foreign Affairs and Trade responsible for the negotiating of the Western and Central Pacific Fisheries Convention. He was Deputy Director Oceans Law (2004 -2006) prior to assuming his current position in October 2006. Before joining the then Department of External Affairs Mr. Sanford had three careers. He taught junior high school in Calgary, Alberta; served as Staff Officer Naval Control of Shipping at Maritime Command Headquarters in Halifax; and as a solicitor for the Attorney General of Nova Scotia. Mr. Sanford retired from the Canadian Forces Naval Reserve with the rank of Lieutenant Commander and is the recipient of the Canadian Forces decoration.

Jacob Verhoef

Dr. Jacob Verhoef is the Director of Geological Survey of Canada-Atlantic, a Division of Natural Resources Canada (NRCan), in Dartmouth, Nova Scotia. After completing his Ph.D. in the Netherlands, he joined GSC Atlantic in 1986 to investigate the structure and evolution of Atlantic and Arctic Oceans. He was principal investigator on a project to compile all magnetic data for the North Atlantic and Arctic Oceans, a major effort to convince about 45 institutes in 15 different countries to release their data. He chaired an international committee for the compilation of geophysical data in the Arctic and was a member of several other international working groups. He was appointed to his current position (Director, GSC Atlantic) in 1996, and has regional responsibilities for Atlantic Canada as well as national responsibilities for the Oceans file. Presently, he is also the chair of the Management Board that oversees Canada's program for a claim of the extended continental shelf under UNCLOS (United Nations Convention on the Law of the Sea).