NOT FOR THE FAINT-HEARTED: MAPPING CANADA'S ARCTIC CONTINENTAL SHELF

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In spite of ice, fog and cold, Canadian scientists are successfully mapping the Arctic seabed beyond 200 nautical miles. This article examines what are they doing and how are they doing it. The coastal state is responsible for defining its continental shelf beyond 200 nautical miles. Canada must submit its scientific data and analysis to the United Nations Commission on the Limits of the Continental Shelf by the end of 2013. The progress being made by Canadian scientists, both independently and in cooperation with scientists from Denmark, the United State and Russia, bodes well for a successful submission.

En dépit du froid, du brouillard et des glaces, les scientifiques canadiens poursuivent leur cartographie du fond océanique de l'Arctique au-delà de la limite des 200 milles marins. À quelles fins et selon quelles méthodes ? Tout État côtier a la responsabilité d'établir sa portion du plateau continental au-delà de cette limite. D'ici à la fin de 2013, le Canada doit ainsi présenter son analyse et ses données scientifiques à la Commission sur les limites du plateau continental des Nations unies. Les progrès accomplis à ce jour par nos scientifiques, tant par leurs propres moyens qu'en collaboration avec leurs confrères danois, russes et américains, augurent d'une présentation fructueuse.

With dense fog, bone chilling temperatures and ice that is often too thick to navigate through, even with a powerful icebreaker, or too rough to land on, Arctic research is not for the faint-hearted. Yet in spite of the challenges, Canadian scientists are succeeding in mapping the Arctic seabed beyond 200 nautical miles. What are they doing? How are they doing it?

According to the United Nations Convention on the Law of the Sea (LOS), coastal states have sovereign rights to the resources in the water column and seabed within 200 nautical miles from shore. When the continental shelf extends beyond 200 nautical miles, the coastal state has sovereign rights to explore and exploit the non-living resources and sedimentary species of the seabed and subsoil. These sovereign rights are exclusive to the coastal state and do not depend on occupation, proclamation or use. Responsibility for defining its continental shelf rests with the coastal state, which must conduct scientific research to determine if its continental shelf extends beyond 200 nautical miles and, if so, the limits of its outer edge. Canada must submit its scientific data and analysis delineating its continental shelf extension to the United Nations Commission on the Limits of the Continental Shelf by the end of 2013.

The area to be mapped is vast, stretching a thousand kilometres from east to west. Moreover, the profiles need to be charted more than 500 kilometres out from the coast. In accordance with article 76 of the LOS Convention, the outer limits of the continental shelf will be defined by straight lines joining points no more than 60 nautical miles apart. In theory, profiles need to be taken at least every 60 nautical miles out from shore to establish these points. To compensate for unavoidable diversions, such as those occurring when an icebreaker needs to go around large, impenetrable ice floes — problems not addressed in the LOS Convention — Canadian scientists plan Arctic profiles to be 50 nautical miles apart.

Research on Canada's Arctic continental shelf extension is concentrated in two six-to-eight-week periods a year. As the sun does not come up until the end of February, the spring program cannot begin before mid-March and it continues to the end of April. As temperatures rise in May, snow and ice fog prevent further operations in the spring. The fall program is conducted when the sea ice is thinnest; thus it begins in mid-August and runs to the end of September. By October, temperatures are again frigid, the ice is closing in, and the days are becoming shorter, which severely limits the hours available to work.

Seismic and bathymetric surveys are conducted in the spring and fall sessions. Bathymetric surveys measure ocean depths to establish the foot of the slope of the continental shelf and to define the contours of the seabed. Seismic surveys penetrate the layers of the ocean bed to measure sediment thickness and the sound velocity of the rock structures to determine if the rocks are of the same composition as the continental shelf adjacent to Canada's coastline. While the spring and fall programs involve both types of research, the objectives and methodologies for conducting them vary considerably, in part as a result of different climatic challenges in the eastern and western Arctic; hence, each program is discussed separately below. Before turning to these discussions, it is important to note that they also face some challenges in common.

One of the most serious challenges is finding sufficient numbers of scientists with expertise in Arctic research. From 1958 until the early 1990s, Canadian hydrographers conducted springtime Arctic surveys annually; thus they had experience working on the ice and putting up ice camps. This pattern stopped in the early 1990s when funding was cut to the point where expensive systematic Arctic surveys could no longer be sustained, and the focus moved to what were considered to be higher priorities in the south. This trend coincided with a general reduction in Arctic scientific work. For some 15 years, little bathymetric and seismic work was done in the Arctic; hence those hired during that period had little opportunity to gain Arctic experience. Most of those who actively engaged in Arctic research prior to the early 1990s are now retired or nearing retirement. The 15-year hiatus saw the pool of Arctic experts dwindle, and those remaining must often put in long hours and spend significant periods away from home.

The science of doing Arctic data collection is complex but the logistics are perhaps even more complicated. One must bring everything that will be needed and take it back when the research project is completed. If something breaks, the chances of getting a replacement from the south before the six-week window closes are pretty slim, especially in summer, when an icebreaker is a week or more outside helicopter range. In August 2007, a new compressor broke after only four days of use.

Climatic conditions are a major determinant of research strategies and their successes or failures. In 2006, during the Lomonosov Ridge Test of Appurtenance (LORITA) expedition, bad weather caused by unusually warm temperatures in April resulted in the loss of 60 to 70 percent of the workdays in the eastern Arctic; nonetheless, Canadian scientists were able to accomplish their primary target: the seismic work. In 2007, when they returned to complete the bathymetric survey, the ice was in motion for 100 miles offshore and they lost 90 percent of their work days to bad weather, which seriously compromised progress on completing the Lomonosov Ridge work.

Bitterly cold temperatures also present problems for the scientists and their equipment. There are some jobs, such as connecting the wires to the detonator when doing seismic surveys on the ice, which can be done only with bare hands, even when the temperature is minus 35 degrees or colder. Minus 50-degree temperatures mean flexible equipment, such as fan belts, hoses and fuel lines for camp stoves, breaks like glass. If you use regular lubricant, instead of cold weather grease, wheels will not turn because the lubricant freezes. Climatic conditions exert such a pervasive influence, yet they are hard to predict.

Yet advanced planning is crucial. All the heavy equipment and supplies for the 2009 spring program had to be shipped up last summer. Four cargo containers and close to 2,000 drums of fuel left Montreal by ship for Eureka, from where they are being transported to the 2009 base ice camp.

In short, Arctic research requires a lot of forethought, extensive preparations and considerable flexibility in adjusting to changing weather conditions and new circumstances. Jacob Verhoef, Director of the Geological Survey of Canada, commented that they have "a five-year plan that changes every month." The direction and objective of preparing Canada's submission remain firm, but the specific logistics must be adapted to the realities encountered in the field. For example, the base camps may need to be moved if the ice breaks up or open water causes ice fogs to descend. Ice fog seriously curtails the use of helicopters, which are essential when working from ice camps.

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The spring research program focuses on mapping the Lomonosov and Alpha Ridges — submarine mountain ranges — to determine if they constitute natural prolongations of Canada's submerged land territory. Canada has been involved in collaborative projects with Denmark to collect data on the seabed north of Greenland and Ellesmere Island since 2006. Canadian and Danish scientists have jointly collected and interpreted data on the Lomonosov Ridge, so they now have a data set on which they both agree. In the spring of 2008, Canadian scientists conducted a similar test of appurtenance on the Alpha Ridge, called the Alpha Ridge Test of Appurtenance (ARTA) project. Research during the spring of 2009 will focus on completing the bathymetric surveying on the southern end of the Lomonosov Ridge, in collaboration with Denmark, and collecting the needed bathymetry in the area between the LORITA and ARTA project regions.

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Last summer Richard MacDougall, Director of the Law of the Sea Project for the Canadian Hydrographic Service, spent two days flying across the islands along the edge of the Arctic Ocean, covering as much as 1,000 miles a day in a Twin Otter aircraft, to find suitable sites for future base camps. In the end, a few — but only a few — possible sites were identified, including lakes on the Ward Hunt Island ice shelf, which is just north of Ellesmere Island. The site of the 2009 ice camp will be in the Ward Hunt Island area. A small two-or-three-person refuelling camp will be located 100 to 150 miles offshore to provide on-site weather information as well as an alternative destination for the helicopters should weather conditions prevent their return to the base camp.

From a base camp, both bathymetric and seismic equipment are set out using the Global Positioning System (GPS) to ensure that accurate profiles are measured. For bathymetric surveys, a helicopter lands at predetermined sites every two to five kilometres along selected profiles, the transducer is placed directly on the ice, and sound penetrates both ice and water and echoes off the seabed. The transducer both emits the sound and records its return. Placing transducers is heavy work as each weighs 50 to 80 pounds. When the helicopter lands, the hydrographer must dig through the snow to place the transducer directly on the ice to ensure accurate readings.

In the eastern Arctic, seismic research is used to determine the velocity of different geological layers, in order to compare the velocity structure of the Lomonosov and Alpha Ridges with the velocity structure on the adjacent continental shelf and see if it is continuous. When seismic surveys are conducted on ice, the sound waves need to penetrate a long way, up to 40 kilometres down into the seabed, so a large sound source (dynamite) is required. Between 115 and 150 seismic recording instruments are set out on the ice, one and a half to two kilometres apart. The dynamite charges are set off in sequence and the echoes from the various layers of sediment and rock beneath the seabed are received at each instrument.

In the western Arctic, Canadian scientists are conducting bathymetric surveys to measure depth, to determine the foot of the slope of the continental shelf and contours of the ocean floor, and seismic research to measure the thickness of the sediments. The Mackenzie River empties enormous amounts of sediments into the Beaufort Sea. The deposits extend for hundreds of miles out from shore. Both types of research are conducted simultaneously from an icebreaker.

Using the Coast Guard cutter *Louis S. St-Laurent*, Canadian scientists are mapping the continental shelf north of the Beaufort Sea. In the fall of 2007, ice conditions were relatively light in the western Arctic and they were able to collect a significant amount of high-quality bathymetric and seismic data. In fact, they gathered 3,000 kilometres of seismic data and 7,800 kilometres of bathymetric data. Last year Canadian scientists continued the work, both unilaterally and in a joint venture with the United States. The survey plan was jointly developed to address both Canadian and American needs for seismic data. The heavier ice conditions were anticipated nearer to the Canadian islands and this area was scheduled for the two-ship operation. During the joint operation, the newest and most technologically advanced US icebreaker, *Healy*, went ahead to break the ice, and the *Louis S. St-Laurent* followed with the seismic equipment. Once the foot of the slope area was reached, the roles were reversed and the *Louis S. St-Laurent* broke ice, while the *Healy* collected multibeam bathymetry of the slope. During the three weeks prior to joining forces with the *Healy*, Canadian and American scientists on the *Louis S. St-Laurent* conducted seismic and bathymetric surveys in the most northerly portion of the area designated for study in 2008. The ice conditions allowed the survey to proceed further north than originally planned for 2008, and the plan was adjusted to complete a survey line originally planned for 2009. It may seem counterintuitive that the ice was less thick in the more northerly climes than was the case further south and closer to the coast. As is the case for spring projects, the fall research session requires much planning so that alternative strategies are available if ice conditions delay (or advance) the schedule or prevent fol-

Ron Verrall

This ice camp at the mouth of Nansen Sound, north of Ellesmere Island (mountains seen in the background), was used for the spring research program. In the foreground is the runway that was created for the planes to land on. The camp was used in March-May 2008 in a survey to establish the structure of the Alpha Ridge.

lowing the preordained profile lines. Canadian and US scientists have agreed in principle to develop one data set for the Canada Basin and to interpret it jointly.

An environmental assessment of the impact of each seismic survey has been done with the involvement of the territorial governments and local communities. In the western Arctic, the Inuvialuit granted permission for the research to be conducted over a five year period on the condition that indigenous mammal observers were on the icebreaker. The environmental assessment dictates that the air guns must not be fired within one kilometre of a mammal. The reasoning behind this requirement is unclear. If the 70 or so people on the icebreaker are able to endure the sound of the air gun going off right below the ship, without apparent distress, why would it bother a polar bear on top of the ice a kilometre away?

While Canadian scientists continue to rely on traditionally proven survey methods, they are also exploring new technologies that could circumvent the problems of conducting research from icebreakers and the laborious task of landing a helicopter every two to five kilometres along profiles to set out echo sounder transducers or each seismic recorder and retrieve them from ice floes. In particular, they tested Icepicks (seismic instruments deployed from aircraft) to extend seismic lines during the spring 2008 survey, and they are considering unmanned autonomous underwater vehicles to collect bathymetric data beneath the ice. The Department of National Defence (DND) has experience using each of these technologies, albeit in a different context. Thus their deployment in the Arctic involves a collaboration between DND and the two departments responsible for mapping the Arctic seabed, Natural Resources, and Fisheries and Oceans.

An autonomous underwater vessel (AUV) is a long cylindrical, unmanned vehicle that can be programmed to follow a pattern under the ice collecting bathymetric data and to come back to a certain point, where the recorded data can be retrieved and the AUV recharged. To be effective, AUVs need to have about 72 hours of battery power, which translates into a range of 400 kilometres. They can be launched anywhere within that 400-kilometre circle, which greatly lessens the dependency on ice conditions, and once launched, they are relatively unaffected by surface weather conditions.

An Icepick contains a seismic receiver and a transmitter. After being dropped from an Aurora airplane, Icepicks parachute down, penetrate through the snow, and lodge in the ice below. These instruments are dropped roughly four kilometres apart. After dropping all the icepicks needed for a profile, the airplane flies to a higher altitude so it can record the data coming from the transmitters on the Icepicks. The dynamite is detonated, and the sound waves detected by the Icepicks are recorded on equipment in the airplane. The Aurora aircraft can fly much further out from the base camp than can a helicopter, thereby covering a wider territory. Timing is critical, as the plane can stay in the air for only a limited period. Thus, setting the dynamite charge, placing the Icepicks, moving the airplane to a higher elevation and deploying the charge must all be carefully coordinated. The Aurora requires a team of 17 to keep it operational as well as a hangar and a paved runway, neither of which is found in the Canadian Arctic islands; hence, once the dynamite charge is set, the airplane must be called from Thule, Greenland. Dropping the instruments is a tricky operation, which can involve flying at a height of only 150 metres and at a speed of 300 miles an hour, in an environment where visibility is frequently limited. The Icepicks are considered biodegradable; hence they are not retrieved.

Canadian scientists deserve our support for the progress they are making in mapping the continental shelf beyond 200 nautical miles, in spite of the many and diverse challenges intrinsic to Arctic research. Furthermore, the degree of cooperation among scientists from Canada, Denmark, the United States and Russia bodes well for a successful submission in 2013.

Elizabeth Riddell-Dixon is a professor of international relations in the Department of Political Science at the University of Western Ontario. This article draws several excerpts from her article, "Canada and Arctic Politics: The Continental Shelf Extension," Ocean Development and International Law *39(4)(2008): 343-59. It benefited greatly from the valuable insights of Jacob Verhoef and Richard MacDougall.*