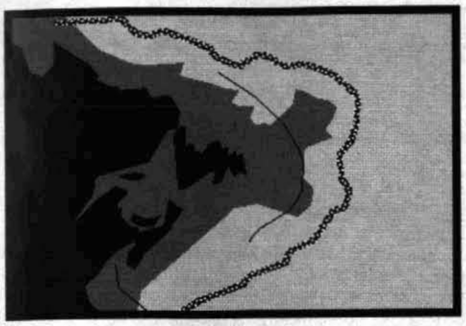

Earth Science and the Law of the Sea: Keys to Canada's Offshore Energy and Mineral Resources beyond 200 Nautical Miles

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SUMMARY

Article 76 of the United Nations Convention on the Law of the Sea allows Canada to establish sovereignty over resources of the seabed beyond the customary 200 nautical mile limit, when certain bathymetric and geological criteria are satisfied. This paper outlines the procedures for meeting those criteria, and describes the mutual benefits that can accrue to the earth sciences and the Law of the Sea through programs for collecting and analyzing the necessary data. In the Atlantic and Arctic oceans, this work could allow Canada to extend energy and mineral jurisdiction into seabed areas that approach the size of the three Prairie Provinces combined.

RÉSUMÉ

L'article 76 de la Convention des Nations Unies sur le droit de la mer permet au Canada d'établir sa souveraineté sur les ressources des fonds marins au-delà de la limite bien connue des 200 miles nautiques, sous réserve de certains critères bathymétriques et géologiques. Le présent article décrit les procédures auxquelles il faut se plier, de même que les retombées positives qui découlent de la cueillette et l'analyse des données nécessaires, autant pour les sciences de la Terre que pour le droit de la mer. En ce qui a trait aux océans Atlantique et Arctique, le Canada pourrait voir sa juridiction s'appliquer à un territoire dont la dimension correspondrait à peu près à l'étendue des trois provinces des Prairies ensembles.

INTRODUCTION

This paper has a three-fold objective: 1) to review the main provisions of the Law of the Sea where it relates to maritime zones, and to the jurisdiction that may be exercised by a coastal state with a wide continental margin over the energy and mineral resources of the seabed beyond the customary limits of national sovereignty; 2) to describe the role of earth science in achieving this extended seabed jurisdiction through the implementation of the relevant provisions of the Law of the Sea; and 3) to outline the implications of this extended jurisdiction for Canada.

MAIN PROVISIONS OF THE LAW OF THE SEA

Table 1 outlines the main provisions of the Law of the Sea. For more details, the reader is referred to the official text of the UN Convention on the Law of the Sea (UNCLOS, United Nations, 1997a). The focus of the discussion that follows will be on the Articles in UNCLOS that pertain to the *continental shelf*, and to *resources of the seabed and subsoil beyond the Exclusive Economic Zones* (EEZs).

Article 76 of UNCLOS defines the continental margin as the *submerged prolongation of a coastal state's land mass* that consists of the seabed and subsoil of the continental shelf, slope, and rise. The margin does not include the deep ocean floor, nor oceanic ridges. This definition relates only to the **physiographic components** of the seabed of the continental margin, as illustrated in the upper part of Figure 1.

Article 76 and other Articles of UNCLOS also refer to **juridical components** of the continental margin, as illustrated in the lower part of Figure 1. Some components apply to the seabed, to the subsoil, and to the superjacent waters, *i.e., the territorial sea, the contiguous zone, the exclusive economic zone, and the high seas*, whereas others apply only to the seabed and subsoil, *i.e., the continental shelf and the Area*. It is worth underscoring here that the juridical continental shelf is **not** the same as the physiographic continental shelf: the former is defined according to bathymetric and geological criteria that are defined in Article 76, while the latter relates strictly to the shape of that portion of the seabed that is adjacent to the coastline.

Article 76 serves as an instrument for extending beyond 200 nautical miles (nm) the sovereignty of a coastal state with a wide continental margin, provided certain bathymetric and geological criteria are satisfied. Article 77 defines that state's rights within the extended zone of sovereignty, with respect to mineral and other non-living resources of the seabed and subsoil, and to biological resources that are characterized as sedentary species. Matters that pertain to living resources of the seabed are beyond the scope of this paper, and will not be addressed here.

In 1970, the United Nations General Assembly issued Resolution 2749, which articulated among other

Table 1 Main provisions of the Law of the Sea.

Scope and Limits of National Jurisdiction
- Territorial Sea: to 12 nautical miles (nm)
- Contiguous Zone: to 24 nm
- Exclusive Economic Zone (EEZ): to 200 nm
- *Continental Shelf: variable past 200 nm**

Rights of Passage for Ships and Aircraft

High Seas (water and air past EEZs)
- International Rights and Obligations
- Conservation and Management of Living Resources

The Area (seabed past EEZs and continental shelves)
- Common Heritage of Mankind
- *Resources of the Seabed and Subsoil**
- International Seabed Authority

Pollution Prevention

Scientific Research

** topics addressed in this paper*

Geological Survey of Canada Contribution No. 2000294

things a declaration of principle concerning the use of seabed resources beyond national jurisdiction:

> the seabed and ocean floor, and the subsoil thereof, beyond the limits of national jurisdiction ... as well as the resources of the Area, are **the common heritage of mankind** [and] shall not be subject to appropriation by any means by states or persons...

In recognition of that principle, Article 82 of UNCLOS establishes a framework for a system of royalties that will be delivered by coastal states to the International Seabed Authority (ISA), upon the extraction of resources from the seabeds of the juridical continental shelves that lie beyond 200 nm. These royalties are to take the form of payments or contributions, beginning at 1% of the value or volume of production at each production site after 5 years of operation, and increasing by 1% annually until the twelfth year (Fig. 2). These provisions are not applicable to states that are net importers of the resource(s) in question. Funds so collected by the ISA will be distributed on the basis of equitable sharing criteria to states that are party to the Convention, taking into account the interests and needs of under-developed and land-locked states.

EARTH SCIENCE AND THE IMPLEMENTATION OF ARTICLE 76

The implementation of Article 76 entails the analysis and interpretation of three classes of geoscientific information: the shape of the seabed, the depth of water, and the thickness of the underlying sedimentary material. It also requires geodetic computations for the accurate derivation of the horizontal co-ordinates of certain key features upon the ellipsoid of revolution. Table 2 outlines the operations and the classes of information that figure in this process. The following paragraphs provide an overview of these operations.

Natural Prolongation

For a given coastal state, the decision to proceed with the implementation of Article 76 depends almost entirely upon the perceived nature and dimension of the submerged component of its land mass, defined as the *natural prolongation of its land territory*. In most cases, a review

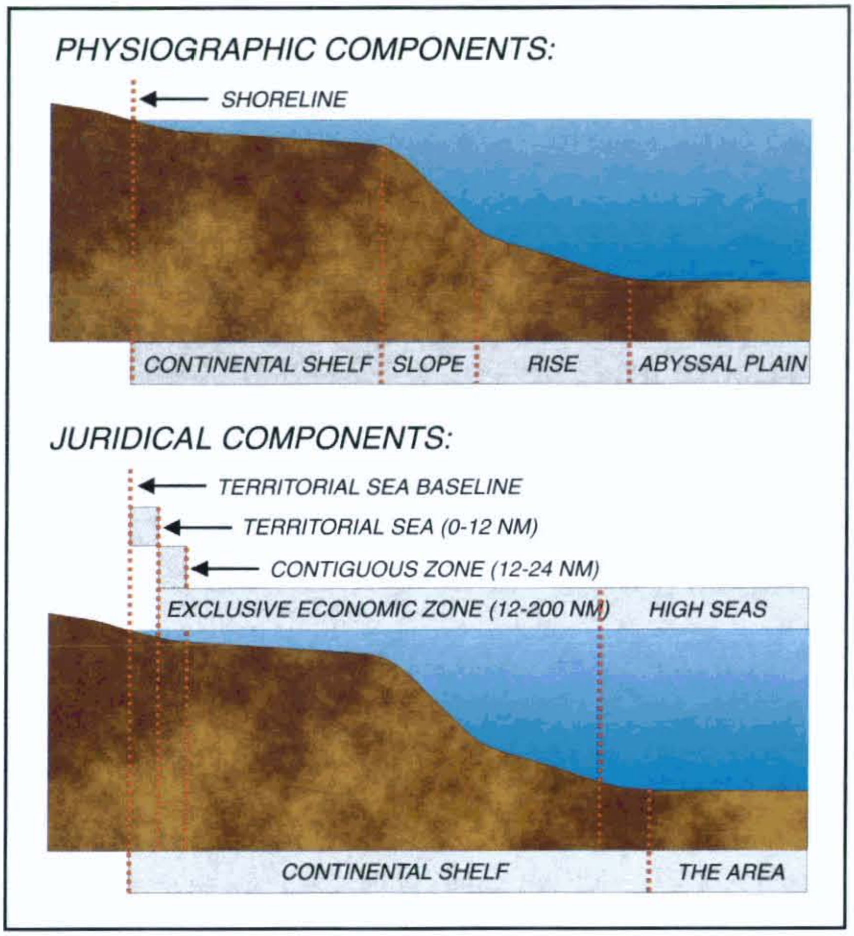

Figure 1 Using physiographic nomenclature, the three components of the continental margin consist of the continental shelf, the slope, and the rise, forming a transition zone between land and the abyssal plain. The juridical nomenclature of UNCLOS defines components that pertain to the seabed and superjacent waters: the *territorial sea*, the *contiguous zone*, the *exclusive economic zone*, and the *high seas*. UNCLOS also defines components that pertain only to the seabed: the *continental shelf* and *the Area*. ***Note that the Juridical Continental Shelf is not the same as the Physiographic Continental Shelf.***

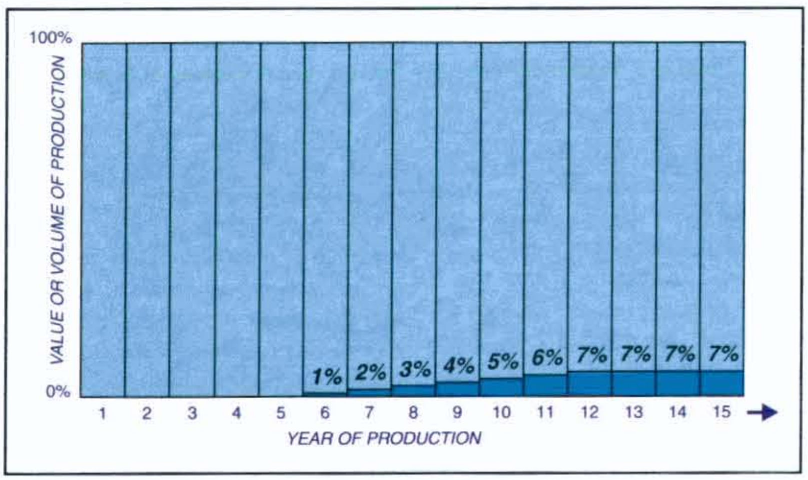

Figure 2 Schedule of royalties paid to the International Seabed Authority, as a percentage of the value of a non-living resource extracted from the seabed beyond 200 nm. Funds so collected are distributed to states party to UNCLOS, taking into account the interests of under-developed and land-locked states.

of the relevant morphological and geological factors will be undertaken to identify the seabed features beyond 200 nm that the coastal state proposes to include within the new outer limit of its continental shelf. This assessment should seek to determine whether a geological or morphological continuity exists between the terrestrial framework and distant seabed features.

Delineating the Foot of the Slope

Article 76 states that *the foot of the continental slope is defined as the point of maximum change in the gradient at its base.* This feature provides a point of departure for subsequent procedures; errors at this stage can propagate into the interpretations and derivations that follow, with a significant effect upon the determination of the outer limit of the continental shelf, and hence upon the size of the area enclosed by this limit.

The most direct technique for determining the location of the foot of the slope is to analyze a series of bathymetric profiles perpendicular to the edge of the continental shelf, with a view to identifying and joining the points of maximum change of seabed gradient in adjacent profiles. This approach evaluates relative changes of depth and hence does not require absolute bathymetric accuracy; however, the geographic co-ordinates of the bathymetric observations must be well known because their position in a horizontal frame of reference is significant. The outcome of this analysis depends heavily upon the quantity and distribution of profiles, the accuracy and resolution of the sounding equipment (wide-beam *versus* narrow-beam, single-beam *versus* multibeam), the processing that has been applied to the data, the criteria applied in their interpretation, and the nature of the sea floor in this particular zone.

Software tools have been developed for making consistent determinations of the foot of the slope through the application of well-defined mathematical and geometric criteria to digital depth information. These procedures may operate directly upon original or synthetic bathymetric profiles (Fig. 3) or upon digital models that use regularly spaced grid points to describe the shape and depth of the sea floor (Ou and Vanicek, 1996).

Applying the Formulae of Article 76

Following the delineation of the foot of the continental slope, the next operation involves the construction of at least one and perhaps two distinct lines, the locations of which are determined with respect to the foot of the continental slope, in accordance with the two formulae explained in the following paragraphs: the *distance formula* and the *sediment thickness formula.*

The *distance formula* is the more straightforward of the two formulae, involving a simple projection of the foot of the slope seaward for a distance of 60 nm. This is best accomplished numerically, using geodetic software that automatically calculates a series of co-ordinates that define a series of intersecting arcs centred upon a succession of points located along the line that delineates the foot of the slope (Fig. 4).

Applying the *sediment thickness formula* is potentially a more complex and expensive operation: depending on the suitability of existing data, this option could entail a costly field program for measuring the thickness of sedimentary rock beneath the ocean floor, coupled with an analysis for determining the point where this thickness equals 1% of the distance back to the foot of the slope (Fig. 4). The limit defined by a succession of such points is known colloquially as the *Gardiner Line,* after one of its principal architects (Gardiner, 1978). Uncertainties in measurement and interpretation may give rise to significant ambiguities in the application of this formula; however, once the interpreter has made some reasonable assumptions about the nature and distribution of the sedimentary material, the determination of the 1% line should be relatively straightforward.

It is not mandatory to apply uniquely the distance formula or the sediment thickness formula throughout the study area, and in any particular location, the coastal state may apply the formula that is most advantageous to its interests. A coastal state may therefore opt initially to apply both formulae in some or all areas, developing one line segment with the distance formula, and another segment with the sediment thickness formula. The two lines may then be compared to determine which single line, or which combination of segments from both lines, encloses the largest possible area beyond 200 nm. The process of developing a composite line is illustrated in Figure 4. For convenience and to acknowledge the technique of its derivation, the term *formula line* is sometimes used to describe this line.

Determining the Cutoff Limits

Regardless of the method chosen for its delineation, the outer limit cannot in general extend beyond a maximum of 350 nm from the state's territorial sea baselines, or 100 nm beyond the 2500 m isobath, whichever is greater.

Table 2 Technical procedures for determining the outer limit of the juridical continental shelf.

OPERATION	COMPUTE Geodesic (horizontal distance)	ANALYZE/INTERPRET Bathymetry (depth of water)	Geology (sediment/bedrock)	Morphology (shape of seabed)
A Does a *natural prolongation* exist?		✔	✔	✔
B Locate the *foot of the slope*			✔	✔
C Apply *the distance formula*	✔			
D Apply *sediment thickness formula*	✔		✔	
E Combine C & D: the *formula line*				
F Construct the *350 nm limit*	✔			
G Project *2500 m isobath 100 nm*	✔	✔		
H Combine F & G: the *cutoff line*				
I Combine E & H: the *outer limit*				

The *350 nm limit* consists of a series of circular arcs centred upon the coastal state's Territorial Sea Baseline (Fig. 5). It is recommended that this limit be constructed numerically by means of geodetic computations. In addition to its accuracy, this approach has the added advantage of creating a series of co-ordinates in digital form that can be saved for later use in portraying this feature on charts at a variety of scales and projections.

The location of the *2500 m isobath plus 100 nm* is more problematic because it necessitates the measurement of absolute water depths with the utmost accuracy, which current international specifications require to be ± 2.3% of the water depth. Again, it is left to the interpreter to make reasonable assumptions about the location of this feature, after which the 100 nm projection can be constructed in a manner that is entirely analogous to the method applied when applying the distance formula (Fig. 5).

To simplify their use, segments of the two limits constructed above may be combined into a single *cutoff line* that encloses the largest possible area beyond tal shelf. The process of developing this line is illustrated in Figure 5.

Determining the Outer Limit of the Juridical Continental Shelf

This step begins with a comparison of the formula and cutoff lines. If the formula line is located entirely inside the cutoff line, then the former will be used to define the outer limit of the continental shelf. Conversely, if the formula line is everywhere outside the cutoff line, then the latter will be used to define the outer limit.

As is often the case, some segments of the formula line are likely to be situated within the cutoff line while others extend beyond the cutoff line. The final outer limit will therefore consist of a composite line, where outlying segments of the formula line are discarded and replaced by intervening segments of the cutoff line, as shown in Figure 6. Note that the final outer limit cannot be a curved line, but that it must be defined by a succession of straight line segments not exceeding 60 nm in length.

Implementation Tasks and Time Frame for their Completion

Article 76 states that the tasks outlined above need to be completed by a coastal state within 10 years of the entry into force of UNCLOS for that particular state. In principle, the 60 states that were among the original ratifiers of UNCLOS have until the year 2004 to carry out this work on their respective continental margins, if applicable, and to present a submission to the Commission on the Limits of the Continental Shelf (CLCS). In this context, it is worth noting that Canada, along with the United States and a few other states, has yet to ratify UNCLOS; for these non-ratifying nations, the time limit for continental shelf delimitation is not yet in effect.

A set of guidelines has been prepared by the CLCS (United Nations, 1999) to assist coastal states in the execution of the tasks described above, in the preparation of a submission, and in the organization of supporting material. In general, the implementation process consists of several successive steps, beginning with an initial desk study that: 1) assembles all available geoscientific information (bathymetry, morphology, and geology); 2) analyzes that information to develop provisional outer limits; and 3) determines whether a requirement exists for more or better geoscientific information.

Depending on the outcome of the desk study, it may prove necessary to conduct fieldwork or to engage in a more exhaustive search for existing information, with a view to improving the data base in certain respects, *e.g.*, determining a definitive territorial sea baseline, upgrading the bathymetric map in certain areas, or defining sediment thickness on the basis of seismic reflection and refraction. New information that is acquired through fieldwork or through an expanded archival search needs to be assimilated into existing data bases. Previous interpretations then require revision and refinement in light of the new data, culminat-

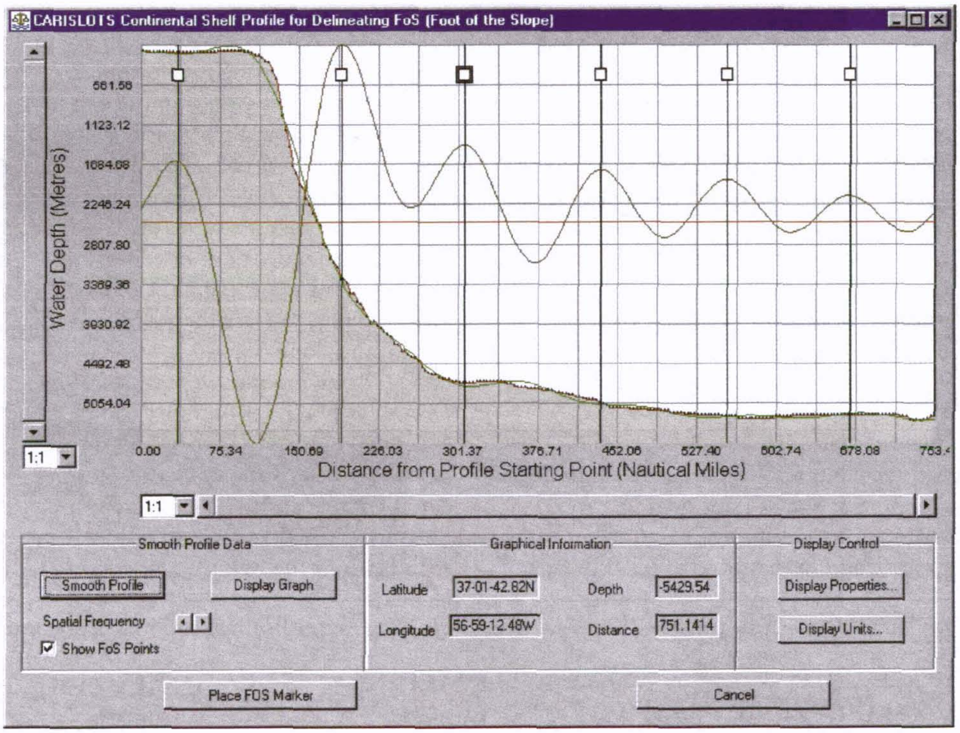

Figure 3 The *Foot of the Continental Slope,* defined by Article 76 as "the point of maximum change in the gradient at its base," is a key element in determining the outer limit of the juridical continental shelf. It may be determined numerically as illustrated in the example above, where a mathematical curve (**light green**) is fitted to a series of original bathymetric observations along a profile perpendicular to the continental margin, or to a synthetic profile extracted from a digital bathymetric model. The quasi-sinusoidal second derivative of the mathematical curve (**dark green**) approximates the change of bottom gradient, and its positive peaks provide objective indicators for locating the points of maximum change (from van de Poll *et al.,* 2000).

ing in the construction of a definitive outer limit.

The penultimate operation involves the preparation of a comprehensive report that documents the procedures outlined above, the data sets that were used in the analysis, and the results of that analysis, expressed as a series of coordinates that define the outer limit of the juridical continental shelf. As the core of a coastal state's submission to the CLCS, this document must present a clear and compelling substantiation of that state's case for an extended continental shelf.

The final step entails presentation of the coastal state's submission to the CLCS for review and recommendation. Another CLCS document (United Nations, 1997b) describes at length the *modus operandi* that governs the process once this stage is reached. In essence, this involves the formation of a subcommission that will perform a technical evaluation of the submission, consult with coastal state representatives, and formulate recommendations.

The terms of reference for the CLCS are defined in Annex II of UNCLOS. In brief, the Commission has a dual function: 1) to review Article 76 submissions by coastal states and to make recommendations; and 2) to provide scientific and technical advice to individual states upon request. Allowing for equitable geographic representation, membership in the Commission is drawn exclusively from states that have ratified the Convention, and consists of 21 elected experts in the field of geology, geophysics, or hydrography. Members are elected for 5-year terms, the first term running from 1997 to 2002. Table 3 contains a listing of the Commission's current member nations, organized in accordance with the UN's customary regional groupings.

Earth Science and Non-living Resources of the Seabed

Inherent in the implementation of Article 76 is the need to develop an understanding of the resources that will come under extended jurisdiction, of their prospective worth, and of the factors that will affect their exploitation. Earth science can contribute to this understanding by several means, *e.g.,* through regional framework studies that identify the characteristics of prospective resources and their modes of emplacement, and through local investigations that estimate the distributions and quantities of those resources. Detailed geoscientific studies are also essential for the selection and development of seabed production sites, and for assessing constraints and hazards that could affect the extraction and management of resources; this includes the potential for destructive interactions between man and the environment.

Impact of Article 76 on Earth Science

Just as earth science is key to the implementation of Article 76, the latter can also contribute to the former's overall advancement. For instance, defining the "natural prolongation" that serves as a basis for defining the outer limit may require consideration and clarification of a region's tectonic framework and history, which in the process could shed new light on the transition zone between continent and ocean. Constructing the outer continental shelf limit may create a need for better descriptions of the seabed and subsoil in areas that have been poorly mapped, leading to the mobilization of surveys that could transcend Article 76 by shedding new light on the composition, distribution, and transport of seabed material: information that is essential for understanding erosional and depositional processes, and which can be of immense practical benefit in engineering applications, for instance in the selection of pipeline and cable routes.

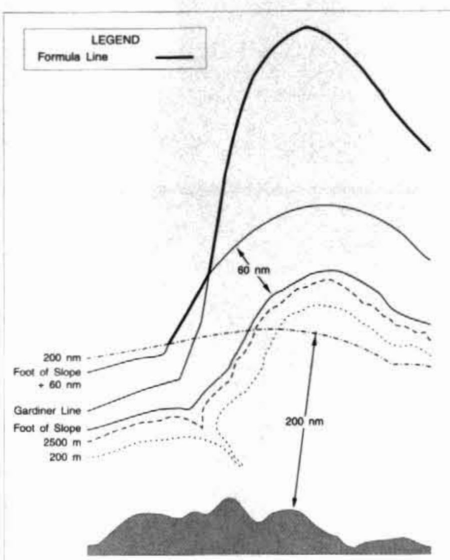

Figure 4 Illustrating the process of amalgamating segments of lines developed with the distance and sediment thickness formulae of Article 76, to develop a composite *formula line*. The drawing is not to scale (adapted from Royal Society, 1982).

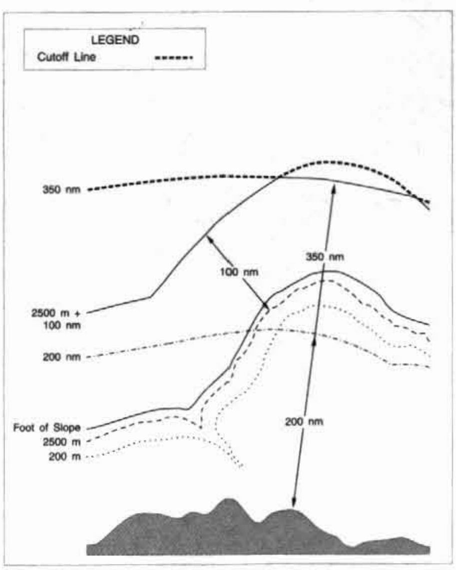

Figure 5 Illustrating the process of amalgamating segments of the 350 nm limit and the 2500 m isobath plus 100 nm, to develop a composite *cutoff line*. The drawing is not to scale (adapted from Royal Society, 1982).

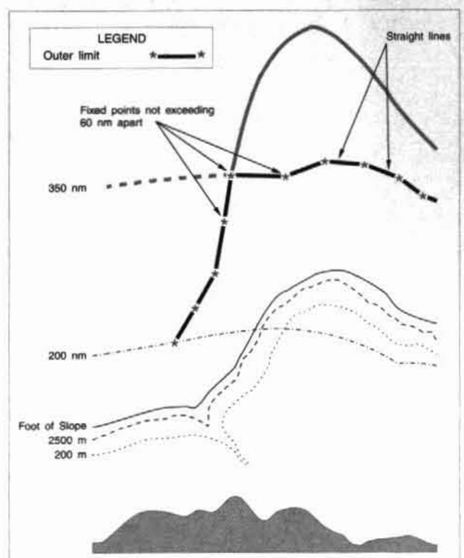

Figure 6 Illustrating the integration of components of the formula line (developed in Fig. 4) and of the cutoff line (developed in Fig. 5), and their subsequent approximation by straight lines to define the *outer limit of the juridical continental shelf*. The drawing is not to scale (adapted from Royal Society, 1982).

The Need for a Long-term View

Extending the edge of the continental shelf beyond 200 nm creates a lasting, if not permanent, change in a coastal state's external configuration. While the immediate benefits of this extension may not be obvious in *all* cases, it is important to anticipate that in the fullness of time, technological improvements likely will enable access to known seabed resources that are presently beyond reach, *e.g.,* gas hydrates. Moreover, new and currently unrecognized resources may still await discovery, *e.g.,* raw materials for the manufacture of pharmaceuticals. Most, if not all, of these advances could require long lead times to realize; committing to such an ongoing effort should be easier to justify when jurisdiction over the target resources has been established beyond question.

ARTICLE 76 IN THE CANADIAN CONTEXT

A preliminary assessment (Geological Survey of Canada, 1994) has revealed that the provisions of Article 76 of UNCLOS could permit Canada to extend seabed jurisdiction over regions of the Atlantic and Arctic oceans that together encompass a total area which nearly equals the three Prairie Provinces combined (Fig. 7). Subject to a detailed review of the geological conditions off the narrow continental margin of the west coast, there appear to be only limited prospects for extending jurisdiction beyond 200 nm in the Pacific Ocean.

Primary Resources

Hydrocarbons are the premier known resource on Canada's Atlantic margin, with sizeable sedimentary basins that are known to extend well past the 200 nm limit (Fig. 8). The potential for hydrocarbons is not so obvious in the extended zone of sovereignty in the Arctic: known basins are contained largely within the EEZs of the coastal states, where jurisdiction is not at issue (Fig. 9). However, the outlook for gas hydrates in that area is much more positive: based on an extrapolation from known deposits in other regions (Fig. 10), it appears that the deep ocean basin could harbour some major hydrate accumulations.

Determining Outer Limits in the Atlantic and Arctic Oceans

Upon Canada's ratification of UNCLOS, programs will be mobilized for defining the outer limit of the juridical continental shelf in the Atlantic and Arctic oceans. This is expected to be a relatively straightforward prospect in the Atlantic, in view of the quantities of legacy data that have been collected for the past several decades over that margin; some surveys may be required in key areas to enhance existing data bases, but by and large, the general framework is known well enough to proceed with the establishment of a credible outer limit.

The situation in the Arctic Ocean is not as straightforward as in the Atlantic, considering the paucity of information that describes the nature of the sea floor beneath the permanent polar ice pack. A program for systematically mapping the

Table 3 Current (1997-2002) national membership in the Commission on the Limits of the Continental Shelf, listed according to the United Nation's customary regional groupings.

AFRICA
Cameroon
Egypt
Mauritius
Nigeria
Zambia

ASIA
China
India
Japan
Malaysia
Republic of Korea

CARIBBEAN - LATIN AMERICA
Argentina
Brazil
Jamaica
Mexico

EASTERN EUROPE
Croatia
Russia

WESTERN EUROPE - OTHERS
France
Germany
Ireland
New Zealand
Norway

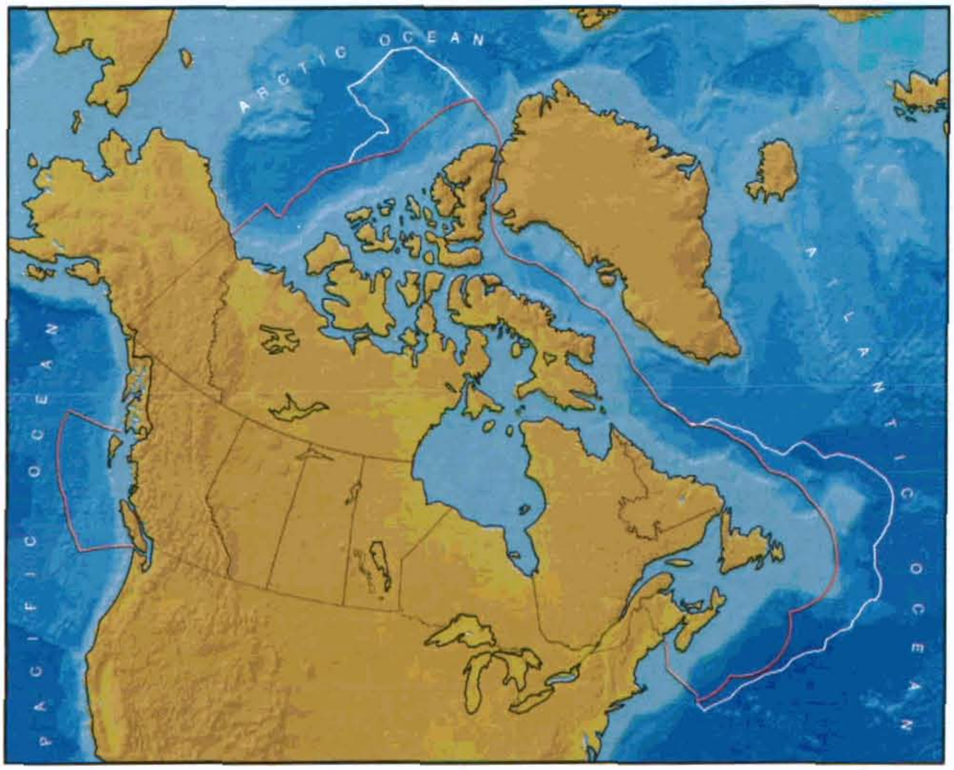

Figure 7 Canada and adjacent oceanic regions, showing **(in red)** the limits of the Exclusive Economic Zone (EEZ) that defines the present extent of Canadian jurisdiction over resources of the seabed, and **(in white)** a preliminary delineation of the juridical continental shelf as prescribed by Article 76 of UNCLOS. Taken together, the regions in the Atlantic and the Arctic oceans beyond 200 nm cover an area nearly equal to Canada's three Prairie Provinces (Geological Survey of Canada, 1994).

seabed in this region would present a formidable — and costly — challenge. Moreover, if the mapping were to be attempted with conventional techniques and with a realistic allocation of resources, the time required to complete the project might well extend beyond the 10-year deadline stipulated by Article 76.

The response to the Arctic situation has been to initiate a series of international collaborations for assembling and merging all available geoscientific information from the region that could have some bearing on the definition of the outer limit: so far, maps and grids that describe bathymetry and the magnetic field of the Arctic Ocean have been constructed (Jakobsson *et al.*, 2000; Verhoef *et al.*, 1996), with a description of the gravity field expected by the end of 2001 (Kenyon and Forsberg, 2000). In the meantime, a new international project to construct a Map of Arctic Sediment Thickness (MAST) has been launched. This pooling and rationalizing of geoscientific information is expected to result in two major benefits: 1) a reduced need for costly and difficult field work by individual coastal states; and 2) a common perception of the nature of the seabed, eliminating or at least reducing some sources of contention among coastal states that must deal with converging and overlapping continental shelf claims.

Scope for Public-private Partnerships

The implementation of Article 76 will require a new infusion of capabilities and resources that may be difficult for Canada's public sector to provide while continuing to meet its existing commitments, but which ought to be obtainable from the private sector. Therefore it is to be expected that opportunities will arise for establishing partnerships between government and commercial organizations. The nature of these partnerships, and of the tasks they address, will vary according to the status of the implementation program.

Prior to implementation, public agencies will perform preliminary investigations, followed by program definition and planning. Working on a contractual basis, private agencies will assist with the construction of data bases and with the development of specialized tools and procedures. In fact, significant components of this work have already been accomplished in Canada, featuring a mix of private and public involvement.

During the implementation phase, private sector agencies, again operating on a contractual basis, likely will perform field operations and provide services related to data management, analysis, and interpretation. Public sector agencies will manage the program, review and approve the results of interpretations, and prepare the submission to the CLCS.

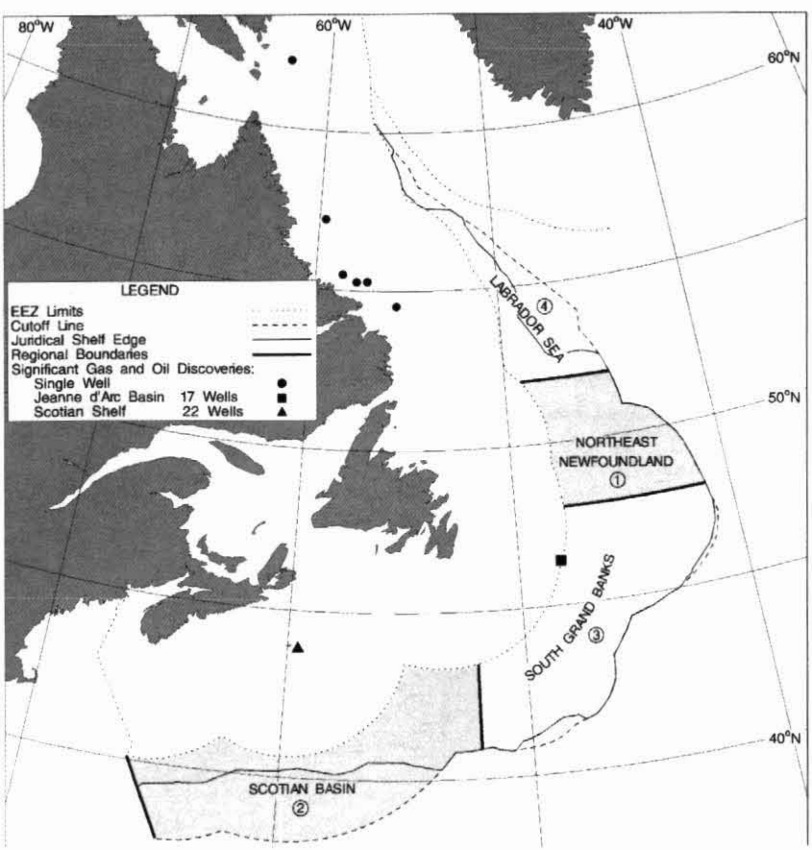

Figure 8 Hydrocarbon evaluation areas and locations of significant gas and oil discoveries on Canada's Atlantic margin. Circled numbers indicate the rankings of the areas in terms of their relative hydrocarbon potential (adapted from Wade, *in* Geological Survey of Canada, 1994).

CONCLUSIONS

By providing a body of knowledge and skills that are needed for assessing and analyzing geoscientific data, earth science is essential to the implementation of Article 76 of the Law of the Sea, and by extension to the establishment of Canadian jurisdiction over resources of the seabed beyond 200 nm in the Atlantic and Arctic oceans.

Conversely, the acquisition and analysis of new information necessary for the implementation of Article 76 can be expected to provide a significant opportunity to improve the state of earth science in Canada through a better understanding of the geological and tectonic structure of the nation's Atlantic and Arctic margins, and to contribute to the development of offshore resources.

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in this paper are based upon public domain information, while the viewpoints expressed are those of the authors alone. Neither the depictions nor the viewpoints necessarily represent the position of the Government of Canada.

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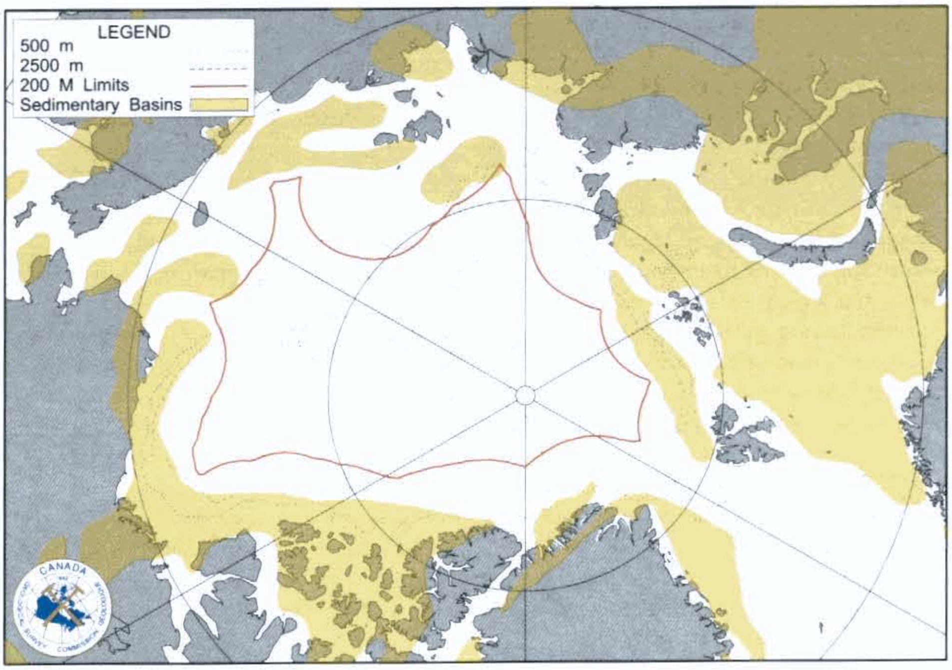

Figure 9 Sedimentary basins of the Arctic Ocean, suggesting that gas and oil reservoirs may be located for the most part within the combined EEZs of the Arctic Coastal States (adapted from Green and Kaplan, 1987).

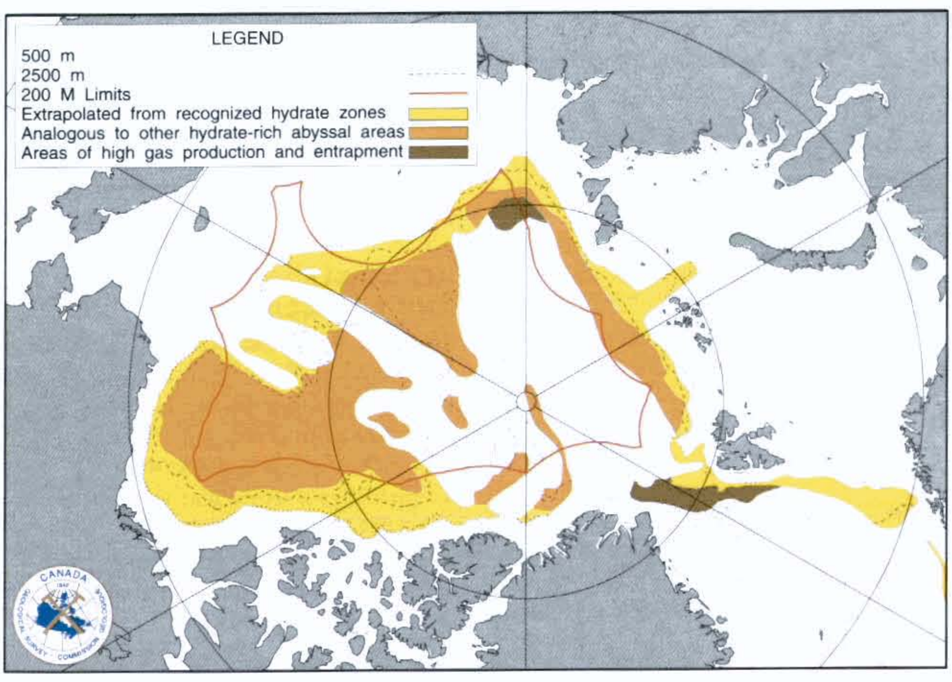

Figure 10 Projected concentrations of gas hydrates in the Arctic Ocean basin, showing them for the most part to be outside the combined EEZs of the Arctic Coastal States (adapted from Max and Lowrie, 1993).