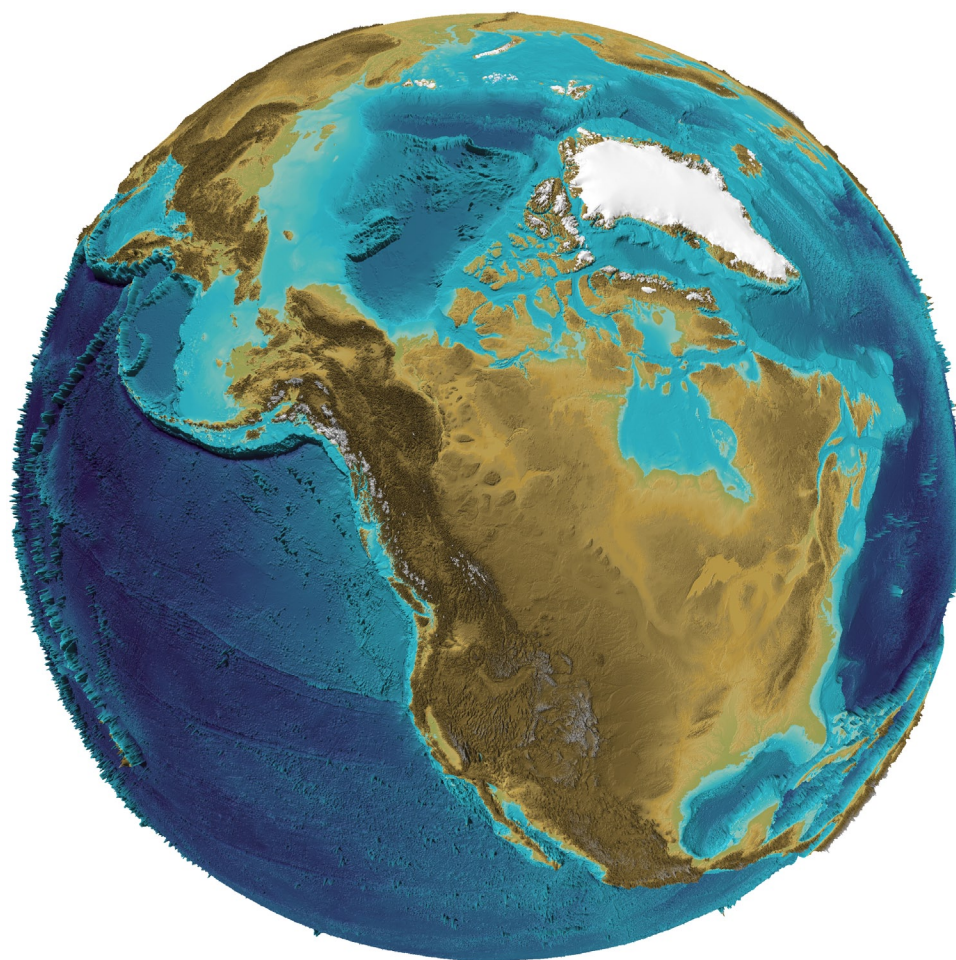


# **The Compilation and Analysis of Data Relevant to a U.S. Claim Under United Nations Law of the Sea Article 76: A Preliminary Report**



**Center for Coastal and Ocean Mapping/Joint Hydrographic Center  
University of New Hampshire**

**Durham, N.H.  
May, 2002**

**Larry Mayer, Martin Jakobsson and Andrew Armstrong**



**The Compilation and Analysis of Data Relevant to a U.S. Claim  
Under United Nations Law of the Sea Article 76**

**Center for Coastal and Ocean Mapping/Joint Hydrographic Center  
University of New Hampshire  
Durham, N.H.**

**Larry Mayer, Martin Jakobsson, and Andrew Armstrong**

Funded by NOAA Grant No. NA17OG2285 to the Center for Coastal and  
Ocean Mapping/Joint Hydrographic Center, University of New Hampshire,  
Durham, New Hampshire

## Table of Content

<b>1</b>	<b><i>Executive Summary:</i></b> .....	<b>6</b>
<b>2</b>	<b><i>Introduction:</i></b> .....	<b>8</b>
<b>2.1</b>	<b>Statement of Task</b> .....	<b>8</b>
<b>2.2</b>	<b>Background:</b> .....	<b>9</b>
2.2.1	History of Article 76: (based on “The Law of the Sea: Definition of the Continental Shelf: United Nations, 1993) .....	9
2.2.2	Relevance of Article 76:.....	11
2.2.3	Other Relevant Articles in UNCLOS:.....	12
2.2.4	Implementation of Article 76: .....	13
<b>3</b>	<b><i>Outline of Approach:</i></b> .....	<b>20</b>
<b>3.1</b>	<b>Identify all major sources of data:</b> .....	<b>20</b>
3.1.1	Bathymetric, seismic and other geophysical data .....	20
3.1.2	Relevant data compilations: .....	22
<b>3.2</b>	<b>Attribution of Data Quality:</b> .....	<b>23</b>
<b>3.3</b>	<b>Put data into ORACLE database:</b> .....	<b>24</b>
<b>3.4</b>	<b>Analysis and Map Products:</b> .....	<b>24</b>
3.4.1	Overview Maps and Selection of Detailed Areas: .....	24
3.4.2	Identify Key Data Sets for Each Detailed Study Area: .....	25
<b>3.5</b>	<b>Identify gaps in existing database:</b> .....	<b>26</b>
<b>3.6</b>	<b>Estimate effort needed to fill data gaps:</b> .....	<b>28</b>
3.6.1	Defining the Survey Box:.....	28
3.6.2	Recommended Survey Approach (Bathymetry): .....	28
3.6.3	Recommended Survey Approach (Seismic): .....	29
<b>3.7</b>	<b>Estimate Costs to fill data gaps:</b> .....	<b>30</b>
3.7.1	Bathymetry .....	30
3.7.2	Seismic .....	30
<b>3.8</b>	<b>Boundaries With Other Nations</b> .....	<b>30</b>
<b>4</b>	<b><i>Methodology</i></b> .....	<b>32</b>
<b>4.1</b>	<b>Collection and transfer of bathymetric trackline and survey polygon data</b> .....	<b>32</b>
4.1.1	NGDC.....	32
4.1.2	U.S.G.S.....	33
4.1.3	NIMA .....	34
4.1.4	Academic institutions and other data providers .....	34
4.1.5	IBCAO .....	35
<b>4.2</b>	<b>Collection and transfer of seismic trackline data</b> .....	<b>35</b>
4.2.1	NGDC.....	35
4.2.2	U.S.G.S.....	35

4.2.3	Minerals Management Service (MMS):.....	36
<b>4.3</b>	<b>Attribution of navigational data quality .....</b>	<b>37</b>
<b>4.4</b>	<b>Collection of additional base data.....</b>	<b>39</b>
4.4.1	NGDC sediment thickness .....	39
4.4.2	WVS/ Digital Chart of the World .....	39
4.4.3	US Territorial baseline points and EEZ limits .....	39
4.4.4	GDA .....	39
4.4.5	IBCAO .....	39
4.4.6	ETOPO2/ETOPO5 .....	40
<b>4.5</b>	<b>Database schema and import to Oracle 9i Object Model.....</b>	<b>40</b>
4.5.1	Reformatting ASCII input data by Perl scripting.....	41
4.5.2	Importing data using SQL-Loader .....	42
<b>4.6</b>	<b>Intergraph's Geomedia Professional: Interface to Oracle Object Model.....</b>	<b>43</b>
<b>4.7</b>	<b>Deriving Article 76 major components using Caris LOTS .....</b>	<b>43</b>
<b>4.8</b>	<b>GIS analyses and map production.....</b>	<b>44</b>
<b>5</b>	<b>Results:.....</b>	<b>46</b>
<b>5.1</b>	<b>Coterminous US and Alaska .....</b>	<b>47</b>
5.1.1	North East Atlantic (Detailed Map NE).....	47
5.1.1.1	General Bathymetry .....	47
5.1.1.2	Existing bathymetry data in area .....	47
5.1.1.3	Estimated bathymetry survey cost.....	47
5.1.1.4	Sediment thickness.....	48
5.1.1.5	Existing seismic data in area .....	48
5.1.1.6	Estimated seismic survey cost.....	48
5.1.2	South East Atlantic (Detailed map SE) .....	49
5.1.2.1	Bathymetry .....	49
5.1.2.2	Existing bathymetry data in area .....	49
5.1.2.3	Estimated bathymetry survey cost.....	49
5.1.2.4	Sediment thickness.....	49
5.1.2.5	Existing seismic data in area .....	50
5.1.2.6	Estimated seismic survey cost.....	50
5.1.3	Gulf of Mexico (Detailed Map MG) .....	50
5.1.3.1	Bathymetry .....	50
5.1.3.2	Existing bathymetry data in area .....	50
5.1.3.3	Estimated bathymetry survey cost.....	51
5.1.3.4	Sediment thickness.....	51
5.1.3.5	Existing seismic data in area .....	51
5.1.3.6	Estimated seismic survey cost.....	51
5.1.4	Gulf of Alaska (Detailed Map GA).....	51
5.1.4.1	Bathymetry .....	52
5.1.4.2	"Bay of Bengal Clause" application along the Alaskan Panhandle .....	52

5.1.4.3	Existing bathymetry data in area .....	53
5.1.4.4	Estimated bathymetry survey cost.....	53
5.1.4.5	Sediment thickness.....	53
5.1.4.6	Existing seismic data in area .....	53
5.1.4.7	Estimated seismic survey cost.....	53
5.1.5	Aleutian Islands and Bering Sea (Detail Map AL) .....	54
5.1.5.1	Bathymetry .....	54
5.1.5.2	Existing bathymetry data in area.....	54
5.1.5.3	Estimated bathymetry survey cost.....	54
5.1.5.4	Sediment thickness.....	54
5.1.5.5	Existing seismic data in area .....	54
5.1.5.6	Estimated seismic survey cost.....	55
5.1.6	Arctic Ocean (Detailed Map ARC).....	55
5.1.6.1	Bathymetry .....	55
5.1.6.2	Existing bathymetry data in Area.....	56
5.1.6.3	Estimated bathymetry survey requirements: .....	56
5.1.6.4	Sediment thickness.....	56
5.1.6.5	Existing seismic data in area .....	56
5.1.6.6	Estimated seismic survey requirement.....	56
5.1.6.7	Estimated combined bathymetric and seismic survey cost .....	57
<b>5.2</b>	<b>US Islands in the Pacific Ocean .....</b>	<b>57</b>
5.2.1	Hawaiian Islands .....	57
5.2.2	Johnson Atoll.....	58
5.2.3	American Samoa .....	58
5.2.4	Mariana Islands (Detailed map MI) .....	58
5.2.4.1	Bathymetry .....	58
5.2.4.2	Existing bathymetry data in area .....	59
5.2.4.3	Estimated bathymetry survey cost.....	59
5.2.4.4	Geophysical Data .....	59
5.2.5	Wake Island.....	59
5.2.6	Kingman Reef and Palmyra Atoll (Detailed Map KP) .....	59
5.2.6.1	Bathymetry .....	59
5.2.6.2	Existing bathymetry data in area.....	60
5.2.6.3	Estimated bathymetry survey time and cost.....	60
5.2.7	Baker and Howland Islands.....	60
5.2.8	Jarvis Island.....	60
<b>6</b>	<b>Summary and Recommendations:.....</b>	<b>63</b>
<b>6.1</b>	<b>Recommendations:.....</b>	<b>69</b>
<b>7</b>	<b>References: .....</b>	<b>73</b>

## 8 *Appendices*

Appendix A:	United Nations Convention on the Law of the Sea:
Appendix B:	Organizations and Individuals collaborating in study
Appendix C:	Appendix -Commission on the Limits of the Continental Shelf
Appendix D:	Statement on Proprietary Data from MMS
Appendix E:	Sonar Specifications
Appendix F:	Coakley and Brass, 2002: Mapping the US Arctic Ocean Margin
Appendix G:	Lookup Table for Assignment of Navigational Accuracy
Appendix H:	Tables of Trackline, Survey Polygon and Point Sounding Data Stored in the Oracle 9i CCOM/JHC Database
Appendix I:	Small Versions of Maps Supplemented With This ReportExecutive Summary

## 1 EXECUTIVE SUMMARY:

Under Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS), coastal states may claim sovereignty over “submerged extensions of their continental margin” beyond the recognized 200 nautical mile limit of their Exclusive Economic Zone. The circumstances that define whether a coastal state can extend its jurisdiction are based on a complex set of rules that involve the analysis of the depth and shape of the seafloor in the areas of interest, as well as the thickness of the underlying sediment. Thus the proper implementation of Article 76 requires the collection, assembly, and analysis of a body of relevant hydrographic, geologic, and geophysical data according to the provisions outlined in the Article.

The United States has not yet acceded to the UNCLOS, but growing recognition that implementation of Article 76 could confer jurisdiction and management authority over large (and potentially resource-rich) areas of the seabed beyond our current 200 nautical mile (nmi) limit has renewed interest in the potential for a U.S. claim. In this context, Congress (through NOAA) has funded the University of New Hampshire’s Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC) to evaluate the content and completeness of the nation’s bathymetric and geophysical data holdings in areas surrounding the nation’s EEZ with emphasis on assuring their usefulness for substantiating the extension of resource or other national jurisdictions beyond the present 200 nmi limit.

Working in collaboration with NOAA’s National Geophysical Data Center, The U.S. Geological Survey and several consultants, the CCOM/JHC collected and assembled all available relevant data into a sophisticated database and Geographic Information System (GIS) for analysis. This database is one of the most efficient of its kind and will be useful for a number of tasks beyond the Law of the Sea project. Using these tools we chose areas surrounding the U.S. where there is **potential** for a claim of an extended continental shelf under Article 76. Areas identified for detailed study included most of the U.S. east coast, the Gulf of Mexico, the Alaskan margin, the Arctic margin, and the areas around Guam and Palmyra Atoll. **We emphasize that this exercise is not designed to establish a U.S. claim but rather to explore regions where there might be potential for an extended claim.** Each area was analyzed to determine the critical data sets required to make a claim for an extended continental shelf under Article 76 (e.g., the 2500 m isobath, the foot of the slope, or the point where the sediment thickness is 1 percent of the distance back to the foot of the slope).

There are few explicit descriptions, and no precedents, that define data acceptable for submission in support of a claim for an extended continental shelf under UNCLOS Article 76. Based on data density alone, existing bathymetric data within most of the U.S. EEZ (with the exception of the Arctic) would probably be sufficient for making a claim. However, the relative positional uncertainty and low resolution with which the bathymetry can be defined in older data sets makes any definition of the 2500 m isobath or the foot of the slope subject to question. We thus recommend the collection of

modern, high-density, complete coverage multibeam sonar data in those areas where the possibility of an extension of the continental shelf depends on delineating either the 2500 m isobath or the foot of the slope. In addition, having well-navigated, complete, high-density coverage of the critical areas of the EEZ also opens up the possibility of maximizing or optimizing a claim (see figures 6.1-6.4). Such data can also serve a range of other environmental, geologic, engineering, and fisheries habitat needs. Therefore, we have defined a bathymetric data “gap” as those regions where we lack either multibeam or very dense modern single beam echo-sounding data. We estimate the total cost of bathymetric data acquisition needed to fill these gaps (with the exception of the Arctic) to be approximately \$10M at 2002 rates. We recommend that a careful analysis of the cost/benefit of surveying in particular regions be carried as a prelude to any data acquisition. For example, it is clear that there is potential for a substantial increase in the area of the continental shelf along the eastern margin of the U.S. and that there may be potential for only a small gain in continental shelf area (if any) in the Pacific Island regions. The Arctic poses special logistical challenges as either icebreakers or nuclear submarines are necessary to collect data in ice-covered regions. The U.S. Arctic Research Commission has estimated that the cost to collect both bathymetry and seismic data in the Arctic in support of a Law of the Sea claim would be approximately \$12M.

Definition of a data gap for seismic (sediment thickness) data is more difficult to quantify as the determination of the adequacy of existing seismic data requires time-consuming interpretation by expert geologists and geophysicists. No new seismic data acquisition should be planned (with the exception of the Arctic) until the adequacy of the existing seismic data is determined. We thus recommend that the U.S.G.S. undertake a study evaluating the adequacy of current seismic data holdings. In the course of such a study, experts from the U.S.G.S. may also explore the potential for the existence of “evidence to the contrary” (i.e., geophysical evidence that may allow an even larger extension of the definition of the continental shelf under Article 76) that could be of advantage to the U.S. in making a claim under Article 76. The U.S.G.S. estimates the cost of such a study to be approximately \$400,000.00. Once the adequacy of the existing seismic data is determined, CCOM/JHC can recommend strategies for new data acquisition. If all the existing data in the database is adequate, then, with the exception of the Arctic, no further acquisition of seismic data will be necessary. To provide an upper-cost constraint, we have estimated the cost to collect all new multichannel seismic data at a density required for making a claim (a very unlikely scenario). At 2002 rates we estimate the cost of full seismic data acquisition to be \$22M-\$25M.

Finally, we also recommend that studies be carried out to develop algorithms and techniques that can optimize a U.S. claim for an extended continental shelf based on newly collected multibeam sonar data. Such a study would propose approaches for using the detailed bathymetry provided by multibeam sonar, in conjunction with a full understanding of the constraints of Article 76, to determine how to maximize a claim based on careful selection of the line segments used to make the claim (as demonstrated in figures 6.1-6.4).

## **2 INTRODUCTION:**

### **2.1 Statement of Task**

Under Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS), coastal states may claim sovereignty over “submerged extensions of their continental margin” beyond the recognized 200 nautical mile limit of their Exclusive Economic Zone. The United States has not yet acceded to the UNCLOS, however, a recent claim by Russia for extension of their limits in the Arctic and Bering Seas, as well as the recognition that implementation of Article 76 could confer jurisdiction and management authority over large (and potentially resource-rich) areas of the seabed beyond our current 200 nautical mile limit (nmi), has renewed interest in the potential for a U.S. claim. Article 76 of UNCLOS (Appendix A) provides several mechanisms by which a coastal state can claim an extension of its continental margin -- each of these involves the analysis of some combination of coastline, bathymetric or geophysical data. Given the growing interest in a potential U.S. claim under Article 76 and the recognition that such a claim would need to be substantiated by high-quality hydrographic and geophysical data, Congress (through NOAA), has funded the University of New Hampshire’s Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC) to evaluate the content and condition of the nation’s data holdings in relevant areas and, in particular, to evaluate what needs to be done to bring these data holdings to a state of completeness such that they may be used, with full confidence, for substantiating the extension of resource or other national jurisdictions beyond the present 200 nmi limit.

Specifically, the CCOM/JHC has been asked to:

1. analyze data needs to identify where existing data are sufficient for delineation of the continental margin as defined in Article 76;
2. identify where data gaps exist
3. determine the survey requirements needed to fill identified data gaps
4. identify the resources required for these surveys
5. outline options for conducting the required surveys
6. complete the initial phase of the study by 31 May 2002

The project began in December 2001 and thus the total time available for these tasks was less than six months. In order to complete this massive undertaking in the short time available, the CCOM/JHC worked closely with several organizations and individuals who made important contributions to this effort. These organizations and individuals are listed in Appendix B; their contributions will be discussed in within the report.

**The tasks described above do not include the preparation of a claim for the United States under Article 76; such a task can only be done by official representatives of the U.S. government. However, in order to judge the appropriateness of available data for making a claim, it is critical to understand the details of the implementation of Article 76.** We thus begin the report with a review Article 76 and related UNLCOS provisions, describe the general criteria (and thus data needed) for making a claim under Article 76, and then present the specific approach that we took in evaluating the adequacy of U.S. data holdings with respect to the Article. Once our methodologies and approaches are described, we present the results on an area-by-area basis, identifying for each area the most critical data needed for making a claim. If data gaps exist, we estimate the level of effort needed to fill these gaps and the costs associated with this effort.

## **2.2 Background:**

### *2.2.1 History of Article 76: (based on “The Law of the Sea: Definition of the Continental Shelf: United Nations, 1993)*

In 1945 President Harry Truman issued a proclamation declaring that the United States government “regards the natural resources of the subsoil and seabed of the continental shelf beneath the high seas but contiguous to the coasts of the United States as appertaining to the United States, subject to its jurisdiction and control,” with the continental shelf to be interpreted as those submerged lands covered by no more than 100 fathoms of water (United Nations, 1993). Many other states followed with their own claims but used different definitions of the continental shelf. The United Nations attempted to formalize a definition of the continental shelf in 1958 but this first attempt proved to be too vague and imprecise. Efforts to formalize the definition of the continental shelf continued and in 1970, the General Assembly of the United Nations adopted the “Declaration of Principles Governing the Seabed, Ocean Floor and Subsoil Thereof, Beyond the Limits of National Jurisdiction” (Resolution 2749 (XXV)). This was followed, in 1975 by the Seabed Committee of the Third U.N. Conference of the Law of the Sea, which produced a draft document containing text that became the basis for the definition of the continental shelf found in Article 76 of the United Nations Law of the Sea Convention:

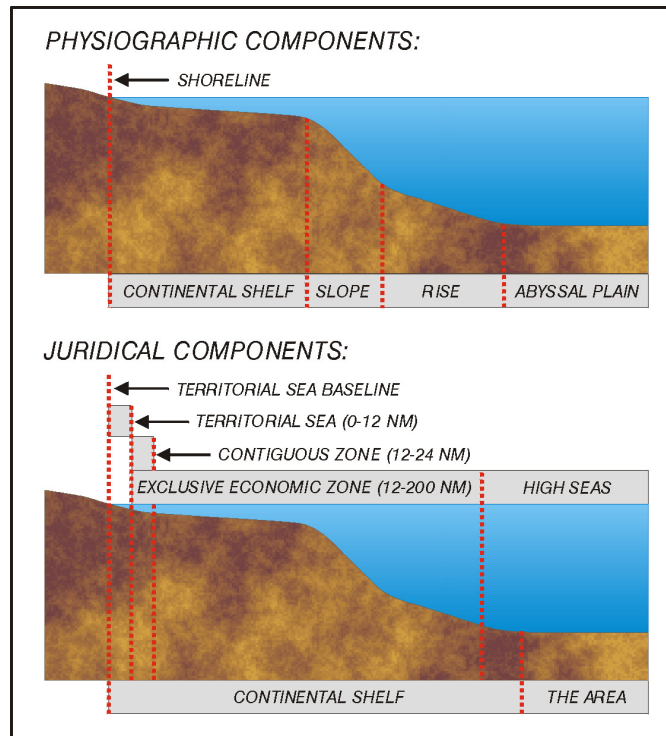
“The continental shelf of a coastal State comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the continental sea is measured where the outer edge of the continental margin does not extend up to that distance.”

This definition embraces several principles that become key elements of Article 76. It upholds the legal concept of the continental shelf and its link to the natural prolongation

of a nation's landmass. It also establishes a link between a legal concept of the continental shelf and the geomorphological concept of the continental margin, and it introduces a distance criteria allowing all states to claim up to 200 nmi even if there is no natural prolongation of their continental margin. While this definition of the continental shelf met general acceptance, concern now turned to how the "outer edge of the continental margin" would be defined.

A number of proposals were put forth regarding the definition of the outer edge of the continental margin of which two were eventually adopted. The first (proposed by H.D. Hedberg of the U.S.) argued that the base of the continental slope was the most natural dividing line between continental and oceanic domains. Because of the uncertainty associated with the location of the base of the slope, Hedberg also proposed that boundary zone of uniform width measured seaward from the best estimate of the base of the slope be established. The second proposal, put forth by P.R Gardiner of Ireland, offered an approach that would allow, in certain circumstances the inclusion of the outer continental rise (consistent with the concept of natural prolongation of the landmass). Recognizing that continental rises are typically represented by a thick wedge of sediment that thins seaward from the base of the slope, Gardiner proposed a definition of the outer limit of the continental margin as that point where the thickness of sediment is 1% of the distance between that point and the foot of the slope.

Gardiner's proposal (also known as the Irish formula) was accepted as part of Article 76 in 1979 as was Hedberg's proposal with the additional stipulation that the outer limits of the continental shelf shall not extend beyond 100 nmi from the 2500 m isobath, OR, not beyond 350 nmi from the territorial baselines. In subsequent negotiations, two other provisions, one dealing with submarine ridges, and one addressing a special situation in the Bay of Bengal were added. With respect to the Bay of Bengal, an Annex was added prescribing a modified procedure for developing an outer limit based on the thickness of sedimentary material. To use "Bay of Bengal Clause" the average distance at which the 200 m isobath occurs must not be more than 20 nmi from the territorial baseline and the sediment thickness along an Article 76 formula line must be greater than 3.5 km. If the first and second criteria apply, then the state is able to establish its outer limit where the sediment thickness is not less than 1 km. With these additions, the completed article was incorporated in the 1982 United Nations Convention on the Law of the Sea (UNCLOS -- see Appendix A for the full text of the Article and the Annex). Under the Convention, each coastal state is charged with establishing the outer limits of its continental shelf where it extends beyond presently established 200 nmi limit of the EEZ. The limits determined by each state are to be submitted to The Commission on the Limits of the Continental Shelf established by the Convention to adjudicate the submission from the coastal states. A detailed description of the Commission and its procedures is presented in Appendix C.



**Figure 2.1.** Physiographic (top) and juridical (bottom) definitions of the continental margin as presented in UNCLOS Article 76. Using physiographic nomenclature, the three components of the continental margin consist of the continental shelf, slope and rise, forming a transition zone between land and the abyssal plain. The juridical nomenclature of UNCLOS defines components that pertain to the seabed and the superadjacent waters: the *territorial sea*, the *Exclusive Economic Zone*, and *high seas*. UNCLOS also defines juridical components that pertain only to the seabed: the *continental shelf* and *the Area*. Note that the juridical continental shelf and the physiographic continental shelf are not the same. (From Macnab and Haworth, 2001).

Before looking at the specific criteria for establishing a claim under Article 76, let us briefly look at several other provisions of UNCLOS that are relevant to extension of continental shelf jurisdiction under Article 76.

### 2.2.3 Other Relevant Articles in UNCLOS:

A number of other articles of UNCLOS define the rights of states who can claim an extended continental shelf under Article 76 and emphasize the potential important benefits of an extended claim to the coastal state. Article 77 defines state's rights within the extended zone of sovereignty, with respect to mineral and other non-living resources of the seabed and the subsoil, and to biological resources that are characterized as sedentary species. While little is known about the value of resources beyond the current EEZ, a recently published study (Murton, et al., 2001) estimates that for the U.S., the value of potential seabed resources (at year 2000 values) available in

### 2.2.2 Relevance of Article 76:

The fundamental importance of UNCLOS Article 76 to coastal states is that based on the complicated set of definitions worked out through the years of negotiations described above, a coastal state can, under certain circumstances, extend their jurisdiction to include resources located beyond the present 200 nautical mile jurisdictional limit of the Exclusive Economic Zone (EEZ). The circumstances that define whether or not a coastal state can extend its jurisdiction are based on the analysis of the depth and shape of the seafloor in the areas of interest, as well as the thickness of the underlying sediment. Thus the proper implementation of Article 76 requires the collection, assembly, and analysis of a body of relevant hydrographic, geologic, and geophysical data according to a series of provisions outlined in the Article.

In its final form, Article 76 of UNCLOS defines the continental margin as the “submerged prolongation of a coastal state’s landmass” that consists of seabed and subsoil of the continental shelf, slope, and rise and not including the deep ocean floor or ocean ridges. This definition is based only the *physiographic components* of the continental margin as illustrated in upper part of Figure 2.1.

UNCLOS also refers to *juridical components* of the continental margin as illustrated in the lower part of Figure 2.1. The juridical components may refer to the seabed, the subsoil, or the superadjacent waters (i.e., *the territorial sea, the contiguous zone, the Exclusive Economic Zone, and the high seas*), or to just the seabed and subsoil (i.e., *the continental shelf and the Area*). It is important to note that based on these definitions, the juridical continental shelf is not the same as the physiographic continental shelf – the juridical shelf is defined by the geological and bathymetric criteria established in Article 76 while the physiosgraphic shelf is defined by strictly by the configuration of the seabed adjacent to the coast.

an extended claim may exceed \$1.3 Trillion. Articles 210 and 216 authorize a coastal state to enact and enforce legislation to prevent, reduce, and control pollution caused by dumping within the extended continental shelf, while Articles 246-249 and 253 define the rights and obligations of coastal states with respect to the conduct and promotion of marine scientific research in their EEZ and on their continental shelf.

Finally, it is important to note that extending the continental shelf beyond the present 200 nmi limit creates a lasting change in a coastal state's configuration. While in some cases there will be obvious and immediate benefits derived from an extension, in others, benefits may only arise in time as technological improvements provide access to known resources that are presently beyond reach, and exploration provides new discoveries of yet unrecognized resources. The exploitation of such resources will be greatly facilitated if jurisdiction is clearly established.

#### *2.2.4 Implementation of Article 76:*

The implementation of Article 76 entails the analysis and interpretation of three classes of geoscientific information:

1. the shape of the seabed;
2. the depth of water, and ;
3. the thickness of the underlying sedimentary material.

It also requires geodetic computations for the accurate derivation of the horizontal coordinates of certain key features upon the ellipsoid of revolution. Included in features that need to be determined are:

1. geodetic distances from the coastal state's territorial baselines;
2. the 2500 m bathymetric contour;
3. the "foot of the slope", and;
4. the thickness of the sedimentary section with respect to the position of the foot of the slope.

Table 2.1 outlines the operations and the classes of information that figure in this process. The table is followed by a general description and overview of these operations. A full description of the implementation process can be found in the Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf (United Nations, 1999).

**Table 2.1.** Technical procedures for determining the outer limit of the juridical continental shelf.

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

*A. Does a natural prolongation exist?*

The first criteria for determining whether or not a coastal state can extend the outer limit of their continental shelf beyond the 200 nmi limit of the EEZ is to determine whether a not a natural prolongation of the continental shelf exists. Unfortunately, neither the Article nor the Commission provides a precise definition of what constitutes a “natural prolongation” of a state’s land territory. The determination must be based on a general knowledge and interpretation of the bathymetry and nature of the seafloor in a region. For example, if a coastal state has a narrow physiographic shelf bounded by a seaward subduction zone (which clearly indicates the transition from continental to oceanic crust) there is no natural prolongation of the continental shelf. The detailed procedures described below for determining the possibility of an extended juridical continental shelf are applied only to those areas that can demonstrate some indication (broad shelves or other extended plateaus and/or thick sediment sections) that suggest a natural prolongation of the continental shelf.

### *B. Delineating the foot of the slope*

For those areas deemed to exhibit the criteria of a natural prolongation of the continental shelf, the detailed tests outlined in Article 76 are applied. The first step in this process is the determination of 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*. Accurate determination of the foot of the slope is important as it 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 coordinates 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 positioning and sounding equipment (wide-beam vs. narrow-beam, single-beam vs. 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 (i.e. regional slopes). In the presence of detailed multibeam sonar data, an accurate 3-dimensional model of the continental slope can be developed, facilitating the determination of the foot of the slope and possibly providing a means of increasing significantly the size of an extended claim (see figures 6.1-6.4).

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 or upon digital models that use regularly-spaced grid points to describe the shape and depth of the sea floor (Ou and Vanicek, 1996). The CCOM/JHC have developed a suite of software tools especially suited for the analysis of 3-dimensional bathymetric data (see figures 6.1-6.4).

### *C. Apply the distance formula:*

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 whose locations are determined with respect to the foot of the continental slope, in accordance with the either the *distance formula* or the *sediment thickness formula*. The *distance formula* involves a simple projection of the foot of the slope seaward for a distance of 60 nmi. This is best accomplished numerically, using geodetic software that automatically calculates a series of coordinates which define a series of intersecting arcs centered

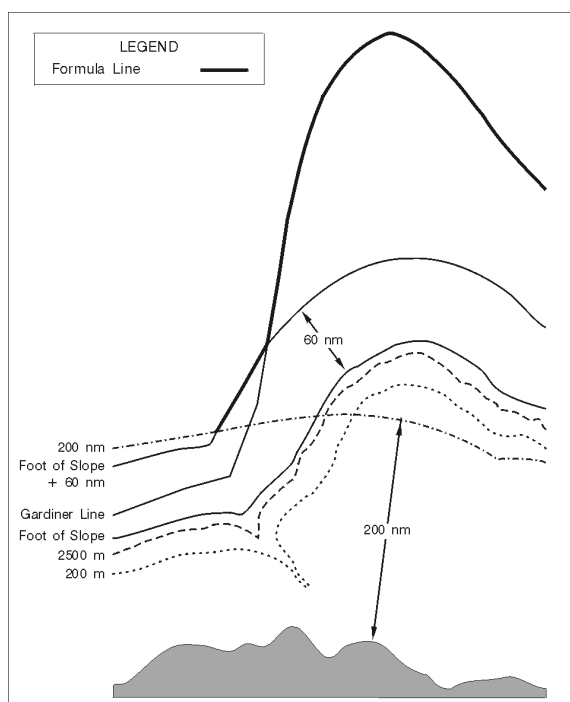
upon a succession of points located along the line that delineates the foot of the slope. Uncertainties in the position of the distance formula line are simply the errors associated with the determination of the foot of the slope.

*D. Apply the sediment thickness formula:*

Once the foot of the slope is determined, the point where the thickness of sedimentary rock beneath the ocean floor becomes one percent of the distance back to the foot of the slope can be determined. Applying the sediment thickness formula (the Irish formula) is potentially a complex and expensive operation as it requires the collection of bathymetric data as well as seismic data capable of determining the thickness of the sediment column. Depending on the suitability of existing data, a costly field program for measuring the thickness of sedimentary rock beneath the ocean floor may be required. As described earlier, the limit defined by a succession of such points is known colloquially as the Gardiner Line. Uncertainties in measurement and interpretation of the seismic data may give rise to some ambiguities in the application of this formula. One possible source of error is related to the fact that the two-way seismic travel time (that is directly measured by a seismic system) can only be converted to depth (or sediment thickness) with an accurate knowledge of the speed of sound in the sediment column. The acquisition of sound speed data implies the collection of multichannel seismic data, refraction experiments or the drilling of boreholes, all of which are expensive. Once the interpreter has made some reasonable assumptions about the nature and distribution of the sedimentary material, the determination of the one percent line should be relatively straightforward. It is important to note however, that the Gardiner Line is measured with respect to the foot of the slope so any errors in interpretation of sediment thickness are compounded with the errors in determining the foot of the slope.

*E. Combine C&D – Construct the Formula Line*

It is not mandatory to apply uniquely the distance formula or the sediment thickness formula throughout the study area, and in any given 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 nmi. The process of developing a composite line is illustrated in Figure 2.2. For convenience and to acknowledge the technique of its derivation, the term *formula line* is sometimes used to describe this line.



**Figure 2.2.** 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)

#### *F. Determine the 350 nmi cutoff*

Regardless of the method chosen for its delineation, the outer limit cannot in general, extend beyond a maximum of 350 nmi from the state's territorial sea baselines, or 100 nmi beyond the 2500 m isobath, whichever is greater. The *350 nmi limit* consists of a series of circular arcs centred upon the coastal state's Territorial Sea Baseline. The Territorial Sea Baseline (or baseline) is normally taken as the low-water line along the coast as marked on large-scale charts officially recognized by the coastal state. In other words it is the coastline that appears on the official charts of the state. 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 coordinates in digital form that can be saved for later use in portraying this feature on charts at a variety of scales and projections.

#### *G. Project the 2500 m isobath 100 nmi*

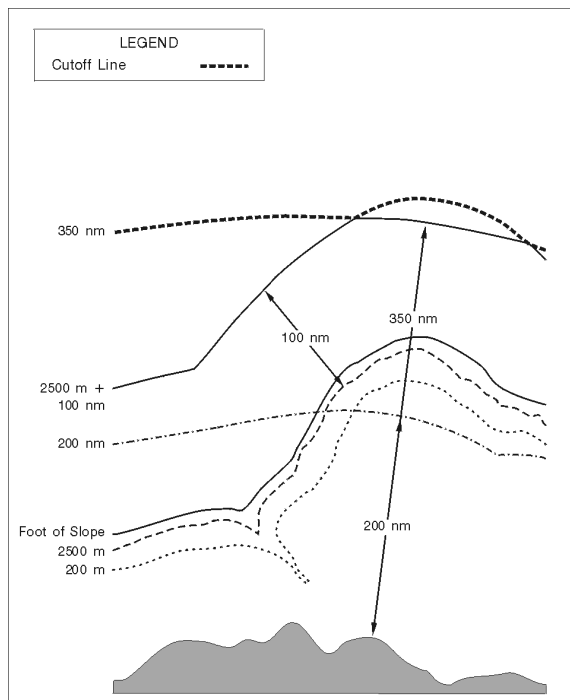
The next step in establishing a potential extension of the continental shelf under Article 26 involves the determining a line 100 nmi seaward of the 2500 m isobath, a compromise added to Article 76 to address concerns over the uncertainty associated with determining the foot of the slope. In some senses determining the location of the *2500 meter isobath plus 100 nmi* is more problematic than determining the foot of the slope because it necessitates an accurate measurement of absolute water depth. Current international specifications require the accuracy to be plus or minus 2.3% of the water depth. Along with any inaccuracies in the depth measurements, inaccuracies in position also add to potential uncertainties in the location of the 2500 m isobath. Again, it is left

to the interpreter to make reasonable assumptions about the location of this feature, after which the 100 nmi projection can be constructed in a manner that is entirely analogous to the method applied when applying the distance formula.

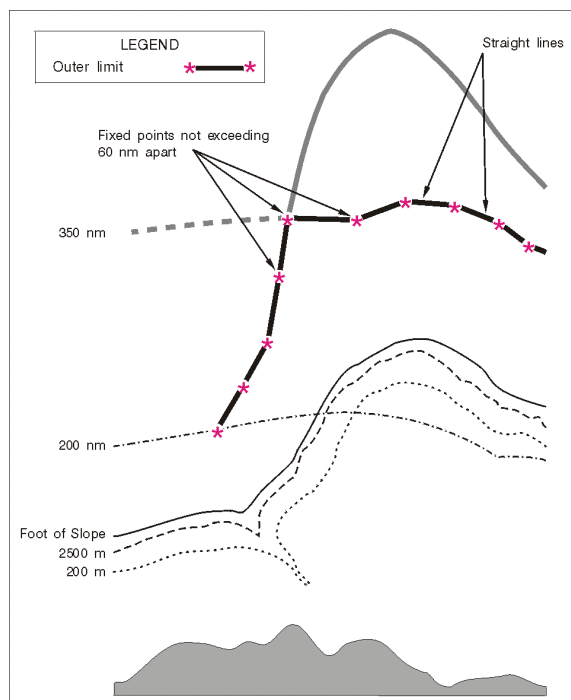
*H. Combine F & G: the cutoff line:*

As with the formula lines, segments of the two limits constructed above (the 350 nmi limit or the 2500 m isobath +100 nmi limit) may be combined into a single *cutoff line* that encloses the largest possible area beyond 200 nmi and which defines the maximum extent of the outer limit of the continental shelf. The process of developing this line is illustrated in Figure 2.3. 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 formula line 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 cutoff line 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 2.4. 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 nmi in length.



**Figure 2.3.** Illustrating the process of amalgamating segments of the 350 nmi limit and the 2500 metre isobath plus 100 nmi, to develop a composite *cutoff line*. The drawing is not to scale. (adapted from Royal Society, 1982)



**Figure 2.4.** Illustrating the integration of components of the formula line (developed in Figure 1-2) and of the cutoff line (developed in Figure 1-3), 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)

### 3 OUTLINE OF APPROACH:

Charged with evaluating the content and condition of existing relevant data holdings in all areas where the U.S. may have a potential claim for extension of the continental shelf beyond the present 200 nmi limit, the Center for Coastal and Ocean Mapping/Joint Hydrographic Center established a work plan and approach that would allow completion of the initial phase of the task within the required time period. A flowchart of the work plan and approach is illustrated in Figure 3.1; it is summarized in the text below.

#### 3.1 Identify all major sources of data:

##### 3.1.1 *Bathymetric, seismic and other geophysical data*

Clearly, one of the most challenging tasks presented to CCOM/JHC was to gather all existing data available in the U.S. EEZ. As outlined in the background section, the fundamental data needed to identify the potential for an extended continental shelf includes:

1. Territorial baselines
2. Bathymetry (to provide the position of the foot of the slope and the position of the 2500 m contour)
3. seismic data (to provide sediment thickness information)

Additional data, like gravity or magnetics can also be useful if questions about the nature of the crust (oceanic or continental) are posed. The challenge we thus faced was to gather, in less than five months, all the existing, bathymetry, seismics, and other geophysical data collected in the U.S. EEZ and relevant to making a claim under Article 76. This is a very daunting task as the Navy, academic institutions, NOAA, the U.S.G.S., MMS, the private sector and others have all been collecting these sorts of data for more than 50 years. Fortunately, the U.S. has established, under NOAA, The National Geophysical Data Center (NGDC) an organization charged with being the central repository for bathymetric and geophysical data sets in the U.S. Contacts and a subcontract were immediately established with NGDC beginning a collaborative effort that allowed the transfer of all relevant holdings (bathymetry, seismic, magnetic, and gravity data) to the CCOM/JHC Law of the Sea (CCOM/JHC LOS) database in a timely manner. The details of this data transfer will be presented in the methodology section.

While the NGDC provides a wonderful resource and starting point for the data collection effort, it unfortunately does not hold all data available. In order to seek other sources of data we also subcontracted with Norm Cherkis, a former Naval Research Lab employee and expert on bathymetric data. Mr. Cherkis' charge was to search for relevant data sets in the U.S. and around the world that were not in the NGDC data set. He provided a number of these (including a very large set of data from NIMA). **One of the immediate beneficial outgrowths of this project is the**

**identification of these data sets that were not in the NGDC repository but that now will be.** It should be noted that both the Navy and NIMA also hold a substantial amount of classified bathymetric data, some of which may be relevant to the LOS study. We have made no attempt to access this data during this phase of the project as even if it were eventually possible, the appropriate arrangements could never have been made within the limited time frame. While every attempt has been made to identify and locate all sources of data available, it is inevitable that there is still some data that has yet been discovered. We will continue to search for data into Phase 2 of the project and will update the database as new data is found.

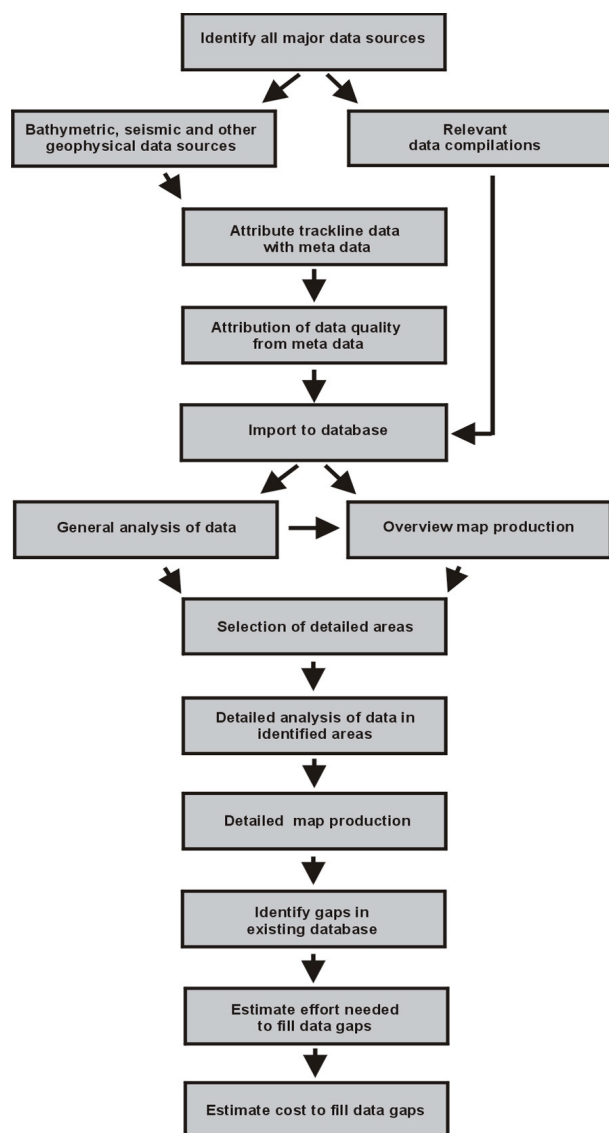


Figure 3.1 Flowchart of the work plan and approach.

Seismic data presents several special challenges. First of all much of it is collected by the private sector and is proprietary in nature. Secondly, to use seismic data for the purpose of defining the Gardiner Line, it is necessary to determine just how thick the sediment section is – a process that requires knowledge of the speed of sound in the sediment column (either through multichannel seismics, refraction experiments or boreholes) as well as interpretation by a skilled geologist or geophysicist. To help with these challenges, we established a collaboration and subcontract with the U.S. Geological Survey (U.S.G.S.), the agency charged with the responsibility of understanding our nation's geological and geophysical framework. The U.S.G.S. also works closely with the Mineral Management Service (MMS), the agency that works with industry when industrial seismic data is collected. Through the U.S.G.S., we were able to get access to non-proprietary MMS data. In addition MMS hold a substantial amount proprietary data that will be available under some conditions for a future preparation of a US claim (see Appendix D). As with the bathymetric data, we have attempted to locate all available seismic data sources. Both we, and the U.S.G.S., will continue to search for seismic data into Phase 2 of the project and will update the database if any is found. Details of the transfer of U.S.G.S. seismic data to the CCOM/JHC LOS database are presented in the methodology section.

### *3.1.2 Relevant data compilations:*

Along with discrete data sets described above, there are also several data compilations that are very relevant to the assigned tasks (including bathymetry, sediment thickness and baseline data). The next step was then to collect all available data compilations that were relevant to the task and add them to the CCOM/JHC LOS database. These data sets include:

1. ETOPO-5 – a 5-minute latitude/longitude (approximately 5 mile) digital global grid of seafloor and land elevations. This bathymetry is based strictly on single beam sonar data collected over a number of years (Data Announcement 88-MGG-02, 1988).
2. ETOPO-2 – a newly released gridded digital dataset of ocean depth and land elevation with approximately 2-minute latitude/longitude (approximately 2 mile) grid spacing. This data set is based on a seafloor compilation between latitudes 64° North and 72° South from Smith and Sandwell (1997). Their compilation is derived from satellite altimetry observations combined with carefully, quality-assured shipboard echo-sounding measurements. The seafloor compilation south of 72° South are from the US Naval Oceanographic Office's (NAVOCEANO) Digital Bathymetric Data Base Variable Resolution (DBDBV), version 4.1, gridded at 5 minute spacing, and in some regions from the older DBDB5 that also was used in ETOPO-5. For the Arctic region north of 64° North ETOPO-2 consist of a sub sampled version of the International Bathymetric Chart of the Arctic Ocean (IBCAO)

Version 1 (see below). ETOPO-2 is available through NGDC at <http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html>)

3. GEBCO Digital Atlas (GDA) is comprised of digital contours, digitized from the General Bathymetric Chart of the Oceans (GEBCO) bathymetry chart series, released on a CD-ROM. The GDA is available from <http://www.ngdc.noaa.gov/mgg/gebco/gebco.html>.
4. Coastal Relief Model – gridded bathymetric data sets for selective coastal regions collected by NOAA NOS and provided as gridded digital terrain models with variable sample spacing (depending on region). Data available through NGDC on a series of CD's. <http://www.ngdc.noaa.gov/mgg/coastal/coastal.html>
5. Sediment Thickness Database: A global compilation and interpolation of interpreted seismic data and other sediment thickness compilations presenting a crude estimate of sediment thickness. This is a gridded product with 5 minute (approximately 5 mile) grid spacing that is provided by NGDC at <http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html>.
6. The International Bathymetric Chart of the Arctic Ocean (IBCAO) - a gridded bathymetry compilation combined with land elevations from ETOPO 30 for the Arctic region above 64° North. IBCAO provides a polarstereographic grid with 2500 m cell spacing and a 1-minute latitude/longitude grid for download at <http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/arctic.html>. The first version of IBCAO was released in the spring of 2000 (Jakobsson *et al.*, 2000).
7. Sedimentary Thickness Map of the Arctic Ocean – a printed contour sediment thickness map of the Arctic Ocean compiled by Jackson and Oakey (1990) from seismic reflection and refraction data and other sediment compilations.

Digital territorial baseline data and official EEZ limit data were also acquired from the following sources:

1. Coastlines were obtained from the World Vector Shoreline (WVS) provided by NIMA (1:250,000 --- 1:1,000,000)
2. U.S. Territorial baselines from the Digital Chart of the World – NIMA
3. U.S. Territorial baselines and EEZ limits – provided by NOAA NOS

### **3.2 Attribution of Data Quality:**

While the compilation of all available data is clearly the first step in evaluating the need for further data collection, an attempt must also be made to understand the

quality of the available data. The data available in the national archives has been collected over the last 50 years using a wide array of sonar and navigation systems. The accuracy of the determination of many of the key features used for making a claim for an extended shelf under Article 76, will be dependant on the type of sonar and navigation system used (e.g., the 2500 m isobath, the foot of the slope, etc.). Given the relatively small uncertainties associated with a sonar's ability to measure depth (typically 10's of meters in the worst cases) compared to the large uncertainties associated with many of the older positioning systems (on the order of km's), it is uncertainty in positioning that will dominate the errors associated with a claim under UNCLOS Article 76. For example, data collected using celestial navigation will have a much higher degree of uncertainty than data collected using the Global Positioning System for navigation. Thus a claim based on GPS-based data will be much more reliable than those based on non-GPS navigated data. It is thus critical to learn as much possible about the data collected (i.e., where, when and how it was collected), create "metadata" files describing these attributes of the data (if not already available) and then finally assigning a level of uncertainty for each data set. The details of this process are described in the methodology section.

### 3.3 Put data into ORACLE database:

Once collected and attributed, the data was converted to a format suitable for entrance into an Oracle 9i database. This transformation was done with the assistance of a consultant from Intergraph who specializes in the management of geophysical data in Oracle databases. Data reformatting and entry went very smoothly with the result being **a database of 39861 tracklines from various ship cruises, 6037 bathymetry survey polygons and several millions of soundings** ready for instantaneous access, sorting and analyses. The Oracle database was linked to Intergraph's GeoMedia Professional GIS package, allowing displays and maps to be created from any combination of data sets. **We believe that the resulting database is one of the most efficient of its sort available and will be useful for a range of tasks beyond the Law of the Sea project.** Details of the data reformatting, the Oracle database and the Intergraph GIS are presented in the methodology section.

### 3.4 Analysis and Map Products:

#### 3.4.1 *Overview Maps and Selection of Detailed Areas:*

Once all data and metadata have been entered into the Oracle database and the Intergraph GIS, the analytical process can begin. In preparation for later analyses a series of overview maps were generated showing the location of all available bathymetric data (Appendix I: *Tracklines*), the location of all available seismic data (Appendix I: *Seismic-tracklines*), as well as overview plots showing where NOAA NOS detailed survey data (Appendix I: *NOS-Polygons*) and multibeam sonar data (Appendix I: *Multibeam-surveys*) are available. To make these maps, series of

cartographic decisions were made regarding common datums, projections and scales. Details of the map production are presented in the methodology section.

The first step in the analysis was to identify those areas surrounding the U.S. where there is potential for a claim for an extended continental shelf under Article 76 (and eliminate areas where there is no potential). This was done so that the effort could be focused only on those areas for which there was hope for an extended claim. This step is the “test of appurtenance” described by the Commission of the Limits of the Continental Shelf, but, as described earlier, one for which subjective decisions must be made (particularly with respect to the demonstration of the “natural prolongation” of the land territory. To establish whether or not a region had **potential** for an existing claim, we produced a series of overview maps that show the best estimate of bathymetry (based on ETOPO-2 compilation), the compiled sediment thickness data, the existing territorial baselines, the official 200 nmi EEZ limits, a rough estimate of the foot of the slope, and the formulae and cutoff lines, determined as described in the section on implementation of Article 76. The details of approach used for determining the foot of the slope are described in the methodology section. **We emphasize that this exercise is not designed to establish a U.S. claim but rather to explore regions where there might be potential for an extended claim.** The data compilations used allow an overview of general bathymetry and sediment thickness; they are probably not detailed enough to be used to make a claim under Article 76.

Based on this procedure, we identified those areas surrounding U.S. territory, for which there may be potential to claim a continental shelf beyond the current 200 nmi EEZ limit (Appendix I: *Detailed-maps*). In doing this we were as conservative as possible so that we would not eliminate any area that may have even the slightest potential. We compared our results to a similar analysis done by the Mineral Management Service (Amato, Thormahlen and Carpenter, 1995; Carpenter, Thormahlen, and Amato, 1996) and found our analysis to be in general agreement with theirs though a bit more conservative (i.e, encompassing a somewhat larger area). Eight regions were identified for further study, including most of the U.S. east coast, the Gulf of Mexico, the Alaskan margin, the Arctic margin, and the areas around Guam and Palmyra Atoll. A narrow continental shelf and/or lack of thick sedimentary sections eliminated the U.S. west coast, as well as areas around Hawaii, Puerto Rico, Johnston Atoll, American Samoa and Wake Island.

#### 3.4.2 *Identify Key Data Sets for Each Detailed Study Area:*

For each of the detailed study areas identified, an analysis was done to determine which of the data sets required to make a claim for an extended continental shelf under Article 76 (the 2500 m isobath, the foot of the slope, or the point where the sediment thickness is 1 percent of the distance back to the foot of the slope) was the most critical. For those areas where only bathymetric criteria were important, further analysis was restricted to the bathymetry. However, in most cases a claim will be based on a

combination of data sets and in these areas both bathymetric and seismic data were analyzed. In Section 4 (Results) the critical data sets are discussed area by area.

### **3.5 Identify gaps in existing database:**

The next and most critical step in the analysis involved determining whether the existing database is adequate for making an extended claim under Article 76. To facilitate this analysis, we have, for each detailed study area generated a series of maps that show: 1- all available trackline data in the area color coded by source and overlain on a shaded relief representing ETOPO2 or IBCAO bathymetry; 2- all available trackline data color coded by our estimated navigational fix accuracy; 3- all available trackline data color coded by source without a shaded relief as a backdrop; 4- the availability of high-density NOS data in the survey area and; 5- the distribution of seismic reflection profile data in the detailed study area overlain on sediment thickness information from NGDC or Jackson and Oakey (1990). All of these maps have been assembled in an 21' x 33.5' sized Atlas supplementing this report and are available in digital form for interactive exploration and analysis through the Oracle database and GeoMedia GIS. In addition, Appendix I contains smaller versions of these maps.

Inasmuch as neither UNCLOS Article 76 nor the Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf explicitly state the data density required for a submission, the identification of a “data gap” is inherently a subjective decision. The Commission requires “a full technical description of the bathymetric database” including:

1. source of the data;
2. sounding survey techniques
3. geodetic positioning methods and reference system
4. time and day of the survey
5. corrections applied to the data for speed of sound in water, calibration and other
6. a priori or posteriori estimates of random and systematic errors
7. geodetic reference system
8. geometric definition of straight, archipelagic, and closing baselines

Cartographic products may include:

1. two-dimensional depth profiles
2. three-dimensional depth profiles
3. charts and maps with contours

Each of these must be accompanied by a detailed description of the methodology used to produce the product; the coastal state may be required to also document the methods of interpolation or approximation used, the density of the measured bathymetric data, and perceptual elements such as map projections, vertical and horizontal scales, etc.

Thus a full description of the data is required but no specification with respect to required data density is made.

The only guideline provided by Article 76 with respect to data density is found in Paragraph 7 which states that: “The Coastal State shall delineate the outer limit of the continental shelf, where that shelf extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by coordinates of latitude and longitude.” This paragraph does not explicitly talk about the density of the underlying data but rather the fact that in constructing a claim the proposed limits must be established at intervals no more than 60 nmi apart.

The only clear requirement is that the data submitted must be acceptable to the Commission, but there is no explicit description of, nor precedent yet established for, what is, or is not, acceptable. Given this uncertainty, our approach to identifying “data gaps” has been very conservative (i.e., if there can be any question, we consider an area a data gap). For each of the detailed survey areas we examine the DENSITY of present data holdings as well as the QUALITY (and associated uncertainty) of the existing data (as defined above and in the methodology section). **Based on data density alone, existing bathymetric data within most of the U.S. EEZ (with the exception of the Arctic) would probably be sufficient to for making a claim (i.e., there is enough data to construct bathymetric profiles at least every 60 nautical miles).** However, when the relative quality of much of the older data sets and the resolution with which the bathymetry can be defined are considered, it is clear that the uncertainty associated with these data sets would make any definition of the 2500 m isobath or the foot of the slope subject to question. **In this light, we have defined a bathymetric data “gap” as a region where either multibeam or very dense modern single beam sonar data is not available. Further justification for this approach will be discussed in the Recommendations section.**

Definition of a data gap for seismic (sediment thickness) data is more difficult to quantify. The database collected shows the presence or absence of seismic data but provides no information on the quality of the seismic data nor the most critical aspect of it -- whether or not the seismic data can resolve basement and whether or not sound speed data is available so that the thickness of the sediment section can be defined. **In order to determine whether or not the seismic data are appropriate for a Law of The Sea claim under Article 76, it must be interpreted by geological and geophysical experts.** This is a time-consuming process that could not be done in the time available for this report, but rather a process that should continue in a second phase of the project. In order to set constraints on the potential magnitude of the seismic effort needed, we have, however, tried to establish end-member scenarios. To do this we examined two alternative assumptions: 1- **that none of the seismic data in the database is appropriate** (certainly a very unlikely assumption but one that will at least provide an end-member constraint), or; 2- **that all of the data in the database are fully appropriate** (also not likely but probably much closer to reality).

In the case of seismic data, the 60 nautical mile constraint helps define a reasonable starting point to test for sufficient data density. A simple Nyquist criterion, calls for sampling at twice the required spatial frequency. Thus for the first assumption (that none of the existing seismic data are appropriate) **we assume that a seismic profile is needed every 30 nautical miles.** For the second assumption (that all of the existing seismic data are appropriate) **we define as gaps only those areas for which a seismic profile crossing the margin does not exist every 30 nautical miles.**

### **3.6 Estimate effort needed to fill data gaps:**

#### *3.6.1 Defining the Survey Box:*

Once the data gaps were defined, a strategy for filling them was devised and the level of effort needed to carry out this strategy estimated. For bathymetry, the area to be surveyed was selected based on a general approach of using the best-available compiled bathymetry (ETOPO-2) to generate a slope map (the derivative of the bathymetric surface). Based on both the bathymetry and slope map, an isobath was selected from the GEBCO Digital Atlas so that any possible position of the foot of the slope was seaward of this contour (typically the 2000 m contour). This contour represents the landward limit of the required survey (see for example figure 5.1A). The seaward limit of the proposed survey was selected based on the ETOPO-2 morphology, the slope map and a series of bathymetric cross-sections analyzed using Caris LOTS. The outer limit is typically found to be where the gradient of the seafloor topography is less than 0.5 degrees, beyond any possible definition of the foot of the slope (see for example figure 5.1A). Between these limits we define a survey corridor within which the critical bathymetric features for establishing the limits of the continental shelf under Article 76 (the 2500 m contour and the foot of the slope) are found.

#### *3.6.2 Recommended Survey Approach (Bathymetry):*

**Within the corridor defined above (the limits of the zone of uncertainty within which most likely lie the foot of the slope and the 2500 m contour, we propose the collection of modern, high density, full coverage multibeam sonar data in those area where multibeam sonar or modern high-density single-beam sonar data does not already exist.** With modern full-coverage multibeam data, both the foot of the slope and the 2500 m isobath can be defined based on an accurate 3-dimensional model rather than sparse 2-d profiles. Additionally, the dense, full-coverage multibeam data may allow for the optimization of the limits selection (by taking advantage of the detailed bathymetry and the inherent flexibility of Article 76 to choose a series of line segments that maximizes the area of the claim. Figures 6.1-6.4 demonstrate the potential advantages of this approach. For each of the detailed map areas, a plot of the corridor to be surveyed is provided (with regions of existing multibeam sonar or modern high-density single-beam data removed). A detailed description of the specific approach taken in each region is presented in the discussion of the recommended survey areas. **It is important to note that this approach is**

**somewhat subjective and intended to cover the broadest possible location of the FOS in each of the recommended survey areas.**

Given the water depths of the areas to be surveyed (~1000 to 5500 m) as well as the desire to collect full-coverage multibeam bathymetry, the survey systems of choice are deep water (12 kHz) multibeam sonars. Several manufacturers offer 12 kHz multibeam systems and there are numerous installations on both government and private sector vessels. Inasmuch as 12 kHz systems are large, survey vessels of at least 200 feet in length with permanently installed systems will be required. While the detailed specifications of these systems vary somewhat from manufacturer to manufacturer (Appendix E), in general these systems provide a set of 1 to 2 degree beams over a swath of from 120 to 150 degrees. To estimate the coverage expected from these systems we use the conservative value of 3 times water depth (just less than 120 degrees) for achievable swath widths in the detailed survey areas. This estimate will allow for sufficient overlap between swaths to assure complete high-resolution coverage of the seafloor as well as provide for the time necessary to collect sound velocity profile data. In making our estimates we assume that the vessels will survey at 10 knots.

### *3.6.3 Recommended Survey Approach (Seismic):*

Seismic data can be collected with a variety of systems ranging from simple single channel systems that have small volume seismic sources (typically airguns) and thus limited penetration into the sediment column to complex multichannel seismic systems that use large volume sources and long hydrophone arrays that are capable of measuring sediment many kilometers thick. A fundamental difference between the two systems (besides, complexity, cost and penetration) is the fact that multichannel seismic profiling also provides information on the speed of sound in the sediment column which is necessary to convert the travel-times measured with the seismic system to true depths or thicknesses. Inasmuch as the location of the Gardiner Line under Article 76 requires a determination of sediment thickness, (and thus the speed of sound in the sediment column in the region must be known), the Committee on the Limits of the Continental Shelf recommends that multichannel seismic data be used for determining sediment thickness. They recognize, however, that there are other means of determining the sound speed in the sediment column (refraction, regional models, etc.) and thus will accept single channel seismic data when supporting evidence for sound speed is available. For planning purposes we will suggest only the collection of multichannel seismic data. The size and configuration of the seismic system to be used (and thus the cost) will vary depending on the estimated thickness of the sediment column in the region.

### 3.7 Estimate Costs to fill data gaps:

#### 3.7.1 Bathymetry

With the regions to be surveyed defined for each of the detailed survey areas and the appropriate survey systems chosen, the estimated cost of each survey can be calculated (see Results section). Our estimated costs are based on an approximation of current rates charged for similar surveys in the U.S. EEZ at this time. It is important to note that commercial rates for surveying are market-driven and thus may vary depending on future market conditions. Based on discussions with several contractors and government organizations, we use an estimated day rate of \$25,000.00 per 20-hour day of survey time along the East and Gulf coasts of the U.S. and \$29,000.00 per day in the more remote areas of Alaska and the Pacific Islands. Extra charges must be added for transit and mobilization/demobilization. Transit time to and from the project area is typically charged at one half to three fourths the full survey rate. It is difficult to estimate mobilization/demobilization costs as this will depend on the status of the equipment and where the vessels are located before the survey begins as well as where they must go after the survey. We have added an approximate mobilization/demobilization charge ranging from \$200,000 to \$400,000 for each survey area. Finally, we add an additional 5 percent to account for weather time and other contingencies.

#### 3.7.2 Seismic

The cost of seismic data acquisition can vary significantly depending upon the depth of penetration required, the area of coverage (line kilometers required), the geographic area of the project and market conditions. For multichannel seismic data in sediments of a few hundred meters thickness, per km line costs, in today's market, including processing, begin at approximately \$300. For sediments of 2 km to 3 km thickness, in remote areas like Alaska, per km line costs can reach about \$675. **Until existing seismic data is geophysically analyzed, the cost of additional data in any particular area cannot be accurately predicted.** We have, therefore, assigned a per km line cost of \$675 for all additional seismic data acquisition. It is unlikely that all new data will cost this much. Mobilization and demobilization and transit charges similar to those for bathymetry have been added for each area.

### 3.8 Boundaries With Other Nations

In every detailed study area, some of the potential U.S. extended claim abuts either the EEZ or the potential extended claims of other nations. In Alaska and the Arctic, bilateral boundaries will exist with Russia and Canada; in the Atlantic, with Canada, possibly Bermuda, the Bahamas, and the Antillean island nations; in the Gulf of Mexico, with Mexico and Cuba. In the Pacific Islands, with Japan and other Island nations. The ultimate locations of these boundaries are the responsibility of the U.S. government and the other governments involved. **In these areas of abutting waters**

**and continental margins, our recommended survey boundaries are only intended as approximations for the purpose of measuring survey area and estimating levels of effort; they should not in any way be viewed as our or the U.S. position on where such boundaries should be drawn.**

## 4 METHODOLOGY

### 4.1 Collection and transfer of bathymetric trackline and survey polygon data

The principal sources of bathymetric trackline data were NOAA's NGDC, the U.S.G.S. and NIMA. In addition data was received from a number of academic institutions including The Lamont Doherty Earth Observatory and GEOMAR in Germany. Finally, for the Arctic, the IBCAO database, which has its current home at CCOM/JHC, was used for trackline information. These data were received in a wide range of formats each of which had to be modified for import into the Oracle 9i Object Model database. This process is described below under *Database schema and import to Oracle 9i Object Model*.

#### 4.1.1 NGDC

The geophysical trackline holdings at NGDC are published on CD-ROMs with accompanying database and retrieval software (GEODAS). Through our collaboration with NGDC they developed an add-on function to GEODAS, which allowed trackline navigation (thinned by filtering for efficient map production) with its accompanying metadata to be downloaded directly from the NGDC CD's. The ASCII-format is described in table 4.1. Hydrographic surveys carried out by NOS are also stored by NGDC on a collection of CD-ROMs. A similar add-on to the GEODAS retrieval software was developed by NGDC to allow the download of survey polygons and metadata that describe NOS surveyed areas. The main differences between the trackline and survey polygon format is that the coordinates for the survey polygon are provided instead of tracklines and the data type code is not needed since the NOS surveys always contain only bathymetry.

**Table 4.1.** Example showing NGDC ASCII trackline format as retrieved with an add-on function to GEODAS. Each line is described in the right column.

Format	Description
ARES1BWT	NGDC survey identifier
15040002	NGDC number
R/V THOMAS WASHINGTON	Ship
SCRIPPS INSTITUTION OF OCEANOGRAPHY	Institute
19701204	Start YearMonthDay
19701222	End YearMonthDay
SATNAV,AUTOLOG GYRO + EMLOG	Navigational instrumentation
LINEAR INTERP.BETWEEN ADJACENT FIXES	Geodetic datum/Position determination method
12KHZ/GIFFT RECORDER/WIDE(60DEG)BEAM	Bathymetry instrumentation
40CU.IN.AIRGUN,10-300HZ,PDR MK 10 REC.	Seismic instrumentation
SEISMICS_SS_CODES: usenav	Internal code not imported to CCOM/JHC LOS database
-27.0128 -109.7846 11000001	latitude [deg] longitude [deg] followed by a code for
-26.5933 -110.8083 22011002	data type of the trackline. The 8-digit code following the latitude
-26.3761 -111.3131 22022002	longitude coordinates represents start stop codes for 7 parameters:
-25.8355 -112.8839 22022002	A) navigation B) bathymetry travel time C) bathymetry corrected depth
-25.2441 -114.4152 22022002	D) magnetics total field E) magnetics residual field F) gravity observed
-24.8533 -115.4300 22033002	G) gravity free-air anomaly
-24.8483 -115.4400 33000003	The start/stop codes: 1=start of track 2=continue 3=stop 4=isolated point
-25.2066 -115.5933 10011001	
-25.1900 -115.6000 21022002	
-25.1454 -115.6274 23022002	
-24.9970 -115.7213 21022002	

#### 4.1.2 U.S.G.S.

Trackline information for bathymetry available from the U.S.G.S. was mainly gathered online from U.S.G.S. CMG infobank (<http://walrus.wr.U.S.G.S..gov/infobank/>). The ASCII-data formats for the trackline information available for download vary somewhat -- an example is shown in table 4.2. The relevant metadata was mostly found in a header preceding the navigation data, although in some cases this information was found in the html document describing the cruise. Perl scripting was used to merge the metadata with the trackline navigation data during the import process to the Oracle 9i Object Model database. This is described below under *Database schema and import to Oracle 9i Object Model*.

In addition to the online trackline information, the U.S.G.S. has also published a CD-ROM from the Pacific Mapping Project where multibeam data was acquired (Dartnell and Gardiner, 1999). The GeoTiff images on this CD were brought into our Access GeoMedia database (see below) and the outline of each survey was digitized to form a survey polygon.

**Table 4.2.** Example of U.S.G.S. ASCII-format for trackline data available for download from the U.S.G.S. CMG Infobank (<http://walrus.wr.U.S.G.S..gov/infobank/>). The navigation data is preceded with a header (not shown in this table) where metadata is included.

---

```
! time, lat, long, time(sec) to nearest nav fix, data values
19873042154010 34.39733 -124.32138 123.0 5.9212 1
19873042157040 34.39490 -124.31999 60.0 5.9197 1
19873042200080 34.39254 -124.31842 146.0 5.9233 1
19873042203060 34.39028 -124.31692 32.0 5.9224 1
19873042206110 34.38803 -124.31544 181.0 5.9209 1
```

---

#### 4.1.3 NIMA

NIMA provided trackline data from their unclassified database (HYSAS: <http://www.ngdc.noaa.gov/mgg/dhi/hysas.HTML>) and prepared files (NIMA documents) that were transferred to NGDC where these documents (1115 documents, 1,974,579 records) were merged into one file. Subsequently this file was processed by NGDC producing an ASCII-file containing navigation for tracklines, decimated for optimal plotting, with the ASCII-format described in table 4.3. In addition, the metadata was assembled by NGDC in a table so that the NIMA document number could link each trackline with its metadata. This linking procedure was done by Perl scripting at CCOM/JHC during the import process to the Oracle 9i Object Model database described below.

**Table 4.3.** Example showing the result from NGDCs processing of the NIMA documents.

---

**Trackline format:**

NIMA_doc	LAT	LON	CODE
02794	60.87983	-147.67270	1
02794	60.79766	-147.78300	3
02795	48.51300	-122.59050	1
02795	48.51517	-122.59120	3

**Corresponding metadata to the document 02794 in the example above:**

DOC #	PLATFORM	START-STOP	CC	SCALE	SDC	HDC	COMMENTS
02794	NOAAS RAINIER	01-OCT-93 31-OCT-93	US	0	MLLW	W84	FEATURE 1 = 3 & 1/4 ..

---

#### 4.1.4 Academic institutions and other data providers

The trackline data received from the various academic institutions had different ASCII-formats and metadata structures. These data sets had to be modified and linked

to the metadata during the import process to the Oracle 9i database. Data was transferred to CCOM/JHC either by FTP or by shipment of CD-ROMs.

The Monterey Bay Aquarium Research Institute (MBARI) has published a set of CD ROMs with data from multibeam surveys in the Pacific Ocean (see <http://www.mbari.org/>). These data were treated in the same fashion as the multibeam data from the U.S.G.S. Pacific Mapping Project, with GeoTiff images showing the data extent from the MBARI surveys brought into our Access GeoMedia database and digitized to form a survey polygon.

#### *4.1.5 IBCAO*

The IBCAO database contains spot sounding and trackline data (acquired mainly by the Canadian Hydrographic Service in the Arctic Ocean and Canadian Arctic Archipelago) but not adequate metadata. Recently, however, IBCAO has received metadata and some of these data are from the deep Arctic Ocean, where the Article 76 bathymetric components will have to be established. The relevant data were extracted from the IBCAO database and displayed on maps presented in this report. Similarly, other relevant data from the Arctic region that is not currently included in any database was provided by IBCAO for our analysis. This includes the tracklines from the US nuclear submarine SCICEX project.

## **4.2 Collection and transfer of seismic trackline data**

The major sources of seismic trackline data were NGDC, the U.S.G.S. and MMS.

#### *4.2.1 NGDC*

The format described in table 4.1 for the data downloaded from the GEODAS CD-ROMs allowed, through the 8-digit code, those portions of the tracks containing seismic data to be extracted and made into separate trackline features. In addition navigation was received from NGDC for seismic reflection data gathered by Lamont Doherty Earth Observatory. These data were originally sent to NGDC as analog paper records; NGDC scanned these records and entered them into their digital database.

#### *4.2.2 U.S.G.S.*

An inventory was made by the U.S.G.S. of seismic data collected by the U.S.G.S. and of relevance for this project. This trackline information was partly sent as ArcView shape files and partly as ASCII files with the format closely conforming to the one described in table 4.2 with the difference that a seismic line number was included. All this data was transferred to CCOM/JHC by ftp.

#### *4.2.3 Minerals Management Service (MMS):*

The Minerals Management Service has recently released declassified seismic trackline information and scanned records of acquired seismic reflection data on a series of CD's. The seismic information contained on the released CD's was acquired in 1976 by the U.S. Geological Survey, Conservation Division; now the Minerals Management Service (MMS). All information was acquired through permits issued in the Gulf of Mexico and Atlantic Outer Continental Shelf (OCS). According to federal regulations the geophysical information acquired under OCS permits shall be released 25 years after the information was submitted to the MMS. Navigational information was extracted from these CD's; the format is described in table 4.4. For the Alaskan area recently declassified MMS data has not yet been stored on CD and in this case the trackline data was provided through NGDC.

**Table 4.4.** Example of trackline navigation ASCII format of the data stored in recently declassified information released by MMS. A header records precedes the trackline navigation which is give in a straight forward format described on the bottom line.

---

```

H0000000011111111122222222233333333334444444445555555555666666666777777777
2345678901234567890123456789012345678901234567890123456789012345678
PERMIT NUMBER >>>>> L75-1661
DATE MAP WAS DIGITIZED >>>>>
MAP PROJ. OF DATA IN THIS FILE >>> STATE PLANE LOUISIANA SOUTH 1702
C. M. OF DATA IN THIS FILE >>> -91.333333333 DECIMAL DEGREES
DATUM >>>>>> NAD27 CLARKE 1866 ELLIPSOID
AREA IN GOM >>>>>
LOWER LEFT AREA = ST
UPPER RIGHT AREA = MP
COMPANY NAME ON MAP >>>> MOBIL
GEODETIC LATITUDE << DDMMSSSS >> DECIMAL INFERRED, COLUMNS 27-35
GEODETIC LONGITUDE << DDMMSSSS >> DECIMAL INFERRED, COLUMNS 36-45
GRID COORDINATES IN US SURVEY FT.
EASTING OR GRID_X << INTEGER >> COLUMNS 46-53
NORTHING OR GRID_Y << INTEGER >> COLUMNS 54-61

0000000011111111122222222233333333334444444445555555555666666666777777777
2345678901234567890123456789012345678901234567890123456789012345678
lg-003      70 28560790N 89105300W 2688401 104236
lg-003      72 28560770N 89105710W 2688037 104211
lg-003      84 28560440N 89112030W 2685987 103841
lg-003      96 28555920N 89114190W 2684074 103278
lg-003     108 28555010N 89120060W 2682425 102327
lg-003     120 28554310N 89122110W 2680618 101584
lg-003     132 28553520N 89124090W 2678879 100756
lg-003     144 28552450N 89125880W 2677303 99650
Line#      Latitude      Longitude  Easting  Northing  <-description

```

---

### 4.3 Attribution of navigational data quality

We have attributed navigational data quality based on estimated horizontal navigational fix accuracy. Although some of the elements of an extended claim under Article 76 are unquestionably affected by depth measurement accuracy, the greatest variation in data quality and thus the greatest impact on the location of the 2500 m contour and the FOS are a result of variations in sounding position accuracy. The accuracy value we have assigned to data sets is the accuracy of a discreet navigation fix. We have not tried to assess the accuracy of data between fixes for several reasons. Foremost among these is that inter-fix accuracy depends on the dead reckoning procedures employed in the survey or cruise, and these are not usually documented in the trackline metadata. Also, in most trackline data sets, it is not feasible to distinguish soundings at fix locations from soundings between fixes. In NOAA hydrographic and bathymetric surveys, the accuracy of soundings between fixes is well documented, but

on other types of bathymetric tracklines, procedures may vary greatly from cruise to cruise.

For each data set, we identified where possible the navigation system or systems employed. We divided these systems into several classes. Each class was assigned an estimated accuracy value, the radius of a circle of 95% error probability, and each dataset was assigned to one of the classes:

Unknown	10,000 m
Celestial	10,000 m
Piloting	2,000 m
OMEGA	7,300 m
Loran A	1,200 m
Loran C	500 m
TRANSIT	500 m
GPS	100 m
Starfix	50 m
Survey	50 m
DGPS	20 m
GPS Code	20 m

To determine the accuracy values for individual systems and system classes we referred, wherever possible, to authoritative reference material. References employed included Bowditch (Defense Mapping Agency [1984] and National Imagery and Mapping Agency [1995]), Dutton's (Maloney [1985]), The Hydrographic Manual (U.S. Dept. of Commerce [1942, 1960, 1976]), and Ingham (1984). When no authoritative reference was available, accuracy values are based on the professional consensus of JHC/CCOM and NGDC experts.

For any specific dataset, the actual positioning accuracy may be somewhat better or somewhat worse than the assigned value. This actual accuracy could only be determined by an in-depth analysis of each survey, examining such factors as reference station locations, calibration and operational procedures, and redundant positioning. A full description of this approach can be found in Jakobbson et al., in press. For most datasets, this sort of information is not available.

Many cruises employed multiple positioning sensors. Assigned accuracy was generally based on the weakest of the systems employed. In some cases, particularly during the later period of the transition from TRANSIT (the Navy Navigation Satellite System) to the Global Positioning System, a stronger system was judged to have improved the weaker system to a degree sufficient to assign the more accurate value. Where no positioning system metadata existed, the accuracy was labeled as unknown and assigned the default worst probable case value. The look-up table of assigned accuracy for the NGDC data set is included as Appendix G to the Report.

## 4.4 Collection of additional base data

### 4.4.1 NGDC sediment thickness

The NGDC sediment thickness compilation (<http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html>) was retrieved from NGDC and stored in a GeoMedia Access database as a series of color-coded GeoTiff images created from the 5 x 5 min grid compilation using the software *Fledermaus* from IVS (<http://www.ivs.unb.ca/>). In addition, the original source data points used by NGDC in their compilation process were provided for incorporation into the Oracle 9i database. These original source points were useful in the analysis of sediment information in the various regions.

### 4.4.2 WVS/ Digital Chart of the World

The World Vector Shore Line (Soluri and Woodson, 1990) produced by NIMA in its latest edition (World Vector Shoreline Plus) was incorporated into a GeoMedia Access database at three resolutions; 1:250,000, 1:1,000,000 and 1:3,000,000. For the all the maps produced in this report the 1:3,000,000 version was used. The higher resolution versions of the coastlines were used for the GIS analysis. Another NIMA product, The Digital Chart of the World, provided country limits and extent of large-scale lakes and rivers. These too were incorporated into a GeoMedia Access database for our map production.

### 4.4.3 US Territorial baseline points and EEZ limits

Coordinates for the US territorial baseline points were provided by NOS as paper documents. These points were entered into a GeoMedia Access database. The US EEZ limit was provided digitally by NOS; these limits were also stored in the Access database for this project.

### 4.4.4 GDA

Contours from the GEBCO Digital Atlas were provided on CD-ROM, were extracted as ASCII files, and brought into a GeoMedia Access database.

### 4.4.5 IBCAO

All the information from the IBCAO project was already available in a Geomedia Access database. This includes contours generated from the IBCAO grid, bathymetric source data, and GeoTiff images representing renderings of the Arctic Ocean sea floor.

#### 4.4.6 ETOPO2/ETOPO5

The ETOPO2 gridded database was used to generate shaded relief GeoTiff images that were stored in the GeoMedia database. These renderings provided a general overview of the seafloor morphology and were used as backdrops in the maps Appendix I:*Tracklines-ETOPO2-(NE,SE,GM,GA,AL,KP,MI)* and figures presented in Section 4. The 2500 m contour was extracted from ETOPO5 and used as a supplement in those areas where the GDA did not contain this isobath (Appendix I:*Map Tracklines-ETOPO2-AL*). The contour was derived from the ETOPO5 5 x 5 min grid by using Z/I Imaging's tool MGE Terrain Analyst (MTA). MGE Terrain Analyst is the terrain modeling component in Intergraph's MGE (Modular GIS Environment) family of software applications (for further information about these programs see Z/I Imaging (<http://www.ziimaging.com/>) and Intergraph (<http://www.intergraph.com/>) web pages).

### 4.5 Database schema and import to Oracle 9i Object Model

One of the main challenges of this project was to rapidly create a database design (schema) and to establish a database where all collected bathymetric and seismic trackline data as well point and polygon data could be stored with its associated metadata. The database chosen for this purpose was the newly released *Oracle 9i* database. This database was chosen because it provided:

1. Efficient data bulk loading capabilities through scripting.
2. Efficient access to all data through a GIS interface. Intergraph's GeoMedia Professional was chosen as the GIS software (see below).
3. Short waiting times for retrieval and geographic display of selected features.
4. Powerful querying capabilities

We contracted one of Intergraph's Oracle experts, Chuck Woodbury to consult for the initial setup, schema design, and bulk data loading of the Oracle 9i database. Each of the lines (tracklines), polygons (survey polygons) and point features (e.g. spot soundings) were associated with a set of attributes created from the metadata. A simple data model was chosen whereby each feature was stored directly with its attributes in a Table-design generally conforming to the one described for one of U.S.G.S.' trackline features in table 4.5. In Appendix H all table designs for the stored features with their respective attributes are shown. The general procedure of database initialization and loading may be described by the following steps:

1. Connecting to the Oracle 9i database
2. Create GeoMedia's Metadata Schema GDOSYS (only done once)
3. Creating a User Account in Oracle
4. Creating Tables by SQL-scripting through SQL-Plus
5. Reformatting ASCII input data by Perl scripting
6. Bulk Loading Tables with SQL-Loader

7. Entering Oracle Metadata (Information of coordinate system type and resolution)
8. Validating Data (e.g. checking for redundant points)
9. Spatially Indexing Data (R-TREE-indexing was used)
10. Building GeoMedia Metadata (Information about geodetic datums and feature types)

Step 5 and 6 will be covered in more detail below; the rest of the steps are standard procedures that do not need further explanation.

#### 4.5.1 Reformatting ASCII input data by Perl scripting

All ASCII input data (tracklines, points and survey polygons) was converted to three individual ASCII formats depending on what feature type (Oracle Geometry Type: SDO\_GTYPE) they would represent in the database. Table 4.6 shows the Oracle Geometry types we made use of. Ideal data formats for loading into Oracle 9i were recommended by Chuck Woodbury and examples for these three types are shown in table 4.7. Perl proved to be a very efficient high-level script programming language to make these transformations. In particular, the powerful capability of Perl to construct associative arrays, so called *hashes*, was used as the metadata often had to be merged from separate files based on position as the common link.

**Table 4.5.** Example of the table designs from one of the stored U.S.G.S. trackline features. The PID and the GEOMETRY columns are required and the PID must be a primary key column. The other columns are attributes according to the requirements from the data.

---

Attribute	Oracle datatype
<i>PID</i>	<i>NUMBER(10,0) PRIMARY KEY,</i>
<i>SURVEY_ID</i>	<i>VARCHAR2(8),</i>
<i>NGDC_NUMBER</i>	<i>VARCHAR2(8),</i>
<i>SHIP_NAME</i>	<i>VARCHAR2(50),</i>
<i>INSTITUTION</i>	<i>VARCHAR2(50),</i>
<i>START_DATE</i>	<i>NUMBER(8,0),</i>
<i>END_DATE</i>	<i>NUMBER(8,0),</i>
<i>NAV_INSTRUMENT</i>	<i>VARCHAR2(50),</i>
<i>DATUM_POS_METHOD</i>	<i>VARCHAR2(50),</i>
<i>BATHY_INSTRUMENT</i>	<i>VARCHAR2(50),</i>
<i>SEISMIC_INSTRUMENT</i>	<i>VARCHAR2(50),</i>
<i>SEISMIC_INFO</i>	<i>VARCHAR2(75),</i>
<i>NAV_CLASS</i>	<i>VARCHAR2(50),</i>
<i>NAV_ACCURACY</i>	<i>NUMBER(8,0),</i>
<i>GEOMETRY</i>	<i>MDSYS.SDO_GEOMETRY</i>

---

**Table 4.6.** A simplified summary of the Oracle 9i geometry types we made use of for loading tracklines, point data, and survey polygons. The symbol “d” indicates the dimension, d=2 for 2D data and d=3 for 3D data.

Oracle Gtype	Geometry type	Description	Loaded Features
d001	Point	Contains one point	Sediment thickness points, CHS soundings, GEODAS soundings
d006	Multiline string	Contains multiple line strings	All trackline data
d007	Multipolygon	Contains multiple polygons that are disjoint	NOS survey polygons

**Table 4.7.** The three data formats for the geometries shown in table 4.6 . These input formats to SQL-Loader were created by using Perl programming. The section after “pt” is the element information array that describes the interpretation of the following latitude and longitude coordinates (see Oracle 9i documentation).

---

2D-format for point (used for sediment thickness since the thickness was stored as an attribute):

PID#"Attribute 1"|"Attribute 2"|2001| |pt|1|0|6000|4|1|1|1|0|0|lon|lat|:

3D-format for point used for soundings:

PID#"Attribute 1"|"Attribute 2"|3001| |pt|1|0|6000|4|1|1|1|0|0|lon|lat|depth|:

2D-format for multipolygon:

PID#"Attribute 1"|"Attribute 2"|2007| |pt|1|1003|1|lon|lat|lon|lat|lon|lat| lon|lat|:

2D-format for multiple linestring:

PID#"Attribute 1"|"Attribute 2"|2006| |pt|1|2|1|5|2|1|lon|lat|lon|lat|lon|lat| lon|lat|:

---

#### 4.5.2 Importing data using SQL-Loader

All data was loaded via SQL-Loader using the data generated from the original source with Perl scripts as described above. A specific *control file* that conforms to the input data format and the features corresponding database Table has to be provided to SQL-Loader during the loading process.

#### **4.6 Intergraph's GeoMedia Professional: Interface to Oracle Object Model**

Intergraph's GeoMedia Professional GIS software includes support for Oracle 9i and as well several other databases (e.g., Microsoft's SQL Server and Access). In addition, many other common GIS formats can directly be accessed with GeoMedia Pro (see: <http://www.intergraph.com/gis/> ). For example, this includes formats from MapInfo 6.5, ESRI's ArcView and ArcInfo, AutoCAD, and MicroStation. The ability to create maps from a mixture of sources as well as its projection and datum transformation capabilities were among the reasons for selecting GeoMedia Pro as the GIS for this project.

#### **4.7 Deriving Article 76 major components using Caris LOTS**

CARIS LOTS (Law Of The Sea) software includes the necessary tools to delineate and manage geodetic limits and boundaries as defined in Article 76. Caris provides a Digital Atlas including ETOPO2 and the sediment thickness compilation by NGDC in a format readily accessible to the LOTS software. LOTS was used for the following tasks:

1. Deriving the 2500 m + 100 nmi from a 2500 m contour interpolated in the provided Caris Digital Atlas from ETOPO2. Additional IBCAO files were provided by Ron Macnab.
2. Defining the FOS along bathymetric 2D-profiles based on ETOPO2 and IBCAO for the Arctic Ocean.
3. Defining the Gardiner line from 1% sediment thickness markers from the FOS based on the NGDC sediment compilation and, for the Arctic, the sediment compilation of Jackson and Oakey (1990). The latter sediment compilation, which originally is a printed contour map, had been digitized, gridded and prepared for Caris LOTS by Ron Macnab and co-workers.
4. Defining the 60 nmi from the FOS limit.
5. Defining the 350 nmi limit for the US Baseline points provided by NOS.
6. Defining the 20 nmi from the US Baseline points in the areas where the "Bay of Bengal Clause" may be considered.

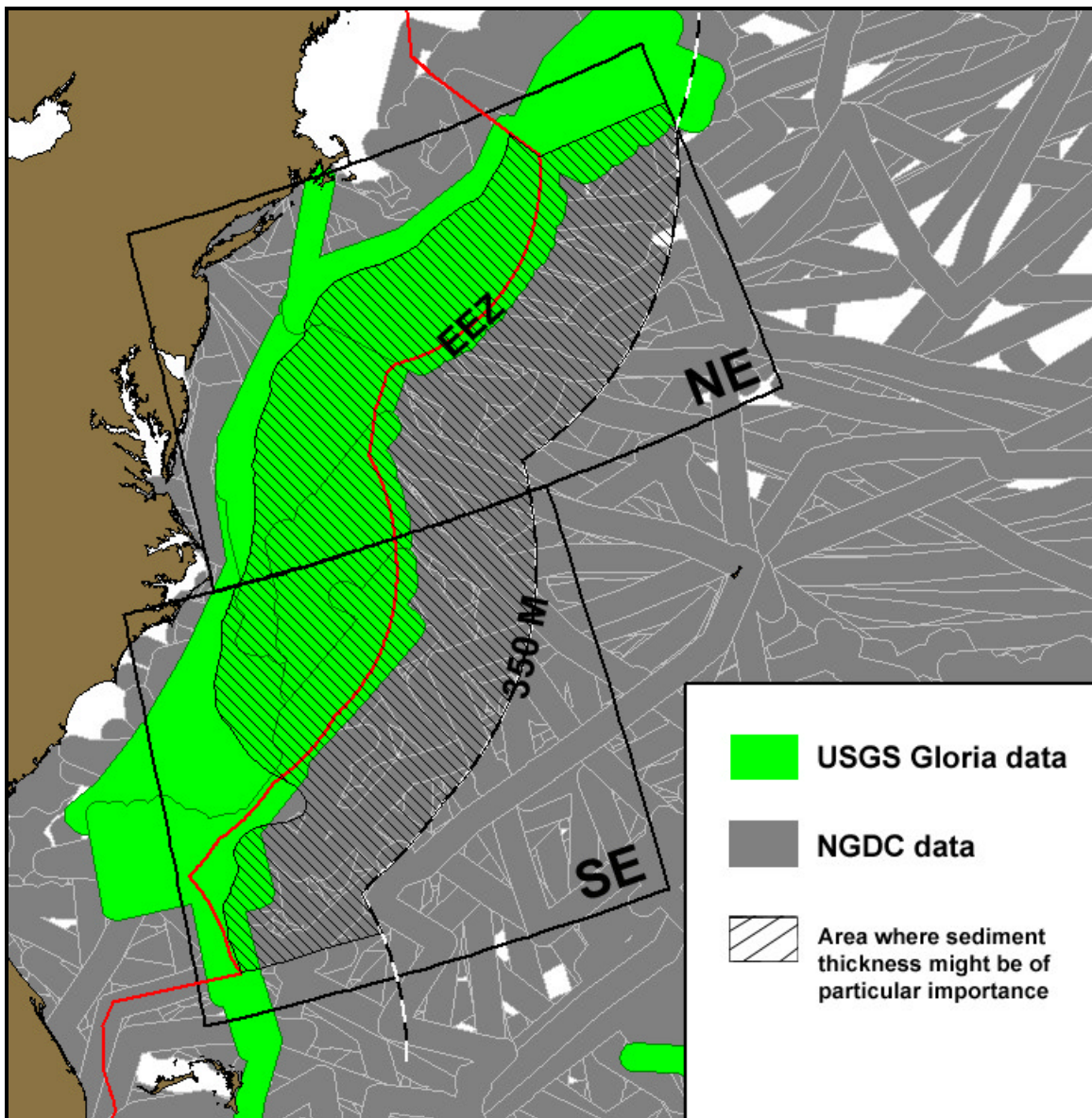
These limits were analyzed in Caris LOTS and subsequently exported to DXF files, which were then imported, the GeoMedia Pro Access database for further analysis and map production.

## 4.8 GIS analyses and map production

Queries were run on all our trackline and spot data holdings through the GeoMedia Pro interface and the results were displayed as maps for this report. For example, the assigned navigational fix accuracy, was queried for the entire database and the tracklines were colored by the resulting values (e.g., Appendix I:Map *Navigational-fix-accuracy*, and all the detailed maps Appendix I:*Navigational-fix-accuracy-(NE,SE,GM,GA,AL,KP,MI,ARC)*).

The survey areas shown in the figures in Section 5 and map *More-bathymetry-required* were constructed by merging all the necessary data and database queries for GIS analysis in GeoMedia Pro. These data sets included: depth contours from GDA, IBCAO and in some areas derived from ETOPO5; analyzed bathymetric profiles from Caris LOTS; FOS and 1% sediment markers from the FOS created in Caris LOTS; NGDC sediment thickness raster and source points; shaded relief maps from ETOPO2 and IBCAO; slope raster maps derived from ETOPO2 and IBCAO; derived 200 nmi (EEZ) and 350 nmi limits from the US territorial baselines; World Vector Shore line from NIMA; all the trackline, polygon and point features stored in our database. By having access to all this information through the GIS interface we could outline the required survey areas and account for available high-quality data. GeoMedia Pro carried out the area computations presented in the Section 5 with the option set to compute areas on the spheroid rather than on the planar map projection.

The possible need for additional seismic data was addressed with the two hypotheses described in Section 3. In order to find if we could fail to reject the second hypothesis (that all data is usable but exist with a trackline spacing not more than 30 nmi) a buffer zone of 15 nm (creating a 30 nmi with trackline) was created around each seismic trackline feature (Figure 4.1).



**Figure 4.1.** Example showing 15 nmi (30 nmi wide trackline) buffer zones generated in Geomedia Pro around seismic tracklines from NGDC and the U.S.G.S. Gloria project. This was done to analyze if the line spacing was more than 30 nmi.

## 5 RESULTS:

The results of our analyses are presented for each of the individual detailed survey areas. We start with five areas surrounding the coterminous U.S. and Alaska, then move on to the Arctic and finally U.S. territories in the Pacific. For each of these areas we discuss the general bathymetry of the region (based on the compiled data sets discussed in the Approach and Methodology sections), the general trends of sediment thickness in the region (based on the sediment thickness compilations), and which of these basic criteria (bathymetry or sediment thickness) will be most critical for making an extended claim. We then explore the existing bathymetric and sediment thickness database in the region and finally describe how we determine the extent of the area in need of further survey work (if any). Once the area to be surveyed is defined, we estimate the costs associated with collecting the needed data.

For each of the detailed survey areas, we determine the approximate location of the 2500 m isobath, the maximum potential seaward location of the Foot of the Slope (FOS), and in some areas, where necessary, the 200 m isobath. Similarly, we determine the approximate sediment thickness contours from the sediment thickness compilations. In those areas where the bathymetric and sediment characteristics indicate a potential extended claim, we determine the maximum limits of new surveys in the manner described in the Approach section. Bathymetric survey limits have typically been drawn to begin at the 2000 m isobath and extend seaward beyond the line of maximum seaward location of the FOS.

Within the limits defined for potential new survey work, the amount and quality of existing bathymetric and geophysical data were assessed to further refine the area requiring new surveys. Typically, we have not recommended new surveys where modern full-coverage multibeam surveys have already been completed. In those areas where the most precise or advantageous location of the foot of the slope is not required, we have also accepted high quality, systematically collected, single beam survey data. In other areas, claims based on single beam sonar data would be less authoritative than those based on multibeam data, and should be considered only if the acquisition of new multibeam data is not feasible. The arguments for supplementing old, sparse, single-beam sonar data with well-navigated, high-density, complete coverage multibeam data have been presented in the Approach section (Section 3.6) and graphically demonstrated in figures 6.1-6.4. Where the sediment thickness compilations are based on sparse data, or where the exact sediment thickness is critical, we have recommended a geophysical analysis of the existing seismic data as a first step in establishing the need for very expensive new seismic surveys.

## 5.1 Coterminous US and Alaska

### 5.1.1 North East Atlantic (*Detailed Map NE*)

#### 5.1.1.1 General Bathymetry

In the North East Atlantic (NE), the 2500 m contour line will not be of great importance since the 2500 m + 100 nmi line always falls well inside the 350 nmi limit and, thus, will not take effect as the cutoff line anywhere. Therefore, bathymetric work in the NE can focus on defining the FOS, as it is defined in Article 76. Given the sea floor morphology in this region the 2500 m depth contour will also be covered with by any survey that is trying to define the FOS. We estimate the area necessary to define the FOS using ETOPO2, a slope map derived from ETOPO2 and the 2000 m depth contour from GDA (Figures 5.1A and B). The 2000 m depth was chosen as the landward limit of the proposed survey area since this depth always appears to occur inside the most landward possible location of the FOS. The outer limit is based on the seafloor morphology as represented by ETOPO2 bathymetry, the slope model of ETOPO2 and analyzed bathymetric cross profiles (Figures 5.1A, B and 5.2). This outer limit of the estimated survey area is placed where the gradient of the seafloor topography is generally less than 0.5°. This is beyond the point on a bathymetric profile where the FOS could be defined by any definition found in Article 76. Figure 5.2 shows the ambiguity of picking the FOS according to Article 76. This ambiguity, and the resultant possibility of significant variations in the area of a claim, are the basis for the wide extent of the recommended survey in figures 5.1A and B.

#### 5.1.1.2 Existing bathymetry data in area

Multibeam surveys, carried out between 1990 and 1992 by *NOAA Ship Mt Mitchell*, cover a portion of the area on detailed map NE where the FOS needs to be established (Appendix I: *Maps Tracks-NE* and *Navigational-fix-accuracy-NE*). The area covered by these surveys is excluded from the estimated area for future surveying (Figure 5.1A,B and Appendix I: *Map More-bathymetry-required*). Also, the University of Rhode Island carried out multibeam surveys in a small portion of the western part of the corridor of interest during 1986 and 1989. These multibeam surveys partly overlap the NOS hydrographic surveys and their coverages have also been excluded from the area of new surveys. A small portion of the corridor of interest is covered by systematic single beam hydrographic surveys from NOAA ships *Oceanographer* (1935; scale 1:120,000), *Lydonia* (1938; 1:120,000), and *Mt Mitchell* (1971-1976; scale 1:80,000) (Appendix I: *Map NOS-surveys-NE*). Due to the age, accuracy, and density of these surveys, the area they cover has not been subtracted from the estimated area of surveying in the corridor of interest.

#### 5.1.1.3 Estimated bathymetry survey cost

The calculated survey area in detail map NE is estimated to  $\approx 220 \times 10^3 \text{ km}^2$  and the mean depth to  $\approx 3447 \text{ m}$  (Table 5.1). Using the criteria described in the Approach

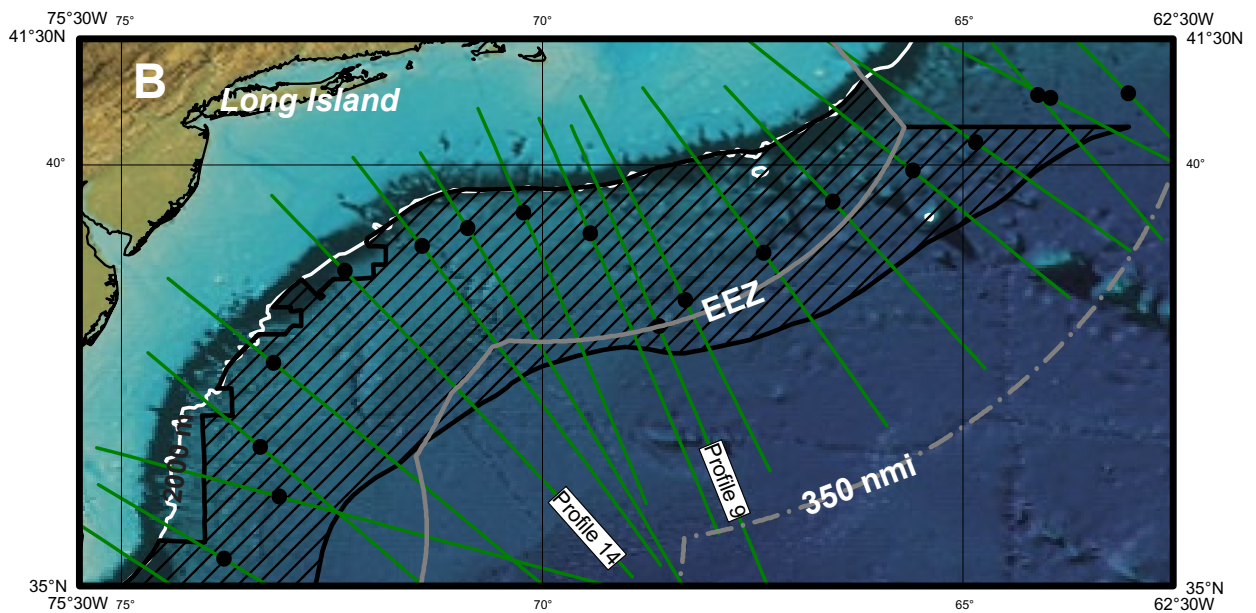
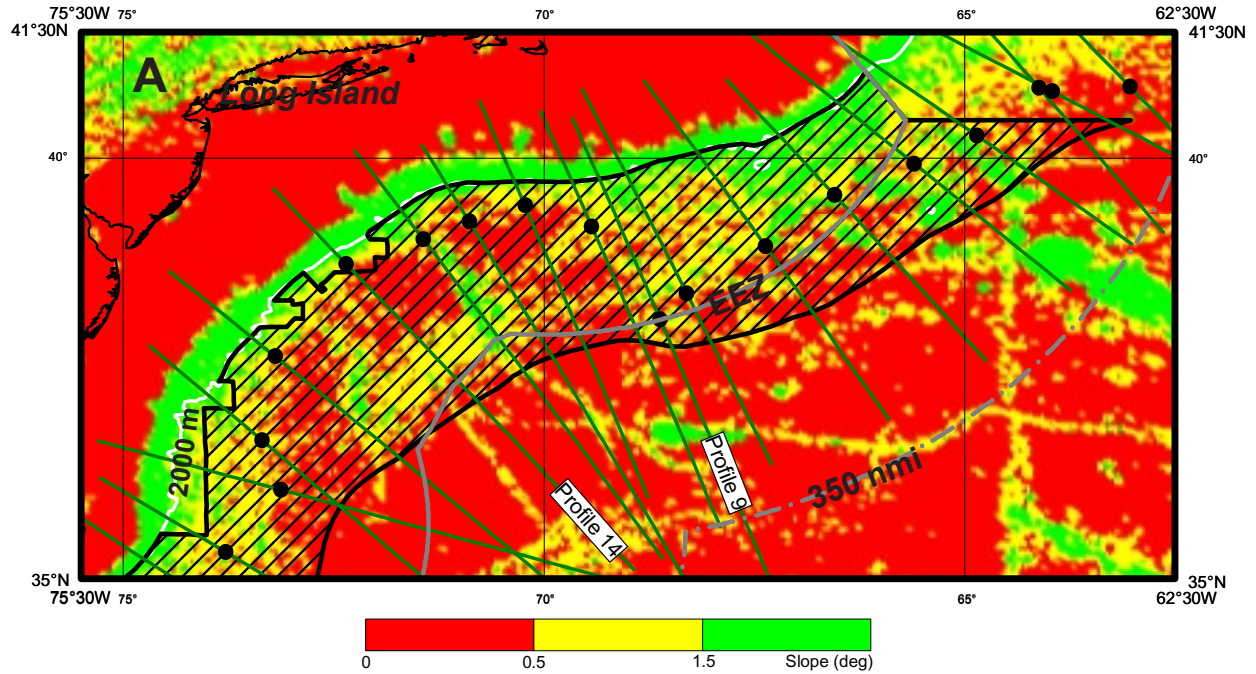


Figure 5.1. A: Slope of seafloor by color in detailed area NE. Multiple bathymetric profiles are drawn through the area and possible locations of the FOS are marked with black dots. Variation in slope and resulting ambiguity in location of the selected FOS influences the size of the area (hatched) for which detailed bathymetry is required.

B: Bathymetry from ETOPO2 in detailed area NE, drawn bathymetric profiles, and possible locations of the FOS. Labeled profiles are shown in figure 5.2.

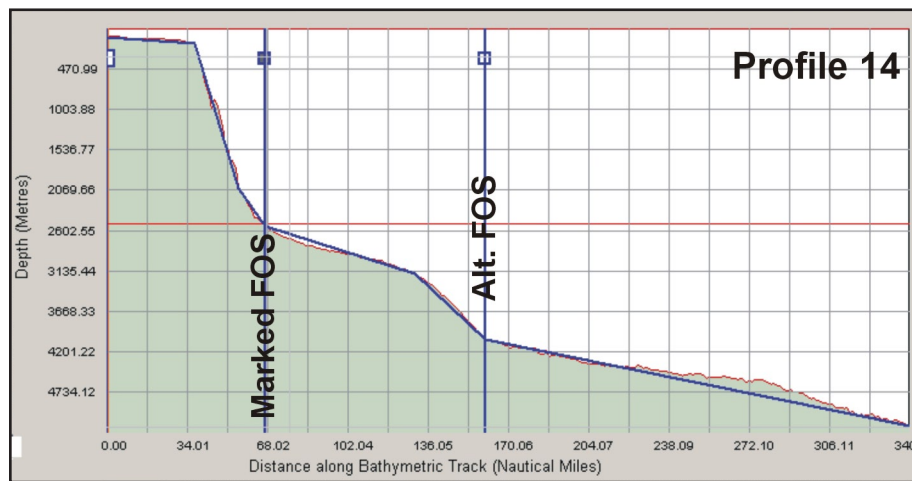
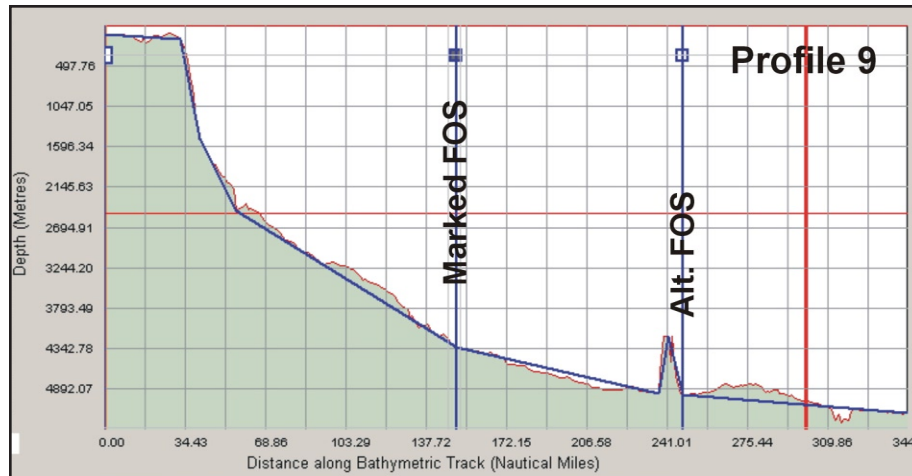


Figure 5.2. Bathymetric profiles 9 and 14 in detailed study area NE. The locations of these profiles are shown in figures 5.1A and B. The ambiguity in location of the FOS is clearly illustrated. The “Marked FOS” is the location marked with a dot in figure 5.1A and B. Alternative locations for the FOS are shown in each profile. Note that the vertical exaggeration in the bathymetric profile accentuates gradient changes.

section, we estimate the total survey time necessary to cover this area to be approximately 50 days; with transit, mob/demob and contingency, the total cost for the bathymetric survey would be approximately \$1.9M.

#### *5.1.1.4 Sediment thickness*

The sediment appears to be thick enough to support an extended claim in this area, but apparently not so thick that the Gardiner line would fall outside the 350 nmi cutoff line (Appendix I:Map *Seismic-tracklines-sediment-NE*). Therefore the claim will depend upon a precise location of both the FOS and the determination of where the sediment thickness equals 1 percent of the distance from the FOS. For this reason, the sediment thickness will be critical in the entire detailed area NE to maximize the extension of the US continental margin according to Article 76.

#### *5.1.1.5 Existing seismic data in area*

Seismic reflection data from multiple sources exist with line spacing closer than 30 nmi for the portion of the area within the current US EEZ (Appendix I:Map *Seismic-tracklines-sediment-NE*). During the U.S.G.S. Gloria project, single channel seismic data were acquired over the entire EEZ with a line spacing of approximately 8-15 nm. It must be noted that the data acquired during the Gloria surveys was all single-channel seismic data. Single channel seismic data does not, in its own right, provide and estimate of the speed of sound in the sediment column (necessary to calculate sediment thickness). Thus, to determine if the existing seismic reflection data in detailed area NE is adequate to define the thickness of the sedimentary rock beneath the ocean floor, a thorough seismic data analysis is required. This is beyond the scope of this report (see *Approach* Section 3). Until such an analysis is complete, the amount of new seismic surveying required in this part of the area is uncertain. Outside the current EEZ limits, the seismic trackline coverage is much sparser, and new seismic data acquisition will almost certainly be required.

#### *5.1.1.6 Estimated seismic survey cost*

In order to accurately specify the amount of seismic data required to support an extended claim, two presently unknown factors must be established. First, the existing seismic data must be analyzed to determine whether or not sediment thickness can be derived, and second, the location of the FOS needs to be established as a starting point since the Article 76 Gardiner formula line is derived by finding where the sedimentary rock beneath the ocean floor thins to one percent of the distance back to the FOS (see *Approach*, Section 3). Given that the total requirement for seismic surveying cannot be established without additional analysis and new bathymetric surveys, we have estimated both the maximum and the minimum possible need for additional seismic surveys based on the two end-member scenarios outlined in the *Approach* (Section 3.5). The first scenario assumes that entire area from the most landward possible location of the FOS out to 350 nmi from the US baseline needs to be covered with new seismic reflection data with a trackline spacing of 30 nmi. The second scenario assumes that all

current and available seismic data for which we hold trackline information is of sufficient quality to establish the thickness of sedimentary rock beneath the ocean floor.

The entire area from 2000 m out to 350 nmi is estimated to  $437 \times 10^3 \text{ km}^2$  (Table 5.2). Thus for scenario one (all new data needs to be collected with a trackline spacing of 30 nmi), approximately 7872 km of reflection seismic profiles need to be acquired. Assuming the U.S.G.S.-provided rate/km for acquiring MCS by commercial contract (\$675/km, see *Approach* Section 3.7.2) plus mobilization/demobilization and transit, this could be done for a cost of approximately \$ 6.0 million. If scenario two is accepted (that all existing data adequately defines the sediment thickness) then no new data would be necessary in detailed area NE since the amalgam of seismic tracklines from all sources do not leave any gaps exceeding 30 nmi.

### *5.1.2 South East Atlantic (Detailed map SE)*

#### *5.1.2.1 Bathymetry*

For the same reasons as in the NE area, the 2500 m contour line will not play a role in the SE detailed map area for defining a possible extended claim. In this area, the FOS is the bathymetric component that needs to be surveyed. The survey corridor of interest has been outlined using the same procedure and same compilations as for detailed map NE described above (Figures 5.3A and B). The profile shown in figure 5.4 confirms that additional data are needed to establish the outermost possible location of the FOS.

#### *5.1.2.2 Existing bathymetry data in area*

We were unable to find either modern multibeam datasets or high-resolution single-beam survey data in the proposed survey corridor marked in figures 5.3A and B. Available data consist mainly of sparse tracklines assigned low navigational fix accuracy (Appendix I:Map *Tracks-SE*, *Navigational-fix-accuracy-SE* and *NOS-surveys-SE*). Thus the entire corridor of interest requires a new survey.

#### *5.1.2.3 Estimated bathymetry survey cost*

The corridor requiring a complete bathymetric survey to locate the FOS is estimated to  $\approx 154 \times 10^3 \text{ km}^2$ . With an average depth of 4247 m this gives a survey time of approximately 30 days. With transit, mob/demob and contingency, the total bathymetric survey cost would be approximately \$1.3M.

#### *5.1.2.4 Sediment thickness*

As in NE, the sediment thickness in this area appears thick enough to support a claim, but not thick enough for a claim to reach the 350 nmi cutoff line except possibly in the area between about 28°N and 30°30'N (Appendix I:Map *Seismic-tracklines-sediment-SE*). Together with the FOS, the sediment thickness will thus be critical in the entire detailed area SE to maximize an extension of the US continental margin under Article 76.

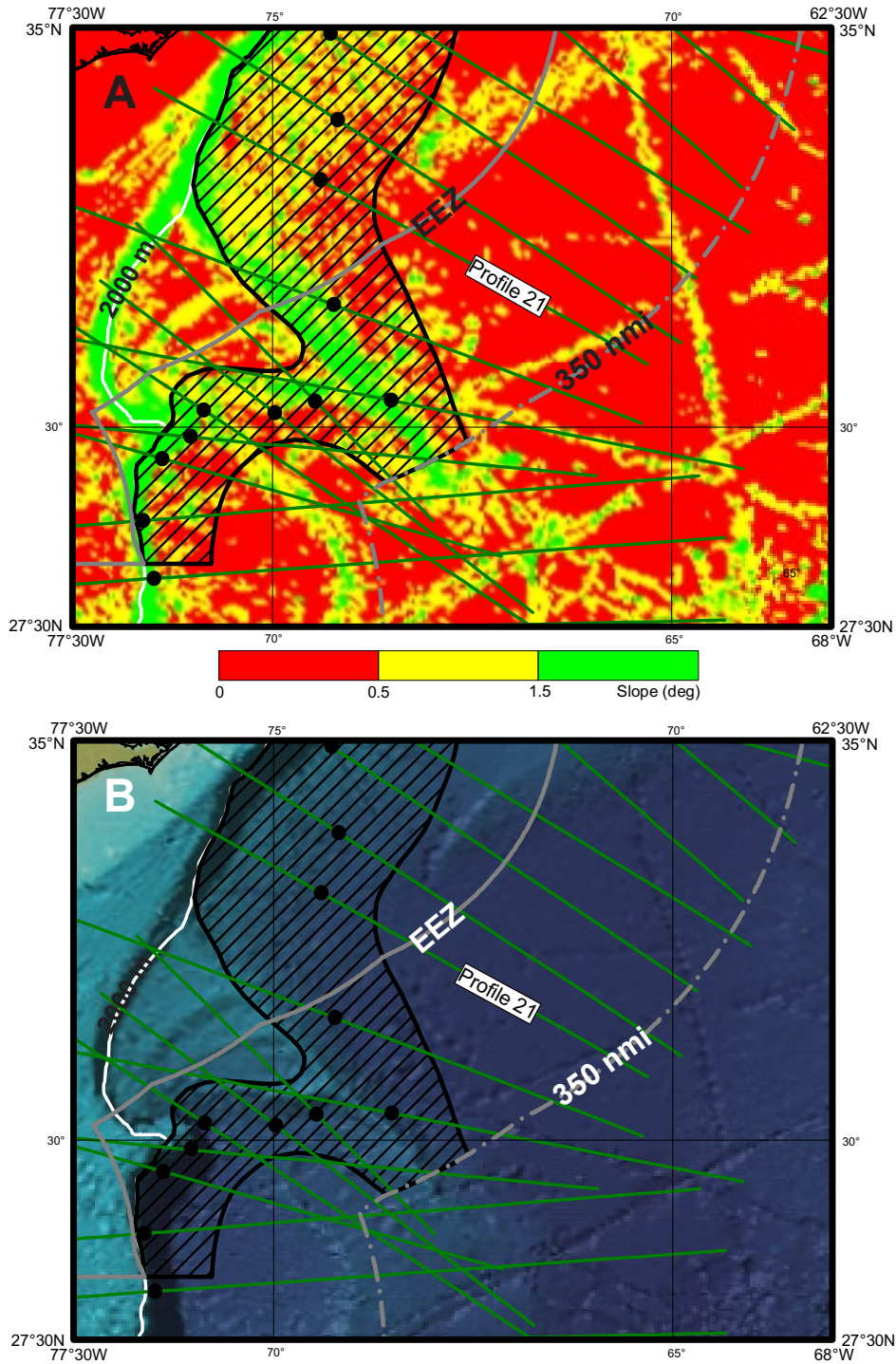


Figure 5.3. A: Slope of seafloor by color in detailed area SE. Multiple bathymetric profiles are drawn through the area and possible locations of the FOS are marked with black dots. Variation in slope and resulting ambiguity in location of the selected FOS influences the size of the area (hatched) for which detailed bathymetry is required.

B: Bathymetry from ETOPO2 in detailed area SE, drawn bathymetric profiles, and possible locations of the FOS. Labeled profile is shown in figure 5.4.

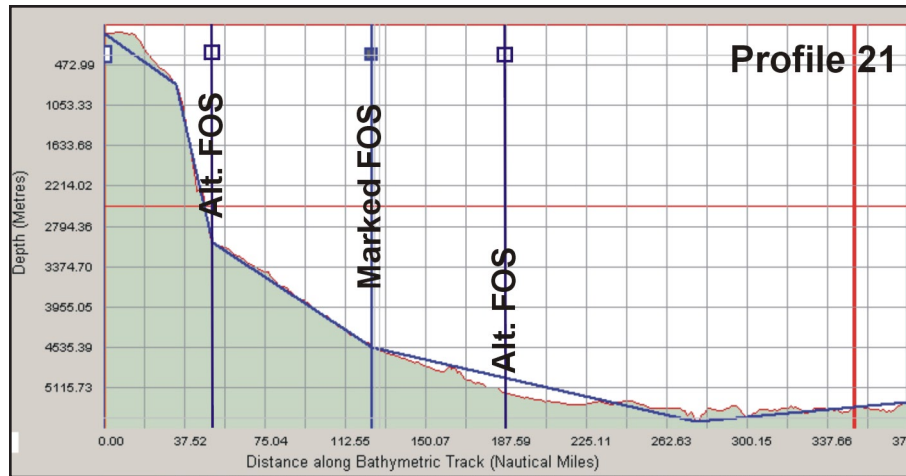


Figure 5.4. Bathymetric profile 21 in detailed study area SE. The locations of this profile is shown in figures 5.3A and B. The ambiguity in location of the FOS is clearly illustrated. The “Marked FOS” is the location marked with a dot in figure 5.3A and B. Alternative locations for the FOS are shown in each profile. Note that the vertical exaggeration in the bathymetric profile accentuates gradient changes.

#### 5.1.2.5 *Existing seismic data in area*

Seismic reflection data from multiple sources exist with a coverage that is denser than 30 nmi between the tracklines in the entire detailed area SE (Appendix I:Map *Seismic-tracklines-sediment-SE*). A geophysical analysis of the existing data is necessary to determine whether or not those data are adequate to define sediment thickness throughout the area.

#### 5.1.2.6 *Estimated seismic survey cost*

If none of the existing data are adequate, the area of  $\approx 365 \times 10^3 \text{ km}^2$  needs to be covered with reflection seismic profiles, which would require approximately 6568 km of tracklines. The estimated cost for this maximum survey effort is \$5.0 million at the assumed rate/km for acquiring MCS by commercial contract. If all existing data were adequate to determine sediment thickness, no new seismic survey would be required.

### 5.1.3 *Gulf of Mexico (Detailed Map MG)*

#### 5.1.3.1 *Bathymetry*

In the Gulf of Mexico, the 2500 m contour falls landward of the Mexican EEZ limit and well inside 350 nmi from the US territorial baseline. Therefore the 2500 m + 100 nmi is not required to establish the cutoff line in the Gulf of Mexico. However, the FOS needs to be located between about 93°30-91°W and 88°30-85°30W to get base points for the sediment thickness profiles in these areas. With a well-defined FOS, and given the very thick sediments in the area, there should be no question that all the area outside of the present U.S. EEZ out to the Mexican EEZ is claimable by the U.S. or Mexico according to Article 76. In figures 5.5A and B the survey area of interest in the eastern part of the MG detailed map is based on the rough estimation of the FOS using the ETOPO2 data. The area in the western part, where additional bathymetric survey might be required, is reduced somewhat by existing multibeam data acquired by NOS (see below). However, in this area the FOS may be located within the Mexican EEZ as can be seen in figures 5.5A and B. Based on ETOPO2, the FOS appears to be prominent and easily located in the eastern part of detailed map GM but more complex, with several options, in the western part (Figure 5.6).

#### 5.1.3.2 *Existing bathymetry data in area*

NOS single beam hydrographic surveys from 1950 and 1952 completely cover the eastern area between about 88°30-85°30W where the FOS needs to be established (Appendix I:Map *NOS-surveys-GM*). In addition, the University of Rhode Island carried out a multibeam survey from the ship *R/V Atlantis II* in 1986 of the easternmost strip of the corridor of interest marked in figures 5.5A and B (See for example maps Appendix I:*Tracks-GM*, *Navigational-fix-accuracy-GM*). Woods Hole Oceanographic Institute (WHOI) completed a multibeam survey in this eastern strip during 1990 using the ship *R/V Atlantis II*. The metadata in the NGDC database does not include the type of navigation used for WHOI's survey with *R/V Atlantis II* and, thus, the estimated

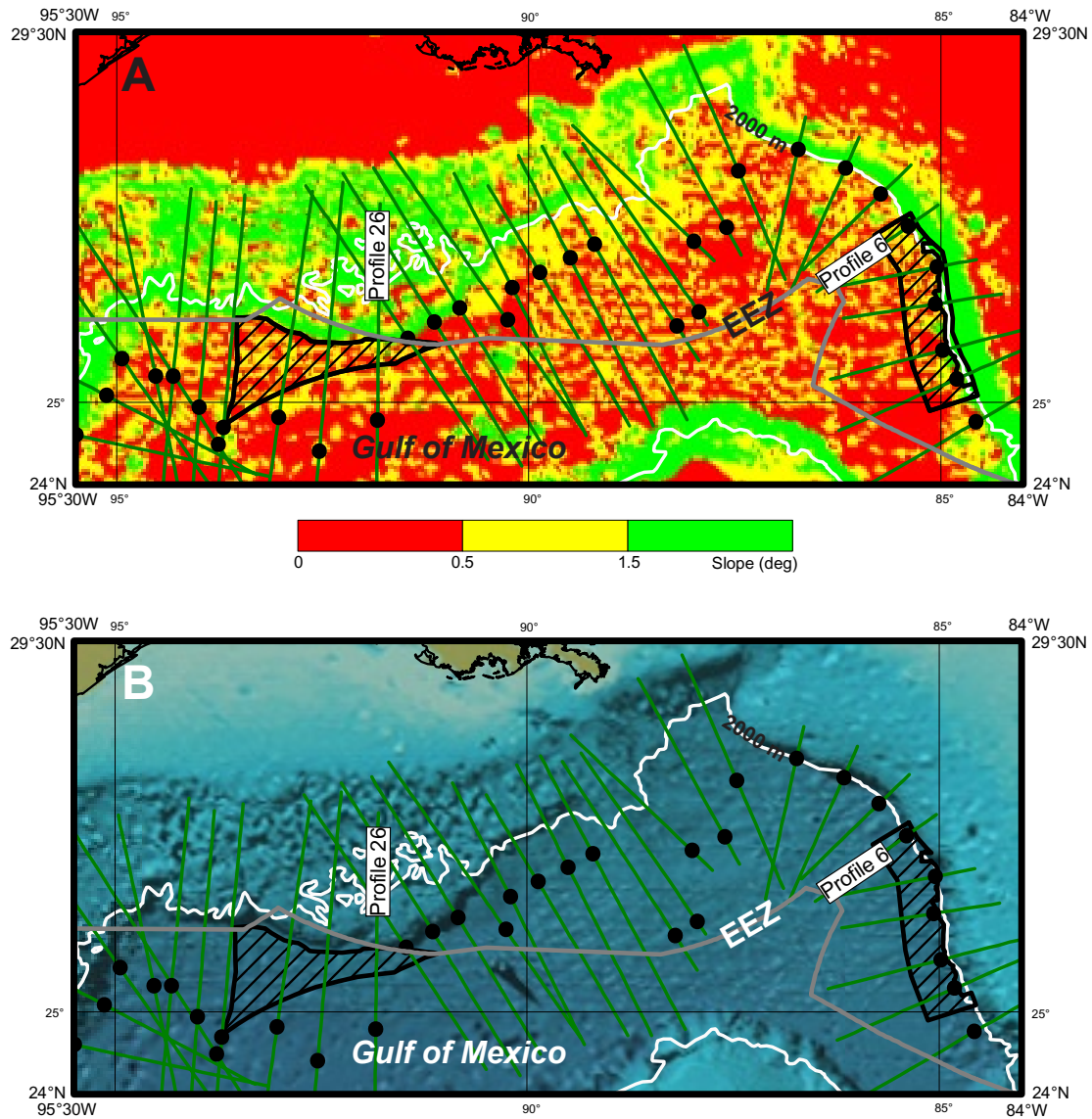


Figure 5.5. A: Slope of seafloor by color in detailed area GM. Multiple bathymetric profiles are drawn through the area and possible locations of the FOS are marked with black dots. Variation in slope and resulting ambiguity in location of the selected FOS influences the size of the area (hatched) for which detailed bathymetry is required.

B: Bathymetry from ETOPO2 in detailed area GM, drawn bathymetric profiles, and possible locations of the FOS. Labeled profiles are shown in figure 5.6.

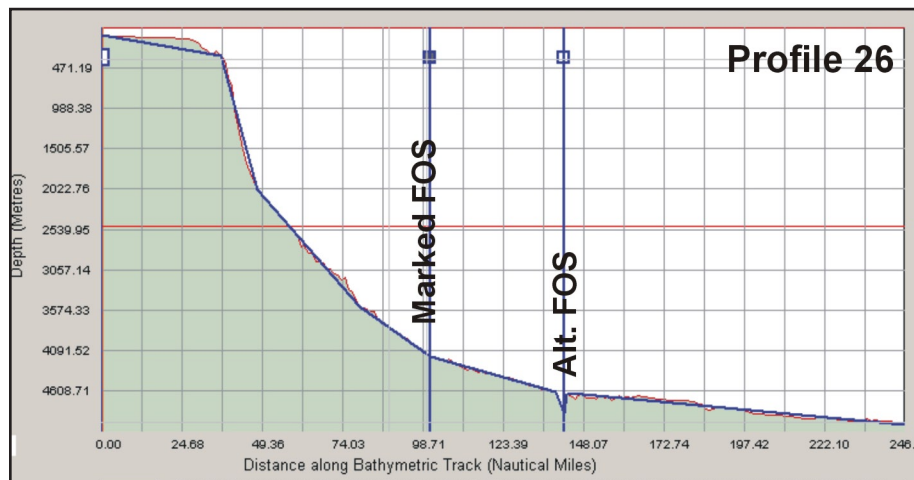
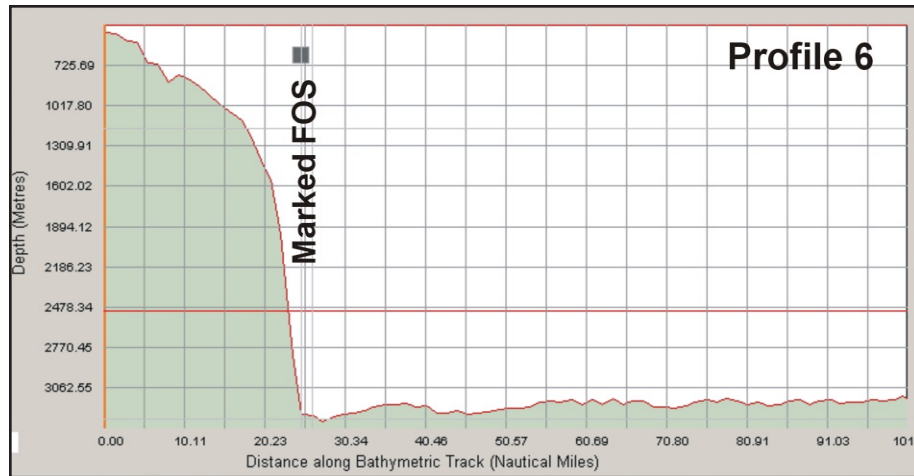


Figure 5.6. Bathymetric profiles 6 and 26 in detailed study area GM. The locations of these profiles are shown in figures 5.5A and B. The ambiguity in location of the FOS is clearly illustrated. The “Marked FOS” is the location marked with a dot in figure 5.5A and B. Alternative locations for the FOS are shown in each profile. Note that the vertical exaggeration in the bathymetric profile accentuates gradient changes.

navigational fix accuracy in detail map *Navigational-fix-accuracy-GM* was assigned, by default, the worst case value. However, given the dates, it is probable that a GPS system was used. Because the exact location of a FOS in this area is not critical to the ultimate breadth of a claim, existing surveys should be adequate, and no new surveys are recommended. In the western area, modern multibeam surveys do not completely cover the corridor of interest. A small area of bathymetric survey is required to establish the location of the FOS or to establish that it is farther offshore in the Mexican EEZ.

#### *5.1.3.3 Estimated bathymetry survey cost*

The corridors of interest are estimated to  $\approx 13 \times 10^3 \text{ km}^2$  (eastern) and  $\approx 14 \times 10^3 \text{ km}^2$  (western) respectively, with an average depth of 3200 m in the eastern area and 3300 m in the western area. The existing data available in the eastern area precludes the need for new survey data. The estimated time to survey the corridor in the western area is approximately 4 days; with transit, mob/demob and contingency, the total survey cost should be approximately \$0.7 million.

#### *5.1.3.4 Sediment thickness*

Based on the NGDC sediment compilation there should be no question that the sediments in the Gulf of Mexico are of sufficient thickness such that the areas outside the current EEZs are claimable either by the U.S. or by Mexico (Appendix I: *Map Seismic-tracklines-sediment-GM*).

#### *5.1.3.5 Existing seismic data in area*

The coverage of existing seismic reflection lines in detailed area GM leaves no gaps greater than 30 nmi. The U.S.G.S. Gloria project collected single channel seismic data in regular tracklines extending beyond the present EEZ limits. Again, the adequacy of this single beam data must be examined by geophysical experts.

#### *5.1.3.6 Estimated seismic survey cost*

Although there appears to be enough available seismic reflection data to adequately determine the sedimentary thickness beneath the sea floor, we recommend that existing data be analyzed for confirmation. We do not, however, believe that additional seismic data will be required in detailed area GM.

### *5.1.4 Gulf of Alaska (Detailed Map GA)*

The existing compilations of bathymetry and sediment thickness do not support an extended claim in the Gulf of Alaska. Potential claim lines based on the FOS plus 60 nmi fall inside the current EEZ, but are close to this limit line in some areas. Should new high-resolution multibeam surveys support a more seaward location of the FOS, a claim would be possible. There also appears to be some potential for an extended claim based on sediment thickness in the eastern corner of the Gulf of Alaska. The existing bathymetric and seismic databases are too sparse in this area to draw definitive

conclusions, and therefore, a survey area is proposed. It is possible, however, that these additional surveys will indicate that no claim is feasible.

#### *5.1.4.1 Bathymetry*

The 2500 m contour will not be of great significance in the Gulf of Alaska since the 350 nmi line will always fall outside the 2500 m + 100 nmi line. The FOS, however, will be of great importance in order to determine if the U.S. can extend a claim in this area. The suggested survey area is based on ETOPO2, a slope map derived from ETOPO2, and the sediment compilation from NGDC. The outlined survey area in detail map GA (Figures 5.7A and B) is sized to account for the possibility that the FOS may actually be farther out than our initial analyses of ETOPO2 indicates. The NGDC sediment thickness compilation shows sediments transported from the margin onto a more gradual continental slope than is found in nearby areas (Appendix I: Map *Seismic-tracklines-sediment-GA* and figure 5.8). The 2000 m contour from GEBCO has been used to define the landward limit for the survey area.

#### *5.1.4.2 “Bay of Bengal Clause” application along the Alaskan Panhandle*

At least one authority (Prescott, 2000) has suggested that the situation along the Alaskan Panhandle (and south of the Alaska Peninsula) may warrant application of the provisions of Annex II of the Final Act of the Third UN Conference on the Law of the Sea (frequently called the “Bay of Bengal Clause” or the “Sri Lanka Clause”). This Annex is included in Appendix A. This Annex addresses the special situation where a coastal state is disadvantaged by a combination of circumstances, i.e. a narrow continental margin, and a proportionally greater accumulation of sedimentary material beneath the continental rise, in which an application of the regular provisions of Article 76 could prevent the affected state from establishing its jurisdiction over a significant portion of the resources of the seabed. The Annex accordingly prescribes a modified procedure for developing an outer limit based on the thickness of sedimentary material. The first criterion necessary to be able to use “Bay of Bengal Clause” is that the average distance at which the 200 m isobath occurs is not more than 20 nmi (although not specifically stated, this is presumed to be 20 nmi from the baseline). A first analysis using the 200 m isobath from GEBCO Digital Atlas shows that this appears to be the case between about 147°W – 142°W and from 137°W to the Canadian border (Figures 5.7A and B). The second criterion is that the sediment thickness along a derived formula line according to Article 76 is not less than 3.5 km. Thirdly, if the first and second criteria apply, the state is able to establish its outer limit where the sediment thickness is not less than 1 km. We have examined the NGDC sediment compilation for sediment thickness and found that while we cannot find regions where the compilations show the appropriate sediment thickness, the apparent thicknesses are close enough to possibly justify a closer look. The estimated sediment of the continental rise reaches a thickness of 1 km close to the current EEZ limits near 141°W, and there are two areas outside the EEZ (141°30’W-137°W and 146°30’W-142°30’W) where the NGDC-estimated sediment thickness is just below 1 km. Given the very coarse nature of the NGDC compilation, this suggests that additional analysis of the existing sediment thickness data in these areas is warranted. If the analysis indicates the possibility that

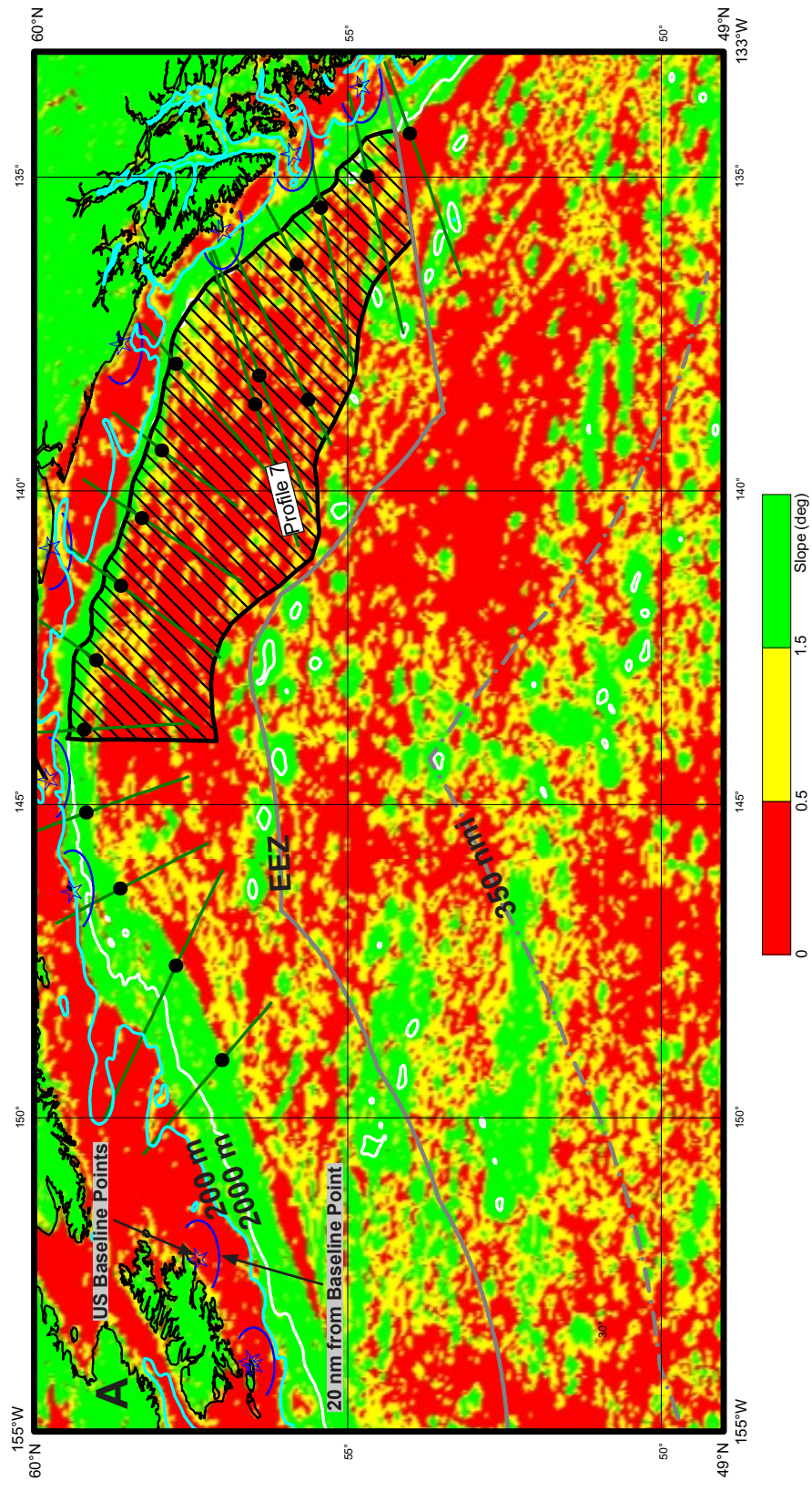
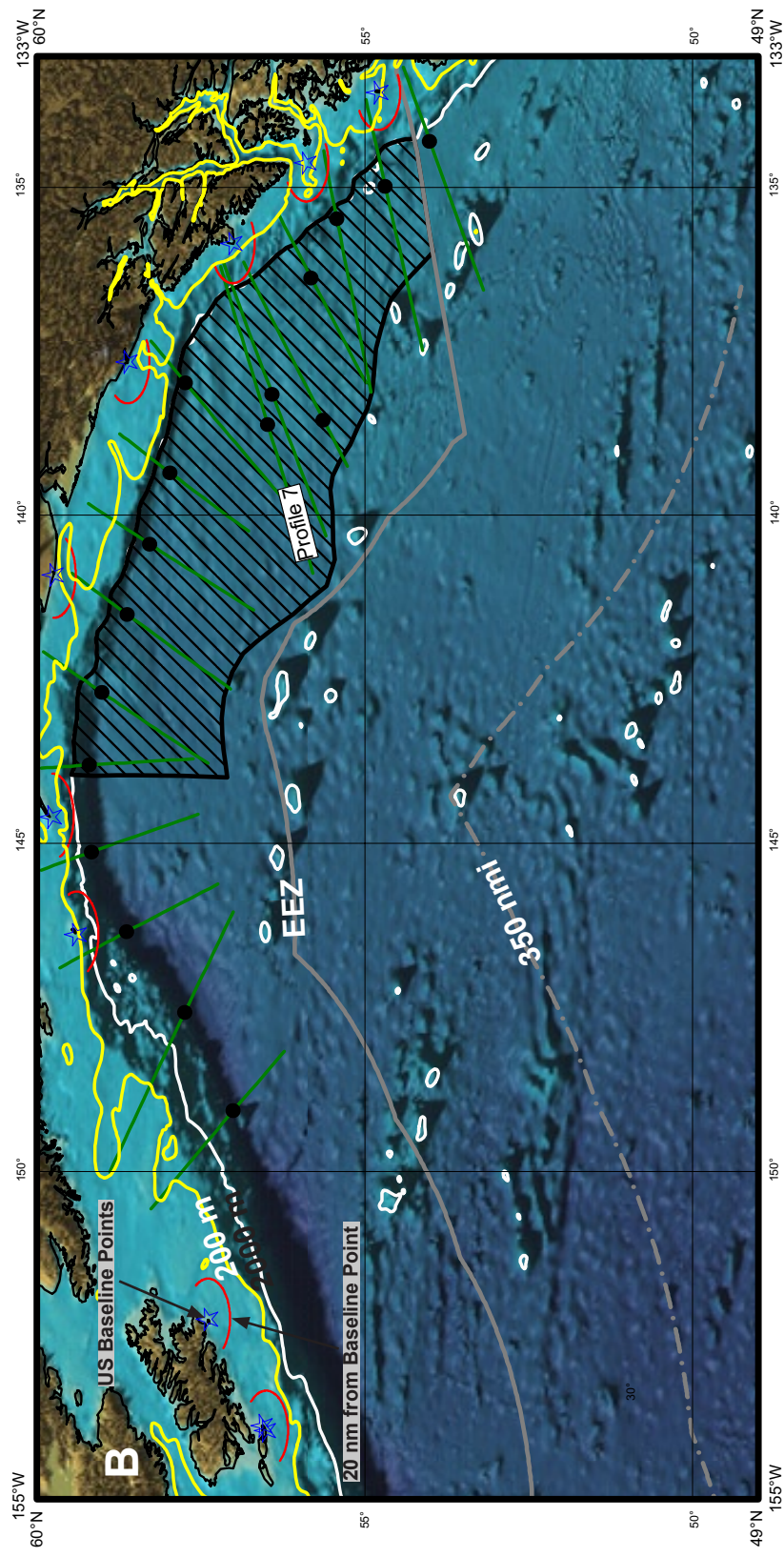


Figure 5.7A. Slope of seafloor by color in detailed area GA. Multiple bathymetric profiles are drawn through the area and possible locations of the FOS are marked with black dots. Variation in slope and resulting ambiguity in location of the selected FOS influences the size of the area (hatched) for which detailed bathymetry is required.



5.7B. Bathymetry from ETOPO2 in detailed area GA, drawn bathymetric profiles, and possible locations of the FOS. Labeled profile is shown in figure 5.8.

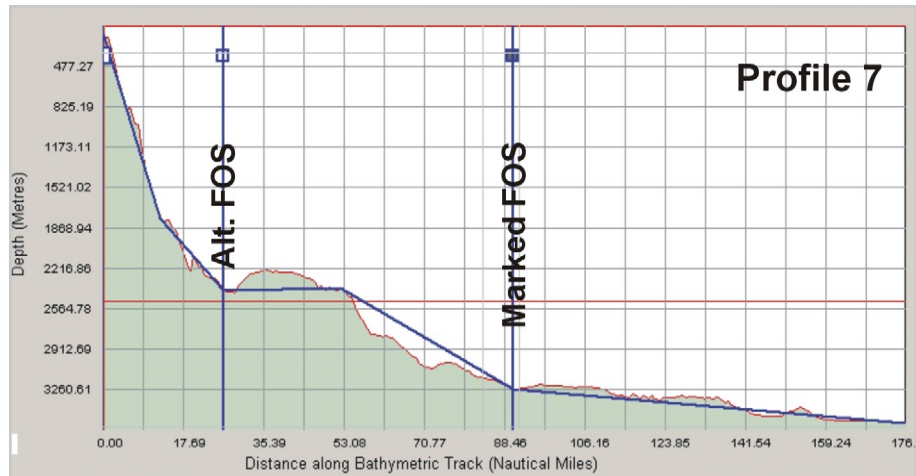
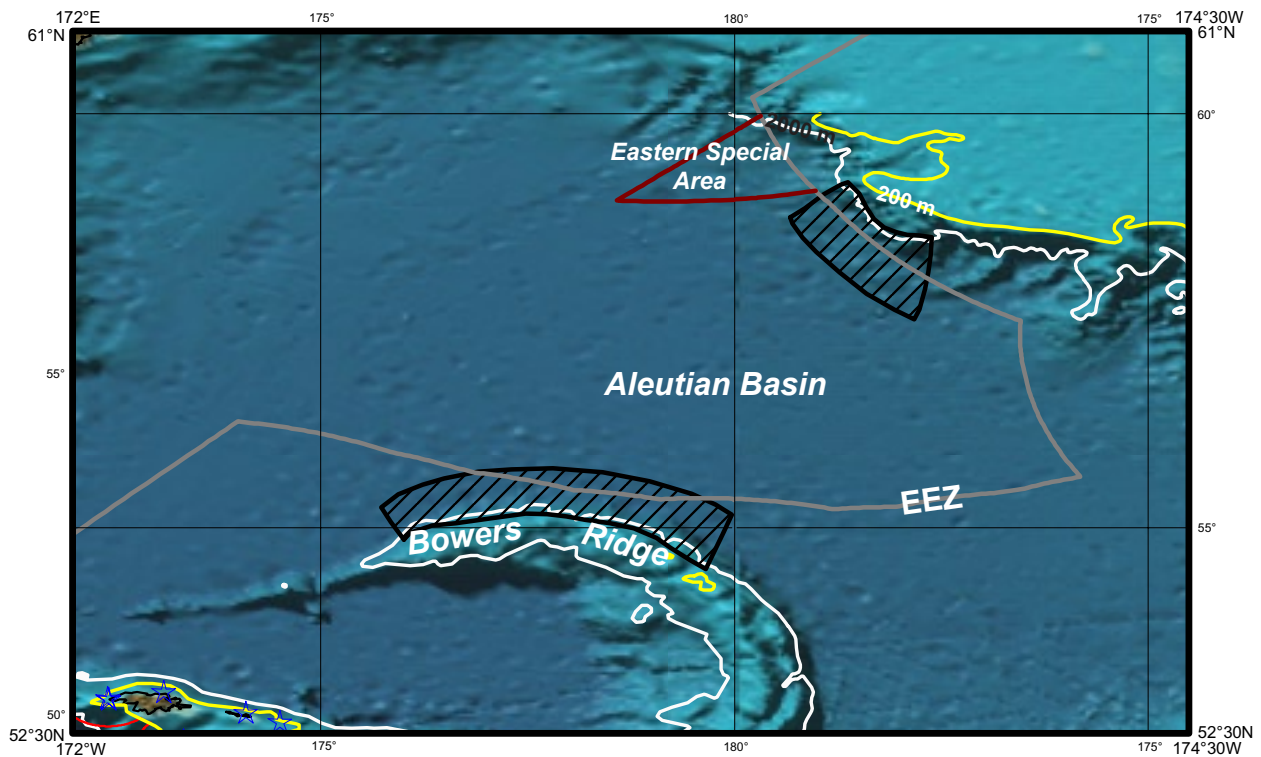


Figure 5.8. Bathymetric profile 7 in detailed study area GA. The locations of this profile is shown in figures 5.7A and B. The ambiguity in location of the FOS is clearly illustrated also in this area. The “Marked FOS” is the location marked with a dot in figure 5.7A and B. An alternative location for the FOS is shown in the profile. Note that the vertical exaggeration in the bathymetric profile accentuates gradient changes.



5.9. Bathymetry from ETOPO2 in the Aleutian Basin.

presently compiled thicknesses are understated it would justify acquisition of additional seismic data and bathymetric data.

#### *5.1.4.3 Existing bathymetry data in area*

NOAA Ship Surveyor carried out a systematic single beam survey during 1972 in the northern part of the area shown in figures 5.7A and B. In the southern part of the area, the Canadian Geological Survey completed a single beam survey from the ship *Parizeau* in 1978. The age, accuracy, and density of these surveys are such that new multibeam bathymetry is warranted throughout the corridor of interest.

#### *5.1.4.4 Estimated bathymetry survey cost*

The area requiring new surveys covers a total of  $\approx 161 \times 10^3 \text{ km}^2$  with a mean depth of approximately 3400 m. Total survey time required is approximately 39 days; with transit, mob/demob, and contingency, the estimated cost is approximately \$1.9 million. In the Gulf of Alaska, we recommend that bathymetric surveys be deferred until a thorough analysis of sediment thickness is completed. Should the sediment thickness analysis indicate that a Gardiner line is not feasible, the need for bathymetric surveys would be considerably reduced.

#### *5.1.4.5 Sediment thickness*

The sediment thickness information will be critical in order to establish if an extended claim according to Article 76 is warranted in detailed area GA.

#### *5.1.4.6 Existing seismic data in area*

Within the current EEZ in detailed area GA, our seismic trackline database indicates a seismic line spacing that is everywhere closer than 30 nmi (Appendix I:Map *Seismic-tracklines-sediment-GA*). The U.S.G.S. Gloria project carried out a regular seismic survey with approximately 10-20 nmi line spacing. This survey also reaches slightly beyond the EEZ between about 139°-146°W. Apart from the GLORIA data there are only a few sparse seismic tracklines that reach beyond the EEZ out to 350 nmi from the US Baseline (Appendix I:Map *Seismic-tracklines-sediment-GA*).

#### *5.1.4.7 Estimated seismic survey cost*

The maximum seismic survey requirement (hypothesis 1, no existing seismic data is adequate for sediment thickness measurement) between 147°W and the Canadian border, covering the entire area from the most landward possible location of the FOS out to the cutoff line is an area of approximately  $\approx 432 \times 10^3 \text{ km}^2$ . With a line spacing of 30 nmi a total seismic trackline length of approximately 7770 km. The cost of this maximum seismic survey alternative is estimated at approximately \$6.1 million. Should all existing seismic data be of sufficient quality to establish the sediment thickness, according to hypothesis 2, no area will require surveys.

### *5.1.5 Aleutian Islands and Bering Sea (Detail Map AL)*

This portion of the US continental margin south of the Aleutian Island largely comprises a subduction zone where little terrestrial sediment is likely to have accumulated on the seabed (Appendix I:Map *Tracklines-ETOPO2-AL*). The first criterion of the “Bay of Bengal Clause” (the average distance at which the 200 m isobath occurs is not more than 20 nmi from the country’s baseline) will apply along the Aleutian Islands south narrow margin, but the NGDC sediment compilation indicates that the sediments are far too thin here to support any extended claim (Appendix I:Map *Seismic-tracklines-sediment-AL*). North of the Aleutians, the area outside U.S. EEZ in the Bering Sea is part of the Aleutian Basin, as shown in figure 5.9. The sediments in this area are thick enough that a claim should be possible (Map *Seismic-tracklines-sediment-AL*).

#### *5.1.5.1 Bathymetry*

The FOS needs to be established in order to extend a claim in the area in the Aleutian Basin. New surveys are required, although they can focus on a fairly small area from which sediment thickness profiles would originate. For this purpose the FOS may be established along the Bowers Ridge, which should be considered a natural prolongation of the Aleutian Islands and the Alaskan Peninsula. In addition a small area should be surveyed to locate the FOS on the northern part of the Aleutian Basin as an alternative starting point for sediment thickness profiles.

#### *5.1.5.2 Existing bathymetry data in area*

There is very little available bathymetry data in this area. The only systematic survey data is from the U.S.G.S. GLORIA project wherein single beam bathymetry was acquired with wide trackline spacing.

#### *5.1.5.3 Estimated bathymetry survey cost*

A small survey of  $\approx 17 \times 10^3 \text{ km}^2$  along to establish the FOS along the Bowers Ridge is outlined in figure 5.9. In addition a small survey of  $\approx 9 \times 10^3 \text{ km}^2$  is suggested, on the northern part of the Aleutian Basin. The mean depths in these regions are 3400 and 3200 m respectively; total survey time to cover these areas would be approximately 7 days with a total cost including transit, mob/demob and contingency of approximately, \$1.1 million.

#### *5.1.5.4 Sediment thickness*

The thick sediment accumulations in the Aleutian Basin should make it possible to develop a claim that encompasses the entire area not currently covered by the EEZs of US and Russia.

#### *5.1.5.5 Existing seismic data in area*

The GLORIA survey data covers most of the potential claim in the Aleutian Basin. These data must be analyzed in detail before any additional surveys are planned.

#### *5.1.5.6 Estimated seismic survey cost*

Should the analysis of existing seismic lines indicate that new data needs to be acquired, a maximum area of  $\approx 201 \times 10^3 \text{ km}^2$  will need to be surveyed which give an accumulated track length of 3618 km. The existing data covers the area with far denser trackline spacing than 30 nmi. If those data are satisfactory to determine sediment thickness no additional seismic data are required. If new MCS reflection data will be needed for the entire area it would cost of \$3.4 million at the assumed rate for commercial contract.

#### *5.1.6 Arctic Ocean (Detailed Map ARC)*

##### *5.1.6.1 Bathymetry*

In the Arctic Ocean the 2500 m depth contour is of great importance along the Chukchi Cap and Northwind Ridge until it intersects the 350 nmi line at about 153°51'W, 77°10N (Figure 5.10A and B). Up to the point of this intersection, the 2500 m + 100 nmi will be the cutoff line and thus the limit of maximum possible extension beyond the current EEZ. The estimated survey area around the Chukchi Cap and Northwind Ridge in figure 5.10A and B begins with 2000 m contour from the IBCAO bathymetry. The outer limit is based on a slope map derived from the IBCAO grid and the outermost possible locus of the FOS from bathymetric profiles created in Caris LOTS software. Both the 2500 m contour and the FOS will be covered by the survey area suggested in figures 5.10A and B. Although the FOS is required as a starting point for sediment thickness profiles, it is the 2500 m contour that will play the critical role because the vast sediment thickness should allow the claim line to extend all the way to the 2500 m + 100 nmi cutoff line (see below).

A small new survey area has been included off the Beaufort Shelf (Figures 5.10A and B) to establish the FOS and a starting point for sediment profiles. In this area the FOS appears to be well defined in the IBCAO bathymetry (Figure 5.11). However, the IBCAO bathymetry grid here is mainly derived from contours based on data much too sparse to support a claim.

***Special Note***—In the Arctic Ocean, it may be possible to make use of the FOS and 2500 m contour on the western side of the U.S.—Russia treaty line. If so, 100 nmi measured from the 2500 m isobath of the Alpha-Mendeleev Ridge, assuming that ridge is held to be a “natural prolongation” of the continental margin (in this case the Russian continental margin), would create a different cutoff line within which a much larger area could be claimed. For the same reason, a line 100 nmi from the 2500 m contour along the Canadian Arctic margin could create a cutoff line outside the US 350 nmi line at about 135°W (Figures 5-10A and B). This is a very complex situation that must be resolved by legal experts. The survey implications are minimal, however, as they involve only defining the location of the 2500 m contour along the Alpha Mendeleev Ridge.

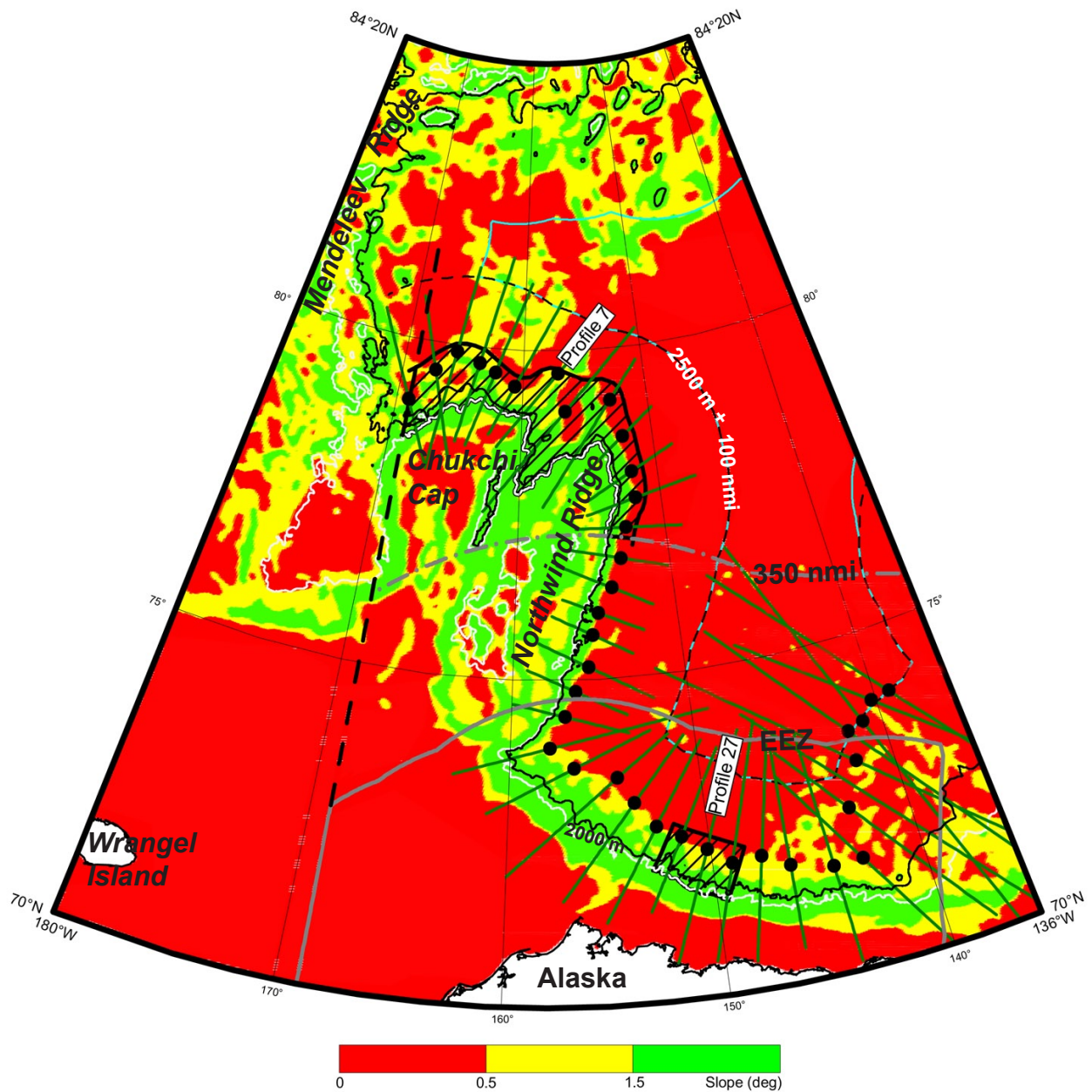
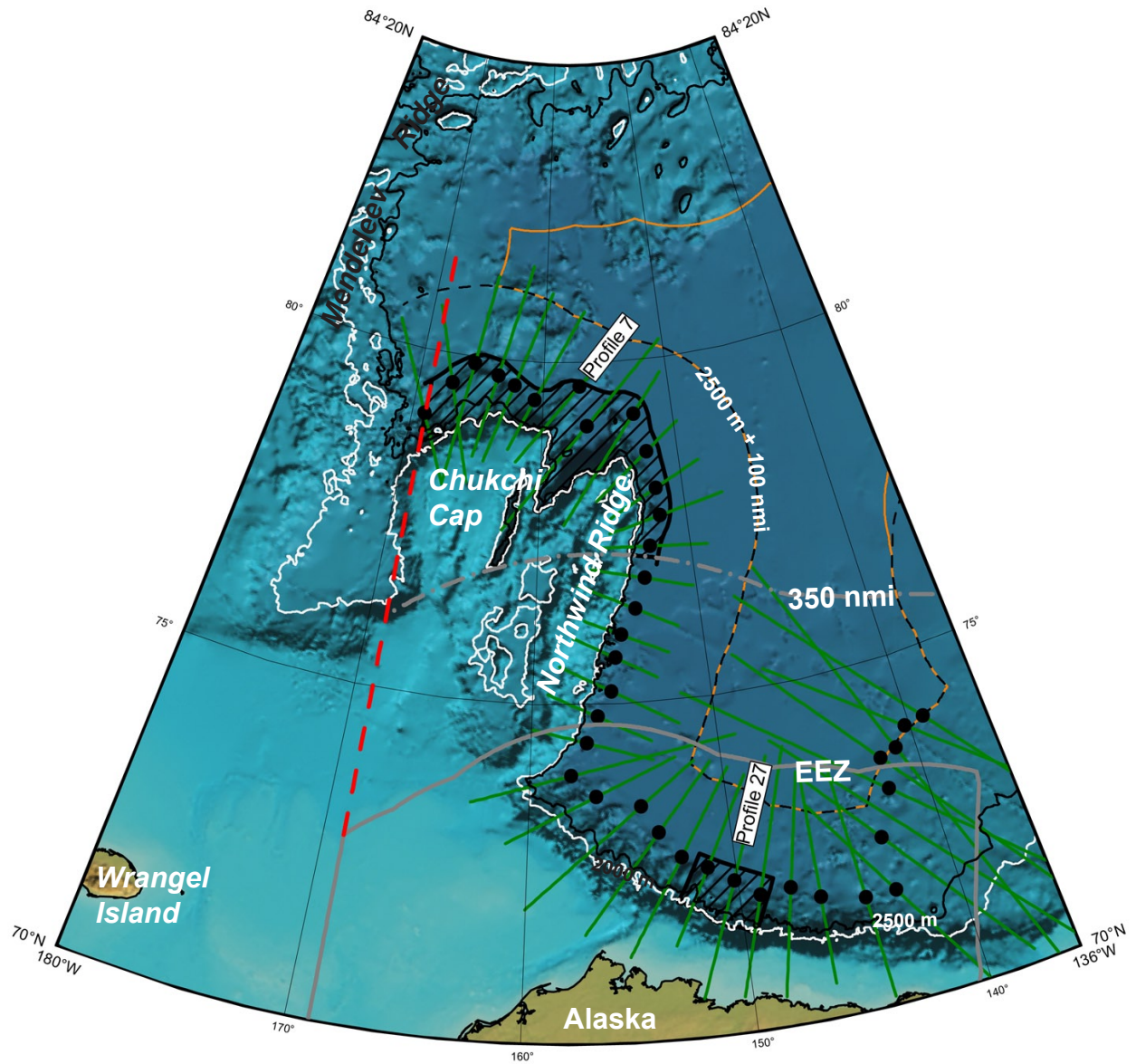


Figure 5.10A. Slope of seafloor by color in detailed area ARC. Multiple bathymetric profiles are drawn through the area and possible locations of the FOS are marked with black dots. Variation in slope and resulting ambiguity in location of the selected FOS influences the size of the area (hatched) for which detailed bathymetry is required.



5.10B. Bathymetry from IBCAO in detailed area ARC, drawn bathymetric profiles, and possible locations of the FOS. Labeled profile is shown in figure 5.11. Note that the orange line, which represents the 2500 m + 100 nm, makes use of the 2500 m contour of the Alpha-Mendeleev Ridge as well as the Canadian shelf.

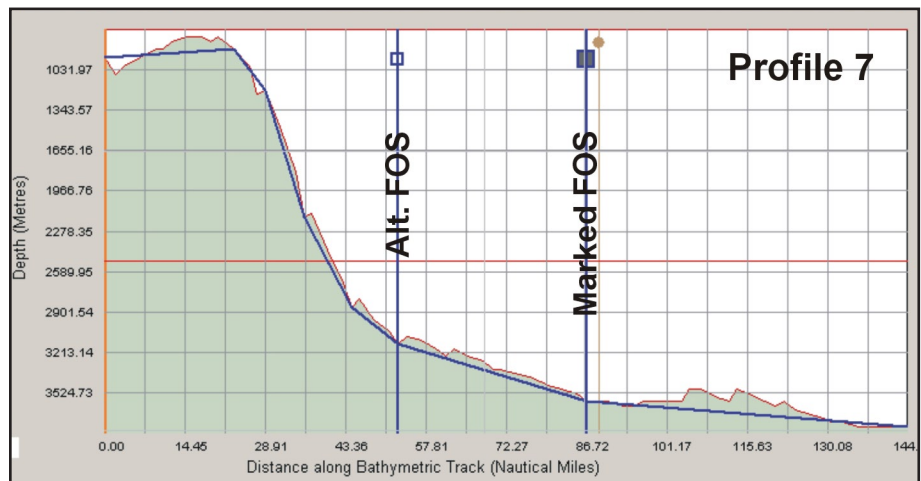
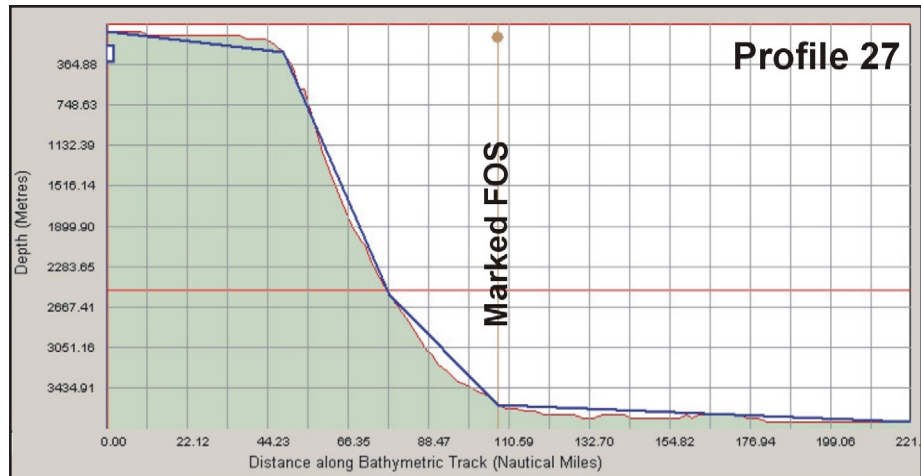


Figure 5.11. Bathymetric profiles 27 and 7 in detailed study area ARC. The locations of these profiles are shown in figures 5.10A and B. The ambiguity in location of the FOS is clearly illustrated in the area off the Beaufort Shelf. The “Marked FOS” is the location marked with a dot in figure 5.10A and B. An alternative location for the FOS is shown in profile 7. Note that the vertical exaggeration in the bathymetric profile accentuates gradient changes.

#### 5.1.6.2 *Existing bathymetry data in Area*

The only available multibeam data in the areas recommended for survey are the interferometric sonar bathymetry from the *USS Hawkbill* SCICEX cruises in 1998 and 1999 (Map *Tracklines-ARC*). However, the *Hawkbill* data do not comprise a systematic survey, and merely abut the southernmost part of the area off the Beaufort shelf area. All other existing data are sparse single beam bathymetry.

#### 5.1.6.3 *Estimated bathymetry survey requirements:*

The total area to be covered with bathymetric surveys is here  $\approx 62 \times 10^3 \text{ km}^2$  (Off the Beaufort shelf: 11892.7  $\text{km}^2$ ; off the Northwind Ridge and Chukchi Cap: 50402.1  $\text{km}^2$ ). Acquiring bathymetry in the Arctic ice covered regions presents a series of logistical challenges that make the requirements for high Arctic work much different from those for other areas. Standard survey vessels cannot operate safely in ice covered regions and thus specialized platforms must be considered for data collection. Three options exist: surveying from icebreaker, surveying from nuclear submarines, or using autonomous underwater vehicles. The feasibility of using both icebreakers and nuclear submarines has already been demonstrated (see Appendix F). AUV's probably hold out the greatest long-term hope for efficient surveying under the ice but present-day technological limitations with respect to endurance, power requirements, and positioning make the use of AUV's for collecting wideswath multibeam bathymetry and seismic data under the ice not yet practical. We thus conclude that the most feasible way of collecting bathymetry and seismic data in the high Arctic is from either an icebreaker or a nuclear submarine.

#### 5.1.6.4 *Sediment thickness*

In the southern Canada Basin the sediment thickness has been estimated to range between 6.5 km in water depths greater than 3800 m and 11 km where the water depths, is 2000 m (May and Grantz, 1990). The sediment compilation by Jackson and Oakey (1990) further indicates a sediment thickness in the order of 6 km in the northern Canada Basin. This large thickness of sediment should make it possible to extend a potential US claim out to the cutoff line as defined in Article 76 (see above).

#### 5.1.6.5 *Existing seismic data in area*

The existing seismic reflection data in the southern Canada Basin are comprised of multi-channel seismic (MCS) data acquired by U.S.G.S. in 1977 (Grantz *et al.*, 1982) and digital single channel seismic data acquired in 1992 and 1993 (Grantz *et al.*, 1993) (Map *Seismic-tracklines-sediments-ARC*). Available refraction data are summarized at the "Arctic Refraction Catalogue" hosted by the Geological Survey of Canada (<http://agcwww.bio.ns.ca/pubprod/arctic/index.html>).

#### 5.1.6.6 *Estimated seismic survey requirement*

Although U.S. Coast Guard icebreakers can be equipped with compressors and air guns for collection of MCS reflection data in the Canada Basin, restrictions imposed by the pack ice make it difficult to carry out major systematic surveys. Recognizing the special circumstances in the Arctic Ocean, the Commission has indicated that it may be

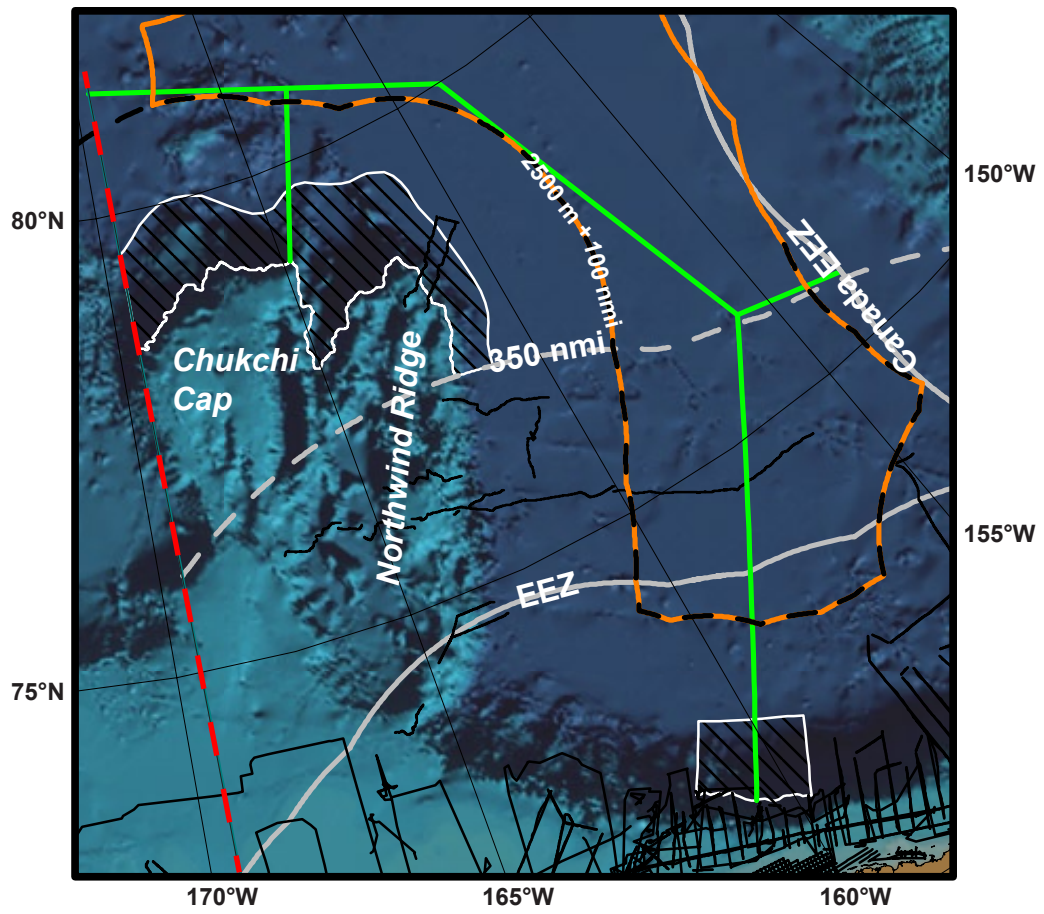


Figure 5.12. Estimation of additional MCS reflection profiles (green) that need to be collected in the Arctic Ocean. Together the total length reach approximately 1794 km.

accept less dense data in this region. Thus it may be sufficient to collect only a few additional long MCS reflection profiles (Figure 5.12). One approach is to collect a long line that starts from an established FOS off the Beaufort Shelf and continues out through Canada Basin, crossing the profile previously collected by Dr. Art Grantz of the U.S.G.S., to reach outside 350 nmi of the US Baseline. A second profile could then be collected that starts from outside the Canadian EEZ, and runs outside 350 nmi from the U.S. baseline to intersect with the first profile. Furthermore, starting from the intersection of the first two profiles a series of profiles running sequentially seawards of the 2500 m +100 nmi line off the Northwind Ridge and Chukchi Cap may be required. Finally, one line that connects the Chukchi Cap's FOS with the previous profiles is needed in order to adhere to the recommendations of Article 76. These lines should be sufficient to establish the Gardiner Line with the required 1% sediment thickness markers. Together they add up to approximately 1750 km.

#### *5.1.6.7 Estimated combined bathymetric and seismic survey cost*

Coakley and Brass (2002), in a report by the U.S. Arctic Research Commission (attached as Appendix F) have estimated a complete combined cost of \$12 million for 60 operational days in the Arctic using an icebreaker for acquiring of MCS pre-survey support for bathymetry, and 60 operational days on a U.S. Navy submarine equipped with the SCAMP survey system to map the bathymetry. The U.S. Arctic Research Commission is an authoritative source on Arctic operations. We believe that the suggested 60 icebreaker plus 60 submarine days should be sufficient to complete the necessary surveys in the Arctic and thus use their estimate of \$12M to cover Arctic survey costs.

## **5.2 US Islands in the Pacific Ocean**

The U.S. Islands in the Pacific are unlikely to see substantial extensions of seabed resource jurisdiction. However in at least two places, there may be interpretations of Article 76 under which **modest** extended claims are possible: (1) in area west of the Mariana Islands; and (2) an area southwest of Kingman Reef and Palmyra Atoll. In this section we outline the situation in all the U.S. Pacific island areas.

### *5.2.1 Hawaiian Islands*

The Hawaiian Islands consist of a series of semi-isolated peaks rising from the deep ocean floor. A simple envelope of arcs represents their joint EEZ limit (Appendix I:Map *Detailed-maps*). Neither the surrounding seabed morphology nor the sedimentary configuration would appear to offer the possibility of extending an outer continental shelf limit beyond 200 nautical miles.

### 5.2.2 *Johnson Atoll*

Johnson Atoll is an isolated peak situated south of Hawaii, near the intersection of Necker and Christmas Ridges (Appendix I:Map *Detailed-maps*). Its EEZ limit is essentially circular. The morphology of the surrounding seabed provides no opportunity for an application of the distance formula, although the sedimentary configuration, featuring an elongated structure that trends from the southwest to the northeast, might present some possibilities in relation to the “Bay of Bengal Clause.” However, before an additional bathymetric survey is outlined in this area a geophysical analysis of existing seismic data is warranted to determine if the sediment thickness reaches the requirements for the “Bay of Bengal Clause”. The NGDC compilation used in this study shows a maximum sediment thickness of 400 m in the northeast corner of the elongated sediment structure, which would not be sufficient to support a claim. The seismic data collected during the U.S.G.S. Gloria project (not included in NGDC’s sediment compilation) should be analyzed for this purpose since it covers the current EEZ of Johnston Atoll.

### 5.2.3 *American Samoa*

The EEZ of American Samoa is formed almost entirely by boundaries with neighboring island nations. The combination of bilateral boundaries and seafloor morphology of the islands offers no opportunity for an extended claim.

### 5.2.4 *Mariana Islands (Detailed map MI)*

The Mariana EEZ limit encloses a kidney-shaped region (Map *Detailed-maps*). The northwestern part is bounded by a straight line that forms a bilateral boundary with the Japanese Islands to the north, while the southern part consists of a series of line segments that define a bilateral boundary with the Federated States of Micronesia.

#### 5.2.4.1 *Bathymetry*

A narrow zone west of the Mariana Islands EEZ might qualify as an extended continental shelf. The Mariana complex encompasses the crescent-shaped and north-south trending Mariana Basin that is bounded on the west by the West Mariana Ridge (also known as the South Honshu Ridge), and on the east by the East Mariana Ridge (Figure 5.13A and B). Several peaks in the East Mariana Ridge rise above sea level to form the Mariana Islands. There could be a geological and/or tectonic basis for considering the entire ridge-basin-ridge complex as a structural entity, and for arguing that it should be treated as a “natural prolongation” of the islands’ landmass. These issues are still unresolved with respect to UNCLOS Article 76. If arguments of this sort are accepted with respect to island arcs, there may be the possibility of placing the FOS seaward of the West Mariana Ridge, for use in developing one or both of the Article’s two formula lines. Of the two, the distance formula (FOS + 60 nmi) is more advantageous in this region, in light of the paucity of sediment indicated in the NGDC

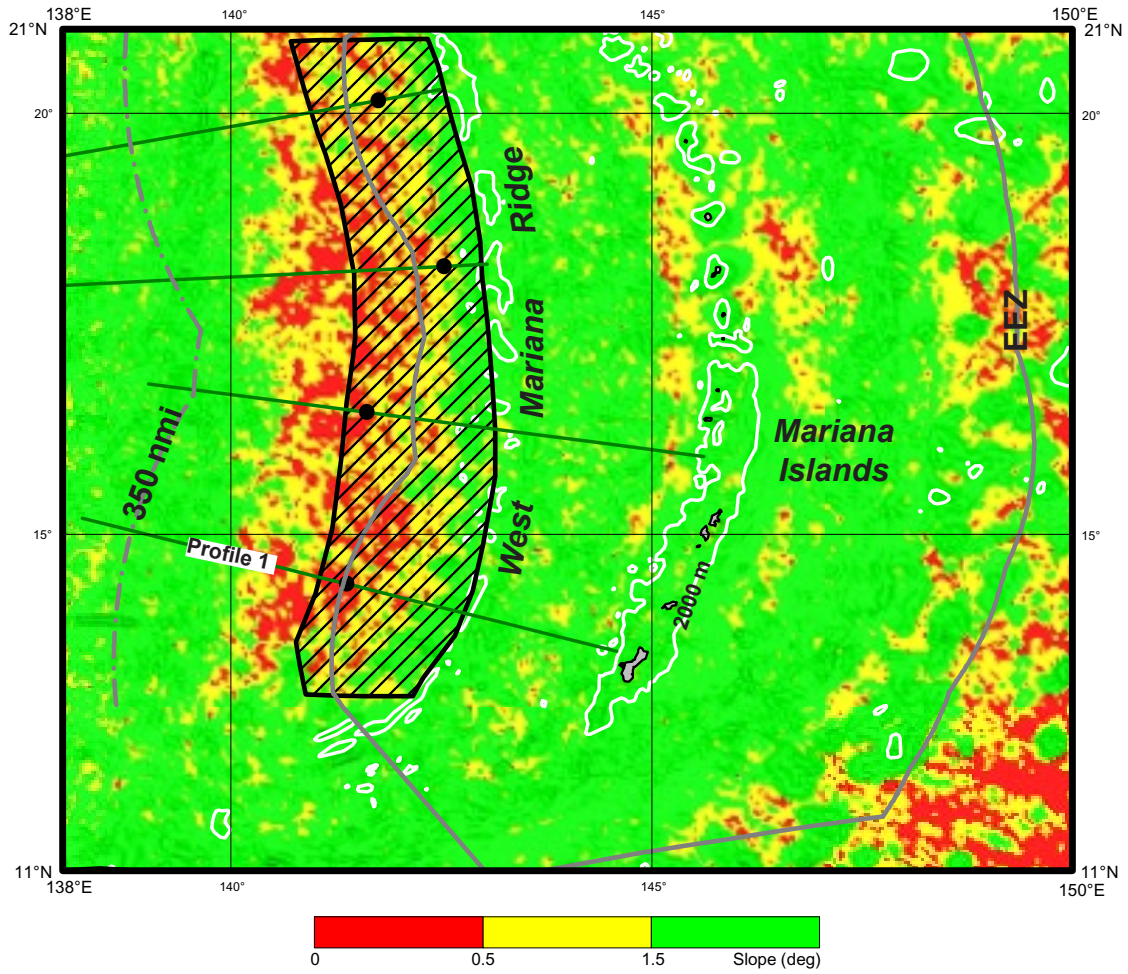
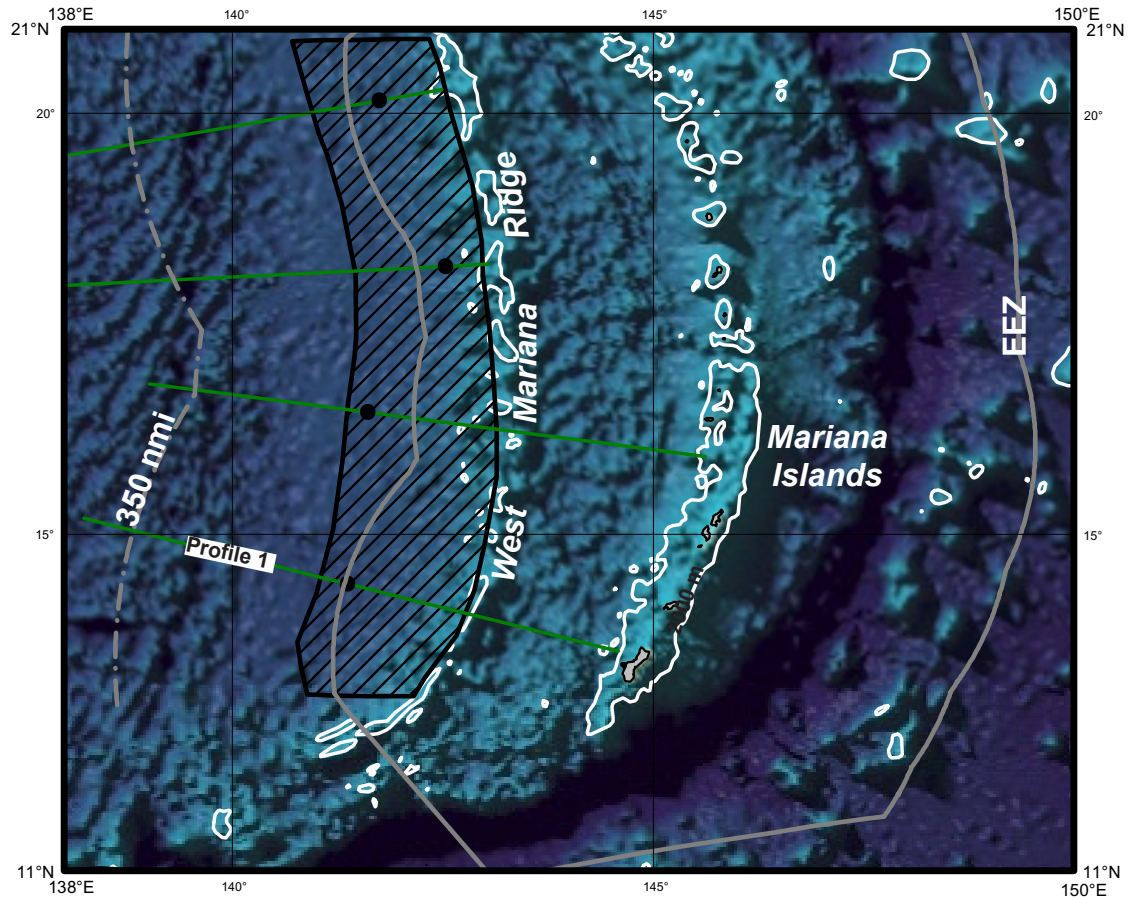


Figure 5.13A. Slope of seafloor by color in detailed area MI. Multiple bathymetric profiles are drawn through the area and possible locations of the FOS are marked with black dots. Variation in slope and resulting ambiguity in location of the selected FOS influences the size of the area (hatched) for which detailed bathymetry is required.



5.13B. Bathymetry from ETOPO2 in detailed area MI, drawn bathymetric profiles, and possible locations of the FOS. Labeled profile is shown in figure 5.14.

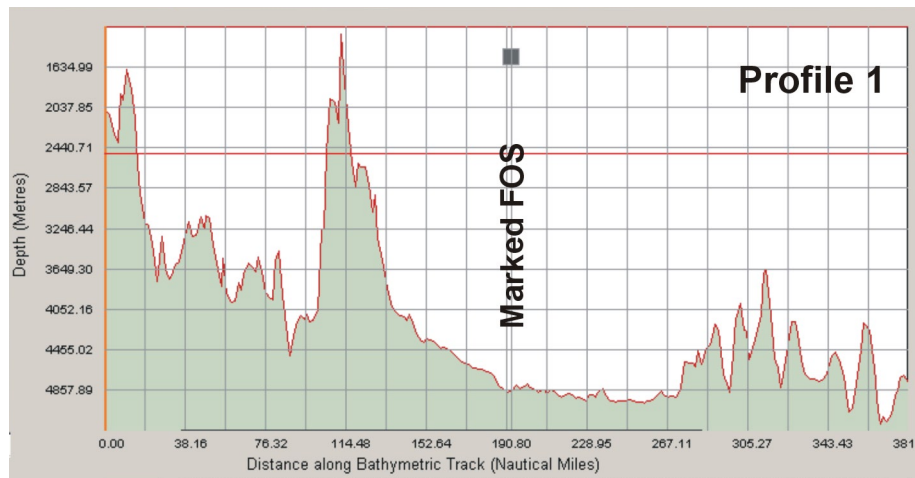


Figure 5.14. Bathymetric profile 1 in detailed study area MI. The location of this profile is shown in figures 5.13A and B. The “Marked FOS” is the location marked with a dot in figure 5.13A and B. Note that the vertical exaggeration in the bathymetric profile accentuates gradient changes.

sediment thickness compilation. The cutoff line for the Mariana Islands will be the 350 nmi line. The proposed survey area is designed to establish the FOS.

#### *5.2.4.2 Existing bathymetry data in area*

We find no multibeam or systematic single beam surveys sufficiently dense or accurate enough to support an extended claim (Appendix I:Map *Tracklines-MI*). One small multibeam cruise of very limited extent was located in the area.

#### *5.2.4.3 Estimated bathymetry survey cost*

The total area to be covered with the bathymetric surveys suggested here is  $\approx 155 \times 10^3 \text{ km}^2$ , with a mean depth of about 4000 m; survey time for this area is estimated to be approximately 30 days. With transit, mob/demob and contingency, we estimate the total cost of the bathymetric survey in this region to be approximately \$2.3 million.

#### *5.2.4.4 Geophysical Data*

In order to build a claim based on a FOS on the western side of the West Mariana Ridge, an analysis of existing geophysical data is required. Following that analysis, it may be necessary to gather additional geophysical data as “evidence to the contrary” on the location of the FOS. With the information presently available, we are unable to estimate what the cost of new data acquisition might be. However, we can say that with the cost of mobilization/demobilization and transit, a minimum cost for any new data acquisition would be approximately \$1.5 million.

#### *5.2.5 Wake Island*

Located among a cluster of isolated seafloor highs known as the Mid-Pacific Seamounts, Wake Island is one of the few to rise above sea level. Its EEZ limit is generally circular, except in the southeast where it consists of a straight line that defines a bilateral boundary with the Marshall Islands. The morphology of the surrounding seabed appears to offer little or no possibility for applying the provisions of Article 76.

#### *5.2.6 Kingman Reef and Palmyra Atoll (Detailed Map KP)*

Situated close together at the northern extremity of the Line Islands, these two features represent high points on Christmas Ridge (Appendix I:Map *Detailed-maps*). Their combined EEZ limit is slightly oval, except in the southeast where a straight-line segment defines a bilateral boundary with a neighboring island state. Any claim of extended jurisdiction would be based on bathymetric data.

##### *5.2.6.1 Bathymetry*

Northeast of the islands, neither the surrounding seabed morphology nor the sedimentary configuration would appear to support an extension. Southwest of the islands, a multibeam survey might establish the FOS near the 200 nmi limit line

(Figures 5.15A and B). If this were so, a claim to the FOS + 60 nmi line could result in a small extended claim.

#### *5.2.6.2 Existing bathymetry data in area*

Two multibeam tracks pass the area covered by the US EEZ around Palmyra Atoll and Kingman Reef. However, neither of these tracks goes through the area where the FOS might be placed in deeper water. Only a few single beam tracks are located in this area. (Map *Tracklines-ETOPO2-KP*) None of these data are sufficient to support a claim, or to determine with any certainty if a claim is even feasible.

#### *5.2.6.3 Estimated bathymetry survey time and cost*

Based on ETOPO2, the suggested survey area is designed to locate the FOS southwest of the islands (Figure 5.15A and B). The area is  $\approx 54 \times 10^3 \text{ km}^2$  with a mean water depth of approximately 4400 m, representing approximately 10 days of survey time. The estimated cost, including transit, mob/demob and contingency is approximately \$1.2 million.

#### *5.2.7 Baker and Howland Islands*

These two islands are situated close to each other in the south end of the Central Pacific Basin (Map *Detailed-maps*). Their combined EEZ limit is slightly oval, except in the southeast where a straight-line segment defines a bilateral boundary with the Phoenix Islands. Neither the surrounding seabed morphology nor the sedimentary configuration would appear to offer any possibility of claiming an outer continental shelf limit beyond 200 nautical miles.

#### *5.2.8 Jarvis Island*

Jarvis Island is located west of the Line Islands. About half of its EEZ limit is circular; the remainder consists of a series of straight-line segments that define bilateral boundaries with the Line Islands situated to the east and northeast. Neither the surrounding seabed morphology nor the sedimentary configuration would appear to offer any possibility of claiming an outer continental shelf limit beyond 200 nautical miles.

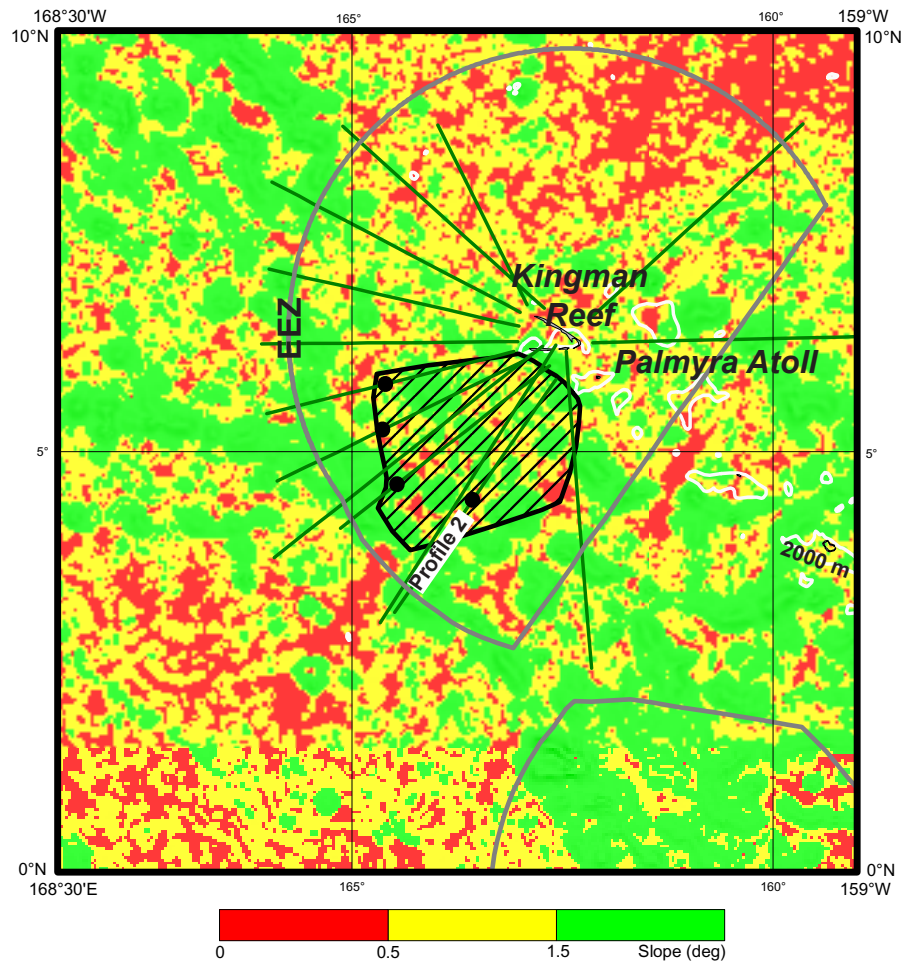
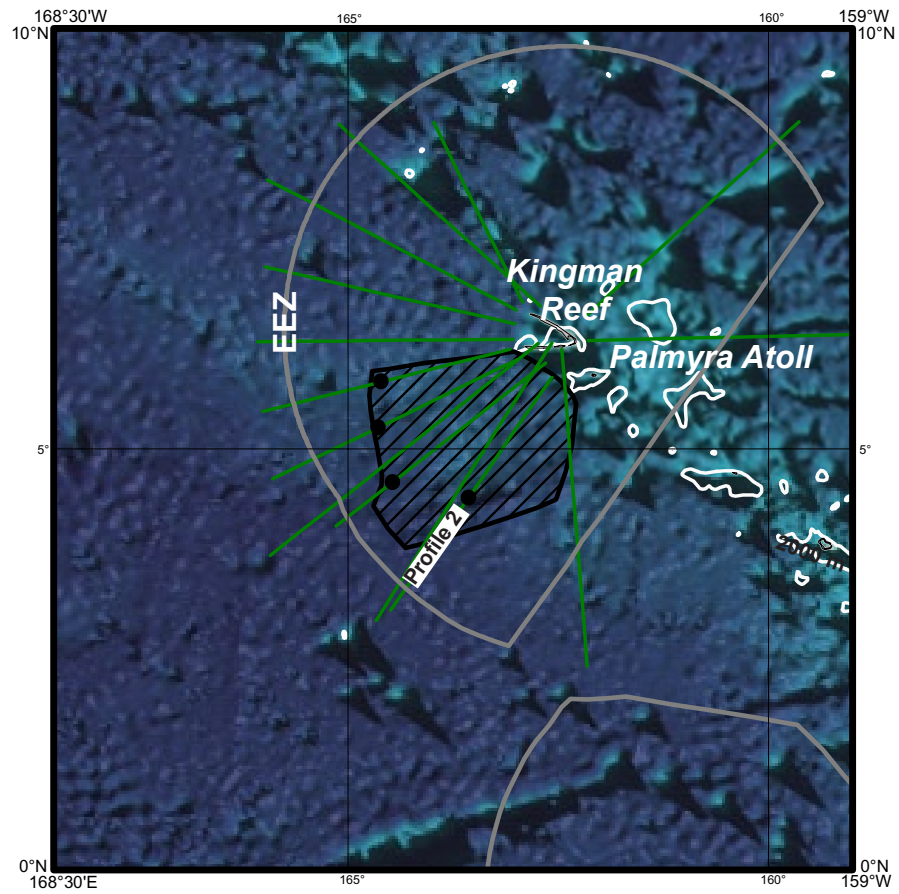


Figure 5.15A. Slope of seafloor by color in detailed area KP. Multiple bathymetric profiles are drawn through the area and possible locations of the FOS are marked with black dots. Variation in slope and resulting ambiguity in location of the selected FOS influences the size of the area (hatched) for which detailed bathymetry is required.



5.15B. Bathymetry from ETOPO2 in detailed area KP, drawn bathymetric profiles, and possible locations of the FOS. Labeled profile is shown in figure 5.16.

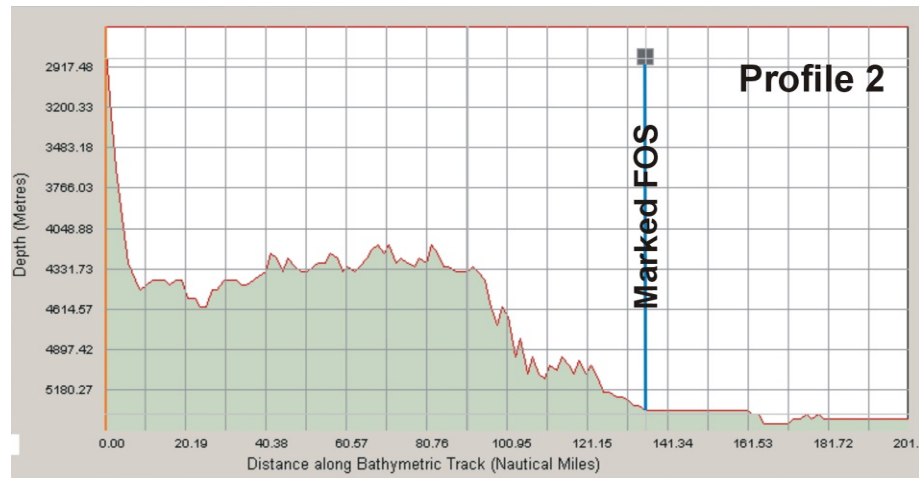


Figure 5.16. Bathymetric profile 2 in detailed study area KP. The location of this profile is shown in figures 5.15A and B. The “Marked FOS” is the location marked with a dot in figure 5.15A and B. Note that the vertical exaggeration in the bathymetric profile accentuates gradient changes.

**Table 5.1. Bathymetric Survey Costs:** Estimates of the areas suggested for detailed survey in regions where there may be a potential claim for an extended continental shelf under Article 76. A general discussion of how the areas were selected is found in Section 3.6; detailed discussions are presented area by area in Section 5. For each region, the area to be surveyed, the average depth, estimated bathymetric survey line length, and survey cost (for high-resolution multibeam sonar data) are presented. Costs are based on estimates of current (2002) rates for commercial surveys and include cost of mobilization/demobilization, transit, and contingency. Rates vary depending on the location of the survey area. Costs for the Arctic represent the total cost for all Arctic work (off Chuckchi and Beaufort Shelf) and are based on proposal by U.S. Arctic Research Commission to use a nuclear submarine and icebreaker (Appendix F). It is important to recognize that the potential gain from an extended claim is quite variable from area to area (e.g., the potential increase in the area of the continental shelf is much greater off the east coast of the U.S. than it is around the Pacific Island (if any increase is at all possible around the Pacific Islands)).

Survey area	Area (km <sup>2</sup> )	Mean Depth	Estimated track length (km)	Estimated cost (USD)
				Million
NE	219614.3 ( $\approx 220 \times 10^3$ )	3447	20952	1.9
SE	154122.9 ( $\approx 154 \times 10^3$ )	4247	12844	1.3
GM (EAST)	12520.2 km <sup>2</sup> ( $\approx 13 \times 10^3$ )	3235	1444	.4
GM (WEST)	13803.4 ( $14 \times 10^3$ )	3337	1401	.3
GA	160996.3 ( $\approx 161 \times 10^3$ )	3132	15784	1.9
AL (South)	17124.2 km <sup>2</sup> ( $17 \times 10^3$ )	3520	1667	.95
AI (North)	9199.7 ( $\approx 9 \times 10^3$ km <sup>2</sup> )	3281	958	.14
ARC (Off Chukchi-Northwind)	50402.1 ( $\approx 50 \times 10^3$ )	3149	N/A	12*
ARC (Off Beaufort Shelf)	11892.7 ( $\approx 12 \times 10^3$ )	3099	N/A	*
MI (Mariana Islands)	155147.7 ( $\approx 155 \times 10^3$ )	4053	12917	2.2
Palmyra Atoll and Kingman Reef	54355.2 ( $\approx 54 \times 10^3$ )	4527	4091	1.2

**Table 5.2. Seismic Survey Costs:** Estimate of the area where there is a **possible** need for additional seismic surveys. **It is impossible to judge the appropriateness of existing seismic data without careful geophysical analysis. Until such analyses can be done we offer two end-member hypotheses to frame the range of potential costs:** 1) that the entire area from the most landward possible location of the FOS out to 350 nmi from US baseline needs to be covered with new multichannel seismic reflection data with a trackline spacing of 30 nm, (very unlikely) and: 2) that the area described above needs to be covered but all current available data for which we hold trackline information is of sufficient quality to establish the thickness of sedimentary rock beneath the ocean floor (more likely but some new data may be needed). Only a careful analysis of existing data can determine this. This methodology is described more in detail in the Methodology (Section 3). Costs are based on discussions with several commercial contractors and reflect today's market. Costs vary with the depth of penetration required, the complexity of processing and the remoteness of the area to be surveyed. Costs for collecting seismic in the Arctic are covered in the same \$12M estimate provided by the U.S. Arctic Research Commission for the collection of bathymetry (Appendix F).

Survey area	Hyp.1 Area (km <sup>2</sup> )	Track length (km)	Hyp. 2 Area (km <sup>2</sup> )	Track length (km)	Hyp. 1 Cost (\$ million)	Hyp. 2 Cost (USD)
NE	437371.1 (≈437x10 <sup>3</sup> )	7872	0	0	6.0	0
SE	364924.1 (≈365x10 <sup>3</sup> )	6568	0	0	5.0	0
GM	0	0	0	0	0	0
GA	431680.9 (≈432X10 <sup>3</sup> )	7770	0	0	6.1	0
AL	201052.6 (≈201x10 <sup>3</sup> )	3618	0	0	3.4	0
ARC	N/A	1750	N/A	1750	*	*
MI	unk	unk	unk	unk	> 1.5	0
KP	0	0	0	0	0	0

## 6 SUMMARY AND RECOMMENDATIONS:

Under Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS), coastal states may claim sovereignty over “submerged extensions of their continental margin” beyond the recognized 200 nautical mile limit of their Exclusive Economic Zone. The circumstances that define whether or not a coastal state can extend its jurisdiction are based on a complex set of rules that involve the analysis of the depth and shape of the seafloor in the areas of interest, as well as the thickness of the underlying sediment. Thus the proper implementation of Article 76 requires the collection, assembly, and analysis of a body of relevant hydrographic, geologic, and geophysical data according to the provisions outlined in the Article.

The United States has not yet acceded to the UNCLOS but, with growing recognition that implementation of Article 76 could confer jurisdiction and management authority over large (and potentially resource-rich) areas of the seabed beyond our current 200 mile limit, there has been renewed interest in the potential for a U.S. claim. In light of this growing interest, Congress (through NOAA), has funded the University of New Hampshire’s Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC) to evaluate the content and condition of the nation’s bathymetric and geophysical data holdings in areas surrounding the nation’s EEZ and, in particular, to evaluate what needs to be done to bring these data holdings to a state of completeness such that they may be used, with full confidence, for substantiating the extension of resource or other national jurisdictions beyond the present 200 nautical mile limit.

In order to complete this extensive evaluation in the short time available, the CCOM/JHC worked with the NOAA’s National Geophysical Data Center, The U.S. Geological Survey and several consultants. Our first task was to gather all available bathymetric and geophysical data as well as the relevant data compilations needed to understand the morphological and sedimentological characteristics of the seafloor that would be used in making an extended margin claim under Article 76. These data were evaluated for quality and assigned an uncertainty value based on age and/or type of positioning system used during data collection. The data were then entered into an ORACLE 9i database to facilitate instantaneous access, sorting and analyses. The Oracle database was linked to an Intergraph GEOMEDIA Professional Geographic Information System (GIS), allowing a range of displays and maps to be created from any combination of data sets. We believe that this database, one of the most efficient of its kind available, will be useful for a number of tasks beyond the current Law of the Sea project.

Once entered into the database and GIS, analysis of the data could begin. The first step was to identify those areas surrounding the U.S. where there is **potential** for a claim of an extended continental shelf under Article 76 (and eliminate areas where there is no potential). Eight regions were identified for further study, including most of

the U.S. east coast, the Gulf of Mexico, the Alaskan margin, the Arctic margin, and the areas around Guam and Palmyra Atoll. **We emphasize that this exercise is not designed to establish a U.S. claim but rather to explore regions where there might be potential for an extended claim.** A narrow continental shelf and/or lack of thick sedimentary sections eliminated the U.S. west coast, as well as areas around Hawaii, Puerto Rico, Johnston Atoll, American Samoa and Wake Island. For each of the eight detailed study areas identified, an analysis was done to determine which of the data sets required to make a claim for an extended continental shelf under Article 76 (the 2500 m isobath, the foot of the slope, or the point where the sediment thickness is 1 percent of the distance back to the foot of the slope) was the most critical.

The next and most critical step in the analysis involved determining whether the existing database is adequate for making an extended claim under Article 76. The only guideline provided by Article 76 with respect to data density is found in Paragraph 7 which states that: “The Coastal State shall delineate the outer limit of the continental shelf, where that shelf extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by coordinates of latitude and longitude.” This paragraph does not explicitly talk about the density of the underlying data but rather the fact that in constructing a claim the proposed limits must be established at intervals no more than 60 nmi apart. The only clear requirement is that the data submitted must be acceptable to the Commission, but there is no explicit description of, nor precedent yet established for, what is, or is not, acceptable. Given this uncertainty, our approach to identifying “data gaps” has been very conservative (i.e., if there can be any question, we consider an area a data gap).

For each of the detailed survey areas we examine the DENSITY of present data holdings as well as the QUALITY (and associated uncertainty) of the existing data (as defined above and in the methodology section). Based on data density alone, existing bathymetric data within most of the U.S. EEZ (with the exception of the Arctic) would probably be sufficient for making a claim (i.e., there is enough data to construct bathymetric profiles at least every 60 nautical miles). However, when the relative quality of much of the older data sets and the resolution with which the bathymetry can be defined is considered, it is clear that the uncertainty associated with these data sets would make any definition of the 2500 m isobath or the foot of the slope subject to question. We thus recommend the collection of modern, high-density, complete coverage multibeam sonar data in those areas where the possibility of an extension of the continental shelf depends on delineating either the 2500 m isobath or the foot of the slope. We also contend that having well-navigated, complete, high-density coverage of the critical areas of the EEZ, not only allows for a more accurate selection of the bathymetric features needed for making an extended claim under UNCLOS Article 76, but also opens up the possibility of maximizing or optimizing a claim (see figures 6.1-6.4). Such data can also serve a range of other environmental, geologic, engineering and fisheries habitat needs. In this light, we have defined a bathymetric data “gap” as those regions where we lack either multibeam or very dense modern single beam sonar data.

Definition of a data gap for seismic (sediment thickness) data is more difficult to quantify. The database collected over the past few months shows the presence or absence of seismic data but does not provide information on the quality of the seismic data nor the most critical aspect of it -- whether or not the seismic data can resolve basement or has the sound speed information necessary to define the thickness of the sediment section. In order to determine whether or not the seismic data is appropriate for a Law of The Sea claim under Article 76, it must be interpreted by geophysical experts. This time-consuming process could not be done in the time available for this report, but should be undertaken by experts at the U.S. Geological Survey. In order to set constraints on the potential magnitude of the seismic effort needed, we have, however, tried to establish end-member scenarios. To do this we have made two alternative assumptions: 1- that none of the seismic data in the database is appropriate (certainly an unlikely assumption but one that will at least provide an end-member constraint), or; 2- that all of the data in the database are fully appropriate (also not likely but probably much closer to reality). In the case of seismic data, the 60 nautical mile constraint helps define a reasonable starting point to test for sufficient data density. A simple Nyquist criterion, suggests sampling at twice the required spatial frequency. Thus for the first assumption (that none of the existing seismic data is appropriate) we assume that a seismic profile is needed every 30 nautical miles. For the second assumption (that all of the existing seismic data is appropriate) we define as gaps only those areas for which a seismic profile crossing the margin does not exist every 30 nautical miles.

Once the data gaps were defined, the next step was to determine the approach and level of effort necessary to fill those gaps. For bathymetry, the area to be surveyed was selected based on a general approach of using the best-available compiled bathymetry (ETOPO-2) to generate a slope map (the derivative of the bathymetric surface). Based on both the bathymetry and slope map, an isobath was selected from the GEBCO Digital Atlas so that any possible position of the foot of the slope was seaward of this contour (typically the 2000 m contour). This contour represents the landward limit of the required survey. The seaward limit of the proposed survey was selected based on the ETOPO-2 morphology, the slope map and a series of bathymetric cross-sections. Thus we define a survey corridor in which a detailed multibeam survey would much more accurately determine the location of the foot of the slope and the 2500 m isobath. Removed from this area are any regions for which multibeam sonar data or modern very high-density NOS survey data already exists.

Given the relatively deep water depths in the proposed survey corridors (1000 – 5000 m) as well as the desire to collect full-coverage multibeam bathymetry and thus allow for the precise determination of critical bathymetric features as well as potential optimization of a claim (see below), the survey of systems of choice are deep-water (12 kHz) multibeam sonars. Several manufacturers offer 12 kHz multibeam systems and there are numerous installations on both government and private sector vessels. Inasmuch as 12 kHz systems are large, survey vessels of at least 200 feet in length with

permanently installed systems will be required. While the detailed specifications of these systems vary somewhat from manufacturer to manufacturer, in general these systems provide a set of 1 to 2 degree beams over a swath of from 120 to 150 degrees. To estimate the coverage expected from these systems we use the conservative value of 3 times water depth (just less than 120 degrees) for achievable swath widths in the detailed survey areas. This estimate will allow for sufficient overlap between swaths to assure complete high-resolution coverage of the seafloor as well as provide for the time necessary to collect sound velocity profile data. In making our estimates we assume that the vessels will survey at 10 knots and include the time necessary to collect the sound velocity profiles needed for accurate bathymetry.

Inasmuch as the location of the Gardiner Line under Article 76 requires a determination of sediment thickness (for which the speed of sound in the sediment column in the region must also be known), the Committee on the Limits of the Continental Shelf recommends that multichannel seismic data be used for determining sediment thickness. They recognize, however, that there are other means of determining the sound speed in the sediment column (refraction, boreholes, regional models, etc.) and will therefore accept single channel seismic data when supporting evidence for sound speed is available. For planning purposes we will suggest only the collection of multichannel seismic data. The size and configuration of the seismic system to be used (and thus the cost) will vary depending on the estimated thickness of the sediment column in the region.

With the regions to be surveyed defined for each of the detailed survey areas and the appropriate survey systems chosen, the estimated cost of each survey can be calculated. Our estimated costs are based on an approximation of current rates charged for similar surveys in the U.S. EEZ. Based on discussions with several contractors and government organizations, we use an estimated day rate of \$25,000.00 per 20 hour day of survey time on the East and Gulf coasts, and \$29,000 per day in Alaska and the Pacific Islands. Transit time is typically charged at one half to three quarters the full survey rate and extra charges are added for mobilization/demobilization. Finally, we add an additional 5 percent to account for weather time and other contingencies. It is important to note that these costs are based on today's rates and that subject to market pressures, these rates can vary in the future.

The cost of seismic data acquisition can vary significantly depending upon the depth of penetration required, the area of coverage (line kilometers required), and the geographic area of the project. For multichannel seismic data in sediments of a few hundred meters thickness, per km line costs including processing begin at approximately \$300. For sediments of 2 km to 3 km thickness, in remote areas like Alaska, per km line costs can reach about \$675. Again, these costs are based on today's rates; they may change in the future. Until existing seismic data is geophysically analyzed, the cost of additional data in any particular area cannot be accurately predicted. We have, therefore, assigned a per km line cost of \$675 for all additional seismic data acquisition. It is unlikely, however, that all new data will cost this much.

The above-described approach was applied to all of the detailed survey areas with the exception of the Arctic. Acquiring bathymetry in the Arctic ice-covered regions presents a series of logistical challenges that make the requirements for high Arctic work much different from those for other areas. Standard survey vessels cannot operate safely in ice covered regions and thus specialized platforms must be considered for data collection. The most feasible way of collecting bathymetry and seismic data in the high Arctic is from either an icebreaker or a nuclear submarine. For estimating the costs of these very specialized platforms we have deferred to experts from the United States Arctic Research Commission. They have estimated the cost of 60 days of nuclear submarine survey work and 60 days of icebreaker survey work to be \$12M.

<b>Bathymetric Survey area</b>	<b>Estimated track length (km)</b>	<b>Estimated cost M\$</b>
East Coast NE	20952	1.9
East Coast SE	12844	1.3
Gulf of Mexico	2845	.7
Gulf of Alaska	15784	1.9
Aleutians	2625	1.1
Arctic	N/A	12
Mariana Islands	12917	2.2
Palymra Atoll and Kingman Reef	4091	1.2
Total (without Arctic)		10.3
Total with Arctic		22.3

**Bathymetric Survey Costs:** Estimates of the costs for multibeam bathymetric surveys in the regions where there may be a potential claim for an extended continental shelf under Article 76. A general discussion of how the areas were selected is found in Section 3.6; detailed discussions are presented area by area in Section 5. Costs are based on estimates of current (2002) rates for commercial surveys and include estimates for mobilization/demobilization, transit and contingency. Rates vary depending on the location of the survey area. Costs for Arctic are based on proposal by U.S. Arctic Research Commission to use a nuclear submarine and icebreaker (Appendix F). It is important to recognize that the potential gain from an extended claim is quite variable from area to area (e.g., the potential increase in the area of the continental shelf is much greater off the east coast of the U.S. than it is around the Pacific Island (if any increase is at all possible around the Pacific Islands).

<b>Seismic Survey area</b>	<b>Hyp. 1 Track length (km)</b>	<b>Hyp. 2 Track length (km)</b>	<b>Hyp. 1 Cost M\$</b>	<b>Hyp. 2 Cost M\$</b>
Atlantic NE	7872	0	6.0	0
Atlantic SE	6568	0	5.0	0
Gulf of Mexico	0	0	0	0
Gulf of Alaska	7770	0	6.1	0
Aleutians	3618	0	3.4	0
Arctic	1750	1750	*	*
Mariana Islands	unk	unk	> 1.5	0
Palmyra Atoll and Kingman Reef	0	0	0	0
<b>TOTAL</b>			<b>&gt;22</b>	<b>0</b>

**Seismic Survey Costs:** Two estimates of costs of multichannel seismic surveys in those regions where there is a need for additional seismic surveys for an extended claim under UNCLOS Article 76. **It is impossible to judge the appropriateness of existing seismic data without careful geophysical analysis. Until such analyses can be done we offer two end-member hypotheses to frame the range of potential costs:** 1) that the entire area from the most landward possible location of the FOS out to 350 nmi from US baseline needs to be covered with new multichannel seismic reflection data with a trackline spacing of 30 nm, (very unlikely) and: 2) that the area described above needs to be covered but all current available data for which we hold trackline information is of sufficient quality to establish the thickness of sedimentary rock beneath the ocean floor (more likely but some new data may be needed). Only a careful analysis of existing data can determine this. A general discussion of how the areas were selected is found in Section 3.6; detailed discussions are presented area by area in Section 5. Costs are based on estimates of current (2002) rates for commercial surveys and include estimates for mobilization/demobilization, transit and contingency. Costs vary with the depth of penetration required, the complexity of processing and the remoteness of the area to be surveyed. Costs for collecting seismic in the Arctic are covered in the same \$12M estimate provided by the U.S. Arctic Research Commission for the collection of bathymetry (Appendix F).

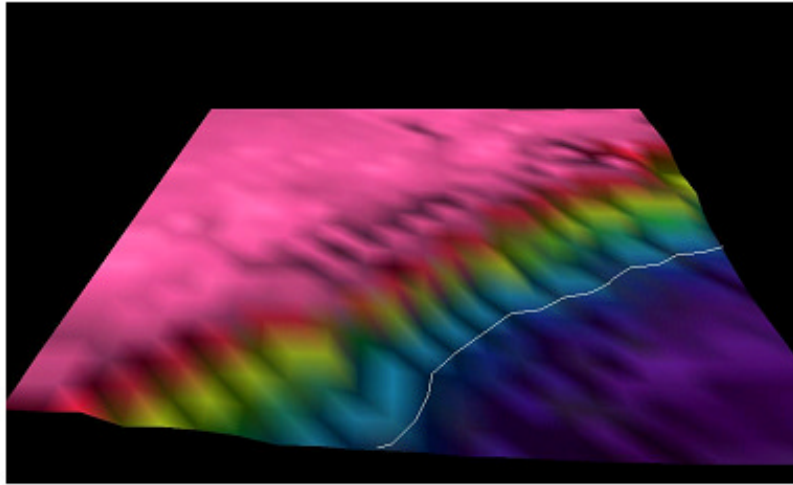
## **6.1 Recommendations:**

Based on the data collected to date and the analyses performed, we draw the following conclusions and make the following recommendations:

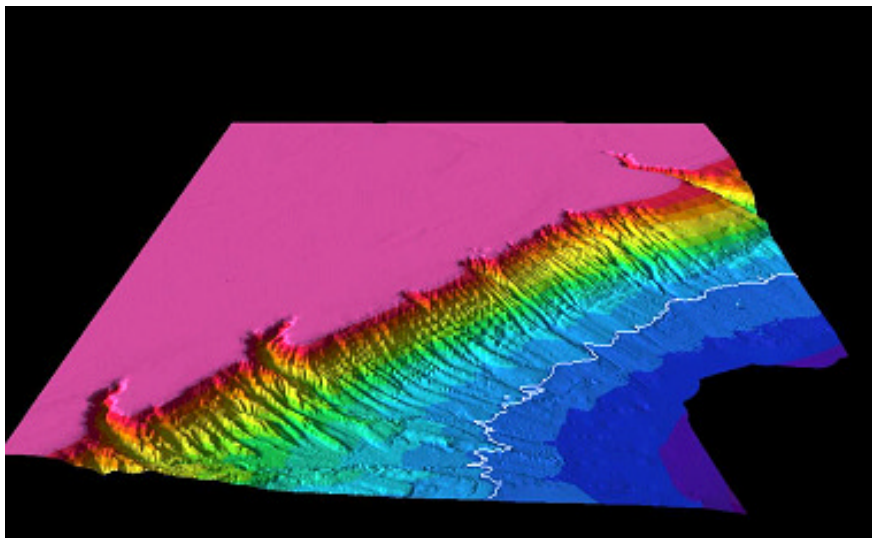
- 1- That while, with the exception of the Arctic, the current holdings of U.S. bathymetric data may be sufficient to make claims for an extended EEZ under UNCLOS Article 76, the errors associated with most of the existing database are such that any claim made would be based on poorly constrained information and subject to high degrees of uncertainty.
- 2- We thus recommend a strategy whereby complete coverage, high-resolution multibeam sonar bathymetric data are collected in carefully selected corridors in those regions where there is a potential for an extended U.S. claim under Article 76. These surveys could be carried out with existing sonar systems available to both government agencies and the private sector for an estimated cost of approximately \$10M (excluding the Arctic). Such surveys would precisely define the location of the 2500 m isobath as well as the Foot of the Slope, both needed for making an extended claim under Article 76. Complete high-resolution coverage not only more accurately defines key bathymetric features, but also allows the selection of line segments to be used for a claim to be optimized and thus can increase, significantly, the area claimed. An example of this is presented in figures 6.1-6.4. The collection of high-resolution multibeam data would also serve to provide an unprecedented perspective of the nature of the seafloor in the outer limits of the U.S. EEZ. These data will be invaluable for a range of ancillary purposes including resource analysis, fisheries habitat studies, and offshore engineering and environmental studies.
- 3- For the Arctic margin, we recommend a combined bathymetric and geophysical survey using a U.S. Navy submarine and a U.S. Coast Guard ice breaker, as proposed by the U.S. Arctic Commission report on Mapping the U.S. Arctic Ocean Margin (Brass and Coakley). The cost for these surveys is estimated to be \$12M. Inasmuch as the 350 nmi cutoff line is also critical in the Arctic a careful examination of the U.S. territorial baselines in this region may be in order.
- 4- In many of the areas where an extended claim may be made, such a claim would be made based on the position of the Gardiner Line (the point where the sediment thickness becomes 1 per cent of the distance back to the Foot of the Slope). While the multibeam bathymetry recommended above would define the Foot of the Slope, multichannel seismic data will be necessary to define the thickness of the sediment column. In most areas of the EEZ, existing seismic data is of sufficient density (lines spaced closer than 30 nmi apart) to be acceptable for a claim under Article 76, but further study is necessary to determine whether or not the existing data adequately show the thickness of the sediment column to be useful for a claim. Until the adequacy of the existing seismic data is determined, it is impossible to

estimate (except for the Arctic) the need for (or cost of) further seismic surveys. We therefore provide an estimate of the highest-cost possible end-member for seismic surveys (\$22M-\$25M) and strongly recommend that scientists from the U.S.G.S. (the agency responsible understanding our nation's geological and geophysical framework) carry on a careful examination and interpretation of the existing seismic database and determine precisely where the existing data is capable of defining the thickness of the sediment column. In the course of such a study, experts from the U.S.G.S. may also explore the potential for the existence of "evidence to the contrary" (i.e., geophysical evidence that may allow an even larger extension of the definition of the continental shelf under Article 76) that could be of advantage to the U.S. in making a claim under Article 76. The U.S.G.S. estimates the cost of such a study to be approximately \$400,000.00. Once the adequacy of the exiting seismic data is determined, CCOM/JHC can recommend strategies for new data acquisition.

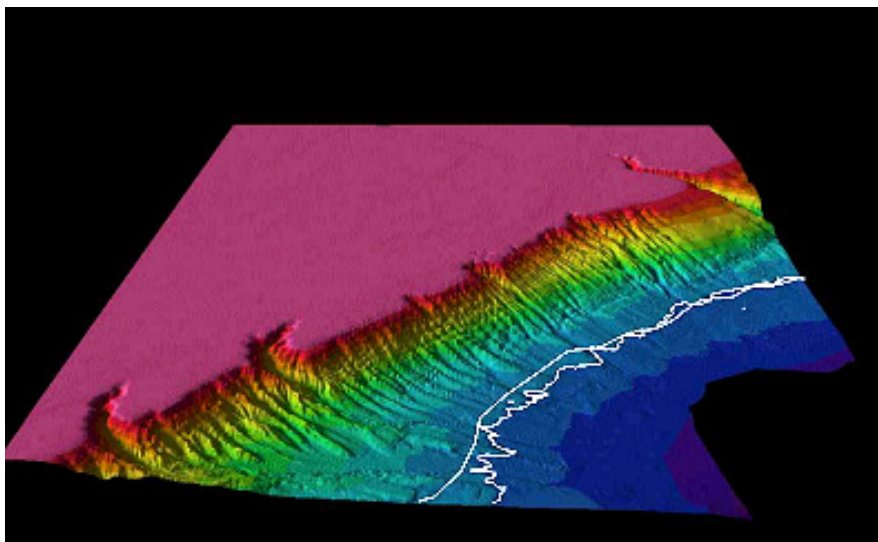
- 5- We also recommend that studies be carried out to develop algorithms and techniques that can optimize a U.S. claim for an extended continental shelf based on newly collected multibeam sonar data. Such a study would propose approaches for using the detailed bathymetry provided by multibeam sonar, in conjunction with a full understanding of the constraints of Article 76, to determine how to maximize a claim based on careful selection of the line segments used to make the claim (as demonstrated in figures 6.1 – 6.4).
- 6- It is important to note that the survey estimates presented have been made without consideration for the relative cost/benefit of surveying in a particular area. For example, it is clear that there is potential for a substantial increase in the area of the continental shelf along the eastern margin of the U.S. and that there may be potential for only a small gain in continental shelf area (if any) in the Pacific Island regions. Thus we also recommend that a careful analysis of the cost/benefit of surveying in particular regions be carried as a prelude to any data acquisition.



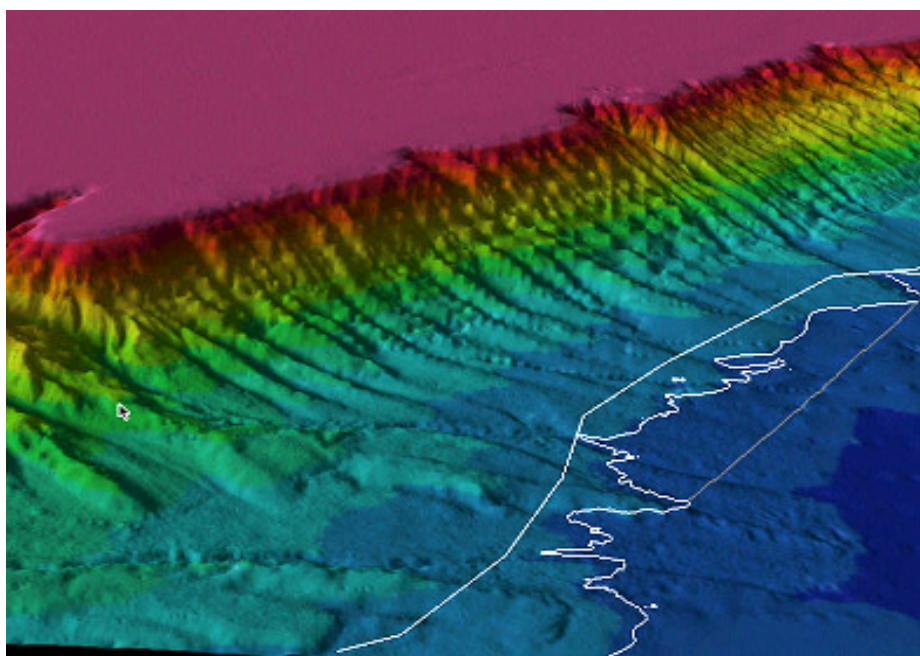
**Figure 6.1** An example of how full-coverage multibeam data can result in a significant extension of a claim beyond the claim that could have been made based on single beam sonar data. Figure 6.1 shows a 200 km long by 160 km wide section of the continental margin off New Jersey as depicted from data contained in the ETOPO-5 bathymetric compilation from NGDC (based on single beam soundings). The white line represents the 2500 m isobath derived from these data.



**Figure 6.2** The same piece of seafloor as depicted with multibeam sonar data. The high-resolution definition of seafloor features and topography makes these data very valuable for a range of environmental, geological, engineering and fisheries applications. The white line represents the 2500 m isobath as derived from the multibeam data.



**Figure 6.3** The contour derived from ETOPO-5 and the contour derived from the multibeam bathymetry superimposed. Note the much greater detail of the 2500 m contour derived from the multibeam data. Using this detail and the flexibility provided in constructing limit lines provided by UNCLOS Article 76 (e.g., profiles AT LEAST 60 nm apart -- but they can be closer--connected by straight line segments) seaward facing promontories can be selectively chosen to extend the claim).



**Figure 6.4** An example of the ability to extend a claim by selectively choosing bathymetric profile points. In this small example (just a 200 km section of the margin), the claim is extended by 600 km<sup>2</sup>. Multiply this by the entire margin and there is the potential for hundreds of thousands of extra kilometers.

## 7 REFERENCES:

Amato, R., Thormahlen, L. and Carpenter, G., 1996, Preliminary Determinations of the U.S. Continental and Territorial Shelves Based on Law of the Sea (Article 76) Provisions, 27<sup>th</sup>, *Annual Underwater Mining Institute*, (Abstract)

Carpenter, G.B., Thormahlen, L.F., and Amato, R.V., 1996, A determination of the U.S. Atlantic continental shelf under the provisions of the Law of the Sea convention, *Marine Georesources and Geotechnology*, v. 14, pg. 353-359

Dartnell, P. and Gardner, J.V., 1999, Seafloor images and data from Multibeam surveys in San Francisco Bay, Southern California, Hawaii, The Gulf of Mexico, and Lake Tahoe, California-Nevada, *Digital Data Series DDS-55* Version 1.0, U.S. Geological Survey.

Defense Mapping Agency, 1984, American Practical Navigator( Bowditch)

Grantz, A., Mann, D.M., and May, S.D., Multichannel seismic-reflection data collected by the U.S. Geological Survey in the Beaufort and Chukchi Seas in 1977 for which profiles and stack tapes are available, *U.S. Geological Survey Open-File Report 86-206*, 3 p., 1982.

Grantz, A., Barnes, P.W., Gray, L.B., Hart, P.E., Hogg, D.J., May, S.D., McCormick, M., McLaughlin, M.W., Mullen, M.W., Phillips, R. L., Olson, W.P., O'Toole, J.K., Reimnitz, E., Rideout, R.W., Robinson, W.C., Foley, K.M., Bischof, J, Gagnon, A.R., Jeffries, M.O., Li, S., Schwartz, K., Norgaard-Pedersen, N., Perkin,R., Cruise to the Chukchi Borderland, Arctic Ocean, *Eos*, Transactions, American Geophysical Union, v. 74 (22), p. 249, 253-254, 1993.

Ingham, A.E., 1984, Hydrography for the Surveyor and Engineer, John Wiley and Sons, New York, 132 pp.

Jackson, H.R., and Oakey, G.N., Sedimentary thickness map of the Arctic Ocean, Plate 5 in Grantz, A., Johnson, L., and Sweeney, J. F. (Eds.), *The Arctic Ocean Region, The Geology of North America* DNAG v. L., 1990.

Jakobsson, M., Calder, B., and Mayer, L., *in press*, On the Estimation of Random Errors in Gridded Bathymetric Compilations, *Journal of Geophysical Research*.

Jakobsson,M., N.Z. Cherkis, J. Woodward, R.Macnab, and B. Coakley. 2000 New grid of Arctic bathymetry aids scientists and mapmakers; *Eos*,Transactions, American Geophysical Union, v.81, no.9, p. 89,93,96.

[Click here for more details.](#)

May, S.D., Grantz, A., Sediment Thickness in the Southern Canada Basin, *Marine Geology*, v. 93, p. 331-347, 1990.

MacNab, R., and Haworth, R. 2001, Earth Science and the Law of the Sea: Keys to Canada's offshore energy and mineral resources beyond 200 nautical miles, *Geoscience Canada*, v. 28, no. 2., p.79-86.

Maloney, E. S., 1985. Dutton's Navigation & Piloting: Fourteenth Edition, Naval Institute Press, Annapolis, Maryland, 1-571.

Murton, B.J., Parson L.M., Hunter P. and Miles P., Global non-living resources on the Extended Continental Shelf; Prospects for the year 2000 [International Seabed Authority](#) )

NGDC, 2002a. Global Seafloor Topography from Satellite Altimetry.  
[http://www.ngdc.noaa.gov/mgg/announcements/announce\\_predict.html](http://www.ngdc.noaa.gov/mgg/announcements/announce_predict.html)

NGDC, 2002b. Total Sediment Thickness of the World's Oceans & Marginal Seas.  
<http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html>

NGDC, 2002c. World Vector Shoreline.  
<http://rimmer.ngdc.noaa.gov/coast/wvs.html>

NOAA, 1976, 1960, 1942, Hydrographic Manual, U.S., Dept. of Commerce

NOAA, Data Announcement 88-MGG-02, Digital relief of the Surface of the Earth. National Geophysical Data Center, Boulder, Colorado, 1988.

Ou, Z., and Vanicek, P., 1996, Automatic tracing of the foot of the continental slope, *Marine Geodesy*, v. 19, (2), p. 181- 195.

Prescott, V., Resources of the Continental Margin and International Law, In Cook,P.J, and Carleton, C.M. (eds.), *Continental Shelf Limits*, Oxford University Press, 2000, p. 64-83.

Rideout, R.W., Robinson, W.C., Foley, K.M., Bischof, J, Gagnon, A.R., Jeffries, M.O., Li, S., Schwartz, K., Norgaard-Pedersen, N., Perkin,R., 1993 Cruise to the Chukchi Borderland, Arctic Ocean, *Eos*, Transactions, American Geophysical Union, v. 74 (22), p. 249, 253-254.

Royal Society, 1982, A guide to the provisions of the 1982 United Nations Convention on the Law of the Sea relating to marine scientific research, London.

Smith, W.H. and Sandwell, D.T., 1997, Global Sea Floor Topography from Satellite Altimetry and Ship Depth Soundings, *Science*, vol. 277, no. 5334

Soluri, E. A., and V. A. Woodson, 1990, World Vector Shoreline, *International Hydrographic Review*, LXVII(1).

United Nations, 1993, The Law of the Sea: Definition of the Continental Shelf, Division for Ocean Affairs and the Law of the Sea, Office of Legal Affairs, United Nations, New York, 49 pp.

United Nations, 1999, Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf