Geological Survey of Canada
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AN IMPROVED BATHYMETRIC PORTRAYAL OF THE NORTHWEST ATLANTIC, FOR USE IN DELIMITING THE JURIDICAL CONTINENTAL SHELF ACCORDING TO ARTICLE 76 OF THE LAW OF THE SEA

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ARTICLE 76: IMPLEMENTATION AND UNCERTAINTIES

INTRODUCTION

Canada has been investigating options for claiming jurisdiction over resources of the seabed and the sub-seabed beyond 200 nautical miles in the Atlantic and Arctic Oceans, in accordance with the provisions of Article 76 of the Law of the Sea.

Existing deep-water bathymetric data bases off Canada's Atlantic and Arctic coasts are inadequate for determining accurately the key hydrographic criteria for implementing Article 76, i.e. the location of the foot of the continental slope, and the location of the 2500-m isobath.

The Geological Survey of Canada and the Canadian Hydrographic Service have initiated a joint project to assemble, merge, and adjust all available bathymetric observations in order to create a coherent, accurate data base that will allow reliable determination of these criteria.

This presentation provides an overview of work initiated in November 1995; the focus is on the development of a bathymetric data base off Canada's Atlantic coast. To date, most known public-domain observations have been assembled and merged; preliminary corrections have been applied.

The results presented here are strictly provisional, and are intended primarily to acquaint viewers with the procedures developed by the Geological Survey of Canada for handling and treating large quantities of digital bathymetric data. Further processing and adjustment are

FIGURE 1: ARTICLE 76 IMPLEMENTATION

In describing procedures for determining the outer limit of the juridical continental shelf, Article 76 of the law of the sea stipulates bathymetric and geological criteria for locating key features on and beneath the sea floor. Bathymetric requirements include the shape of the seabed for identifying the foot of the continental slope and water depth for the 2500 metre isobath, geological criteria focus on sediment thickness for the so-called Gardiner Line, where sediment thickness equals 1% of the distance back to the foot of the slope.

FIGURE 2: DISTANCE FORMULA

The outer limit of the juridical continental shelf in the Atlantic, based on the application of the distance formula with pre-existing information. In Part A, the foot of the continental slope is projected 60 nautical miles seaward from a provisional outer limit. In Part B, this is combined with the 200 mile limit and the bounding line to form a new outer limit that is based on the distance formula alone.

FIGURE 3: SEDIMENT THICKNESS FORMULA

The outer limit of the juridical continental shelf in the Atlantic, based on the application of the sediment thickness formula with existing information. In Part A, the foot of the continental slope is projected out to the Gardiner Line (where the thickness of sediment is equal to 1% of the distance to the foot of the slope) to form a provisional outer limit. In Part B, this combined with the 200 mile limit and the bounding line to form a new outer limit that is based on the sediment thickness formula alone.

TABLE 1: OUTER LIMIT UNCERTAINTIES

The matrix illustrates potential uncertainties caused by errors in the measurement and interpretation of hydrographical and geological parameters. Hydrographic parameters (highlighted) consist of seafloor morphology and water depth. Uncertainties associated with these parameters can be substantially reduced through use of a well-controlled hydrographic data base that describes the sea floor with sufficient resolution. This requirement provided the rationale for undertaking a project to improve the data base of deep water observations off Atlantic Canada.

FIGURE 1: ARTICLE 76 IMPLEMENTATION

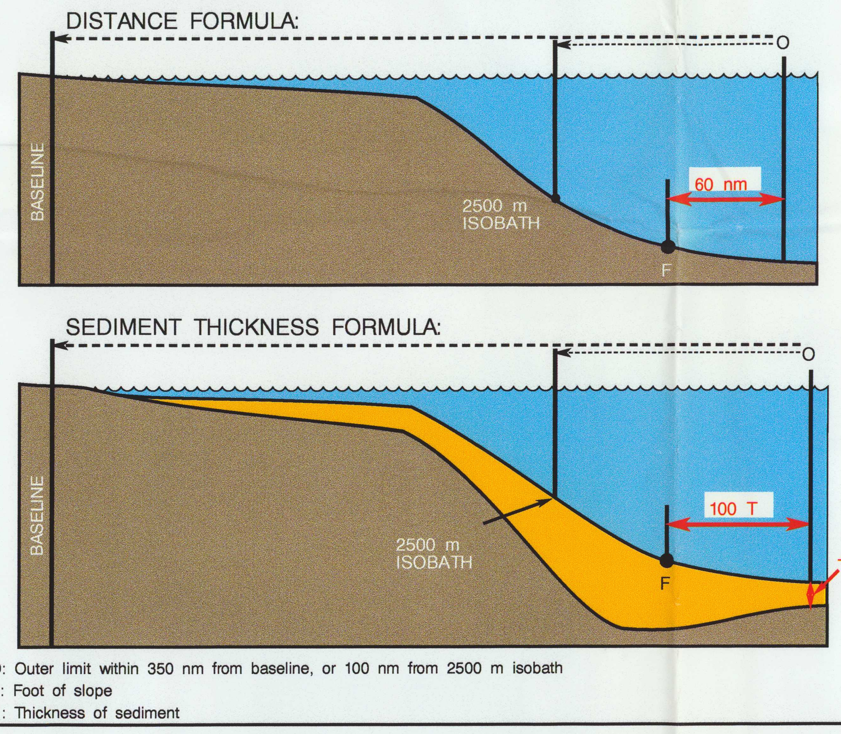


FIGURE 2: DISTANCE FORMULA

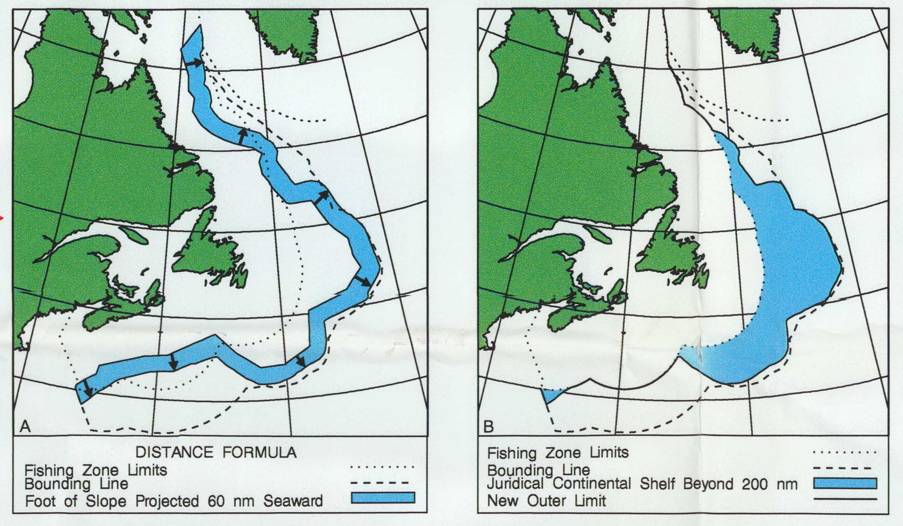


FIGURE 3: SEDIMENT THICKNESS FORMULA

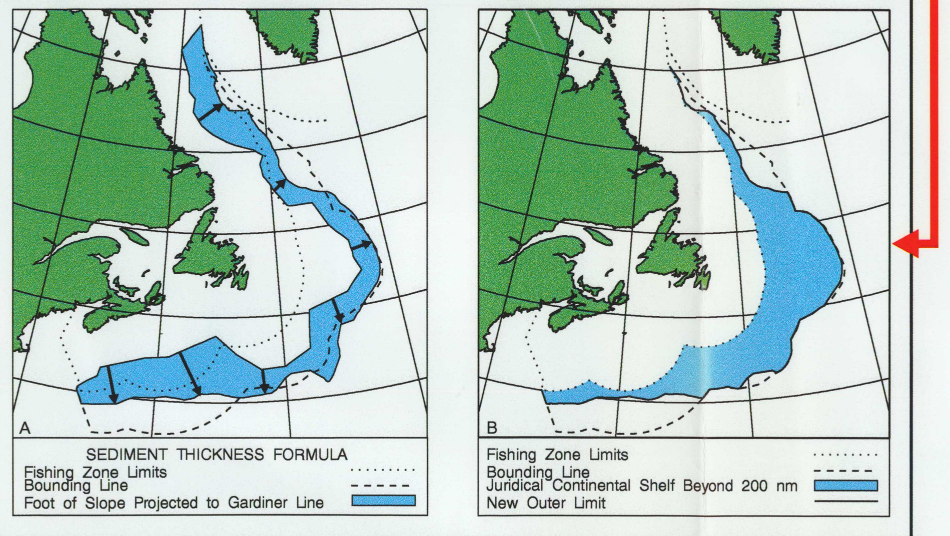
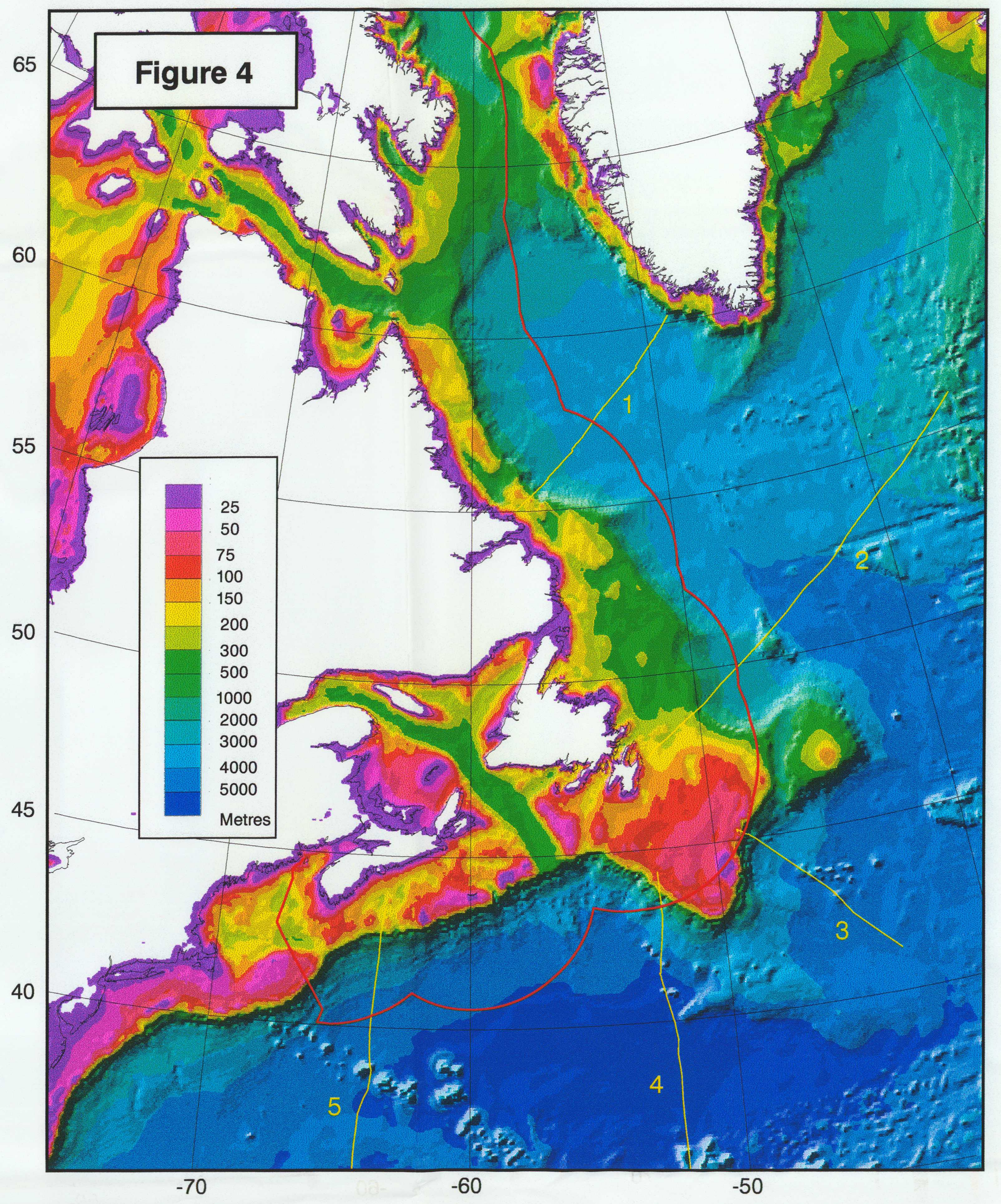


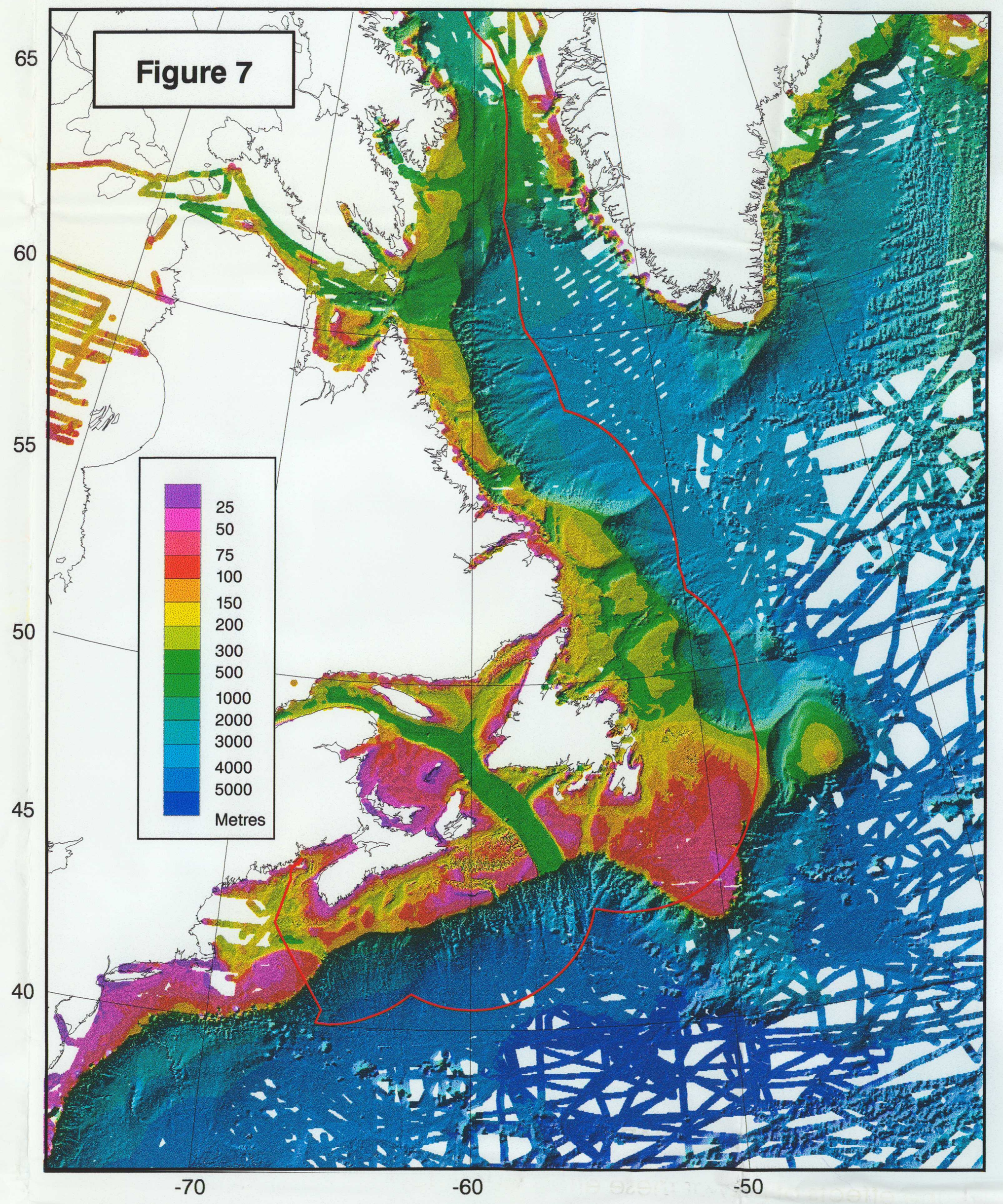
TABLE 1: OUTER LIMIT UNCERTAINTIES

PROCEDURE	PARAMETER	TECHNIQUE	SOURCE OF UNCERTAINTY	POTENTIAL UNCERTAINTY
Construct arcs centred along given baselines	Horizontal distance	Geodetic calculation	None (assuming known baseline locations)	Low or none
Determine foot of continental slope	Sea floor morphology	Acoustic measurement & interpretation	Sounding errors, interpretive criteria	10's of kilometres
Determine location of the 2500-metre isobath	Water depth	Acoustic measurement	Sounding errors	100's of metres
Determine location of Gardiner Line	Sediment thickness	Acoustic measurement & interpretation	Experimental errors, interpretive criteria	10's of kilometres

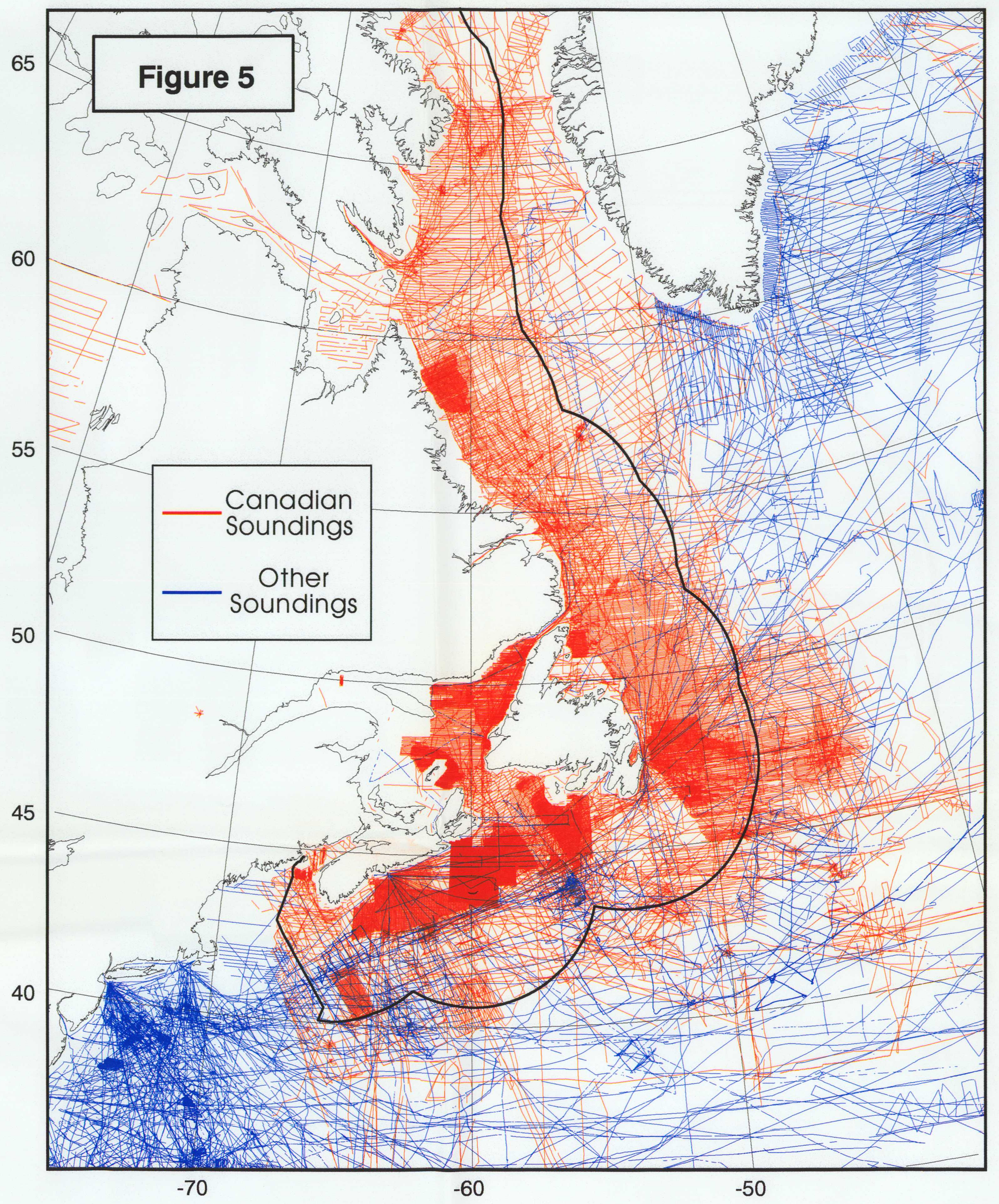
BATHYMETRIC DATABASE



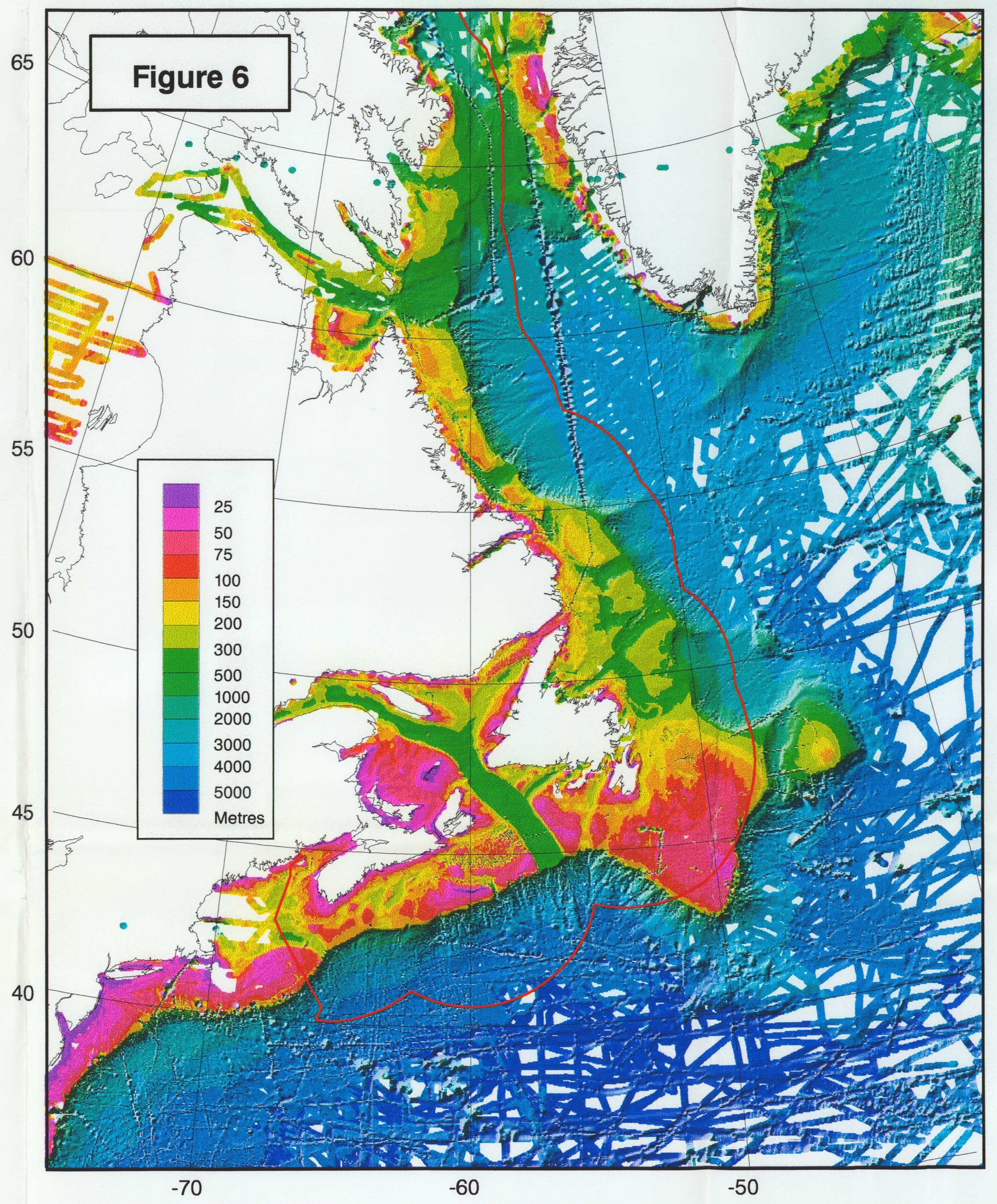
ETOPO5 bathymetry re-sampled by simple interpolation to 20 points per degree of latitude and longitude. The red line portrays the location of the 200 nautical mile limit and the yellow lines show the location of observed bathymetric profiles shown in Figure 10.



Preliminary corrected soundings, gridded over a 1 km x 1km matrix using minimum curvature. The applied corrections improve the dataset but problems still exist. Compared to ETOPO5 (Figure 4), the grid shows a more detailed rendering of the sea floor. The red line portrays the location of the 200 nautical mile limit.



Assembled sounding lines in the compilation. The black line portrays the location of the 200 nautical mile limit.



Unedited bathymetry from original soundings gridded over a 1 km x 1 km matrix using minimum curvature. This form of presentation emphasises data errors and variations associated with different sounding corrections. The red line portrays the location of the 200 nautical mile limit.

FIGURE 8: SOUNDING ERRORS AT TRACK INTERSECTIONS

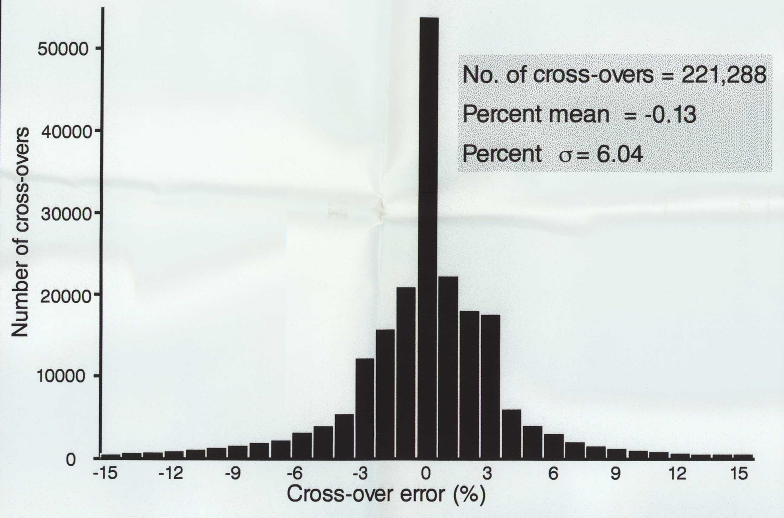


FIGURE 9: AUTOMATED SPIKE DETECTION

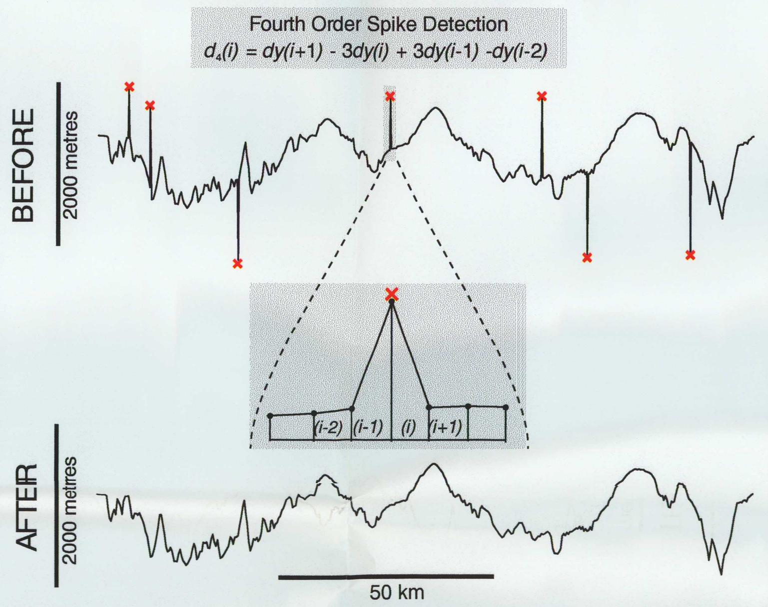


FIGURE 10: BATHYMETRY PROFILES

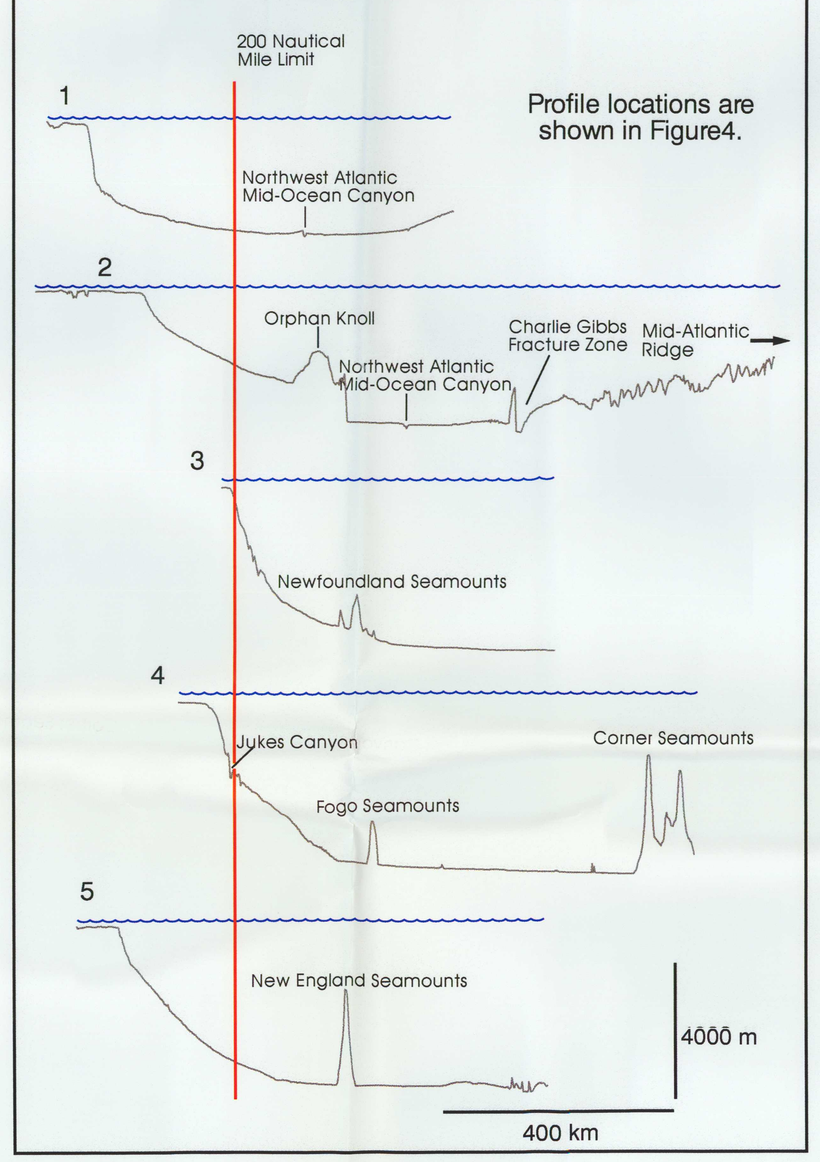


FIGURE 4: ETOPO5 BATHYMETRY

ETOPO5 represents the state of the art in global gridded bathymetry that is available in the public domain. Unlike the more detailed maps of the seafloor that are derived from satellite altimetry, ETOPO5 was developed from true bathymetric observations, but the details of its construction remain undocumented; with a cell size measuring 5' of latitude by 5' of longitude, its resolution is limited for visualizing small-scale features. ETOPO5 offers a general portrayal of the sea floor, and does not lend itself to the sort of detailed analysis that is required for the implementation of Article 76.

FIGURE 5: DATA DISTRIBUTION

A substantial body of bathymetric observations exist in the public domain; this figure illustrates all data sets assembled in digital form, from Canadian and non-Canadian sources. In its present form, the data base contains about 1.8 million soundings in the study area, representing some 2.4 million km of ship tracks. There are about 200,000 track intersections; a statistical analysis of observational discrepancies at the intersection points yields an average cross-over error of -0.15% (normalized against water depth) with a normalized standard deviation of 6% (Figure 8).

FIGURE 6: RAW DATA

Assembled data sets were gridded with a minimum curvature algorithm, and plotted in shaded relief form to facilitate the detection of errors which manifest themselves as isolated highs or lows, or as ridges or trenches. Many of the problems were traced to the use of different sound velocities for converting two-way travel times to observed depths; others were related to inconsistencies in the methodologies applied to correct for location-dependent variations of sound velocity. Some problems were related to errors in navigation.

FIGURE 7: PRELIMINARY CORRECTED DATA

The effects of many of these errors were reduced or eliminated through a variety of means: automated detection of spikes (Figure 9); use of a standard sound velocity for converting two-way travel times to observed depths; and finally, simple visual removal of errors. After application of these corrections, a new grid was prepared and used to construct a preliminary yet significantly improved shaded relief plot. As an ongoing project, the data discarded from the final grid is analyzed to determine the source of error and if the error is correctable, the data is returned to the database. Comparison with the ETOPO5 data shows a much more realistic rendering of the sea floor.

FIGURE 10: BATHYMETRY PROFILES

The database, consisting of observed bathymetry, facilitates ready access to profile information necessary for studies to determine the foot of the continental slope. Shown are representative profiles extracted from the bathymetry database. This demonstrates the complexity of hydrographic observations in relation to the implementation of Article 76.

CONCLUSION

A bathymetric data base has been developed for the NW Atlantic, which even in preliminary form offers greater detail and resolution than the standard public-domain ETOPO5 grid. Further processing will improve the data base and render it suitable for Article 76 investigations off Canada's Atlantic coast, and also for other applications (e.g. verifying satellite predictions of bathymetry).

Quantitative techniques have been applied through all stages of construction, adjustment, and verification of the data base. These techniques ensure the reproducibility of results and may be easily applied to observations from other oceanic regions wherever warranted by data quantity.

Upon completion, the data base will be placed in the public domain as a computer-readable grid with a final cell size that best suits the overall density of observations. The grid format will facilitate future revisions, as well as additions of new data. For more information, contact Ron Macnab of GSC Atlantic, macnab@agc.bio.ns.ca