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Abstract

The Decade of North American Geology Volume 8: "Geology of the Continental Margin of Eastern Canada", includes digital gravity and magnetic anomaly data plotted at 1:5,000,000 Lambert Conformal projection. As a companion compilation, depth to basement data in digital format have been produced. This digital data can be displayed at any scale and projection for comparison and integrated processing. As input for this compilation we used published depth to basement maps. Seismic data have been used by various authors to produce basement topography maps for all basins in the Eastern Canada region. Hand digitizing and computer processing of data from eight areas has resulted in a comprehensive digital depth to basement data set. The gridded topography has the same grid resolution (.05x.05 degrees) as the previously published gravity and magnetic anomaly data sets. This Data compilation is a mixture of several basement types and is intended as a comprehensive prototype database that is easily updatable.

INTRODUCTION

Depth to 'Basement' is a fundamental parameter toward understanding the evolution of any sedimentary basin. For example, basement highs often provide sediment sources and the topography controls the direction of sediment transport. Rates of subsidence and thermal structure also relate to variations in crustal thickness and sediment cover. The term 'basement', however, has different meanings depending on application and requires some clarification.

In continental areas, structural basement may be defined as deformed crystalline crust with a fabric related to the conditions of stress. The crustal material is often buried through sedimentation after deformation has occurred. The contact between the crystalline rocks and the overlying sediments may have several physical characteristics that can be identified by geophysical and geological investigations.

The velocity contrast is usually large along this contact, and often produces a strong seismic reflector. If the acoustic contrast is laterally coherent, the basement surface can be easily identified with seismic techniques. Unfortunately, this feature can be obscured by excessive sediment cover, where the acoustic signal is absorbed, or by highly reflective features within the sediment cover, such as salt domes.

The basal contact often displays a strong contrast in density and magnetization. The overlying sediments are less dense than crystalline rocks and virtually non-magnetic. Basement surfaces described by potential field methods have been used to define large scale regional crustal features, but in detail, potential field source depths do not necessarily coincide with structural basement. Faulting and volcanic activity can affect large areas and overprint older events. Volcanic events must be quite large before they will influence the gravity field, but even small dykes can be detected with seismic techniques as well as with magnetic data if the magnetization of the body is large enough. Magnetic anomalies caused by dykes and other volcanic events are often interpreted as 'magnetic basement' although there is little correlation with older structural basement.

Most of continental Eastern Canada is exposed crystalline Archean and early Paleozoic crust with isolated basins in areas where the crust has been attenuated. In many of the sedimentary basins several phases of deposition have occurred corresponding to different orogenic events. Although the base of each phase of deposition can be accurately described as basement, the basins are ultimately underlain by older crystalline crust. In the Carboniferous basins (Magdalen, Sydney and Saint Anthony) there are large volumes of sediment derived from the locally eroding Appalachian mountains. These sediments, along with the older Paleozoic basement, have been deformed by more recent tectonics and overlain by younger sediments.

The last orogenic event in Eastern Canada was the opening of the Atlantic and the associated rifting. Because the times of opening change for different areas along the margin, the sediment cover is of different ages. The rifted margin generally shows a thin veneer of syn-rift sediments and a much thicker post-rift sedimentary cover. The 'breakup unconformity', at the top of the syn-rift sediments, is usually a strong seismic reflector and is commonly called 'basement'. The breakup unconformity identifies similar stages of development along the margin but does not truly represent the crystalline basement. The syn-rift sediments overlie both early Paleozoic crust and Triassic sediments on the Scotian Margin and Carboniferous sediments in the Saint Anthony Basin.

In oceanic basins, 'basement' is basaltic crust formed from seafloor spreading. The basaltic crust is a strong seismic reflector easily identified below the sedimentary cover. The identification of oceanic basement may become difficult close to the continent where sedimentary cover can exceed 10 kilometres.

It becomes apparent that a depth to basement compilation for Eastern Canada cannot represent a simple boundary between sediments and a uniform crust. However, such a compilation of depths to the various basement types does account for a significant portion of the sediment overburden and allows for a systematic overview. The origins of the data from the different areas and the style of basement depicted in each must be understood (see appendix) in order to critically assess the coherency of basement compilation.

GENERAL PROCEDURE FOR EACH MAP AREA

Digitizing and Conversion

The source maps for each area had been published individually as contour map sheets at different scales and projections. The map sheets were digitized using the AUTOCAD drafting package, isolating the contour intervals as separate entities in order to flag line segments in later processing. Closed contours are marked so that the last point digitized is the same as the first. Full-scale plots of the digitized contours were produced for each of the map sheets to check for errors. The AUTOCAD drawing file was then converted into an ASCII format output and copied into the MICROVAX environment for further processing.

The ASCII output was decoded to extract the X-Y-Z table coordinates and the contour intervals assigned to each point. The table coordinates were then converted to geographic coordinates using known points on the map and projection (Oakey and Wadsworth, 1988). Once in geographic coordinates the contours were gridded, i.e. a grid in geographical coordinates is overlaid on the map and every grid cell through which a contour passes is assigned the value of the contour. The final compilation consists of grid cells of .05x.05 degrees but some of the sub-areas were gridded finer for intermediate processing, and then regridded before merging with other map areas. This was needed to ensure that closely spaced contours were assigned to separate grid cells. The software used for manipulation and display of gridded data on the MICROVAX were developed at the Atlantic Geoscience Centre, Regional Reconnaissance Subdivision (Usow and Verhoef, 1988).

Interpolation

The digital file with the gridded contours added has only about 10% of the cells filled. In order to interpolate between the existing data points a minimum curvature algorithm was used (Swain,1976) (Briggs,1974) (Tubler,1977). This procedure calculates a smooth analytical surface through all points without changing the existing values. Thus, instead of a color coded map, a continuous field of data has been created. Unfortunately, a minimum curvature surface often overshoots contour intervals, especially when local gradients change abruptly. Also, the edges of the map areas sometimes have artifacts introduced by the filling routine due to the inability to extrapolate accurately. For this reason control points were manually added to the gridfile so that the interpolated surface and edges did not exceed given contour intervals. The filled gridfile was compared with the original contours and control points added until the data accurately represented the information of the published map sheet.

Merging

Once the gridfiles for each area were completed they were merged into a master file. It is a common problem that the quality of any individual compilation decreases toward the edges of the study area. Because of this, overlapping maps sheets always had discrepancies which needed to be resolved. The overlapping segments were superimposed and the boundaries recontoured by hand (Figure 1). Generally, the manipulation needed to join map sheets was minimal and well within original interpretation errors. There were no major discrepancies between different authors. The seams were then digitized, gridded and joined into the master file with the adjacent pieces. Minimum curvature interpolation was then used to fill the seam. If the grid in the subarea was not .05x.05 degrees in size, the file was regridded to this size for compatibility prior to merging.

Topography

The basement surface is constrained by topography: i.e., it cannot exceed the topographic surface. In order to check our basement surface, we needed to compare the resulting depth to basement values at each grid cell with the topography. ETOPO-5 (1986) topographic data, which has a resolution of 12 points per degree, was quite suitable for our purpose (Figure 2). The topography data was regridded to .05x.05 degrees (20 points) and subtracted from the basement gridfile. The resulting total sediment isopach must be everywhere positive (Figure 3) and in

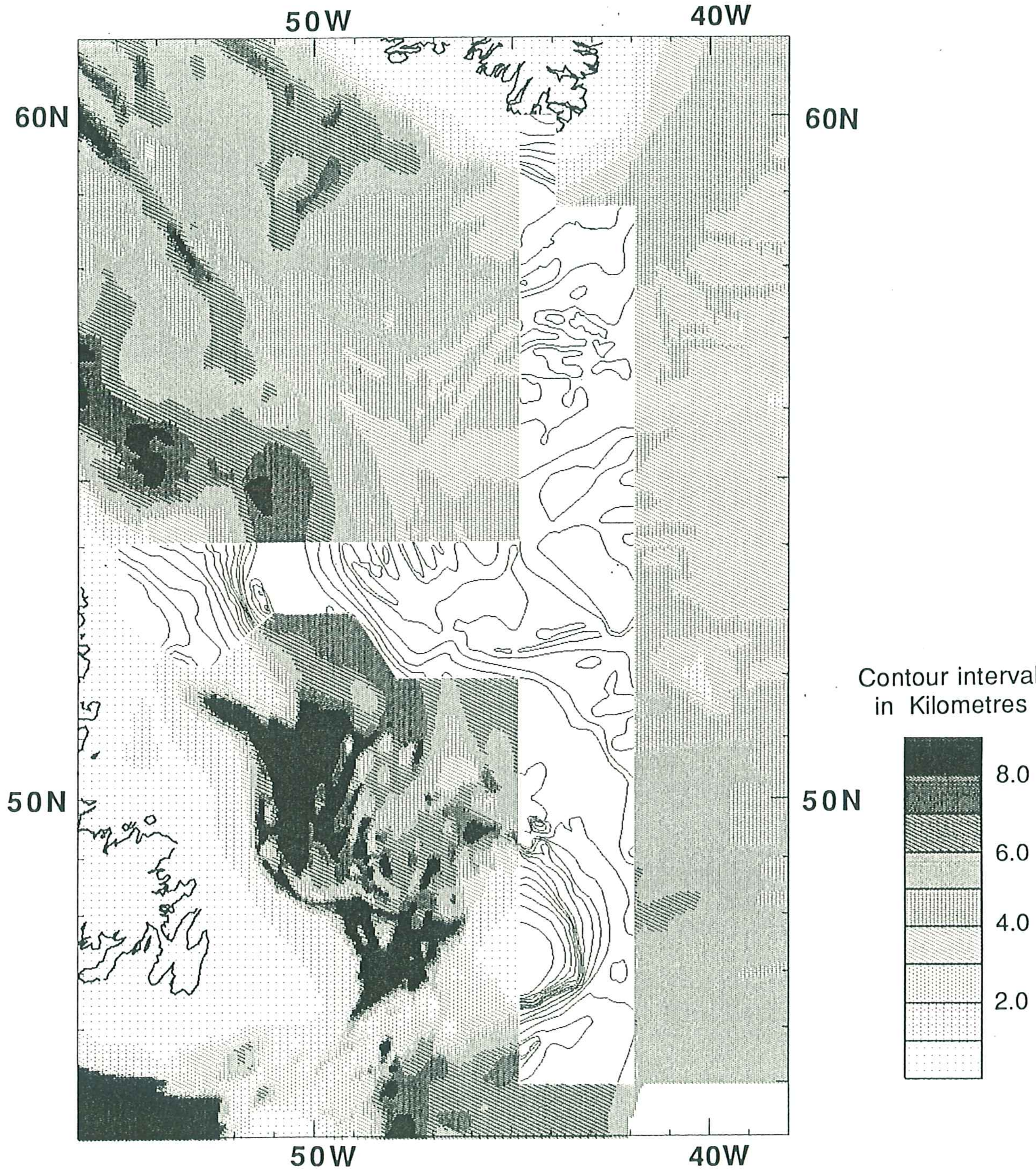

Figure 1 Shown here are the gridded data from the separate areas and the hand drawn seam from the overlap.

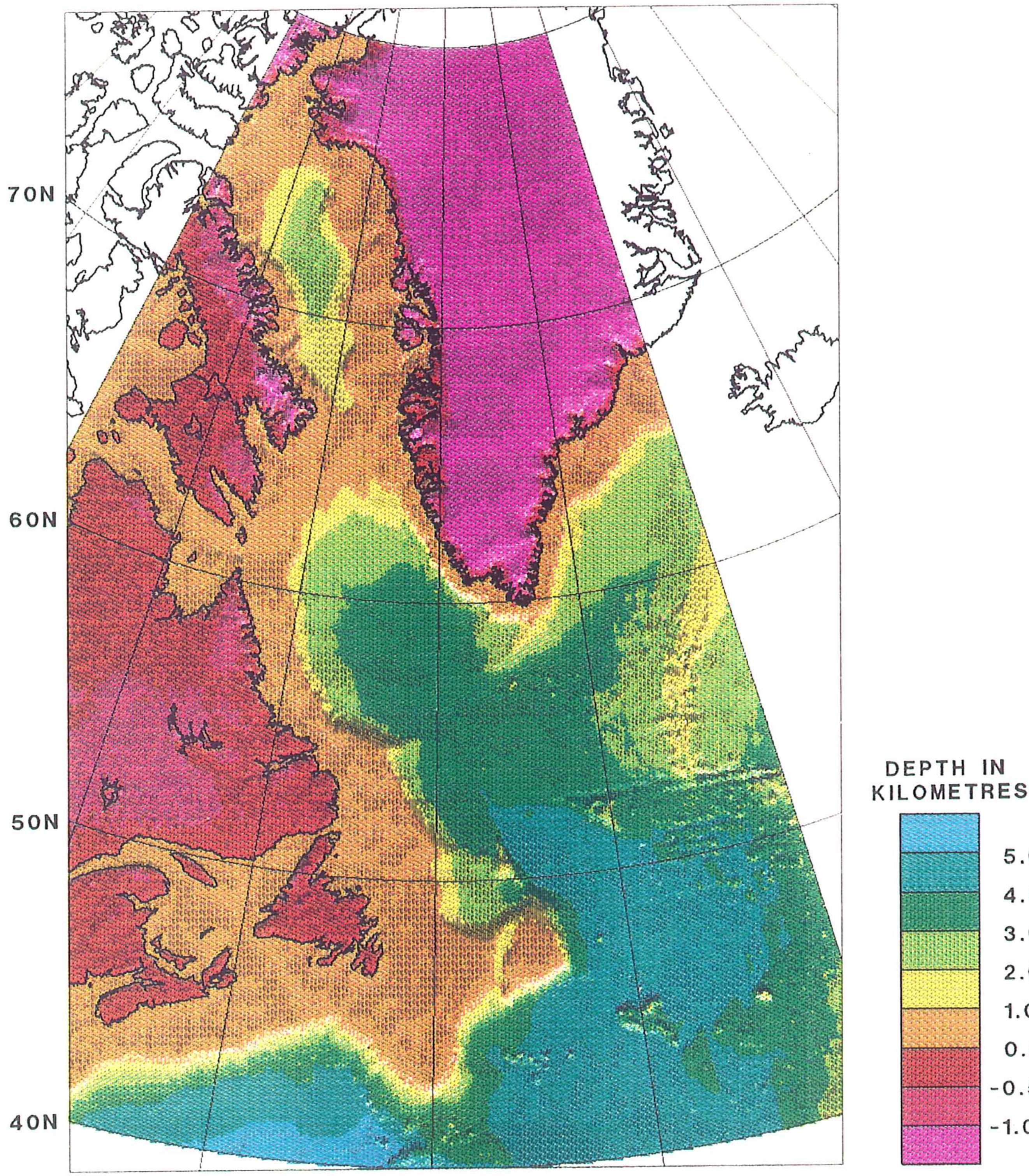

FIGURE 2 ETOPO-5 Topography

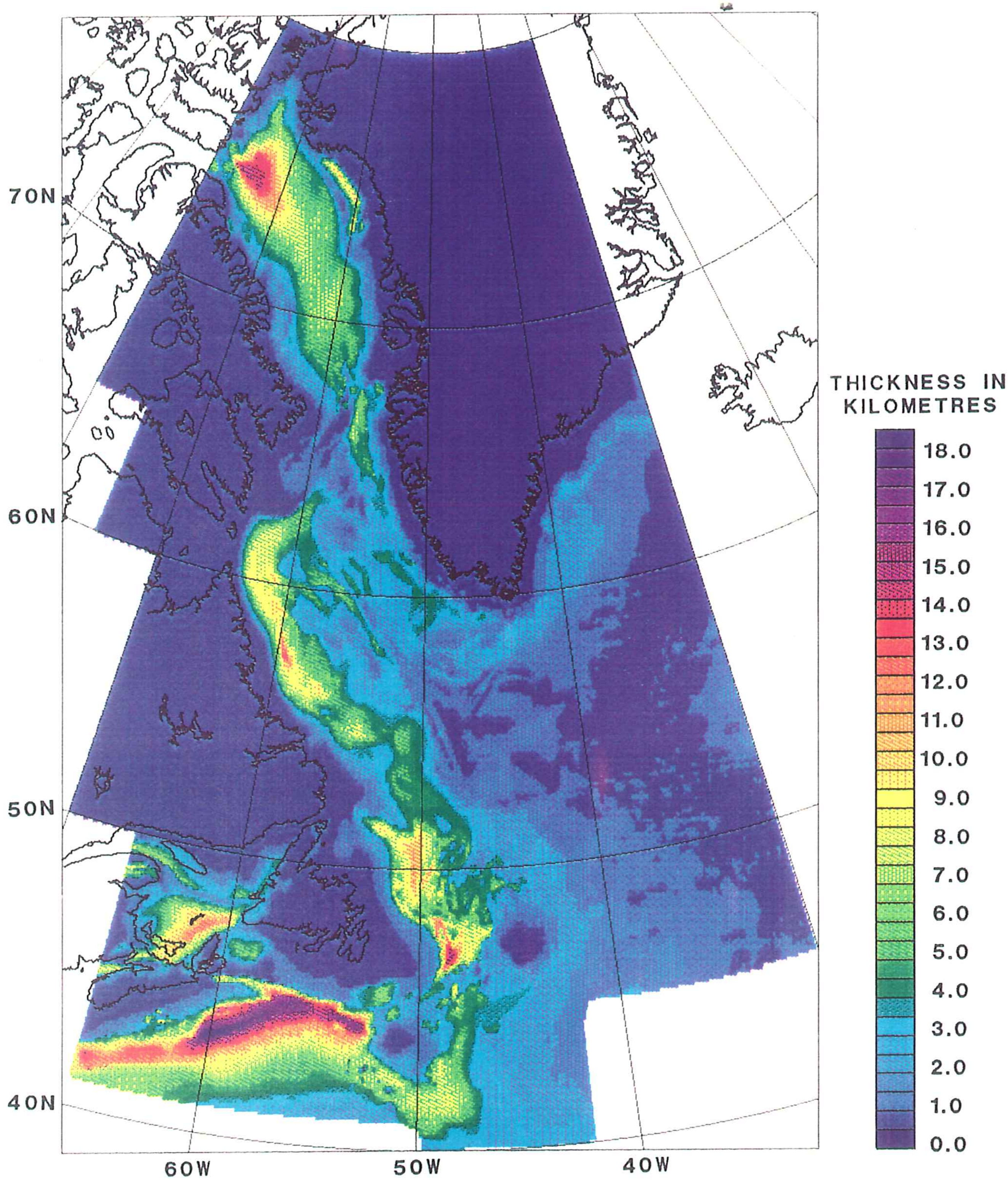

FIGURE 3 Total Sediment Isopach

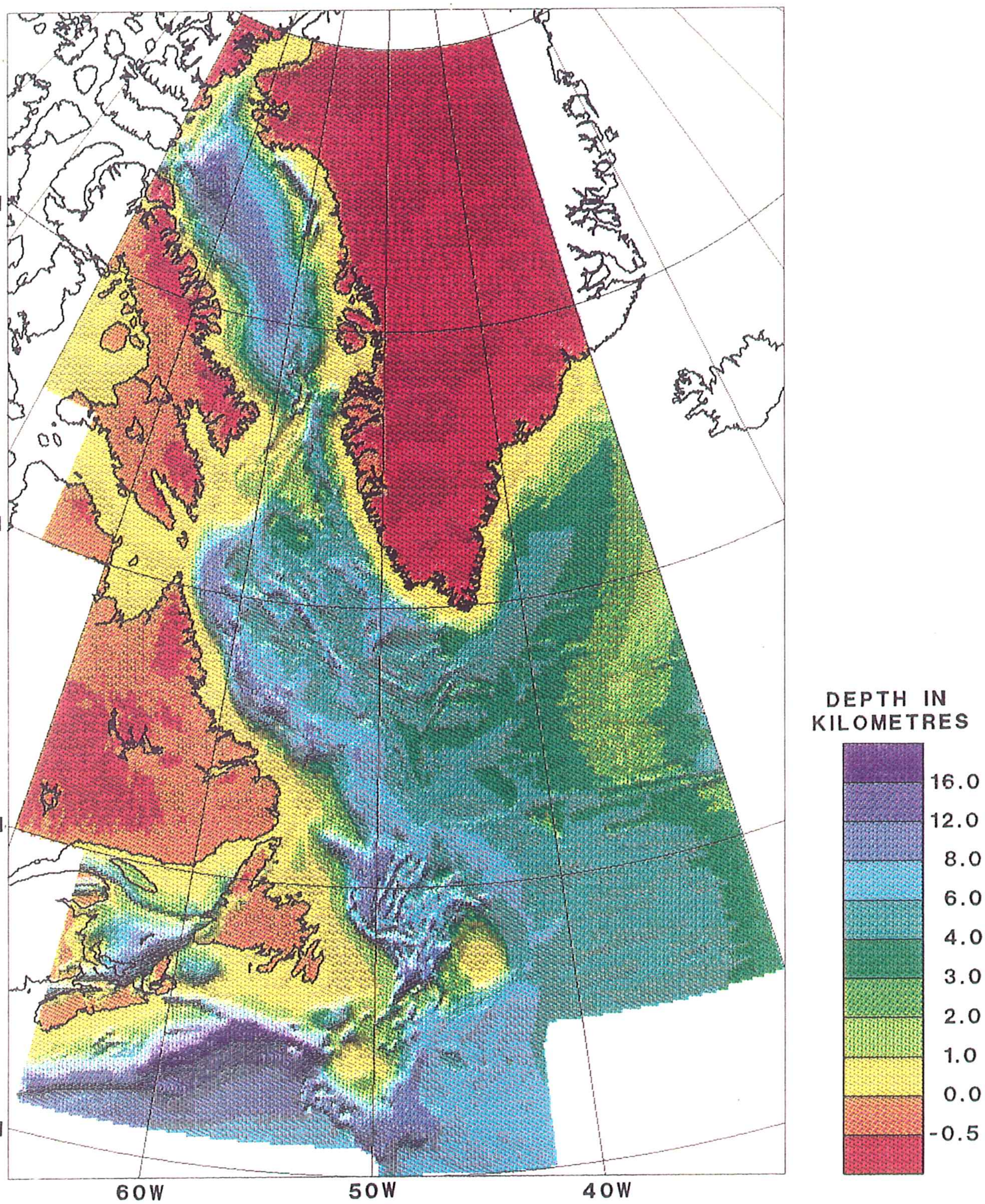

FIGURE 4 Basement Topography

locations where this was not originally true, the basement level was adjusted to 10m below topography. By assigning a minimum sediment thickness of 10m the value 'zero' is eliminated and avoids possible errors in future processing. This adjustment of basement was most critical over the mid-Atlantic ridge where sediment cover is negligible and the topographic irregularities are extreme.

Topography data were also used on land areas where no basement surface data exist. Such areas include Labrador, the Arctic Islands and Greenland. The gridded topography was merged with the basement grid and the seams were again interpolated with the minimum curvature routine.

DISCUSSION

The finished compilation (Figure 4) is quite extensive, but with color display even a small plot shows many of the fine details. The relative depths of the marginal basins vary by many kilometres. The Scotian Basin exceeds 18km which is similar to the depth of the Magdalan Basin. These depths are not surprising because both areas are in close proximity to sediment sources from the erosion of the Appalachians. Prominent structural features in this area are: the Appalachian Deformation Front in the Gulf of Saint Lawrence, and the Orpheus Graben which extends from the southern edge of Cape Breton and sweeps into the Southern Newfoundland Transform Margin east of Newfoundland. The complex rifting of the Orphan Basin produced a highly irregular basement topography with some very deep basins. Davis Strait, the connection between the Labrador Sea and Baffin Bay, shows an extensive transform system with small interconnected basins. The Labrador Margin has basin depths exceeding 10km while the depth of the Greenland margin opposite is only about 8km deep. The Reykjanes Ridge is virtually sediment free and displays a typical spreading ridge topography deepening away from the ridge crest. The extinct ridge system in the Labrador Sea stands out clearly, although the details of the fracture zone topography is limited.

ACKNOWLEDGEMENTS

We are grateful to the various authors who provided large scale unpublished basemaps for different subareas; some of these were personal working copies. Special thanks to Al Grant and Ruth Jackson for their review of the manuscript and critique of the data compilation. Also, thanks to Kevin Wood of TEKTRONIX for continued maintenance support for the plotter.

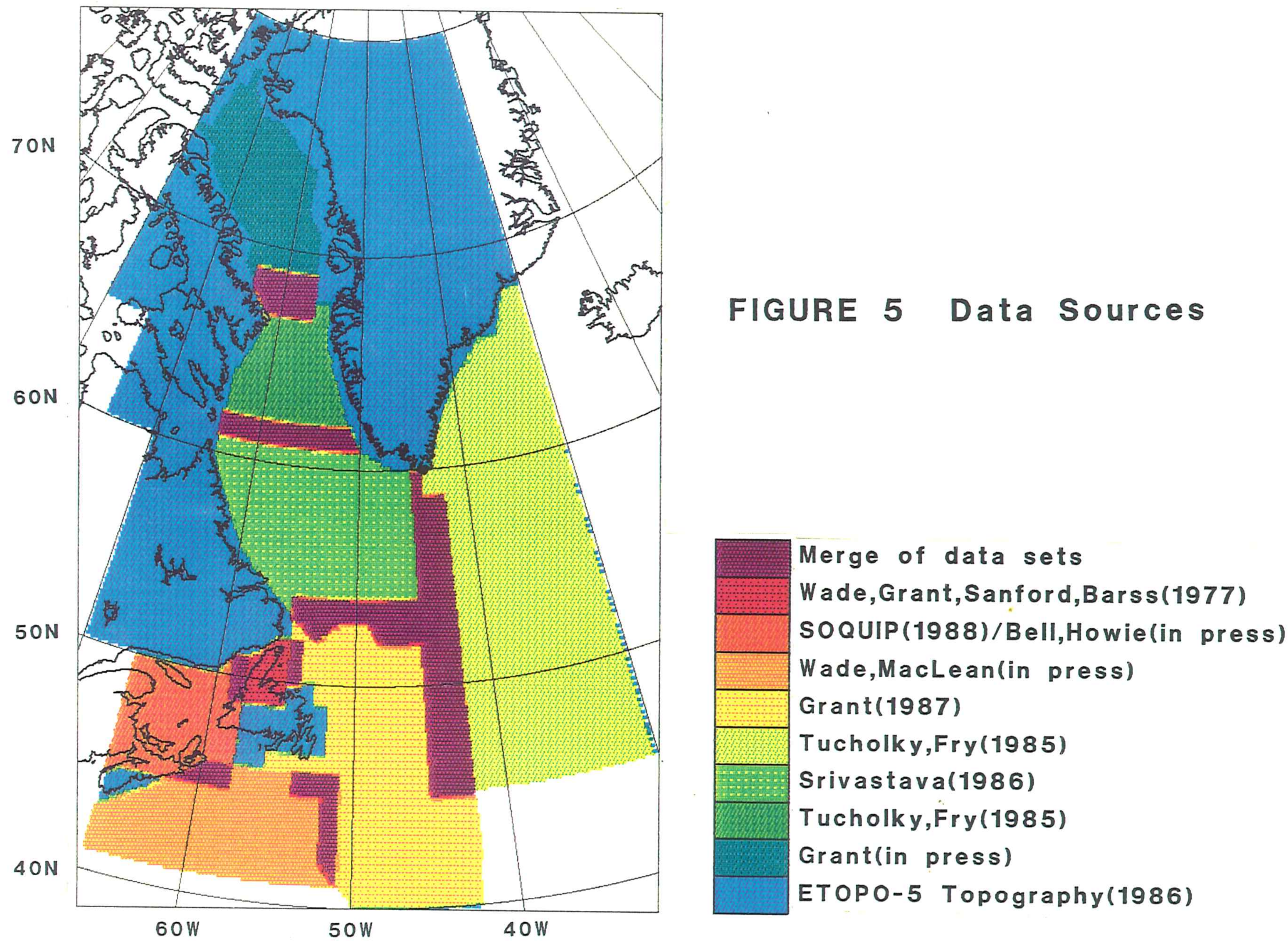

FIGURE 5 Data Sources

APPENDIX 1 : MAP SECTIONS

Although a general procedure for the compilation of basement topography has been outlined above, there were unique problems in merging all of the map areas together. The following section describes the individual sources of data (Figure 5) and the specific steps needed for each.

SCOTIAN MARGIN

Depth to Mesozoic basement (Wade and McLean, in press) was extracted from a 1:1,000,000 Lambert Conformal map (Figure 6) with standard parallels of 43 and 66 degrees. Depth contours were at intervals of 1km below sea level. The digital contour were gridded at .025x.025 degrees for interpolation because of the high gradients flanking the deep basins. The data were regridded before merging with the adjacent areas.

GULF OF SAINT LAWRENCE

The data for this area was obtained from a gridded digital file with a resolution of .025x.025 degrees (Marillier, Verhoef, submitted) (Figure 7). The data were regridded to .05x.05 degrees using linear interpolation before merging. There are three sources of data in the area. North of the Appalachian deformation front (heavy line in Figure 7) basement depths were compiled from stacked isopach maps with contour intervals of 250msec (SOQUIP, 1987). A non-linear depth conversion, based on drillhole velocity

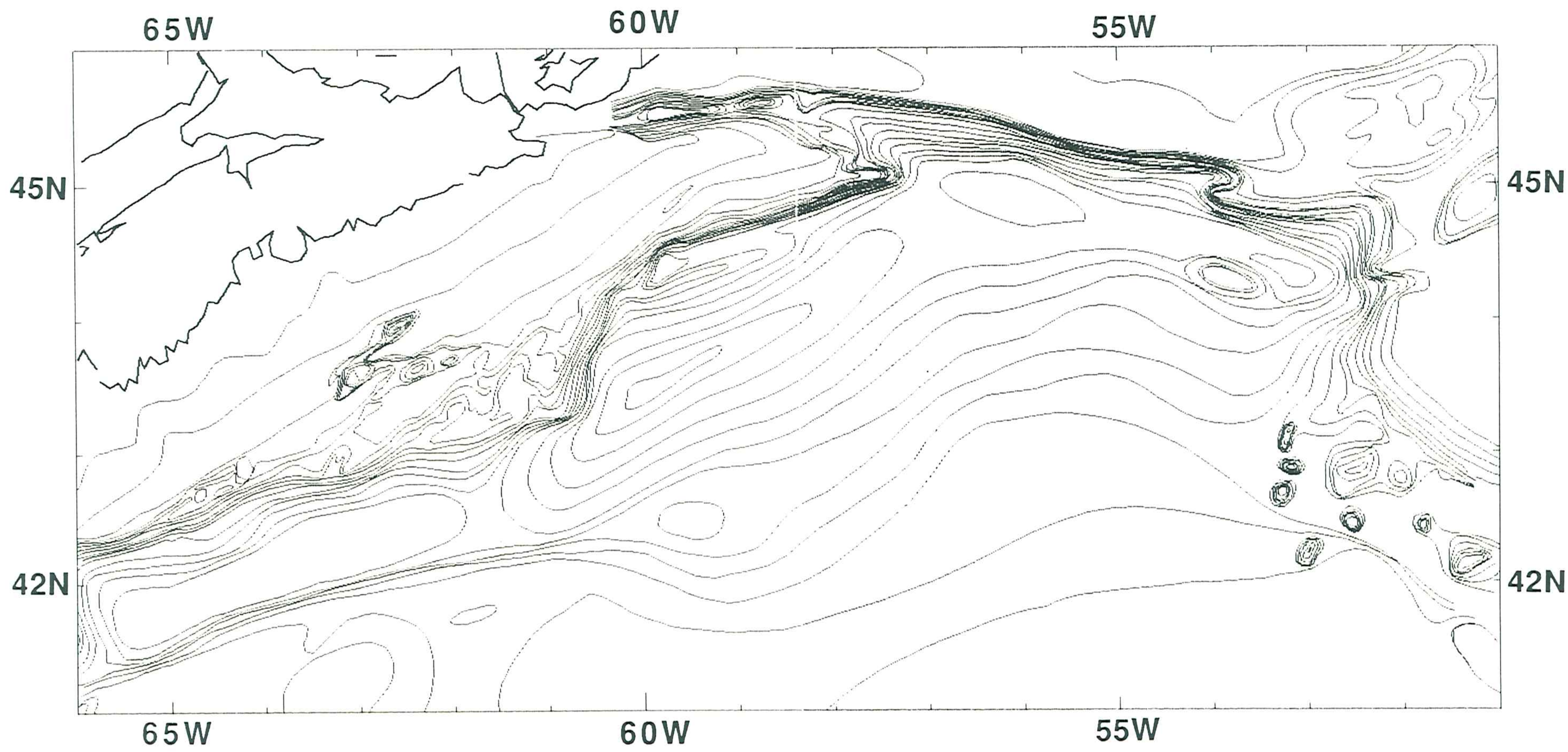

Figure 6 Scotian Margin

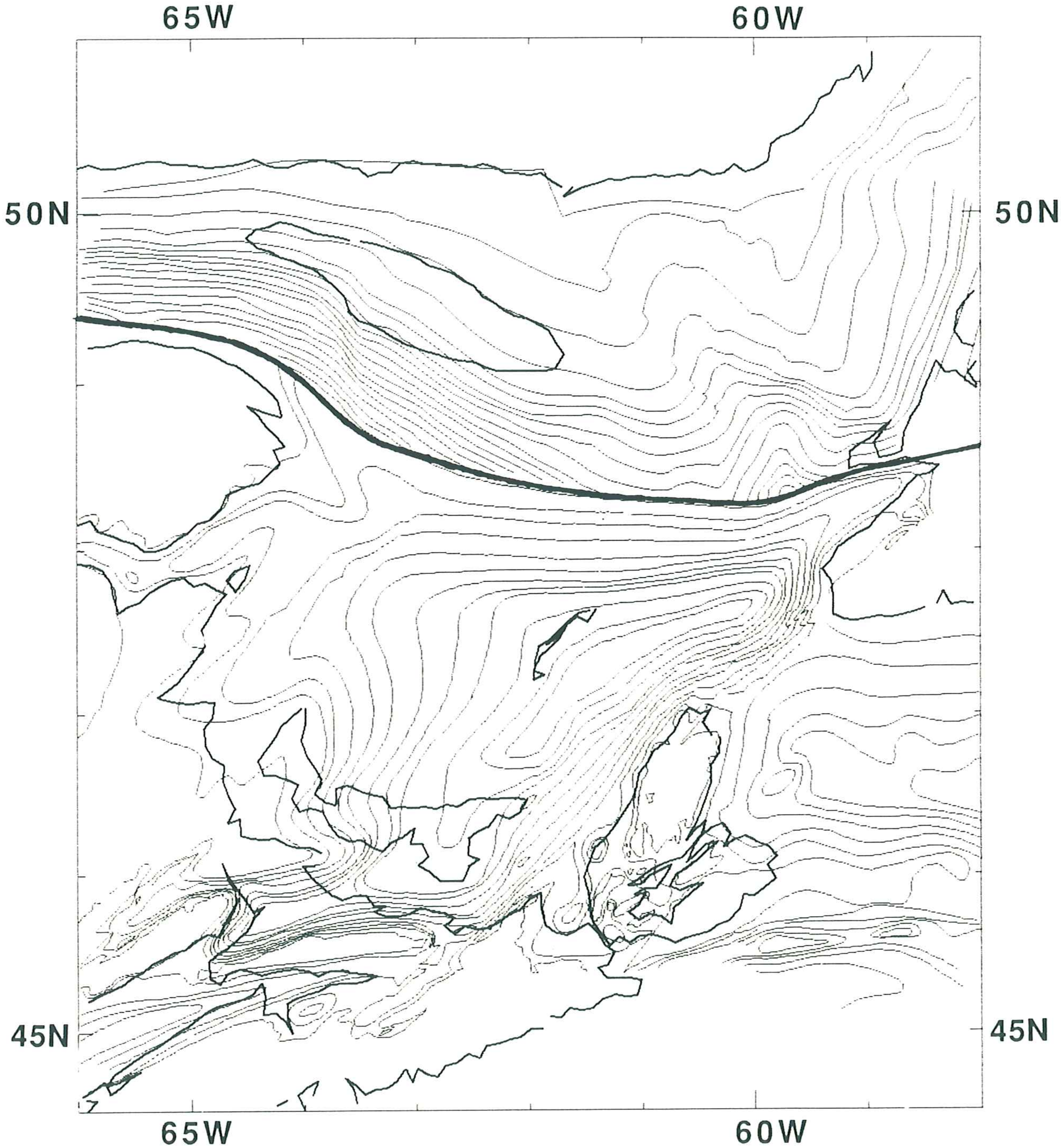

Figure 7 Gulf of St. Lawrence

logs, was used in two parts: 1) upper unit (Top of Trenton) and 2) basal sediments. The maps were published at 1:750,000 UTM projection. South of the deformation front depth contours were at 1km contour intervals for shallow depths and 2km interval for deeper areas (Howie, 1987) (Bell and Howie, in press). This map delineates both Carboniferous and Mesozoic basins which cover large areas of Nova Scotia and New Brunswick. The map of Gaspe peninsula was published with 1 km contour intervals at 1:2,000,000 Lambert Conformal with standard parallels of 45 and 66 degrees (Wade et.al., 1977).

NORTHERN NEWFOUNDLAND AND SAINT ANTHONY BASIN

The Long Range mountains of Northern Newfoundland are flanked by Carboniferous and Mesozoic basins, some of which have sediments exposed above sea level. Basement was published in 1km contours (Wade et.al.,1977) (Figure 8).

GRAND BANKS AND ORPHAN BASIN

The depths to basement for the Grand Banks region (Grant, 1987)(Grant, in press) was published with a 2km contour interval below sea floor (Figure 9). The digitized contours were extracted from a 1:1,000,000 Lambert Conformal base with standard parallels of 45 and 66 degrees. After interpolating the gridded contours, the seafloor topography from ETOPO-5 was added. Some of the small contours in the southern section of the map sheet were removed because of sparse coverage.

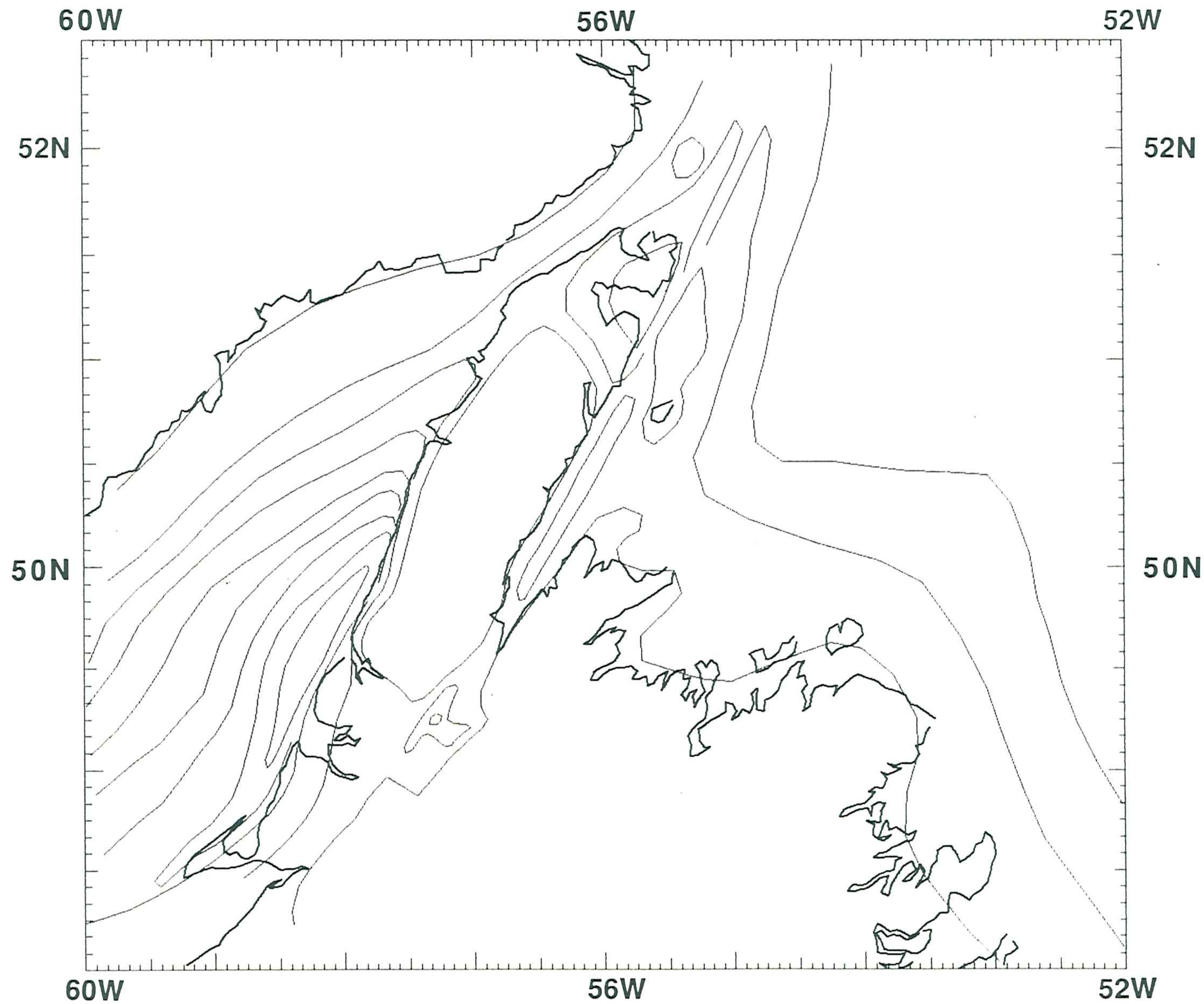

Figure 8 Northern Newfoundland and St. Anthony Basin

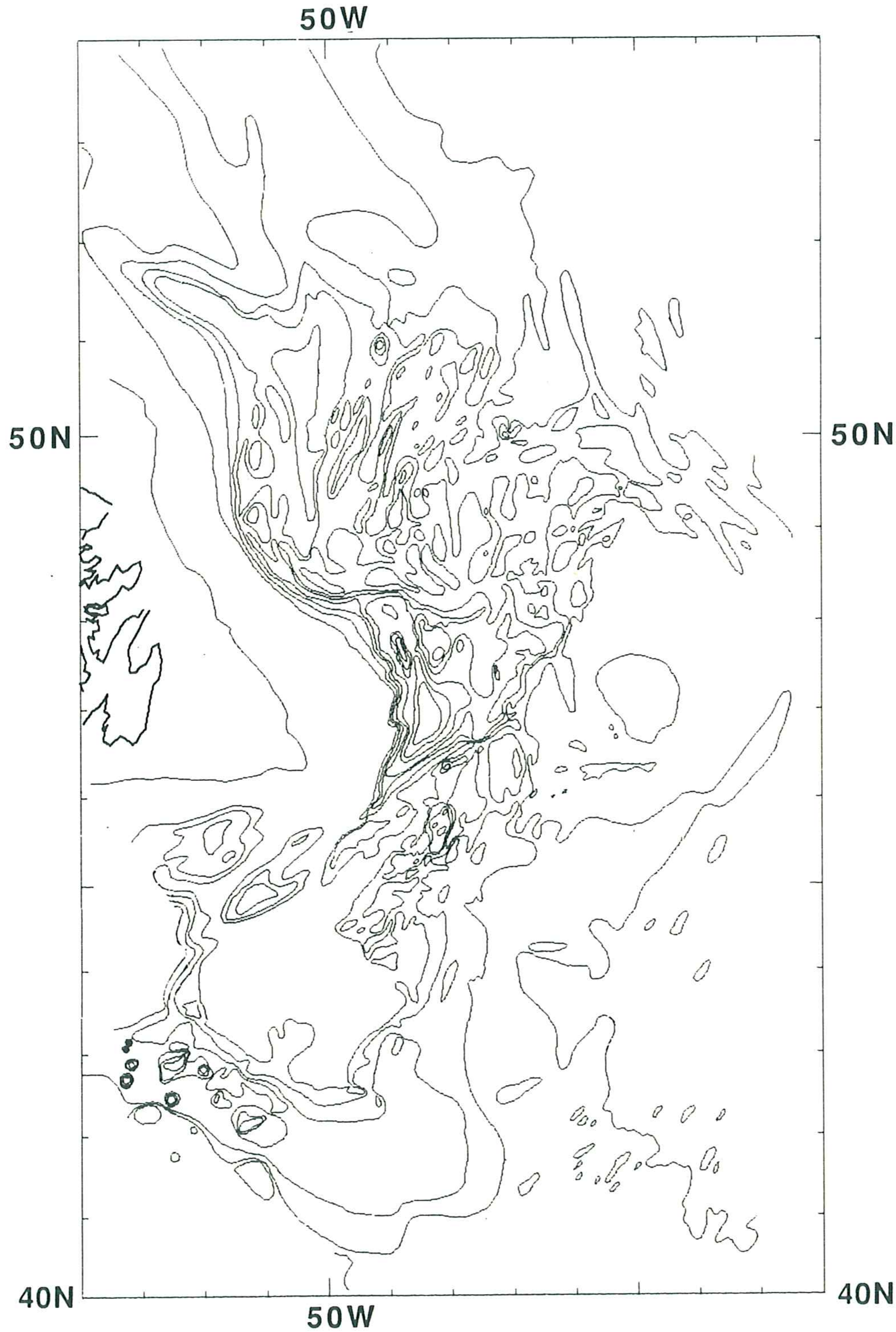

Figure 9 Grand Banks and Orphan Basin

LABRADOR SEA

Basement contours for the Labrador Sea (Figure 10) are at intervals of one second two-way time (Srivastava, 1986). Using a water velocity of 1500m/s, a correction for the water depth was calculated and removed from the interpolated grid. A non-linear sediment velocity function: $H=1.84T+0.5(1.31T^2)$, where H: thickness (in km) and T: two way travel time (in seconds) was used to convert the residual sediment cover to kilometres (Tucholke and Fry, 1986) . The isopach depths were then added to the bathymetry for the depth to oceanic basement.

SOUTHEAST GREENLAND, REYKJANES RIDGE AND DAVIS STRAIT

Marine basement depths for the North Atlantic Ocean are at .5km intervals for shallow depths and 1km intervals for depths exceeding 4km (Tucholke and Fry, 1986). Data for the area southeast of Greenland, the Reykjanes Ridge (Figure 11) and the Davis Strait (Figure 12) were extracted as sepearate pieces from the 1:2,000,000 Mercator map.

BAFFIN BAY

Basement depths for Baffin Bay (Figure 13) were extracted from a 1:5,000,000 Lambert Conformal map with standard parallels of 49 and 77 degrees (Grant, in press). The contours are at intervals of 1km.

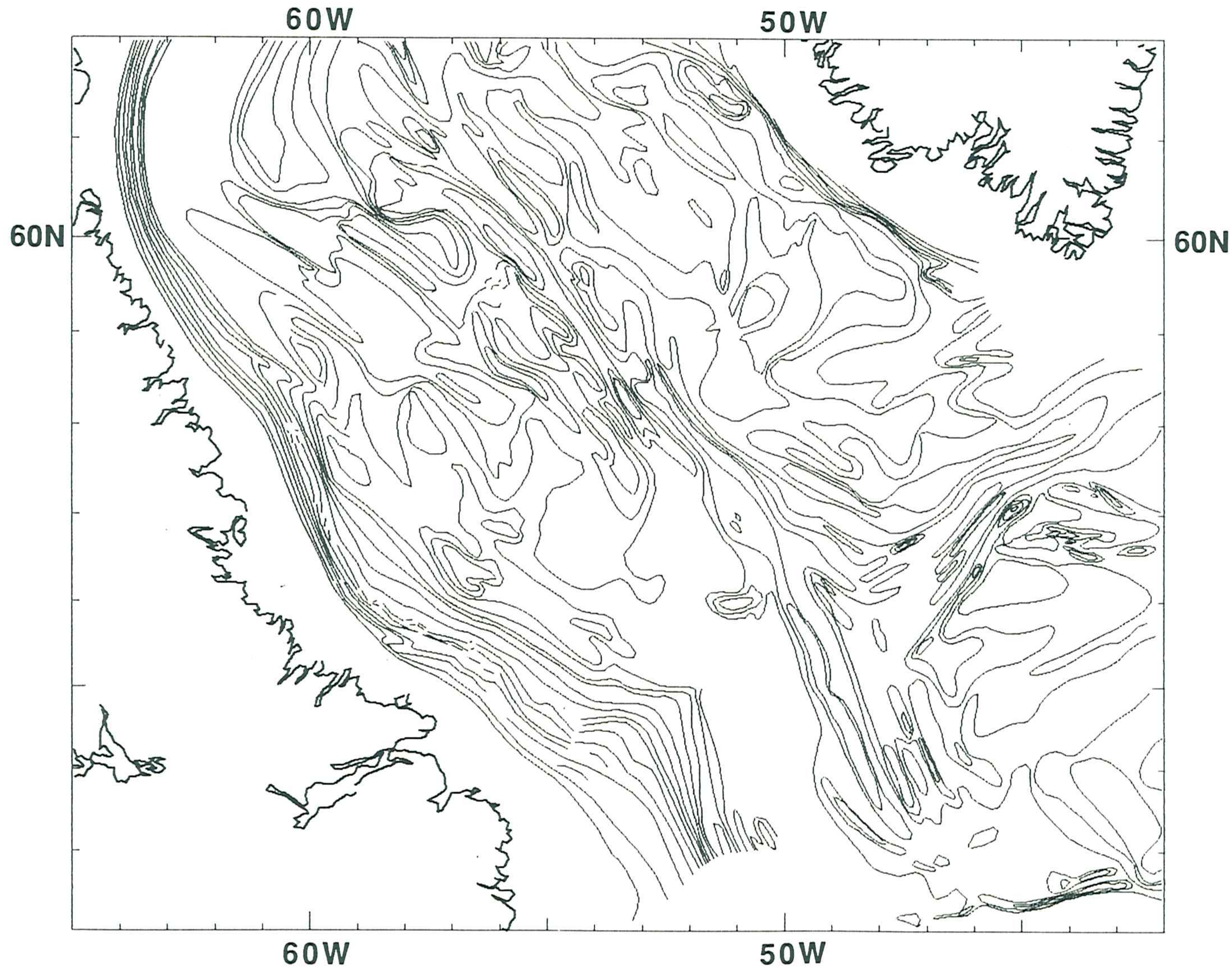

Figure 10 Labrador Sea

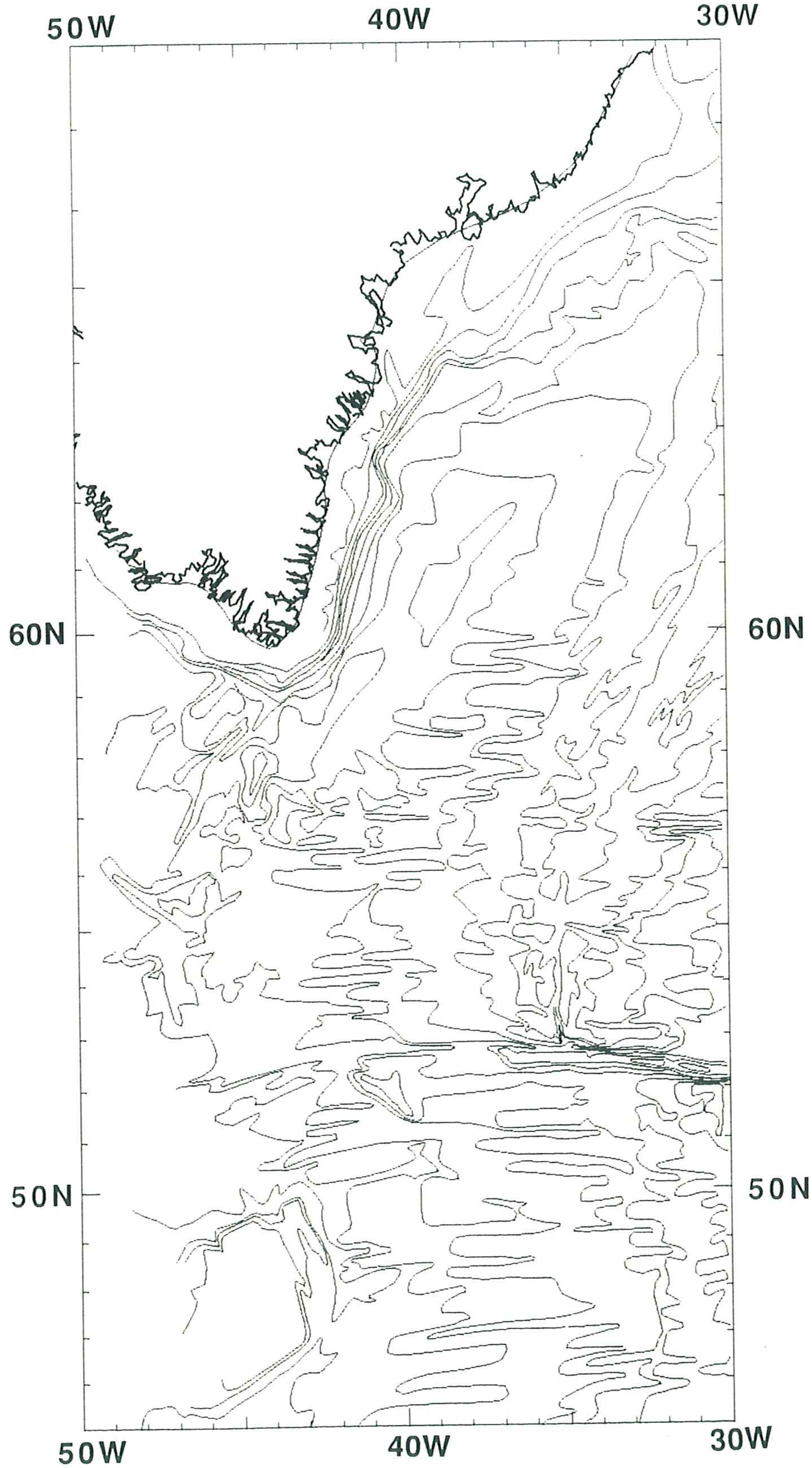

Figure 11 South East Greenland Margin and Reykjanes Ridge

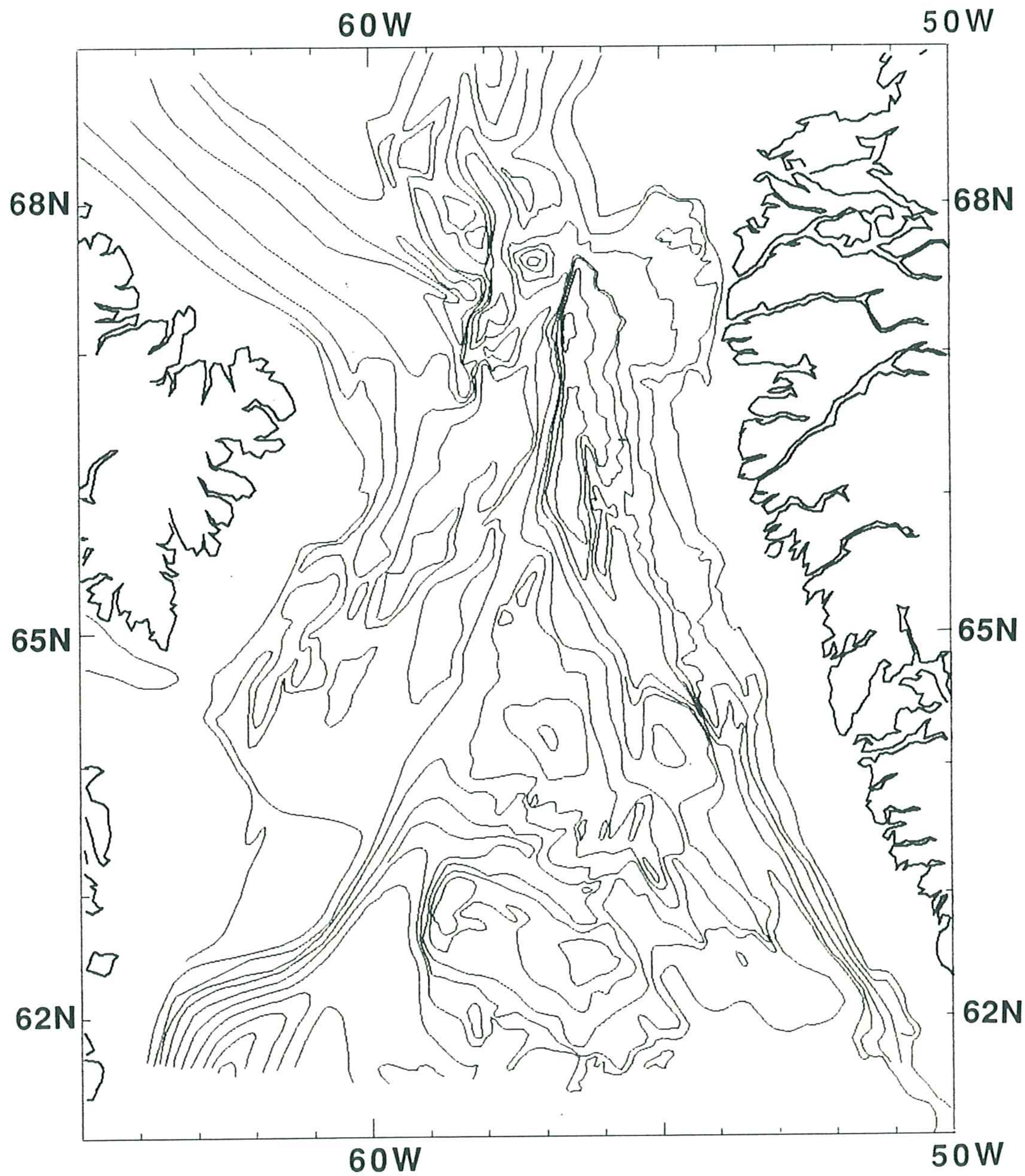

Figure 12 Davis Strait

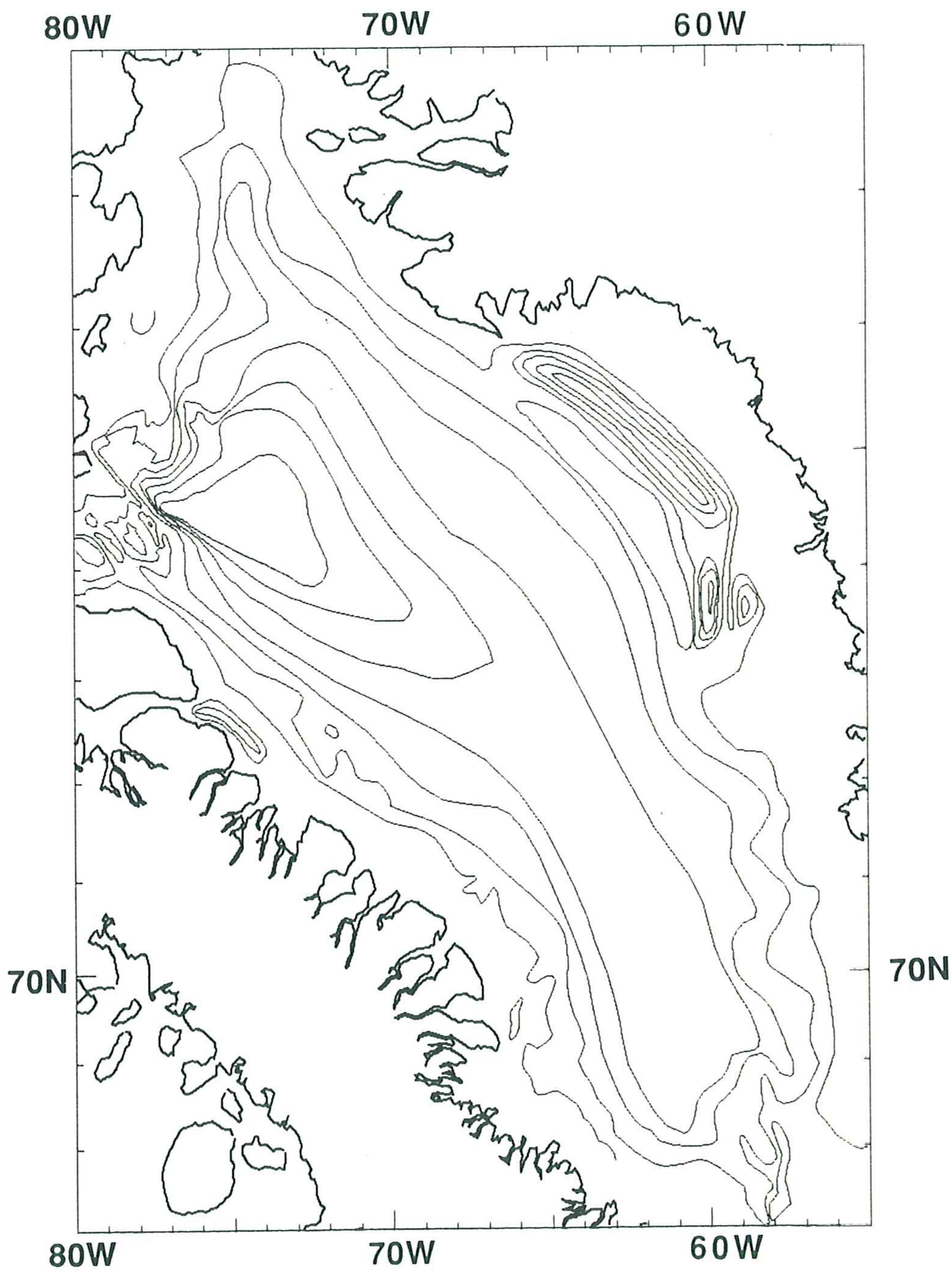

Figure 13 Baffin Bay

APPENDIX 2 : DATA FORMAT AND DISTRIBUTION

The gridded depth to basement data can be obtained through the Atlantic Geoscience Centre in blocked ascii format on a standard nine-track magnetic tape. Formal requests should be addressed to :

Gordon Oakey
Regional Reconnaissance Subdivision
Atlantic Geoscience Center
PO Box 1006, Dartmouth, Nova Scotia
B2Y 4A2

For general inquiries call : (902)-426-3548

Data Format

The basement topography is gridded with a .05x.05 degree cell size. The area of coverage is from 40 north latitude to 80 north latitude and from 30 west longitude to 80 west longitude. The values are in metres with a positive down orientation.

The first record is a header, describing the area limits and cell sizes :

element	value	parameter
1	40.0	low latitude
2	80.0	high latitude
3	-80.0	low longitude
4	-30.0	high longitude
5	0.05	latitude cell size
6	0.05	longitude call size

The number of points per record is defined by the range in longitude and the longitude cell size:

$$((-30.) - (-80.)) / .05 + 1 = 1001$$

In the header record, elements 7 thru 1001 are buffered with the value '0.0' in order to maintain a single record size.

The number of data records is defined by the range in latitude and the latitude cell size:

$$((80.) - (40.)) / .05 + 1 = 801$$

The data records are written in swaths from west to east. Each record corresponds to grid values at the same latitude and the first data record is the southernmost trace.

The following program can be used to read the data file:

```
      PROGRAM TRACE
C
      REAL*4 TRACE(5000)
      CHARACTER*20 NAMFT
C
      PRINT*,'GIVE NAME OF INPUT FILE:'
      READ(*,'(A20)')NAMFT
      INQUIRE(FILE=NAMFT,RECL=IL)
      IREC=IL/4
      OPEN(1,FILE=NAMFT,STATUS='OLD',ACCESS='DIRECT',RECL=IREC)
      PRINT*,'RECORDSIZE =',IREC
C
      READ(1,REC=1)(TRACE(I),I=1,IREC)
C
      DO 100 I=1,10
100     PRINT*,I,TRACE(I)
      XLAT=TRACE(1)
      DLAT=TRACE(5)
      XLON=TRACE(3)
      DLON=TRACE(6)
C
      NTRAC=JINT(TRACE(2)-TRACE(1))/TRACE(5)+1
      PRINT*,'NUMBER OF TRACES =',NTRAC
C
      DO 210 I=2,NTRAC+1
         READ(1,REC=I)(TRACE(II),II=1,IREC)
         ALAT=XLAT+(I-1)*DLAT
         DO 200 J=1,IREC
           ALON=XLON+(J-1)*DLON
200   CONTINUE
210   CONTINUE
      END
```

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