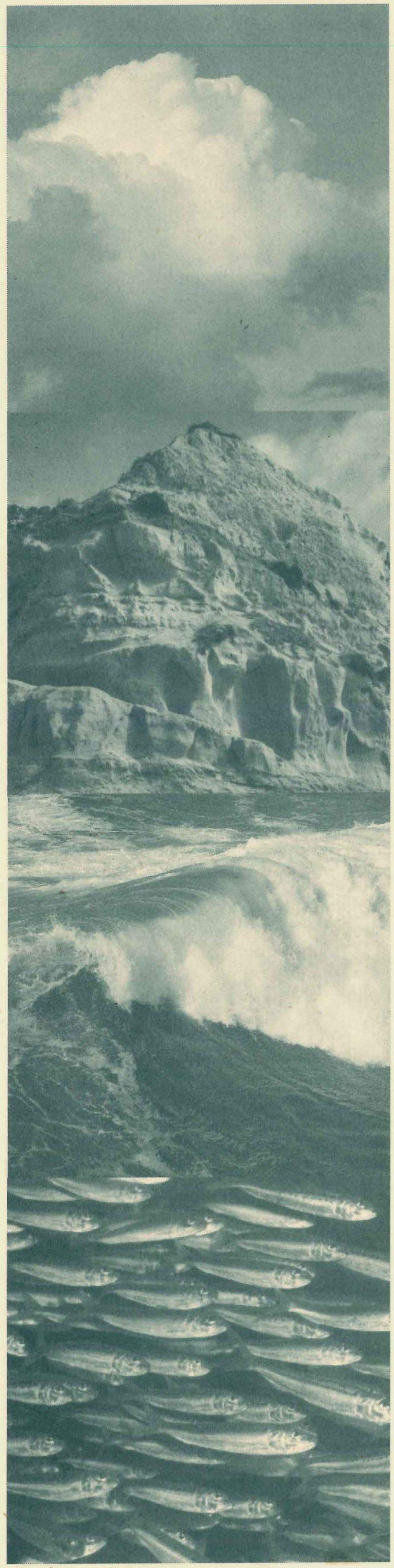


Scripps Institution of Oceanography

Reference Series

UNIVERSITY OF CALIFORNIA, SAN DIEGO

GEOPHYSICAL SYNTHESIS OF THE INDIAN / SOUTHERN OCEANS: PART 1, THE SOUTHWEST INDIAN OCEAN.

by

John G. Sclater[1], Marc Munschy[2], Robert L. Fisher[1], Pauline Weatherall[3], Steven C. Cande[1], Philippe Patriat[4], Hugh Bergh[5] and Roland Schlich[2].

[1]Geosciences Research Division-0215
Scripps Institution of Oceanography,
The University of California at San Diego,
La Jolla, CA 92093-021, USA
(jsclater@ucsd.edu)

[2]Université Louis Pasteur (Strasbourg I)
École et Observatoire des Sciences de la Terre,
Laboratoire de Géophysique Marine (CNRS-ULP UMR EP 0533)
67084 Strasbourg Cedex, FRANCE
(mmunschy@eost.u-strasbg.fr)

[3]British Oceanographic Data Centre,
Proudman Oceanographic Laboratory,
Bidston Observatory, Birkenhead,
Merseyside, L43 7RA, UNITED KINGDOM
(bodcmail@pol.ac.uk)

[4]Institut de Physique du Globe de Paris,
4, place Jussieu,
75252 Paris Cedex 05, FRANCE
(ppa@ccr.jussieu.fr)

[5]The Department of Geological Sciences,
The University of Cape Town,
Cape Town, SOUTH AFRICA
(alr@geology.uct.ac.za)

June 1997

SIO Reference Series No 97-6
EOST Publication No. 97.001
Ae Publication No. 1

THE INTERNATIONAL INDIAN OCEAN COMPILATION PROJECT (IODCP)
(aka "Alliance exotique" (Ae))

The "Alliance exotique" as an ad hoc scientific collaboration was formed in 1987. The following individuals and institutions comprise the investigators involved in the project.

Principal Investigators as Individuals:

S. C. Cande, R. L. Fisher and J. G. Sclater (SIO)

M. Munschy and R. Schlich (EOST)

These individuals comprise the "board" of the project.

Principal Investigators as Institution:

Scripps Institution of Oceanography (SIO)

École et Observatoire des Sciences de la Terre, Strasbourg (EOST)

Institute for Geophysics, University Of Texas at Austin (UTIG)
- M. Coffin

Lamont-Doherty Earth Observatory (LDEO) - J. Cochran

Australian Geological Survey Organization (AGSO)

British Oceanographic Data Centre (BODC) - P. Weatherall

Department of Geological Sciences, University of Cape Town - H. Bergh

Associate Principal Investigators as Individuals:

D. Sandwell (SIO) and Ph. Patriat (IPG, Paris)

HOW TO OBTAIN THE LARGE SCALE PLOTS

All figures in this report are presented using a Mercator projection at page size, 1:30,000,000. Figures 3 - 6 are also available using a Mercator projection at 1:5,000,000, that is, twice the scale of the General Bathymetric Chart of the Ocean sponsored by the International Hydrographic Organization, Intergovernmental Oceanographic Commission (GEBCO).

The text, appendices and page-size and twice GEBCO-size plots are to be made available through the Geological Data Center of Scripps Institution of Oceanography (GDCSIO) or from EOST Strasbourg.

Currently, the report and the figures can be obtained from John G. Sclater at SIO (e-mail : jsclater@ucsd.edu) or from M. Munschy at EOST (e-mail : MMunschy@eost.u-strasbg.fr).

The figures presenting the data were produced using the Generic Mapping Tools (GMT) software package (Wessel and Smith, 1991).

A www server is in construction at EOST. Data, interpretations and plots will be available through this server: http://barkeria.u_strasbg.fr /~iodep.

SUMMARY

Commencing in 1987, an international panel of sea-going scientists has collaborated in compiling and interpreting all available sea floor topographic, magnetic and satellite-derived gravity data in the Indian Ocean overall, from 5°W to 166°E and from Africa-Asia-Australia south to Antarctica. The purpose of the project is to evaluate uniformly comparable data from academic and agency sources, to provide large scale working charts of these compilations and to produce a detailed digital state-of-the-art tectonic chart for the entire Indian and contiguous Southern Oceans. The compilations and the tectonic chart will be used to reconstruct the history of the seafloor and the continents surrounding these oceans. This technical report, Part 1 of the project, provides the data compilation plots and the tectonic chart for the southwestern Indian Ocean which lies between southern Africa and Antarctica. Lying between 31°S and 71°S, and 5°W and 71°E, it represents almost one third of the entire area of the Indian Ocean and the contiguous Southern Oceans.

The topographic contours portray the shape and relief of the sea floor itself. They also display well the long-wavelength depth anomalies such as oceanic plateaus and swells. The satellite-derived gravity field does not resolve local fine detail but reflects the longer wavelength (> 20 km) density contrasts beneath the oceans. Like the bathymetry, it is dominated in the Southwest Indian Ocean by the spreading ridge axis, the active transform faults and the major fracture zones. It also reveals the sediment-covered extension of these fracture zones and the basement relief of the oceanic plateaus. Identification of magnetic anomaly data permits the determination of the age of the oceanic crust. The three data bases, combined and abstracted into a tectonic chart, together present a very clear summary of the present overall morphology of the ocean floor and also reveal the masking effects of sedimentation. They present a unique data base from which to reconstruct the history of the seafloor in the southwestern Indian Ocean.

1 INTRODUCTION

Since 1987, three US institutions, the Institute for Geophysics at the The Scripps Institution of Oceanography, The University of Texas at Austin and the Lamont-Doherty Earth Observatory, one French Institution, l'École et Observatoire des Sciences de la Terre, Strasbourg, and, - from time to time - Philippe Patriat of the Insitut de Physique de Globe, Paris and Hugh Bergh of the Department of Geological Sciences at the University of Cape Town, have been involved in a cooperative project to compile all available topographic, magnetic and satellite altimetry data in the Indian Ocean and contiguous Southern Oceans. As the focus of the data synthesis has moved eastwards, three Australian agencies (Australian Geological Survey Organization [AGSO], Council of Scientific and Industrial Organizations [CSIRO] and the Royal Australian Navy Hydrographic Department) are becoming contributors/participants in varying degree. The area examined is bordered at the west by the Bouvet triple junction at the 5°W line of longitude and at the east by the Macquarie triple junction at the 166°E line of longitude. Africa, the Eurasian continent, the Indonesian arc, Australia and the Tasman Sea (south of 25°S) bound the area to the north. To the south it is bounded by Antarctica.

The intent of this on-going collaboration is to assemble all available comparable data from widely different sources in a uniform manner and to produce a detailed state-of-the-art tectonic chart for the entire Indian Ocean. The compilations and the tectonic charts will then form the basis for reconstructing the tectonic history of the Indian Ocean.

The group has subdivided the ocean into 16 sectors (Figure 1 and Table 1) to be reproduced using a Mercator projection at a scale of 1: 5,000,000 at the equator (twice that of GEBCO). We choose the boundaries of each sector to illustrate, in totality, major features of the ocean floor. We choose a scale to create charts that are large enough to show clearly all the topographic features and permit easy identification of the magnetic anomalies plotted perpendicular to track. The resultant charts are approximately 36" long and 48" wide and fit easily within a standard map case. Each of the 16 sectors has a quintet of charts in color: topographic contours, ships' sounding track lines, residual magnetic anomaly profiles, satellite-derived gravity and a summary tectonic chart. The group has completed the charts in the southwestern sectors (Sectors 7, 8, 12 and 13; see Figure 1). The early de-classification of the GEOSAT satellite altimetry data south of 30°S had a major impact in the order in which we tackled the sectors. We decided to proceed eastward, completing the sectors south of 30°S in the expectation that the corresponding GEOSAT altimetry data north of 30°S would become available to us before we reached these areas. This has, in fact, happened.

In this initial technical report we start by providing a brief summary of previous compilations and follow by discussing in detail how the three basic data sets (bathymetric, magnetic and satellite-derived gravity) for sectors 7, 8, 12 and 13 (see Figure 1) were compiled. We present charts of the topographic contours, ships' track lines, magnetic anomaly profiles plotted perpendicular to track and the satellite-derived gravity field. From the plots of the magnetic anomalies and some additional South African publications, we constructed a consistent set of magnetic anomaly picks for the Southwest Indian Ocean between 5°W and 80°E and 29°S and 71°S. From the three data sets and the magnetic anomaly picks we constructed a tectonic chart for the same area. We conclude this technical report by discussing the prominent features in each of the sectors and by comparing the bathymetric and satellite-derived data sets.

2 PREVIOUS COMPILATIONS AND NEW DATA

The last major compilation of topographic data was that carried out from 1973 to 1981 for several sheets of the 5th Edition of GEBCO (i. e., Laughton, 1975; Fisher et al., 1982; Hayes and Vogel, 1983; Falconer and Tharp, 1981; Monahan et al., 1982). This topographic contouring was completed before satellite altimetry methods for determining the marine gravity field came into general use (Sandwell, 1984; Haxby, 1985). There is an overall correlation between this gravity field and local seafloor topography. Thus, the gravity field is very useful in remote areas of the ocean floor, where there may be few ship's tracks, for improving the overall accuracy of the trends in the topographic contours. As segments of the Indian Ocean zone south of 50-55°S and north of 65°S are such regions, use of this gravity data could significantly improve the quality of the topographic/tectonic elements in a large section of the ocean.

Magnetic anomaly profiles perpendicular to track can be used to identify the position on the seafloor of specific magnetic reversals. These reversals give the age of the ocean floor. There have been two previous compilations of magnetic anomaly profiles perpendicular to track that covered most of the Indian Ocean. Sclater et al., (1971) produced the first, publishing it as a Technical Report of Marine Physical Laboratory of the

Scripps Institution of Oceanography. Matthews (1975) assembled the second. Weissel and Hayes (1972) made a compilation of magnetic anomaly profiles perpendicular to track and magnetic anomaly identifications for the seafloor between Australia and Antarctica. The compilation of Sclater et al (1971) was updated in the eastern Indian Ocean by Sclater and Fisher (1974), in the south central Indian Ocean by Schlich (1975), Schlich (1982), Patriat (1983) and Royer (1988), and on the Southwest Indian Ridge by Tapscott et al., (1980), Sclater et al., (1981), Patriat (1983) and Fisher and Sclater (1983). In addition, short sections of magnetic anomaly profiles perpendicular to track in the southwest Indian Ocean appeared in papers by Bergh and Norton (1976), Bergh (1977), Bergh and Barrett (1980) and Patriat et al., (1985).

Much of the recent data acquired in the Indian Ocean has been on non-US research vessels. For example, the topographic and magnetic anomaly data collected by French investigators is concentrated in the region of the South Central Indian Ocean around and between scientific bases at Kerguelen, Réunion, Amsterdam - St Paul and Crozet. The South African data are located principally between South Africa and Antarctica, the Australian data between Australia and Antarctica, the plateaus offshore of Kerguelen and on the Australian shelf. Because of the amount of new data and the geographical extent, it is necessary to have an international cooperative research project to produce any definitive new compilation.

The amount of new data collected since the early 70's alone would justify new topographic and magnetic compilations. However, the recent publication of a revised satellite-derived gravity field using declassified GEOSAT data (Smith and Sandwell, 1995) gives an additional reason to consider a new compilation of both data sets at this time. Combining the information from the topographic and magnetic compilations with that from the gravity field will permit the construction of a state-of-the-art tectonic chart for the whole Indian Ocean that will combine the latest information on swells, plateaus, spreading centers, fracture zones and the age of the ocean floor.

3 THE RAW DATA

The basic presentations of the raw data consist of large scale 1:5,000,000 (twice GEBCO) Mercator projections colored plots of the topographic contours, ships' sounding track lines, magnetic anomaly profiles perpendicular to track, satellite-derived gravity and a summary tectonic chart which includes the earthquake epicenters. Each of these sets of data requires a different method of compilation and presentation. In this section we describe how each data set was compiled and why we chose the particular presentation.

3.1 Seafloor topography

The topographic compilations were assembled at SIO by Robert L. Fisher from world-wide academic, governmental agency and individual sources for all available depth soundings collected between 1953 and 1994. Tracks of soundings were received variously: as raw records, as hard copy values plotted along track and in digital format. All were reduced to hard copy values printed perpendicular to track and compiled prior to contouring. Compilations were prepared at a scale of 4 inches to 1 degree of longitude, on a standard Mercator projection, comparable to the United States Navy Oceanographic Office (USNOO) "oceanic plotting sheets". At this scale, the vast area covered in this project comprises 242 such sheets. During compilation sounding track values, particularly on older lines, were corrected - by inspection of raw data or by interline comparisons - for improper sounder scale or echo-sounder frequency aberrations. Where required, pre-satellite-navigated tracks were adjusted slightly by hand to minimize or eliminate cross-over discrepancies. However, particularly in the 1950's - 1960's, the celestial navigation on the geological-geophysical research ship cruises was meticulous for the times, and had been reviewed during operations by the concerned scientists themselves. The number of tracks that had to be adjusted were small.

Sheet by sheet, employing multiple cruise sounding overlays as required for legibility and clarity, the depth data compilations were interpreted and correlated for topographic/geological reasonableness and contoured by hand. In contouring, "final" compiled soundings were rectified for sounding velocity differences in the numerous geographical sectors delineated by on-site seawater properties. Hence, these contours portray "depths" in "corrected meters"; the correction values applied were those of Carter's Tables (3rd edition, UK Hydrographic Department, 1980). As is the practice for the worldwide GEBCO, the standard contour interval is 500 meters, plus the 200 m contour near shore. Very occasionally - on wide shelves - the 100 m contour was also drawn.

Contoured sheets at a scale of 4" per degree of longitude and their corresponding ships' track line index plots were duplicated by SIO and sent to BODC. There the contours were digitized, employing raster scanning and then converted to latitude, longitude and depth and stored on a computer. However, parts of sectors 7 and 12, i. e. between 10°W and 20°E, were digitized by hand at SIO and the files transmitted to BODC where they were merged to augment the overall data base underpinning these four sheets.

The bathymetric contour data digitized at BODC and the combined SIO contours are being phased into the GEBCO Digital Atlas. The region 20°E - 140°E: 31°S - 72°S (from 0° to 20°E between 46° 40'S and 72°S: from 10°W to 0° between 46° 40'S and 65°S) has been included in the Second Release of the GEBCO Digital Atlas CD-ROM, GEBCO-97. The CD-ROM can be obtained through BODC, e-mail: bodcmail@pol.ac.uk, or web pages can be found at the URL http://www.nbi.ac.uk/bodc/gebco.html.

For each of the sectors 7, 8, 12 and 13, we present here colored page-size plots (at a scale of 1:30,000,000) of the digitized contours (Figures 3a, 4a, 5a and 6a). These are reduced-scale versions of the "full-scale" 1 : 5,000,000 plots and are for display purposes only. The "full-scale" versions can be obtained from the Scripps Institution of Oceanography Geological Data Center (SIOGDC) or EOST (See page 3 for instructions).

We present the digitized ships' track lines index charts (Figures 3b, 4b, 5b and 6b) at page-size scale for the same sectors. Details on the production of the topographic contours and ships' track index charts shown in Figures 3a, 3b, 4a, 4b, 5a, 5b, 6a and 6b are provided in Appendices Ia and Ib. The data sources for the topographic data are listed in Appendix II.

3.2 Magnetic anomalies at-right-angles-to-track.

Magnetic anomaly data have been collected in the Indian Ocean since 1958. Profiles of magnetic anomaly plotted perpendicular to track were constructed from a compilation of all available magnetic anomaly data up to January 1, 1994 archived in the US National Geophysical Data Center in Boulder, Colorado, and supplemented by all SIO, L-DEO, and EOST, Strasbourg data that had not yet reached the NGDC. Furthermore, additional data from French cruises in the area were made available to us by Philippe Patriat of IPG, Paris. Hugh Bergh provided the same for recent South African data.

The regional field was removed from the compiled data set applying the IGRF for the appropriate epoch. Residual intermediate-wavelength anomalies with wavelengths longer than 200 km were removed by high-pass filtering the along-track profiles using a Gaussian 1-D filter. The track lines and the residual magnetic anomalies plotted perpendicular to track are here presented at page-size (at a scale of 1:30,000,000) for sectors 7, 8, 12 and 13 (Figures 3c, 4c, 5c and 6c). These are reduced-scale versions of the "full-scale" 1:5,000,000 plots and are for display purposes only. The "full-scale" versions can be obtained from the GDCSIO or EOST (See page 3 for instructions).

Details on the production of the magnetic anomaly charts and the areas digitized and stored can be found in Appendices Ic and Id. A listing of all the cruises used in the magnetic anomaly data compilation can be found in Appendix III.

3.3 Picking the selected magnetic anomalies

We plotted the magnetic anomalies perpendicular to track using a Mercator projection at twice GEBCO scale i.e. at 1:5,000,000. Using a block model from the reversal time scale of Kent and Gradstein (1985), we constructed synthetic magnetic profiles across the Mid-Atlantic, Southwest Indian and Southeast Indian Ridges. We used these synthetic anomalies to identify specific times at which the magnetic field reversed on the magnetic anomaly profiles. A listing of the field reversals we chose to identify is presented as Table 2. We selected easily identified anomalies at approximately 4 million year intervals. Over the slow spreading Southwest Indian Ridge we did not attempt to pick anomalies 3A, 11, 21. 23 or 27. For the tracks in the Cape, Crozet and Madagascar Basins (Africa - Antarctica and India - Antarctica motions) the anomalies were picked principally by M. Munschy at EOST. For those in the Cape and Agulhas Basins (South America - Africa, South America - Malvinas and South America - Africa motions) the anomalies were identified by S. Cande and J. Sclater at SIO.

In addition to the digitally-available data there are some published plots of magnetics anomalies perpendicular to track that have been published but for which we were unable to obtain the digital data. We enlarged the figures from these papers and picked the anomalies . These include picks of (a) anomalies 29 -34 in the Agulhas Basin from Bergh and Barrett (1980), (b) anomalies M0 - M12 in the Transkei Basin from Martin et al., (1982), (c) anomalies 6 -34 from Livermore and Woollett (1993) and 29 - 34 from Bergh (1987) in the Weddell Abyssal Plain, (d) anomalies 1 - 34 north and east of the Andrew Bain Fracture Zone from Bergh and Norton (1976) and (e) anomalies M0 - M22 from Bergh (1987) and M0 - M10 in the Enderby Abyssal Plain from Roeser et al., (1990).

We superimposed the magnetic anomaly picks on the charts of magnetic anomaly perpendicular to track (Figures 3c, 4c, 5c and 6c). Appendix IV provides a more detailed outline of how we identified the anomalies and the routines used to plot these picks on the magnetic charts for the individual sectors.

3.4 Satellite-derived gravity data

Smith and Sandwell (1995) have compiled the satellite-derived altimetric data for the world and computed a 2-minute interval gravity grid This includes the SEASAT, completely declassified GEOSAT data and the ERS-1 missions. Standard GMT programs (Wessel and Smith, 1991) were used to extract and plot the gridded data in the four sectors.

We present the colored gridded satellite-derived free-air gravity anomalies (Figures 3d, 4d, 5d and 6d) at page size. These are reduced-scale versions of the "full-scale", 1:5,000,000 plots, and are for display purposes only. The "full-scale" versions can be obtained from the SIOGDC or EOST (See page 3 for instructions). Appendix V describes the construction of the plots.

3.5 Other digital data

We used the seismicity data from the updated L-DEO worldwide earthquake epicenter data base to help identify the axis of spreading. In addition, we used the World Vector Shoreline compilation included in the GMT package for the coastlines except Antarctica. For the Antarctic coastline between 10°W and 35°E, we constructed a digital combination of the ice coastline and the ice shelf front from SCAR's Antarctic coastline. Digitized versions of the various Antarctic coastlines can be found on CD-ROM GEBCO 97 available from the BODC.

4 CONSTRUCTING THE TECTONIC CHARTS

A tectonic chart for each sector was constructed from the 2000 m and 4000 m contours, the position of the ridge axis, the magnetic anomaly picks, the earthquake epicenters, the major fracture zones, and other linear features which show up in the satellite-derived gravity field.

4.1 Selected topographic and satellite-derived gravity contours

Initially it was not planned to digitize the bathymetric contours and for sectors 7, 8, 12 an 13 only, the 2000 m and 4000 m contours were digitized directly from 50% reductions of the hand-drawn contour sheets. After digitization, the 2000 and 4000 m contours were plotted out at a scale of 1:5,000,000 and then compared with the colored satellite-derived gravity data (Figures 3d, 4d, 5d and 6d). In two tracts either side of the Andrew Bain Fracture Zone the gravity indicated en-echelon topographic relief that did not appear clearly in the topographic contours. In this area, we added the 40 and 20 mgal contours to supplement the topographic contours.

4.2 Transform faults, fracture zones and extinct spreading centers

For the tectonic chart, the transform faults, major fracture zones, less-obvious fracture zones and the other linear features delineating extinct spreading centers were determined from the bathymetric charts as amplified and refined by 1:5,000,000 colored gravity plots (Figures 3d, 4d, 5d and 6d) and separately constructed gravity contour charts. These features were taken to be defined by the minimum in the gravity field. To investigate the validity of this approach, we superimposed profiles along track of the digital topographic data on top of the gravity charts and compared the minimum in the topography with that in the gravity. Only where there is a large positive topographic anomaly associated with the fracture zone is there any tendency for the fracture zone as defined by the gravity minimum to be offset slightly towards the topographic high. The amount of shift was always less than 10 km. This distance of 10 km is similar to the error determined by Müller et al., (1991) in their analysis of the comparison between detailed topography and profiles of the satellite-derived deflection-of-the-vertical over the Kane Fracture Zone in the North Atlantic. For this study, it is not considered significant. These features were digitized at SIO.

4.3 The active spreading centers

The location of the active spreading centers were determined by plotting the earthquake epicenters and the magnetic anomalies at the same 1:5,000,000 scale as the colored gravity charts. Where a central magnetic anomaly could be identified it was used to determine the position of the spreading center. Elsewhere, the spreading axis was determined from the prominent low in the gravity data, the axial valley, if any, in the topography, the associated earthquake epicenters and then digitized at SIO.

4.4 The tectonic chart

The 2000 m and 4000 m contours and the additional 20 mGal and 40 mGal gravity contours were superimposed upon the digitized fracture zones, spreading centers, transform faults and magnetic anomaly picks to create the tectonic charts for each sector. To simplify the charts we did not plot the earthquake epicenters. The internationally-accepted names of the prominent topographic features in the Southwest Indian Ocean as listed in the GEBCO Gazetteer (Anonymous 1995) were added to these charts. Feature names in quotes have not yet been approved by internationally-designated seafloor nomenclature panels. We present the tectonic charts at page size as Figures 3e, 4e, 5e and 6e. These are reduced-scale versions of the "full-scale" 1:5,000,000 plots and are for display purposes only. The "full-scale" versions can be obtained from the GDCSIO or EOST (See page 3 for instructions). Appendix VI summarizes how the chart was constructed.

5 DISCUSSION

5.1 The structure of the Southwest Indian Ridge

The sea floor morphology of the southwestern Indian Ocean is dominated by the very slow-spreading Southwest Indian Ridge. The ridge extends 7700 km from the Bouvet triple junction at 55°S, 0°E to the Rodrigues triple junction at 25°S, 70°E and traverses diagonally the whole area. Along the ridge, topographic and gravity expression (sectors 7 and 8; Figures 3a and 3c and 4a and 4c) vary in concert in a series of seven "provinces" each of which has a characteristic axial offset and depth, fracture zone spacing, relief, width, frequency, lip massiveness, and crustal composition-exposure. From the Bouvet triple junction to the the Shaka Fracture Zone the ridge axis is offset by a series of left-stepping intermediate length transform faults (Figures 3a and 3d). East of the Shaka Fracture Zone to the Du Toit Fracture Zone at 25°E, the linear spreading ridge is hardly disrupted. In marked contrast, from the Du Toit Fracture Zone to the Prince Edward Fracture Zone at 35°E, short segments of the ridge are splayed sharply north-eastwards, in a crenulated pattern of narrow linear-to-sinuous lips, by the Andrew Bain and "Marion" and Prince Edward fracture zones (Figures 3a and 3d). From 35°E to the Discovery II Fracture Zone (a double offset with massive lips) at 42°E, the ridge shallows abruptly (> 2000m) and the axial trough is difficult to follow. Between 42°E and 52°E, the ridge is still shallow but the axis now appears as a longer continuous trough offset by a single fracture zone. The "shoal axis" fourth and fifth provinces lie between the elevated topography of the Madagascar Plateau and Del Cano Rise (Figures 4a and 4d). From 52°E to 61°E the crestal depth increases abruptly and short ridge segments are offset left-laterally by numerous deep fracture zones that together provide linear furrowed topography. East of 61°E, the narrowing ridge crest bisects a triangular gore with the apex at Rodrigues triple junction. This, the final and "seventh province", lies to the northwest of the northeast corner of sector 8 (Figures 4a and 4d).

The Southwest Indian Ridge is cut by a series of north-eastwards (Figures 3a and 3d) to north (Figures 4a and 4d) trending fracture zones which segment the axis of the ridge. The most prominent of these is the deep, multiple Andrew Bain Fracture Zone which offsets the ridge axis 700 km north-eastwards and splits the length of the ridge axis into two almost equidistant sections. Locally, this chasm descends to a depth of more than 6500 m and has lips that shoal to less than 2500 m. It has a sill depth of approximately 4500 m and is the major passage by which Antarctic Bottom Water passes from the Crozet Basin into the Mozambique Basin to the North.

5.2 Other major topographic features

Although the Southwest Indian Ridge is the dominant structural tectonic element in the Southwest Indian Ocean, there are other topographic features, including plateaus, ridges and swells, that are important.

At the western extremity of the Southwest Indian Ocean the general depth of the sea floor, as indicated by the 4000 m contour on the topographic and tectonic charts for sector 7 (Figures 3a and 3e), is reduced by a swell in the overall topography associated variously with the Discovery Seamounts, Meteor Rise, Shona Ridge, Bouvet Island and the junction of the Southern Mid-Atlantic and Southwest Indian ridges.

To the east of the Andrew Bain Fracture Zone, the Southwest Indian Ocean seafloor is dominated by a broad swell illustrated best by the 4000 m contour on the sector 8 topographic and tectonic charts (Figures 4a and 4e). This area extends from the east-west-trending Del Cano Rise/Crozet Archipelago and isolated Marion and Prince Edward Islands in the south across the multiply-offset Southwest Indian Ridge to the Madagascar Plateau in the north. Magnetic anomaly patterns link Madagascar Plateau and Del Cano Rise in former times.

Two major features not topographically associated either with the axis of the Southwest Indian Ridge or the continents show up clearly on the bathymetric charts. These are the Agulhas Plateau south of South Africa on the sector 7 topographic and tectonic charts (Figures 3a and 3e) and the WNW-ESE-trending Conrad Rise that lies 700 to 800 km south of the Del Cano Rise and is obvious on the sector 8 topographic and tectonic charts (Figure 4a and 4e).

In the north on the topographic charts for sectors 7 and 8 (Figures 3a and 4a) lie the intermediate Madagascar and Mozambique Plateaus both of which are directly connected to their respective continental neighbors. The eastern flank of the Mozambique Plateau is long and linear and exhibits a very steep descent to great depths along its entire length. To the south it terminates close to the northern extremity of the offset crenulations associated with the Andrew Bain Fracture Zone Complex Further, to the south, off Antarctica, the serrated almost E-W continental slope trend is broken by three northward protuberances between 0^{o} and 35^{o}E (Figures 5a and 5b); these are, from west to east, the plateau-like Maud Rise, Astrid Ridge and Gunnerus Ridge.

5.3 Comparison of the topographic contours and the gravity data

Overall there is good correspondence between the two with respect to large-scale features on the ocean floor. The broad-based isostatically-compensated swells appear more clearly on the bathymetric charts. The shorter wavelength features, such as the offsets of the ridge axis at small fracture zones/transform faults, are more obvious in the gravity field. Furthermore, in the areas south of the ridge axis the converging satellite passes give a much more closely spaced track density than the existing ships' sounding tracks. Ships' soundings data give fine detail along-track but little information laterally. This is contrasted with the satellite data which has the advantage of close track spacing and hence good lateral coverage but poorer detail due to the lack of high frequency information.

Four features that are obvious on the gravity plots are poorly shown or not detectable on the topography. A discrete linear high-and-low trending southwest-northeast, from 56°S, 28°E to 67°S, 13°E, (i.e., the southwest extension of the Andrew Bain Complex to the Astrid Ridge) is observed in the gravity (Sector 12, Figure 5d) but is not apparent on the topographic chart except at its northernmost end (Figure 5a). There are no sounding lines crossing the southernmost end of this feature indicating that the absence of soundings is the reason that this feature does not show on the bathymetric chart (Figure 5a). The 300 by 250 km equilateral "high" (at 62°S, 12°E), equally sparsely sounded does appear quite clearly. However, the increased lateral information provided by the gravity coverage is demonstrated by two obvious tracts of sinuous "crenulations', tectonically related, on opposite sides adjoining the Andrew Bain Fracture Zone system (Figure 4d) : (1) a 200 km-wide band extending north-northeast from 49°S, 30°E to 40°S, 36°E and (2) a similar-width band form 55°S, 28°E to 50°S, 31°E. Because of abundant ships' sounding tracks between South Africa and bases at Marion/Prince Edward islands these trends do appear, if rudimentarily, on the bathymetric plot northwest of 46°S, 32° 30'E (sector 8, Figure 4a). For the southwest sector of that northwest band, and for the entire mirrored tract east of the Andrew Bain Complex, the sinuous crenulations are not there detectable. Hence, this clearly is a function of ship track density. A pronounced linear low in the gravity field, extending from 55°S, 55°E to 60°S, 47° 30'E, shows up to the southwest of the Kerguelen Plateau (Figure 6a). The sparse but precise sounding lines crossing this linear feature indicate extremely flat bottom; the topographic relief of the feature has been masked or inundated by the pelagic sedimentation in these latitudes.

The two linear features on the gravity charts (Figures 5d and 6d) which do not appear on the topographic charts (Figures 5a and 6a) are matched by major topographic features to the north. The striking relief of the Mozambique Escarpment can be followed to the south across the Southwest Indian Ridge at the Andrew Bain Fracture Zone to match the long linear gravity feature extending south by southwest to the Astrid Ridge. We believe that this gravity feature probably marks a major, perhaps partially buried, fracture zone for which we suggest the name "Astrid Fracture Zone". The linear gravity feature to the southwest of Kerguelen was first recognised by Royer and Sandwell (1989) from profiles of deflection-of-the-vertical on satellite tracks crossing the area. They "named" this feature "Kerguelen Fracture Zone". In the strict sense of the definition of a seafloor fracture zone this is improper because there is no topographic or as yet published reflection seismic evidence for its existence. However, it appears connected across the Southeast Indian Ridge to the Ninetyeast Ridge to the north and it is probably an important tectonic feature. Hence, we have retained the name suggested by Royer and Sandwell (1989) and believe it to be a 'possible buried fracture zone' (Figure 6e).

Differential comparison of the bathymetry and the gravity in some regions can reveal the actual basement characteristics beneath topographic entities. At Astrid Ridge, protruding from Antarctica near 11°E (Figures 5a and 5d) the gravity values indicate that most of the positive topographic relief is of sedimentary origin, masking and abutting a denser spine. Del Cano Rise (~45°S, 45°E), an extensive elevation lying between, and separated from, the foundations of Quaternary volcanic Marion/Prince Edward Islands and Crozet Archipelago (Figure 4a), has been hypothesized largely on magnetic data (e.g. Goslin et al., 1980, 1981) to have been joined formerly to the south edge of the Madagascar Plateau. Inspection of the gravity aspect overall (Figure 4d) makes this interpretation seem obvious.

5.4 The tectonic charts

The tectonic charts (Figures 3e, 4e, 5e and 6e) are dominated by the crest of the slow-spreading Southwest Indian Ridge that extends from the Bouvet triple junction on the southwest corner (sector 7, Figure 3e) to the Rodrigues triple junction which is just off the north-east corner (sector 8, Figure 4e). This ridge axis appears clearly in both the gravity as a pronounced negative and in the topographic charts as an axial valley or graben. Also, it is characterized by strong earthquake activity. Between 25°E and 35°E the ridge is offset left-laterally 1100 km by the Du Toit, multiple Andrew Bain and dual Prince Edward fracture zones. The greatest offset, 700 km, occurs along the Andrew Bain complex.

Other major feature of the tectonic charts (Figures 3e, 4e, 5e and 6e) are the long linear fracture zones trending away from, and perpendicular to, the axial segments of the Southwest Indian Ridge and the en-echelon crenulations in the topography either side of the Andrew Bain Fracture Zone Complex (Figures 3a, 3d and 3e)

In the southeastern South Atlantic, the Agulhas Fracture Zone is another strikingly long linear feature clearly apparent on both the topography and the gravity charts for sector 7 (Figures 3a and 3d). It marks the motion between the African and South American plates. Three important fracture zones appear just east of the Crozet Plateau on the gravity chart for sector 8 (Figure 4d). Prior to the gravity observations, these minor relief fracture zones had been identified, principally on magnetic anomaly profiles in this area. However, the gravity data have defined the extent and trend of these sediment buried features.

6 CONCLUSIONS

We present in this technical report a compilation and synthesis of selected marine geophysical observations from the southwestern Indian Ocean collected over the past four decades from many sources. We display the raw data compilations in a set of large scale plots of the topographic contours, ships' tracklines, magnetic anomalies perpendicular to track and the satellite-derived gravity field. From these compilation we construct a tectonic chart. The topographic charts present the best overall picture to date of the long-wavelength compensated features such as the oceanic swells and aseismic plateaus characteristic of the Indian Ocean. They also portray the shape, extent and miniscule relief of the abyssal plains that mask pronounced basement relief in regions of marked pelagic sedimentation. In addition, they show the measurable dimensions, relief and detailed morphological characteristics of peaks, chasms, hills, faulted ridges, depressions and lineaments. The recent satellite-derived gravity plots indicate the apparent high-frequency basement relief and provide clues to the extent and lineations of tracts of buried topography. These plots when considered with magnetic anomaly identifications, earthquake epicenters and surface ship ground truth reveal variations in trends of the transform faults which offset the seismically-active spreading mid-ocean ridges. Taken together, these geophysical data demonstrate how and where the plates are currently moving, and how they may have moved differently in the past, with respect to each other.

In general, we find good agreement in shape of sea floor entities between the satellite-derived gravity field and the topographic contours. In only three areas, the complex tectonic region either side of the Andrew Bain complex, the southward continuation of the principal trough of the Andrew Bain Fracture Zone and a linear trough southwest of Kerguelen Archipelago, do obvious features in the gravity not show up in the topographic contours. In the first and second case, the differences are attributed to the absence of adequate track coverage for the topography, in the third by the masking of relief by sedimentation.

Throughout the region covered by this collaboration the magnetic anomaly profiles can be used to pinpoint myriad localities whose crustal age is well established. Hence, in combination with the gravity charts and the sea floor topography they permit detailed reconstructions, not only of the past positions, but also of the relief of the paleo-ocean floor.

APPENDIX I : CHARTS OF BATHYMETRY, TRACKLINE AND MAGNETIC ANOMALY PLOTTED AT-RIGHT-ANGLES-TO SHIPTRACK

Ia.1 The Bathymetric Data:

The bathymetric contours and the ships' sounding tracks were digitized from R.L. Fisher's hand-drawn "four inches equals one degree of longitude" compilations of the Indian Ocean. The data from 10°W to 20°E were digitized by Karen Walters at Scripps Institution of Oceanography. They were stored by chart using the Paleomap (Royer and Winn, 1987) format. Pauline Weatherall and staff at the British Oceanographic Data Center, Merseyside, digitized the data from 20°E to 80°E. The digitized bathymetric contours and the digitized ships' sounding tracks are stored in separate files in ASCII format.

Ia.2 Storage of the Bathymetric Data:

The bathymetric contour data compiled at SIO are stored according to the individual chart number, "USNOO oceanic series" . These charts are numbered 0105S to 0117S, 3605S to 3617S, and 3505S to 3517S (Figure 2), for example. The contour data are stored with the suffix .contform and the shiptrack data are stored with the suffix .trackform.

The bathymetric contour data digitized at BODC and the combined SIO contours can be obtained through the BODC by contacting Pauline Weatherall at the BODC, e-mail: bodcmail@pol.ac.uk.

Ia.3 Construction of the Rainbow-Colored Bathymetric Contour Chart:

The routine for the construction of Figure 3a, the rainbow-colored bathymetric contour chart, involves the following steps:

- Convert the bathymetry to GMT format.

- Separate the data into individual contour level files.

- Create the rainbow colored contour image using the "psxy" command from the GMT package.

Ib Construction of the Trackline Charts:

The computer procedure for setting up the trackline plots (Figure 3b) involves the following steps

- Convert the ships' sounding tracks to GMT format.

- Plot the tracks within the sector chosen using the "psxy" command from the GMT package.

Ic Charts with the Profiles of Magnetic Anomalies Plotted Perpendicular to Track:

The routines for the construction of the magnetic anomaly profiles (Figure 3c) are as follows

- Extract the relevant cruise data using "gmtpluslegs" and "gmtpluslist" from the GMT package.

- Use the "pswiggle" command from the GMT package to plot the magnetic anomalies perpendicular to track.

Id The Dimensions used for digitizing are different from those used for plotting. The basic data were digitized and stored in a larger area than that in which they are presented in the Technical Report.

Id.1. Range for storage and digitization:

SWIO (combined files)	5°W, 80°E, 29°S, 71°S
Sector 7	5°W, 40°E, 29°S, 56°S
Sector 8	40°E, 80°E, 29°S, 56°S
Sector 12	5°W, 40°E, 56°S, 71°S
Sector 13	40°E, 80°E, 56°S, 71°S

Id.2. Range for display:

Sector 7	5°W, 40°E, 31°S, 57°S
Sector 8	26°E, 71°E, 31°S, 57°S
Sector 12	5°W, 40°E, 55°S, 71°S
Sector 13	26°E, 71°E, 55°S, 71°S

APPENDIX II THE DATABASE FOR THE BATHYMETRIC CONTOUR CHARTS

IIA Listing of digital along-track echo sounding legs by country

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
ANTIII3	GER	R/V POLARSTERN	ANTIII/3	850102	PUNTA ARENAS	850305	CAPE TOWN
ANTIV3	GER	R/V POLARSTERN	ANTIV/3	851206	PUNTA ARENAS	8603	CAPE TOWN
ANTIV4	GER	R/V POLARSTERN	ANTIV/4	860318	CAPE TOWN	860429	PUNTA ARENAS
ANTIX2	GER	R/V POLARSTERN	ANTIX/2	901216	N/A	901222	N/A
ANTIX3	GER	R/V POLARSTERN	ANTIX/3	910110	N/A	910320	N/A
ANTV3	GER	R/V POLARSTERN	ANTV/4	860928	CAPE TOWN	861214	CAPE TOWN
ANTV4	GER	R/V POLARSTERN	ANTV/4	861226	CAPE TOWN	870317	PUERTOMADRY
ANTVI3	GER	R/V POLARSTERN	ANTVI/3	871219	USHUAIA	880317	CAPE TOWN
ANTVIII5	GER	R/V POLARSTERN	ANTVI/II	891223	N/A	900304	N/A
ANTVIII6	GER	R/V POLARSTERN	ANTVI/II	900319	N/A	900423	N/A
ANTX2	GER	R/V POLARSTERN	ANTX/	920113	N/A	920318	N/A
ANTXI3	GER	R/V POLARSTERN	ANTXI/	940318	N/A	940319	N/A
ANTXI4	GER	R/V POLARSTERN	ANTXI/4	940419	N/A	940508	N/A
ANTXII3	GER	R/V POLARSTERN	ANTXII/3	950110	N/A	950311	N/A
19930045	UK	RRS BRANSFIELD	PASSAGES	930103	N/A	930105	N/A
DI101	UK	RRS DISCOVERY	CRUISE101	790410	CAPE TOWN	790506	PORT VICTORIA
DIS199	UK	RRS DISCOVERY	CRUISE199	921223	PUNTA ARENAS	930131	CAPE TOWN
DIS200	UK	RRS DISCOVERY	CRUISE200	930206	CAPE TOWN	930306	CAPE TOWN
DIS201	UK	RRS DISCOVERY	CRUISE201	930327	CAPE TOWN	930502	CAPE TOWN
DIS202	UK	RRS DISCOVERY	CRUISE202	930507	CAPE TOWN	930601	CAPE TOWN
DIS202T	UK	RRS DISCOVERY	CRUISE202	930605	CAPE TOWN	930608	CAPE TOWN
78009911	FRA	R/V J. CHARCOT	WALVIS1-CH88	781220	CAPE TOWN	790114	CAPE TOWN
79000211	FRA	R/V J. CHARCOT	WALVIS2-CH85	790125	CAPE TOWN	790220	CAPE TOWN
79000212	FRA	R/V J. CHARCOT	WALVIS3-CH86	790224	CAPE TOWN	790315	CAPE TOWN
79001311	FRA	R/V J. CHARCOT	TRANSWAL	790318	CAPE TOWN	790412	BREST
84000111	FRA	R/V J. CHARCOT	HYDROAM	840224	N/A	840328	N/A
90001611	FRA	R/V J. CHARCOT	N/A	900731	N/A	900901	N/A
JC01	FRA	R/V J. CHARCOT	N/A	781128	N/A	781216	N/A
GALA0A67	FRA	M/V GALLIENI	N/A	670101	N/A	N/A	N/A
GALA1A68	FRA	M/V GALLIENI	N/A	680101	N/A	N/A	N/A
GALA2A69	FRA	M/V GALLIENI	N/A	690101	N/A	N/A	N/A
GALA3A70	FRA	M/V GALLIENI	N/A	700101	N/A	N/A	N/A
GALA4A71	FRA	M/V GALLIENI	N/A	710216	RÉUNION	710219	MAURITIUS
PAT96	FRA	R/V L ATALANTE	N/A	950927	N/A	951025	N/A
MD00	FRA	M/V MARION DUFRESNE	N/A	730428	N/A	730606	N/A
MD01	FRA	M/V MARION DUFRESNE	N/A	730611	N/A	730711	N/A
MD03	FRA	M/V MARION DUFRESNE	N/A	740427	N/A	740425	N/A
MD05	FRA	M/V MARION DUFRESNE	N/A	750413	N/A	750525	N/A
MD06	FRA	M/V MARION DUFRESNE	N/A	750528	N/A	750630	N/A
MD07	FRA	M/V MARION DUFRESNE	N/A	750824	N/A	750926	N/A
MD09	FRA	M/V MARION DUFRESNE	N/A	760430	N/A	760909	N/A
MD11	FRA	M/V MARION DUFRESNE	N/A	760913	N/A	761025	N/A
MD16	FRA	M/V MARION DUFRESNE	N/A	780422	N/A	780608	N/A

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
MD26	FRA	M/V MARION DUFRESNE	N/A	810310	N/A	810429	N/A
MD37	FRA	M/V MARION DUFRESNE	N/A	830707	N/A	830802	N/A
MD47	FRA	M/V MARION DUFRESNE	N/A	960109	N/A	860216	N/A
MD34	FRA	M/V MARION DUFRESNE	N/A	830207	N/A	830225	N/A
MD35	FRA	M/V MARION DUFRESNE	N/A	830302	N/A	830305	N/A
MD38A	FRA	M/V MARION DUFRESNE	N/A	840104	N/A	840111	N/A
MD38B	FRA	M/V MARION DUFRESNE	N/A	840114	N/A	840219	N/A
MD38C	FRA	M/V MARION DUFRESNE	N/A	840225	N/A	840305	N/A
MD43	FRA	M/V MARION DUFRESNE	N/A	850223	N/A	850330	N/A
MD53	FRA	M/V MARION DUFRESNE	N/A	870103	N/A	870221	N/A
MD67	FRA	M/V MARION DUFRESNE	N/A	910228	N/A	910406	N/A
MD68	FRA	M/V MARION DUFRESNE	N/A	910415	N/A	910517	N/A
MD70	FRA	M/V MARION DUFRESNE	N/A	910824	N/A	910923	N/A
MD77	FRA	M/V MARION DUFRESNE	N/A	930907	N/A	930926	N/A
MD80	FRA	M/V MARION DUFRESNE	N/A	940506	N/A	940614	N/A
MDOP84A	FRA	M/V MARION DUFRESNE	N/A	840703	N/A	840708	N/A
MDOP88	FRA	M/V MARION DUFRESNE	N/A	880627	N/A	880627	N/A
MDOP89	FRA	M/V MARION DUFRESNE	N/A	890302	N/A	890305	N/A
MDOP91	FRA	M/V MARION DUFRESNE	N/A	910104	N/A	910222	N/A
CP-36	AUST	M/V CAPEPILLAR	N/A	800229	N/A	800407	N/A
ND-34	AUST	M/V NELLA DAN	N/A	820101	N/A	820314	N/A
RS-47	AUST	RIGSEISMIC	RESEARCHCRU	850307	SYDNEY	850429	MELBOURNE
ANTAC10	JAP	R/V FUJI	N/A	6812	N/A	6904	N/A
ANTAC12	JAP	R/V FUJI	N/A	6911	N/A	7005	N/A
ANTAC13	JAP	R/V FUJI	N/A	7012	N/A	7103	N/A
ANTAC19	JAP	R/V FUJI	N/A	7712	N/A	7803	N/A
ANTAC20	JAP	R/V FUJI	N/A	7812	N/A	7902	N/A
ANTAC21A	JAP	R/V FUJI	N/A	7911	N/A	N/A	N/A
ANTAC21B	JAP	R/V FUJI	N/A	8004	N/A	N/A	N/A
ANTAC22	JAP	R/V FUJI	N/A	801216	N/A	810309	N/A
ANTAC23	JAP	R/V FUJI	N/A	811216	N/A	820327	N/A
ANTAC24	JAP	R/V FUJI	N/A	830208	N/A	830310	N/A
ANTAC7	JAP	R/V FUJI	N/A	6511	N/A	6512	N/A
ANTAC8A	JAP	R/V FUJI	N/A	6612	N/A	N/A	N/A
ANTAC8B	JAP	R/V FUJI	N/A	6704	N/A	N/A	N/A
ANTAC9B	JAP	R/V FUJI	N/A	6803	N/A	N/A	N/A
ANTAC25	JAP	R/V SHIRASE	N/A	840225	N/A	840313	N/A
ANTAC26	JAP	R/V SHIRASE	N/A	841114	TOKYO	850319	TOKYO
ANTAC2	JAP	R/V SHIRASE	N/A	851203	N/A	860314	N/A
UM66-C	JAP	R/V UMITAKA MAR	CRUISE 1966	670107	55W,40S	670215	N/A
MN766	RSA	M/V M.NAUDE	CRUISE76/6	760322	DURBAN	760403	DURBAN
RSA72-2	RSA	M/V RSA	ANT.SUPPLYVYG	720208	N/A	720224	N/A
RSA73-1	RSA	M/V RSA	ANT.SUPPLYVYG	730111	N/A	730119	N/A
RSA73-2	RSA	M/V RSA	ANT.SUPPLYVY	730206	N/A	730216	N/A
RSA75-1	RSA	M/V RSA	ANT.SUPPLYVY	750113	N/A	750120	N/A
RSA75-3	RSA	M/V RSA	ANT.SUPPLYVY	750218	N/A	750227	N/A
TBD396	RSA	R/V T.B.DAVIE	TRCK#657-665	790822	N/A	790913	N/A

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
TD377	RSA	R/V T.B.DAVIE	CRUISE377 IPOD	780523	CAPE TOWN	780607	CAPE TOWN
TD388	RSA	R/V T.B.DAVIE	CRUISE388 SITE	790306	CAPE TOWN	790323	CAPE TOWN
TD397	RSA	R/V T.B.DAVIE	CRUISE397 SURV	791011	CAPE TOWN	791029	CAPE TOWN
AG04	RSA	M/V S.A.AGULHAS	N/A	781026	WALVIS BAY	781116	CAPE TOWN
AG06	RSA	M/V S.A.AGULHAS	N/A	790718	CAPE TOWN	790726	CAPE TOWN
AG08	RSA	M/V S.A.AGULHAS	N/A	790501	N/A	790514	CAPE TOWN
AG10	RSA	M/V S.A.AGULHAS	N/A	801016	CAPE TOWN	801124	CAPE TOWN
AG16	RSA	M/V S.A.AGULHAS	N/A	791025	CAPE TOWN	791116	CAPE TOWN
AG022	RSA	M/V S.A.AGULHAS	CRUISE22 LEG1	811030	N/A	811103	N/A
AG029	RSA	M/V S.A. AGULHAS	N/A	830426	N/A	830521	N/A
AG044	RSA	M/V S.A.AGULHAS	CRUISE44 LEG1	860427	N/A	860507	N/A
AG053	RSA	M/V S.A.AGULHAS	N/A	880325	N/A	880419	N/A
MONS4AAR	USA	R/V ARGO	MONSOONLEG4A	601210	MAURITIUS	610102	FREMANTLE
LUSI08AR	USA	R/V ARGO	LUSIADLEG08	630604	CAPE TOWN	630708	FREETOWN
LUSI6BAR	USA	R/V ARGO	LUSIADLEG6B	621030	PT.LOUIS	621128	FREMANTLE
LUSI7DAR	USA	R/V ARGO	LUSIADLEG7D	630518	MOMBASA	630529	CAPE TOWN
DODO08AR	USA	R/V ARGO	DODOLEG8	640911	PT.LOUIS	641009	CEYLON
CIRC08AR	USA	R/V ARGO	CIRCELEG8	681009	LOURENCO	68110	LUANDA
A2015L04	USA	R/V ATLANTISII	CRUISE15,LEG4	650627	DURBAN	650827	KOBE
A2060L04	USA	R/V ATLANTISII	CRUISE60,LEG4	710410	MONTEVIDO	710430	CAPE TOWN
A2060L05	USA	R/V ATLANTISII	CRUISE60,LEG5	710510	CAPE TOWN	710608	LUANDA
A2067L02	USA	R/V ATLANTISII	CRUISE67,LEG2	720204	DAKA	720222	CAPE TOWN
A2067L03	USA	R/V ATLANTISII	CRUISE67,LEG3	720227	CAPE TOWN	720320	CAPE TOWN
A2067L04	USA	R/V ATLANTISII	CRUISE67,LEG4	720324	CAPE TOWN	720408	WALVIS BAY
A2067L05	USA	R/V ATLANTISII	CRUISE67,LEG5	720412	WALVIS BAY	720506	WALVIS BAY
A2093L02	USA	R/V ATLANTISII	CRUISE93,LEG2	751119	RECIFE	751217	CAPE TOWN
A2093L03	USA	R/V ATLANTISII	CRUISE93,LEG3	751222	CAPE TOWN	760108	CAPE TOWN
A2093L04	USA	R/V ATLANTISII	CRUISE93,LEG4	760113	CAPE TOWN	760208	CAPE TOWN
A2093L05	USA	R/V ATLANTISII	TRIPLEJUNC	760213	DURBAN	760308	MAURITIUS
A2107L06	USA	R/V ATLANTISII	CRUISE107,LEG6	800305	N/A	800406	N/A
CH099L04	USA	R/V CHAIN	CRUISE99,LEG4	700612	LUANDA	700702	MOZAMBIQUE
CH115L02	USA	R/V CHAIN	CRUISE115,LEG2	731214	DAKAR,	740110	CAPE TOWN
CH115L03	USA	R/V CHAIN	CRUISE115,LEG3	740114	CAPE TOWN	740211	CAPE TOWN
CH115L04	USA	R/V CHAIN	CRUISE115,LEG4	740215	CAPE TOWN	740315	CAPE TOWN
CH115L05	USA	R/V CHAIN	CRUISE115,LEG5	740323	CAPE TOWN	740417	RIO DE JANEIRO
C0801	USA	R/V ROBERT D. CONRAD	CRUISE8,LEG1	631126	SAN JUAN	631229	CAPE TOWN
C0802	USA	R/V ROBERT D. CONRAD	CRUISE8,LEG2	640105	CAPE TOWN	640202	PERTH
C1103	USA	R/V ROBERT D. CONRAD	CRUISE11,LEG3	670131	BUENOS AIRES	670227	CAPE TOWN
C1104	USA	R/V ROBERT D. CONRAD	CRUISE11,LEG4	670302	CAPE TOWN	670403	MAURITIUS
C1214	USA	R/V ROBERT D. CONRAD	CRUISE12,LEG14	690202	BUENOS AIRES	690303	CAPE TOWN
C1215	USA	R/V ROBERT D. CONRAD	CRUISE12,LEG15	690331	CAPE TOWN	690505	COLOMBO
C1313	USA	R/V ROBERT D. CONRAD	c1313	701003	CAPE TOWN	701104	CAPE TOWN
C1314	USA	R/V ROBERT D. CONRAD	c1314	701209	CAPE TOWN	710111	CAPE TOWN
C1401	USA	R/V ROBERT D. CONRAD	c1401	710117	CAPE TOWN	710228	MAURITIUS
C1504	USA	R/V ROBERT D. CONRAD	c1504	720105	N/A	720205	N/A
C1703	USA	R/V ROBERT D. CONRAD	c1703	731203	ABIDJAN	731231	CAPE TOWN
C1704	USA	R/V ROBERT D. CONRAD	c1704	740105	CAPE TOWN	740219	CAPE TOWN
C1705	USA	R/V ROBERT D. CONRAD	c1705	740225	CAPE TOWN	740411	PT.ELIZABETH
C1706	USA	R/V ROBERT D. CONRAD	c1706	740417	PT.ELIZABETH	740514	MAURITIUS
C2709	USA	R/V ROBERT D. CONRAD	c2709	861002	MAURITIUS	861105	CAPE TOWN

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
C2710	USA	R/V ROBERT D. CONRAD	c2710	861114	CAPE TOWN	861130	CAPE TOWN
C2711	USA	R/V ROBERT D. CONRAD	c2711	861203	CAPE TOWN	870102	RIO DE JANEIR(
ELT46	USA	R/V ELTANIN	CRUISE046	701120	FREMANTLE	710119	FREMANTLE
ELT47	USA	R/V ELTANIN	CRUISE047	710203	FREMANTLE	710412	MELBOURNE
ELT48	USA	R/V ELTANIN	CRUISE048	710628	NEWCASTLE	710819	FREMANTLE
ELT54	USA	R/V ELTANIN	CRUISE054	720620	FREMANTLE	720729	FREMANTLE
FM01-04	USA	R/V FRED H. MOORE	N/A	790516	WALVIS BAY	790611	CAPE TOWN
FM01-05	USA	R/V FRED H. MOORE	N/A	790618	CAPE TOWN	790716	RIO DE JANEIR(
DSDP25GC	USA	D/V GLOMAR CHALLENGER	DSDPLEG25	720628	PT.LOUIS	720822	DURBAN
DSDP26GC	USA	D/V GLOMAR CHALLENGER	DSDPLEG26	720906	DURBAN	721029	PERTH
DSDP39GC	USA	D/V GLOMAR CHALLENGER	DSDPLEG39	741006	AMSTERDAM	741217	CAPE TOWN
DSDP40GC	USA	D/V GLOMAR CHALLENGER	DSDPLEG40	741220	CAPE TOWN	750215	ABIDJAN
DSDP73GC	USA	D/V GLOMAR CHALLENGER	DSDPLEG73	800413	SANTOS	800601	CAPE TOWN
DSDP74GC	USA	D/V GLOMAR CHALLENGER	DSDPLEG74	800606	CAPE TOWN	800724	WALVIS BAY
LUSI02HO	USA	R/V HORIZON	LUSIADLEG2	621031	PT.LOUIS	621128	FREMANTLE
ODP113JR	USA	D/V JOIDES RESOLUTION	ODP	870105	PUNTA ARENAS	870311	EASTCOVE
ODP114JR	USA	D/V JOIDES RESOLUTION	ODP	870314	EASTCOVE	870514	PT.LOUIS
ODP118JR	USA	D/V JOIDES RESOLUTION	ODP	871022	PT.LOUIS	871214	PT.LOUIS
ODP119JR	USA	D/V JOIDES RESOLUTION	ODP	871218	PT.LOUIS	880221	FREMANTLE
ODP120JR	USA	D/V JOIDES RESOLUTION	ODP	880226	FREMANTLE	880430	FREMANTLE
INMD05MV	USA	R/V MELVILLE	INDOMEDLEG5	780128	PT.LOUIS	780225	FREMANTLE
INMD08MV	USA	R/V MELVILLE	INDOMEDLEG8	780429	PT.LOUIS	780528	PT.LOUIS
VLCN05MV	USA	R/V MELVILLE	VULCANLEG5	801202	VALPARAISO	810111	PUNTA ARENA:
PROT04MV	USA	R/V MELVILLE	PROTEALEG4	831104	PUNTA ARENAS	831213	CAPE TOWN
PROT05MV	USA	R/V MELVILLE	PROTEALEG5	840114	CAPE TOWN	840215	CAPE TOWN
HYDR02MV	USA	R/V MELVILLE	HYDROSLEG2	881207	PUNTA ARENAS	890115	CAPE TOWN
HYDR03MV	USA	R/V MELVILLE	HYDROSLEG3	890123	CAPE TOWN	890308	MONTEVIDEO
I1176	USA	R/V ELTANIN/ORCADAS	I1176	761029	BUENOS AIRES	761219	CAPE TOWN
I1277	USA	R/V ORCADAS	N/A	770104	CAPE TOWN	770302	BUENOS AIRES
I1578	USA	R/V ORCADAS	N/A	780118	BUENOS AIRES	780310	BUENOS AIRES
V1809	USA	R/V VEMA	CR18,LEG9	620509	BUENOS AIRES	620531	CAPE TOWN
V1810	USA	R/V VEMA	CR18,LEG10	620603	CAPE TOWN	620620	PT.LOUIS
V1911	USA	R/V VEMA	CR19,LEG11	630828	MOMBASA	630916	CAPE TOWN
V1912	USA	R/V VEMA	CR19,LEG12	630920	CAPE TOWN	631024	ABIDJAN
V2010	USA	R/V VEMA	CR20,LEG10	640921	PT.LOUIS	641009	CAPE TOWN
V2011	USA	R/V VEMA	CR20,LEG11	641014	CAPE TOWN	641107	RECIFE
V2204	USA	R/V VEMA	CR22,LEG4	660316	BUENOS AIRES	660412	CAPE TOWN
V2205	USA	R/V VEMA	CR22,LEG5	660416	CAPE TOWN	660425	CAPE TOWN
V2206	USA	R/V VEMA	CR22,LEG6	660426	CAPE TOWN	660428	DAKAR
V2411	USA	R/V VEMA	CR24,LEG11	670921	PT.LOUIS	671011	CAPE TOWN
V2412	USA	R/V VEMA	CR24,LEG12	671016	CAPE TOWN	671114	RIO DE JANEIR(
V2710	USA	R/V VEMA	CR27,LEG10	700102	RECIFE	700130	CAPE TOWN
V2711	USA	R/V VEMA	CR27,LEG11	700206	CAPE TOWN	700210	CAPE TOWN
V2712	USA	R/V VEMA	CR27,LEG12	700213	CAPE TOWN	700312	ABIJAN
V2903	USA	R/V VEMA	CR29,LEG03	720120	PT.LOUIS	[illegible]0214	PT.LOUIS
V2904	USA	R/V VEMA	CR29,LEG04	720218	PT.LOUIS	720316	CAPE TOWN
V2905	USA	R/V VEMA	CR29,LEG05	720321	CAPE TOWN	720416	CAPE TOWN
V2906	USA	R/V VEMA	CR29,LEG06	720421	CAPE TOWN	720518	LUANDA
V3409	USA	R/V VEMA	CRV34,LEG09	771102	PT.VICTORIA	771206	PT.LOUIS
V3410	USA	R/V VEMA	CRV34,LEG10	771210	PT.LOUIS	771229	CAPE TOWN

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
V3411	USA	R/V VEMA	CRV34,LEG11	780104	CAPE TOWN	780131	CAPE TOWN
V3501	USA	R/V VEMA	CRV35,LEG01	780218	CAPE TOWN	780305	PT. VICTORIA
V3620	USA	R/V VEMA	CR36,LEG20	810119	DURBAN	810210	CAPE VERDE IS
MRTN10WT	USA	R/V T.WASHINGTON	LEG10	841215	RIO DE JANEIRO	850116	CAPE TOWN
MRTN13WT	USA	R/V T.WASHINGTON	LEG13	850401	CAPE TOWN	850501	RECIFE
AKU20	USSR	R/V AKAD.KURCHATOV	AKU120	750212	KALININGRAD	750525	KALININGRAD
KO20-A	USSR	R/V AKAD.KURCHATOV	N/A	750118	N/A	750426	N/A
KO20-B	USSR	R/V AKAD.KURCHATOV	N/A	750428	N/A	750525	N/A

A list of non-digital echo sounding legs by country

SHIP	YEAR
ARGENTINA	
CAPTAIN CANEPA	1957
ZAPIOLA	1963
DENMARK	
M/V DANA	1928-30
M/V GALATHEA	1951
GERMANY	
R/V METEOR	1933
SCHWABENLAND	1938-39
JAPAN	
R/V FUJI 8	1967
R/V FUJI 14	1972-73
R/V FUJI 16	1974
R/V FUJI 17	1976
M/V SOYA	1957
M/V SOYA	1958
M/V SOYA	1959
M/V SOYA	1961
R/V UMITAKA MARU	N/A
R/V UMITAKA MARU	1961-62
RSA	
M/V AFRICANA II	1961
M/V AFRICANA II	1962
M/V AFRICANA II	1963
M/V AFRICANA II	1964
M/V AFRICANA II	1965
M/V AFRICANA II	1966
M/V AFRICANA II	1968
M/V AGULHAS	1982
"H. Bergh 202"	N/A
"H. Bergh 208"	N/A
"H. Bergh 209"	N/A
"H. Bergh 210"	N/A
"H. Bergh 217"	N/A
"H. Bergh 221"	N/A
"H. Bergh 410"	N/A
"H. Bergh 415"	N/A
"H. Bergh 417"	N/A
R/V THOMAS B. DAVIE	1968
R/V THOMAS B. DAVIE	1971
M/V MEIRING NAUDE	1969
M/V NATAL	1957
M/V NATAL	1958
M/V NATAL	1962
M/V NATAL	1965
M/V NATAL	1966
M/V PRETORIUS	N/A
SAS PROTEA	1974
SAS PROTEA	1975
UK	
HMS ACHERON	1955
RRS BRANSFIELD	1979
HMS CHALLENGER	1952
HMS DAMPIER	1967
HMS DALRYMBLE	1954
R/S DISCOVERY II	N/A
R/S DISCOVERY II	1935-37
R/S DISCOVERY II	1951
R/S DISCOVERY II	1961
R/S DISCOVERY II	1962
HMS DREADNOUGHT	1967
HMS HECLA	1966
HMS MERCURY	1965
HMS OWEN	1961
HMS PROTECTOR	1964
HMS PROTECTOR	1966
HMS PUMA	1960
R/V W. SCORESBY	N/A
RRS SHACKLETON	1960
RRS SHACKLETON	1975-76
M/V SHROPSHIRE	1965
HMS VIDAL	1967
HMS VIDAL	1968-69
USA	
USS EASTWIND	N/A
R/V ATLANTIS	1959
A. BRUUN 5	1964
USS ARNEB	1956
USS GLACIER	N/A
U.S.H.O.	1951
U.S.H.O.	1955
U.S.H.O.	1962
R/V VEMA 14	1958
R/V VEMA	1959
R/V VEMA 16	1960
USS WESTWARD	N/A
USS WILKES	1984
USS WYANDOT	N/A
USSR	
R/V OB	1957-58
R/V OB	1959-60
R/V VITYAZ 36	1964-65
COUNTRY UNKNOWN	
ASTRO	N/A
M/V BENETAC	1969
GULFREX	1970
M/V HOPEPEAK	1964
M/V NORTHERN STAR	1964
M/V SOUTHERN CROSS	1963
SUPERIOR OIL	1968
M/V TAFELBERG	1968

APPENDIX III THE TRACKLINE BASE FOR THE MAGNETIC ANOMALY PROFILES

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
zap23	ARG	ZAPIOLA	N/A	630328	PUNTA ARENAS	630412	CAPE TOWN
zap24	ARG	ZAPIOLA	N/A	630412	CAPE TOWN	630511	MONTEVIDEO
bm31a	AUST.	M/V NELLA DAN	N/A	791019	MELBOURNE	791231	MELBOURNE
bm31b	AUST.	M/V NELLA DAN	N/A	800110	MELBOURNE	800319	N/A
bm32a	AUST.	M/V NELLA DAN	N/A	801117	MELBOURNE	801230	MELBOURNE
bm32b	AUST.	M/V NELLA DAN	N/A	800110	HOBART	800324	MELBOURNE
bm33a	AUST.	M/V NELLA DAN	N/A	811105	HOBART	811217	HOBART
bm33b	AUST.	M/V NELLA DAN	N/A	820101	HOBART	820314	HOBART
bmr36	AUST.	M/V NELLA DAN	N/A	800229	PERTH	800407	PERTH
cp360	AUST.	M/V CAPE PILLAR	N/A	800229	FREMANTLE	800407	FREMANTLE
ps851	GER	R/V POLARSTERN	N/A	850301	N/A	850303	CAPE TOWN
ps861	GER	R/V POLARSTERN	N/A	860309	N/A	860313	CAPE TOWN
ps862	GER	R/V POLARSTERN	N/A	860318	CAPE TOWN	860324	N/A
ps863	GER	R/V POLARSTERN	N/A	860928	CAPE TOWN	86100	N/A
ps864	GER	R/V POLARSTERN	N/A	861210	N/A	861213	CAPE TOWN
ps865	GER	R/V POLARSTERN	N/A	861226	CAPE TOWN	861231	N/A
ps881	GER	R/V POLARSTERN	N/A	880312	N/A	880315	CAPE TOWN
jc001	FRA	R/V JEAN CHARCOT	N/A	781128	DJIBOUTI	781216	CAPE TOWN
jc132	FRA	R/V JEAN CHARCOT	N/A	890224	RÉUNION	890328	RÉUNION
jch71	FRA	R/V JEAN CHARCOT	N/A	781220	CAPE TOWN	790114	CAPE TOWN
jch72	FRA	R/V JEAN CHARCOT	N/A	790125	CAPE TOWN	790220	CAPE TOWN
jch73	FRA	R/V JEAN CHARCOT	N/A	790224	CAPE TOWN	790315	CAPE TOWN
jch74	FRA	R/V JEAN CHARCOT	N/A	790318	CAPE TOWN	790412	CAPE TOWN
ggal0	FRA	R/V GALLIENI	N/A	661202	RÉUNION	670128	MAURITIUS
ggal1	FRA	R/V GALLIENI	N/A	680314	RÉUNION	680410	MAURITIUS
ggal2	FRA	R/V GALLIENI	N/A	681228	RÉUNION	690323	RÉUNION
ggal3	FRA	R/V GALLIENI	N/A	691215	CAPE TOWN	700405	RÉUNION
ggal4	FRA	R/V GALLIENI	N/A	710216	RÉUNION	710505	
ggal5	FRA	R/V GALLIENI	N/A	720210	RÉUNION	720319	MAURITIUS
mdf00	FRA	M/V MARION DUFRESNE	N/A	730428	MAURITIUS	730606	RÉUNION
mdf01	FRA	M/V MARION DUFRESNE	N/A	730611	RÉUNION	730711	MAURITIUS
mdf03	FRA	M/V MARION DUFRESNE	N/A	740427	MAURITIUS	740425	
mdf05	FRA	M/V MARION DUFRESNE	N/A	750413	MAURITIUS	750525	MAURITIUS
mdf06	FRA	M/V MARION DUFRESNE	N/A	750528	RÉUNION	750630	CAPE TOWN
mdf07	FRA	M/V MARION DUFRESNE	N/A	750824	CAPE TOWN	750926	MAURITIUS
mdf09	FRA	M/V MARION DUFRESNE	N/A	760430	MAURITIUS	760609	MAURITIUS
mdf11	FRA	M/V MARION DUFRESNE	N/A	760913	MAURITIUS	761025	N/A
mdf12	FRA	M/V MARION DUFRESNE	N/A	770301	N/A	770324	N/A
mdf16	FRA	M/V MARION DUFRESNE	N/A	780422	MAURITIUS	780608	DJIBOUTI
mdf23	FRA	M/V MARION DUFRESNE	N/A	800708	DURBAN	800805	PORT VICTORIA
mdf26	FRA	M/V MARION DUFRESNE	N/A	810310	RÉUNION	810429	RÉUNION
mdf37	FRA	M/V MARION DUFRESNE	N/A	830707	MAURITIUS	830802	MAURITIUS
mdf47	FRA	M/V MARION DUFRESNE	N/A	860109	KERGUELEN	860216	RÉUNION

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
um66c	JAP	R/V UMITAKA MARU	CRUISE 1966	670107	MARDEL PLAT	670215	WALVIS BAY
tha81	JAP	N/A	N/A	820101	VALPARAISO	820209	VALPARAISO
ag004	RSA	M/V S.A. AGULHAS	N/A	781026	WALVIS BAY	781116	CAPE TOWN
ag006	RSA	M/V S.A. AGULHAS	N/A	790718	CAPE TOWN	790726	CAPE TOWN
ag008	RSA	M/V S.A. AGULHAS	N/A	790501	N/A	790514	CAPE TOWN
ag010	RSA	M/V S.A. AGULHAS	N/A	801016	CAPE TOWN	801124	CAPE TOWN
ag016	RSA	M/V S.A. AGULHAS	N/A	791025	CAPE TOWN	791116	CAPE TOWN
ago22	RSA	M/V S.A. AGULHAS	N/A	811030	N/A	811103	N/A
ago44	RSA	M/V S.A. AGULHAS	N/A	860427	N/A	860507	N/A
ago29	RSA	M/V S.A. AGULHAS	N/A	830426	N/A	830521	N/A
ago53	RSA	M/V S.A.AGULHAS	N/A	880325	N/A	88O419	N/A
mn766	RSA	M/V MEIRING NAUDE	CRUISE 76/6	760322	DURBAN	760403	DURBAN
rig02	RSA	M/V RIG SEISMIC	N/A	850307	DEVONPORT	850429	MELBOURNE
hb100	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb102	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb103	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb105	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb106	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb107	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb108	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb109	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb200	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb201	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb209	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb210	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb211	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb212	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb213	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb214	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb215	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb216	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb220	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb221	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb306	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb307	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb308	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb309	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb310	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb311	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb312	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb315	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb316	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb317	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb318	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb319	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb400	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb409	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb410	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A
hb413	RSA	M/V RSA	N/A	N/A	N/A	N/A	N/A

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
a731	RSA	M/V RSA	N/A	730111	N/A	730119	CAPE TOWN
sa732	RSA	M/V RSA	N/A	750113	CAPE TOWN	730216	CAPE TOWN
sa751	RSA	M/V RSA	N/A	750110	CAPE TOWN	750120	CAPE TOWN
sa753	RSA	M/V RSA	N/A	750218	CAPE TOWN	750227	CAPE TOWN
tbd01	RSA	R/V THOMAS B. DAVIE	N/A	741003	CAPE TOWN	741013	CAPE TOWN
tbd02	RSA	R/V THOMAS B. DAVIE	N/A	741015	CAPE TOWN	741025	CAPE TOWN
td267	RSA	R/V THOMAS B. DAVIE	N/A	711018	DURBAN	711101	DURBAN
td277	RSA	R/V THOMAS B. DAVIE	N/A	721016	DURBAN	721110	DURBAN
td377	RSA	R/V THOMAS B. DAVIE	CRUISE 377	780523	CAPE TOWN	780607	CAPE TOWN
td388	RSA	R/V THOMAS B. DAVIE	CRUISE 388|	790306	CAPE TOWN	790323	CAPE TOWN
td396	RSA	R/V THOMAS B. DAVIE	657-665,667	790822	CAPE TOWN	790913	CAPE TOWN
td397	RSA	R/V THOMAS B. DAVIE	CRUISE 397	791011	CAPE TOWN	791029	CAPE TOWN
BN76_11a	RSA	|	N/A	N/A	N/A	N/A	N/A
BN76_11b	RSA	| Tracks digitized	N/A	N/A	N/A	N/A	N/A
B77_2	RSA	| from figures	N/A	N/A	N/A	N/A	N/A
BB80_1	RSA	| in publications	N/A	N/A	N/A	N/A	N/A
BB80_5a	RSA	| of Hugh Bergh.	N/A	N/A	N/A	N/A	N/A
BB80_5b	RSA	|	N/A	N/A	N/A	N/A	N/A
BB80_5c	RSA	| See list of	N/A	N/A	N/A	N/A	N/A
B86_2	RSA	| references.	N/A	N/A	N/A	N/A	N/A
akk20	USSR	R/V AKAD.KURCHATOV	AKU1 20	750212	KALININGRAD	750525	KALININGRAD
B87_6	RSA	|	N/A	N/A	N/A	N/A	N/A
B87_8	RSA	|	N/A	N/A	N/A	N/A	N/A
di101	UK	RRS DISCOVERY	CRUISE 101	790410	CAPE TOWN	790506	PORT VICTORIA
sh75a	UK	RRS SHACKLETON	N/A	751106	DURBAN	751203	N/A
00211	USA	AEROMAG DATA	PROJ. MAGNET	630129	BEUNOS AIRES	630130	CAPE TOWN
00213	USA	AEROMAG DATA	PROJ. MAGNET	641030	CAPE TOWN	641031	CAPE TOWN
00215	USA	AEROMAG DATA	PROJ. MAGNET	630201	CAPE TOWN	630202	CAPE TOWN
00217	USA	AEROMAG DATA	PROJ. MAGNET	630420	RIO DE JANERIO	630421	CAPE TOWN
00218	USA	AEROMAG DATA	PROJ. MAGNET	630423	CAPE TOWN	630424	CAPE TOWN
00239	USA	AEROMAG DATA	PROJ. MAGNET	670127	CAPE TOWN	670128	CAPE TOWN
2207x	USA	AEROMAG DATA	PROJ. MAGNET	640330	CAPE TOWN	640331	CAPE TOWN
2208x	USA	AEROMAG DATA	PROJ. MAGNET	631110	RIO DE JANERIO	631111	CAPE TOWN
2212x	USA	AEROMAG DATA	PROJ. MAGNET	641026	MONTEVIDEO	641027	CAPE TOWN
2237x	USA	AEROMAG DATA	PROJ. MAGNET	670123	RIO DE JANERIO	670124	CAPE TOWN
msn4a	USA	R/V ARGO	MONSOON LG 4A	601210	MAURITIUS	610102	FREMANTLE
lus6b	USA	R/V ARGO	LUSIAD LEG 6B	621030	PT.LOUIS	621128	FREMANTLE
lus7d	USA	R/V ARGO	LUSIAD LEG 7D	630518	MOMBASA	630529	CAPE TOWN
dodo8	USA	R/V ARGO	DODO LEG 8	640911	PT.LOUIS	641009	CEYLON
cir08	USA	R/V ARGO	CIRCE LEG 8	681009	LOURENCO	681105	LUANDA
a0604	USA	R/V ATLANTIS II	N/A	710410	MONTEVIDEO	710430	CAPE TOWN
a1076	USA	R/V ATLANTIS II	N/A	800305	PUNTA ARENAS	800406	CAPE TOWN
a2153	USA	R/V ATLANTIS II	N/A	650412	COLOMBO	650621	DURBAN
a2154	USA	R/V ATLANTIS II	CRUISE 15, LEG 4	650627	DURBAN	650827	KOBE
a2605	USA	R/V ATLANTIS II	CRUISE 60, LEG 5	710510	CAPE TOWN	710608	LUANDA
a2672	USA	R/V ATLANTIS II	N/A	720204	DAKAR	720222	CAPE TOWN

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
a2673	USA	R/V ATLANTIS II	CRUISE 67, LEG 3	720227	CAPE TOWN	720320	CAPE TOWN
a2674	USA	R/V ATLANTIS II	CRUISE 67, LEG 4	720324	CAPE TOWN	720408	WALVIS BAY
a2675	USA	R/V ATLANTIS II	CRUISE 67, LEG 5	720412	WALVIS BAY	720506	WALVIS BAY
a2932	USA	R/V ATLANTIS II	CRUISE 93, LEG 2	751119	RECIFE	751217	CAPE TOWN
a2933	USA	R/V ATLANTIS II	CRUISE 93, LEG 3	751222	CAPE TOWN	760108	CAPE TOWN
a2934	USA	R/V ATLANTIS II	CRUISE 93, LG 4	760113	CAPE TOWN	760208	CAPE TOWN
a2935	USA	R/V ATLANTIS II	TRIPLE JUNC	760213	DURBAN	760308	MAURITIUS
a9310	USA	R/V ATLANTIS II	N/A	760701	MOMBASA	760720	MAURITIUS
ch994	USA	R/V CHAIN	N/A	700612	LUANDA	700702	MOZAMBIQUE
cn152	USA	R/V CHAIN	CRUISE 115,LG 2	731214	DAKAR	740110	CAPE TOWN
cn153	USA	R/V CHAIN	CRUISE 115,LG 3	740114	CAPE TOWN	740211	CAPE TOWN
cn154	USA	R/V CHAIN	CRUISE 115,LG 4	740215	CAPE TOWN	740315	CAPE TOWN
cn155	USA	R/V CHAIN	CRUISE 115,LG 5	740323	CAPE TOWN	740417	RIO DE JANEIR
gg125	USA	D/V GLOMAR CHALLENGER	DSDP LEG 25	720628	PT.LOUIS	720822	DURBAN
gg126	USA	D/V GLOMAR CHALLENGER	DSDP LEG 26	720906	DURBAN	721029	PERTH
gg139	USA	D/V GLOMAR CHALLENGER	DSDP LEG 39	741006	AMSTERDAM	741217	CAPE TOWN
gg140	USA	D/V GLOMAR CHALLENGER	DSDP LEG 40	741220	CAPE TOWN	750215	ABIDJAN
gg173	USA	D/V GLOMAR CHALLENGER	DSDP LEG 73	800413	SANTOS	800601	CAPE TOWN
gg174	USA	D/V GLOMAR CHALLENGER	DSDP LEG74	800606	CAPE TOWN	800724	WALVIS BAY
c0801	USA	R/V ROBERT D. CONRAD	N/A	631126	SAN JUAN	631229	CAPE TOWN
c0802	USA	R/V ROBERT D. CONRAD	N/A	640105	CAPE TOWN	640202	PERTH
c1103	USA	R/V ROBERT D. CONRAD	CRUISE 11, LG 3	670131	BUENOS AIRES	670227	CAPE TOWN
c1104	USA	R/V ROBERT D. CONRAD	N/A	670302	CAPE TOWN	670403	MAURITIUS
c1105	USA	R/V ROBERT D. CONRAD	N/A	670406	MAURITIUS	670506	PERTH
c1214	USA	R/V ROBERT D. CONRAD	CRUISE 12, LG 14	690202	BUENOS AIRES	690303	CAPE TOWN
c1215	USA	R/V ROBERT D. CONRAD	N/A	690331	CAPE TOWN	690505	COLOMBO
c1313	USA	R/V ROBERT D. CONRAD	N/A	701003	CAPE TOWN	701104	CAPE TOWN
c1314	USA	R/V ROBERT D. CONRAD	N/A	701209	CAPE TOWN	710111	CAPE TOWN
c1401	USA	R/V ROBERT D. CONRAD	N/A	710117	CAPE TOWN	710228	MAURITIUS
c1703	USA	R/V ROBERT D. CONRAD	N/A	731203	ABIDJAN	731231	CAPE TOWN
c1704	USA	R/V ROBERT D. CONRAD	N/A	740105	CAPE TOWN	740219	CAPE TOWN
c1705	USA	R/V ROBERT D. CONRAD	N/A	740225	CAPE TOWN	740411	PT.ELIZABETH
c1706	USA	R/V ROBERT D. CONRAD	N/A	740417	PT.ELIZABETH	740514	MAURITIUS
c2709	USA	R/V ROBERT D. CONRAD	N/A	861002	MAURITIUS	861105	CAPE TOWN
c2710	USA	R/V ROBERT D. CONRAD	c2710	861114	CAPE TOWN	861130	CAPE TOWN
c2711	USA	R/V ROBERT D. CONRAD	c2711	861203	CAPE TOWN	870102	RIO DE JANEIR
eel46	USA	R/V ELTANIN	CRUISE 046	701120	FREMANTLE	710119	FREMANTLE
eel47	USA	R/V ELTANIN	CRUISE 047	710203	FREMANTLE	710412	MELBOURNE
eel48	USA	R/V ELTANIN	CRUISE 048	710628	NEWCASTLE	710819	FREMANTLE
eel54	USA	R/V ELTANIN	CRUISE 054	720620	FREMANTLE	720729	FREMANTLE
e9307	USA	R/V EWING	N/A	931006	RIO DE JANEIRO	931021	CAPE TOWN
e9308	USA	R/V EWING	N/A	931024	CAPE TOWN	931111	CAPE TOWN
lus2h	USA	R/V HORIZON	LUSIAD LEG 2	621031	PT.LOUIS	621128	FREMANTLE
save3	USA	R/V KNORR	N/A	880129	RIO DE JANEIRO	880307	ABIDJAN
ant07	USA	R/V MELVILLE	ANTIPODE	701127	MAURITIUS	701216	MAURITIUS
inm05	USA	R/V MELVILLE	INDOMED LEG 5	780128	PT.LOUIS	780225	FREMANTLE
inm08	USA	R/V MELVILLE	INDOMED LEG 8	780429	PT.LOUIS	780528	PT.LOUIS
vlcn5	USA	R/V MELVILLE	VULCAN LEG 5	801202	VALPARAISO	810111	PUNTA ARENA
prt04	USA	R/V MELVILLE	PROTEA LEG 4	831104	PUNTA ARENAS	831213	CAPE TOWN
prt05	USA	R/V MELVILLE	PROTEA LEG 5	840114	CAPE TOWN	840215	CAPE TOWN

CRUISE ID	COUNTRY	SHIP	EXPEDITION	START DATE (yymmdd)	START PORT	END DATE (yymmdd)	END PORT
hydr2	USA	R/V MELVILLE	HYDROS LEG 2	881207	PUNTA ARENAS	890115	CAPE TOWN
hydr3	USA	R/V MELVILLE	HYDROS LEG 3	890123	CAPE TOWN	890308	MONTEVIDEO
fm014	USA	R/V FRED H. MOORE	N/A	790516	WALVIS BAY	790611	CAPE TOWN
fm015	USA	R/V FRED H. MOORE	N/A	790618	CAPE TOWN	790716	RIO DE JANEIRO
i1176	USA	R/V ELTANIN/ORCADAS	I1176	761029	BUENOAIRES	761219	CAPE TOWN
i1277	USA	R/V ORCADAS	N/A	770104	CAPE TOWN	770302	BUENOS AIRES
i1578	USA	R/V ORCADAS	N/A	80118	BUENOS AIRES	780310	BUENOS AIRES
jr113	USA	D/V JOIDES RESOLUTION	ODP	870105	PUNTA ARENAS	870311	EAST COVE
jr114	USA	D/V JOIDES RESOLUTION	ODP	870314	EAST COVE	870514	PT.LOUIS
jr118	USA	D/V JOIDES RESOLUTION	ODP	871022	PT.LOUIS	871214	PT.LOUIS
jr119	USA	D/V JOIDES RESOLUTION	ODP	871218	PT.LOUIS	880221	FREMANTLE
jr120	USA	D/V JOIDES RESOLUTION	ODP	880226	FREMANTLE	880430	FREMANTLE
v1409	USA	R/V VEMA	N/A	580314	S SANDWICH	580407	CAPE TOWN
v1604	USA	R/V VEMA	N/A	591122	MAURITIUS	591221	CAPE TOWN
v1605	USA	R/V VEMA	N/A	591227	CAPE TOWN	600122	MAURITIUS
v1606	USA	R/V VEMA	N/A	600125	MAURITIUS	600222	PERTH
v1809	USA	R/V VEMA	CRUISE 18,LG 9	620509	BUENOS AIRES	620531	CAPE TOWN
v1810	USA	R/V VEMA	CRUISE 18,LG 10	620603	CAPE TOWN	620620	PT.LOUIS
v1911	USA	R/V VEMA	CRUISE 19,LG 11	630828	MOMBASA	630916	CAPE TOWN
v1912	USA	R/V VEMA	CRUISE 19,LG 12	630920	CAPE TOWN	631024	ABIDJAN
v2010	USA	R/V VEMA	CRUISE 20,LG 10	640921	PT.LOUIS	641009	CAPE TOWN
v2011	USA	R/V VEMA	CRUISE 20,LG 11	641014	CAPE TOWN	641107	RECIFE
v2204	USA	R/V VEMA	CRUISE 22,LG 4	660316	BUENOS AIRES	660412	CAPE TOWN
v2205	USA	R/V VEMA	CRUISE 22,LG 5	660416	CAPE TOWN	660425	CAPE TOWN
v2206	USA	R/V VEMA	CRUISE 22,LG 6	660426	CAPE TOWN	660428	DAKAR
v2411	USA	R/V VEMA	CRUISE 24,LG 11	670921	PT.LOUIS	671011	CAPE TOWN
v2412	USA	R/V VEMA	CRUISE 24,LG 12	671016	CAPE TOWN	671114	RIO DE JANEIRO
v2710	USA	R/V VEMA	CRUISE 27,LG 10	700102	RECIFE	700130	CAPE TOWN
v2711	USA	R/V VEMA	CRUISE 27,LG 11	700206	CAPE TOWN	700210	CAPE TOWN
v2712	USA	R/V VEMA	CRUISE 27,LG 12	700213	CAPE TOWN	700312	ABIJAN
v2903	USA	R/V VEMA	CRUISE 29,LG 03	720120	PT.LOUIS	720214	PT.LOUIS
v2904	USA	R/V VEMA	CRUISE 29,LG 04	720218	PT.LOUIS	720316	CAPE TOWN
v2905	USA	R/V VEMA	CRUISE 29,LG 05	720321	CAPE TOWN	720416	CAPE TOWN
v2906	USA	R/V VEMA	CRUISE 29,LG 06	720421	CAPE TOWN	720518	LUANDA
v3409	USA	R/V VEMA	CR V34,LG 09	771102	PT.VICTORIA	771206	PT.LOUIS
v3410	USA	R/V VEMA	CRV34,LG 10	771210	PT.LOUIS	771229	CAPE TOWN
v3411	USA	R/V VEMA	CR V34,LG 11	780104	CAPE TOWN	780131	CAPE TOWN
v3501	USA	R/V VEMA	CR V35,LG 01	780218	CAPE TOWN	780305	PT.VICTORIA
v3619	USA	R/V VEMA	N/A	801220	MOMBASA	810114	PT ELIZABETH
v3620	USA	R/V VEMA	CRUISE 36,LG 20	810119	DURBAN	810210	CAPE VERDE IS
mrt10	USA	R/V T.WASHINGTON	LG10	841215	RIO DE JANEIRO	850116	CAPE TOWN
mrt13	USA	R/V T.WASHINGTON	LG13	850401	CAPE TOWN	850501	RECIFE

APPENDIX IV : THE MAGNETIC ANOMALY PICKS

IV.1 The Magnetic Anomaly Picks:

The magnetic anomaly picks were chosen from charts containing the magnetic profiles plotted perpendicular to track. From the Kent & Gradstein (1986) magnetic reversal time scale, Marc Munschy (EOST) and Jean-Yves Royer (GEMCO, Villefranche-sur-mer) selected either the beginning or the end of a magnetic reversal approximately 5 million years apart. Picks were chosen by Steve Cande and John Sclater at SIO and by Marc Munschy at EOST, after which both sets were compared and a final, consistent set of magnetic anomaly picks was created.

IV.2 The Magnetic Reversals

34 magnetic reversal at an interval of approximately 5 million years, except during the Cretaceous "quiet zone", were selected from the the Jurassic to Recent chronolgy of Kent and Gradstein (1986) (Table 2).

IV.3 The Magnetic Anomaly Picks

We constructed synthetic magnetic anomaly profiles for the various spreading sections within the Southwest Indian Ocean. We picked the anomalies by direct comparison of the residual magnetic anomaly profiles with the synthetics.

All the anomalies were picked directly from the actual profiles except for 11 through 34 in the far southwest corner of the area which were digitized from Livermore and Woollett (1993). We also digitized four "M series" anomalies from Roeser et al. (1990) off the coast of Enderby Land.

IV.4 Superimposing the magnetic anomaly picks on the Profiles-at-Right -Angles-to-Track (Figure 3c):

The routines used to superimpose the anomaly picks on the profiles at right angles to track are given below

- Add the anomaly number to the anomaly picks as text file

- Add the position of the picks using the "psxy" command and the number using the "pstext" command from the GMT package.

APPENDIX V : COLORED SATELLITE-DERIVED GRAVITY CHARTS

V.1 The Global Marine Gravity Database :

We used the global gravity image of Smith and Sandwell (1995) as the source for the gravity charts for IODCP. The gravity data are available via anonymous FTP from site /baltica/ftp in directory /pub/global_grav/.world_grav.img.7.2.

V.2 The Construction of the Colored Gridded Satellite-Derived Gravity Plots:

The routines for the construction of the gravity chart for sector 7 (Figure 3d) are presented below.

- Extract the gravity data:using the "img2latlongrid" command available in the latest version of the GMT package.

- Create the gravity image using the GMT command "grdimage"

APPENDIX VI : THE TECTONIC CHART

VI.1 Construction of the Tectonic Chart:

Once the bathymetric chart, the magnetic anomalies perpendicular to track, the identified magnetic anomaly picks chart and the gridded gravity chart were completed a tectonic chart was created using the following steps:

VI.1.1 Determining the position of the active plate boundaries (ie spreading centers and transform faults):

Overlay the topography, magnetics anomaly chart with picks and the gridded colored gravity with earthquakes superimposed. Utilizing the magnetic anomaly picks, and, the lows in the topography and gravity, determine the position of the spreading center on an overlay sheet.

VI.1.2 Determining the position of the fracture zones and any other linear tectonic features:

Overlay the gravity onto the topography and draw in the linear features. These include the transform faults, fracture zones (distinct and not so distinct) and arguable extinct spreading centers. For the fracture zones and transform faults the minimum in the gravity was chosen as the trace of the fault.

VI.1.3 The position of the 2000 m and 4000 m contours:

Reduce R. L. Fisher's hand-drawn bathymetric charts by 50% and digitize the 2000 m and 4000 m contour.

VI.1.4 Use the following color scheme for the tectonic data:

Ridge Axis:	Black	
Transform Faults:	Turquoise	
Fracture Zone(fz1):	Blue	(distinct)
(fz2):	Green	(less distinct)
(fz3):	Orange	(other linear features)
Extinct Spreading centers	Purple	
Magnetic Anomalies:	Red circles	
Bathymetry:	Black lines	

VI.2 Data Storage:

Once digitized, the compiled data was then stored according to data type by sector and then the sectors were combined into one file gebSW_XXX where XXX designates the data type.

VI.2.1 The bathymetric data:

The contoured bathymetric data was digitized from R.L. Fisher's hand-drawn interpretations prepared at S.I.O. From these contours, the 2000 m and 4000 m lines were chosen since they delineate best the broad swells and aseismic ridges in the Indian Ocean. The 2000 m and 4000 m contours were stored by sector.

VI.2.2 The fracture zone data:

The fracture zone data were divided into three different categories; obvious fracture zones, less obvious fracture zones, and other linear tectonic elements. Gravity contour charts and colored gridded gravity charts were constructed. The obvious fracture zones were located using the minimum in the gravity contours. The less obvious fracture zones were delineated from trends observed on the colored gravity charts. Other linear features that showed up on the colored gravity chart were also identified and digitized.

VI.2.3 The magnetic anomaly picks:

The magnetic anomaly data is discussed in APPENDIX IV : "THE MAGNETIC ANOMALY PICKS".

VI.2.4 The ridge axis and transform fault data:

The ridge axis and transform fault system was determined using a combination of the gravity, magnetics, bathymetry and earthquake epicenter data. The gravity, earthquake epicenters, and bathymetry all served to indicate the approximate vicinity of the spreading center providing a preliminary glimpse of the trends. The magnetics were then examined to determine the exact center of the spreading center along the entire length of the ridge axis.

VI.3 Generating the Tectonic Chart (Figure 3e):

To generate the tectonic chart with the listed color scheme, the following steps were taken:

- Change Data from Paleomap format to GMT format:

- Plot out the various sets of data using the "psxy" and "pstext" commands from the GMT package

ACKNOWLEDGMENTS

In the US NSF Grants #OCE 86-17193, #OCE 86-09137/#OCE 90-96287 and # OCE 86-19862 supported this work variously at the Institute for Geophysics at The University of Texas at Austin, the Scripps Institution of Oceanography and the Lamont-Doherty Earth Observatory. In France the "Ministere de l'Education Nationale, de l'Ensiegnemet Superieur et de la Recherche" action specifique, 1988, and DAGIC action Internationale, 1991; Centre Nationale de la Recherche Scientifique, Action initiative no 88Ng20052,1988 and no 91Ng0081,1991" supported l'École et Observatoire de Strasbourg. We also benefited from University of California at San Diego Senate grants RT 165S-Sclater 1993 and RV153-S/Sclater 1995 which provided funds to digitize the topographic contours.

David Sandwell provided the initial deflection-of-the-vertical charts for the IODCP. He also made available preliminary versions of the satellite-derived gravity field prior to their release.

At Scripps Institution of Oceanography, we would like to thank Jon Anderson for computer help that permitted this project to get underway. Sarah Greer started the digitization of the various data bases and Karen Walters digitized most of the topographic data west of 20°E. Chris Mahn digitized the tectonic charts and Margaret Imhof digitized the data from the publications of Hugh Bergh and tabulated the cruise tracks for the topographic and magnetic data.

At l'École et Observatoire des Sciences de la terre de Strasbourg (EOST) we would like to thank Marie-Odile Boulanger for maintaining and updating the data base, Monique Blanck and Jean Daniel Tissot with help in drawing the maps and developing the www server.

At the British Oceanographic Data Centre, Bidston Observatory, we would like to thank the National Environmental Research Council for support for this project.

We thank Andrew Goodwillie of SIO for reviewing an early version of this technical report.

REFERENCES

Anonymous (1995) "IHO-IOC Gazetteer of Geogrphical Names of Undersea features" B-8, International Hydrographic Bureau, Monaco, 122pp

Bergh, H. W. (1977). "Mesozoic Sea Floor off Dronning Maud Land, Antarctica." Nature 269: 686-687.

Bergh, H. W. (1987). "Underlying Fracture Zone Nature of Astrid Ridge off Antarctica's Queen Maud Land." Journal of Geophysical Research 92(B1): 475-484.

Bergh, H. W. and D. M. Barrett (1980). "Agulhas Basin Magnetic Bight." Nature 287: 591-595.

Bergh, H. W. and I. O. Norton (1976). "Prince Edward Fracture Zone and the Evolution of the Mozambique Basin." Journal of Geophysical Research 81(29): 5221-5239.

Falconer, R. H. K. and M. Tharp (1981). Sheet 5-14, General Bathymetric Chart of the Oceans. Ottawa, Canada, Canadian Hydrographic Service.

Fisher, R. L., M.Z. Jantsch and R.L. Comer (1982). Sheet 5-09, General Bathymetric Chart of the Oceans. Ottawa, Canada, Canadian Hydrographic Service.

Fisher, R. L. and J. G. Sclater (1983). "Tectonic Evolution of the Southwest Indian Ocean Since the Mid-Cretaceous: Plate Motions and Stability of the Pole Antarctica/Africa for at Least 80 Million Years." Geophysical Journal of the Royal Astronomical Society 73: 553-576.

Goslin, J., J. Ségoufin, R. Schlich and R.L. Fisher (1980). "Submarine Topography and Shallow Structure of the Madagascar Ridge, Western Indian Ocean." Geological Society of America Bulletin 91: 741-753.

Goslin, J., M. Recq and R. Schlich (1981). "Structure Profonde du Plateau de Madagascar: Relations avec le Plateau de Crozet." Tectonophysics : 75-97.

Haxby, W. F. (1985). "Gravity Field of the World's Oceans." Sponsored by the Office of Naval Research, United States Navy; Lamont-Doherty Geological Observatory, Palisades, New York.

Hayes, D. E. and M. Vogel (1981). Sheet 5-13, General Bathymetric Chart of the Oceans. Ottawa, Canada, Canadian Hydrographic Service.

Kent, D. V. and F. M. Gradstein (1986) A Jurassic to Recent Chronology. The Western North Atlantic Region. DNAG Volume. Geological Society of America. 45 - 50.

Livermore, R. A. and R. W. Woollett (1993). "Seafloor Spreading in the Weddell Sea and Southwest Atlantic since the Late Cretaceous." Earth and Planetary Sciences Letters 117: 475-495.

Matthews, D. H. (1975). "Magnetic Anomalies,." in The Geological-Geophysical Atlas of the Indian Ocean, G. B. Udintsev, Editor, Main Administration of Geodesy and Cartography, Academy of Sciences of the USSR, Moscow : 65-80.

Martin, A. K., S. W. Goodlad, C. J. H. Hartnady and A. du Plessis (1982). "Cretaeous Paleopositions of the Falkland Plateau Relative to Southern Africa using Mesozoic Seafloor Spreading Anomalies." Geophysical Journal of the Royal Astronomical Society 71: 567-579.

Monahan, D. F., R.H. K. and M. Tharp (1982). Sheet 5-10, General Bathymetric Chart of the Oceans (GEBCO). Ottawa, Canada, Canadian Hydrographic Service.

Müller, R. D., D.T. Sandwell, B. E. Tucholke, J. G. Sclater and P.R.Shaw (1991). "Depth to Basement and Geoid Expression of the Kane Fracture Zone: a Comparison." Marine Geophysical Researches 13: 105-129.

Patriat, P. (1983). Evolution du Système de Dorsales de l'Ocean Indien. Ph. D. Thesis. Université Pierre et Marie Curie, Paris.

Patriat, P., J. Ségoufin, J. Goslin and P. Beuzart (1985). "Relative Positions of Africa and Antarctica in the Upper Cretaceous for Non-stationary Behaviour of Fracture Zones." Earth and Planetary Letters 75: 204-214

Roeser, H. A., J. Fritsch, K. Hinz, P. Kewitsch, H. Meyer, U. Schradar and B. Schreckenberger (1990). "Geophysical Investigations on the Crustal Structure off East Antarctica between longitudes 0 and 40 E." Final Report PFS POLARSTERN ANT VIII/6, Bundesanstalt fur Geowissenschaften und Rohstoffe, Hanover : 83-92.

Royer, J.-Y., and K. Winn (1987). "Paleomap: A User's Guide." Paleoceonogrphic Mapping Project, Progress Report 38-1287, The Institute for Geophysics, The University of Texas at Austin, Austin, Tx.. : p18.

Royer, J.-Y., Ph. Patriat, H. W. Bergh and C. R. Scotese (1988). "Evolution of the Southwest Indian Ridge from the Late Cretaceous (Anomaly 34) to the Middle Eocene (Anomaly 20)." Tectonophysics 155: 235- 260.

Royer, J.-Y., J. W. Pierce and J. K.Weissel. (1991). Tectonic Constraints on Hotspot Formation of the Ninetyeast Ridge. Proceedings ODP Scientific Results 120. Ocean Drilling Program College Station, TX. 121-122.

Sandwell, D. T. (1984). "Along-track Deflection of the Vertical from Seasat: GEBCO Overlays." NOAA Tech. Memo. NOS NGS-40: 8 pp.

Sandwell, D. T. and W. Smith (1995). An Updated Gravity Map of the World. SIO Reference Series.

Schlich, R. (1975). "Structure et Age de l'Océan Indien Occidental." Mémoire hors série Societie de Géologie de France (6): 103.

Schlich, R. (1982). The Indian Ocean: Aseismic Ridges, Spreading Centers and Basins. The Indian Ocean. Edited by Nairn, A. E. and F. G. Stehli, New-York, Plenum Press. 51-147.

Sclater, J. G., U. Ritter, W. Hilton, L. Meinke and R. L. Fisher (1971). "Charts of Residual Magnetic Field Plotted along Track for the Indian Ocean." SIO Reference series 71-7: 2p, 36 Fig.

Sclater, J. G. and R. L. Fisher (1974). "Evolution of the East-Central Indian Ocean, with Emphasis on the Tectonic Setting of the Ninetyeast Ridge." Geological Society of America Bulletin 85: 683-702.

Sclater, J. G., R. L. Fisher, Ph. Patriat, C. Tapscott and B. Parsons (1981). "Eocene to Recent Development of the Southwest Indian Ridge, a Consequence of the Evolution of the Indian Ocean Triple Junction." Geophysical Journal of the Royal Astronomical Society 64: 587-604.

Smith, W. H. F. and D. T. Sandwell (1995). "Marine Gravity Field from Declassified GEOSAT and ERS-1 Altimetry." Eos Trans. 76 (46): 156.

Tapscott, C., Ph. Patriat, R. L. Fisher, J. G. Sclater, H. Hoskins and B. Parsons (1980). "The Indian Ocean Triple Junction." Journal Of Geophysical Research 85: 4723-4739.

Weissel, J. K. and D. E. Hayes (1972). Magnetic Anomalies in the Southeast Indian Ocean. Antarctic Oceanology II: The Australian-New Zealand Sector. 165-196.

Wessel, P. and W. H. F. Smith (1991). "Free Software Helps Map and Display Data,." Eos, Transactions, American Geophysical Union, 72, 441: 445-446.

TABLE 1

Maps at 1 : 5.000.000: Border

Sector	Northern Latitude	Southern Latitude	Western Longitude	Eastern Longitude
1	30°N	4°S	29°E	74°E
2	30°N	4°S	58°E	103°E
3	30°N	4°S	91°E	136°E
4	0°N	34°S	29°E	74°E
5	0°N	34°	58°E	103°E
6	0°N	34°	91°E	136°E
7	31°S	57°S	5°W	40°E
8	31°S	57°S	26°E	71°E
9	31°S	57°S	58°E	103°E
10	31°S	57°S	91°E	136°E
11	31°S	57°S	121°E	166°E
12	55°S	71°S	5°W	40°E
13	55°S	71°S	26°E	71°E
14	55°S	71°S	58°E	103°E
15	55°S	71°S	91°E	136°E
16	55°S	71°S	121°E	166°E

TABLE 2

Selected Magnetic Reversals
From Kent and Gradstein (1986)

REVERSAL AGE

Young	Old	Chron #	EOST #	Position
0.00	0.73	1	a1	old
5.35	5.53	3A	a11	yng
8.92	10.42	5	a20	old
16.22	16.52	5C	a33	yng
19.35	20.45	6	a39	old
25.67	25.97	7	a49	old
31.23	31.58	11	a57	yng
35.29	35.47	13	a60	yng
42.30	42.73	18	a72	old
44.66	46.17	20	a74	old
48.75	50.34	21	a75	old
51.95	52.62	22	a76	old
54.09	54.70	23	a78	old
55.66	56.14	24	a80	old
58.64	59.24	25	a81	yng
60.21	60.75	26	a82	old
63.03	63.54	27	a83	yng
65.50	66.17	29	a85	yng
68.52	69.40	31	a87	yng
71.37	71.65	32	a88	yng
74.30	80.17	33	a91	yng & old
84.00	118.00	34	a92	yng
118.70	121.81	M0	a93	yng
122.25	123.03	M1	a94	old
125.36	126.46	M3	a95	old
130.19	130.57	M10	a101	yng
131.65	132.53	M10N	a104	yng
137.10	137.39	M13	a111	old
139.58	141.20	M15	a113	old
148.33	149.42	M20	a120	yng
152.53	152.66	M22	a124	yng
156.55	156.70	M25	a132	yng

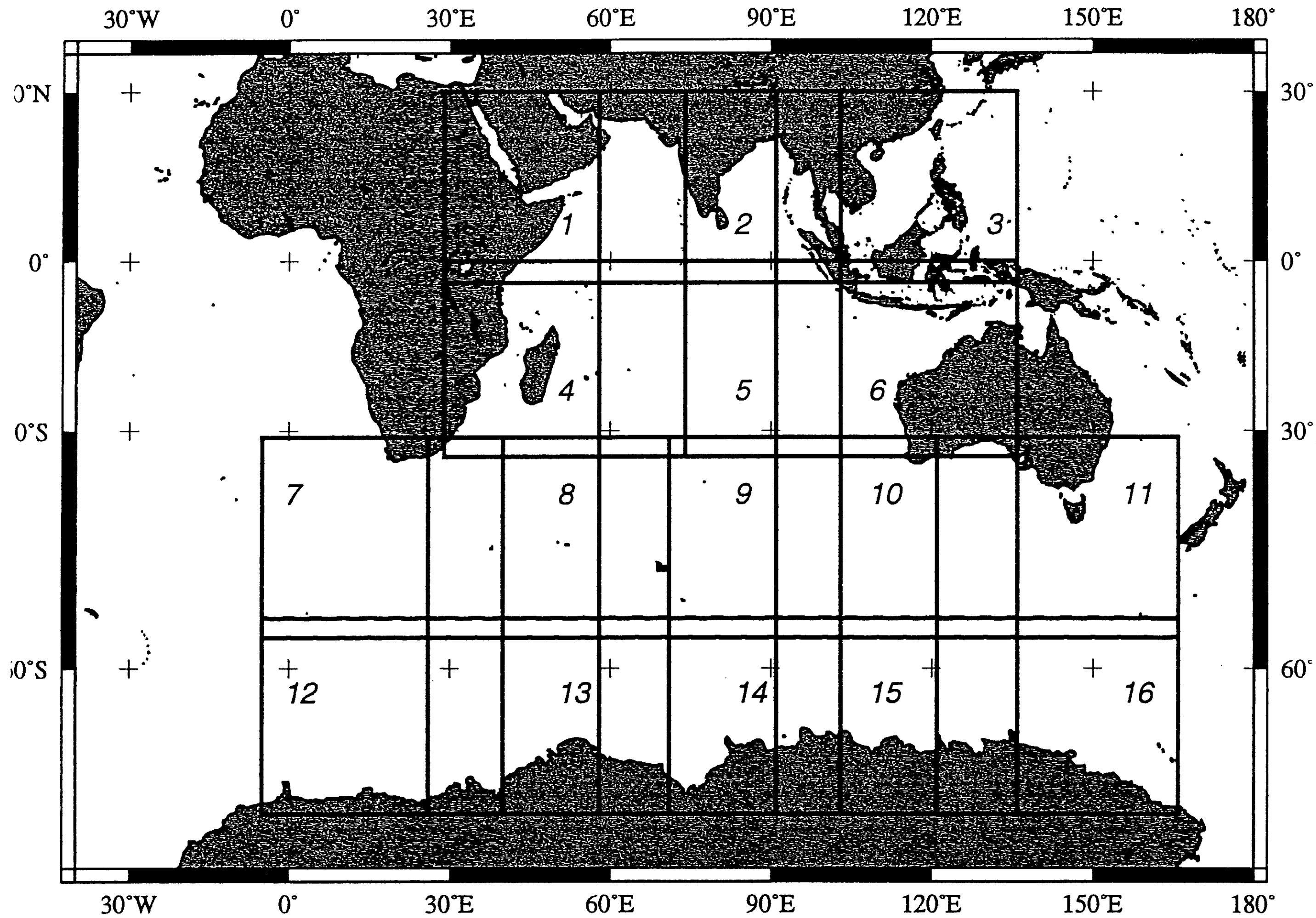


Figure 1: The sixteen sectors of the Indian Ocean for each of which a quintet of charts has been produced. The dimensions of each chart have been chosen so they will easily fit in a standard map case. The four southwestern sectors discussed in this report are bounded by:

Sector 7: 5 W to 40 E and 57 S to 31 S
Sector 8: 26 E to 71 E and 57 S to 31 S
Sector 12: 12 E to 40 E and 71 S to 55 S
Sector 13: 26 E to 71 E and 71 S to 55 S

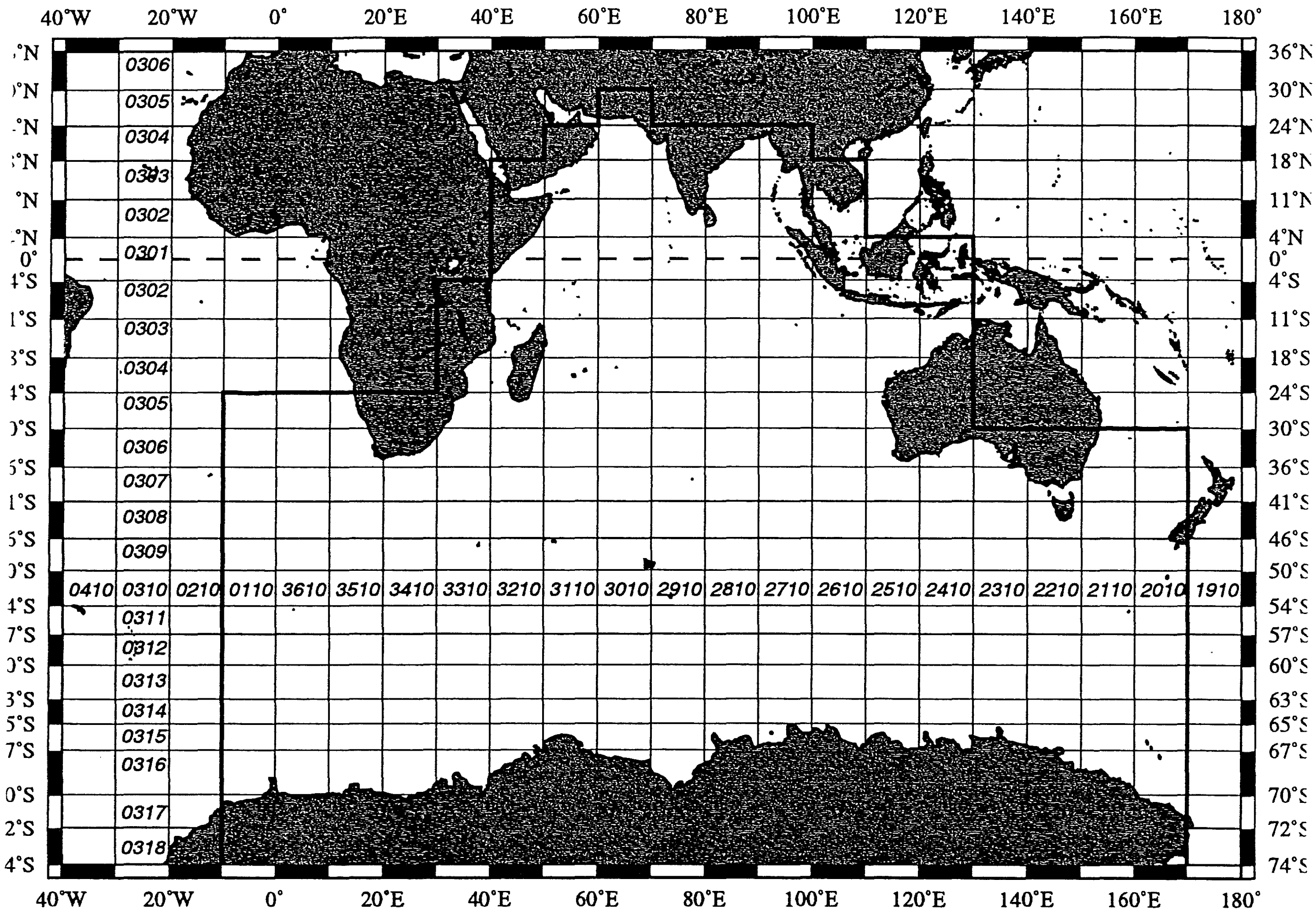


Figure 2: The light straight lines outline the dimensions of the individual (4 inch = 1 deg. longtitude at the equator) charts used in the compilation of the topographic data. The heavy lines indicate the boundary of the Indian and contiguous Southern Ocean. The numbers identify one north south column and one east west row of charts.

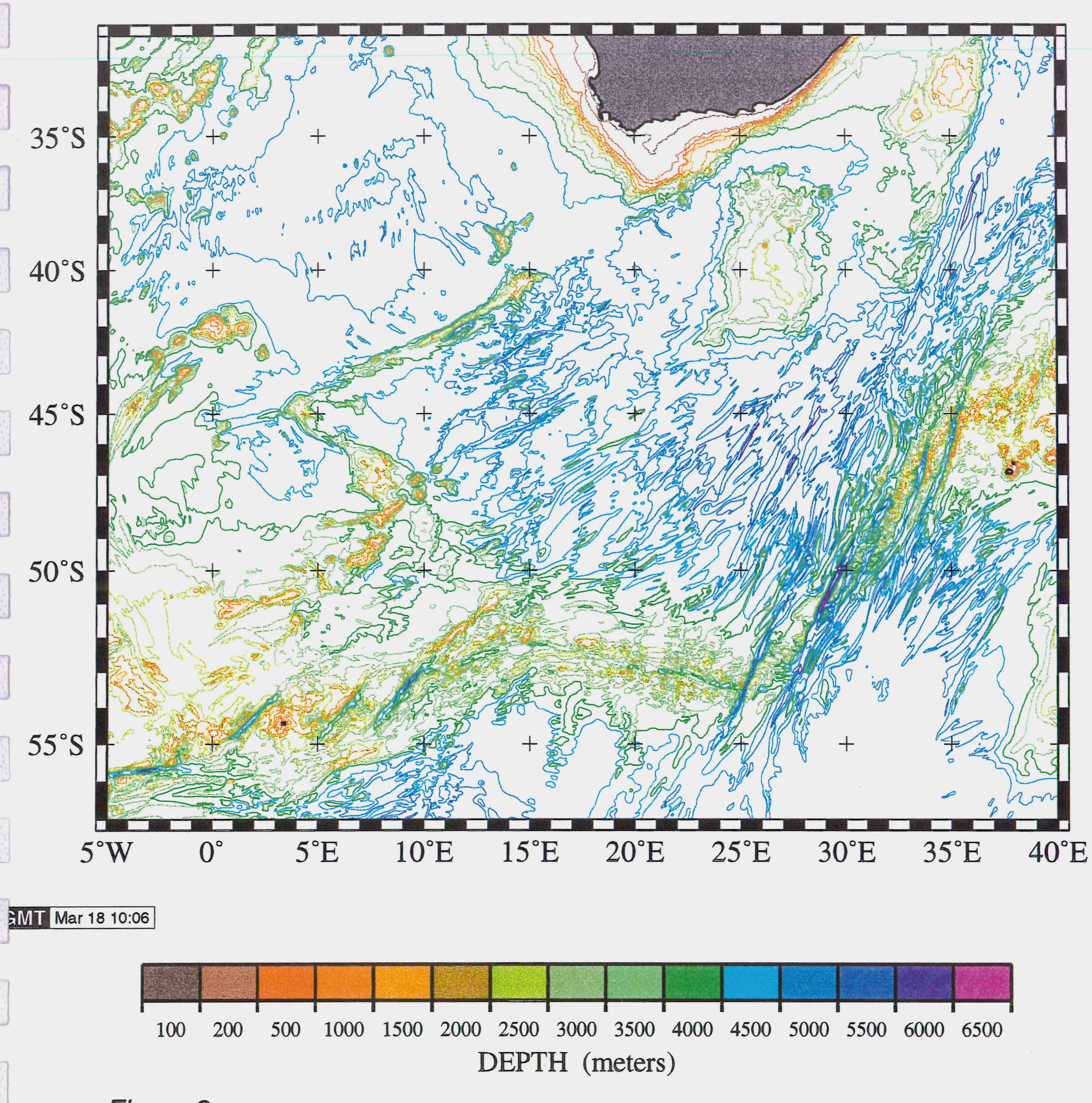


Figure 3a

Sector 7: a colored bathymetric contour chart (100, 200, 500 m and every 500 m thereafter to 6500 m). Contours available from "CD ROM GEBCO 97" (BODC).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

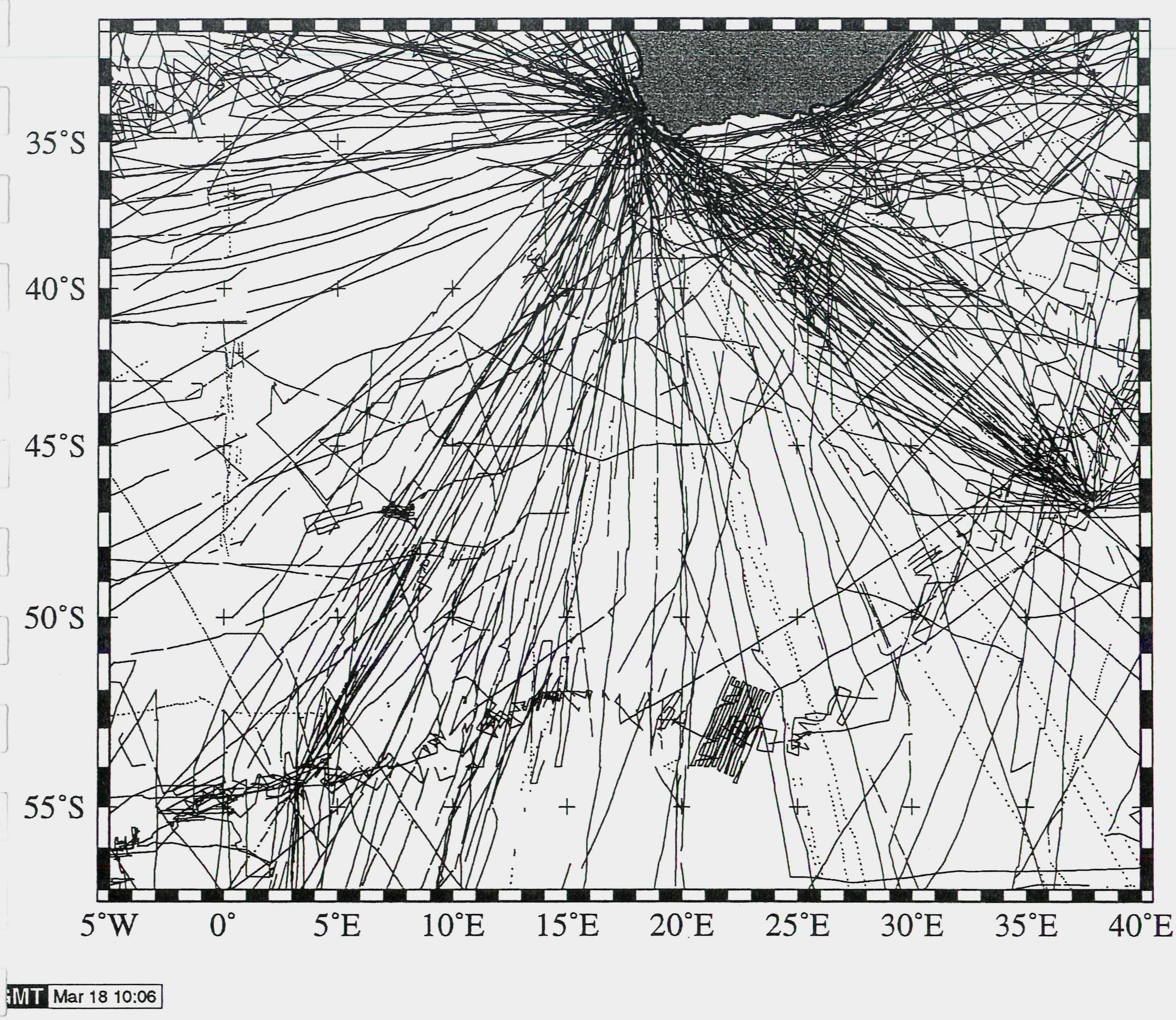


Figure 3b

Sector 7: tracks used in the compilation of the bathymetric data from "CD ROM GEBCO 97" (BODC).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

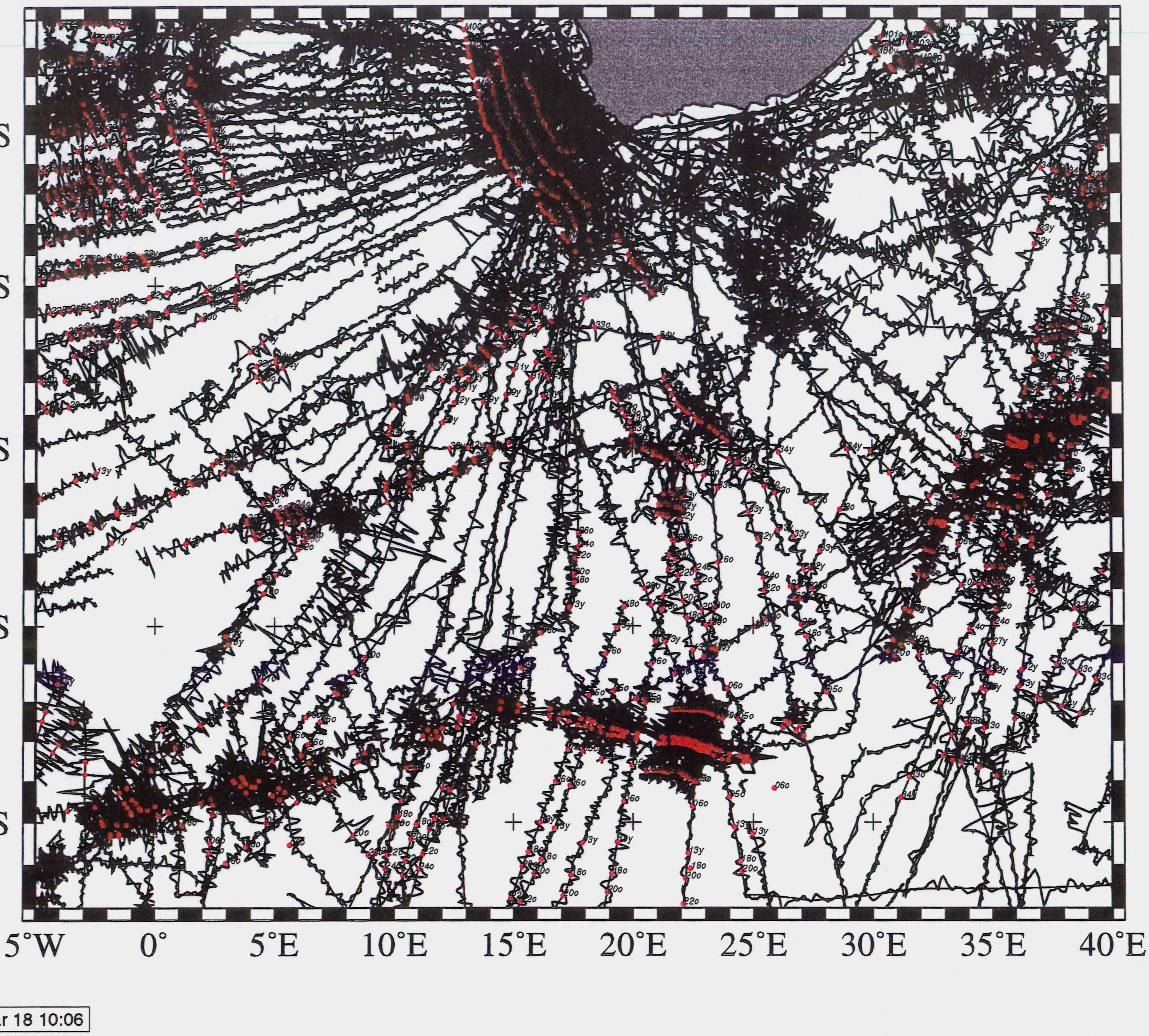


Figure 3c

Sector 7: magnetic anomalies at right angles to track at a scale of 7200 nT per inch with labeled anomaly picks (red dots, central anomaly not labeled). Data gaps of 20 km or more are shown.

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

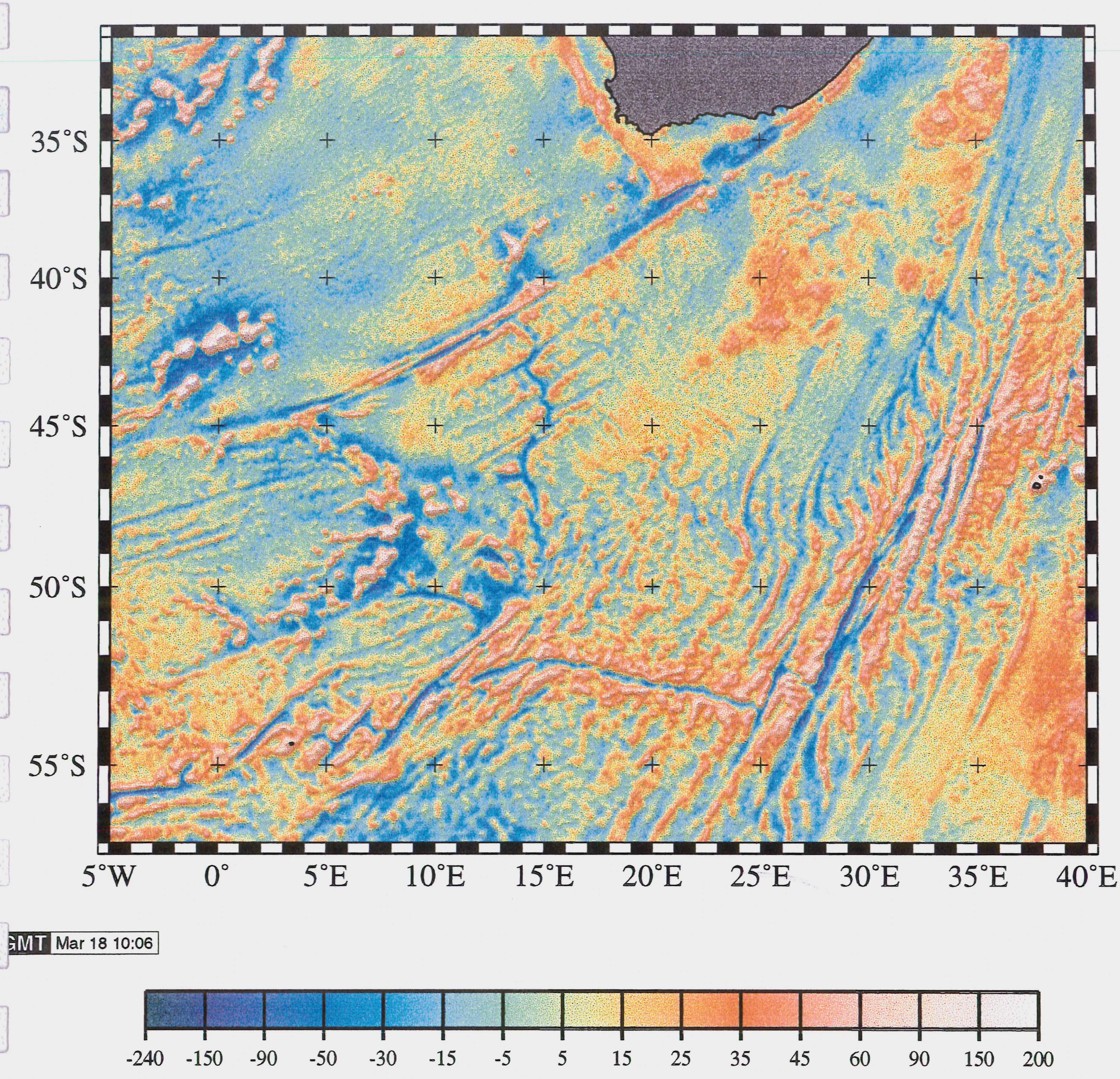


Figure 3d

Sector 7: colored chart of gridded satellite-derived free-air gravity anomalies (after Sandwell and Smith 1995).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

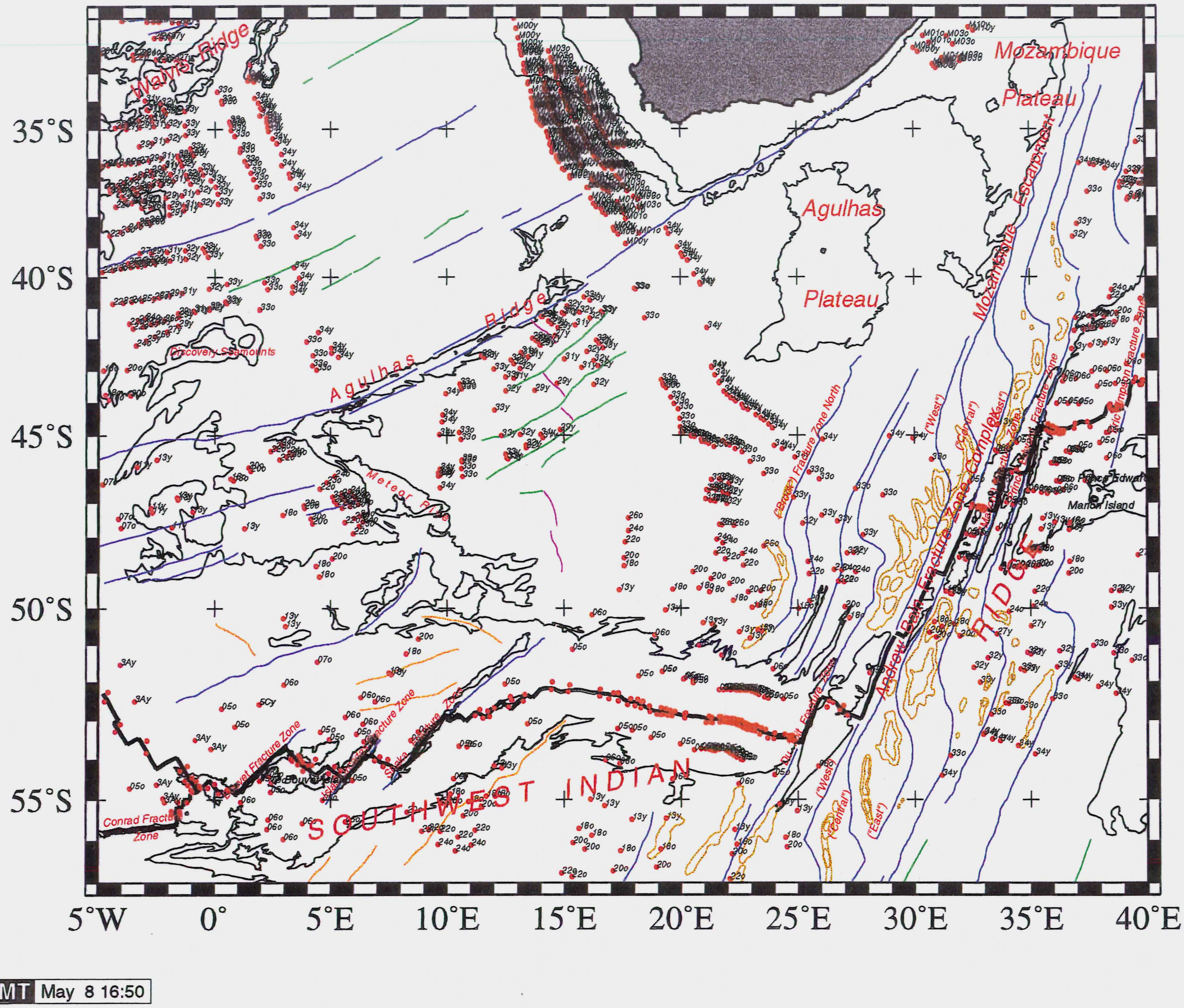


Figure 3e

Sector 7: a tectonic chart including the 2000 and 4000 m contours (black), selected 20 and 40 mgal gravity contours (brown), plate boundaries (thick black line), extinct spreading centers (purple), major and minor fracture zones (blue and green lines), linear features of unknown origin (buff lines) and magnetic anomaly picks (red dots, central anomaly not labeled).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

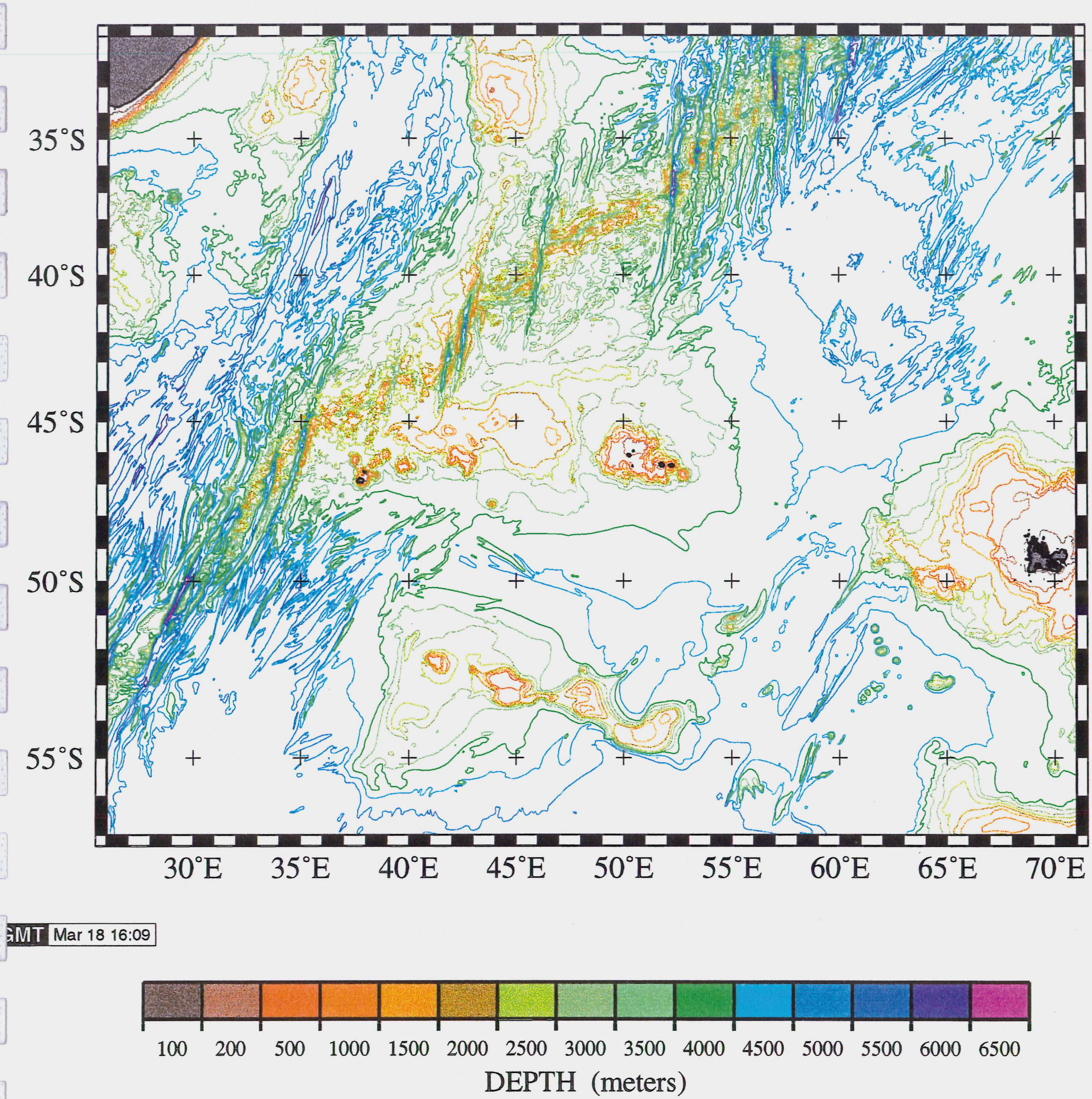


Figure 4a

Sector 8: a colored bathymetric contour chart (100, 200, 500 m and every 500 m thereafter to 6500 m). Contours available from "CD ROM GEBCO 97" (BODC).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

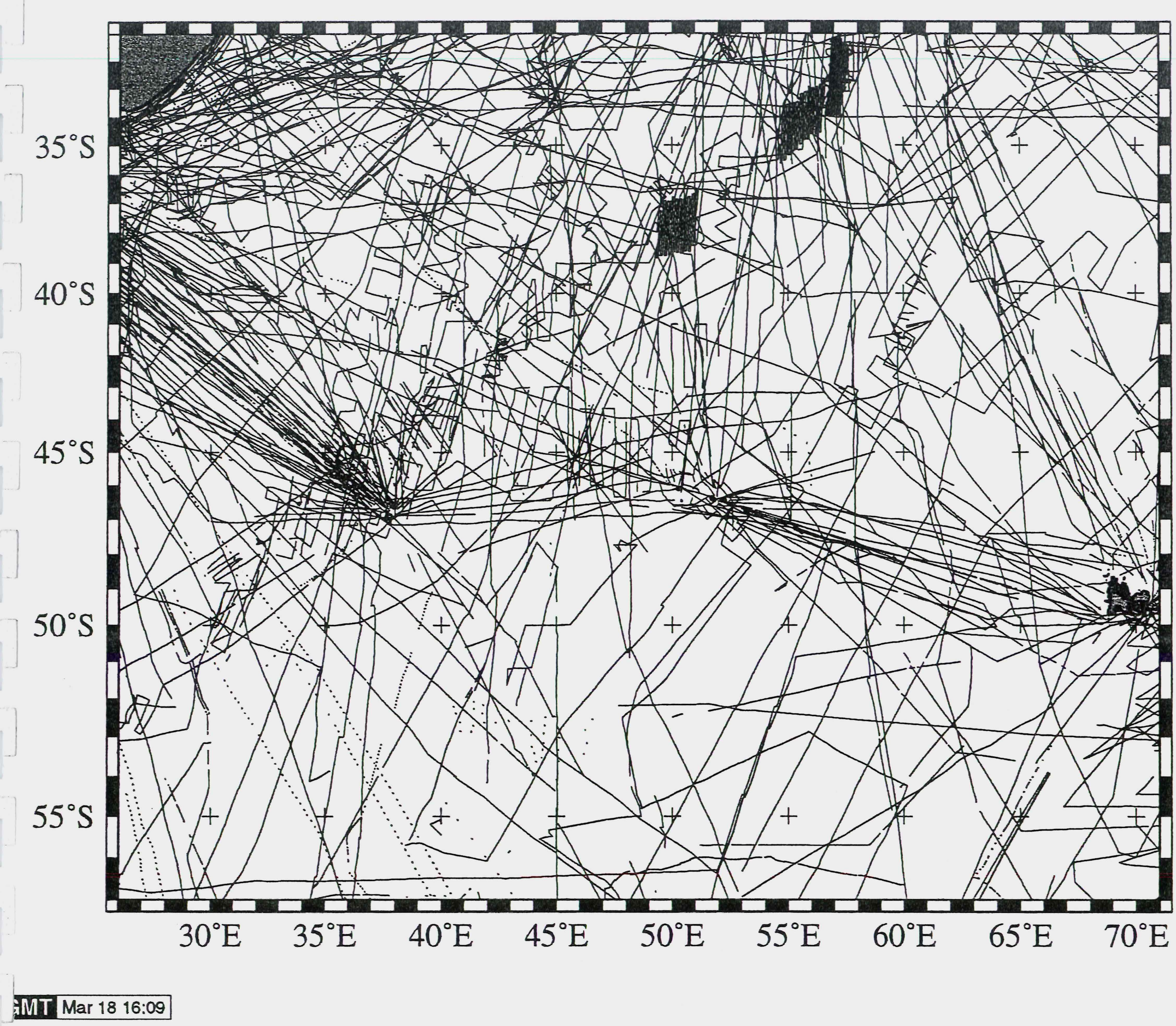
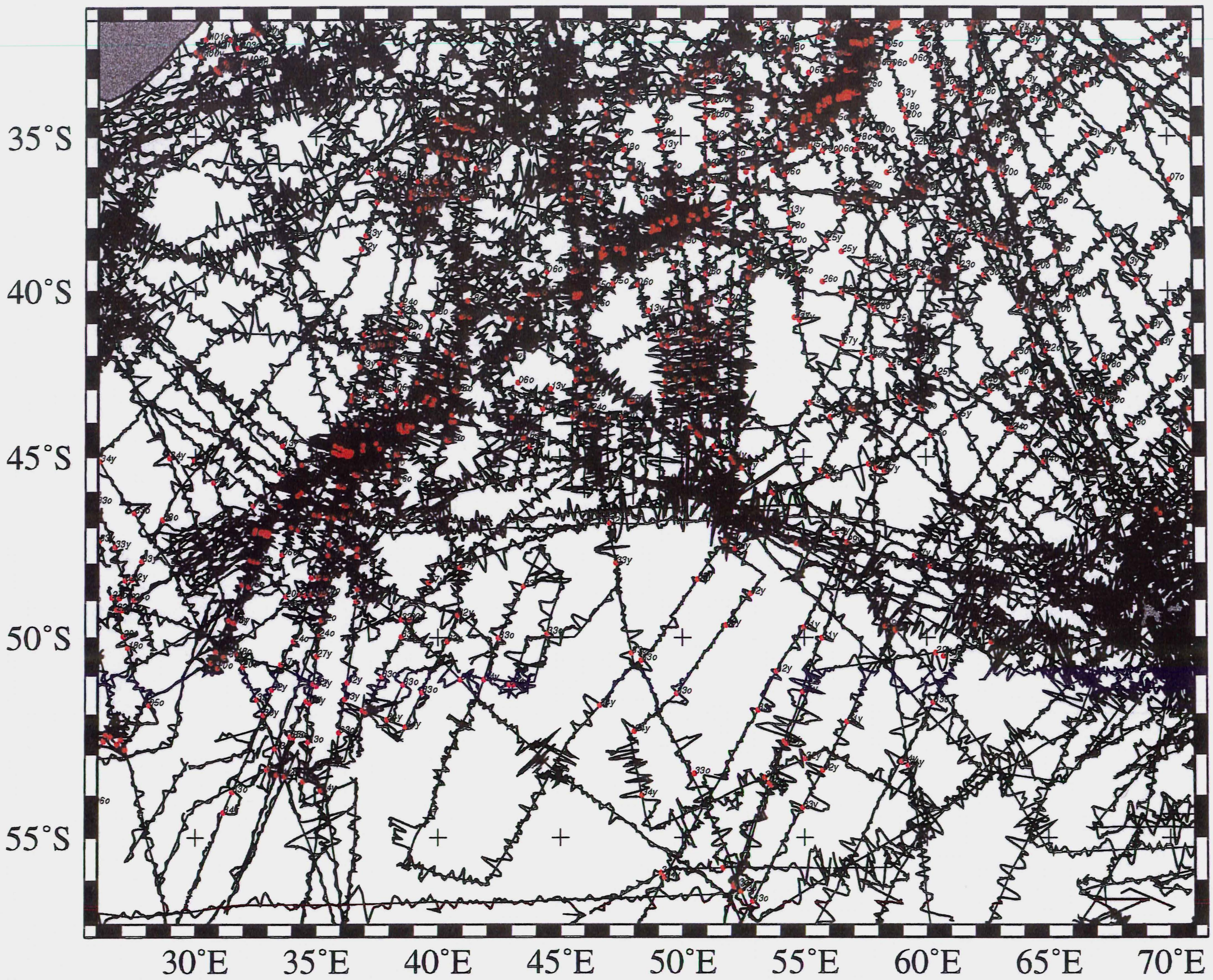


Figure 4b

Sector 8: tracks used in the compilation of the bathymetric data from "CD ROM GEBCO 97" (BODC).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.



GMT Mar 18 16:09

Figure 4c

Sector 8: magnetic anomalies at right angles to track at a scale of 7200 nT per inch with labeled anomaly picks (red dots, central anomaly not labeled). Data gaps of 20 km or more are shown.

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center *- see page 3 for details.*

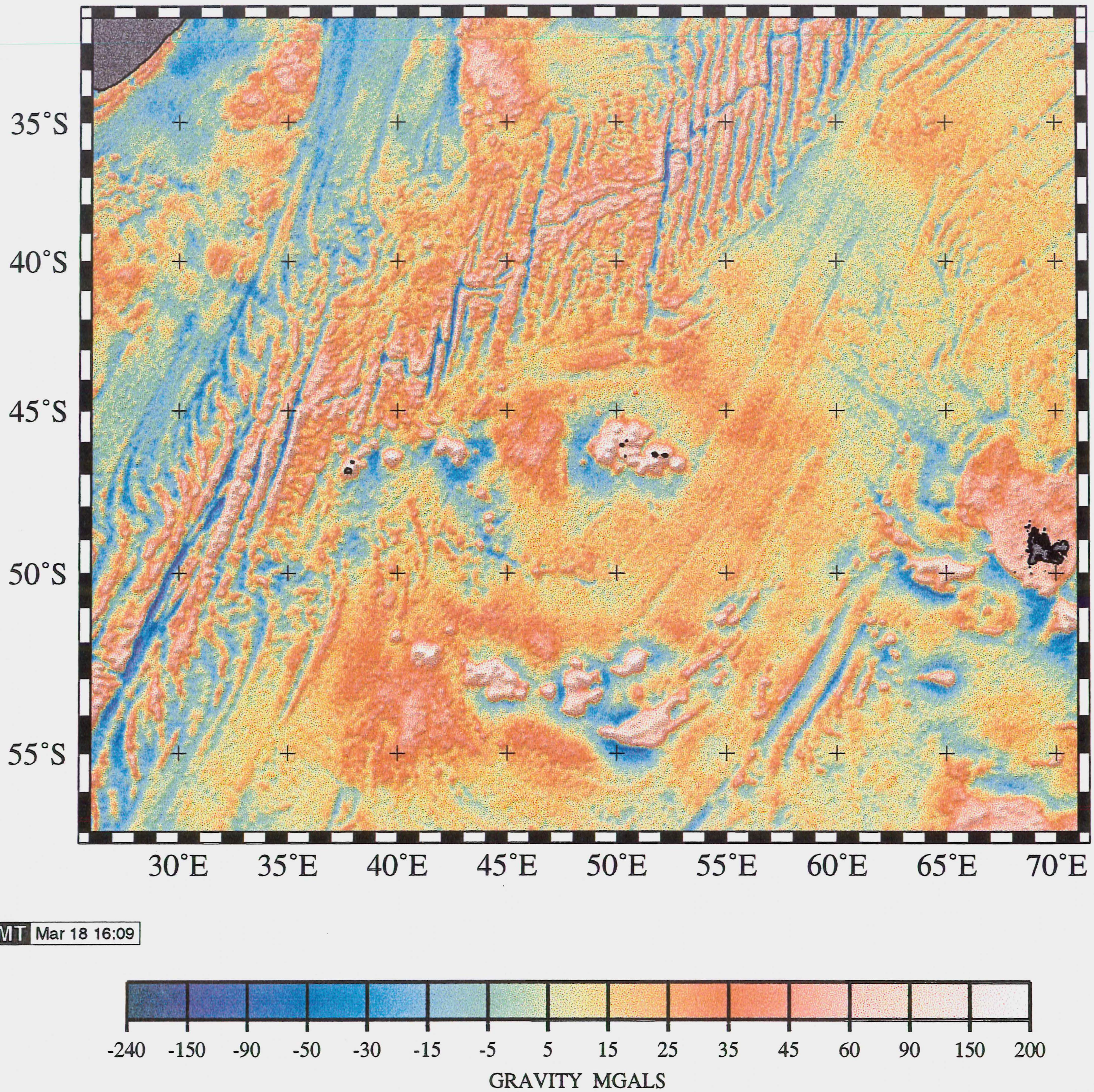


Figure 4d

Sector 8: colored chart of gridded satellite-derived free-air gravity anomalies (after Sandwell and Smith 1995).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

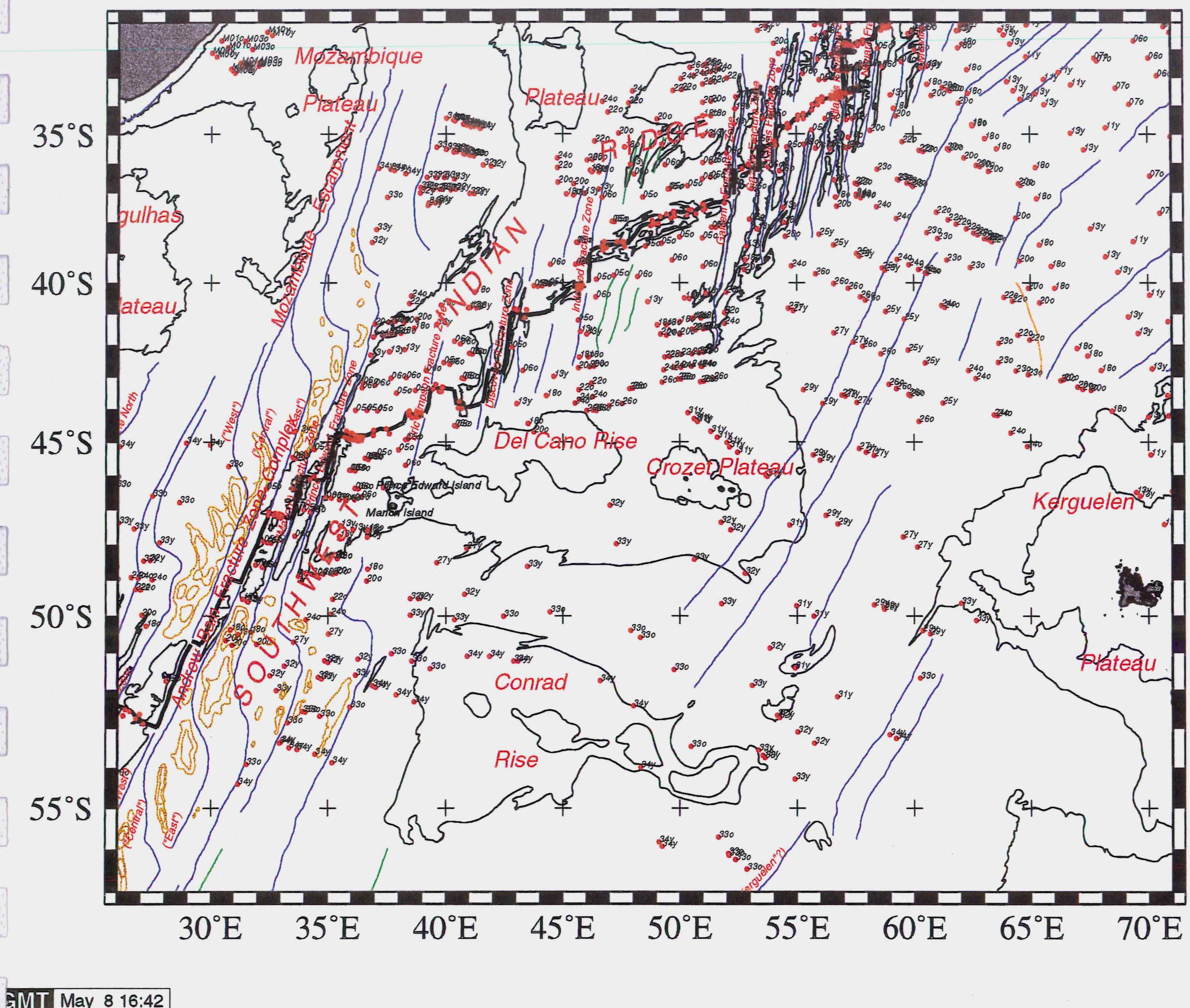


Figure 4e

Sector 8: a tectonic chart including the 2000 and 4000 m contours (black), selected 20 and 40 mgal gravity contours (brown), plate boundaries (thick black line), extinct spreading centers (purple), major and minor fracture zones (blue and green lines), linear features of unknown origin (buff lines) and magnetic anomaly picks (red dots, central anomaly not labeled).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

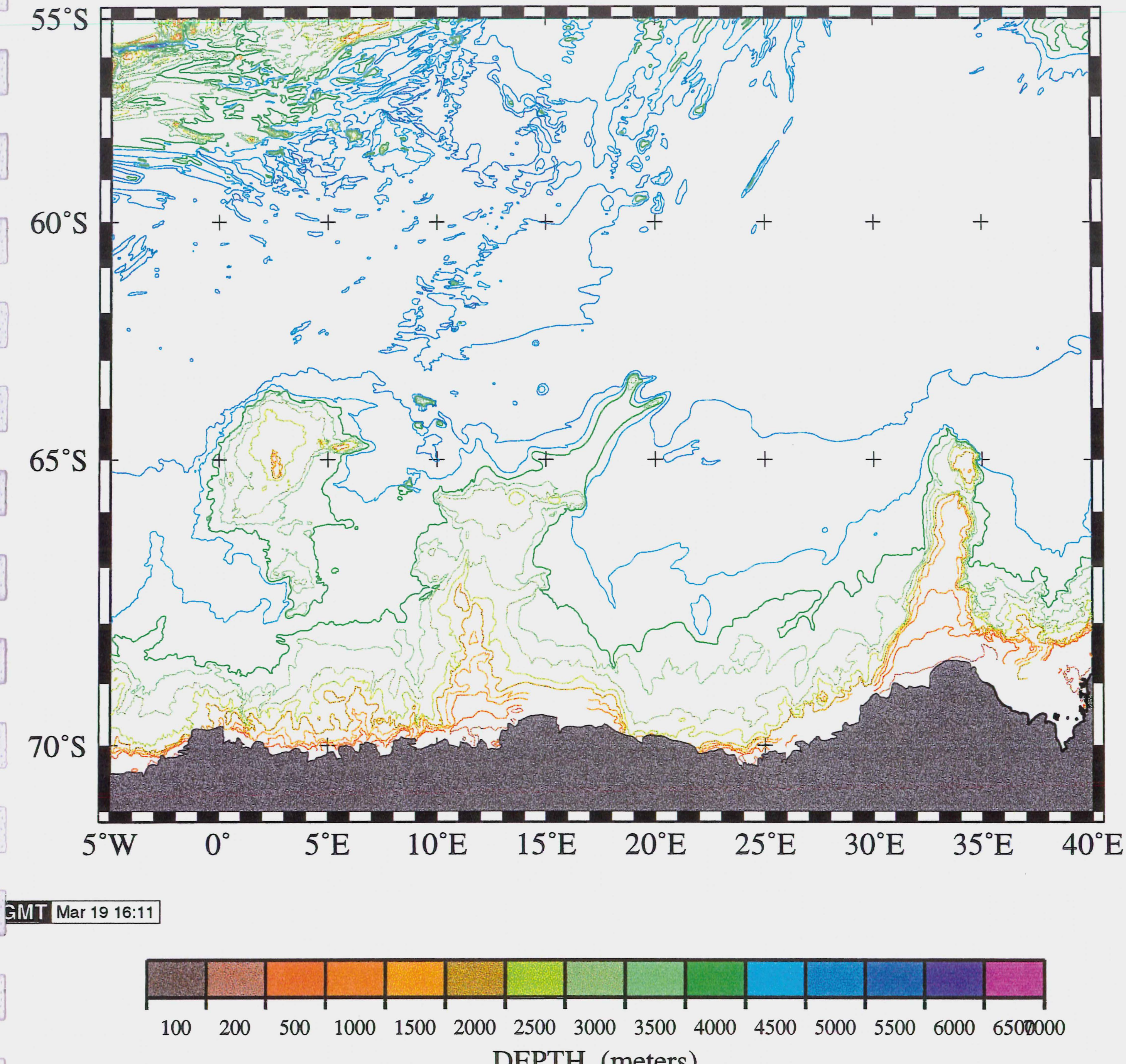


Figure 5a

Sector 12: *a colored bathymetric contour chart (100, 200, 500 m and every 500 m thereafter to 6500 m). Contours available from "CD ROM GEBCO 97" (BODC).*

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center *- see page 3 for details.*

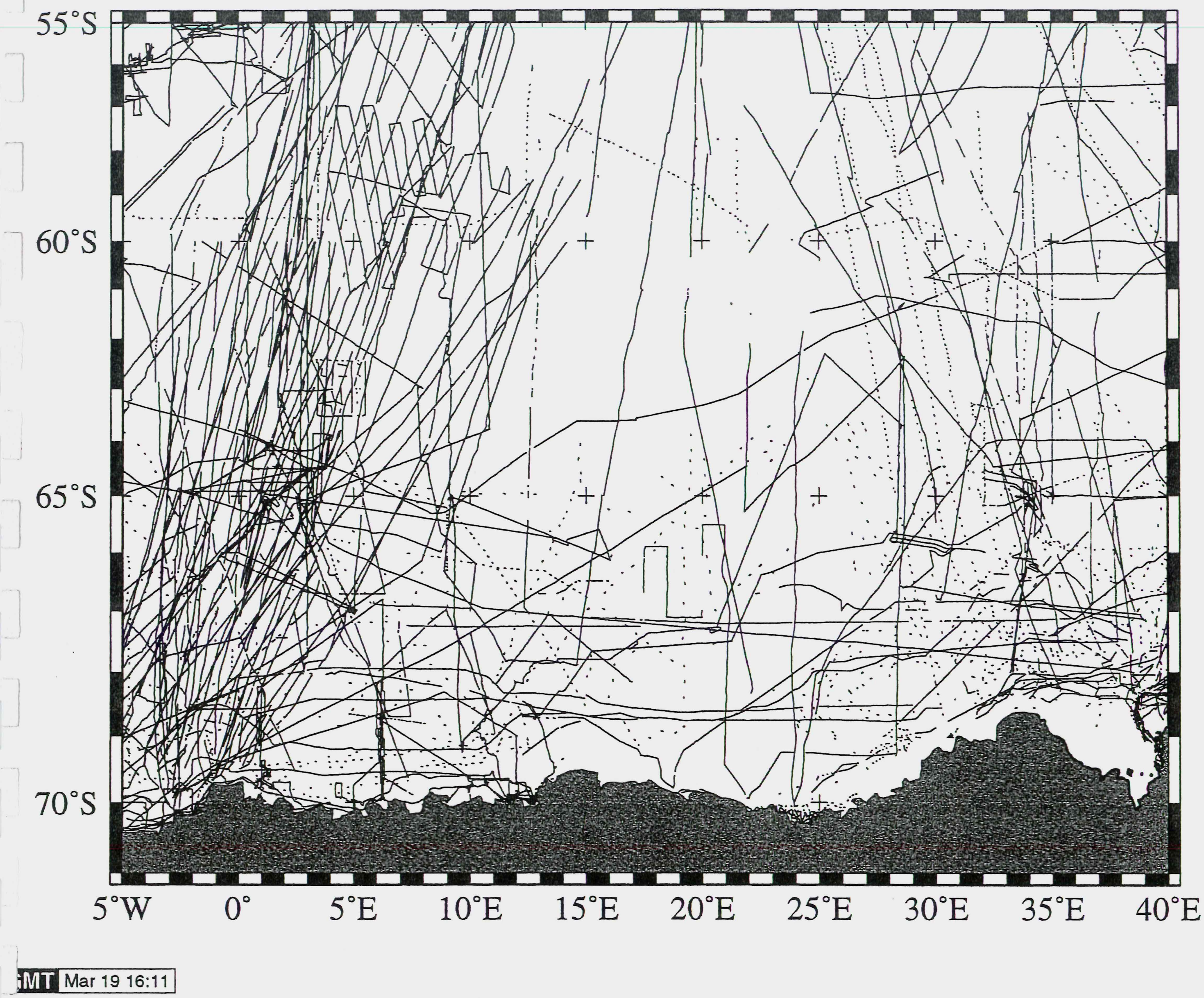


Figure 5b

Sector 12: tracks used in the compilation of the bathymetric data from "CD ROM GEBCO 97" (BODC).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center *- see page 3 for details.*

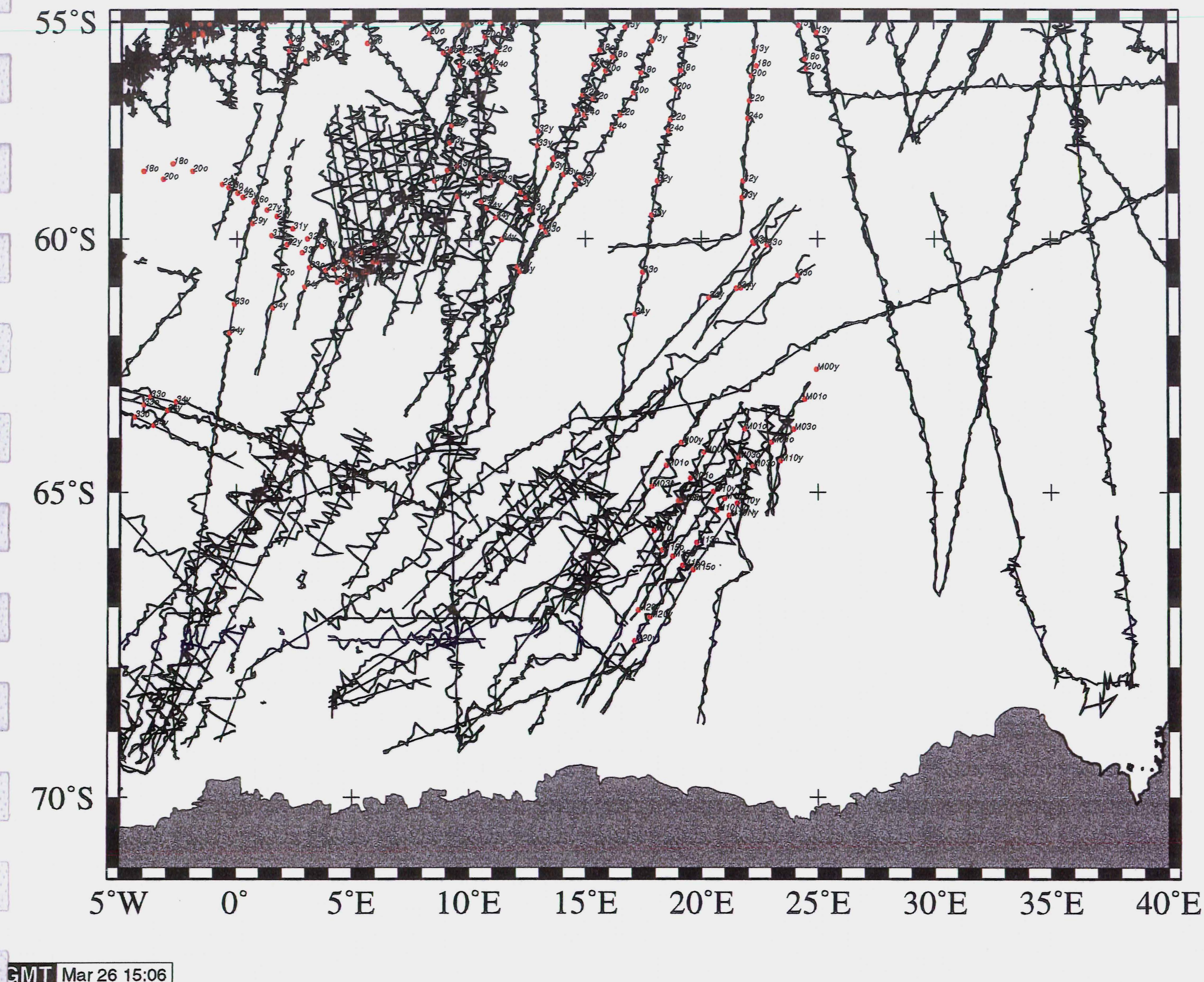


Figure 5c

Sector 12: *magnetic anomalies at right angles to track at a scale of 7200 nT per inch with labeled anomaly picks (red dots, central anomaly not labeled). Data gaps of 20 km or more are shown.*

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

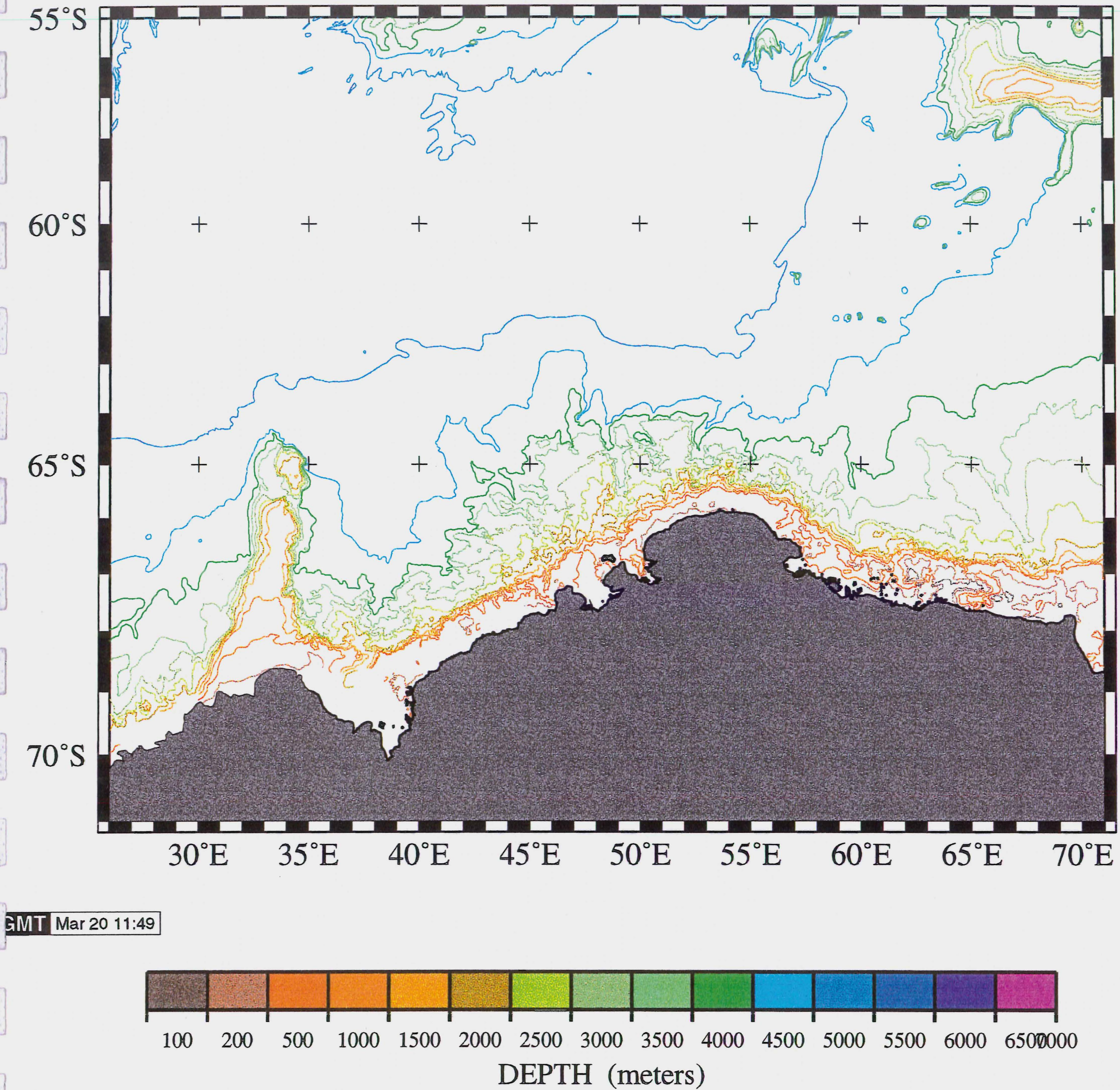


Figure 6a

Sector 13: *a colored bathymetric contour chart (100, 200, 500 m and every 500 m thereafter to 6500 m). Contours available from "CD ROM GEBCO 97" (BODC).*

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

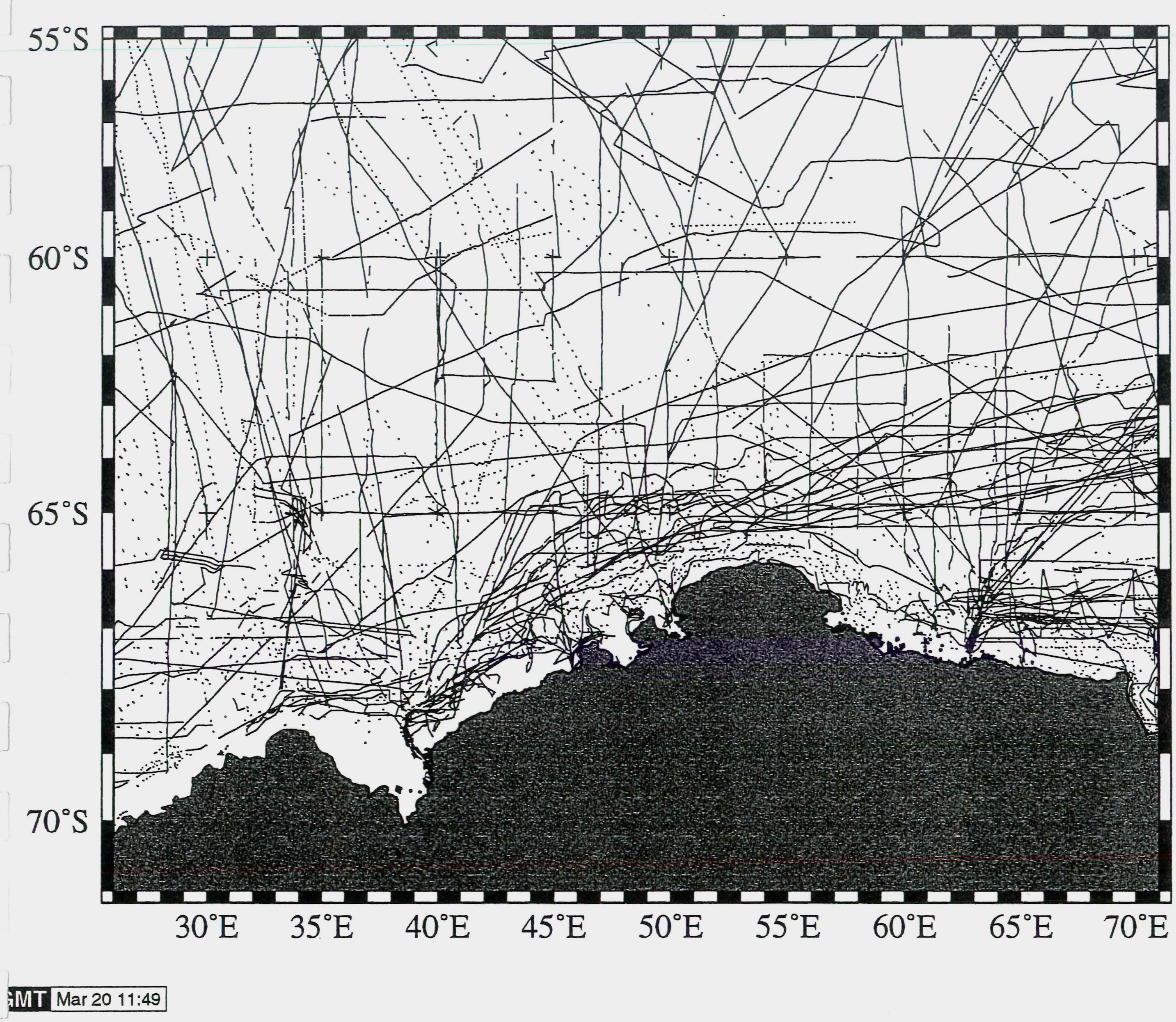


Figure 6b

Sector 13: *tracks used in the compilation of the bathymetric data from "CD ROM GEBCO 97" (BODC).*

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

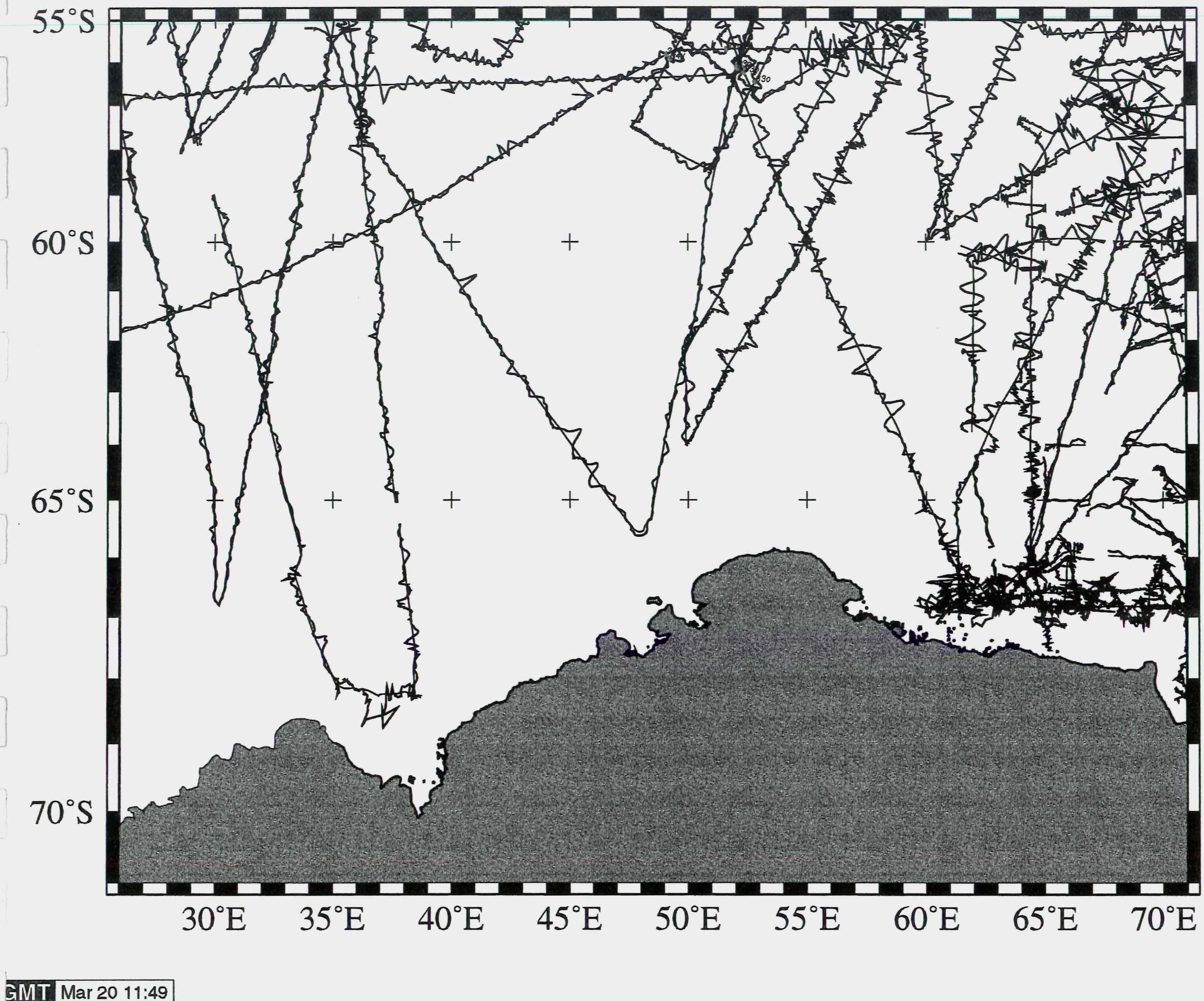


Figure 6c

Sector 13: *magnetic anomalies at right angles to track at a scale of 7200 nT per inch with labeled anomaly picks (red dots, central anomaly not labeled). Data gaps of 20 km or more are shown.*

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center - see page 3 for details.

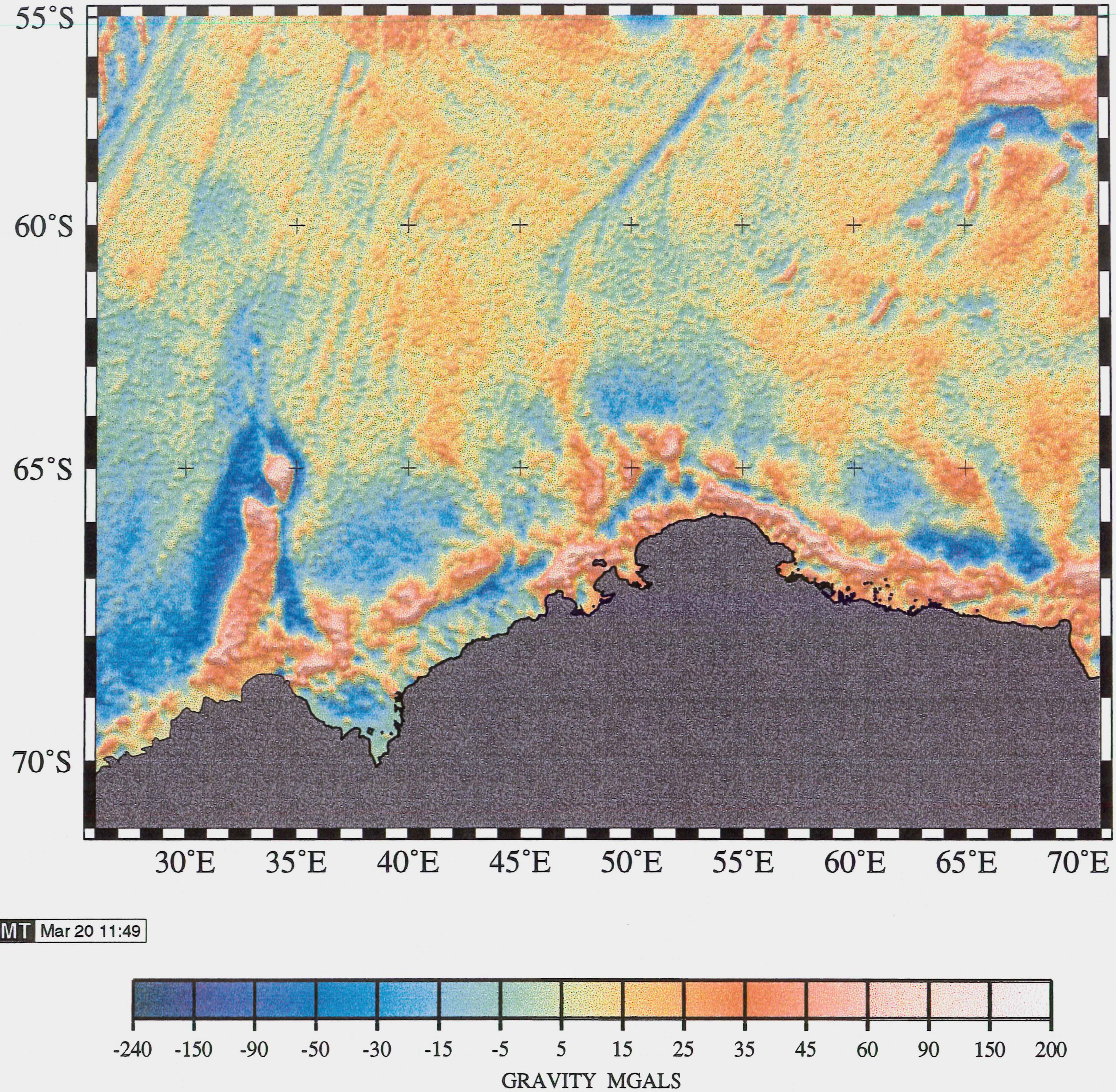


Figure 6d
Sector 13: colored chart of gridded satellite-derived free-air gravity anomalies (after Sandwell and Smith 1995).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center *- see page 3 for details.*

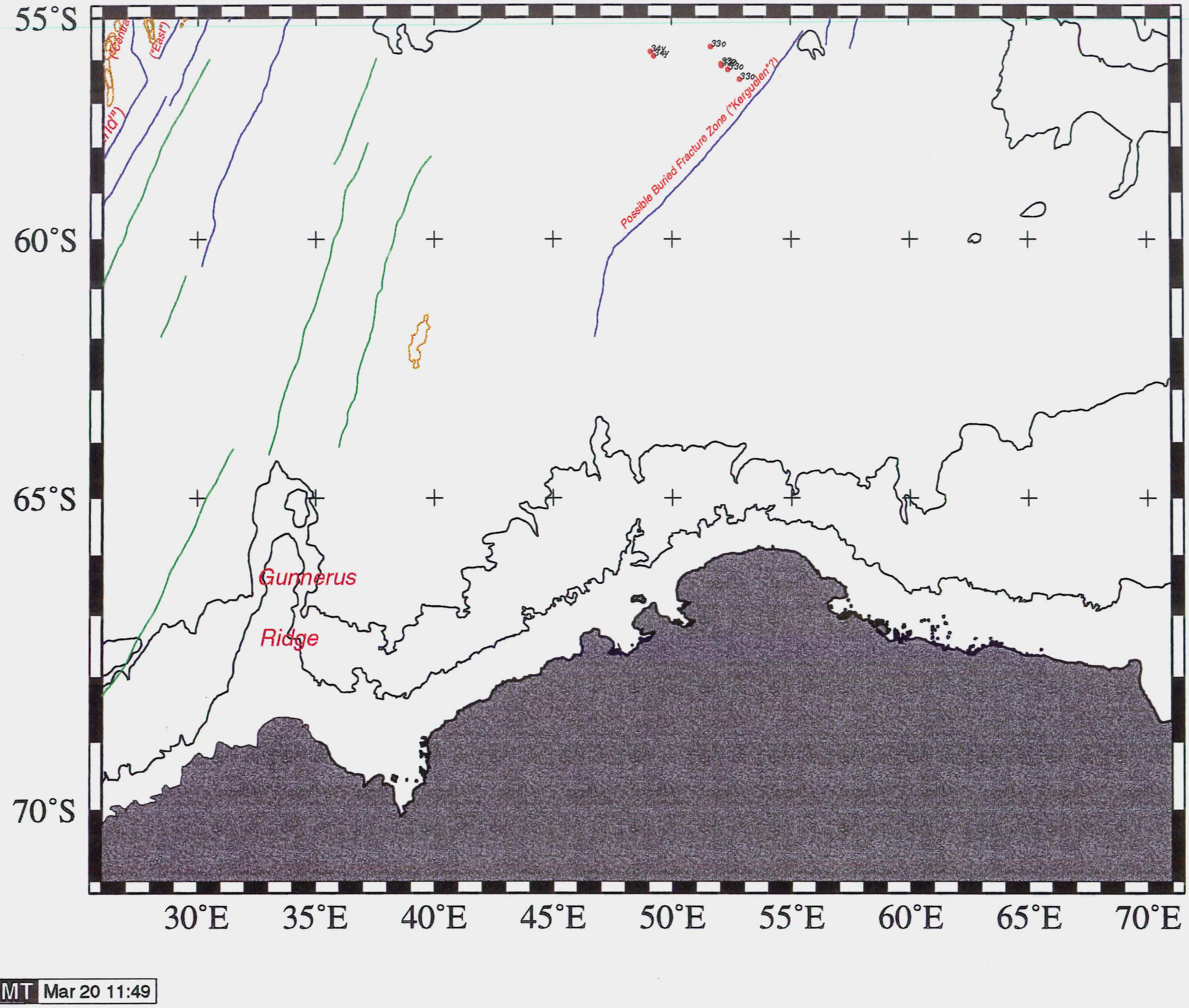


Figure 6e

Sector 13: a tectonic chart including the 2000 and 4000 m contours (black), selected 20 and 40 mgal gravity contours (brown), plate boundaries (thick black line), extinct spreading centers (purple), major and minor fracture zones (blue and green lines), linear features of unknown origin (buff lines) and magnetic anomaly picks (red dots, central anomaly not labeled).

Note: this plot is a 1:30.000,000 reduced-scale version of the full size 1:5,000,000 plot and gives an overall view. The full-scale plot is available from the SIO Geological Data Center *- see page 3 for details.*