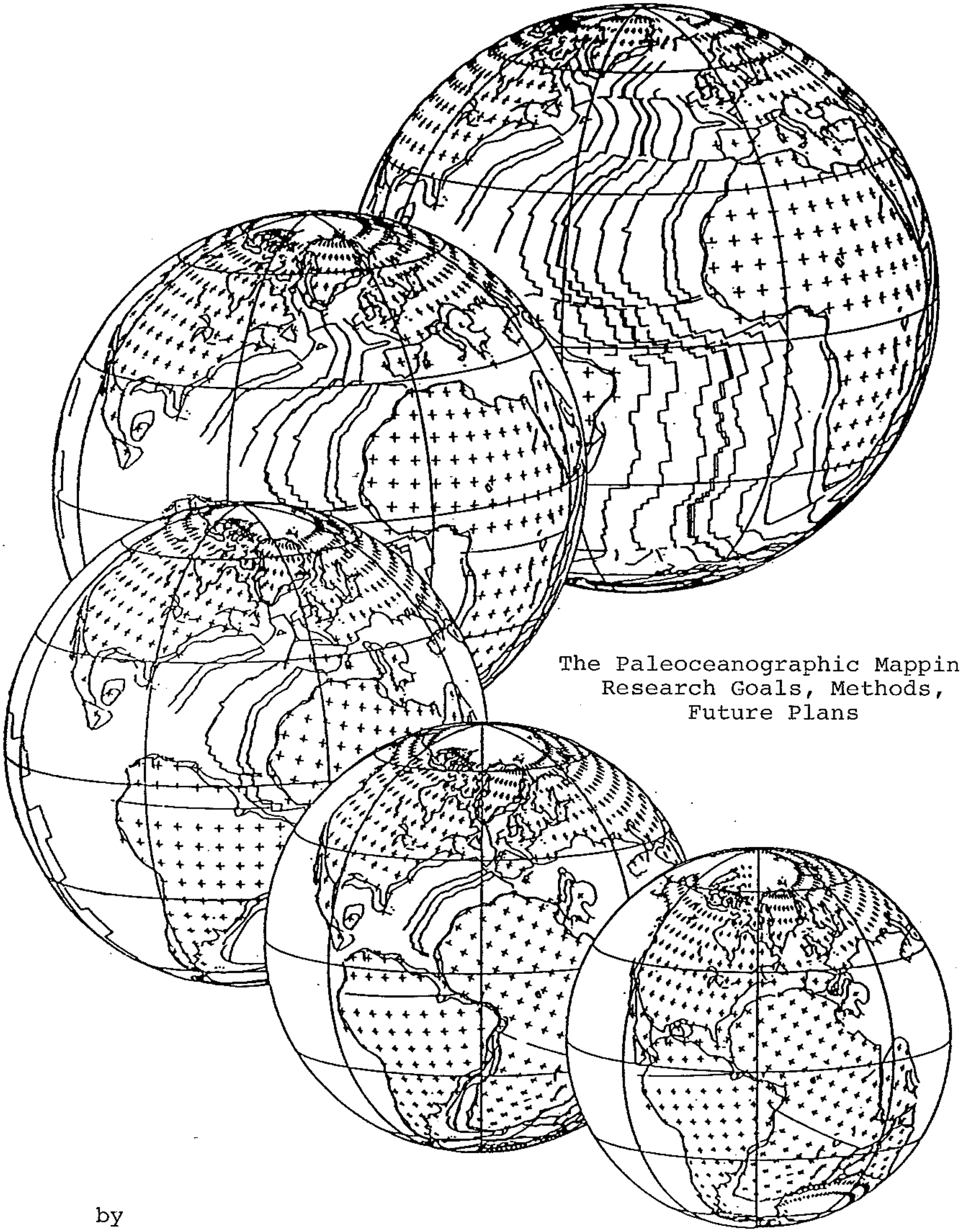
PALEOCEANOGRAPHIC MAPPING PROJECT
PROGRESS REPORT NO. 02-1184



The Paleoceanographic Mapping Project: Research Goals, Methods, and Future Plans

by
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University of Texas Institute for Geophysics Technical Report No. 50

The Paleoceanographic Mapping Project (POMP): Research Goals, Methods, and Future Plans

Paleoceanographic Mapping Project Report #02-1184

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The Institute for Geophysics, the University of Texas,
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Introduction

THe goal of the Paleoceanographic Mapping Project is to produce a global, computer model of plate motions during the last 200 million years. The basis of this computer model will be a new compilation and synthesis of linear magnetic anomaly data, ocean floor bathymetry, and continental margin tectonics. The most novel aspect of this project is the use of interactive computer graphics to reconstruct the ocean basins and to dynamically illustrate the plate tectonic solutions through computer animations.

This report, and the accompanying progress report, describe the work that was done during the intial phase of the Paleoceanographic Mapping Project (POMP) as well as our plans for the next several years. Also described are the resources available at the Institute for Geopohysics, University of Texas, the methods we will employ in achieving our goals, and the products that will be available to sponsors of the project.

A. Resources

1. Principal Investigators.

The principal investigators of the Paleoceanographic Mapping Project are Christopher R. Scotese, Lawrence A. Lawver, John G. Sclater, and Dale Sawyer (Curriculum Vitae, Appendix 1), all of the Institute for Geophysics, the Unversity of Texas at Austin. Scotese is the coordinator of the project and responsible for the development of the computer software and the structure of the computer data base. Sclater and Lawver are ocean-going scientists with extensive experience in the Indian and Atlantic Oceans. Sawyer brings to the team his expertise in the tectonic evolution of continental margins.

2. Academic and Industrial Reviewers

In addition to the principal investigators, a network of external reviewers is being assembled that will provide up-to-date information and constructive feedback on the plate tectonic models proposed by POMP. These reviewers include researchers both in academia and industry who have significantly contributed to our understanding of the plate tectonic evolution of the ocean basins. Table 1 lists those scientists who have agreed to be POMP reviewers. During the course of the project, we hope to be able to invite to Austin, those reviewers who might benefit from the access to our interactive computer graphic system.

3. Computing Facilities

All computing for the Paleoceanographic Mapping Project will be done on the Institute for Geophysics' VAX 11/780 computer system. Peripherals to the VAX include: a CALCOMP 965 4-pen plotter, a 4' by 6' CALCOMP digitizing tablet, a 30" Versatec electrostatic plotter, a Gould-Dianza image processor, and an Evans and Sutherland Professional Systems 300 interactive graphics terminal.

The Evans and Sutherland interactive graphics terminal is probably the single most important hardware component, and lies at the 'heart' of the project's interactive approach. The application of interactive computer graphics to plate tectonic problems was pioneered by Scotese, first at the University of Illinois (Scotese and Baker, 1975), and then in conjunction with Shell Development Co. (Scotese et al., 1980). The use of interactive computer graphics to solve plate tectonic problems is becoming more widespread, and similar systems are now in operation at Stanford, and the University of Chicago, as well as within the oil industry.

B. Methods

1. Interactive Computer Graphics

A global synthesis of Mesozoic and Cenozoic plate motions is now possible because the necessary tools and data sets are now at hand. During the past four years a revolution has occurred in the computer graphics industry, made possible by faster microprocessors and inexpensive mass memory. Anyone who has played a computer video game is intimately familiar with both the power and lure of interactive computer graphics.

Plate tectonics lends itself ideally to the interactive graphics approach due to the fact that plate motions can be modelled by the rotation of rigid, spherical caps on the surface of the globe. By manipulating plates and continental fragments in 'real-time' plate tectonic models can be proposed and rigorously tested in a matter of minutes. Using interactive computer graphics, work that normally would have taken weeks, can now be accomplished in days.

Interactive computer graphics can be used both to solve plate tectonic problems, and to generate computer animations that illustrate the possible plate tectonic solutions. An important aspect of the Paleoceanographic Mapping Project will be the production of a series of computer animations illustrating the plate tectonic evolution of the world's ocean basins and continental margins.

Included with this report is an example of the type of computer animation that will be produced. This film, "The Evolution of the Southern Oceans" was made in conjunction with Shell Development Co., and illustrates a prelimianry plate tectonic model for the evolution of the Indian Ocean.

2. Data Management

Though interactive computer graphics can be used to solve plate tectonic problems, these solutions will not be of lasting value unless they can be cataloged and stored in a comprehensive computer database system. Such a system must be able to inventory existing data, accommodate new data, and permit changes in the global plate tectonic model as new information becomes available.

The software that is used to model the plate tectonic evolution of the ocean basins and continents was developed jointly with the Paleogeographic Atlas Project, University of Chicago, headed by A. M. Ziegler. A recent revision of this software now permits more detailed and precise plate tectonic modelling. The major feature of this software revision is the establishment of a cataloging system that will permit the geographic data collected by the Texas and Chicago groups to be easily incorporated into standard data base management systems. The new format for the geographic data base and a description of the main plate tectonic mapping program are given in Appendix 2.

C. Geophysical Data

Though interactive computer graphics and structured data bases are powerful tools, the validity of any plate tectonic model ultimately depends on the accuracy and rigor of the data that form its foundations. In this section, we briefly describe the marine magnetic and bathymetric data set that were compiled to produce the maps illustrated in the accompanying Progress Report 01-0684, and briefly outline the other kinds of data that will be compiled during the next phase of the project.

1. Marine Magnetic Anomalies

Marine magnetic anomalies provide the temporal framework for all plate tectonic reconstructions. As a result of recent oceanographic surveys, detailed maps of linear magnetic anomalies are now available for nearly every ocean basin (Sclater et al., 1981; Larson et al., 1984).

The magnetic anomalies used to produce the plate tectonic reconstructions illustrated in figures 2 - 10 of the POMP Progress Report 01-0684, were compiled from 28 different sources. The lineations were cartographically transferred to a standard set of mercator maps at a scale of 1:10,000,000, digitized, and then incorporated into the plate tectonic software program, PALEOMAP (Figure 1).

During the intial phase of the project a similar compilation will be made for Atlantic and Pacific ocean basins. This 'quick and dirty' summary will help us identify the problem areas that need to be investigated in further detail, and will serve to build up our library of oceanographic references. In the second phase of data compilation, we plan to return to the original surveys and evaluate the magnetic signatures used to define the lineations.

2. Ocean Floor Bathymetry

Though sea floor magnetics provides the temporal framework for plate motions, most of the tectonic information required to reconstruct the ocean basins comes from the detailed mapping of the bathymetry of the ocean floor. Two new data sets are available that provide independent means of mapping the depths of the oceans.

The first data set is a digital version of the recently published GEBCO bathymetric charts (SYNBAPS). This data set consists of a 5' by 5' grid of sea floor bathymetry. Software has been written at Texas to recontour and plot the SYNBAPS data set; an example is given in Figure 2.

A second, independent estimate of sea floor bathymetry is now available from satellite altimetry (SEASAT). Measurements of the height of the sea surface, when corrected for long wave length effects of the geoid, appear to be excellent estimators of the topography of the ocean floor. Computer graphic plots of sea surface heights produced by William F. Haxby, Lamont-Doherty, have provided a new and exciting insights into the major tectonic features of the ocean basins.

In conjuction with a team of scientists working with Prof. Byron Tapley, Department of Aeronautical Engineering (U. Texas), we will be reprocessing and imaging the original SEASAT data in order to better map the tectonic features of the sea floor. Figure 4 is a preliminary plot of a three dimensional representation of sea surface heights, produced using the Evans and Sutherland interactive computer graphic system.

D. Products

1. Progress Reports, Maps, and Films

Sponsors and reviewers of the Paleoceanographic Mapping Project will receive quarterly reports similar in style and content to Progress Report 01-0684 that accompanies this proposal. Though these progress reports, per se, will not be published, we reserve the right to publish the data and plate tecttonic models that are described within them. In most cases, the information in the quarterly reports will be made available to sponsors 9 - 18 months before publication.

The progress reports will be accompanied by maps and reconstructions plotted at scales ranging from 1:10,000,000 to 1:40,000,000. Included with this report is a plate tectonic reconstruction of the Indian Ocean (65 Ma), drawn at a scale of 1:40,000,000.

Though the maps and reports will document our interpretations, they can not capture the dynamics of the plate tectonic process. The best way to illustrate plate motions is through the use of computer graphic animations. In addition to the reports and maps, sponsors of the project will receive preview copies of all computer animations.

2. Computer Software and Data Bases

As discussed in the introduction, the goal of the Paleoceanographic Mapping Project (POMP) is to produce a global model of plate motions based on an oceanwide compilation of marine geophysical data. The most valuable products of the project, therefore, will be: 1) a global data base of marine magnetic anomaly information, 2) a global database describing the major tectonic features of the ocean floor and continental margins, and 3) the computer software required to produce plate tectonic reconstructions illustrating these data (Appendix 2).

The marine magnetic data set will consist of files composed of a) magnetic 'picks', b) interpreted magnetic lineations, and c) isochrons that map the age of the ocean floor. The bathymetric data set will consist of tectonic features of the ocean floor identified from a) the location of earthquake epicenters, b) the GEBCO and SYNBAPS data sets and c) our reinterpretation of SEASAT altimetry. A worldwide map estimating the amount of extension along passive margins, and delineating the boundaries between continental, stretched-continental, transitional, and oceanic crust, will be compiled by Dale Sawyer.

Computer software will be supplied to sponsors of POMP that will produce plate tectonic reconstructions illustrating the age and tectonics of the ocean floor and continental margins. The software will be updated on a yearly basis so that new geographic data and new plate tectonic models can be incorporated into the sponsor's computer system. It should be noted that this software will be completely compatible with the data sets and software distributed by the Paleogeographic Atlas Project, University of Chicago.

E. Schedule

We expect that it will take three years, starting from January 1, 1985, to compile the magnetic anomaly and bathymetric data sets described in the previous sections. The computer model of plate motions, based on this compilation, will be produced concurrently.

1. The First Year

Two major projects will be undertaken during the first year of the project. The first project will be the completion of a 'rough draft' global overview, done in the same style as our pilot project for the Indian Ocean (see POMP Progress Report 01-0684). This phase of the project will help to identify those problem areas that need to be investigated in greater detail, and will serve to build up our library of oceanographic references. The research products of this phase, will be a revised age of the ocean floor map and new model of Mesozoic and Cenozoic plate motions.

The second project, which will be started but not completed during the first year, is a rigorous compilation of the detailed magnetic, bathymetric, and gravity data, that will form the foundation of the ultimate plate model. This more detailed compilation will begin in the Indian Ocean, and will proceed westwards toward the Scotia Sea, and South Atlantic. Much of this work will be carried out in collaboration with scientists at other institutions.

Several film animations will also be produced during the first year. These will probably include: a global plate tectonic animation based on our revised age of the oceans map, and animations of the tectonic evolution of the western Indian Ocean, Scotia Sea, and possibly the Gulf of Mexico and Caribbean.

2. Future Years

The major effort during the following years of the project will be the completion of the detailed version of the magnetic, bathymetric, and gravity data base, and the resulting refinement of the global plate tectonic model. Our tentative plan is to proceed from the South Atlantic up into the North Atlantic and Arctic Oceans. It is necessary to reconstruct the passive margins of the Indian and Atlantic Ocean in order to better constrain the relative plate motions along the circum-Pacific margin.

Though we will probably not begin the Pacific in earnest until 1986 or 1987, we plan to undertake a pilot project in the NW Pacific in conjunction with the thesis research of one of our students, Merriam Renkin. This project will be a review of the tectonic models proposed for the Mesozoic evolution of the Pacific, Kula and Farralon plates.

During the upcoming years, as new data is compiled, it will be digitized, plotted on plate tectonic reconstructions, described in POMP Progress Reports, and sent to sponsors in yearly updates. These reports and updates will be accompanied by computer animations illustrating the tectonic evolution of these areas; we anticipate that the final films will be in full color.

Conclusion

Reconstructing the plate tectonic history of the world's ocean basins is a daunting task; however, we believe that the tools, personnel, and information are now available that make such a task possible. In fact, ten years from now, we will probably look back at the 1980's as the time during which the great volume of marine geophysical data, acquired during the 1960's and 70's, were synthesized into a unified model of the plate tectonic evolution of our planet.

In a sense, we are embarking on the second voyage of Columbus; however, this time it is a voyage in time rather than in space. The goal of the Paleoceanographic Mapping Project is to use interactive computer graphics to create a framework that will allow us to look at the historical development of the Earth from a new perspective. We anticipate that this global framework will provide us with new insights, not only into the history of the plate tectonic process, but also into the dynamics of the process as well.

Table 1. Academic and Industrial Reviewers

A. Academic Reviewers

Name	University
A. W. Bally	Rice
P. Barker	Birmingham
H. Bergh	Bernard Price
K. Burke	LPI
D. Engebretson	U. Washington
J. Francheteau	Paris
R. Fisher	Scripps
R. Gordon	Northwestern
T. Hilde	Texas A&M
K. Klitgord	USGS
R. Larson	URI
P. Molnar	MIT
P. Patriat	Paris
W. C. Pitman	Lamont
D. B. Rowley	Chicago
W. Sager	Texas A&M
S. Uyeda	Tokyo
R. Van der Voo	Michigan
A. M. Ziegler	Chicago
Jean Mascle	LABORATOIRE de GEODYNAMIQUE S-M BP48 06230 Villefranche (mer

B. Industrial Reviewers

Name	Company
S. F. Barrett	AMOCO
S. Bowman	Marathon
J. Evans	Texaco
W. K. Gealey	Chevron
X. Golovochenko	Marathon
I. Norton	EXXON
D. G. Roberts	BP
S. Snelson	Shell
C.P. Summerhayes	BP
L. Tennyson	Phillips
P. Unthernehr	ELF
T. Nelson	EXXON
P. Ziegler	Shell

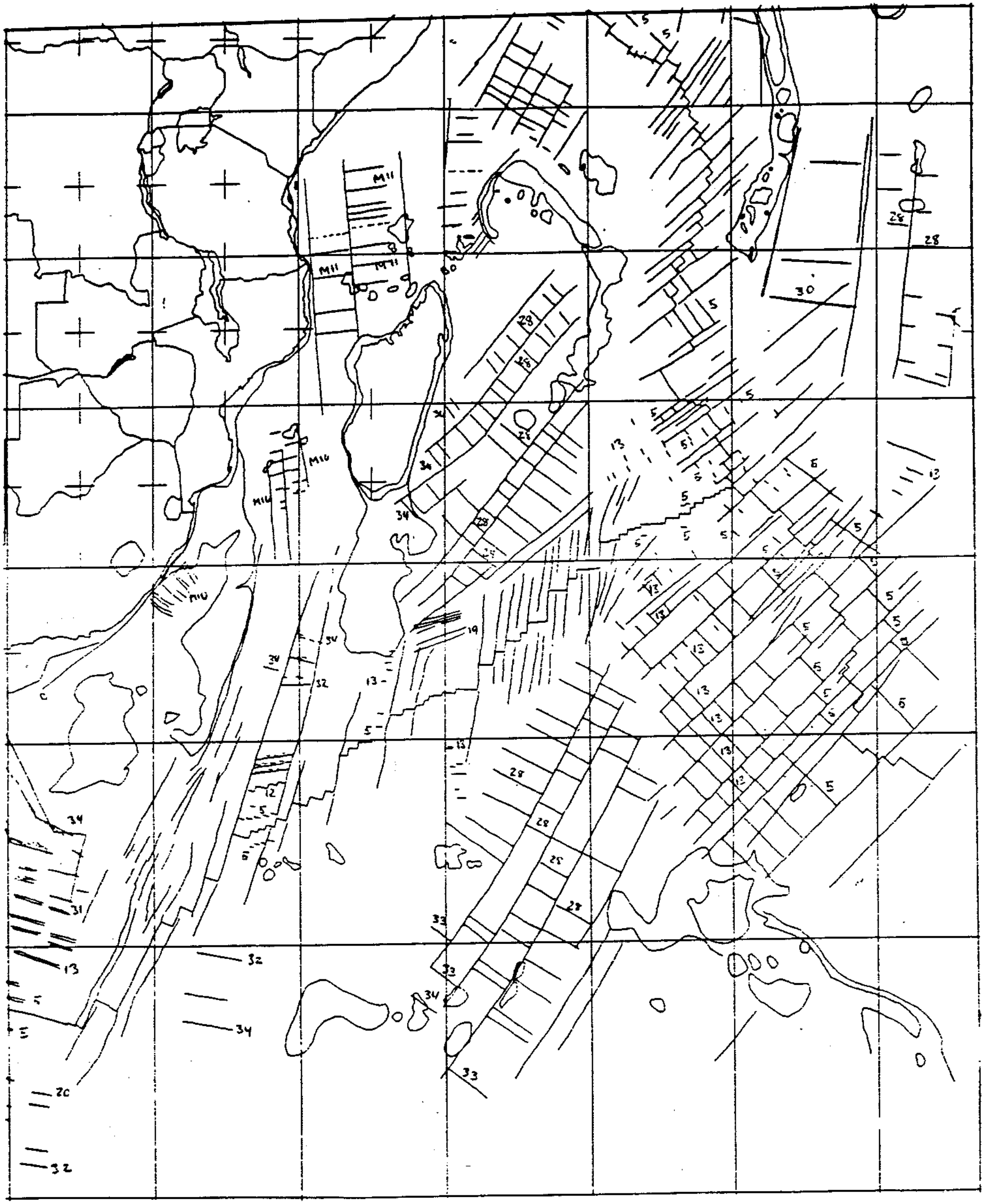


Figure 1. Linear Magnetic Anomaly and Tectonic Feature Data collected for Indian Ocean during pilot project (see POMP Progress Report 01-0684).

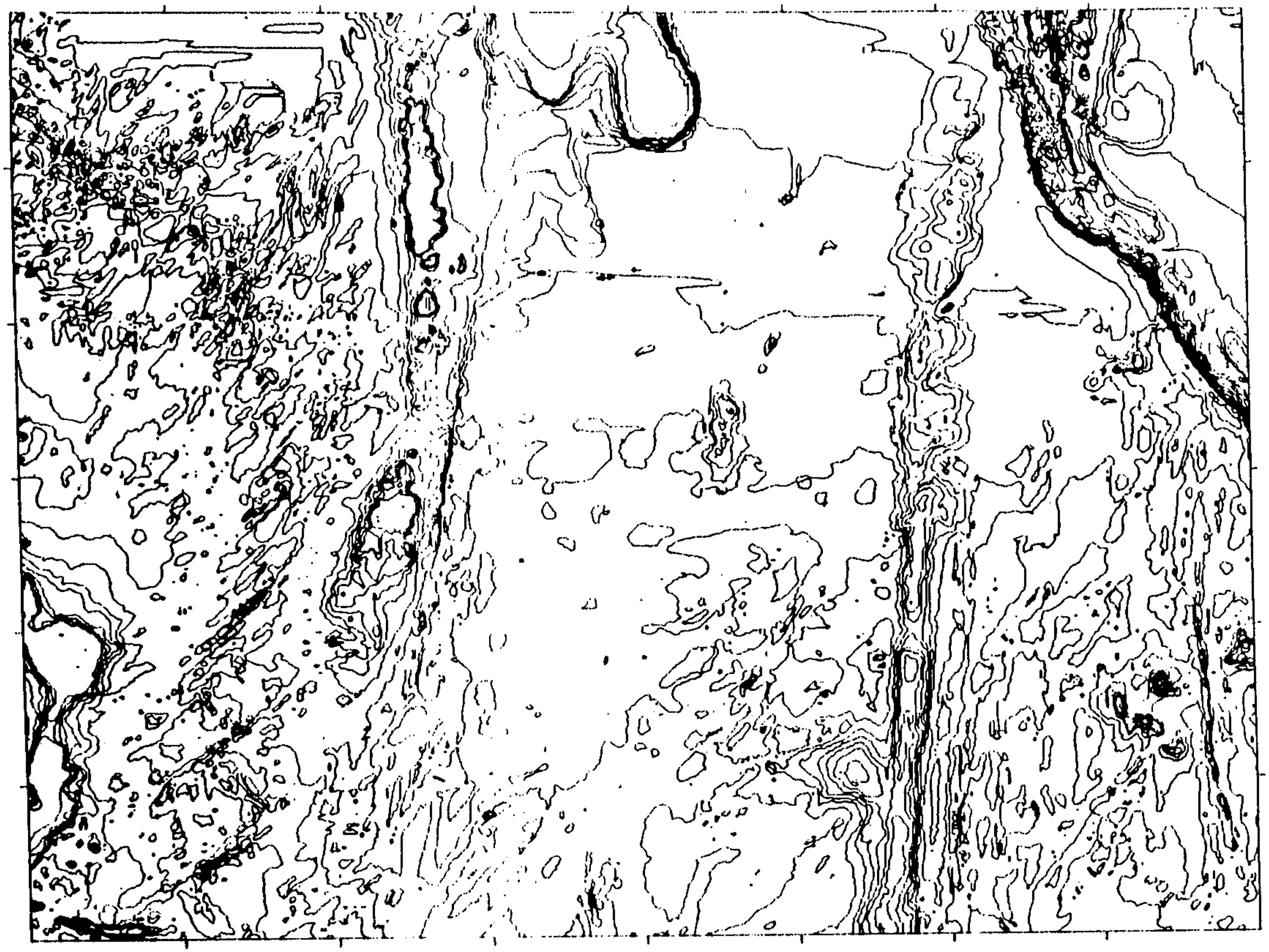


Figure 2. Bathymetry of Central Indian Ocean contoured from SYNBAPS digital data base (Sri Lanka is located at the center of the top of the map.)

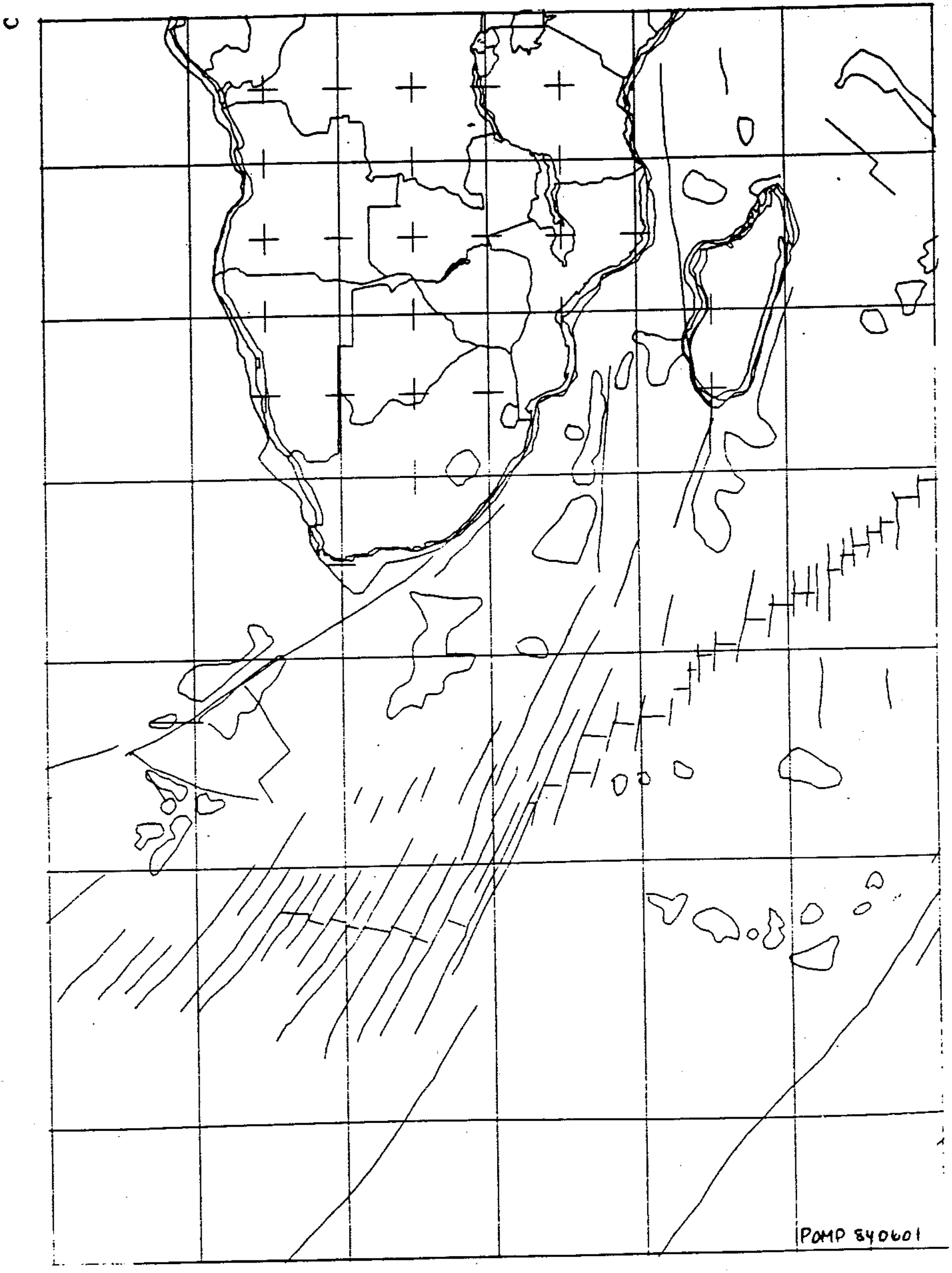


Figure 3. Tectonic Lineations digitized from Haxby (1984).

Appendix 1. Curriculum Vitae of Principal Investigators

CV's were removed.

Appendix II: Software description: PALEOMAP

Introduction

PALEOMAP is the name of the program that produces plate tectonic reconstructions. The programs that comprise PALEOMAP were developed as part of the Paleogeographic Atlas Project at the University of Chicago, and were rewritten and consolidated into a single master program during the summer of 1984, while CRS was on sabbatical at the BP Research Centre, Sunbury-on-Thames.

Figure 1 is a flow-chart illustrating the use of the program, and indicating the various routes a user might choose to follow. Sample responses to input requests are provided.

This flow-chart should be used as a guide when running the program.

A. Program Structure and User Input

Part I. In the first part of the program the rotations required to produce the plate tectonic reconstructions are calculated. In this section the user enters the age in millions of years of the reconstructed base map.

Part II. In this section of the program the user enters the parameters that determine the style of map display. These parameters include: the type of map projection, the scale of the map, the latitudinal and longitudinal limits of the viewing area, and the spacing of the superimposed latitude/longitude graticule.

Part III. Here, special viewing options may be selected. These options include features that minimize the distortion of the map projection or produce transverse or oblique projections.

Part IV. In the final section, the user chooses the geographic data set that will be plotted. A detailed geographic base for 'hard-copy' maps may be chosen, or a less detailed geographic base for quick screen displays may be selected.

B. Types of Map Output

This section describes the variety of reconstructions that can be produced using PALEOMAP. Examples of each type of map are illustrated in Figures 2 - 10.

1. Plate Tectonic Basemap

The simplest type of map that can be produced is a plate tectonic reconstruction based on paleomagnetic data and recent summaries of plate motions. A map for any time from the latest Precambrian (600 Ma) to the present, may be selected.

In addition to present-day shorelines, the map includes 200 m isobaths, country boundaries, major suture zones, and a set of 5 by 5 crosses that rotate with the continents. The geographic database is sufficiently detailed that maps may be plotted at scales ranging from 1:200,000,000 to 1:5,000,000 without any loss of resolution. Four different map projections are available: a) Mercator, b) Mollweide, c) Van der Grinten, and d) polar (azimuthal equidistant).

A geographic 'window' that delimits the viewing area is specified by entering the latitudinal and longitudinal limits of the viewport. The conventions +N, +E, -S, and -W are used to identify the latitudinal and longitudinal limits of the window.

An example of a Mercator reconstruction for 100 Ma is given in Figure 3. A Mollweide reconstruction for 435 Ma (Early Silurian) is illustrated in Figure 2.

2. Special Options

In addition to the standard map projections, several special options are available that allow the user to modify the map projection. These options are:

a) Keep one continent fixed in modern coordinates.
b) Center viewing area to minimize the map distortion.
c) Rotate entire reconstruction by a user specified global rotation.

Option a) allows the user to produce a reconstruction in which one continent is held fixed in its present position and the remaining continents are reassembled around it. This option is especially useful when transferring data from present-day maps onto reconstructed basemaps. An example of such a reconstruction is given in Figure 4.

If Option b) is selected, the latitude/longitude window (for example 90 N to -30 S latitude, and 80 E to -20 W longitude) is reprojected and centered about the origin of the map projection. This results in a distorted, but nearly equal area and equidimensional map.

An example of a Mercator projection centered to minimize the distortion is given in Figure 5.

Option c) is a very useful and also very powerful option. This option allows the user to specify a 'global' rotation about which the entire reconstruction can be rotated. For example, if one wanted to have a better view of the backside of a reconstruction, then a global rotation of 180 degrees about a pole located at 90 N and 0 E would move the 180 degree meridian from the edge of the map to the center of the map.

Figure 6 is an example of a Paleozoic reconstruction that has been rotated 120 degrees in order to better center the wide ocean basin opposite Pangea.

Option c) can also be used to produce oblique and transverse map projections. For instance, in order to produce a transverse Mercator in which the prime meridian lies along the equator of the map projection, the following global rotation can be applied.

Pole or rotation:	Latitude of Pole	0 N
	Longitude of Pole	0 E
	Angle of rotation	90 degrees

An example of a transverse Mercator projection is given in Figure 7.

C. Subroutine Structure and Function

In addition to the main program that controls user input and map format, there are 15 subroutines: ADDER, AZIEQUI, CIRCLE, FRAME, GRID, GRNTEN, MERCA, MOLLY, PLOT, PROJ, ROTATE, ROTFND, SYMBOL, TICMARK, XYMIN. 8 major external data files are invoked. These subroutines are best understood if they are regrouped according to the functions they perform.

Subroutine Functions

1. Plate Tectonic Reconstructions

The rotations required to produce the plate tectonic base maps are calculated in the subroutine ROTFND using the rotations stored in the data files MESO5.DAT, PALEO8.DAT, and PALEO9.DAT.

2. Map Making

The subroutine PROJ routes latitude/longitude values to one of 4 different projections: Mercator (MERCA), Mollweide (MOLLY), Van der Grinten (GRNTEN), or Azimuthal equidistant polar (AZIEQUI). The latitude/longitude ticmarks are drawn by subroutine TICMARK. The entire reconstruction is surrounded by a solid border drawn by the subroutine FRAME, and the proper origin offset is calculated by the subroutine XYMIN.

A variety of geographic data can be plotted. At present, all reconstructions are produced using the coastline and suture information contained in files SUTURE1.DAT

(Paleozoic file) and SUTURE2.DAT (Mesozoic-Cenozoic file).

3. Graphics subroutines

PALEOMAP is designed to be linked with the standard CALCOMP plotting library or an equivalent graohics package. The only CALCOMP subroutines required by PALEOMAP are subroutines PLOT and SYMBOL. An additional graphics subroutine CIRCLE, was written to plot regular polygons of varying sizes and shapes.

4. Numerical Calculations

Finite rotations are concatenated using quaternions in the subroutine ADDER. Spherical rotations about inclined axes are calculated in the subroutine ROTATE.

D. Format of Geographic Data

Through the use of interactive computer graphics we are currently refining our plate tectonic models in order to produce more detailed paleogeographic reconstructions. Whereas the previous reconstruction software (RECON6, BASEMAP) was designed to handle a maximum of 100 'plates' or independently rotating elements, the new software anticipates the requirement that there will be several thousand independent tectonic elements. In order to handle this amount of new information, a new format for the geographic data records was designed. The following section describes the major features of this new record keeping system.

1. Definition of a Geographic Record

A geographic record is a sequence of latitudinal and longitudinal pairs accompanied by a pen command (draw, skip). The information that composes a geographic record must be of the same data 'type', must belong to the same 'tectonic element', and must be active over the same time interval.

2. Definition of Header Information

a. Name of the Geographic Record

The geographic record is indentified by a 3 digit numeric prefix, 'the geographic identifier', a 4 digit numeric suffix 'the sequence number ', and a 70 character alphanumeric 'geographic name'. The geographic identifier is obtained from the code number of the geographic region as listed in Appendix 2, 'Area Categories', of the Paleogeographic Atlas Project Reference System (PAPeRS). The sequence number is an incremental number associated with the Master Catalog for that region.

The geographic name will be assigned either by the person who defined the line, or by the person who digitized the geographic record. In addition to the 'name' of the feature, this record may also include any useful auxilliary information (i.e. comments, notes)

The three elements that comprise the name of the geographic record occupy the first line of the 'header'. For example:

134 0072 Bering Slope-Rise Break
936 0154 Walvis Ridge Hot Spot Track
331 0003 Polish Trough (reactivated Caledonian suture)
012 0879 Tintina Fault (1350 km dextral offset)

b. Documentation of Data Acquisition

The next line of the header begins with the date the geographic record was digitized (day/month/year), the location of the data source (Chicago/Texas), the author(s) of the geographic interpretation (AMZ/DBR/etc.), person who digitized the information (ALL/CRS/etc), and an abbreviated reference, if required.

Some examples:
092884 Chicago AMZ DBR LAL Stone et al. 1979
042384 Texas CRS LAL KCM Norton and Sclater, 1980

c. Definition of Data Type

The third line of the header begins with a 5 digit code describing the data type. The first 2 digits are descriptive alphabetic characters (CS, coastline; RI ridge; AN, anomaly, BA, bathymetry etc.), the last 4 digits are an alphanumeric code that further modifies the prefix (BA 3000, AN 0M22).

d. Line Style and Color

Also on the third line of the header are three two-digit variables that contain information concerning the color (hue and intensity), and line style or pattern.

e. Rotation Group

Probably the most important bit of information that must be recorded in the header is the rotation group, or plate identification number. This identifier defines the tectonic element that the data are 'attached to'. The rotation group, or plate identification numbers, are created using the same convention described in section a. In other words, the plate identification number is a couplet consisting of an Area Category # taken from Appendix 2 of the Paleogeographic Atlas Project Reference System, and a sequence number which corresponds to a specific tectonic element within that region.

For example, the old rotaton groups would translate as follows:

Name	Old Number	New Numbers
North America	01	001 000
Greenland	02	010 000
N. Slope	03	130 000
Mexico	04	020 000
Baja	05	203 000
Madagascar	50	946 000
India	54	053 000

An example of new rotation groups might be:

Stikinia	-	012 001
Cache Creek	-	012 002
Wrangellia (S)	-	012 003
Wrangellia (N)	-	013 001 or 131 001

f. Time Window

The third line of the header also includes the time interval over which the data are 'active', i.e. on the map. The first number refers to the time when the data first appear (oldest stage) and the second number refers to the time when the data 'disappear' (youngest stage). The numbers correspond to the base of stage boundaries, rather than an absolute time. In this numbering system, the base of the Recent is 0, and the base of the Cambrian is 77. The advantage of this system is that it allows time scale changes to be incorporated with great ease.

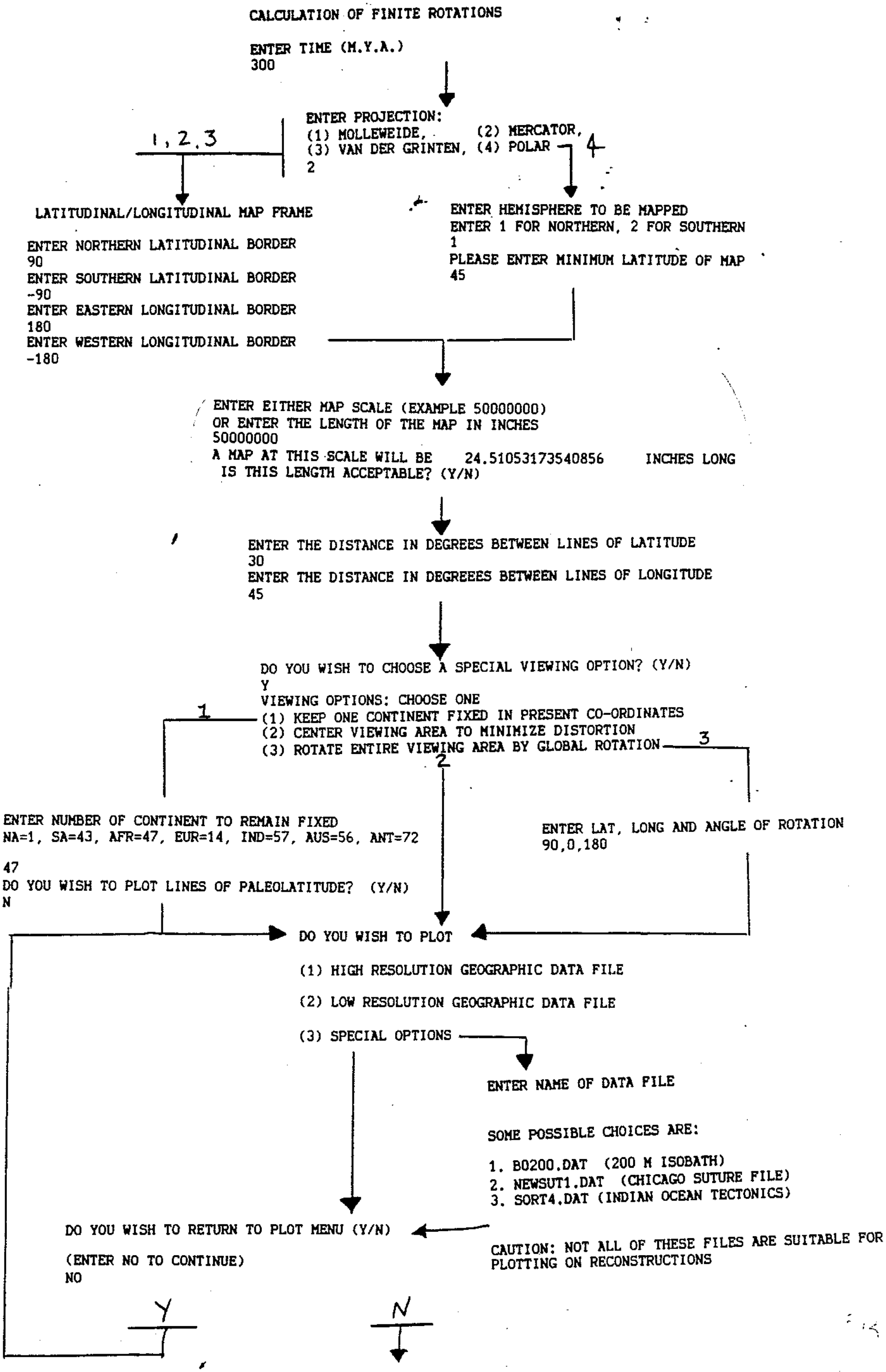
Appear at:	Disappear at:
60 (base of Cenomanian)	65.5 (mid-Maestrichtian)

Area Categories

* 000	World	World
* 1xx	N.America	North America
* 10x	Greenland	Greenland
100	N.Greenlnd	North Greenland
101	N.GrnlndSh	North Greenland Shelf
102	E.Greenlnd	East Greenland
103	E.GrnlndSh	East Greenland Shelf
104	W.Greenlnd	West Greenland
105	W.GrnlndSh	West Greenland Shelf
* 11x	E.Canada	Eastern Canada
110	Quebec	Quebec
111	Newfndland	Newfoundland
112	Labrador	Labrador
113	PrEdwIsl	Prince Edward Island
114	NovaScotia	Nova Scotia
115	NewBrunsw	New Brunswick
116	G.StLawren	Gulf of St. Lawrence
117	E.CanadaSh	Eastern Canada Shelf Area
* 12x	W.Canada	Western Canada
120	NW.Terr	North West Territories
121	HudsonBay	Hudson Bay
122	Ontario	Ontario
123	Manitoba	Manitoba
124	Saskatch	Saskatchewan
125	Alberta	Alberta
126	BritColum	British Columbia
127	Yukon	Yukon Territory
* 13x	Alaska	Alaska
130	N.Alaska	Northern Alaska
131	S.Alaska	Southern Alaska
132	AlaskaPanh	Alaskan Panhandle
133	AleutIs	Aleutian Islands
134	BeringSh	Bering Shelf
135	BeringBs	Bering Basin
* 14x	NE.USA	Northeast United States
140	NewEngland	New England
141	NE.USA.Sh	Northeast USA Shelf Area
142	NewJersey	New Jersey
143	Delaware	Delaware
144	Maryland	Maryland
145	W.Virginia	West Virginia
146	Pennsylvan	Pennsylvania
147	NewYork	New York

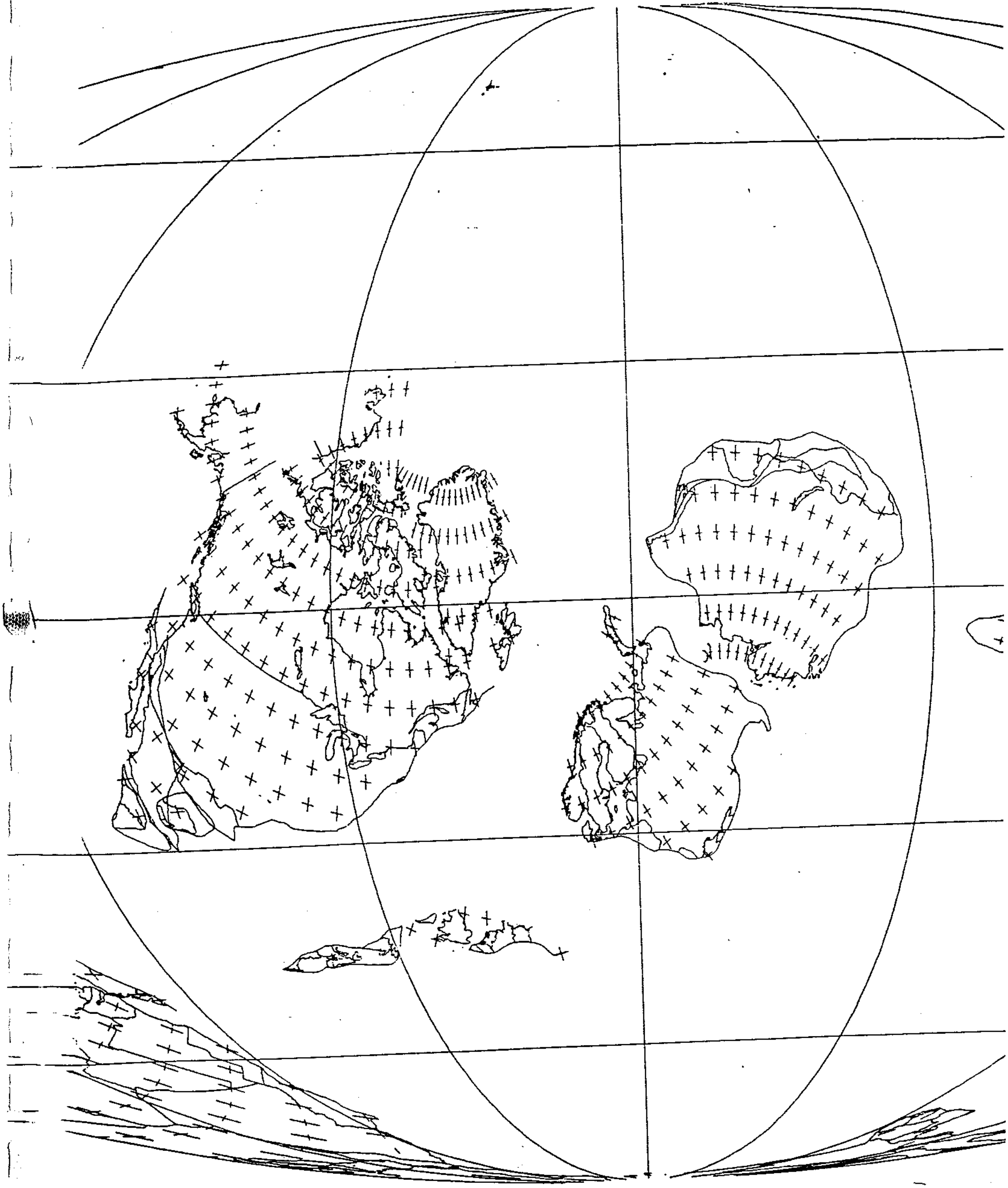
* 15x	SE.USA	Southeast United States
150	Virginia	Virginia
151	N.Carolina	North Carolina
152	S.Carolina	South Carolina
153	Georgia	Georgia
154	Florida	Florida
155	Alabama	Alabama
156	Tennessee	Tennessee
157	Kentucky	Kentucky
158	SE.USA.Sh	Southeast USA Shelf Area
* 16x	SC.USA	South Central United States
160	Missouri	Missouri
161	Arkansas	Arkansas
162	Mississipp	Mississippi
163	Louisiana	Louisiana
164	Texas	Texas
165	Oklahoma	Oklahoma
166	Kansas	Kansas
167	SC.USA.Sh	South Central USA Shelf Area
* 17x	NC.USA	North Central United States
170	Minnesota	Minnesota
171	Wisconsin	Wisconsin
172	Michigan	Michigan
173	Ohio	Ohio
174	Indiana	Indiana
175	Illinois	Illinois
176	Iowa	Iowa
177	Nebraska	Nebraska
178	S.Dakota	South Dakota
179	N.Dakota	North Dakota
* 18x	RockyMtUSA	Rocky Mountain United States
180	Montana	Montana
181	Wyoming	Wyoming
182	Colorado	Colorado
183	NewMexico	New Mexico
184	Arizona	Arizona
185	Utah	Utah
* 19x	Wn.USA	Westernmost United States
190	Washington	Washington
191	Idaho	Idaho
192	Oregon	Oregon
193	Nevada	Nevada
194	California	California
195	W.USA.Sh	Shelf Area Western USA

21 cl 20
cl



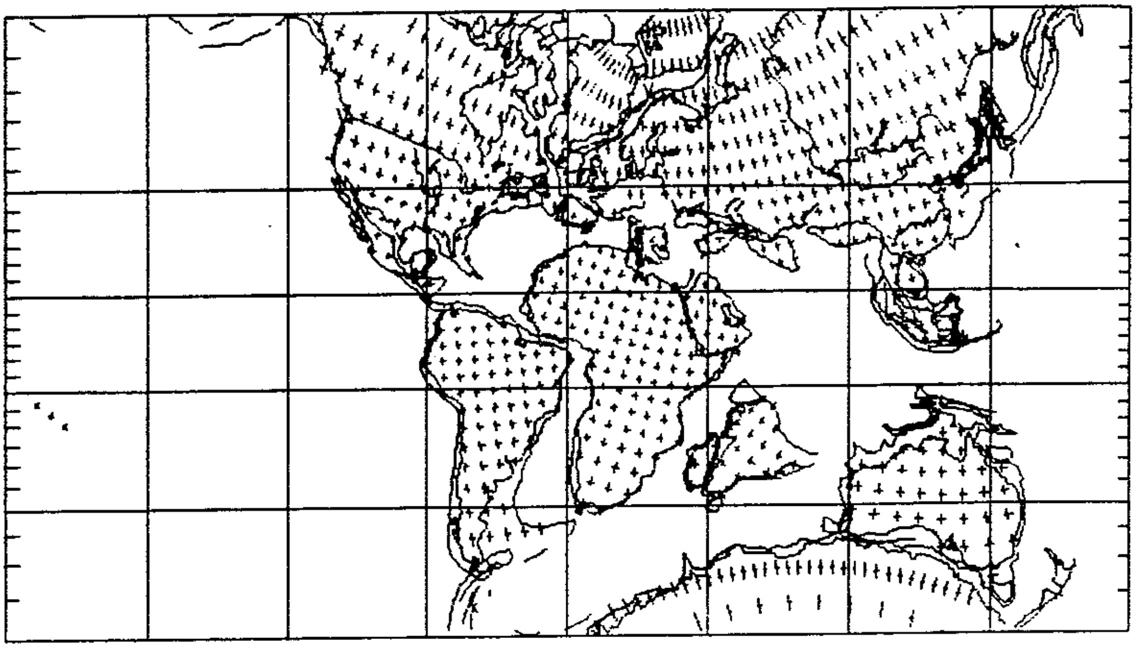
```
CALCULATION OF FINITE ROTATIONS

ENTER TIME (M.Y.A.)
300

ENTER PROJECTION:
(1) MOLLEWEIDE,        (2) MERCATOR,
(3) VAN DER GRINTEN,   (4) POLAR
2

LATITUDINAL/LONGITUDINAL MAP FRAME

ENTER NORTHERN LATITUDINAL BORDER
90
ENTER SOUTHERN LATITUDINAL BORDER
-90
ENTER EASTERN LONGITUDINAL BORDER
180
ENTER WESTERN LONGITUDINAL BORDER
-180

ENTER HEMISPHERE TO BE MAPPED
ENTER 1 FOR NORTHERN, 2 FOR SOUTHERN
1
PLEASE ENTER MINIMUM LATITUDE OF MAP
45

ENTER EITHER MAP SCALE (EXAMPLE 50000000)
OR ENTER THE LENGTH OF THE MAP IN INCHES
50000000
A MAP AT THIS SCALE WILL BE    24.51053173540856     INCHES LONG
 IS THIS LENGTH ACCEPTABLE? (Y/N)

ENTER THE DISTANCE IN DEGREES BETWEEN LINES OF LATITUDE
30
ENTER THE DISTANCE IN DEGREEES BETWEEN LINES OF LONGITUDE
45

DO YOU WISH TO CHOOSE A SPECIAL VIEWING OPTION? (Y/N)
Y
VIEWING OPTIONS: CHOOSE ONE
(1) KEEP ONE CONTINENT FIXED IN PRESENT CO-ORDINATES
(2) CENTER VIEWING AREA TO MINIMIZE DISTORTION
(3) ROTATE ENTIRE VIEWING AREA BY GLOBAL ROTATION

ENTER NUMBER OF CONTINENT TO REMAIN FIXED
NA=1, SA=43, AFR=47, EUR=14, IND=57, AUS=56, ANT=72

47
DO YOU WISH TO PLOT LINES OF PALEOLATITUDE?  (Y/N)
N

ENTER LAT, LONG AND ANGLE OF ROTATION
90,0,180

DO YOU WISH TO PLOT

(1) HIGH RESOLUTION GEOGRAPHIC DATA FILE

(2) LOW RESOLUTION GEOGRAPHIC DATA FILE

(3) SPECIAL OPTIONS

ENTER NAME OF DATA FILE

SOME POSSIBLE CHOICES ARE:

1. B0200.DAT  (200 M ISOBATH)
2. NEWSUT1.DAT  (CHICAGO SUTURE FILE)
3. SORT4.DAT (INDIAN OCEAN TECTONICS)

CAUTION: NOT ALL OF THESE FILES ARE SUITABLE FOR
PLOTTING ON RECONSTRUCTIONS

DO YOU WISH TO RETURN TO PLOT MENU (Y/N)

(ENTER NO TO CONTINUE)
NO
```

T Ty ←



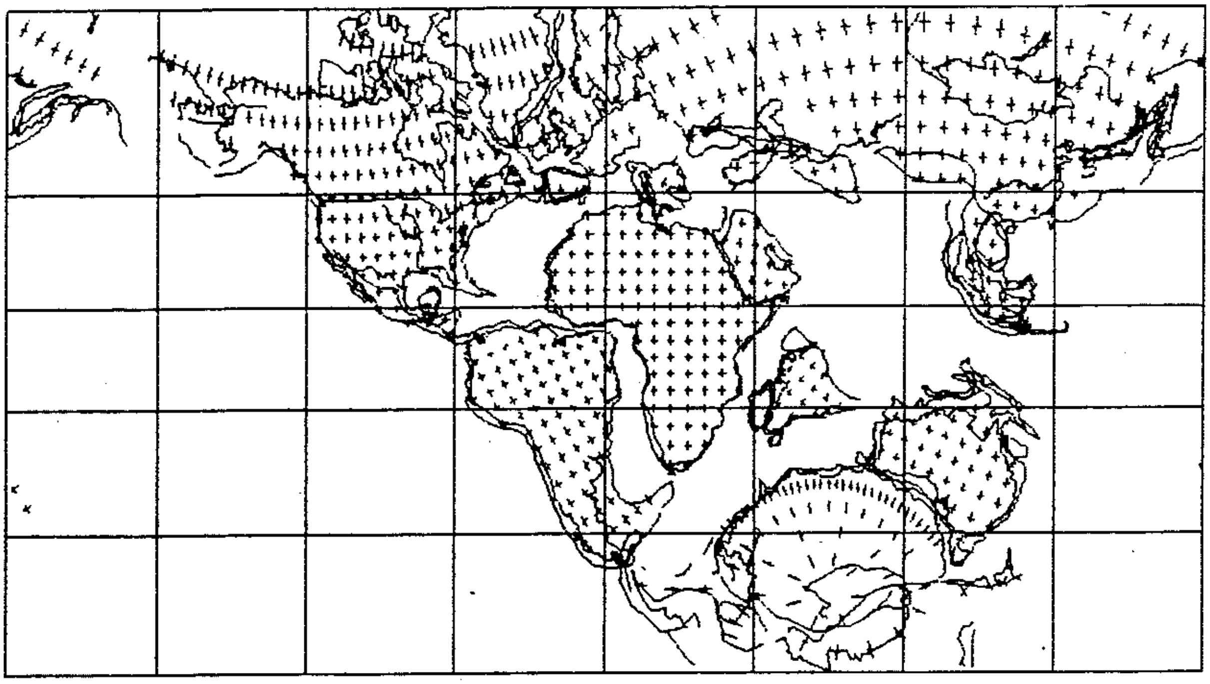
[illegible]

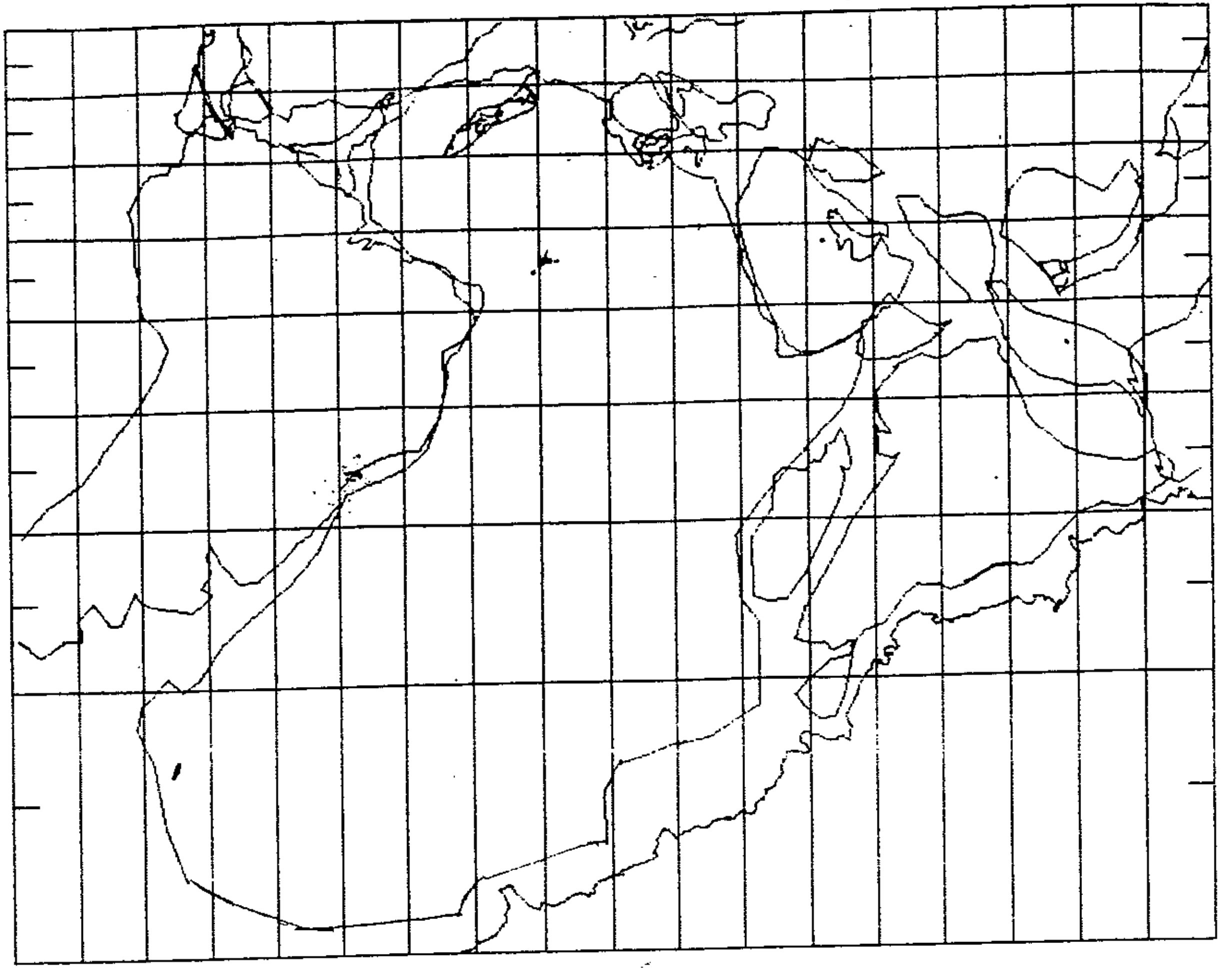
Fig 3



a) w.r.t. magnetic pole

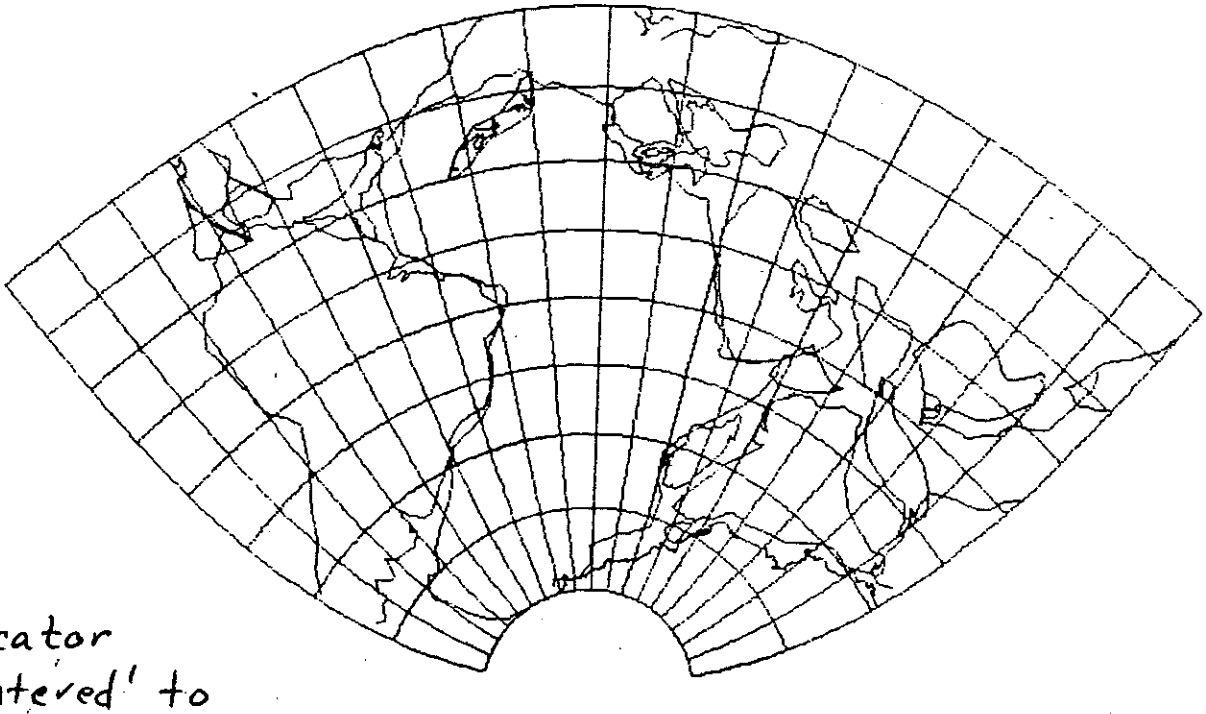
Fig. 4



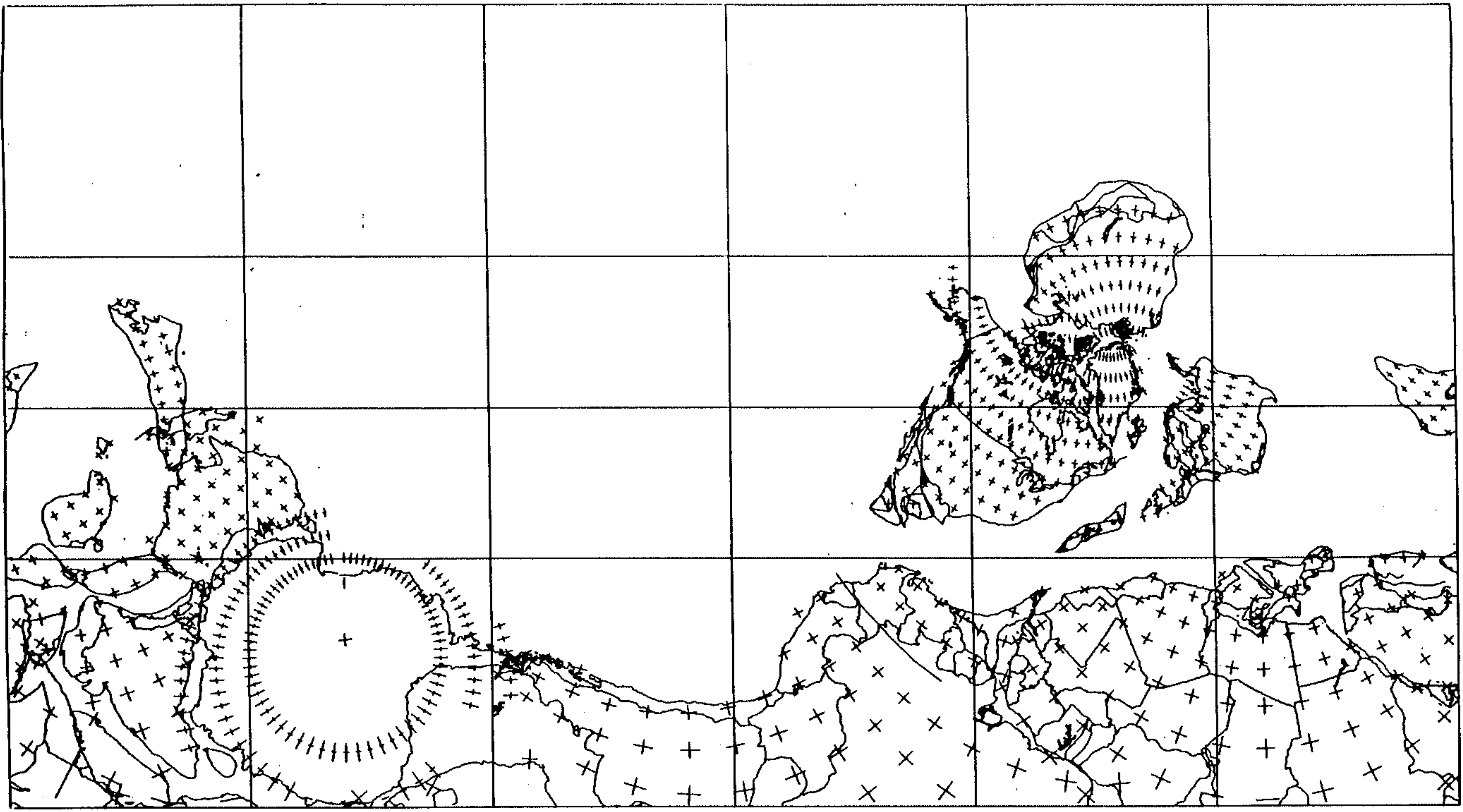


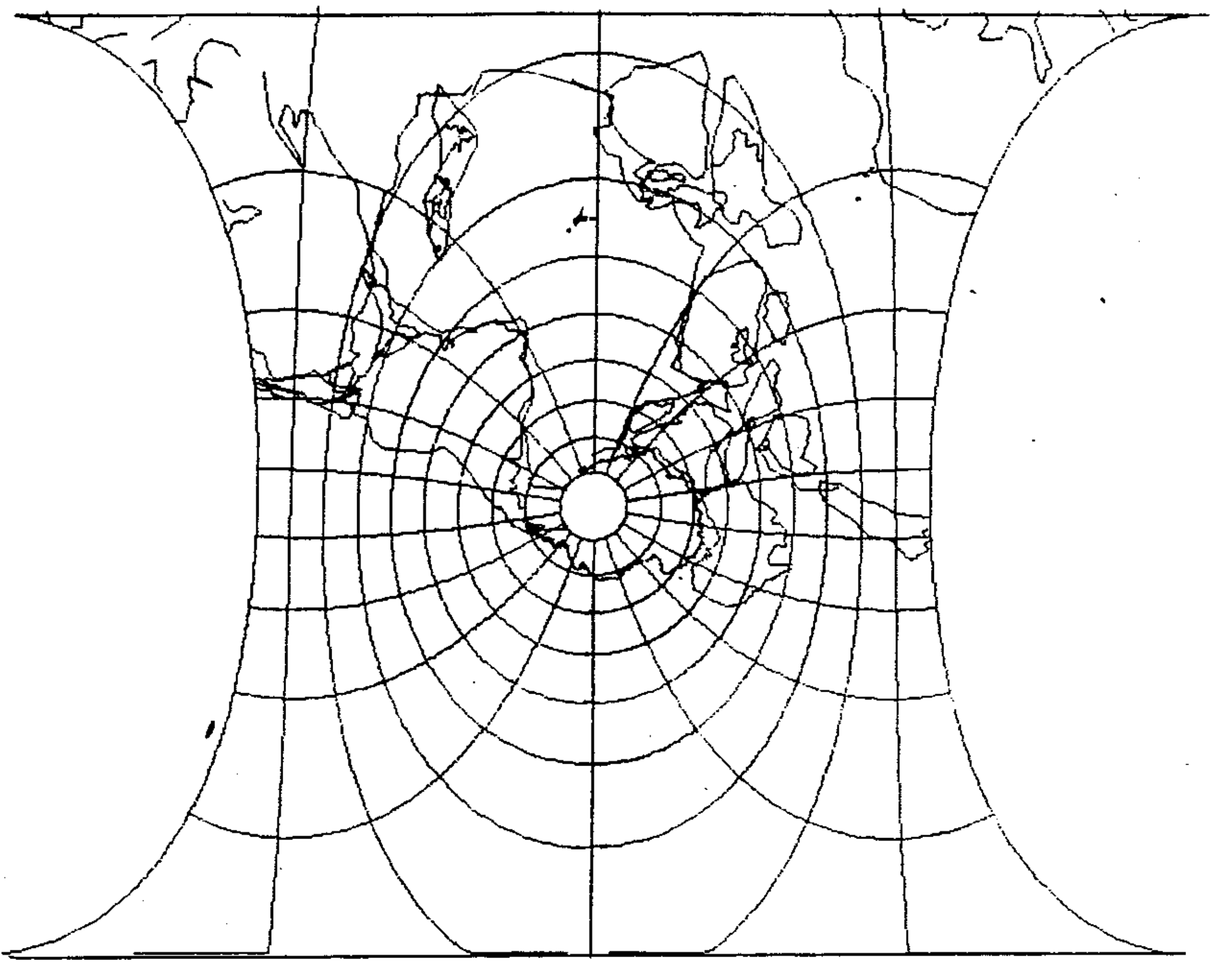
Mercator Projection

Fig 5.



Mercator
'centered' to





transverse polar Mercator projection

Fig. 7.